AN ENERGY AND ECONOMIC EFFICIENCY COMPARISON OF THE BUILDING ENVELOPE OF AN APARTMENT BUILDING IN ANKARA, TURKEY

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ABSTRACT

AN ENERGY AND ECONOMIC EFFICIENCY COMPARISON OF THE BUILDING ENVELOPE OF AN APARTMENT BUILDING IN ANKARA, TURKEY

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The main aim of this thesis is to study the energy and the economic performance of the building envelope of an apartment floor consisting of three flats in Etlik, Ankara. Three flats namely flat-1 facing South-West, flat-2 facing South-East and flat-3 facing North are considered. Three different glazing window types namely ISICAM KLASIK, ISICAM SINERJI and ISICAM SINERJI 3+ with different thermal transmittance values are investigated as well as the Base Case wall section, four wall sections involving Aerated Autoclaved Concrete Blocks, four wall sections involving Heavyweight Concrete Blocks and four wall sections involving Lightweight Concrete Blocks. The wall sections applied are of different configurations one without insulation and the remaining three are having insulation on the exterior, sandwiched and in the interior. Both the initial investment and operation costs of all these alternatives are found and a performance sequence is obtained to find out the most efficient alternative. In terms of the glazing window units, the most efficient alternative both energy wise and economy wise is ISICAM SINERJI 3+ for flat-1 and flat-2. The result for flat-3 is an exception because it received the least solar energy making the ISICAM KLASIK glazing unit the most efficient. When considering both the energy and economy performance of the wall sections, the most efficient are those with insulation in the exterior and interior for both the AAC

Blocks and Lightweight Concrete Blocks. This is mainly due to the low conductivity values of AAC blocks followed by the Lightweight Concrete Blocks.

Keywords: Building Envelope, Design Builder, Energy and Economic Performance

ÖZ

ANKARA, ETLİK' TEKİ BİR BİNANIN DIŞ YAPI KAPUĞU MALZEMELERININ ENERJİ VE EKONOMİK VERİMLİLİKLERİNİN KARŞILAŞTIRILMASI

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Bu tezin ana hedefi Ankara, Etlik'teki üç daireli bir binanin diş yapı kapuğu malzemelerının enerji ve ekonomik performansının değerlendirilmesidir. Üç dairenin konumları belirtildiği gibidir: Daire 1 Güneybatı cepheli; Daire 2 Güneydoğu cepheli ve Daire 3 kuzey cepheli. Yapılan ilk değerlindermelerde üç farklı tip doğrama tespit edilmiştir: ISICAM KLASİK, ISICAM SİNERJİ ve ISICAM SİNERJİ 3+. Her üç doğrama çeşidinin farklı ısı iletkenlik değerleri bulunmaktadır. Bunun yanısıra, cephe duvarları da farklılık göstermektedir. Dört duvarda gazbeton blok, dört duvarda ağır beton blok ve diğer dört duvarda da hafif beton blokla imalat yapıldığı gözlenmiştir. Duvar kesitlerinde farklı yalıtım uygulamaları da tespit edilmiştir. Hiçbir yalıtım uygulanmayan duvarın yanısıra, diğer üç duvar tipinde dıştan yalıtım ve sandviç duvar tespit edilmiştir. Duvarların iç yüzleriyle ilgili araştırma devam etmektedir. Bu alternatiflerin yıllık enerji performansı, ilk yatırım maliyeti ve hem de işletme maliyetleri tespit edilmiş ve performans etkisi elde edilerek en verimli alternatif bulunmuştur. Dış cephe doğramaları arasında 1 ve 2 numaralı dairelerde bulunan ISICAM SİNERJİ 3+'ın enerji ve ekonomi açısından en verimli olduğu tespit edilmiştir. 3 numaralı dairede bulunan ISICAM KLASİK doğramalar en az güneş ışığına maruz kaldığı için istisnai olarak tespit edilmiştir. Aksi takdirde söz konusu doğramalar en verimli olarak belirlenebilecekti. Duvar kesitleri enerji ve ekonomik performansları açısından ele alındığında, gazbeton ve hafif beton blok duvarların en vermli oldukları belirlenmiştir. Bu tespitin temel sebebi, gazbetonun ve takip eden hafif beton blokların düşük iletkenlik.

Anahtar kelimeler: Dış yapı kapuğu, Design Builder, Enerji ve Ekonomik Performans

To my Family, Friends and all my Teachers

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TABLE OF CONTENTS

ABSTACT……………………………………………………………………...v
ÖZ………………………………………………………………………………vii
ACKNOWLEDGMENTS……………………………………………………..x
TABLE OF CONTENTS……………………………………………………...xi
LIST OF TABLES…………………………………………………………..xvii
LIST OF FIGURES………………………………………………………….xxiii
CHAPTERS
1. INTRODUCTION………………………………………………..………1
1.1 Argument………………………..…………………..…….............1
1.2 Aim and Objective…………………………………….................2
1.3 Procedure……………………………….……………...............4
1.4 Disposition……………………………………………………………4
2. LITERATURE SURVEY…………………………………….............7
2.1 Energy Conservation and Consumption………………………………7
2.1.1 Global Warming ………...9
2.1.2 Kyoto Protocol………………………………………...........10
2.1.3 Statistics in Turkey …..11
2.2 Passive Design Principles...13
2.2.1 Orientation ……………………………………………......17
2.2.2 Ventilation……………………………………………………...19
2.2.3 Thermal Comfort ………………………………………………19
2.2.4 The Building Envelope ………....................................22
2.2.4.1 Windows (Openings)………………………………….32
2.2.4.2 Window Frames……………………………………50
2.2.4.3 Masonry Walls…………………………….............52
2.2.4.4 Wall System (Autoclaved Aerated concrete (AAC) Block)...56
2.2.4.5 Plasters and Renders…...58

2.2.4.6 Insulation……………………….………………...59
2.3 Thermal Simulation……………………….................................71
2.4 Life Cycle Cost Analysis……………………………………………73
3. MATERIAL AND METHODOLOGY……………………………………75
3.1 Material…………………………………………..…………75
3.1.1 Windows Under Investigation…………………..……………..81
3.1.2 Wall Sections Under Investigation…….……………………83
3.2 Ankara Climate……………………..…………………………..88
3.2.1 Ankara Climatic According to Climate Consultant…………..88
3.3 Methodology……………………………………………………...89
3.3.1 Method…………………………………………………......90
4. RESULTS AND DISCUSSION……………………………………..95
4.1 Comparing Monthly Heat Gains Through the Different Glazing Windows in Flat-1, Flat-2 and Flat-3…………….............95
4.2 Comparing Monthly Heat Load Production by the Heating System Through All the Different Wall Sections in Flat-1, Flat-2 and Flat-3…………………………………………..……………97
4.3 Comparing Yearly Heat Gains Through the Different Glazing Windows in Flat-1, Flat-2 and Flat-3…………..…........................103
4.4 Comparing Yearly Heat Load Production by the Heating System Through All the Different Wall Sections in Flat-1, Flat-2 and Flat-3…………………………………………………………104
4.5 Percentages (%) of Heat Gains and Losses Through the Window Glazings in Flat-1, Flat-2, Flat-3…………………………………...107
4.6 Percentages (%) of Heat Losses through the Wall Sections in Flat-1, Flat-2, Flat-3……………………………………………..109
4.7 Initial capital investment calculation……………………….............113
4.8 Operation cost calculation……………………….…...................122
4.9 Comparing the Initial Investment and Operation Costs of Glazing Units in Flat-1, Flat-2, Flat-3…………..…....................................122

4.10 Comparing the Initial Investment and Operation Costs of the Wall Sections in Flat-1, Flat-2, Flat-3……………..124
5. CONCLUSION……………………………………………..……..….131
REFERENCES……………………………………………………………139
BIBLIOGRAPHY………………………………………………………...161
APPENDICES
A. QUESTIONNAIRES FLAT-1, FLAT-2 AND FLAT-3…………………169
B. DIFFERENT CONSTRUCTION SYSTEM UNDER INVESTIGATION (BS EN ISO 6946)…………………………………………………...193
C. DIFFERENT INSULATION MATERIALS UNDER INVESTIGATION (URALITA)…………………………………………………………195
D. DIFFERENT WINDOW FRAMES UNDER INVESTIGATION (BS EN ISO 6946)…………………………………………………..197
E. ORIGINAL EXTERNAL WALL SYSTEM (SECTION BASE CASE)..199
F. HVAC TEMPLATE (DESIGN BUILDER)……………………………..201
G. LIGHTING TEMPLATE (DESIGN BUILDER)………………………...203
H. GLAZING TEMPLATES (DESIGN BUILDER)…..……………………205
I. PROPOSED EXTERNAL WALL SYSTEM (SECTIONS 1A, 1B, 1C AND 1D)……………………………………………………………...207
J. PROPOSED EXTERNAL WALL SYSTEM (SECTIONS 2A, 2B, 2C AND 2D)……………………………………………………………...209
K. PROPOSED EXTERNAL WALL SYSTEM (SECTIONS 3A, 3B, 3C AND 3D)……………………………………………………………...211
L. ORIGINAL FLAT ROOF SYSTEM…………………………………….213
M. ORIGINAL AND PROPOSED PITCHED ROOF SYSTEM…………...215
N. ORIGINAL AND PROPOSED INTERNAL PARTITION SYSTEM…..217
O. ORIGINAL SEMI-EXPOSED WALL SYSTEM (BASE CASE)……….219
P. PROPOSED SEMI-EXPOSED WALL SYSTEM (SECTIONS 1A, 1B, 1C AND 1D)………………………………………………………....221
Q. PROPOSED SEMI-EXPOSED WALL SYSTEM (SECTIONS 2A, 2B, 2C AND 2D)………………………………………………............223

R. PROPOSED SEMI-EXPOSED WALL SYSTEM (SECTIONS 3A,
3B, 3C AND 3D)…………………………………………………..........225
S. ORIGINAL AND PROPOSED SEMI-EXPOSED CEILING SYSTEM...227
T. ORIGINAL AND PROPOSED SEMI-EXPOSED FLOOR SYSTEM…. 229
U. ORIGINAL AND PROPOSED GROUND FLOOR SYSTEM………….231
V. ORIGINAL AND PROPOSED EXTERNAL FLOOR SYSTEM……..…233
W. ORIGINAL AND PROPOSED INTERNAL FLOOR SYSTEM………..235
X. ORIGINAL SUB-SURFACES WALL SYSTEM (BASE CASE)……….237
Y. ORIGINAL AND PROPOSED SUB-SURFACES INTERNAL
WALL SYSTEM……………………………………………………......239
Z. ORIGINAL AND PROPOSED SUB-SURFACES ROOF SYSTEM……241
AA. PROPOSED SUB-SURFACES WALL SYSTEM (SECTIONS 1A,
1B, 1C AND 1D)…………………………………………………..243
BB. PROPOSED SUB-SURFACES WALL SYSTEM (SECTIONS 2A,
2B, 2C AND 2D)…………………………………………………...245
CC. PROPOSED SUB-SURFACES WALL SYSTEM (SECTIONS 3A,
3B, 3C AND 3D)…………………………………………………...247
DD. ORIGINAL AND PROPOSED SUB-SURFACES EXTERNAL
AND INTERNAL DOOR SYSTEMS……………………………….249
EE. ORIGINAL AND PROPOSED INTERNAL THERMAL MASS
SYSTEMS……………………………………………………………251
FF. COMPONENT BLOCKS SHADING AND REFLECTION
SYSTEMS………………………………………………………...253
GG. AIR TIGHTNESS…………………………………………………255
HH. WINDOW OPENING SYSTEM………………………………….257
II. DOOR OPENING SYSTEM……………………………………...259
JJ. INTERIOR WINDOW SYSTEM…………………………………261
KK. ROOF WINDOW / SKYLIGHT SYSTEM……………………….263
LL. VENT OPENING SYSTEM………………………………………265
MM. OCCUPANCY SCHEDULES FOR FLATS-1, FLAT-2 AND
FLAT-3…………………………………………………………….267

NN. PRODUCTION UNITS PER MASON ACCORDING TO BLOCK WEIGHT…………………..……………………………………..269
OO. TYPE OF CONCRETE BLOCKS, DIMENSIONS, PRICES AND PRODUCTION DAYS IN TURKISH LIRAS………………….271
PP. SKILLED TECHNICAL STAFF (MASONS) AVERAGE MONTHLY PAY…………………………………...……………..273
QQ. THE MASONS SALARY FOR THE CONSTRUCTION OF THE BUILDING ENVELOPE FOR ONE FLOOR INCLUDING FLATS-1, FLAT-2 AND FLAT-3……………...………………………275
RR. COMPARING ENERGY CONSUMPTIONS THROUGH GLAZING UNITS IN THE INVESTIGATED FLATS………………..277
SS. COMPARING ENERGY CONSUMPTIONS THROUGH THE WALL SECTIONS IN THE INVESTIGATED FLATS………………..279
TT. PERCENTAGES (%) OF HEAT GAINS AND LOSSES THROUGH THE GLAZING ALTERNATIVES IN FLAT-1, FLAT-2 AND FLAT-3……………………………………………….281
UU. PERCENTAGES (%) OF HEAT GAINS AND LOSSES THROUGH THE WALL SECTIONS IN FLAT-1, FLAT-2 AND FLAT-3…………………………………………………….……...285
VV. MONTHLY HEAT GAINS TRANSMITTED THROUGH THE THREE GLAZING ALTERNATIVES IN FLAT-1, FLAT-2 AND FLAT-3…..289
WW. MONTHLY HEAT LOAD PRODUCTION OF THE HEATING SYSTEM IN FLAT-1, FLAT-2 AND FLAT-3 IN KWH………………291
XX. PERCENTAGE HEAT LOSSES AND HEAT GAINS FOR THE GLAZING WINDOWS AND HEAT LOSSES THROUGH ALL WALL SECTIONS FOR FLAT-1, FLAT-2 AND FLAT-3…………….293
YY. HOLLOW CMU CHARACTERISTICS……………………………….309
ZZ. SAMPLE CALCULATIONS………………………………………..311

AAA. ANKARA CLIMATE: 1) DRY BULB TEMPERATURE AND RELATIVE HUMIDITY; 2) SUN SHADING CHART (DECEMBER 21st TO JUNE 21st); SUN SHADING CHART (JUNE 21st TO DECEMBER 21st); WIND WHEEL……………………313
BBB. MONTHLY HEAT LOAD PRODUCTION BY THE HEATING SYSTEM FOR ALL THE WALL SECTIONS IN THE INVESTIGATED FLAT-1, FLAT-2 AND FLAT-3 (KWH)……………..317

LIST OF TABLES

TABLES

Table 1 Distribution of the expected energy usage within the different fields against the years in % (WEC-TNC, 1995); (Bolattürk, 2006).)..................11

Table 2 Energy usage division within buildings in percentage (%) (Çengel, 1998); (Bolattürk, 2006).)..13

Table 3 Thermal mass for various materials (Baggs and Mortensen, 2006)…...........29

Table 4 Heat conductivities (k) of gases used in double and triple windows (Çetiner and Özkan, 2004).……………………………………………40

Table 5 U-value and SHGC of a double glazing with and without Low-e coating (http://www.adelaidecitycouncil.com, Last Accessed 11 / 11 / 2013)...........48

Table 6 Product Dimensions of AAC Masonry Blocks (www.akg-gazbeton.com, Last Accessed 05 / 03 / 2014)...57

Table 7 The Properties of Glass Wool (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)...69

Table 8 Characteristics of used materials of the case study…………………………82

Table 9 The zonal and window size information (Keçiören Municipality)………………………………………………………………..87

Table 10 Ankara climatic details (Turkish State Meteorological Service)………….88

Table 11 The factors used in the Initial Investment and Operation Costs Estimation.………………………………………………………………94

Table 12 The Three Window Alternatives Under Investigation Square-Meter Unit Costs (Trakya (http://www.trakyacam.com.tr/, Last Accessed 18 / 03 / 2014)..114

Table 13 Flat-1 Total Block Costs (http://www.corumbloktugla.com/,(Last Accessed 20 / 03 / 2014) (www.akggazbeton.com, Last Accessed 05 / 03 / 2014), (http://www.escsi.org/, Last Accessed 23 / 03 / 2014)………...115

Table 14 Flat-2 Total Block Costs (http://www.corumbloktugla.com/,(Last Accessed 20 / 03 / 2014) (www.akggazbeton.com, Last Accessed 05 / 03 / 2014), (http://www.escsi.org/, Last Accessed 23 / 03 / 2014)………………...116
Table 15 Flat-3 Total Block Costs (http://www.corumbloktugla.com/,(Last Accessed 20 / 03 / 2014) (www.akggazbeton.com, Last Accessed 05 / 03 / 2014), (http://www.escsi.org/, Last Accessed 23 / 03 / 2014)………………...117
Table 16 Flat-1 Total Insulation Costs (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)...118
Table 17 Flat-2 Total Insulation Costs (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)…………………………………………………119
Table 18 Flat-3 Total Insulation Costs (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)…………………………………………………120
Table 19 The Glazing Areas of The Three Alternatives Under Investigation (m2)…………………………………………………….121
Table 20 The total initial capital investment for the glazing units in the flats (TL)……………………………………………………………121
Table 21 The total initial capital investment for the Wall Sections in the flats (TL)……………………………………………………………121
Table 22 Annual energy prices of the glazings of the case study flats (TL)……………………………………………………………122
Table 23 Annual energy prices of the wall sections of the case study flats (TL)…..122
Table 24 Initial Investment and Operation Costs of Flat-1 Glazing Alternatives (TL)……………………………………………………123
Table 25 Initial Investment and Operation Costs of Flat-2 Glazing Alternatives (TL)……………………………………………………123
Table 26 Initial Investment and Operation Costs of Flat-3 Glazing Alternatives (TL)……………………………………………………124
Table 27 Initial Investment and Operation Costs of Flat-1 Wall Sections Base, 1A, 1B, 1C, and 1D (TL)………………….……………..124

Table 28 Initial Investment and Operation Costs of Flat-1 Wall
Sections 2A, 2B, 2C, and 2D (TL)……………………………………….124
Table 29 Initial Investment and Operation Costs of Flat-1 Wall
Sections 3A, 3B, 3C, and 3D (TL)……………………………………….125
Table 30 Initial Investment and Operation Costs of Flat-2 Wall
Sections Base, 1A, 1B, 1C, and 1D (TL)………………………………...125
Table 31 Initial Investment and Operation Costs of Flat-2 Wall
Sections 2A, 2B, 2C, and 2D (TL)……………………………………….125
Table 32 Initial Investment and Operation Costs of Flat-2 Wall
Sections 3A, 3B, 3C, and 3D (TL)……………………………………….125
Table 33 Initial Investment and Operation Costs of Flat-3 Wall
Sections Base, 1A, 1B, 1C, and 1D (TL)………………………………...126
Table 34 Initial Investment and Operation Costs of Flat-3 Wall
Sections 2A, 2B, 2C, and 2D (TL)……………………….………………126
Table 35 Initial Investment and Operation Costs of Flat-3 Wall
Sections 3A, 3B, 3C, and 3D (TL)……………………….………………126
Table 36 A comparison of percentages (%) of total initial investment
and operation costs of the glazing units according to
Isicam Klasik in Flat-1, Flat-2 and Flat-3……………….………………130
Table 37 A comparison of percentages (%) of total initial investment
and operation costs of the wall sections according to
the base section in Flat-1, Flat-2 and Flat-3………...……………………130
Table 38 A comparison of the energy efficiency and economy
efficiency of the investigated wall sections…………..…………………131
Table 39 Ranking by the total energy efficiency of the investigated wall
sections for all the three flats……………………………………………..132
Table 40 Ranking by the total economy efficiency of the investigated wall
sections for all the three flats……………………………………………..133
Table 41 Ranking by both the total energy efficiency and economy efficiency
of the investigated wall sections for all the three flats…………..……….134

Table 42 A comparison of the energy efficiency and economy efficiency of the investigated glazing units……………………………..………...135
Table 43 Ranking by the total energy efficiency of the investigated glazing alternatives for all the three flats……………………………......135
Table 44 Ranking by the total economic efficiency of the investigated glazing alternatives for all the three flats…………………….………..135
Table 45 Ranking by both the total energy and economic efficiency of the investigated glazing alternatives for all the three flats…………….136
Table 46 Different Construction System Under Investigation (BS EN ISO 6946)...191
Table 47 Different Insulation Materials Under Investigation (Uralita)…………….193
Table 48 Different Window Frames Under Investigation………………………….195
Table 49 Original External Wall System (Section Base Case)……………………..197
Table 50 HVAC Template (Design Builder)……………………………………….199
Table 51 Lighting Template (Design Builder)……………………………………..201
Table 52 Glazing Template (Design Builder) – Part-1…………………………….203
Table 52 (Continued) Glazing Template (Design Builder) – Part-2……………….204
Table 53 Proposed External Wall System (Section 1A, 1B, 1C and 1D)………….205
Table 54 Proposed External Wall System (Sections 2A, 2B, 2C and 2D)…………207
Table 55 Proposed External Wall System (Sections 3A, 3B, 3C and 3D)…………209
Table 56 Original Flat Roof System………………………………………………..211
Table 57 Original and Proposed Pitched Roof System…………………………….213
Table 58 Original and Proposed Internal Partition System………………………...215
Table 59 Original Semi-Exposed Wall System (Base Case)……………………….217
Table 60 Proposed Semi-Exposed Wall System (Sections 1A, 1B, 1C and 1D)…..219
Table 61 Proposed Semi-Exposed Wall System (Sections 2A, 2B, 2C and 2D)…..221
Table 62 Proposed Semi-Exposed Wall System (Sections 3A, 3B, 3C and 3D)…..223
Table 63 Original and Proposed Semi-Exposed Ceiling System…………………..225
Table 64 Original and Proposed Semi-Exposed Floor System…………………….227
Table 65 Original and Proposed Ground Floor System…………………………….229
Table 66 Original and Proposed External Floor System…………………………...231
Table 67 Original and Proposed Internal Floor System……………………………233

Table 68 Original Sub-Surfaces Wall System (Base Case)………………………...235
Table 69 Original and Proposed Sub-Surfaces Internal Wall System……………...237
Table 70 Original and Proposed Sub-Surfaces Roof System………………………239
Table 71 Proposed Sub-Surfaces Wall System (Sections 1A, 1B, 1C and 1D)……241
Table 72 Proposed Sub-Surfaces Wall System (Sections 2A, 2B, 2C and 2D)……243
Table 73 Proposed Sub-Surfaces Wall System (Sections 3A, 3B, 3C and 3D)……245
Table 74 Original and Proposed Sub-Surfaces External and Internal Door Systems…………………………………………………………...247
Table 75 Original and Proposed Internal Thermal Mass Systems…………………249
Table 76 Component Blocks Shading and Reflection Systems……………………251
Table 77 Air Tightness……………………………………………………………..253
Table 78 Window Opening System………………………………………………..255
Table 79 Door Opening System……………………………………………………257
Table 80 Interior Window System…………………………………………………259
Table 81 Roof Window / Skylight System…………………………………………261
Table 82 Vent Opening System…………………………………………………….263
Table 83 Flat-1 Occupancy Schedule………………………………………………265
Table 84 Flat-2 Occupancy Schedule………………………………………………266
Table 85 Flat-3 Occupancy Schedule……………………………………………....266
Table 86 Production Units Per Mason According to Block Weight……………….267
Table 87 Type of Concrete Blocks, Dimensions, Prices and Production Days in Turkish Liras………………………………………………………..269
Table 88 Skilled Technical Staff (Masons) Average Monthly Pay………………..271
Table 89 The Masons Salary For the Construction of the Building Envelope for One Floor Including Flats 1, 2 and 3…………………………………273
Table 90 The energy consumption through the glazing units in the flat-1…………275
Table 91 The energy consumption through the glazing units in the flat-2…………275
Table 92 The energy consumption through the glazing units in the flat-3…………275
Table 93 The energy consumption through the Wall Sections in the Flat-1……….277
Table 94 The energy consumption through the Wall Sections in the Flat-2……….278
Table 95 The energy consumption through the Wall Sections in the Flat-3……….278

Table 96 The heat losses (kWh) through the three window options in Flat-1 obtained from the simulation results according to windows types………279
Table 97 The heat losses (kWh) through the three window options in Flat-2 obtained from the simulation results according to windows types………279
Table 98 The heat losses (kWh) through the three window options in Flat-3 obtained from the simulation results according to windows types………280
Table 99 The heat gains (kWh) through the three window options in Flat-1 obtained from the simulation results according to windows types………280
Table 100 The heat gains (kWh) through the three window options in Flat-2 obtained from the simulation results according to windows types……..280
Table 101 The heat gains (kWh) through the three window options in Flat-3 obtained from the simulation results according to windows types……..181
Table 102 The heat losses (kWh) through the wall sections of Flat-1……………..183
Table 103 The heat losses (kWh) through the wall sections of Flat-2……………..184
Table 104 The heat losses (kWh) through the wall sections of Flat-3……………..184
Table 105 The heat gains (kWh) through the wall sections in Flat-1……………...185
Table 106 The heat gains (kWh) through the wall sections in Flat-2……………...185
Table 107 The heat gains (kWh) through the wall sections in Flat-3……………...186
Table 108 The Monthly Heat Gains Transmitted Through the Three Glazing Alternatives in Flat-1……………………………………………………187
Table 109 The Monthly Heat Gains Transmitted Through the Three Glazing Alternatives in Flat-2……………………………………………………187
Table 110 The Monthly Heat Gains Transmitted Through the Three Glazing Alternatives in Flat-3……………………………………………………187
Table 111 The Monthly Heat Load Production of The Heating System in Flat-1…189
Table 112 The Monthly Heat Load Production of The Heating System in Flat-2…190
Table 113 The Monthly Heat Load Production of The Heating System in Flat-3…190
Table 114 The image, dimensions, density, weight, block per cube, fire ratings of a number of available hollow concrete masonry units (http://www.superiorblockcorp.com), Last Accessed 12 / 12 /2013)……......309

LIST OF FIGURES

FIGURES

Figure 1 Different factors influencing buildings (Persson, 2006)……………………….8

Figure 2 Yearly CO2 quantities in the atmosphere (Saydam, 2000)………………...10

Figure 3 Rates of energy use per sector in Turkey (2001) (Source: TÜBİTAK, 2003); (Yıldız, 2008) (MTOE = Tonne of oil equivalent)………………….12

Figure 4 Estimated rates of energy use per sector in Turkey (2010) (Source: TÜBİTAK, 2003); (Yıldız, 2008) (MTOE = Tonne of oil equivalent)…....12

Figure 5 Orientation (http://www.ecowho.com, Last Accessed 04 / 01 / 2014)…….18

Figure 6 ASHRAE comfort zone (ASHRAE Handbook, 1997)…………………….22

Figure 7 Factors that influence the building envelope design (Oral et. al., 2004)……………………………………………………..26

Figure 8 Thermal Mass (http://www.britishprecast.org, Last Accessed 26 / 04 / 2014)……………………………………………28

Figure 9 Different factors related windows (Persson, 2006)………………………...33

Figure 10 Typical features of windows (http://www.wbdg.org, Last Accessed 18 / 11 / 2013)…………………………………………..41

Figure 11 Different Tints (http://www.wbdg.org, Last Accessed 18 / 11 / 2013)…..44

Figure 12 Energy Distribution for Double Glazing Clear Glass (http://www.commercialwindows.org, Last Accessed 10 / 11 / 2013)…...46

Figure 13 Energy Distribution for Double Clear Glass with Low-e coating (http://www.cl-windows-doors.com/glazing, Last Accessed 10 / 11 / 2013)……………………………………………...…47

Figure 14 Energy distribution for Triple Clear Glass (http://www.bettaglaze.co.uk, Last Accessed 11 / 11 / 2013)…………………………………………49

Figure 15 Energy distribution for Triple Clear Glass with Low-e Coating (http://www.greenspec.co.uk, Last Accessed 13 / 11 / 2013)…………….50

Figure 16 Hollow Concrete Blocks (Ramachandran, 2013)………………………...54

Figure 17 Aerated Autoclaved Concrete (Aroni et. al., 1993)
(www.akg-gazbeton.com, Last Accessed 05 / 03 / 2014)………………...57
Figure 18 Aerated Autoclaved Concrete - close-up view (Aroni et. al, 1993)………57
Figure 19 Thermal regions of 81 cities for Turkey (Ankara being numbered as city 6 in region 3) (TS 825 Standard)…………………………………..60
Figure 20 Thermal Transmittance requirements according to (TS 825 Standard)…..61
Figure 21 Classification of the most used insulating materials
(Papadopoulos, 2005)……………………………………………...66
Figure 22 The thermal transmittance of several common insulation materials with five centimeter thicknesses compared to the thermal transmittance of a concrete block (Al-Homoud, 2004).…………………..67
Figure 23 Percentage consumption of insulation materials in Europe and Turkey
(Society of Polystyrene Manufacturers, 2003)……………………………68
Figure 24 İzocam Cephepan or Façade insulation (http://www.izocam.com.tr,
Last Accessed 15 / 03 / 2014)……………………….……………………69
Figure 25 İzocam Wall Board or Mid-wall insulation
(http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)……………....70
Figure 26 İzocam Optimum Wall or Interior insulation
(http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)………………70
Figure 27 Apartment photograph (14 / 11 / 2013)…………………………………..75
Figure 28 Apartment first floor plan (Keçiören Municipality)……………………...76
Figure 29 Project section details (Keçiören Municipality)………………………….77
Figure 30 Flat-1 South-Western perspective (Design Builder)……………………...78
Figure 31 Flat-1 Interior zone details (Design Builder)……………………………..78
Figure 32 Flat-2 South-Eastern perspective (Design Builder)………………………79
Figure 33 Flat-2 Interior zone details (Design Builder)……………………………..79
Figure 34 Flat-3 Northern Eastern perspective (Design Builder)…………………...80
Figure 35 Flat-3 Interior zone details (Design Builder)……………………………..80
Figure 36 Aerated Autoclaved Concrete Blocks for four different Wall
System Sections and The Base Case Section……………………………..84

Figure 37 Hollow Heavyweight Concrete Blocks for four different Wall System Sections and The Base Case Section……………………………..85
Figure 38 Hollow Lightweight Concrete Blocks for four different Wall System Sections and The Base Case Section……………………………..86
Figure 39 Monthly temperature range within Ankara according to Climate Consultant…………………………………………………......89
Figure 40 Monthly heat gains through the three window glazing alternatives in the investigated flat-1, flat-2, flat-3 kWh……………………………..96
Figure 41 Monthly heat load production by the heating system for some Wall Sections in the investigated flat-1 kWh……………………………100
Figure 42 Monthly heat load production by the heating system for some Wall Sections in the investigated flat-2 kWh……………………………101
Figure 43 Monthly heat load production by the heating system for some Wall Sections in the investigated flat-3 kWh……………………………102
Figure 44 Yearly heating gains through the three window glazing alternatives in the investigated flat-1, flat-2 and flat-3- kWh/y……………………..103
Figure 45 Yearly heating load production of the Wall Sections- Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D units in flat-1, kWh / year…..104
Figure 46 Yearly heating load production of the Wall Sections- Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D units in flat-2, kWh / year…..105
Figure 47 Yearly heating load production of the Wall Sections- Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D units in flat-3, kWh / year…..106
Figure 48 Heat losses (%) through the three window glazing alternatives in flat-1, flat-2 and flat-3 obtained from the simulation results…………107
Figure 49 Heat gains (%) through the three window glazing alternatives in flat-1, flat-2 and flat-3 obtained from the simulation results…………109
Figure 50 Heat losses (%) through all the Wall System Sections in flat-1 obtained from the simulation results…………………………………….110
Figure 51 Heat losses (%) through all the Wall System Sections in flat-2 obtained from the simulation results…………………………………….111

Figure 52 Heat losses (%) through all the Wall System Sections in flat-3 obtained from the simulation results……………………………………113
Figure 53 The summation of initial investment and operation costs of the Investigated three window glazing units in Flat-1, Flat-2, Flat-3 (TL)…123
Figure 54 Total initial investment and operation costs of the investigated the wall sections Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D in Flat-1 (TL)……………………………………………………127
Figure 55 Total initial investment and operation costs of the investigated the wall sections Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D in Flat-2 (TL)…………………………………………………...128
Figure 56 Total initial investment and operation costs of the investigated the wall sections Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D in Flat-3 (TL)……………………………………………………129
Figure 57 Heat losses (%) through the three window glazing options in flat-1 obtained from the simulation results……………………………………293
Figure 58 Heat losses (%) through the three window glazing options in flat-2 obtained from the simulation results……………………………………294
Figure 59 Heat losses (%) through the three window glazing options in flat-3 obtained from the simulation results……………………………………295
Figure 60 Heat Gains (%) through the three window glazing options in flat-1 obtained from the simulation results……………………………………296
Figure 61 Heat Gains (%) through the three window glazing options in flat-2 obtained from the simulation results……………………………………297
Figure 62 Heat Gains (%) through the three window glazing options in flat-3 obtained from the simulation results……………………………………298
Figure 63 Heat losses (%) through the Wall Sections Base and 1A in flat-1 obtained from the simulation results……………………………………299
Figure 64 Heat losses (%) through the Wall Sections 1B, 1C, 1D, 2A, 2B, 2C, 2D in flat-1 obtained from the simulation results…………………..300
Figure 65 Heat losses (%) through the Wall Sections 3A, 3B, 3C and 3D in flat-1 obtained from the simulation results…………………….…….301

Figure 66 Heat losses (%) through the Wall Sections Base and 1A in flat-2 obtained from the simulation results……………………………………302
Figure 67 Heat losses (%) through the Wall Sections 1B, 1C, 1D, 2A, 2B, 2C, 2D in flat-2 obtained from the simulation results……………..........303
Figure 68 Heat losses (%) through the Wall Sections 3A, 3B, 3C and 3D in flat-2 obtained from the simulation results…………………………...304
Figure 69 Heat losses (%) through the Wall Sections Base and 1A in flat-3 obtained from the simulation results…………………………………….305
Figure 70 Heat losses (%) through the Wall Sections 1B, 1C, 1D, 2A, 2B, 2C, 2D in flat-3 obtained from the simulation results…………………...306
Figure 71 Heat losses (%) through the Wall Sections 3A, 3B, 3C and 3D in flat-3 obtained from the simulation results…………...………………307
Figure 72 Dry Bulb Temperature and Relative Humidity Within Ankara According to Climate Consultant……………………………………..315
Figure 73 Sun Shading Chart (December 21st to June 21st) Within Ankara According to Climate Consultant……………………………………..316
Figure 74 Sun Shading Chart (June 21st to December 21st) Within Ankara According to Climate Consultant……………………………………..317
Figure 75 Wind Wheel Within Ankara According to Climate Consultant………...317
Figure 76 Monthly heat load production by the heating system for all the Wall Sections in the investigated flat-1 kWh…………...………………319
Figure 77 Monthly total heat loads produced by all the Wall Sections in the investigated flat-2 kWh……………………………………...……320
Figure 78 Monthly total heat loads produced by all the Wall Sections in the investigated flat-3 kWh…………………………………………………321

CHAPTER 1

INTRODUCTION

The introduction part of this thesis puts forward the main arguments that are to be investigated, followed by the aims and objectives set out in the thesis. In addition to these, the procedure and methodology that is implemented is mentioned and finally the disposition which describes the different chapters within the thesis is added.

1.1 Argument

In the past, much of the worldly energy was wasted especially in different buildings. Thus, the introduction of new regulations by different countries regarding the energy potential of construction systems became common in an attempt to control wasted energy and conserving it as well as reducing the burning of energy resources that may release pollutants in the form of CO2 that may harm the environment and increase global warming.

Turkey is a developing country which has been influenced by little consideration to energy conservation. Since Turkey imports a lot of the energy it consumes, the need to save it has become an important issue. Therefore, importance was given to the construction systems in terms of energy conservation by the release of new energy related regulations that would help much in the reduction of the increasingly needed energy usage throughout Turkey. Thus, both interior thermally suitable environment and interior occupant thermal comfort could be achieved.

From all of Turkey, the City of Ankara has been selected for this thesis study because it is the capital of Turkey and many improvements in construction had to be done to modernize it and avoid the old habit of constructing inefficiently. At the same time since dwellings of all types ranging from villas, dormitories and apartments etc. are the most buildings in demand due to the rising population of Ankara, dwellings have to be constructed in modern energy efficient ways.

In this thesis, the case study building is a typically newly constructed apartment residential building, designed and built after energy efficiency regulations have been issued. This apartment could be considered as a base case for all newly constructed building.

By the study of the above mentioned apartment in the temperate cold dominated climate of Ankara and the application of some proposed opaque and transparent building envelope options, the most energy efficient alternatives would be recommended.

1.2 Aim and Objective

The main aim of this thesis is to test several building envelope systems that would influence the energy and the economic efficiency of the design. By means of a summation of the initial investment and operation costs and a comparison of yearly energy loads obtained with the usage of an energy oriented computer simulation program, the performance of few window types as well as a number of different wall systems will be tested.

Another aim is to investigate and compare the performance of the same three typical, conventional and common window systems which are available in the market. They represent different window glazing alternatives used throughout the years of glazing technology performance. Ranging from a basic window glazing type with a relatively high thermal transmittance of 2.715 W/m2.k which was chosen as the base case alternative, to a window glazing type with a reasonably low thermal transmittance of 1.548 W/m2.k lower than the standard required minimum and finally a high performance glazing window type with a thermal transmittance of 0.778 W/m2.k.

Included in this investigation are three different block materials namely Aerated Autoclaved Concrete Blocks, Heavyweight Concrete Blocks and Lightweight Concrete Blocks which have different characteristics of heat conductivity. This property of the blocks influences the heat transfer through the total wall system sections to be tested. The influence of this property on the interiors of the apartment will be tested for all wall system sections under investigation with the results being obtained from the simulation program Design Builder.

Another important aim is to test the absence of insulation in all the three different block wall system sections to see its effect on the opaque building envelope and to find out its importance in the cold climate of Ankara.

As an attempt to find alternative block materials to be used in wall system sections, this thesis deals with the basic originally used wall system section and investigates the efficiency of the three different construction wall systems namely Aerated Autoclaved Concrete Blocks, Heavyweight Concrete Blocks and Lightweight Concrete Blocks. Here, the important factor which is to be investigated is the distribution and location of the insulation layer. It is tested by either locating the insulation to the outside of the exterior wall or sandwiched between block wall layers or located inside the exterior wall. Studies have been implemented to decide which location is the most efficient location. This thesis also attempts to clarify this issue by means of understanding and comparing the simulation undertaken using the computer program Design Builder.

In addition to the energy and economic efficiency performance investigation of the three glazing window alternatives and the different wall system sections, an orientation energy comparison of the first floor of three different flats-1, 2 and 3 that face South-West, South-East and North respectively is investigated. The influence of the solar energy caused by the prevailing sun from the morning to the evening passing from dawn’s eastern sun to the mid-days southern sun through to the western setting sun is analyzed from the results of the simulation.

According to these aims, the objectives are not only to reduce the release of pollutants such as CO_2 produced by the burning of fossil fuels used in heating the interiors but also to reduce the energy spent by the mechanical equipment that is used for heating during the winter in the temperate cold dominant climate of Ankara.

1.3 Procedure

Thanks to computer technology, energy performance of buildings could be simulated before construction. This advantageous capability is something which was not easily known in the past. By means of simulation of the location, climate and weather, orientation, shape of the building, building materials with their material specifications, windows with their different sizes and different specification, as well as different wall configurations, architects and builders are able to simulate the thermal performance of the building that is to be built. The main approach of this thesis is to use a thermally oriented software named Design builder to study the opaque and transparent parts of the building envelope. The main source of data for this thesis is the digital "EPW file for Ankara City" which is the digital climatic source typical to Ankara City.

Moreover, the benefits of this computer program are made use of in this thesis to investigate different alternatives of the opaque and transparent components of the building envelope namely three different glazing window types and different wall system types. They are analyzed in terms of both energy and economy efficiency. As a result, the most energy and economic efficient alternatives are selected and the best alternatives are recommended for usage in the market.

1.4 Disposition

The thesis consists of five chapters whose contents are described as documented in the following paragraphs:

Chapter-1 includes the introduction of the thesis. It states the argument, the aim and objectives, the procedure of thesis as well as the disposition of the various chapters being consequently mentioned.

Chapter 2 constitutes of a literature survey covering the thesis' main issues. Some information regarding both energy conservation and consumption are mentioned. Then information about global warming and the Kyoto protocol are mentioned followed by some statistics about Turkey. Then details about passive design principles, orientation and ventilation are noted followed by information regarding the building envelope and some of related characteristics that influence it are mentioned next including thermal comfort. Important details about windows and related characteristics, followed by information regarding different glazing types and window frames are mentioned. Next, information regarding masonry concrete blocks and autoclaved aerated concrete blocks are considered followed by details about plasters and renders, as well as the important topic of insulation. Then details regarding glass wool insulation are given followed by information regarding building energy simulation. The final part related to the main topic of this thesis in chapter 2 are details regarding the life cycle cost analysis, initial investment and operation cost.

Chapter 3 discusses the material, Ankara climate and methodology followed in the thesis. First of all, a photograph of case study apartment is given. The typical first floor plan is documented together with a partial section indicating the important specifications of the building followed by the procedure. Here, the window and wall specifications under investigation are tabulated. The second part includes information of Ankara climate obtained from Climate Consultant program. And finally the methodology and method of simulation is mentioned and clarified.

Chapter 4 deals with the results obtained after the computer simulations. The resulting data from the graphs and tables of the simulation are obtained first of all then they would be analyzed and discussed.

Chapter 5 compares and discusses the proposed energy and economic efficiency which was dealt in the investigation of the building envelope together with conclusions related to the results gathered.

CHAPTER 2

LITERATURE SURVEY

The literature survey of this thesis mentions the topics of energy conservation and consumption, with additional information regarding global warming and the Kyoto Protocol and its importance in reducing CO2 pollution in the world. Energy conservation important statistics from the other parts of the world and Turkey are also mentioned followed by information regarding passive design principles, orientation, ventilation and thermal comfort. Then, the building envelope's opaque and transparent components such as windows and wall components with their influential characteristics such the thermal transmittance are mentioned. Glazing types, window frames, masonry walls including AAC, heavyweight concrete blocks and lightweight concrete blocks details are given. Finally, information about insulation, thermal simulation, life cycle cost analysis and initial investment and operation costs are added.

2.1 Energy Conservation and Consumption

Those factors affecting the performance of buildings are shown in figure 1 below. The main necessary functions of buildings are to provide both shelter and safety. Moreover, a building should also provide electricity for lighting and electrical appliances, provide interior heating and cooling, provide fresh air by means of ventilation as well as fulfilling the occupant's water requirements. Other functions such as design and exterior aesthetics are also important. Furthermore, the effect of surrounding trees and other buildings in the energy outcomes and shading the building are also significant. Besides all these factors, the climate plays a major role in influencing the total yearly energy calculations of buildings and in this thesis dwellings, are given the main importance (Persson, 2006).

There are many different types of residential buildings. The main types are listed namely as detached and semi-detached houses, terraced houses as well as apartment block houses. In temperate cold climates, such as in Ankara, heating requirements are more than cooling requirements in residential buildings and proper windows that allow solar gains but also prevent heat loss are recommended. Since people spend most of their time within these buildings, it is a necessity to make them comfortable and healthy. Here, the most important energy components are the occupants, the heating system, the ventilating system, the building envelope's thermal insulation, walls and windows (Persson, 2006).

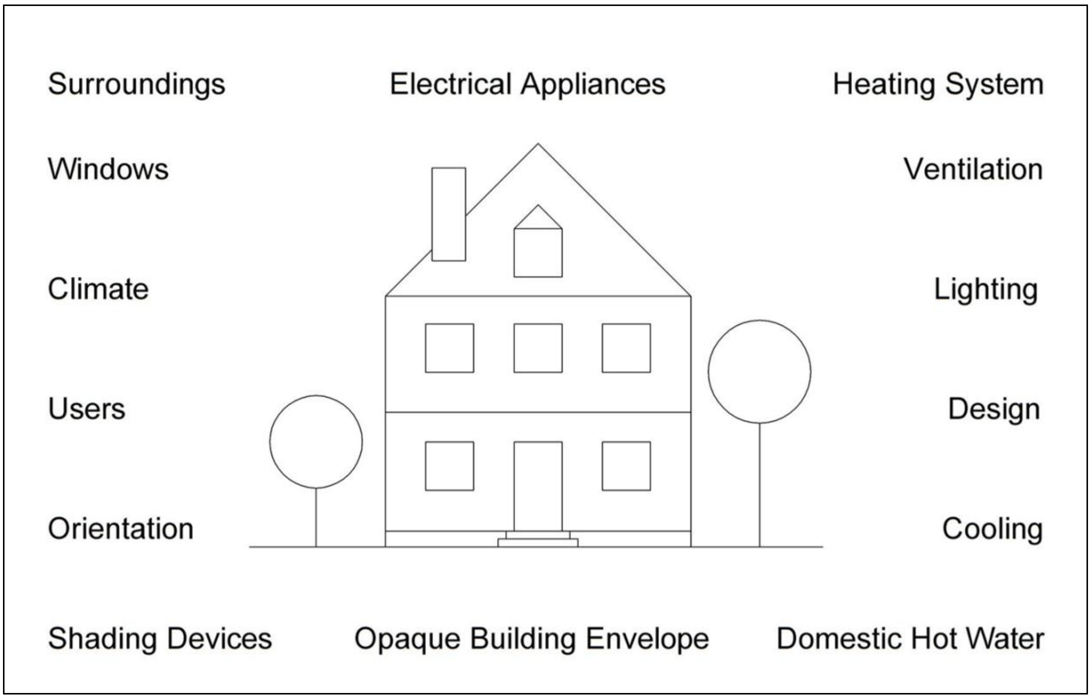

Figure 1 Different factors influencing buildings (Persson, 2006).

In terms of energy, designing a building efficiently at the start could be beneficial along its life span. For example, the usage of suitable thermal insulation saves reasonable amounts of energy in addition to the avoidance of thermal bridges over the life span of the building. In addition, an efficient ventilation system with an exhaust heat recovery system as well as the application of energy efficient windows could replace the usage of a supporting separate heating system (Persson, 2006).

Applying proper window glazing systems to buildings, interior thermal comfort could be achieved by reducing energy consumption. Moreover, much energy is necessary to maintain comfortable indoor temperatures (Omer, 2008); (Jindal et al., 2013).

Energy conservation depends on several parameters namely location on earth, orientation of the building, building shape, thermo-physical and optical features of the building envelope, size of the building, accommodation type whether residential or commercial, the distance between buildings as well as the natural ventilation arrangement (Berköz et al., 1995); (Bostancıoğlu and Telatar, 2013).

The facts that more people will live in smaller houses and the population number will rise, both will lead to the construction of new power plants to satisfy their energy needs. A rising fact is the need of designing more sustainable and eco-friendly houses and buildings. Therefore, starting immediately from today the need to reduce energy consumption is important not only for future house designs but also for the retrofitting of existing ones (Atikol et al., 2008).

2.1.1 Global Warming

The major harm to the environment is the global warming or the greenhouse effect that releases CO2, C, CFCs, halons, N2O, ozone and peroxyacetylnitrate to the atmosphere, in an increasing manner. As a result, these gases, lead to the trapping of heat radiated from the earth's surface, thus increasing the earth's temperature. For example the earth's surface temperature was raised by a value of 0.6°C within the period of the last hundred years with the result of an increase of 20 cm to the sea levels. These changes have negative influences such as the release of CO2 that result to 50% of the greenhouse effect (Dincer and Rosen, 1999); (Dincer, 1999); (Çomaklı and Yüksel, 2004). Figure 2 shows the increasing of CO2 concentration since industrial revolution (Saydam, 2000); (Çomaklı and Yüksel, 2004).

In addition to the above, the spreading of deserts, the land erosion, the sea pollution, the loss of animal and plant species as well as general destruction of soils are other harmful effects to the environment.

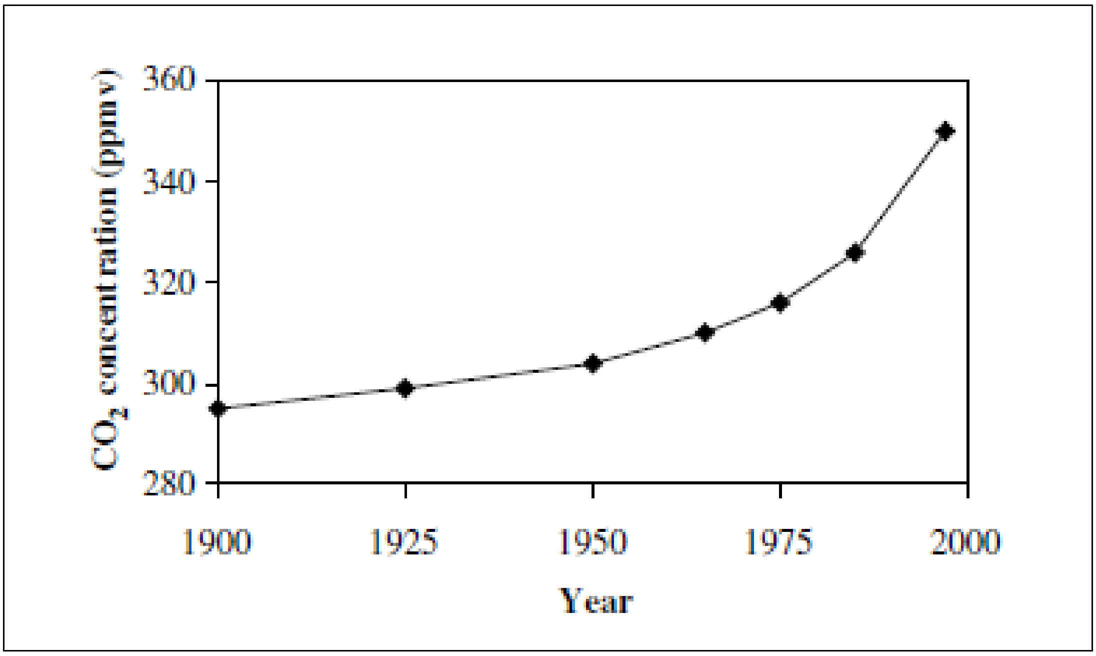

Figure 2 Yearly CO2 quantities in the atmosphere (Saydam, 2000).

2.1.2 Kyoto Protocol

Due to fast depletion of fuel energy resources and the pollution they cause, the control and management of energy consumption should be given great importance. Some aims agreed upon at the Kyoto Protocol were to reduce energy consumption by 20%, reduce carbon emissions by 20% as well as to make sure that 20% of the total energy production is consumed from renewable energy resources by the year 2020 as compared to the values agreed upon in 1990 (Calis, 2009); (Bostancıoğlu and Telatar, 2013).

In buildings, the conserving of energy is very important in improving their thermal performance. Based on the agreements decided after the Kyoto protocol, governments around the world acted consequently and tried to reduce greenhouse gas emissions by applying energy saving policies to decrease energy usage in their countries.

2.1.3 Statistics in Turkey

With the increase of technology, industry, energy, construction and population numbers, consumption has increased significantly relative to production. For example, in the USA which amounts to 5% of the world's population, citizens spend approximately 80,000 kWh in energy per person per year, while in the UK citizens spend around 45,800 kWh in energy per person per year. When comparing these values to Europe, an amount of 36,400 kWh per person per year is registered (Wiggington and Harris, 2002); (Maçka and Yalçın, 2011). In Turkey, it was recorded that 66% of the total consumed energy was imported in 2000, with the expectations that this value would increase to 77% by 2020. This importation not only influences the economy but also affects significant phenomenon such as global warming, environmental pollutions as well as the ever increasing energy costs (Turkish Republic Ministry of Foreign-Trade Counselorship, 2009) (Maçka and Yalçın, 2011).

The population of Turkey is estimated to surpass 100 million by 2020 (Bolattürk, 2006). In Turkey, resources such as hard coal, lignite, asphaltite, petroleum, natural gas, hydroelectric energy and geothermal energy are produced, however since little amounts of these native resources are utilized almost 52% of the energy required in Turkey to satisfy its needs is imported (Bolattürk, 2006).

Table 1 Distribution of the expected energy usage within the different fields against the years in % (WEC-TNC, 1995); (Bolattürk, 2006).

Year	Industry	Buildings	Transportation	Agriculture	Other
1995	35.80	34.41	21.32	5.49	2.98
1999	38.96	33.75	19.82	5.11	2.36
2003	42.24	31.44	19.22	5.08	2.02
2007	45.47	29.25	18.55	4.99	1.74

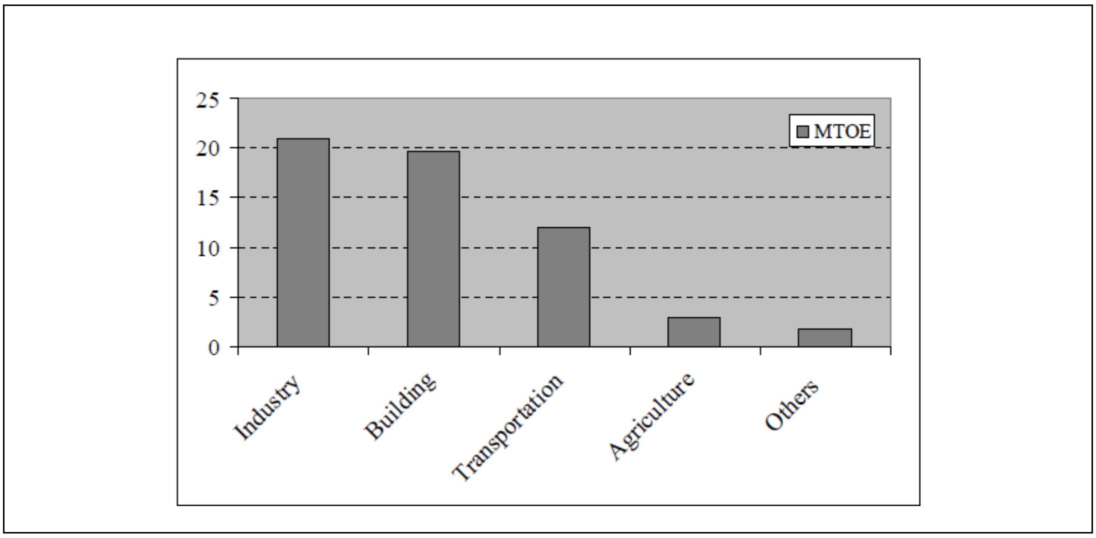

Figure 3 Rates of energy use per sector in Turkey (2001) (Source: TÜBİTAK, 2003); (Yıldız, 2008); (MTOE = Ton of oil equivalent).

Energy is consumed by four major fields namely agriculture, transportation, residential and industrial. Table 1 above, figure 3 above and figure 4 below shows the division of the energy usage within the different fields for the period from 1995 to 2010 in percentages (WEC-TNC, 1995); (Bolattürk, 2006). From table 1 above, it could be concluded that from all the sectors, the industrial field consumes the most energy followed by the residential sector.

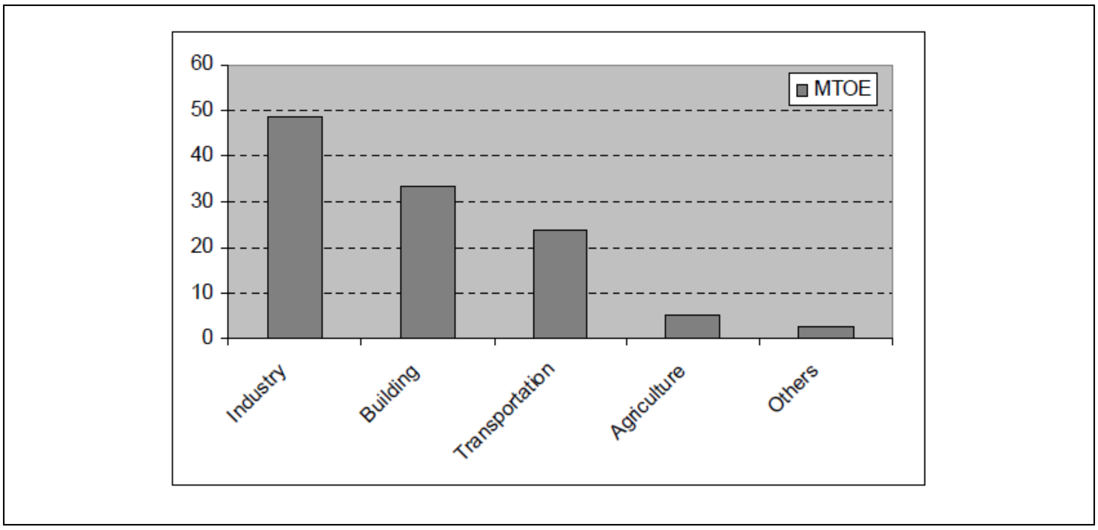

Figure 4 Estimated rates of energy use per sector in Turkey (2010) (Source: TÜBİTAK, 2003); (Yıldız, 2008); (MTOE = Ton of oil equivalent).

From all the sectors mentioned in table 1, figure 3 and figure 4, residential buildings consume a lot of energy in most countries. In Turkey, nearly 25-30% of the energy expenditure is consumed in the residential building sector (Büyükalaca and Bulut, 2004). Therefore, energy efficient building design should be considered. In Turkey, space heating accounts for approximately twice the energy used for water heating, freezing food refrigeration and cooking within residents. Within buildings in Turkey, almost 82% of the energy is used for heating. In a typical building the energy losses are divided as follows: 40% through external walls, 30% through windows, 17% through doors, 7% through the roof, and 6% through floors (Arıcı and Karabay, 2010). Therefore, the usage of thermal insulation within built structures saves energy as well as reduces unwanted pollutants released by burning fossil fuels (Kaynaklı, 2008).

In many countries, the energy used for heating interiors consumes the most of the energy expenditure. For example, space heating accounts for 40% of the entire energy used in houses as could be seen in table 2 below (Çengel, 1998); (Bolattürk, 2006).

Table 2 Energy usage division within buildings in percentage (%) (Çengel, 1998); (Bolattürk, 2006).

	Space heating	Water heating	Air condition ventilation	Lighting illumination	Cooling freezing	Other
Houses	40	17	7	7	12	17
Commercial	32	5	22	25	-	16

From table 2 above, it is concluded that the need for effective thermal protection is very important in decreasing energy consumption that is used to heat interiors in the residential sector. As mentioned earlier, the application of thermal insulation results in the reduction in fuel consumption, unwanted pollutants emitted by burning fossil fuels, as well as increasing thermal comfort obtained from the minimization of heat losses from buildings (Bolattürk, 2006).

2.2 Passive Design Principles

The fundamental objective of interior environmental comfort in both winter and summer as well as day and night is to know the energy efficient necessities of architectural concepts. First of all, the local climatic conditions should be understood whether temperate, hot or cold, dry or humid. Since in this study the concerned city is Ankara (Turkey) which displays a temperate climate, the architectural design should be compact so that as little heat energy as possible is lost to the exterior. Moreover, the south facing façade should utilize maximum sun heat energy specially since Ankara has a cold dominated climate which means that winter is more dominant than summer. Mechanical heating is required during the winter while natural ventilation is required during the summer. If this ventilation is not enough in summer, then mechanical cooling could be a possible option.

As mentioned earlier, in Turkey 80% of the energy is used to provide interior comfort (Kavak, 2005); (Bektaş et. al, 2008). This high percentage of energy usage is due mostly to the existence of so many old buildings and the negligence of passive design awareness that reduce energy consumption that otherwise cause the release of pollutants due to the usage of high amounts of fossil fuels (Bektaş and Aksoy, 2005); (Bektaş et. al, 2008). As a necessity, it is therefore required that energy consumption should be reduced for countries like Turkey which imports much of the energy it consumes. Even though Turkey possesses much solar energy, almost no buildings use this passive solar technique to its advantage (Dilmaç and Kesen, 2003); (Bektaş et. al, 2008).

In order to achieve interior comfort and to conserve energy, proper design of the building envelope is a major factor. Passive heating conditions of the building envelope influenced by the opaque components, for example walls, and transparent components namely windows involves heat flow that changes indoor air and interior surface temperatures (Oral, 2000).

A passive design is one in which the thermal energy flow occurs by natural means. In other words, no external energy is needed for it to function. A part of passive design is to minimize heat loss by using multiple-glazed windows, and energy efficient insulation in the exterior and interior of walls, floors, roof and foundation. The advantage of passive design over fuel using conventional design is that it is nonpolluting, non-depleting of resources and even though costly in the beginning it has a low operating cost in the long run. Proper original construction of the design process together with its post occupancy operation are two important factors of passive design. In such a construction, it is important that the building envelope is air tight something which is achieved with sealed openings (Ogle and John, 1995).

The main factors that determine heat flow towards the interior of buildings are external conditions namely temperature, wind speed and exposure to sun rays, the area of exposure namely the building envelope and the heat transmission namely through the building wall and window system (Ogle and John, 1995).

In addition, when designing buildings, the most important factor to consider is its suitability to climate. An energy conscious designer must consider the local climate, outside temperature, wind, humidity and insolation. After proper consideration of climate analysis, the best choice of interior comfort conditions and the best strategies to be applied in achieving comfort should be selected. In different regions, buildings will have different shapes, materials, orientations and envelope characteristics (Hirst et al., 1986).

Especially in cold climates, the design uses the sun energy to achieve thermal comfort in winter. Most people prefer an indoor air temperature of between 18°C and 30°C and a range of relative humidity between 20% and 80%. Unwanted cold air movements, uncontrolled cold or hot interior surfaces and average radiant temperature conditions created by large glazing areas all affect comfort (ASHRAE Handbook, 1997).

Passive design strategies give the designer means to achieve comfort and reduce energy expenditure by the usage of natural methods. If not provided, mechanical means for heating and cooling in winter and summer should be implemented, that use fuel to achieve these comfort conditions (Krigger and Chris, 2009).

A large window glazing in the southern façade is beneficial for maximum interception of maximum solar radiation in winter while during summer this sun radiation may be reduced by means of curtains. Window location and size is the main factor that influences the energy consumption of the building. Windows located without consideration to sun light may be a source of heat loss or heat gain to the building.

Heat loss through the window is usually the same whenever it is located. Therefore, it is advantageous to locate windows where heat gain from sun radiation is more than heat loss in winter, for example on the southern façade, southern-eastern façade and southern-western façade (Mazria, 1979).

Wind flow around any building depends on its orientation, its relation with the surrounding buildings, plan shape, its height when compared to surrounding buildings, roughness of the terrain that direct wind towards it as well as the architectural features that increase wind flow towards it such as cantilevers on the façade.

Thermal mass with its potential of avoiding or reducing interior overheating has received more attention lately. In the past, this potential of thermal mass was minimally considered when used in passive solar design which works with the building's orientation, glazing type and size as well as the provision of shading.

Thermal mass is an important factor in passive design. The characteristic of thermal mass allows dwellings constructed with concrete and masonry blocks to use their passive solar qualities year round. During summer thermal mass construction helps in absorbing and storing heat existing during the day, thus lowering the interior temperatures and reducing interior overheating during the day. This stored heat may be removed by natural or mechanical ventilation during the night. On the other hand, during the winter the thermal mass absorbs the solar energy transmitted through the walls in the south façade, and then slowly releasing the heat into the interior at night thus maintaining warm spaces. The process of heat absorption and release occurring during the winter is similar to that process in summer with the exception that during the winter nights heat does not escape because the windows are kept closed.

2.2.1 Orientation

The importance of energy saving has increased with the increase of heating in buildings, the cost spent in its production and the pollutants released by the fuels that burn to achieve it. As a result, it is recommended that the building design parameters used in saving energy should also reduce conventional energy usage. Both the interior and exterior environmental conditions are related and affect one another. In order to provide interiors which are climatically comfortable building parameters namely the orientation of the building envelope, the building shape, and the insulation together should be considered by the designer (Aksoy and Inalli, 2006).

According to a study by Mingfang in 2002, the best orientation for both winter and summer is the southern one, since winter solar heat gain and summer solar heat control could be achieved. In his study, the solar control in summer for different geometrical shapes was investigated and the best shape that produces the optimum solar control was a rectangular shape (Mingfang, 2002); (Aksoy and Inalli, 2006).

A study by Lin in 1981 indicated that the energy consumption within building is dependent on the building shape. He found that in cold climates the larger the area of the exterior facing surface of a building, the more energy is required for heating. As a result, he concluded that the minimum exterior facing surfaces provided the optimum energy expenditure in cold climates (Lin, 1981); (Aksoy and Inalli, 2006).

Since the sun rises in the east, the flat spaces under study benefit from the morning sun in winter as shown in figure 5 below. In this eastern side, the morning and afternoon sun heat passes through the envelope and windows, thus maintaining a comfortable interior temperature in winter. During summer though, natural ventilation removes this eastern heat by the allowance of air circulation by the opening of interior windows and doors (Waterfield, 2007).

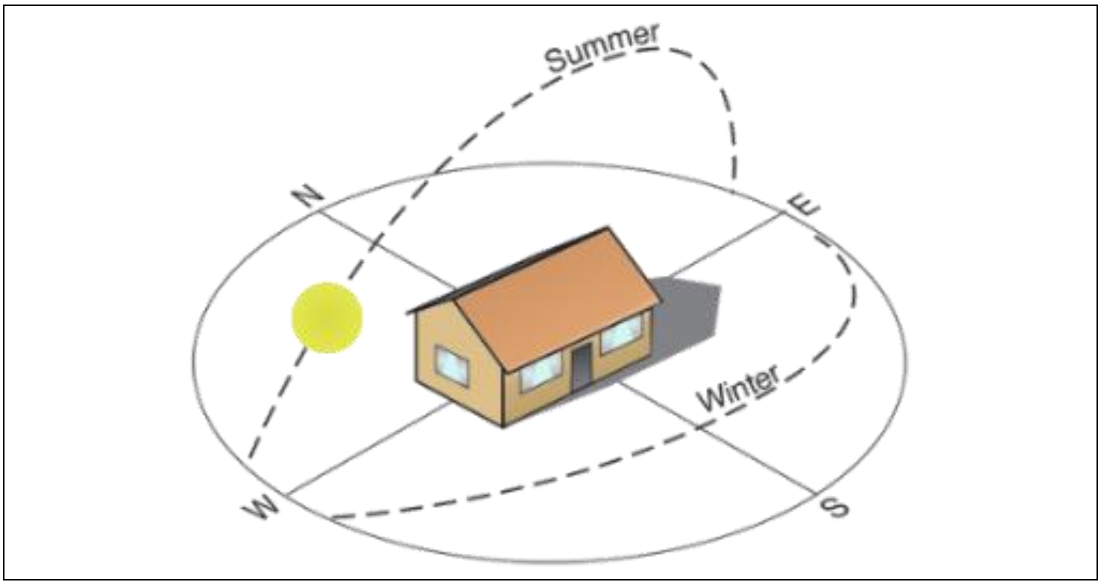

Figure 5 Orientation (http://www.ecowho.com, Last Accessed 04 / 01 / 2014).

The western facing architectural spaces only benefit when the evening sun's heat penetrates the western windows, doors and envelope. Thus, suitable comfort temperatures in the air tight flat is maintained during the winter month and if this comfort is not achieved, interiors could be heated by mechanical means (Kachadorian, 1997).

In the northern side, where the least sun penetrates, a mechanical heating system should be turned on during the winter and the windows should be used for light allowance. During the summer, the windows of the northern facing flat and interior doors are opened for the sake of natural ventilation and cooling to achieve interior spaces comfort (Kachadorian, 1997).

2.2.2 Ventilation

Within buildings, ventilation occurs through openings such as windows or ventilators by means of natural driving forces. By the effect of pressure distribution on the building envelope as well as the location of the different windows in the interior, the air flows. As the pressure distribution acts as the ventilation driving force, the characteristics of the window openings account for the air flow resistance not forgetting other factors (Rousseau and Mathews, 1996).

The factors that cause air flow within the interiors are the wind induced pressures on the building envelope and also the pressures caused by differences in interior and exterior air temperatures. Wind induced pressures are caused by the geometry of the building, the wind speed, the orientation of the building with regard to the wind direction as well as the surrounding environment (Rousseau and Mathews, 1996).

2.2.3 Thermal Comfort

Interior environment thermal comfort is the most important factor for occupants. To achieve this much artificial energy for heating the interiors is necessary especially in cold climates. Furthermore, to achieve interior thermal comfort and decrease heating energy consumption parameters such as building form and building envelope should be considered mutually at early design stages (Oral and Yılmaz, 2003).

The shape of the building as well as the thermal transmittance or overall heat transfer coefficient (U-value) of the building envelope affect the loss of heat through it to achieve interior thermal comfort and heating energy conservation (Oral and Yılmaz, 2002).

Provision for suitable interior temperatures and dwellers comfort should be considered. Thermal comfort is achieved when the state of mind of the occupants is satisfied within the thermal dwelled zone (ASHRAE, 1981); (Oral and Yılmaz, 2002). In cold climates, if thermal satisfaction is not achieved within the occupied zones, then provision of artificial heat would be required. Since more energy is used to fulfill this artificial heating, energy sources are depleting rapidly. Thus, energy conservation has become a major subject in developing countries such as Turkey.

Energy consumption of buildings in the form of heating is a major issue in Turkey. To decrease this form of energy consumption, a regulation was released, as shall be discussed later, in April 1998 (TS 825, 1998); (Oral and Yılmaz, 2002). This regulation recommended that architects construct buildings that maintain an upper limit of yearly heat loss. Even though this new regulation was a significant step to conserve energy, it is still insufficient in affecting design parameters to achieve thermal comfort and total heating energy conservation (Oral and Yılmaz, 2002).

Climate comfort in interiors is the most important biological requirement for its occupants and must be maintained in order for the users to be healthy and productive (Manioğlu and Yılmaz, 2006).

An interior could be described as a passive system if comfort could be achieved without the usage of mechanical means. However, for climates where there is changeable diurnal climate, additional mechanical heating would be necessary for the winter months of the year since designed passive systems would not be enough to heat the interiors (Yılmaz, 1990); (Energy in architecture, 1994); (Manioğlu and Yılmaz, 2006). In such a case where a mechanical heating system becomes necessary, the energy load consumed would be related to the thermal behavior of non-mechanical passive heating system represented by the building envelope. The building envelope, which is the major parameter of this passive heating system, is also the barrier between both the interior and exterior environments and is thus the means through which heat flows into and out of interior. Therefore, the building envelope not only determines the interior climatic environment but also the extra energy released by additional mechanical system (Selamet, 1995); (ASHRAE, 1981); (Manioğlu and Yılmaz, 2006).

Changeable diurnal climates cause intermittent heating system operation, leading to different amounts of interior energy stored and released by the building envelope and the different thermal behavior within the building (Lechner, 1991); (Manioğlu and Yılmaz, 2006).

Thus, the quantity of additional energy is dependent on the thermo-physical characteristics of the building envelope as well as the operation period of the heating system. The builder who designs the dwelling should investigate and select the most economical building envelope and operation period options according to the required heating demand daily period. To achieve a minimum cost value from among the different options, an economic analysis should be done and the most energy efficient and economical alternative should be selected (Manioğlu and Yılmaz, 2006).

It is an important function for buildings to provide thermal and visual comfort (Hunn, 1996); (Jaber and Ajib, 2011). The main aim of the designer is to design buildings that would achieve interior thermal comfort throughout the entire period of the year (Goulding et.al., 1992); (Jaber and Ajib, 2011). Moreover, windows play a major role in achieving both psychological and environmental needs. Suitable window glazing could produce low heating and cooling energy outputs, thus being an important source that cause psychological benefits (Menzies and Wherrett, 2005); (Jaber and Ajib, 2011).

Internationally, the aspect of interior thermal comfort is standardized according to energy balance (static models), for example the ASHRAE standard. According to this standard the temperature range within which comfort is achieved was between 20 and 27°C. Figure 6 below shows the winter and summer limits that must be maintained in order to achieve thermally comfortable interior for the occupants.

The international ASHRAE standard is acceptable as a defining reference of the thermal comfort zone worldwide (Hays et.al, 1995); (ASHRAE Handbook, 1997).

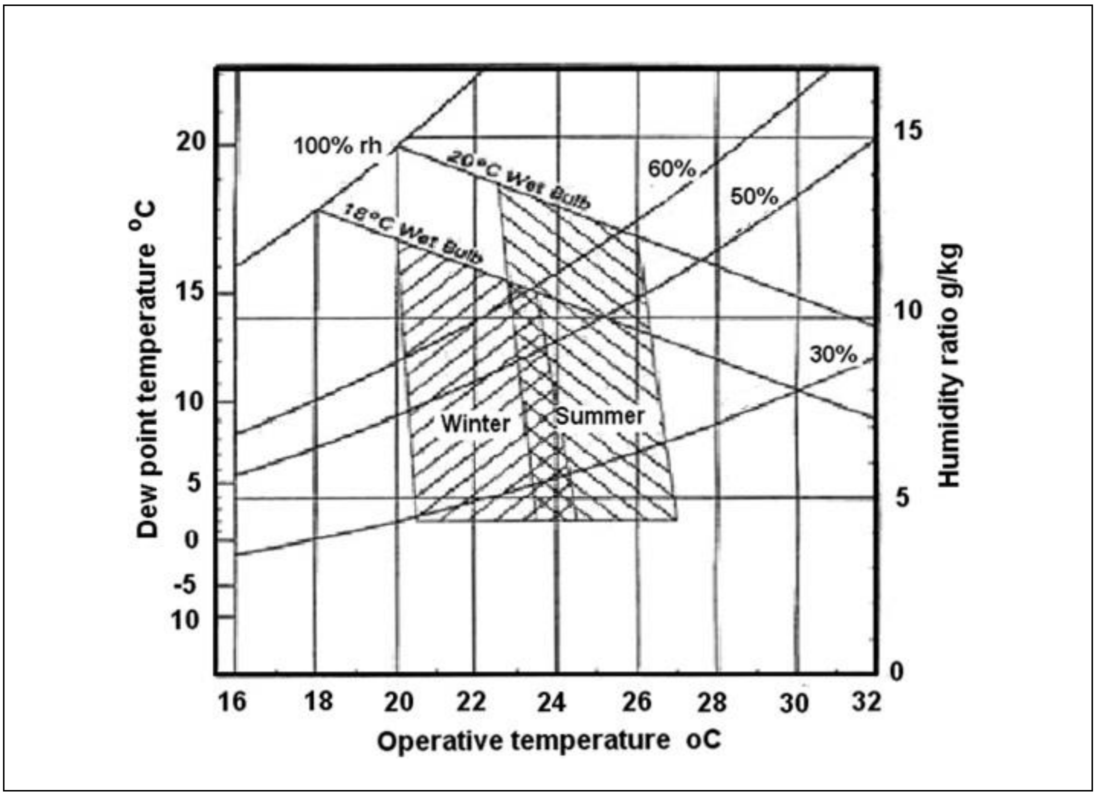

Figure 6 ASHRAE comfort zone (ASHRAE Handbook, 1997).

2.2.4 The Building Envelope

As mentioned earlier, there are several environmental factors within interiors that determine thermal comfort namely temperature, air flow, lighting, noise and humidity. In addition, the presence of the building envelope is to keep the interior environment within acceptable limits (Hutcheon and Handegord, 1989); (Rivard et.al., 1995). As a protective barrier, the building envelope may achieve thermal comfort by means of energy efficiency, cost, durability, and other performance criteria (Gowri, 1990). According to Hutcheon, 1963 a number of necessities required to be fulfilled by the building envelope are proper heat flow, proper air flow and proper sunlight and radiation as well as being economical.

These factors not only apply for walls but also for other parts of the building envelope elements such as roofs and window openings. To obtain energy efficient performance and quality, the above mentioned necessities have to be treated and designed holistically during the early stages. Since they are all inter related such efficient design is a complex task (Gowri, 1990).

The building envelope includes four subsystems namely; the roof, the windows, the walls, floors and contact to ground. These subsystems are made of many components and different materials with different characteristics (Krigger and Chris, 2009)

Buildings that control energy loss during winter as well as reduce energy gain during summer are the most ideal in reducing heating and cooling needs. To achieve energy efficiency in a new building the plan, design and construction should be energy efficient. For residential buildings, energy loss and gain through the exterior envelope are the most important energy occurrences (Krigger and Chris, 2009).

The more the temperature differences between the interiors and exteriors, the more is the expectancy from the building envelope in achieving the necessary degree of comfort. Thus the need to select the proper building envelope components is required. To achieve this, the following should be included:

1) Insulation to controls heat flow,

2) Glazings that permit light and view but at the same time also control heat flow between the exterior and the interior,

According to a study by Balcomb in 1978, the suitable glazing area used in south facing walls as well as proper thermal insulation applied to the wall and roof components were used to maintain a building thermally comfortable by comparing the direct solar gain concept through the south facing windows. He combined thermal insulation and thermal mass in the south wall and evaluated solar energy gain during the day time as well as the night time (Balcomb, 1978); (Jindal et al., 2013).

A number of studies by several authors Persson et. al. in 2006, Nielsen et. al. in 2000, and Sujoy et. al., in 2009 have investigated extensively the energy performance of glazings and windows while considering various parameters like window size, the thermal transmittance (U-value) and total solar energy transmittance (g-value) etc. of the building envelope (Persson et al. 2006); (Nielsen et. al., 2000); (Sujoy et al., 2009); (Jindal et al., 2013)

Several studies by Çomaklı and Yüksel in 2003, Şişman et al. in 2007 and Mahlia et al. in 2007 investigated the effect of the thickness of insulation on the external surface of walls and roof for energy saving (Çomaklı and Yüksel, 2003); (Şişman et al., 2007); (Mahlia et al., 2007); (Jindal et al., 2013).

Since much of the world's energy is used in the building sector resulting in greenhouse gas emissions, an increase in the demand to achieve energy efficiency of buildings is also necessary. Thus concepts such as passive houses and zero emission buildings were introduced. As mentioned earlier, an important part of the achievement of building energy efficiency is thermal insulation. In addition to old insulation materials, new thermal insulation materials with lower thermal conductivities and increasing thicknesses that could be installed within the building envelope are increasingly being created. On the other hand, thicker walls are not recommended since they are economically costly, wasting useful interior area, increasing transport quantities, requiring architectural regulations and other disadvantageous architectural limitations, causing unnecessary waste of materials as well as causing change in already followed construction techniques (Jelle, 2011).

The economy of the building envelope in term of cost may be divided into three ways during the different periods of the design and construction. They include:

1) The initial capital investment construction costs for the design, manufacturing and construction stage,

2) The usage costs including the annual energy expenditure costs,

3) The maintenance costs which include cleaning, repairing of the window glazing and the other envelope parts during their usage life. This also includes their replacement costs after the usage life have expired.

Air temperature is usually the most important factor determining comfort. Outdoor temperature changes depending on the season, the climate and the time of day. If the building envelope is not air tight, heat is lost in winter and gained in summer. Heating and cooling systems create comfort by adding or subtracting heat (Hirst et al., 1986).

The building envelope leaks at edges, corners, openings and joints between the building materials. In addition, thermal energy leaks also occur through insulation, mechanical and electrical components which form the main defects of the building envelope. Heat flows through the building envelope by two means namely transmission and air leakage. Both occur through floors, exterior walls, windows and exterior doors (Hirst et al., 1986).

When compared to other building envelope components, windows have a major impact on comfort due to their low resistance and high solar transmittance compared to other building envelope components. By means of radiation windows cause sensitive human bodies and interiors to heat during the winter in cold climates.

On the other hand, during winter cold air is collected in the interior of the cold window glazing leading this air to move downwards resulting to cool convective currents. Further, air leakage adds to the energy problem losses or gains of the windows. In summer heat through windows heats the interiors leading to increase of interior temperatures and thus causing discomfort (Hirst et al., 1986).

The rate of heat flow or thermal conductivity of a material depends on the materials molecules to send and receive heat. Glass is a good conductor of heat. Insulation materials such as air or gases (argon), with tiny air gaps, are poor heat conductors.

Not all materials absorb thermal radiation. They may reflect or transmit it. This ability of reflectance and transmittance depend on the composition of the surface. Glass allows visible solar radiation while absorbing thermal (infrared long wavelength radiation) that it intercepts when special provisions such as low-e coatings are applied (Mazria, 1979).

The building envelope should be designed to provide for several characteristics namely environmental, technological, socio-cultural, functional and aesthetical as shown in the figure 7 below. When considering the environmental factors namely heat, light, and sound the thermal, visual and acoustical parameters are accounted for. The thermal parameter is concerned with the control of the interior and exterior climatic conditions, while the visual parameter is concerned with ability to see the exterior and allow light. As for the acoustical parameter the concern is to maintain a quieter interior (Oral et. al., 2004).

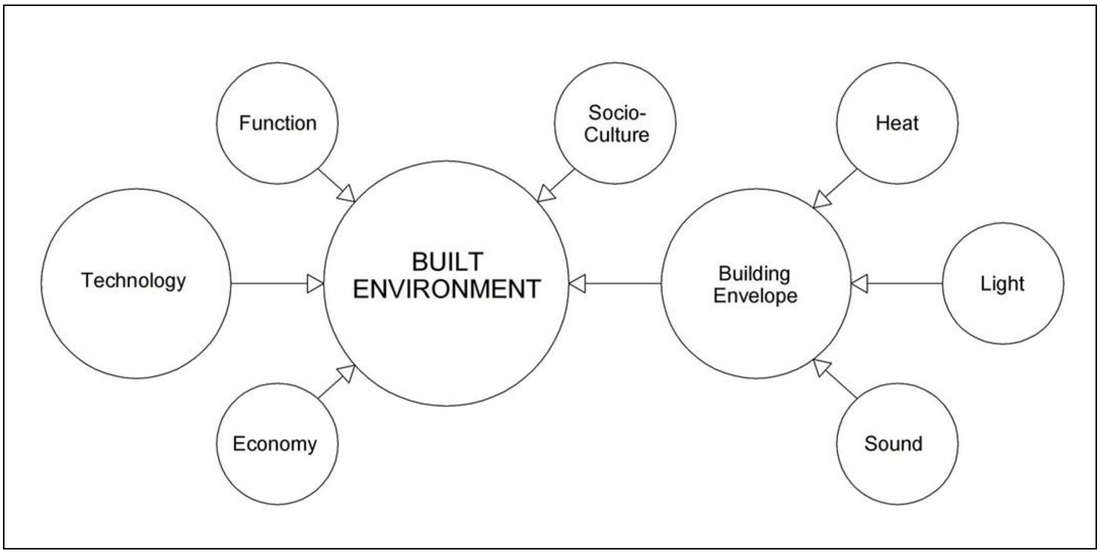

Figure 7 Factors that influence the building envelope design (Oral et. al., 2004).

Part of the physical environmental characteristic is thermal transmittance which may be defined as the heat flow over a period of time through a unit surface area once the difference in temperature between the two concerned surfaces is one degrees Kelvin. It is the reciprocal of the total resistances of all the components of the material concerned as well as the interior and exterior air film resistances. Thermal transmittance is also known as the overall Heat Transfer Coefficient, U-value with the units W/m2-K (Btu/h-ft2-F) (Al-Homoud, 2005).

Specific heat is the quantity stating the amount of heating energy needed to add to the temperature of a certain mass of any substance by a known amount. The lower the specific heat of a material, the faster it heats up and the faster it cools down. On the other hand, the higher the specific heat of a material, the slower it heats up and the slower it cools down. In cold climates, materials with high specific heat values are better because during the day heat is absorbed slowly thus maintaining a warmer interior until late hours of the day when the material cools slowly. Insulation materials have high specific heat values (Hirst et al, 1986).

The true density may be defined as the ratio of a mass of a material to the volume occupied by this same mass. Moreover, the factors that density depends on are temperature and pressure. An increase in pressure of a substance decreases its volume and thus increases its density. An increase in temperature of a substance (with a few exceptions) decreases its density by increasing its volume. The lower the density of a construction material, the lower is its thermal conductivity because of higher distance between molecules that transfer the energy, thus the material is characterized as an insulation material. Thus, the good insulation material namely Expanded polystyrene (EPS) has a low density (Lowell, 1991).

Thermal mass is used because of its importance in both winter and summer. In winter, when the thermal energy stored by a wall system during the sunny daylight hours is released towards the interior during the late hours of the day or night, energy for heating is reduced. During the sunny daylight hours of the summer, heat is stored by the wall system with thermal mass characteristic leading to a time lag or heat transfer delay until late hours of the day or night as shown in figure 8 below (Hall, 2010).

For example, heavyweight concrete masonry block, with its higher density and higher heat capacity, have a higher thermal mass when compared to lightweight concrete masonry blocks. This influences their behavior in summer and winter. In summer the choice of heavyweight concrete masonry results in cooler interiors during the day when compared to light weight concrete. Excess heat may be removed by means of either natural or mechanical ventilation (ASHRAE 90.1.American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2004 & 2007).

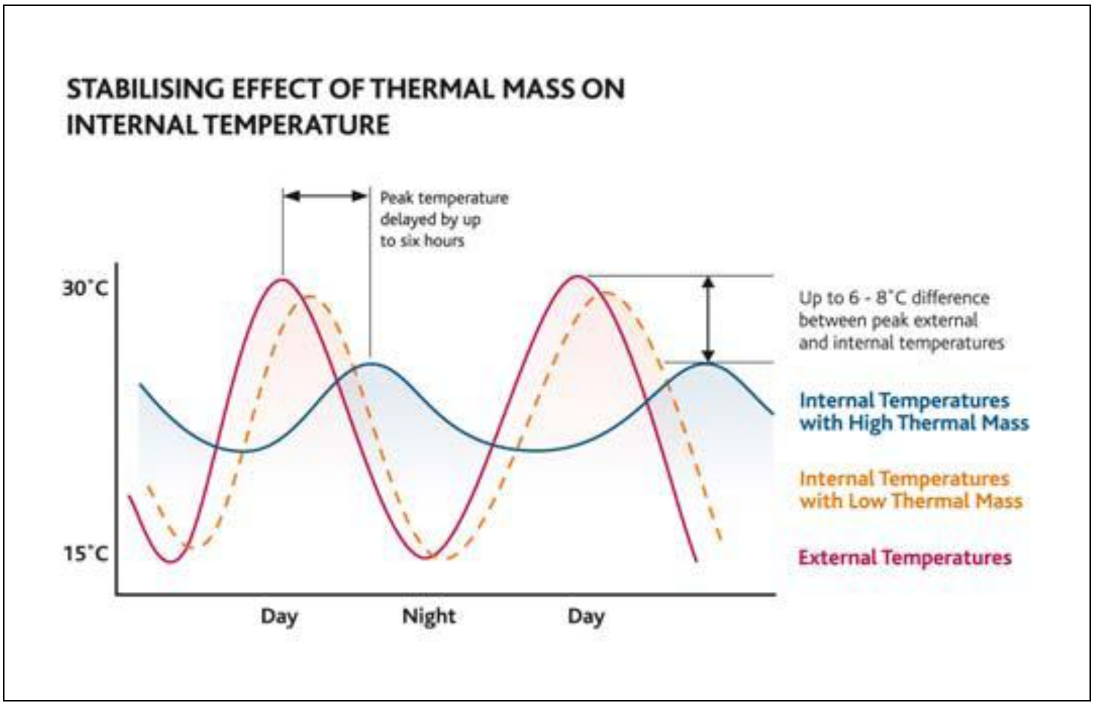

Figure 8 Thermal Mass (http://www.britishprecast.org,Last Accessed 26 / 04 / 2014).

The denser the material, the less air is trapped and thus the higher is its thermal mass. As such concrete has a high thermal mass when compared to Autoclaved Aerated Concrete (AAC) which has moderate to low thermal mass and a low insulation value as shown in table 3 below (Baggs and Mortensen, 2006).

Table 3 Thermal mass for various materials (Baggs and Mortensen, 2006).

Material	**Thermal Mass**
Concrete	2060
Autoclaved aerated concrete	550

Thermal mass also has a significant influence during the night when the outdoor temperatures are lower than the interior temperatures especially in summer. Here the interiors may be cooled by means of natural night ventilation. Moreover, this ventilation helps in removing the convective heat from the mass elements.

Another means of removing convective heat during the night may be the usage of ceiling fans. The implementation of ceiling fans is useful in adding to the interior air circulation and also increasing the convective heat transfer coefficient which helps in the reduction of the heat collected by massive walls at night (Baer, 1983); (Balaras, 1996). Another function of the building envelope in cold climates is to maintain high thermal transmittance at night and low thermal transmittance during the day.

Together both ventilation and thermal mass act as a passive cooling system that may be utilized to preserve the interior environment thus maintaining interior thermal comfort as well as providing acceptable indoor air quality (IAQ). Ventilation has three functions namely to improve indoor air quality, to provide interior occupant cooling and finally to cool the thermal mass of the building (La Roche and Milne, 2004) (Zhou et al., 2008). The last function of ventilation works by the heat storage of interior and exterior mass during the day's hot duration and it's release later in the day (Yam and Zheng, 2003); (Zhou et al., 2008). Moreover, natural ventilation is a good method to remove interior air pollutants and provide an acceptable indoor air quality. As a result, collectively ventilation and thermal mass could lower capital, operational, and maintenance costs, obtain a sustainable building and improve the indoor air quality (Zhou et al., 2008).

The optical and thermo-physical characteristics of the building envelope also affect the passive heating function of its elements namely the opaque (walls) and transparent (windows) components. Optical properties are:

1) Absorptivity which is the ability of the building envelope to absorb heat,
2) Transmissivity which is the ability of the window to transmit heat. It is not valid for opaque components, and
3) Reflectivity which is the ability of the building envelope to reflect heat.

The thermo-physical properties are:

1) Overall heat transfer coefficient or thermal transmittance (U value),
2) Transparency ratio (TR), (TR = window area / facade area).

To achieve thermal comfort by using minimum additional mechanical heating energy, architects should design the building envelope in such a way so as to have the suitable thermo-physical properties (Overall heat transfer coefficient or thermal transmittance) for the local climate. Under these passive heating design conditions of the opaque and transparent components of the building envelope, interior air and surface temperatures change with the change of heat flow. The change of heat flow is therefore the function of the thermo-physical characteristics of the opaque and transparent components of the building envelope, and thus these characteristics determine the interior climate as well as additional mechanical heating energy. Put in another way these thermo-physical characteristics affect the heating load within the immediate space. Moreover, when the mechanical heating or cooling remains switched off, hourly change in interior air temperature becomes relative to the solar energy gain through the window. In addition, the surface temperature of the glazing which has different qualities when compared to the other building envelope surfaces has a major influence on the interior thermal comfort. Therefore, the optical and the thermo-physical characteristics of different windows have a major influence on the interior thermal comfort as well as the supplementary mechanical heating or cooling (Yılmaz, 1987); (Oral, 2000).

At the section of the exterior wall of the building envelope different temperature profiles occur during any instant of a 1-day period. These temperature profiles depend on the interior temperature, the exterior temperature and the thermo-physical properties of the wall. During the 1-day period the outside temperature changes periodically causing new different temperature profiles at any moment of time during the day. During this transient procedure, a heat wave flows through the wall from the exterior to the interior. Here the amplitude of the heat wave indicates the temperature values, while the wavelength of the heat wave indicates the time that these temperatures occur. The amplitude of the heat wave at the exterior surface of the wall has a value of solar radiation and convection occurring in between the exterior wall surface and the exterior air. During the transmission of the heat wave through the wall, its amplitude decreases according to the thermo-physical characteristics of the wall materials. This amplitude continues to have a lower value as it passes through the wall when compared to its value in the exterior surface. The time the heat wave takes to cross through from the exterior surface to the interior surface is called the "time lag" while the decreasing ratio in the value of the amplitude during this process is called the "decrement factor" (Duffin, 1984). Time lag and decrement factors are significant properties in the determination of the heat storage capabilities of any material. Different time lag and decrement values could be obtained with different thicknesses of wall materials and their thermo-physical properties (Asan, 2000). The heat storage in wall structures may be explained by two characteristics namely time lag and decrement factor.

> "Temperature profiles on the wall exposed to periodic solar radiation and varying outdoor air temperature are assumed to be propagated as sinusoidal waves. When a sinusoidal temperature is propagated through the wall from outdoor surface to indoor surface, its amplitude gradually decreases in a manner that depends on the thermo-physical properties of the wall materials." (Özel and Pıhtılı, 2007).

In buildings, the effect of thermal mass must be considered when located in the four different façades to achieve the desirable time lag (Lechner, 1991); (Balaras, 1996). For example, in cold climates it is important to mention that both the North and East orientations could perform without the need for time lag since immediate heat energy is required to be transmitted to the interior. However, for both the South and West façades a time lag of eight hours is enough for the heat energy to delay its transmission from midday until the late evening hours something which is beneficial in summer.

In recently conducted studies by the author Asan in 2000, the effects of the wall's thermo-physical properties, insulation position and thickness on time lag and decrement factor were investigated (Asan, 2000).

It was shown that thermo-physical properties, thickness and position of wall materials have a very profound effect on the time lag and decrement factor. These studies were parametric in nature and most of the results came out from these work were practical. (Asan and Sancaktar, 1998); (Asan, 1998); (Asan, 2000).

On the other hand, thermal mass and thermal insulation, together, are significant because they influence the total thermal performance of a building (Hopkins et.al., 1979); (Balaras, 1996).

2.2.4.1 Windows (Openings)

Since windows are important parts of the building envelope which have significant effect on the energy performance, they have to be chosen with care (Urbikain and Sala, 2009). Within building envelopes, the windows are the main source of thermal losses to the exterior. In cold climates, an amount of 10% to 25% of the heat loss is transmitted through windows to the exterior (Ismail, 2003).

Windows being an important component of the building's energy system transmit solar radiation and thus cause thermal losses. The improvement in window technology has helped in reducing heat losses from interiors in cold climates. (Persson, 2006).

Windows are available with great variety. To choose a specific window for an application many factors have to be considered. These factors may be seen in the figure 9 below. Windows allow light and exterior views, block heat radiation, resist fire and could affect the aesthetics of the exteriors. However, the windows' behavior on energy efficiency as part of the building envelope is considered in this thesis. This does not mean that the other factors are not important (Persson, 2006).

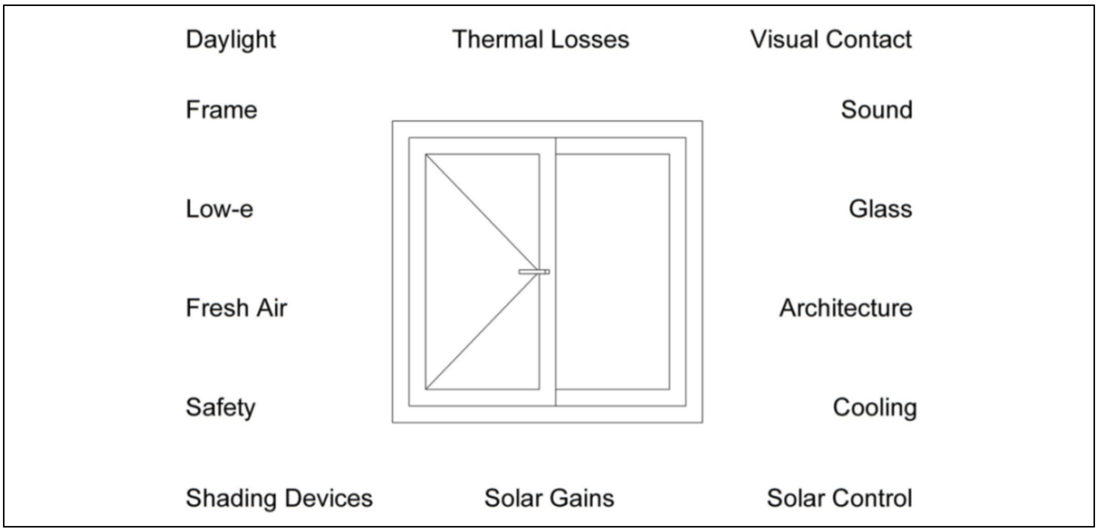

Figure 9 Different factors related windows (Persson, 2006).

In cold climates, window technology may cause them to function in two main ways namely by the application of low emissivity (low-e) coated glazing that save energy by reducing thermal losses and the application of solar control glazing that prevents solar heat gain into the building. Totally, windows should provide for high transmittance of visual light without reducing the effect of the above two mentioned capabilities. This is possible by constructing optically selective window glazings that allow some of the radiation and reflect another part. This gives window glazings an important property since solar radiation consist of not only visual light but also heat radiation in the form of long-wave infrared radiation (Persson, 2006).

The application of different types of glazing tints can block the sun rays. They decrease the visible light transmittance as well as some of the heat radiation, however these tinted glazings have no low emissivity characteristics (Persson, 2006). In efficient design, the selection of a window glazing not only depends on the application of a suitable coating combined with low thermal transmittance, but also on the window size, orientation and the proper usage of shading devices. The selection of large windows not only cause heat losses in cold climates during the winter and nights, but also cause more solar heat energy gain during sunny periods when compared to gains of a well-insulated wall (Persson, 2006).

In Turkey, the usage of large window glazing areas increased leading to the need to the usage of more double pane window glazings. An important factor that affects the energy efficiency of the double pane window glazing is the thickness of the air or inert gas cavity which has a considerable effect on the energy losses through the window. Therefore, the optimum thickness should be used within the double pane window (Aydın, 2000).

According to TS 825 which is the Turkish standard for the minimum U-Value (thermal transmittance) the transparent part of the building envelope, the window, remains much higher than the remaining opaque part. The TS 825 regulation attempts to solve the long prevailing problem of energy conservation within residential buildings.

In addition to being an important parameter where heat is lost in winter, glazing is also concerned with significant solar energy gains in summer (Manz, 2003).

Much research has been studied regarding glazing technology. The researches focused on reducing the heat transmission through glazings to decrease the need for heat and to achieve thermal comfort within interiors in cold climates. Topics such as low emissivity coatings, gas fillings, spacers, evacuated cavities were considered in the following investigations by (Manz, 2008); (Braeuer, 1999); (Collins and Simko, 1998); (Weinlaeder et al., 2005); (Ng and Collins, 2005); (Eames, 2008); (Manz, 2003);

Nielson et al. in 2000 showed an easy way to find the total energy gains of glazing and compare the energy performances of different types of glazing and windows. Khaled in 1998 investigated the ways of controlling the sizes of windows to achieve passive heating, cooling, and illumination in hot arid regions. Oral and Yılmaz presented a methodology for building form factor that provides minimum loss of heat that is transmitted through the building exterior (Oral and Yılmaz, 2003).

A number of investigations have been undertaken that helped builders in choosing the best window options in buildings. An investigation by Apte et al. in 2003 found that when windows with low-e were applied in many US climates around forty percentage of energy could be used (Apte et al., 2003)

Pyeongchan et.al. in their investigation in 2012 simulated several window options within residential buildings in two cities namely Inchon and Ulsan is South Korea. They investigated the window-to-wall ratios, U-value and SHGC values of several window options and compared their impact on heating, cooling and total energy usage in the two cities that represented two different climates in South Korea. The results showed that with the addition of characteristics to the windows neutral and positive energy influences could be obtained to the interiors specifically for the temperate weather of Inchon. It was also found that high levels of SHGC are preferable for windows designed in residential buildings of large windows in mild climates. In Korean window standards, there is provision for U-value but non for SGHC. Moreover, it was obvious that a better energy performance was obtained when double glazing with low-e coating was used in residential buildings when contrasted to plain double glazing. A life-cycle cost analysis of a number of windows concluded that double clear glazed windows with low-e and a cavity filled with argon gas were economical for dwellings in South Korea and were therefore recommended to be used for the standard code. In the other triple, glazing windows with low-e that produced higher energy savings and carbon reductions however were not economical for usage in dwellings in South Korea.

According to Arasteh et al. in 2006 and Freire et al. in 2011, the window percentage for suitable energy composition for heating and cooling according to HVAC standards in the US were twenty four percent for dwellings and thirty two percent for commercial buildings (Arasteh et al., 2006); (Freire et al., 2011).

Moreover, according to Florides et al. in 2002 and Freire et al. in 2011, yearly cooling energy savings of about twenty four percentage of a properly insulated residence could be obtained once a double-glazed window with low-e when contrasted to a clear-glazed window (Florides et al., 2002); (Freire et al., 2011).

Works in the last few years by, e.g. Askar et al. in 2001, Omar and Al-Ragom in 2002, Bahaj et al. in 2008, Loutzenhiser et al. in 2008, Poirazis and Blomsterberg in 2008, Perez and Capeluto in 2009, Papaefthimiou et al. in 2009, Tanaka et al. in 2009, Urbikain and Sala in 2009 and Freire et al. in 2011, increase the knowledge and choice of high performance window glazings that could be used in buildings.

There have been several other studies on the energy efficiency and cost analysis of different windows units. Karlsson et al. in their paper in 2001 further improved a simple model for yearly energy balance of windows by considering their solar radiation and heat losses. They used hourly meteorological data to find out the total energy heat flow through the windows by means of knowing the solar radiation, outside dry bulb temperature, and the windows' optical and thermal performance. By using only the balance temperature as an initial input, the model implemented compared different advanced windows in different buildings, orientations and geographical locations. One example, held in a typical mid-Swedish climate was the evaluation of the energy balance and cost efficiency of a number of window combinations within a building (Karlsson et al., 2001); (Maçka and Yalçın, 2011).

Çetiner and Özkan in their study in 2005 investigated an energy and economic efficiency procedure for different single-glazed and double-glazed building envelope configurations of a 30 floored office block in Istanbul. By following a number of steps such as some aims / limitations, a process of performance criteria and optional alternative solutions, a building model including thermal-optical properties, heat gains/losses, total energy loads and life cycle costs measured by using a software simulation, and finally concluding with a comparison of energy efficiencies and an exploration of efficient optional alternatives. From their results, they found that when comparing the most efficient double-glazed façade to that of the most efficient single-glazed façade the advantage was for the double-glazed option by a percentage of about 22.845. They also found that the most cost effective single-glazed option was about 24.68% more efficient than that of the most cost effective double-glazed option (Çetiner and Özkan, 2005); (Maçka and Yalçın, 2011).

In 2008, Maçka developed the Win-Energy 1.0 software to measure the thermal performance effects and energy loads on different window options. The study involved the investigation of eight widow options of single-pane glass installed in different double-glazed and triple-glazed units, all experimented in different Turkish climatic regions (Maçka, 2008); (Maçka and Yalçın, 2011).

In 2009, Urbikain et al. in their study suggested three ways in calculating the heating loads and energy savings obtained by the testing of different window options of a residential building. The first method investigated the measuring of the energy loss of the windows considering only the climatic conditions. The second method involved the influence of the windows on the energy from the heating system by considering the climatic conditions and building type. The third and final method was the usage of software namely TRNSYS16 and WINDOWS5 to obtain energy simulation results. These three energy oriented methods were applied to ten window types with different orientations and window-to-wall ratios. The first method resulted in insufficient heating saving values within the building. The second method resulted in similar conclusions as the simulation third method, with the exception of the results obtained for the case of the solar control or spectral-selective glazing (Urbikain et al., 2009); (Macka and Yalçın, 2011).

The introduction of double-paned windows to glazing to buildings is one way in reducing heat losses from interiors (Korpela et al., 1982); (Wright, 1996); (Karabay and Arıcı, 2012). The stagnant air layer filing the cavity of the double-paned window prevents heat flow into the interiors. Increasing this air cavity beyond a certain limit provides a negative effect by initiating convective currents and thus increasing heat transfer (Aydın, 2000); (Çengel, 2003); (Karabay and Arıcı, 2012). In order to be able to increase the air cavity triple-paned and quadruple-paned windows have been introduced recently (Robinson and Littler, 1993); (Roos and Karlsson, 1994); (Manz et. al., 2006); (Fang et. al., 2010); (Manz, 2008); (Karabay and Arıcı, 2012). Further energy savings may be achieved with the replacement of this stagnant air layer by inert gasses such as argon, krypton or xenon (Reilly et. al., 1990); (Weir and Muneer, 1998) (Karabay and Arıcı, 2012) or by aerogel (Reim et al., 2002); (Jensen et al., 2004); (Schultz et al., 2005); (Karabay and Arıcı, 2012).

According to a study in 1999, Larrson et al. investigated the combination of few of these considered window design options and designed a high performance window glazing. This super window was tested for efficiency. They found that the window's specification influence on the building interior is dependent on its characteristics, its orientation, and the climatic conditions. (Larrson et al., 1999); (Karabay and Arıcı, 2012).

Another research by Perrson et al. in 2006 studied the effect of the size of windows in Sweden and their energy performance of properly insulated buildings with the usage of a progressive building simulation software. They concluded that if the long-established methods to create lower energy were replaced by the addition of larger north facing windows better lighting could be obtained if triple-glazed windows were used (Perrson et al., 2006); (Karabay and Arıcı, 2012).

According to a research in 2010 by Hassouneh et al., the effect of window glazings in many of Amman's residences and how they influence energy performance was tested. By developing a simulation software using ASHRAE tables and applying it to their investigation, they concluded that glazing area within building could be increased in the case that energy efficient windows were used (Hassouneh et al., 2010); (Karabay and Arıcı, 2012).

According to a study by Sullivan and Selkowitz in 1985, an investigation was undertaken to analyze single, double and triple paned window glazings in terms of their energy efficiency in hot and humid, hot and dry, temperate and cold climates of the USA (Sullivan and Selkowitz, 1985); (Jaber and Ajib, 2011).

According to a study by Rousseau in 1988, an investigation involving double and triple glazed windows which accommodates two and three panes of glass respectively with an air or inert gas layers between their panes was undertaken. These double or triple glazed windows provide more thermal resistance when compared to single pane windows. The reason for this is that the air or inert gas layer prevented the heat flow towards the interior, while the single pane windows did little to hinder the heat flow exchange (Rousseau, 1988); (Jaber and Ajib, 2011).

As mentioned earlier, glazing (windows) add to the high energy losses from the interiors. For this reason, there is a high demand from the energy designer (architect or HVAC engineer) to design the residents according to the local outside climatic environment so as to keep both the interior spaces suitable for living and the occupants comfortable. To achieve this comfort, windows which are double glazed and triple glazed are first tested before being recommended for installation in the residential building.

Also building designers know that windows like triple glazing not only have the property of being highly insulating but also have low solar transmittance. This fact is important in summer were the window allows for reduced solar gains into the interior and reduce energy loads for cooling. However, in winter such reduction in solar gains into the interior overcomes the decrease of thermal losses and thus increases the need for energy in the form of heating (Gasparella, 2011).

Table 4 Heat conductivities (k) of gases used in double and triple windows (Çetiner and Özkan, 2004).

Gases	k value (W/m x K)
Air	0.02730
Argon	0.01772
Krypton	0.00949
Xenon	0.00569

With technology, window glazings have improved by the additions of cavities that act as thermal buffer zones that resists heat propagation (Çetiner and Özkan, 2004); (Bektaş, 2008). Once filled with inert gases mainly argon, krypton or xenon that have lower heat conductivities respectively compared to air these cavities together with panes pasted with low-emittance coatings could perform efficiently. The heat conductivities of these gases used in double or triple windows are shown in table 4 above (Bektaş, 2006); (Bektaş et al, 2008). Such improvements to the window glazings technology has allowed for the design of triple glazing windows with U-Values that could be as low as 0.5 W / m2.K for use in low energy buildings (Manz et al., 2006).

Much of the residential buildings in Turkey have low performance single-glazed windows installed. As a proportion, 87% of the residential buildings in Turkey have single-glazed windows installed, 9% have double-glazed windows, and an amount of 4% have low-e coatings (MVV Consultants and Engineers, 2004). In Turkey, recently, little application of triple-paned window has been seen let alone quadruple-paned windows which are still to be introduced to Turkey.

When the window is placed into the wall, it usually causes a thermal bridge or temperature exchange through the construction. While installing the windows in the center of the opening results in the lowest thermal bridge values. On the other hand, locating the window close to the inner side or outer side of the opening both result in high heat losses (Bülow-Hübe, 2011). Window systems consist of glass panes, structural frames, spacers, and sealants as shown in figure 10 below.

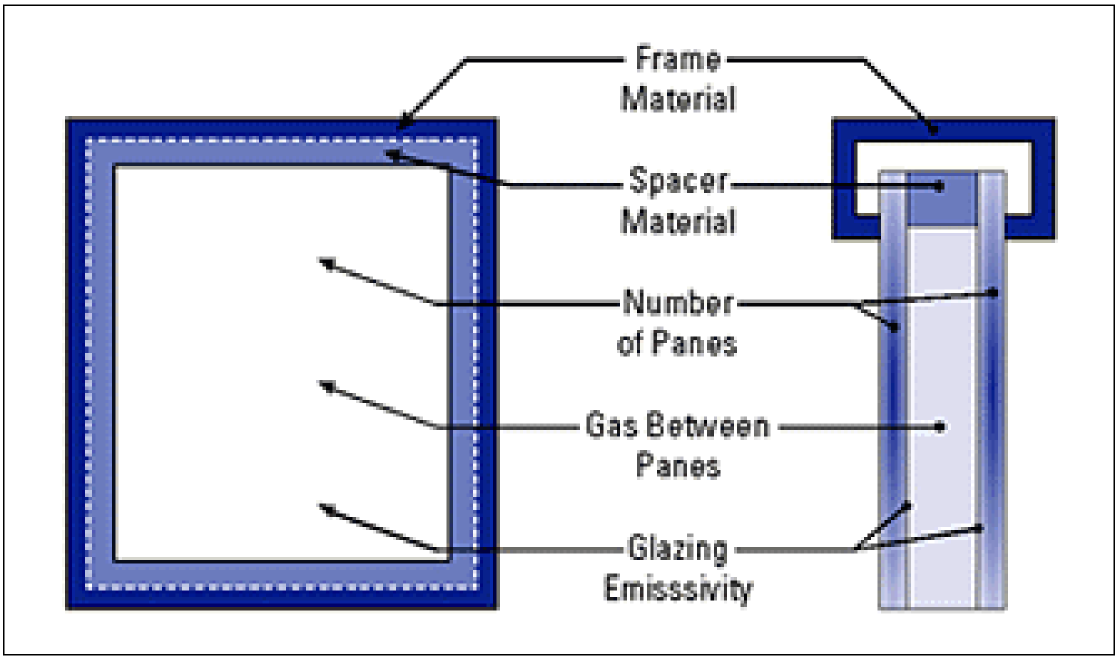

Figure 10 Typical features of windows (http://www.wbdg.org, Last Accessed 18 / 11 / 2013).

Overall, the best selection of window glazings is dependent on the building orientation, the local climate as well as the building type. When selecting windows the following characteristics should be considered:

1) U-value (Thermal Transmittance).
2) Solar Heat Gain Coefficient (SHGC).
3) Visible Transmittance (Tvis-glass).
4) Tints (Colors).
5) Low Emissivity (Low-e) Coating.
6) Air Gap of Double and Triple Glazing.

As mentioned earlier, U-value also known as thermal transmittance coefficient is the property of windows reflecting the extent of heat flow from inside to outside and vice versa due to conduction, convection, and radiation. Low U-values of the building envelope mean a high value of insulation with lower thermal conductivity (λ) making the building envelope advantageous in cold climates by producing interior comfort. If there is a low U-value of the building envelope, lower heating energy demand is required (Ian, 2012; Bülow-Hübe, 2011). During winter the higher the U-value of a window, the more heat is lost from the interior to the exterior. In the cold dominant climate of Ankara, this loss of heat in winter is not recommended; therefore low U-values become necessary. While in summer the lower the U-value, the lesser heat loss occurs to the exterior leading to the need of supporting heat disposition by means of natural ventilation. The units of U-value is the British thermal unit per hour per square foot per °F (Btu/hr · ft² · °F). U-values may range from as high as a value of 1.3 for an aluminum frame single glazed window to as low a value of 0.2 for a multi-paned with low-emissivity coatings and insulated frame. It is important to know that the U-value is calculated by finding the average of glass, slash and frame (Bülow-Hübe, 2011).

The lower the U-value, the lesser heat passes through the building envelope from interior to exterior and vice versa. Thus, this is advantageous for both winter and summer. In both winter and summer, the window option with the lower U-value provides an envelope with lesser heat gain or heat loss.

Glazing has a good heat conductivity value. When comparing both thinner glazing the thicker glazing, the thinner glazing transmits more heat energy and thus an increased temperature value is collected in the interior. In addition, the thicker the glazing the lower is the U-value and the better is this glazing option for both winter and summer.

On the one hand, there is the "U-value" which is defined as thermal transmittance and on the other hand, there is the "R-value" which is defined as thermal resistance.

“R-values” are commonly used in North America and they are merely the reciprocal of the “U-value”.

Solar heat gain coefficient is a central concept for high performance envelope design. SHGC provides a means for measuring blocked heat from the sun. Low SHGC results in high heat blocking and the lesser is the heat gain or loss through the window. The SHGC factor of windows has a value between 0 and 1. SHGC = 0 means that all the incident solar heat subjected to the window is blocked and does not transmit any heat and thus there is no heat gain or loss of the window. On the other hand, SHGC = 1 means that all of the incident solar energy subjected to the window is allowed to be transmitted as heat and thus a maximum heat gain or loss through the window. A window with an SHGC value of 0.6 will transmit double the amount of solar heat as a window with an SHGC of 0.3. Windows with a low value of SHGC are recommended for buildings that are built using passive solar heat principles (Cocina, 2009).

The lower the solar heat gain coefficient of the window, the better it is for both winter and summer. Here, the more the product is blocking solar heat, the lesser it is transmitting heat through the window.

$T_{vis\text{-}glass}$ is the measure of how much of the visible part of the solar spectrum is transmitted through the window glazing. Sunlight is part of the solar spectrum in the form of electromagnetic waves that reaches the earth. The solar spectrum consists collectively of ultraviolet (UV), visible, and infrared (IR) wavelength. Ultraviolet short wavelength cannot be seen by the naked eye, and they are the cause skin damage. Visible light is seen by the eye, and amounts to 47% of the sunlight energy. Infrared long wavelength also cannot be seen to the naked eye amounting to 46% of the sunlight energy (http://www.nfrc.org, Last Accessed 27 / 11 / 2013).

Applying coloring or tinting, coatings or films to glass panes of windows enhances their properties. Glass tints are created during their manufacture by the addition colorants. Other glass tints are created by the addition of colored films. One reason for the addition of tints is aesthetics, while another reason is to reduce solar gains. Window tints can block a significant amount of heat energy while still allowing for light as well as clear outside views as shown in figure 11 below.

Figure 11 Different Tints (http://www.wbdg.org, Last Accessed 18 / 11 / 2013).

Low-emissivity coated glazing (or low-e coated glazing) is a type of energy-efficient glass that prevents heat being transmitted through windows to the cold exterior and vice versa. When Low-emissivity or low-e coatings such as metal oxides are added to the glass panes during manufacture radiant heat transmission between the pane surfaces is reduced. In addition, low-e coatings lower the window's U-value thus reducing heat transfer from the interior to the exterior and vice versa.

In addition, there are two types of low-e coatings namely hard and soft. Windows with the hard coatings are used in coupled windows and they are able to be cleaned. As for soft coatings, they are sensitive to mechanical treatment and have to be protected in a sealed insulating pane. Soft coatings have a very low energy emittance of 1 to 3 %, while hard coatings have energy emittance around of 16% (Bülow-Hübe, 2011).

Old double glazed windows do not have low-e coatings and are thus not energy efficient. With the addition of low-e coatings to the new glazed windows energy efficiency is increased and energy bills are reduced. Windows with low-e keep heat within interior spaces in winter, thus allowing for comfortable occupancy of these spaces for more periods of the year. Usually heat tends to travel from hotter areas to colder spaces. Thus, windows that do not have low-e coatings allow heat to be transmitted through the glazing and towards the colder exterior. On the other hand, windows with low-e coating radiate heat poorly preventing it from being transmitted to the exterior. Instead, windows with low-e coating reflect retarding heat back into the immediate space (Elder, 2000).

The presence of a low-e coating prevents heat in the form of long wavelength infrared rays from being transmitted through windows towards the interior and vice versa, thus being reflected either towards the interior or the exterior. While, on the other hand low-e coatings transmit short waves in the form of visible light through to the interior and vice versa.

The gap filled with air or argon gas in double and triple glazing windows transfer heat by means of convection. Heat transferred by conduction through the outer pane of a double or triple glazing reaches the gas filled gap facing the pane. By means of convection between the solid (glass pane) and the fluid (air or argon) the hot molecules of the pane vibrate and transmit heat to the molecules of the fluid. The molecules start colliding with each other resulting in an increase of energy and vibration. Thus the temperature of the fluid increases and heat is transferred to the surface of the inner pane. The thicker the air gap, the more is the temperature increase and thus more heat is transmitted resulting in a hotter interior.

The heat transmittance through double and triple glazing windows are described below:

1) Double Clear Glazing: This type of window consists of two glazing panes with a sandwiched air gap. The air gap reduces heat transfer due to its insulating properties. When compared to single clear glazing windows, double clear glazing windows reduces heat loss by half. Double clear glazing windows not only reduces heat transmission but also allows high amounts of visible light.

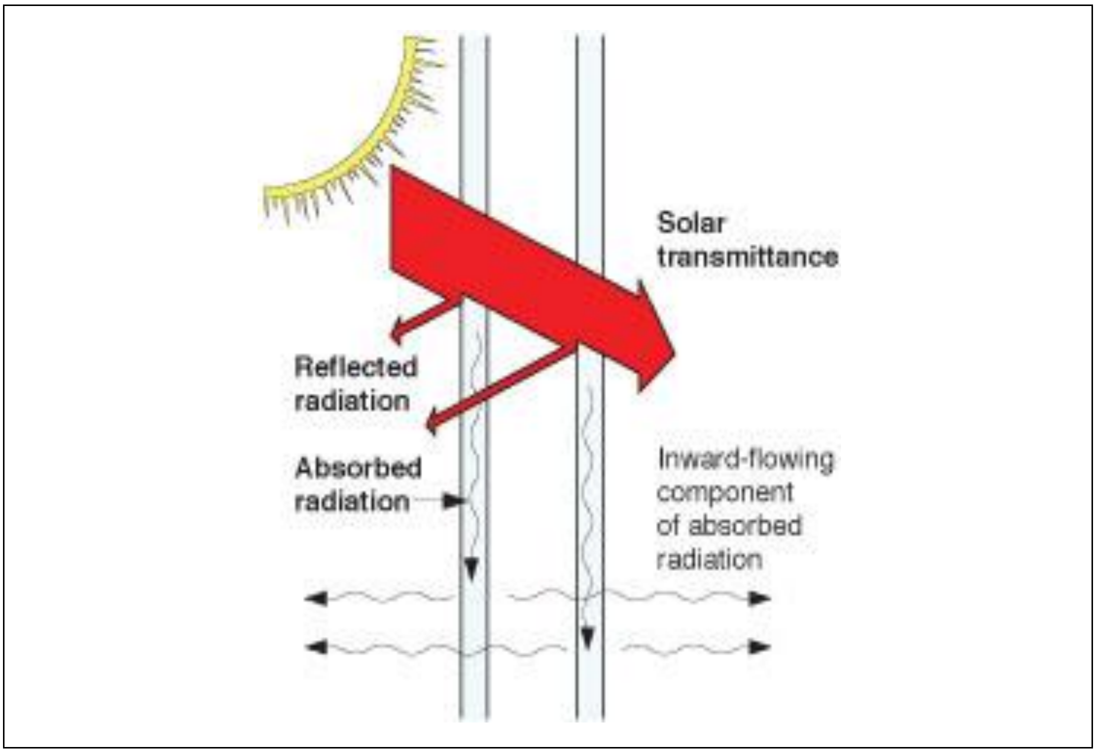

Figure 12 Energy Distribution for Double Glazing Clear Glass (http://www.commercialwindows.org, Last Accessed 10 / 11 / 2013).

Figure 12 above describes the distribution of solar radiation incident at two clear glass panes of a double glazing window. As the incident solar radiation reaches the outer glazing, part of it is reflected to the exterior and a large part is transmitted across into the gap before reaching the inner pane where a large part is transmitted to the interior space and a lesser part is reflected back first passing through the gap and then through the exterior pane to the exterior. During this process, solar heat is absorbed within both the exterior and interior panes. This absorbed heat within both the panes is released partly to the exterior and partly to the interior.

2) Low-e Double Glazing: This type of window consists of two panes with an air or argon gas in between. With the addition of a spectrally selective low-e, coating heat loss in the form of interior long wavelength infrared radiation is reduced in winter and at the same time exterior heat gain in the form of interior long wavelength infrared radiation is reduced in summer.

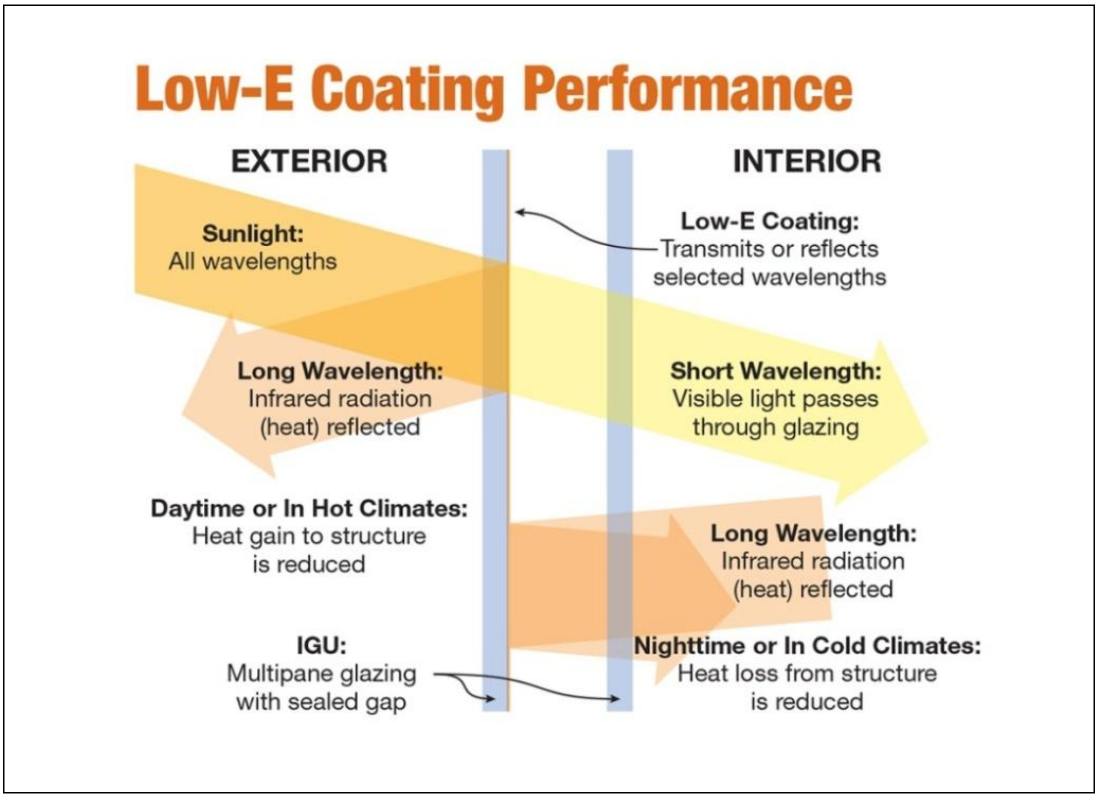

Figure 13 Energy Distribution for Double Clear Glass with Low-e coating (http://www.cl-windows-doors.com/glazing, Last Accessed 10 / 11 / 2013).

Figure-13 above describes the distribution of solar radiation incident at two clear glass panes with a low-e coating located on the inner surface of the exterior facing pane of a double glazing window. As the incident solar radiation reaches the outer glazing, the long wavelength in the form of infrared radiation (heat) is reflected to the exterior while the short wavelength in the form of visible light is transmitted into the gap and then through the inner pane into the interior space. Thus during daytime or in hot climates heat gain to interior is reduced. On the other hand, long wavelength in the form of infrared radiation (heat) radiating from the interior through to the exterior is reflected back to the interior after reaching the pane with the low-e coating. Thus during cold nighttime or in cold climates heat loss from the interior is reduced.

The U-Values and SHGC of two double glazing units one without low-e coating and the other with low-e coating are shown in table 5 below.

Table 5 U-value and SHGC of a double glazing with and without Low-e coating. (http://www.adelaidecitycouncil.com, Last Accessed 11 / 11 / 2013)

Glass Type	U Value (W/m2 x k)	SHGC
Double Clear Glazing	2.70	0.70
Low E Double Glazing	1.90	0.66

1) Triple clear glazing: Triple glazing is manufactured using the same principle as double glazing, but three glass sheets are used. Recently triple glazing windows is the better option for maximum energy transfer between interiors to exteriors.

Figure 14 below describes the distribution of solar radiation (heat) incident at three clear glass panes of a triple glazing window. As the incident solar radiation reaches the outer glazing, part of it is reflected back to the exterior while a larger part is transmitted through to the first gap. Similarly, when this transmitted solar radiation (heat) reaches the middle pane part of it reflected and a larger part is transmitted through to the second gap. Here, the reflected heat passes back to the exterior first through the first gap and then through the exterior facing pane. The transmitted heat that reaches the second gap also passes towards the inner pane where a large part of it is transmitted to the interior space and part is reflected back to the second gap before being transmitted through the middle pane, first gap and exterior pane. On the other hand, interior heat is transmitted to the exterior in the same way but in the opposite direction as the heat transmission from the exterior to the interior.

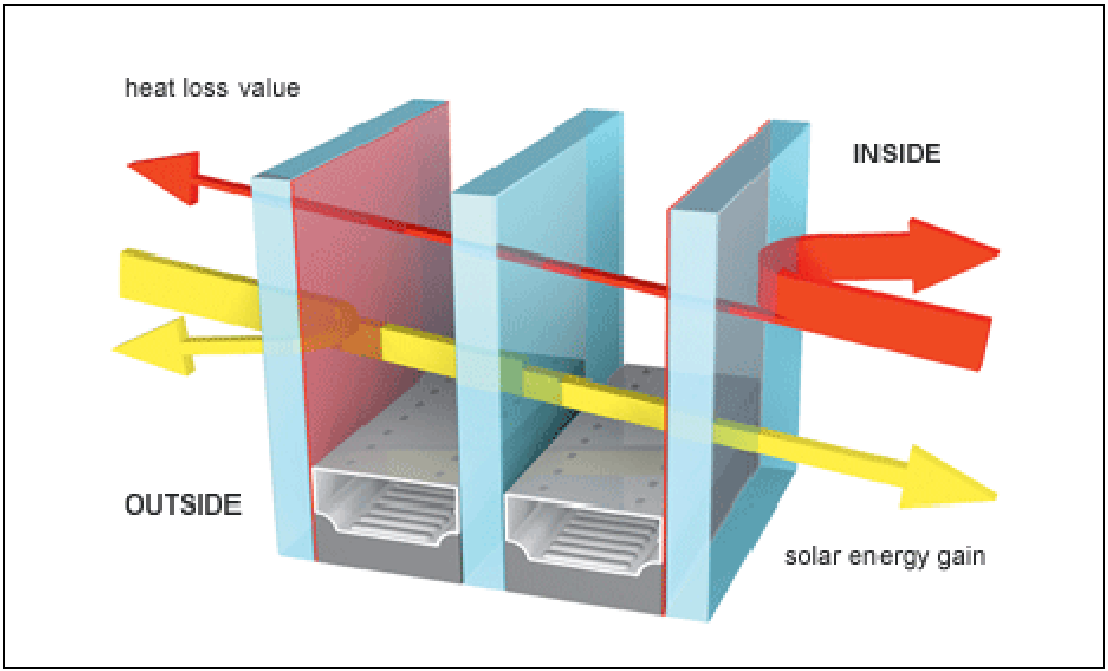

Figure 14 Energy distribution for Triple Clear Glass (http://www.bettaglaze.co.uk, Last Accessed 11 / 11 / 2013).

Figure 15 below describes the distribution of solar radiation (heat) incident at three clear glass panes with a low-e coating located on the exterior surface of the inside pane of a triple glazing window. As the incident solar radiation reaches the outer glazing, part of it is reflected back to the exterior while a larger part is transmitted through to the first gap. Similarly, when this transmitted solar radiation (heat) reaches the middle pane part of it reflected back and a larger part is transmitted through to the second gap. Here, the reflected heat passes back to the exterior first through the first gap and then through the exterior facing pane. The heat transmitted through to the second gap reaches the inside pane. Here, due to the presence of the low-e coating, the short wavelength visible light is transmitted to the interior and the long wavelength infrared heat radiation is reflected back through the second gap, middle pane, first gap and outside pane to the exterior. On the other hand, the long wavelength in the form of infrared heat radiation radiating from the inside through to the exterior is reflected back to the inside after reaching the inside pane because of the low-e coating. Thus, during daytime or in hot climates heat gain to interior is reduced. And during nighttime or in cold climates heat loss from the interior is reduced.

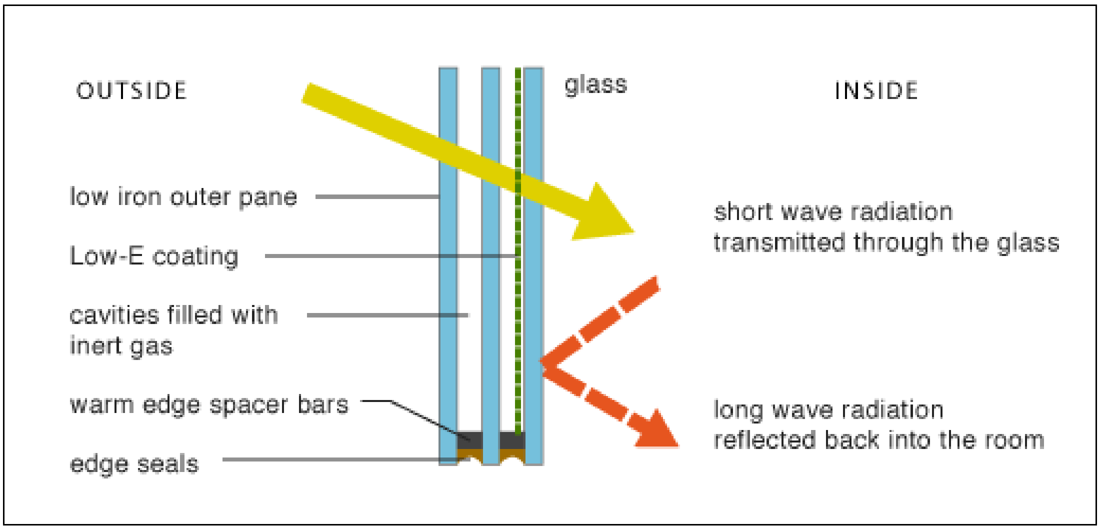

Figure 15 Energy distribution for Triple Clear Glass with Low-e Coating (http://www.greenspec.co.uk, Last Accessed 13 / 11 / 2013).

2.2.4.2 Window Frames

The frame of a window may be made of different materials ranging from UPVC, wood or aluminum. The frame and the window glazing together give the window its characteristics. The selection of the window frame is based on its appearance, thermal efficiency, ease of maintenance, ease of service, cost, availability, shape and its recyclability. Various types of energy efficient window glazing frames are available with energy efficient glass and gas inserted in between the panes (Spence, 2000).

Aluminum windows are made from extruded aluminum structural members. Since aluminum is easy to work complex designs these members are readily produced (Spence, 2000). Aluminum has an excellent strength-to-weight ratio, resists corrosion and easily yields to complex shapes. In addition to its yielding property, aluminum does not rot or deform thus lasting the building lifecycle but requiring periodical maintenance.

In term of prices, aluminum frames have the lowest cost when compared to other window frames. Since aluminum is a good conductor, heat is transmitted easily through the frame. This is a setback which is combated by the addition of a thermal break which comes in the form of a vinyl profile located in between two aluminum sections. The result is a thermally resistant window frame.

Aluminum does not hold brush paint well, so it is recommended that the original paint of aluminum is used in the coloring of the frame (Spence, 2000).

Wooden framed windows are available with fixed and operable sash. They may be clad with plastic or aluminum or left natural and / or painted. Wooden windows are good products both in appearance and qualities. They last long however they are accompanied with a price. Wooden windows are bought with three or more times the price of a similar vinyl window. Not only that but they also require constant maintenance. Low price wooden windows mean long term losses because with time they tend to crumble. These low quality windows need constant maintenance which if not done, will lead to their crumbling.

Not every client could afford the luxury of wooden windows. Such wooden windows, even though expensive, require constant maintenance and painting. Thus, money expenditure never stops in such a case. Wooden frames provide better insulation than metal and plastic windows. However, they do swell and shrink as the moisture content changes (Spence, 2000).

Since its creation in the 1920's, Vinyl has been the most widely used plastic in the world including window frames. Being known as polyvinyl chloride (PVC), it resists both chemicals and corrosion reactions. An extended product unplasticized polyvinyl chloride (UPVC), has the same property of PVC with the addition of offering safety to harmful ultraviolet energy arrival from the sun.

When comparing window frames, the most efficient ones are the UPVC frames. Aluminum frames are thermally not as efficient as timber or UPVC as they will transmit heat and cold air in and out of the building. UPVC could be easily shaped into different forms, providing high thermal resistance and also a good strength to weight ratio. Moreover, UPVC frames could be easily manufactured and given different colors or paints thus favoring it over other frames such as aluminum and wood. Thus UPVC frames are preferred.

Moreover, UPVC frames could be easily manufactured thus favoring it over other frames such as aluminum and wood.

In its natural form, UPVC frames do not rust, swell, pit, peel or corrode and never needs painting. Its members can be produced with the accuracy needed to provide airtight fits (Spence, 2000).

In addition, UPVC frames are very strong thus making them unbreakable and lasting the lifecycle of the building. It could also be added that UPVC frames require no maintenance however some cleaning makes the window looking new. Another quality of UPVC is its good insulation property against both hot and cold making it the better option for both winter and summer. UPVC frames only drawback are their bulky appearance. To solve that modern UPVC frames are toned down to give them smoother appearance. In this thesis, UPVC frames are selected to frame the glazing windows under investigation.

2.2.4.3 Masonry Walls

Masonry is a means of construction made of stone, concrete, brick, gypsum, hollow clay tile, concrete brick, tile, or other similar building units of materials combined and set into close positioning with mortar. A type of building envelope is the heavy construction that is popular in Turkey. Common construction utilizes concrete or clay masonry blocks for walls.

In order to provide low energy consumption with the lower heat losses through masonry walls of masonry blocks, one option is to have insulation material in the form of a sandwich solution with two block layers and thermal insulation in the middle. In this kind of construction, mineral wool or polystyrene or polyurethane would be the most suitable insulating material (Bülow-Hübe, 2011).

Concrete masonry units (CMU) not only are cost efficient, but also increase productivity by reducing construction time. Their light weight reduces energy spent in transportation and improves the builders' workmanship. CMUs are manufactured into three types according to their weight class namely heavyweight, medium weight and light weight. They are distinguished by their pounds per cubic foot (pcf). Heavyweight units weigh 125 pcf or more. Medium weight units weigh between 125 pcf and 105 pcf. Lightweight units weigh less than 105 pcf. A (0.20 x 0.20 x 0.40 m) CMU heavyweight unit is 15.42 kg or more, a medium weight unit is between 12.70 and 15.42 kg, while a lightweight unit is less than 12.70 kg based on a 50% solid unit (Lochonic, 2010).

A standardized shape and size of these concrete blocks is (0.203 x 0.203 x 0.406 m). With further adjustments considering the extra mortar this block size has been reduced to (0.194 x 0.194 x 0.388 m). To achieve wanted properties of the concrete block, constant monitoring is necessary while they are manufactured (Portland Cement Association, 2013); (Ramachandran, 2013).

The concrete used in the production of the concrete blocks is made from the following constituents namely powdered Portland cement, gravel, sand, and water. The result is a light grey, smoothly textured block with a high compressive strength. When compared to other concrete blocks used for general purposes, these blocks have higher sand percentages and lower gravel and water percentages resulting in a very dry and stiff mixture that retain a strong and stable shape once it is removed from its mold.

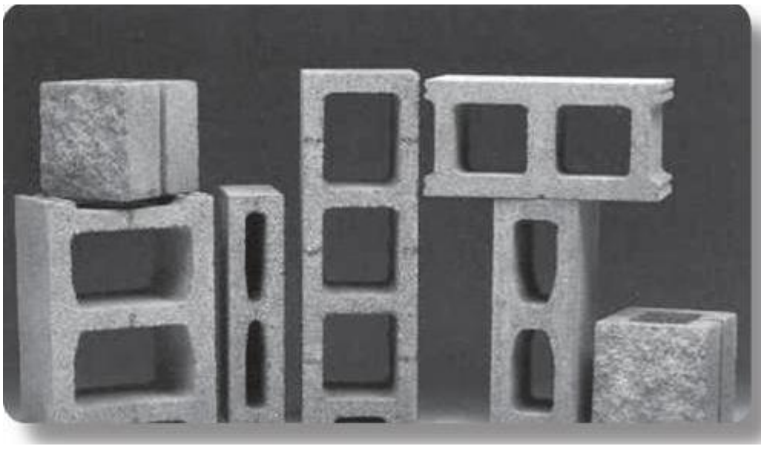

Figure 16 Hollow Concrete Blocks (Ramachandran, 2013).

Hollow CMU blocks are very efficient with a number of advantages, one being its usage as part of the structure in the form of walls and slabs. As mentioned earlier, hollow CMU are fire resistant, sound resistant and have a high thermal mass (Hoke, 1993).

Hollow CMU units exist with a central core that not only reduces the blocks weight but also eases labor effort. Some of the different sizes of hollow concrete blocks are shown in figure 16 above.

Lightweight concrete provide more energy savings because their heat flow resistance is twice that of heavy weight concrete and therefore less energy is needed to heat/cool the interior (Yiğit et. al, 2011).

In comparison to normal aggregates, light weight aggregates have higher water absorption rate as well as lower relative density. Furthermore, not only is it light weight but it also has good strength, high fire resistance and good heat insulation. Using lightweight aggregate in concrete has a number of advantages namely the reduction of dead load, reduction in handling and transportation costs as well as improved fire resistance capability (Yiğit et. al, 2011).

In building construction, lightweight concrete (LC) has been utilized as masonry blocks, wall panels, roof decks as well as precast concrete units. The light weight of the aggregates used in the manufacture of lightweight concrete was beneficial especially for constructions built in seismic zones (Şahin et. al., 2012).

In terms of advantages in cost efficiency, lightweight aggregates with low thermal conductivity could be used to produce lightweight concrete blocks (Al-Jabri et al. 2005).

Natural or artificial lightweight aggregates are found and provided all around the world and with their different characteristics of weight and strength could be used to produce concrete used for different purposes such as internal and external walls, internal layers of exterior cavity walls, fill panels as well as isolation elements of roof decks and floors (Topçu, 2001); (Demirboğa et al. 2001). Lightweight aggregates could be produced from natural materials, by-products or unprocessed materials. With a large number of voids that could occur within in the aggregate, lightweight aggregate concrete could have a higher thermal insulating characteristic when compared to normal heavyweight concrete. Therefore, lightweight concrete is advantageous with its lightness as well as good thermal insulation (Al-Jabri et al. 2005); (Şahin et al., 2012).

When applied to building constructions, these concrete blocks may heat or cool, absorb or radiate heat to the surrounding components of the wall system. The thermal performance of these concrete blocks depends on the one hand on the thermal insulation applied or the on the other hand the different wall layers. Moreover, lightweight concrete blocks provide more a thermal mass effect when compared to other wall systems such as wooden or steel construction. Even with similar thicknesses, lightweight concrete blocks stores less heat when compared heavyweight concrete blocks. However, lightweight concrete releases heat slower, something which adds to its total thermal performance (Ramachandran, 2013).

Energy efficiency could be achieved by masonry construction. Masonry wall systems may use interior insulation, integral insulation, or exterior insulation for maximum design flexibility. Interior insulation comes in the form of fibrous batt or rigid board insulation can be granular or foamed in place insulation or rigid polystyrene inserts. Exterior insulation mainly comes in the form of rigid board attached to a wall's masonry surface and covered with a weather resistant coating or plaster (Simpsons, 2001).

Lightweight blocks have the advantages of improved worker productivity and morale leading to faster construction and projects finishing with minimum mason accidents and injuries.

The data in **APPENDIX-YY** shows the image, dimensions, density, weight, block per cube, fire ratings of a number of available hollow concrete masonry units.

2.2.4.4 Wall System (Autoclaved Aerated concrete (AAC) Block)

Due to its light-weight, low density, high fire resistance and unique thermal and breathing properties, Autoclaved Aerated Concrete (AAC) has been one of the most commonly used construction materials (Taşdemir and Ertokat, 2002); (Andolsun et al, 2005); (Narayanan and Ramamurthy, 2000a). These properties make AAC a suitable material for earthquake-resistance purposes (Taşdemir and Ertokat, 2002). However, AAC has a disadvantage of deteriorating when exposed to water (Andolsun, 2006).

AAC is produced and used in Turkey either as building blocks or steel reinforced panels. AAC building blocks are divided into three types namely masonry blocks, floor blocks and insulation blocks. AAC steel reinforced panels may be used as wall elements, roof and floor deck elements as well as complementary elements such as lintels (www.akg-gazbeton.com, Last Accessed 05 / 03 / 2014). The dimensions and shapes of the different types of AAC are shown in table 6 below and figures 17 and 18 below.

Table 6 Product Dimensions of AAC Masonry Blocks (www.akg-gazbeton.com, Last Accessed 05 / 03 / 2014).

Type of the Masonry Block	**Length (l) (cm)**	**Width (b) (cm)**	**Thickness (d)**
Plain-end wall blocks	60	25	(5 - 35)
Tongue and groove wall blocks	60	25	(15 – 35)
U-blocks	60	25	(20, 25, 30)

		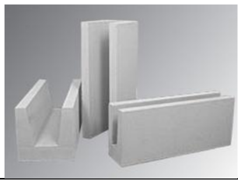
Plain-end wall blocks	Tongue and groove wall blocks	U-blocks

Figure 17 Aerated Autoclaved Concrete (Aroni et. al., 1993) (www.akg-gazbeton.com, Last Accessed 05 / 03 / 2014).

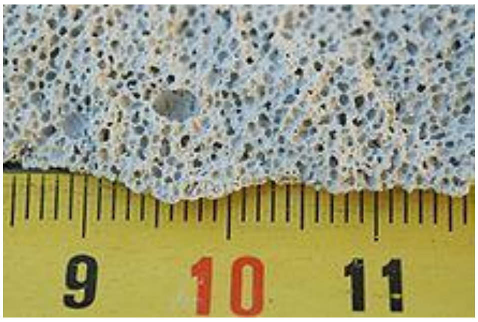

Figure 18 Aerated Autoclaved Concrete - close-up view (Aroni et. al, 1993).

AAC blocks is made from fine aggregates, cement and an expansion agent that gives it the property of being blown just like the bread dough when exposed to heat. Thus, it can be said that AAC consists of 80% air. AAC blocks, shown in figure 17 and 18, created by the Swedish architect Johan Axel Eriksson first appeared in the 1920's (Aroni et al., 1993).

In Turkish Standards, Autoclaved Aerated Concrete may be defined as a lightweight concrete that consists of a mixture of fine grain siliceous aggregate and an inorganic binder agent such as lime or cement that acts with pore-forming agent which decreases the mixture's unit weight. This is followed by a steam curing process which gives the mixture its mechanical strength (TSE, 1988); (Çiçek, 2002). Another definition of Autoclaved Aerated Concrete may be described basically as a mortar with pulverized sand and/or industrial waste like fly ash as filler, in which air is entrapped artificially by chemical means (metallic powders like Al, Zn, H2O2) with the result greatly reduced density (Narayanan & Ramamurthy, 2000b).

2.2.4.5 Plasters and Renders

Mineral-based plasters function as outdoor or indoor plasters and either hand or machine pasted plasters. Plasters and renders for exteriors are weatherproof, moisture, rain and temperature change resistant. Cement-based, lime-based plasters, synthetic resin and silicate dispersion plasters are the best in usage for outdoor plastering.

Plasters applied in interiors must be breathable, abrasion-resistant and appropriate for decoration or coated layers, wall paper and tiles. Internal plasters may be made of gypsum or gypsum-lime or lime-cement or gypsum cement skim, but recently, clay-based plasters are becoming common in the market because of their better environmental impact (Spence, 2000).

In this thesis, Gypsum Insulating Plaster is used for interior and exterior coating because of its low conductivity of (0.18 W/m2 x k) when compared to other plasters. The better the insulation, the less heat gain or loss occurs.

2.2.4.6 Insulation

Thermal insulation may be defined as a material or a collection of materials which when together heat transfer either by conduction, convection, and radiation is slowed down to and from a building because of its high thermal resistance property (ASHRAE, 2001); (Al-Homoud, 2005).

In Turkey, due to little insulation in existing and new buildings, the result is a lot of heat loss and energy waste. Thus enough thermal insulation leads to much energy savings (Bolattürk, 2006).

In modern times as mentioned earlier, energy is a basic requirement for the social and economic progression of societies. This requirement in energy conservation became ever more important after the oil crisis of 1973. For the condition of Turkey which imports much of its energy, this has influenced its national energy strategies. In addition, much more energy would be required due to the population and urbanization increase. It is expected that the population of Turkey would increase to 100 million by 2020, therefore, further energy conservation is required. As mentioned earlier, even though Turkey has resources such as hard coal, lignite, asphaltite, petroleum, natural gas, hydroelectric energy and geothermal energy, it has imported fifty two percentage of the energy it spends from other countries (Oğulata, 2002); (Bolattürk, 2006).

In cold climates, energy in the form of heating is mainly consumed in buildings. With time and technology, one way to minimize this costly energy consumption that otherwise pollutes the environment, was the application of thermal insulation on walls (Aksoy, 2012).

As an influential addition to the wall, thermal insulation within the wall is major in reducing energy usage. Since energy is released by fossil originated fuels and 35-40% of that energy is utilized to heat buildings, the need arises to save it by applying these fuels efficiently (Aytaç and Aksoy, 2006); (Aksoy, 2012).

Wall thermal insulation is one method to decrease heat loss from buildings. An amount of 77% of energy consumed within a building could be saved by adding thermal insulation to roofs and walls (Mohsen and Akash, 2001); (Aksoy, 2012). In the past almost no insulation was applied in buildings in Turkey, something which led to high heating energy consumption. The mean heat usage in residents was above 200 kWh/m2 per year (Dilmaç and Kesen, 2003); (Aksoy, 2012). Thus energy saving gained increased importance in Turkey. Since Turkey imports much energy, the Ministry of Public Works and Housing released a new regulation namely (TS 825) in 1998, once applied, reduced considerable energy consumption in buildings (Turkish Standard Institution, 1998); (Aksoy, 2012).

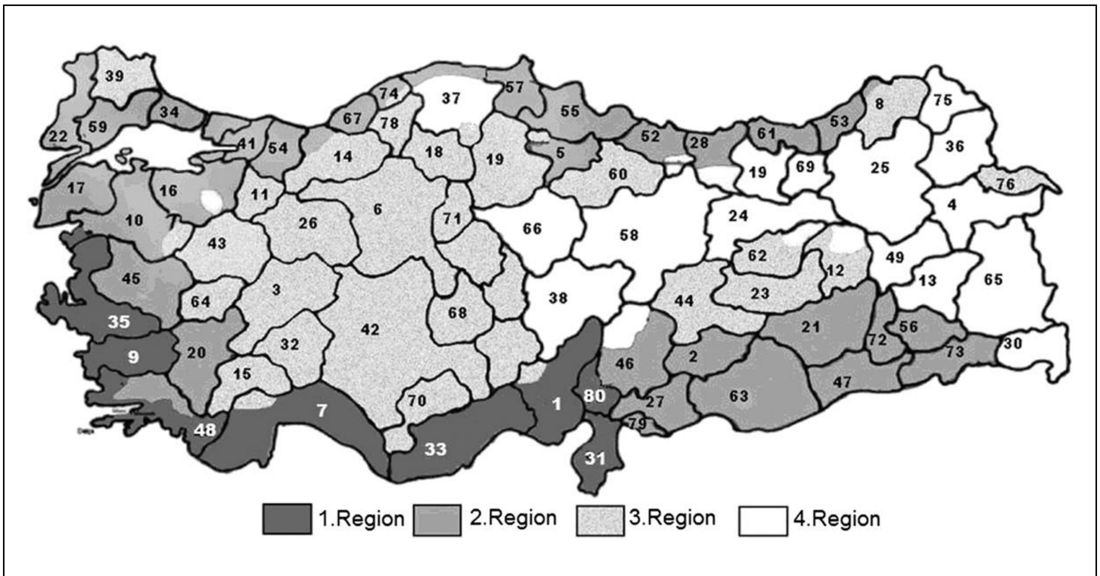

Figure 19 Thermal regions of 81 cities for Turkey (Ankara being numbered as city 6 in region 3) (TS 825 Standard).

The TS 825 Standard provided necessary information of insulation that must be followed in buildings in Turkey (TSE, 2008). In Turkey, TS 825 'Heat Insulation

Code in Building' described from figure 19 above and figure 20 below is the only regulation addressing the insulation issue. In this document, Turkey is separated into four climatic regions, and the maximum heat transmittance coefficient (U-value) of walls, roofs, floors and windows in these regions were determined. According to this, the U-value for Climate Regions I, II, III and IV should be 2.4 W/m2K for all window glazings (TSE, 2008).

	U_{wall} (W/m^2C)	U_{roof} (W/m^2C)	U_{floor} (W/m^2C)	U_{window} (W/m^2C)
1st Region	0,70	0,45	0,70	2,40
2nd Region	0,60	0,40	0,60	2,40
3rd Region	0,50	0,30	0,45	2,40
4th Region	0,40	0,25	0,40	2,40

Figure 20 Thermal Transmittance requirements according to (TS 825 Standard).
Examples for the different regions are as follows:

1) 1st Region = Antalya, Adana (hottest outdoor temperature)
2) 2nd Region = İstanbul, Samsun (moderate outdoor temperature)
3) 3rd Region = Ankara, Konya (cold outdoor temperature)
4) 4th Region = Erzurum, Kars (coldest outdoor temperature)

The walls with all its components such as the masonry blocks, plaster and thermal insulation is very important in the thermal calculations of the building (Aksoy and Inalli, 2003); (Aksoy, 2012) Some Research regarding thermal insulation is as follows:

Bolattürk in 2006 determined the most favorable insulation thickness, energy savings and payback periods of various fuels for sixteen selected locations with four different climates. He found that energy savings ranged between twenty two and seventy nine percentage while the most favorable insulation ranged between two and seventeen centimeters (Bolattürk, 2006).

In 2003, Çomaklı and Yüksel tested the most favorable insulation thickness suitable in cold locations. The optimization was based on the life cycle cost analysis. They concluded that energy savings could be obtained once optimum insulation thicknesses were applied within walls (Çomaklı and Yüksel, 2003).

In 2004, Dombayıcı found that in the city of Denizli, Turkey, once the most favorable expanded polystyrene thickness was applied to the walls, energy consumption was decreased by 46.6% (Dombayıcı, 2004).

In 2008, Özel and Pıhtılı determined the most favorable insulation thickness applied to external walls for Adana, Elazığ, Erzurum and İzmir provinces considering the heating and cooling degree day values (Özel and Pıhtılı, 2008).

In 2010, Uçar and Balo determined the most favorable insulation thicknesses of different wall structures for four different insulation materials and for four climatic zones within Turkey and for different fuel types. They concluded that energy cost savings ranged between 4.2 $/m2 and 9.5 $/m2, according to the city and type of insulation (Uçar and Balo, 2010).

According to the study by Mohsen and Akash in 2001, different building insulations such as polystyrene, rock wool, and air gaps were investigated in regards to the energy they save. They concluded that 77% energy savings could be obtained once polystyrene was used for both walls and roofs insulation. (Mohsen and Akash, 2001); (Bolattürk, 2006).

In a study by Jaber in 2002 regarded space heating load, he concluded that 50% of this load could be decreased by the application of economically suitable thermal insulation material to walls and ceilings (Jaber, 2002); (Bolattürk, 2006).

According to the study by Al-Sallal in 2003, the payback period when both polystyrene and fiberglass roof insulations were applied in warm and cold climates was investigated. He concluded that the payback period in cold climates was less than that in warm climates (Al-Sallal, 2003); (Bolattürk, 2006).

Another study by Hasan in 1999 investigated cost savings and payback periods obtained when both rock wool and polystyrene insulation were applied. He used a life-cycle cost analysis to obtain the most favorable insulation thicknesses. A saving of 21$/m2 of the wall area resulted when rock wool and polystyrene insulation was used. Moreover, a payback period of 1-1.7 years for rock wool insulation and 1.3-2.3 years for polystyrene insulation were obtained, for different wall constructions (Hasan,1999); (Bolattürk, 2006).

According to a study by Al-Sanea and Zedan in 2002, an investigation of the effect of the heat transfer properties on the wall orientation was done with the result that both were closely related and were mutually influenced. However, they concluded that heat transfer, in comparison, had lesser effect on the cost and the most favorable thickness of the considered thermal insulation material. They also studied the economic aspects of the total price and the most favorable thermal insulation thickness (Al-Sanea and Zedan, 2002); (Bolatturk, 2006).

From all these studies, it could be concluded that the building envelope components such as walls and roofs of buildings being the dividing elements that separate interiors from exteriors affect the energy performance of buildings. The addition of thermal insulation should be considered according to climate and the interior thermal comfort needs of occupants. Thermal insulation is usually added as part of the building envelope component to decrease interior heating and cooling, energy usage as well as costs. Increasing thermal insulation thicknesses adds to the monetary costs on the one hand, but on the other hand reduces the costs for interior heating and cooling. Consequently at the most favorable thermal insulation thickness the cost of fuel is minimal. In turn, no extra energy saving would occur if the thickness of the thermal insulation is increased (Mahlia et al., 2007); (Uçar and Balo, 2010). When comparing the thermal insulation materials to other natural or man-made materials differences in behavior occur according to temperature exposure. Much research has been done investigating the influence of operating temperature on the thermal behavior of thermal insulation materials (Al-Homoud, 2005); (Uçar and Balo, 2010).

According to a study by Bolattürk in 2008, the optimum thermal insulation thicknesses according to both the heating and cooling loads were obtained for a number of cities located in the first climatic zone of Turkey as per the TS 825 standard (Bolattürk, 2008).

According to a study by Dombayıcı et al. in 2006, the optimum thermal insulation thickness of the exterior building envelope for two different insulation materials namely expanded polystyrene and rockwool were calculated in Denizli (Dombayıcı et al., 2006)

In their study, Özel and Pıhtılı analyzed differently located insulations in twelve wall systems in different seasons namely winter and summer in the city of Elazığ, Turkey. Different insulation configurations across the different wall systems were investigated with the thicknesses of both the insulation and masonry remained constant. The best location of insulation from the different wall systems with the consideration of their time lag and decrement factor characteristics was investigated in both summer and winter. They concluded that the best option was to locate three insulation layers one on the outside, the second in the middle and the third in the inside. In addition, another conclusion obtained was that locating thermal insulation at the interior and exterior sides of the wall produced the better option when compared to locating insulation with different thicknesses from the maximum time lag and minimum decrement factor perspective (Özel and Pıhtılı, 2007).

It is usual in the construction that the insulation is applied in the exterior, middle or interior of the wall structure. However, according to recent developments in research by (Asan, 2000); (Sodha et al, 1997) (Bojic and Loveday, 1997); (Özel and Pıhtılı, 2007) it was concluded that a higher thermal performance would occur when a double layer of insulation is applied when compared to a single layer of insulation with the same total thickness. From the study, the worst option was locating a single insulation piece at different locations other than that of the exterior. In addition, high time lag and low decrement values were obtained when half of the insulation was located in the exterior surface and half was located in the center of the wall (Asan, 2000); (Özel and Pıhtılı, 2007).

Nowadays, in the insulation industry, it could be noticed that such products are available in sheets with different thicknesses. In new construction, insulation could be installed in the exterior surface, sandwiched in the wall or the interior surface. In the case of already erected walls or built construction, the only locations to place insulation are either the exterior or interior surfaces of the walls (Asan, 2000).

Insulation materials come in many forms as shown in figure 21 below. The first being batts and blankets, the second being rigid materials such as foam boards and fiber boards, the third being sprayed-on materials such as polyurethane and finally loose fill insulation such as cellulose (Simpsons, 2001).

Plastic foam panels or rigid insulation panels are used variously. Polyurethane and polystyrene panels could be used for interior and exterior applications for both residential and commercial constructions.

Rigid fiberglass or mineral wool boards are used to insulate masonry, steel and wood construction components. These insulation products are good in draining water through themselves and away allowing them to be suitable for wet facing areas such as foundations and marine applications. These products are also used for high temperature facing devices such as solar collectors.

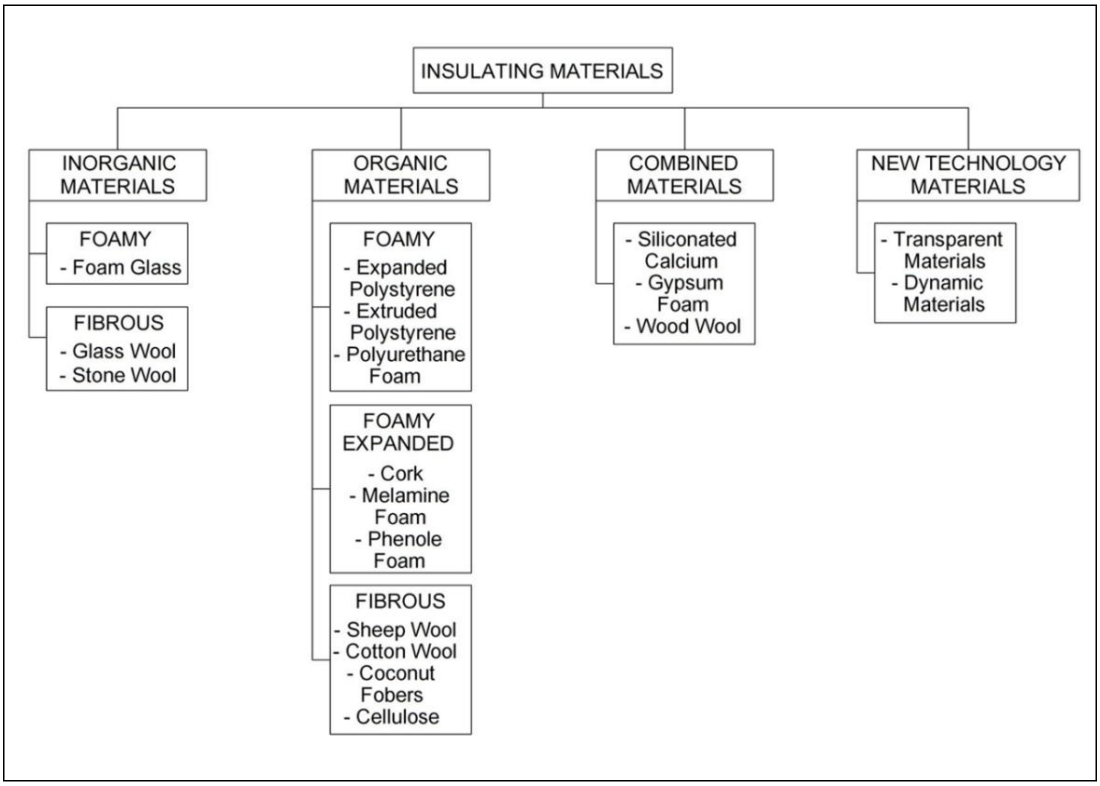

Figure 21 Classification of the most used insulating materials (Papadopoulos, 2005).

Plastic foam insulation panels are also applied in exterior building envelope. For example polystyrene insulation may be attached to the exterior of masonry wall together with a stucco coating that sticks as an outer layer (Krigger and Chris, 2009). Moreover, it is not the thermal insulation fibers that resist the heat flow, however it is the countless microscopic air pores within the insulation material fabric that resist the convective heat transfer by prohibiting air from moving (Al-Homoud, 2005).

Thermal transmittance or U-Values of some insulation results are given in the figure 22 below. Thermal insulation has many benefits from which the following are but a few:

1) Economic benefits: By the application of thermal insulation with a low initial capital investigation, approximately 5% of the total building cost and much energy savings could be achieved which means much energy cost savings and

thus much operating cost savings. Reduction in operating costs equals decrease in HVAC system costs (Al-Homoud, 2005).

2) Environmental benefits: The application of thermal insulation saves energy by reducing operation costs and improving environmental benefits. This could be achieved since pollution producing mechanical systems would be minimized (Al-Homoud, 2005).

3) Thermally comfortable buildings: The application of thermal insulation reduce the energy load expended by the HVAC systems and thus increase the period of indoor thermal comfort (Al-Homoud, 2005).

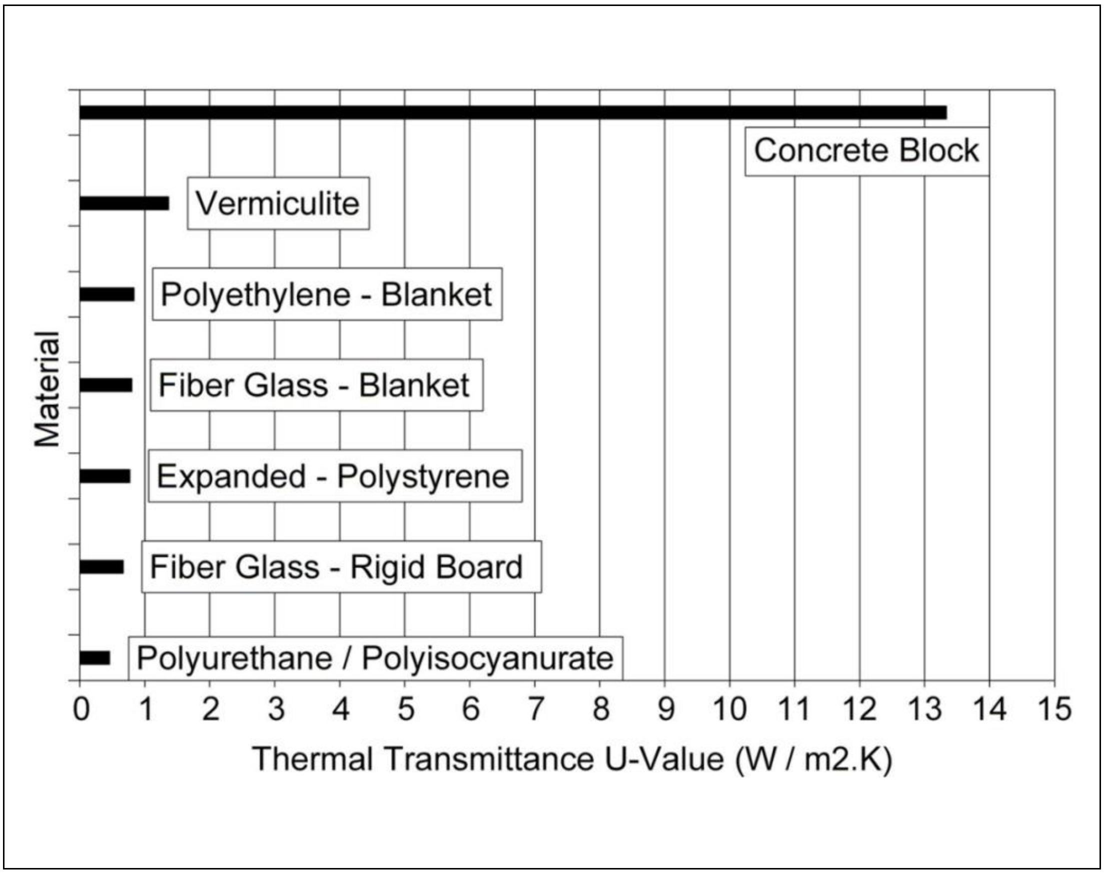

Figure 22 The thermal transmittance of several common insulation materials with five centimeter thicknesses compared to the thermal transmittance of a concrete block (Al-Homoud, 2004).

The percentage of different types of insulations in Turkey and Europe are given in figure 23 below (Society of Polystyrene Manufacturers, 2003).

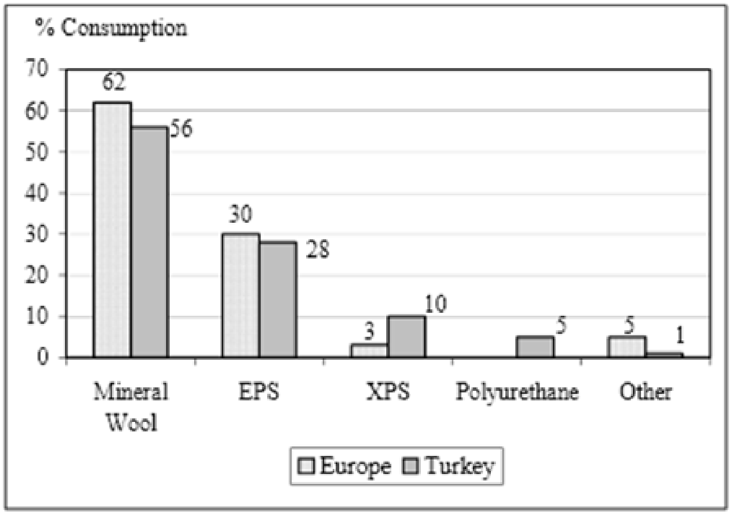

Figure 23 Percentage consumption of insulation materials in Europe and Turkey (Society of Polystyrene Manufacturers, 2003).

> "Glass wool is made from silica sand, an inorganic raw material, which is obtained domestically. It is produced through heating silica sand at 1200˚C - 1250˚C and transforming it into fibers. Glass wool is non-combustible, non-toxic, and resistant to corrosion. It has low weight by volume, low thermal conductivity, stable chemical property, and low moisture absorption rate due to its excellent hydrophobicity. Thanks to its intertwined flexible fibers, glass wool is the best insulating material against noise, cold and heat and also offers excellent fire-resistant properties. It can be manufactured in the forms of blanket, board, pipe or loose in different size and with different technical properties, with different facing materials according to the intended use and the place of use. It is used for thermal insulation, sound insulation, acoustic comfort as well as fire safety." (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014).

İzocam Cephepan (exterior insulation) is a water resistant glass wool board produced with silicone spread and surfaced with yellow or black glass tissue. It is used at curtain wall systems, under the glass, granite, marble and aluminum wall cladding or under plaster for thermal insulation, sound insulation and fire safety purposes as shown in figure 24 below.

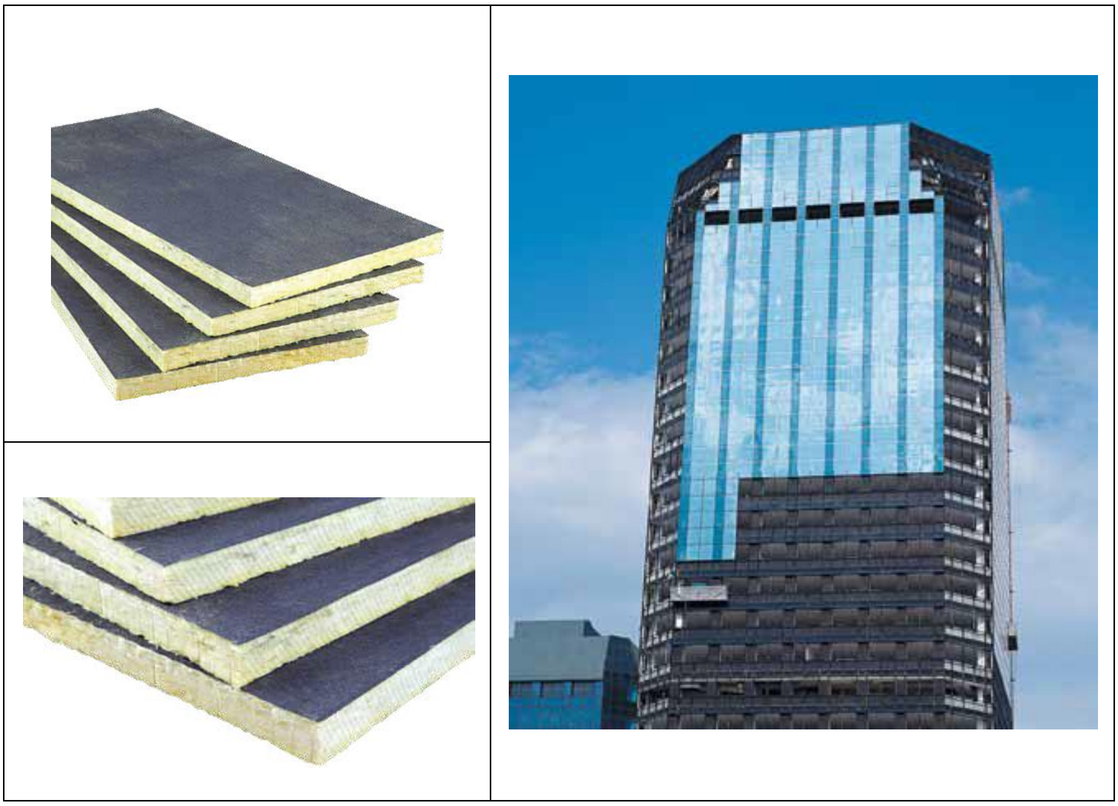

Figure 24 İzocam Cephepan or Façade insulation (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014).

Table 7 The Properties of Glass Wool (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014).

Properties	**Description**	**Symbol**	**Units**
Material	Glass wool	--	-
Density	30	ρ	ρ Kg / m3
Declared Thermal Conductivity (10 °C)	0,032	λ	λ W/m.K
Thickness	50	t	t mm
Thermal Transmittance	0.7143	U-Value	W / m2.K
Specific Heat	840	c	J / kg.K

Some characteristics of glass wool are shown in table 7 above.

Wall board (mid-insulation) is a glass wool insulation material in the form of a board which is a good water repellent due to the silicone constituent it contains. It functions as an insulation layer sandwiched between two wall layers for fire, thermal and sound isolation as shown in figure 25 below.

Figure 25 İzocam Wall Board or Mid-wall insulation (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014).

Figure 26 İzocam Optimum Wall or Interior insulation (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014).

Optimum wall (interior insulation) is a glass wool insulation included under the category of blankets with a special kraft paper layer on one side. It may be applied as a thermal and sound insulation layer located to perform its function over exterior walls, interior surfaces of all kinds of reinforced concrete elements, internal and adjacent walls, boundary walls of staircases and elevator pit walls and as interior wall insulation to timber framed construction. Its parts could be installed with a special system of fastening equipment and accessories as shown in figure 26 above.

2.3 Thermal Simulation

In the past before the creation of computer-aided building simulation, architects and building services depended at large on manual calculations utilizing data of previously designed buildings or the 'rule-of-thumb' estimation or extrapolation methodology for new designs that have not been analyzed previously. As a result, this method of calculation mostly led to oversized heating or cooling systems and thus poor energy performance. Even though such calculations were inaccurate for small buildings, it was unimaginable to design energy efficiency calculations for complex buildings without the usage of computer-aided detailed building simulation programs (BSPs). Nowadays, BSPs working in personal computers help architects and engineers to simulate and design new and variant energy efficient buildings before proceeding to the construction stage. In addition, through parametric analysis, specialists could simulate buildings for new technologies and innovations that could improve energy efficiency (Hong, 2000).

With the advent of computers, building simulation began in the 1960's and further continued through the 1970's. During these years much of the research activities were concentrated in investigations of fundamental theory and algorithms of load and energy approximation. These investigations led to much refinements of the transfer function technique which was put forward by Mitalas and Stephenson (Mitalas, 1967); (Stephenson, 1967), and the widely known methods like the degree-day method, the bin method, and the equivalent full load hour method, all having the function of predicting the energy expenditure in buildings (ASHRAE, 1997). During this time these simulation techniques played an important role in achieving thermal energy efficiency within even the most complex of building.

After the oil crisis was over, during the late seventies and early eighties, interest in achieving energy efficiency in buildings decreased. However with the introduction of desk-top personal computers attention to building energy simulation once again increased. During this same time, the US Department of Energy invested an amount of $1 billion on R&D projects on energy conservation and renewable energy. As a result, a number of popular detailed building and energy systems simulation programs like DOE-2 (US Department of Commerce, 1980), ESP (Clarke, 1988) and TRNSYS (Solar Energy Laboratory, 1988) became available for easy usage by architects and engineers. Even though building simulation programs (BSPs) still existed, they were not used due to their difficult implementation and high cost.

Design Builder 2.2.5.004 v, is a dynamic building energy simulation software that is used to simulate interior thermal environment including the cooling and heating loads in the investigated apartment flats throughout the year. It is the first comprehensive user interface to use the Energy Plus dynamic thermal simulation engine. It can simulate the thermal behavior of any building with a number of zones for various climates and different usage conditions. The input data involves the occupancy schedules, heating and cooling operations periods, HVAC systems, lighting systems, and house equipment. Moreover, as an output, the heat gains / losses through the building elements, the HVAC system, the lighting system, and the occupants and interior thermal conditions, for example, air temperature, radiant temperature, operation temperature, and relative humidity (Maçka and Yalçın, 2011); (http://www.designbuilder.co.uk, 2009, Last Accessed 05 / 02 / 2014).

Climate Consultant is user friendly program that provides an understanding of the local climate to the architect, the builder, the contractor, the homeowner, the student by means of graphic-based output data. An important requirement for the operation of this program is the initial installation of different yearly 8760 hour EPW format climatic data applicable to thousands of weather stations around the world. This Climatic data is available at no cost by the Department of Energy. Climate Consultant uses this climatic data to create a number of informative graphs whose aim is to understand the local climate as well as the climates influence on the building form. In this way advice to more energy efficient and sustainable buildings is forwarded for many climates at many locations on earth (http://www.energy-design-tools.aud.ucla.edu/, Last Accessed 05 / 02 / 2014).

2.4 Life Cycle Cost Analysis

The life Cycle Cost is the total cost of owning, operating, maintaining, repairing, replacing and disposing of a building or a building system over a period of time. By means of an analytical study this summation is done to find an approximation of the net yearly cost for the building unit life under consideration, with attention to the time value of money (Boussabaine and Kirkham, 2003); (Maçka and Yalçın, 2011). In addition, to find the unit's life cycle cost, all the future costs during the study period must be discounted to the present value, except for the initial capital investment of the project. The following formula is used to calculate the life cycle cost (LCC) (Manioğlu, 2002); (Maçka and Yalçın, 2011):

LCC = I + M-R-O + R – RV, where

LCC : Life cycle cost
I : Initial capital investment
M-R-O : Maintain-repair-operation cost
R : Replacement cost
RV : Residual value

However, since the costs for owning, maintaining, repairing, replacing and disposing of the glazing window alternatives and the wall sections investigated in this thesis over the study period of thirty years were not known, only the initial investment and operation costs were documented and their resultant data were used in calculating the economic efficiency.

CHAPTER 3

MATERIAL AND METHODOLOGY

This part of the thesis includes a description regarding the material investigated and informative details regarding Ankara climate obtained from climate consultant program as well as the details clarifying the methodology and method followed.

3.1 Material

The apartment residential building investigated is a typical building in Turkey located in Ankara. The construction completion dated back to 2009 and according to the surrounding buildings it was the latest. This thesis attempted to test the building envelope of all the flats, three in number, in the apartment first floor. Figure 27 below shows the photograph of the apartment building exterior investigated.

Figure 27 Apartment photograph (14 / 11 / 2013).

Figure 28 below shows the typical floor plan (first floor) with three apartments namely the flat-1 facing South-West, flat-2 facing South-East and flat-3 facing North.

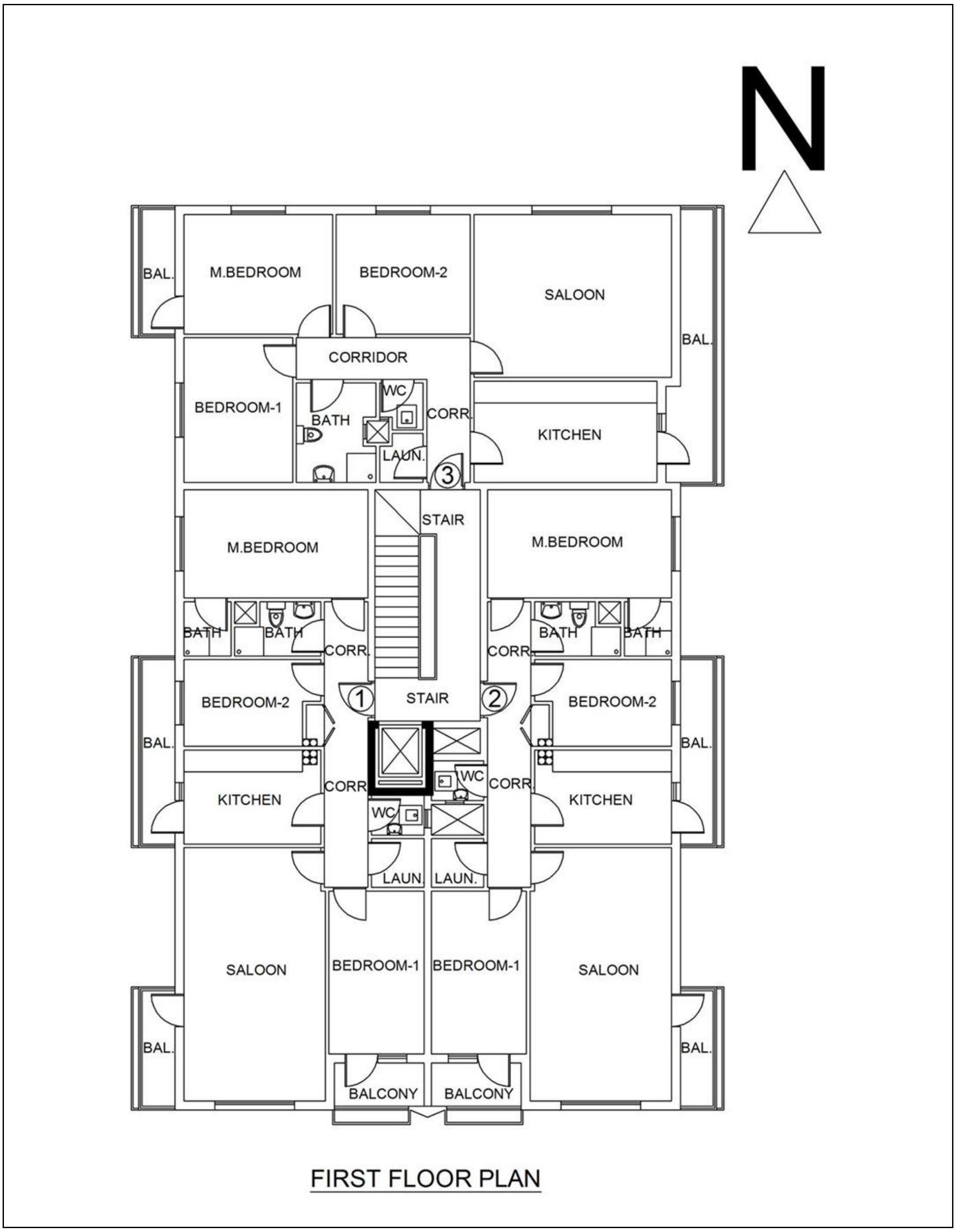

Figure 28 Apartment first floor plan (Keçiören Municipality).

Figure 29 below shows the architectural system section details through the main elevation of the apartment.

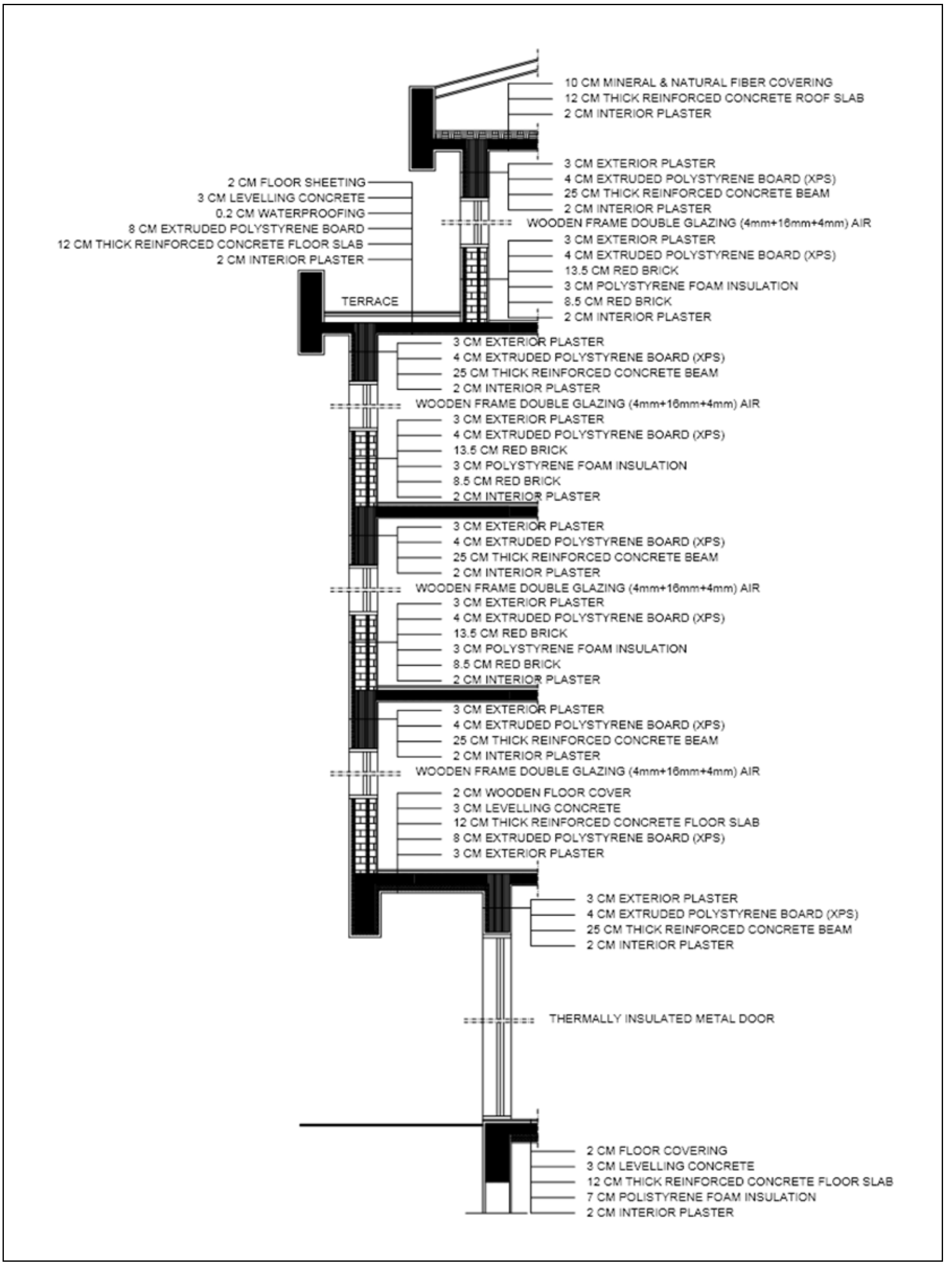

Figure 29 Project section details (Keçiören Municipality).

Figures 30, 31, 32, 33, 34 and 35 show the perspectives and zone details of the flat-1, flat-2 and flat-3 obtained from the simulation software Design Builder.

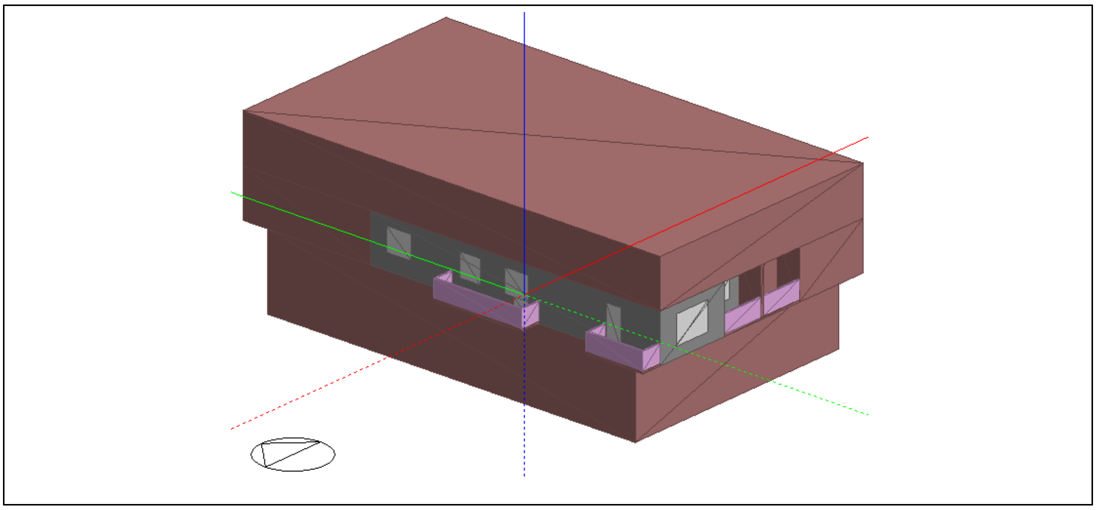

Figure 30 Flat-1 South-Western perspective (Design Builder).

For flat 1 22.2% of the windows face South, 44.4% of the windows face West, while 33.3% are vents facing internal voids.

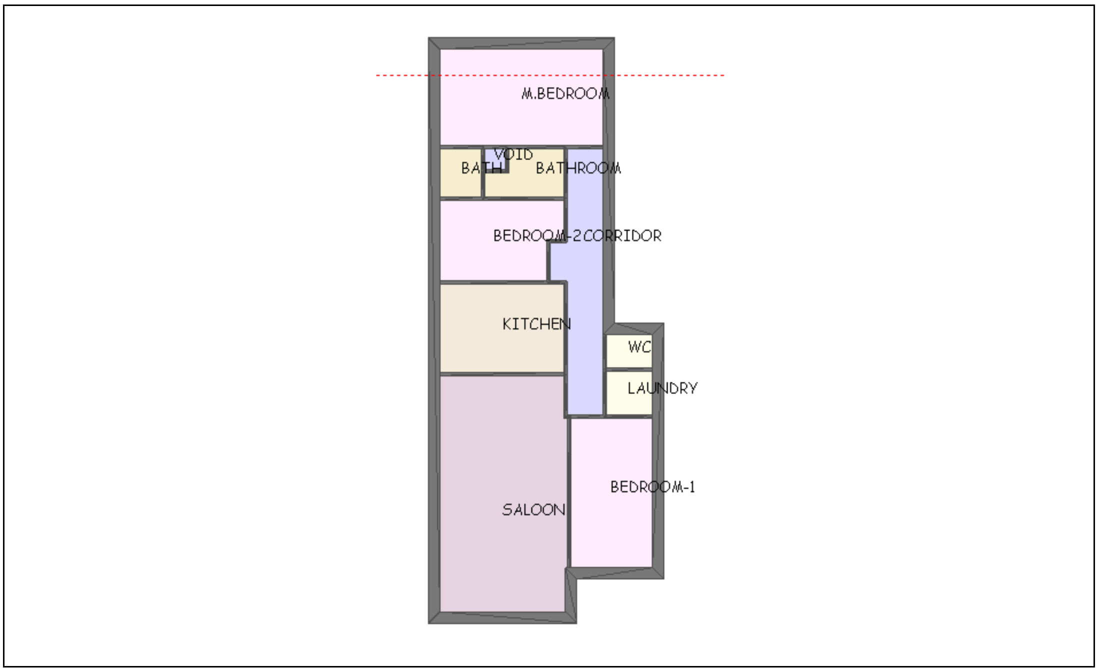

Figure 31 Flat-1 Interior zone details (Design Builder).

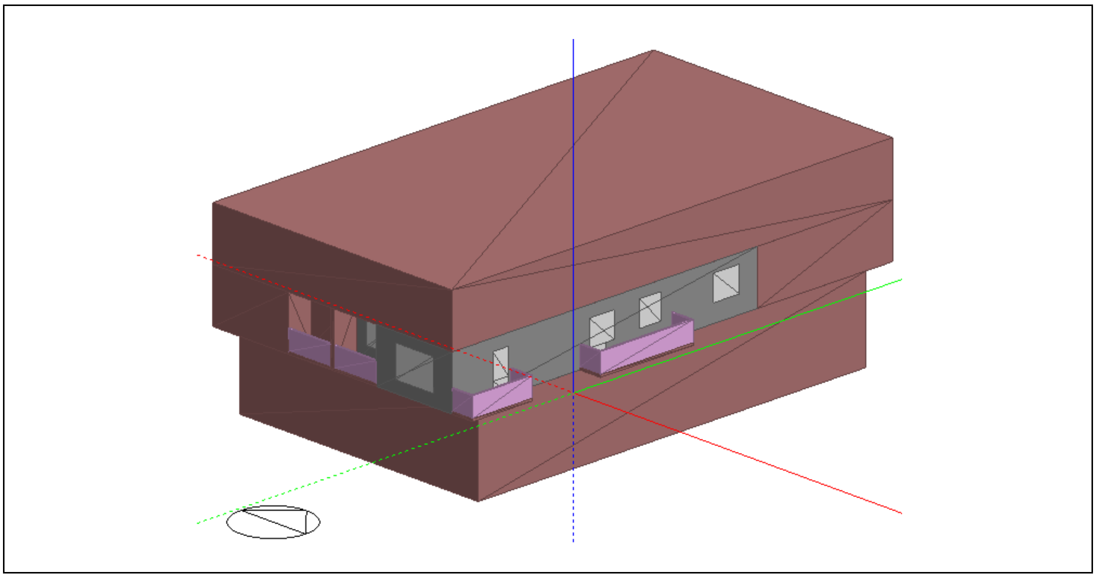

Figure 32 Flat-2 South-Eastern perspective (Design Builder).

For flat 2 22.2% of the windows face South, 44.4% of the windows face East, while 33.3% are vents facing internal voids.

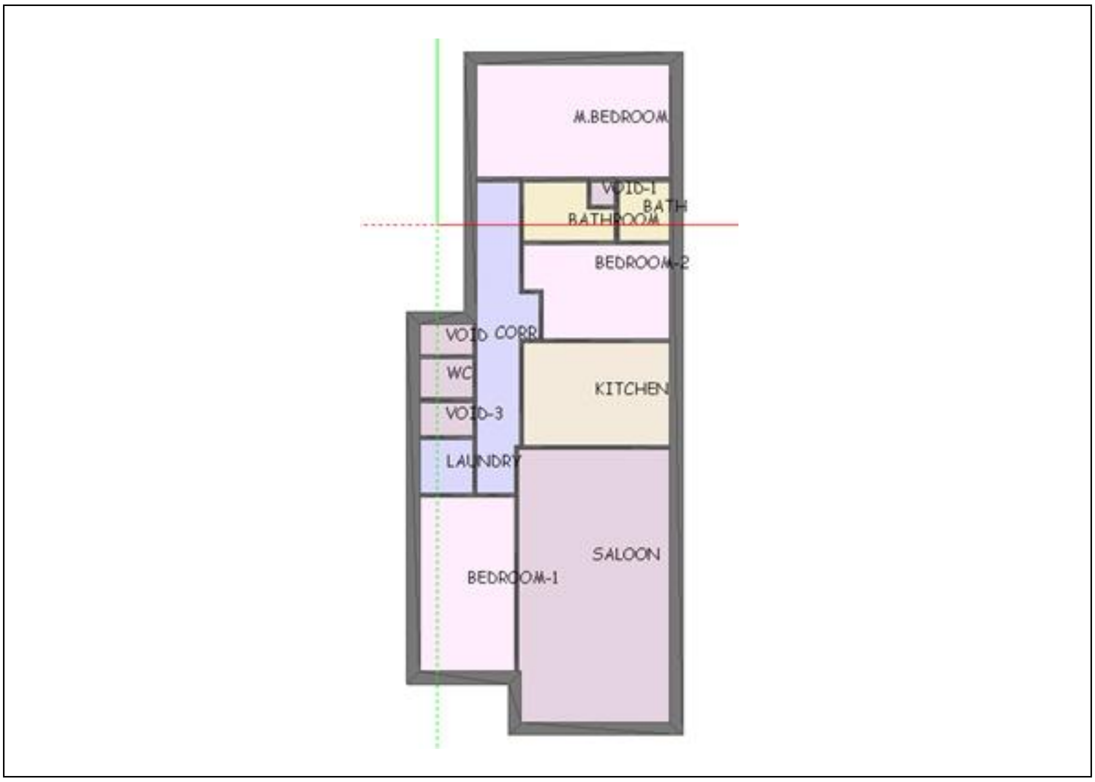

Figure 33 Flat-2 Interior zone details (Design Builder).

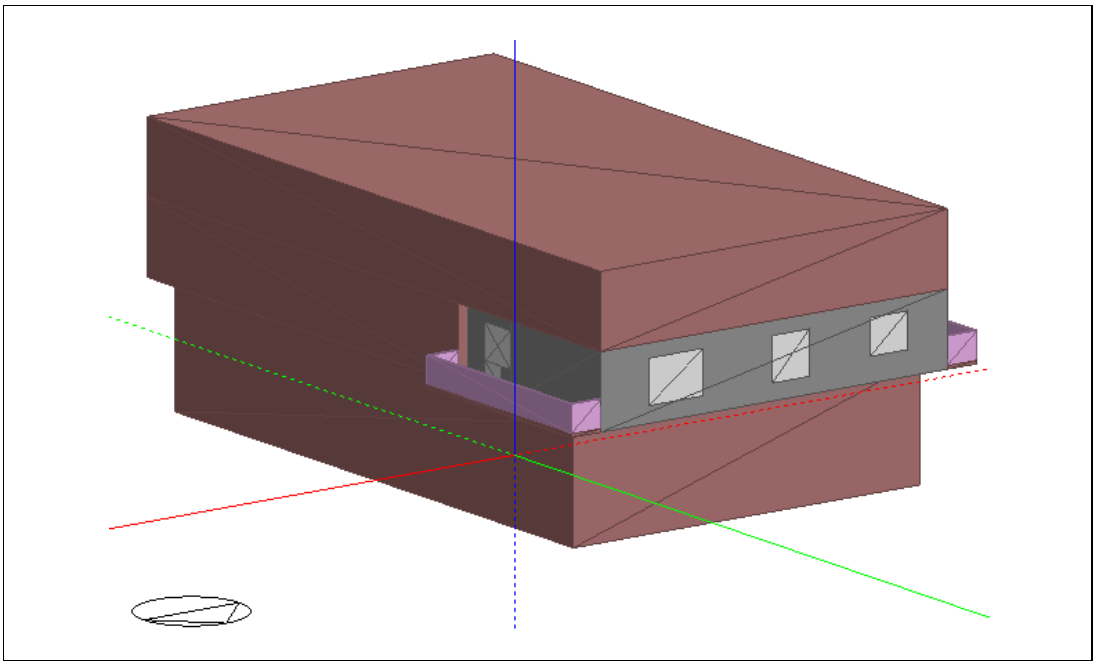

Figure 34 Flat-3 Northern Eastern perspective (Design Builder).

For flat 3 37.5% of the windows face North, 25% of the windows face West, while 12.5% of the windows face East, while 25% are vents facing internal voids.

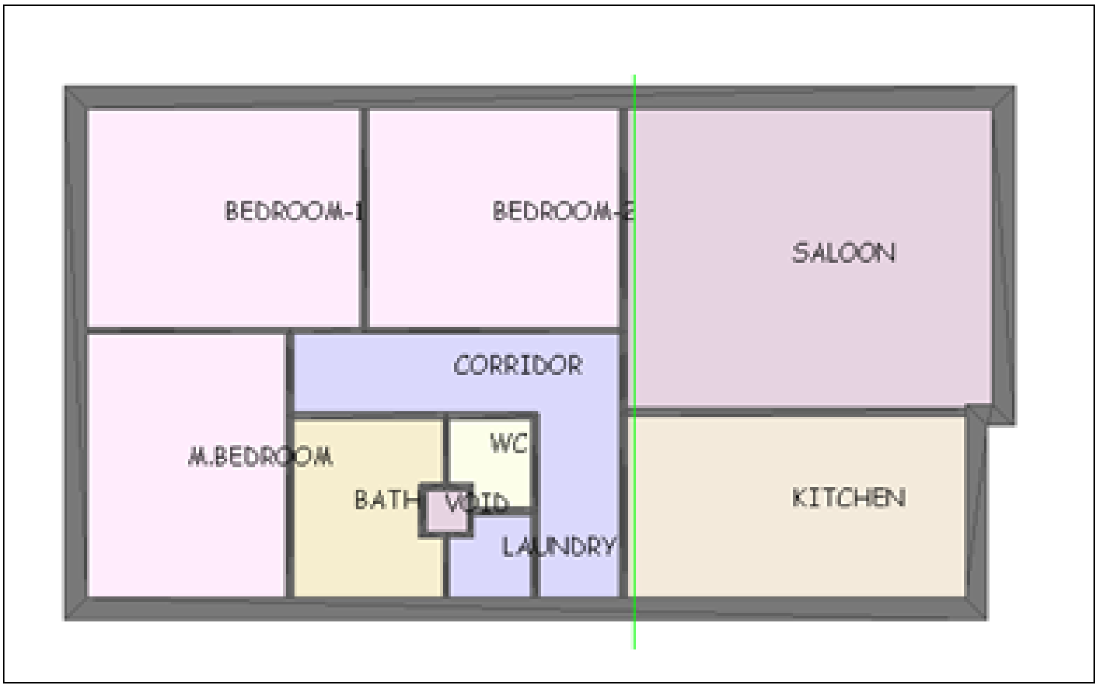

Figure 35 Flat-3 Interior zone details (Design Builder).

As shown in figures 30, 32 and 34 above, an adiabatic surface was used in the ground floor and the second floor as well as the adjacent zones for each of the flats. This application of adiabatic adjacency meant that the heat was not transferred across to the nearby zones from the three flats. This fact was required in this study since the heat released by the heating system was not to be lost to either the ground floor or second floor or to the nearby zones thus a heat equilibrium was maintained. The only thermal activity occurring was that along the entirety of each flat internally and most importantly through the opaque (walls) and transparent (windows) components of each of the three flats building envelopes.

3.1.1 Windows Under Investigation

In this thesis, the part that involved the window glazing investigation included three types of commonly used window alternatives in Turkey. The types are:

1) ISICAM KLASIK (4 + 16 + 4) cm. This was the simplest of the three windows and was used as the reference window. (U-Value = 2.715 W/m2.K).

2) ISICAM SINERJI (4 + 16 + *4) cm. This type of window glazing satisfies the TS 825 standard requirement. Due to this reason it is used widely in Turkey. (* Represents the location of low-e Coating) (U-Value = 1.548 W / m2.K).

3) ISICAM SINERJI 3+ (4* + 16 + 4 + 16 + *4) cm. This type of window glazing provided higher performance in cold climates. It also satisfied the TS 825 Standard. (* Represents the location of low-e Coating) (U-Value = 0.778 W / m2.K)

For the sake of investigation, the window alternative which was the most energy efficient and was the most economically efficient was compared to the other window alternatives. Their thermal behavior was tested for the cold dominant climate of Ankara. To find out the heating loads, the window alternatives were simulated keeping the base case alternative as the basic measure. In addition, this simulation calculated the monthly and yearly heating loads produced by the three different windows for the three different apartment flats and the outputs were obtained.

The initial investment cost of the window alternatives in terms of unit price per square meter was found and by adding this cost for each window to the energy operation cost of each window the required economic efficiency calculations were obtained.

Table 8 Characteristics of used materials of the case study.

	Thermal Conductivity (W / m.K)	Specific Heat Capacity (J / kg.K)	Density (kg / m3)
Gypsum Insulating Plaster	0.180	1000	600
MW Glass wool (High Performance Panels)	0.032	840	30
XPS Extruded Polystyrene-CO2 Blowing	0.034	1400	35
EPS Expanded Polystyrene-Standard	0.040	1400	15
13.5 cm Brick Block	0.320	1000	600
8.5 cm Brick Block	0.320	1000	650
Aerated Autoclaved Concrete (AAC) Block	0.110	896	2800
Heavy Weight Concrete Blocks	1.630	1000	2300
Light Weight Concrete Blocks	0.190	1000	600
Concrete Reinforced (with 2% steel)	2.500	1000	2400
Screed	0.410	840	1200
Wooden Floor	0.140	1200	650

The compositions of the interior partitions, floor and ceiling slabs and floor finishes were maintained the same. Moreover, when the three window options were being investigated all the other base case conditions were maintained as the existing built situation. The properties of the building materials used in the flats are given in table 8.

3.1.2 Wall Sections Under Investigation

The second part of the investigation in this thesis was to test the thermal energy efficiency of four wall system sections for each of three different types of block materials namely Aerated Autoclaved Concrete (AAC) Blocks, Heavy Weight Concrete Blocks, and Light Weight Concrete Blocks. The three different block wall system configurations are shown in the figures 36, 37 and 38. As an investigation the building envelope, represented by the different wall system sections, which was the most energy efficient and most economically efficient was compared from the results of the simulation and the consequent initial investment and operation costs were estimated. To find out the heating loads produced by the heating system, the wall system sections were simulated keeping the base case option as the constant measure.

Here the areas of the different block wall components were calculated to find the initial investment and operation costs and from the data obtained from the simulation their heating loads for the cold dominant climate of Ankara were obtained. The original construction was taken as the base case and the study was held for three different flat apartments in one floor. To obtain the initial capital investment cost of each of the different wall system sections, a calculation including the total unit area in m2 multiplied by the unit cost per square meters was undertaken. To find the operation cost of each of the different wall system sections, a calculation involving the unit cost per kWh of the fuel used for heating was multiplied by the yearly total heating output. By the addition of the initial capital investment costs of the wall system sections to the operation costs which included the block costs per unit area, the insulation as well as the workers' production the investigated calculations were obtained. Moreover, since during the study period of the building the maintenance, repair and replacement costs were not known they were not added to the calculation.

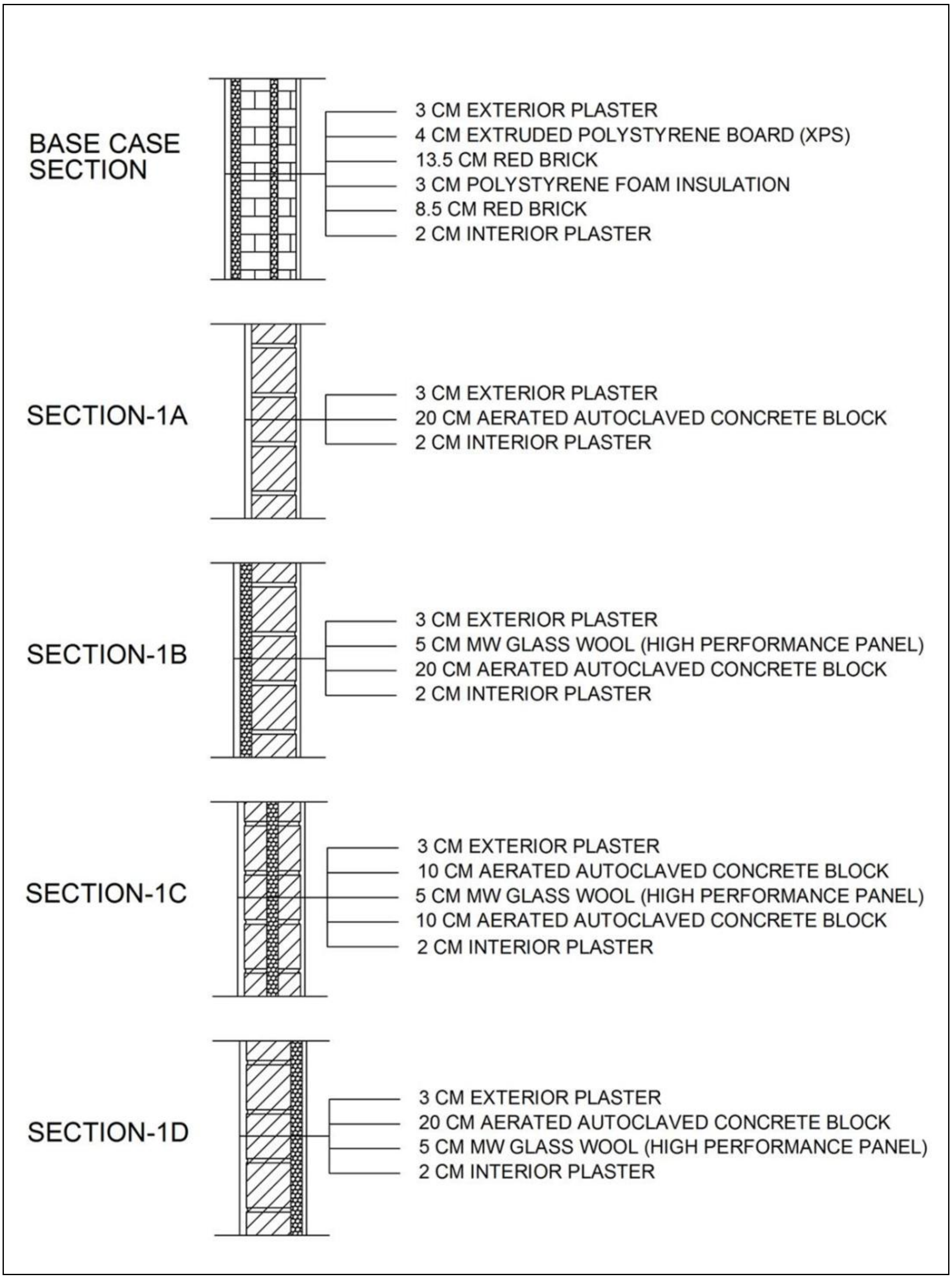

Figure 36 Aerated Autoclaved Concrete Blocks for four different Wall System Sections and The Base Case Section.

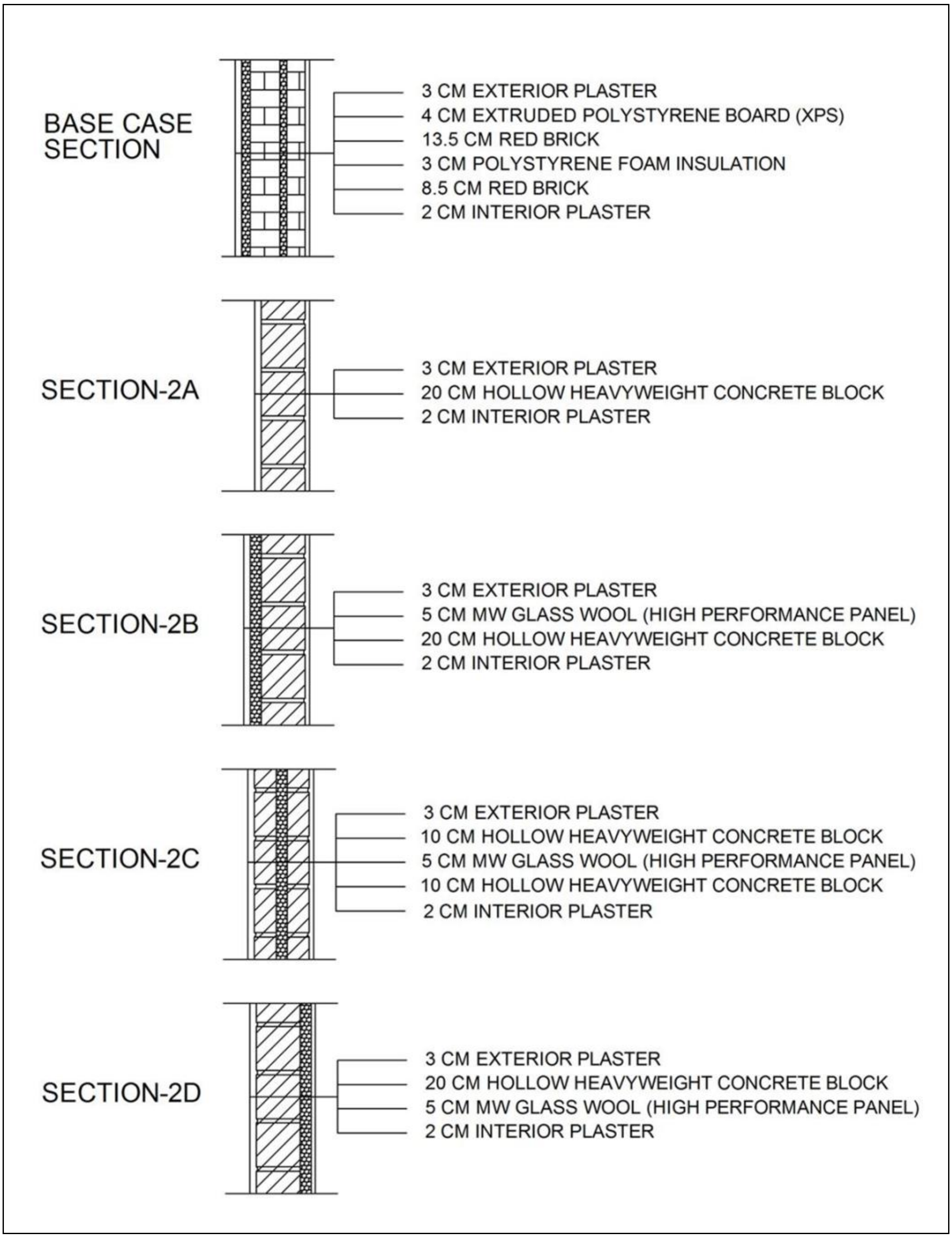

Figure 37 Hollow Heavyweight Concrete Blocks for four different Wall System Sections and The Base Case Section.

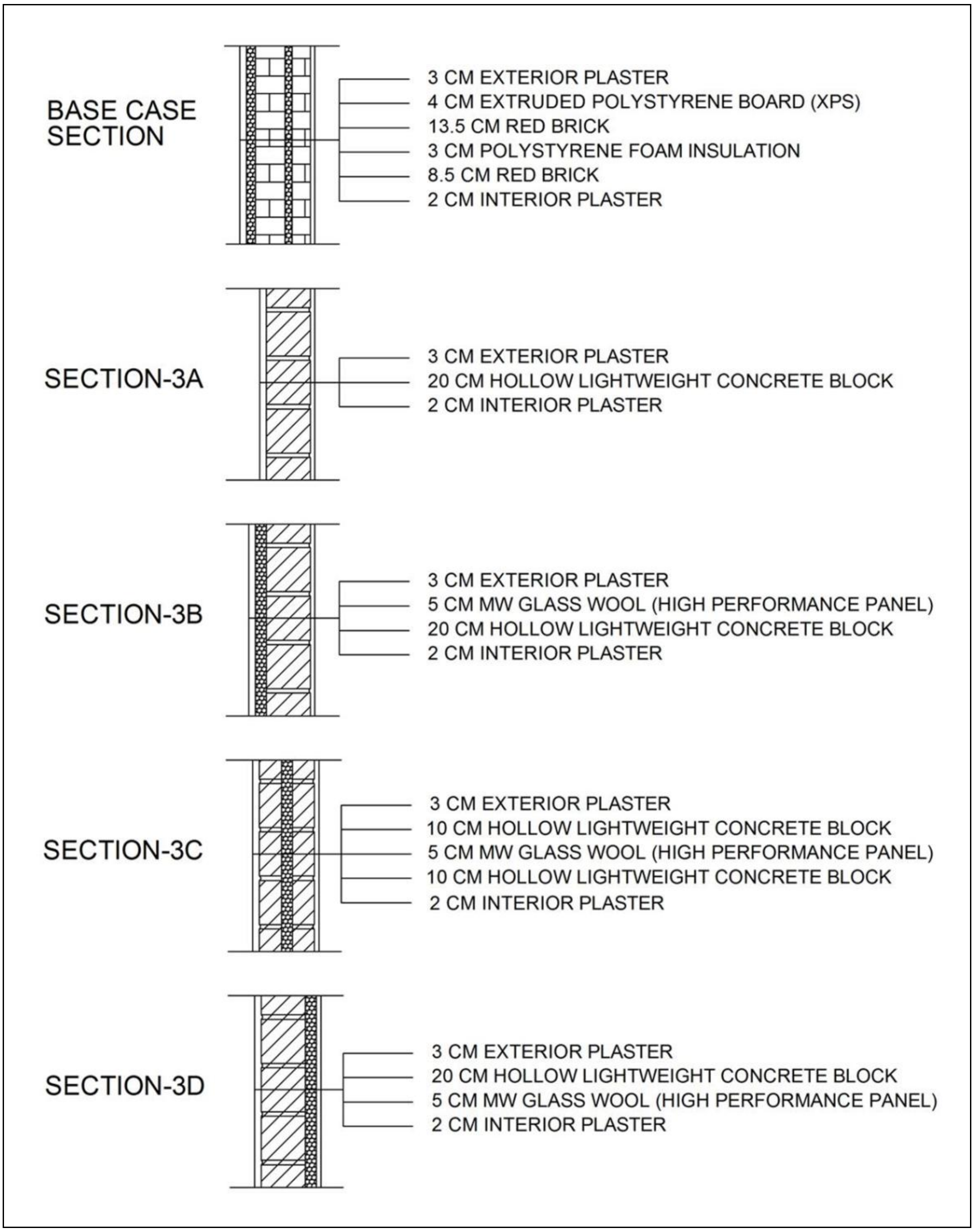

Figure 38 Hollow Lightweight Concrete Blocks for four different Wall System Sections and The Base Case Section.

The information regarding the apartment flat zones, their areas, the total area of each flat and the dimensions and areas of the windows with their orientation were given in table 9 below.

Table 9 The zonal and window size information (Keçiören Municipality).

Zone	Flat-1 Area (m2)	Window Dimension and Orientation			
		L (m)	H (m)	Area (m2)	Direction
Saloon (Win.)	27.1500	2.20	1.60	3.52	S
Saloon (Door)	----	0.90	1.30	2.06	W
Kitchen	9.8150	1.40	1.30	1.82	W
M. Bedroom	15.2250	1.50	1.30	1.95	W
Bedroom-1	11.8125	1.70	1.30	3.10	S
Bedroom-2	8.4350	1.20	1.30	1.56	W
Laundry	1.9575	----	----	---	----
Bathroom	3.0725	0.40	0.50	0.20	IV
Bath	1.9500	0.40	0.50	0.20	IV
WC	1.5950	0.50	0.50	0.25	IV
Corridor	9.4800	----	----	----	----
Total	**103.5632**			= 14.66	
	Flat-2 Area (m2)				
Saloon (Win.)	27.1500	2.20	1.60	3.52	S
Saloon (Door)	----	0.90	1.30	2.06	E
Kitchen	9.8150	1.40	1.30	1.82	E
M. Bedroom	15.2250	1.50	1.30	1.95	E
Bedroom-1	11.8125	1.70	1.30	3.10	S
Bedroom-2	8.4350	1.20	1.30	1.56	E
Laundry	1.9575	----	----	1.78	----
Bathroom	3.0725	0.40	0.50	0.20	IV
Bath	1.9500	0.40	0.50	0.20	IV
WC	1.5475	0.50	0.50	0.25	IV
Corridor	9.4800	----	----	----	----
Total	**105.2381**			= 14.66	
	Flat-3 Area (m2)				
Saloon	24.5250	2.20	1.60	3.52	N
Kitchen	14.1400	1.40	1.30	3.09	E
M. Bedroom	12.0000	1.50	1.30	1.95	W
Bed-1 (Win.)	13.5300	1.50	1.30	1.95	N
Bed-1 (Door)	----	0.90	1.30	1.17	W
Bedroom-2	12.2100	1.50	1.60	2.40	N
Laundry	1.4975	----	----	----	----
Bathroom	5.7700	0.40	0.50	0.20	IV
WC	1.4375	0.30	0.50	0.15	IV
Corridor	8.9400	----	----	----	----
Total	**107.0125**			= 14.43	

3.2 Ankara Climate

Ankara with its elevation, inward location and its cold snowy winters and hot, dry summers is classified to have a continental climate. Ankara's spring and autumn are rainy. Under Köppen's climate classification, Ankara is classified to have a temperate climate. Due to its high altitude and dry summers Ankara's summer nights are cool (World Map of the Köppen-Geiger Climatic Classification, 2010).

Continental climate is known to have yearly changes in temperature because of the non-existence of water bodies in its vicinity. During winter another feature common to continental climate is its cold temperature that is enough to support a common period of snow each year. The data shown in table 10 documents the record high, average high, average low and record low temperatures (°C) of Ankara climate obtained between 1960 and 2012 (Turkish State Meteorological Service).

Table 10 Ankara climatic details (Turkish State Meteorological Service).

Climate data for Ankara (1960–2012)													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Record high °C	16.6	19.9	26.4	30.6	33.0	37.0	41.0	40.4	36.0	32.2	24.4	19.8	41.0
Average high °C	4.3	6.4	11.7	17.2	22.2	26.6	30.2	30.2	26.0	19.9	12.8	6.6	17.8
Average low °C	-3.0	-2.2	1.0	5.7	9.7	13.0	16.0	16.0	11.9	7.4	2.5	-0.6	6.5
Record low °C	-21.2	-21.5	-19.2	-6.7	-1.6	4.7	6.8	6.3	2.5	-3.4	-10.5	-17.2	-21.5

3.2.1 Temperature Range According to Climate Consultant

As seen from the temperature range graph below and according to data obtained from climate consultant, the comfort temperature range for the city of Ankara is between 20 ˚C to 25 ˚C. Starting from January, the recorded high temperature, the design high temperature, the average high temperature, the mean temperature, the average low temperature, the design low temperature, and the recorded low temperature in a sequence increase steadily from January up to July. From August to December these temperatures decrease steadily as shown in figure 39.

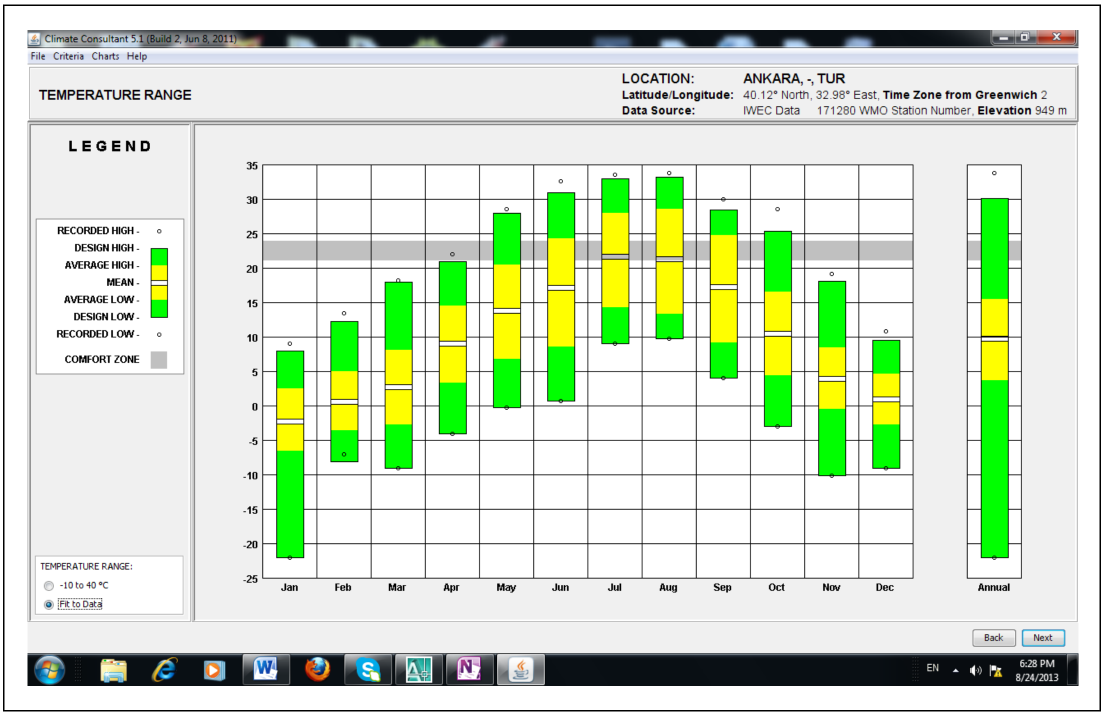

Figure 39 Monthly temperature range within Ankara according to Climate Consultant.

3.3 Methodology

For this investigation, three flats located in the first floor have been selected. Table 9 shows the zones within the flat, the area of the flats, size and area of the windows.

In terms of windows, aluminum frames are thermally not as efficient as timber or UPVC as they will transmit heat and cold air in and out of the building. Moreover since UPVC has more advantages to other frames it was preferable. So the frame that was applied to the three different window glazing alternatives and input into the simulation was UPVC.

3.3.1 Method

The investigation in this thesis constituted the usage of a computer program. It was known as “Design Builder”. Design builder was a multi-zone simulation software which calculated the thermal indoors of the flats investigated during any period of time and in this thesis the period was an entire year. Data collected from this program would help in thermally analyzing the different building envelope alternatives investigated in this thesis.

A wide range of building types could be analyzed using this software and in this case, three flats. Energy simulations of real designs could be obtained. The input data in the software included the following:

1) Activity template:

   From all the activity templates that included different building types such as airport terminals and bus stations to workshops and maintenance depots, the selected template in this thesis was the dwelling template. This template consisted of the following sub-topics:

   i) Occupancy:

      This included the number of people per unit floor area data included within the building zones. It was supported and controlled by the occupancy schedules for example the bed, the bath, the circulation, the lounge, the dining, the kitchen and the toilet schedules.

ii) Metabolic rate:

This was the energy spent in a given period in a particular space or zone. It included values ranging from 1.00 for men, 0.85 for women or 0.75 for children.

iii) Holidays:

This was useful in documenting the days of the year where the occupants were at home or were away from home. It was in the form of a schedule which, once input into the design builder software, was included in the simulation calculation

iv) Domestic Hot Water:

This was the heat energy required for the supplied water in the wet areas.

v) Environmental Control:

This documents the set-point and range of the HVAC heating and cooling as well as the ventilating temperatures, whether they are natural or mechanical. In addition, the fresh air amount per person and the mechanical ventilation per unit area was also included. However, in this investigation, the effect of mechanical ventilation was ignored in order to study the effect of passive design strategies natural ventilation was selected.

vi) Computer:

This was the option of the energy spent using computers.

vii) Office equipment:

This was the option of the energy spent using office equipment.

viii) Miscellaneous equipment:

This was the option of the energy spent for electrical equipment e.g. television, radio etc.

ix) Catering equipment:

This was the option of the energy spent for kitchen electrical equipment e.g. electrical stove, dishwasher etc.

ix) Process equipment:

This was the option of the energy spent for other electrical equipment e.g. washing machine etc.

2) Construction template:

This included the documentation of external walls, internal partitions, flat roofs, pitched roofs, ceilings, and floors.

3) Openings template:

This was the openings or glazing system used within the building spaces or zones. The windows may be single, double or triple with different dimensions, frame types and dividers. Windows may also be external, internal or roof glazing. Doors were also included in this template.

4) Lighting template:

   This was the lighting system used within the building spaces or zones. The lighting location, whether external or internal, is also included.

5) Heating, ventilation and air conditioning (HVAC) template:

   This template allows for the choice for different HVAC systems. It included the fuel whether electrical or natural gas used in its operation. The HVAC system used is hot water radiator in winter and natural ventilation in summer.

The occupants used the flats during the entire day and night. The tables in **APPENDIX MM** indicated the occupancy schedule during the day and night for the weekdays and weekends for all the zones of the three flats including the holidays.

The lighting schedule matches the above occupancy schedules because whenever the different zones are in use the lighting would be in use. On the other hand, the data of other electricity operated devices such as televisions and computers located in the living rooms and bedrooms, the stove, washing machine and refrigerator located in the kitchen, are input in the activity template by switching on the computer, office equipment, miscellaneous, Catering and process options. The zone occupancy schedule also applies for these electricity operated devices with the exception of the refrigerator which continues to be in use even when the kitchen is not in use.

The living room (saloon), kitchen and the entire bedrooms, bathrooms and corridors being the flats constituents are heated by the heating radiators and cooled by natural ventilation, while corridors, bath, WC, and laundry are not heated or cooled. Toilets and bathrooms are ventilated by natural means with a ventilation rate considered as 7 air-changes per hour (achs).

The known factors of initial investment and operation costs in this thesis were considered instead of the entire life cycle cost which involves knowing the total cost of owning, operating, maintaining, repairing, replacing and disposing of a building or a building system over a period of time. As mentioned earlier since all the other factors such as owning, maintenance, repairing, replacing and disposing are not known, they may be considered as typical constants in all calculations. Thus their effect on the total initial investment and operation costs calculations of the glazing alternatives and different wall sections would be relatively proportional. So only the initial investment and operation costs calculations were considered in thesis. The factors used in the initial investment and operation costs estimation are given in table 11 below.

Table 11 The factors used in the Initial Investment and Operation Costs Estimation.

Analysis type	Initial Investment and Operation Costs
Beginning date	2007
Study period	30 years
Planning/Construction period	2 years
Service date	2009
Life of glazing	60 years
Fuel type	Natural gas, electricity
The unit cost of natural gas	0.08686175 TL / kWh (for 01 / 04 / 2014)
The unit cost of electricity	0.28386 TL / kWh (for 01 / 10 / 2012)
The unit cost of Water	2.26 TL / m3 (for 04 / 04 / 2014)

CHAPTER 4

RESULTS AND DISCUSSION

Firstly the monthly and yearly heat gains through the three window glazing alternatives in the investigated flat-1, flat-2 and flat-3 are given. This is followed by monthly and yearly heat load production by the heating system for all the wall system sections in the investigated flat-1, flat-2 and flat-3. The heat losses and gains percentage through all the three window glazing alternatives for flat-1, flat-2 and flat-3 are included next. The heat losses percentage through all the wall sections for flat-1, flat-2 and flat-3 are included. Finally the initial capital investment and operation costs calculations for the three glazing window alternatives and the different wall system sections are also included.

4.1 Comparing Monthly Heat Gains Through the Different Glazing Windows in Flat-1, Flat-2 and Flat-3

From figure 40 and according to the simulation, the monthly heat gains for the three glazing window alternatives are obtained from January to December. The numerical results of the simulation are shown in **APPENDIX VV.**

According to the simulation, a pattern is seen by the three glazing window types in that the winter months receive lesser heat gains when compared to the summer months. A steady rise in heat gain occurs from winter to summer before a steady decline in heat gain from summer to winter is noticeable.

According to the simulation, it could be concluded that in the temperate cold climate of Ankara the least energy gain occurs through ISICAM SINERJI 3+ followed by that through ISICAM SINERJI and finally through ISICAM KLASIK. This may explained due to the respective lower thermal transmittance value (U-Value) from the first alternative to the second alternative to the third.

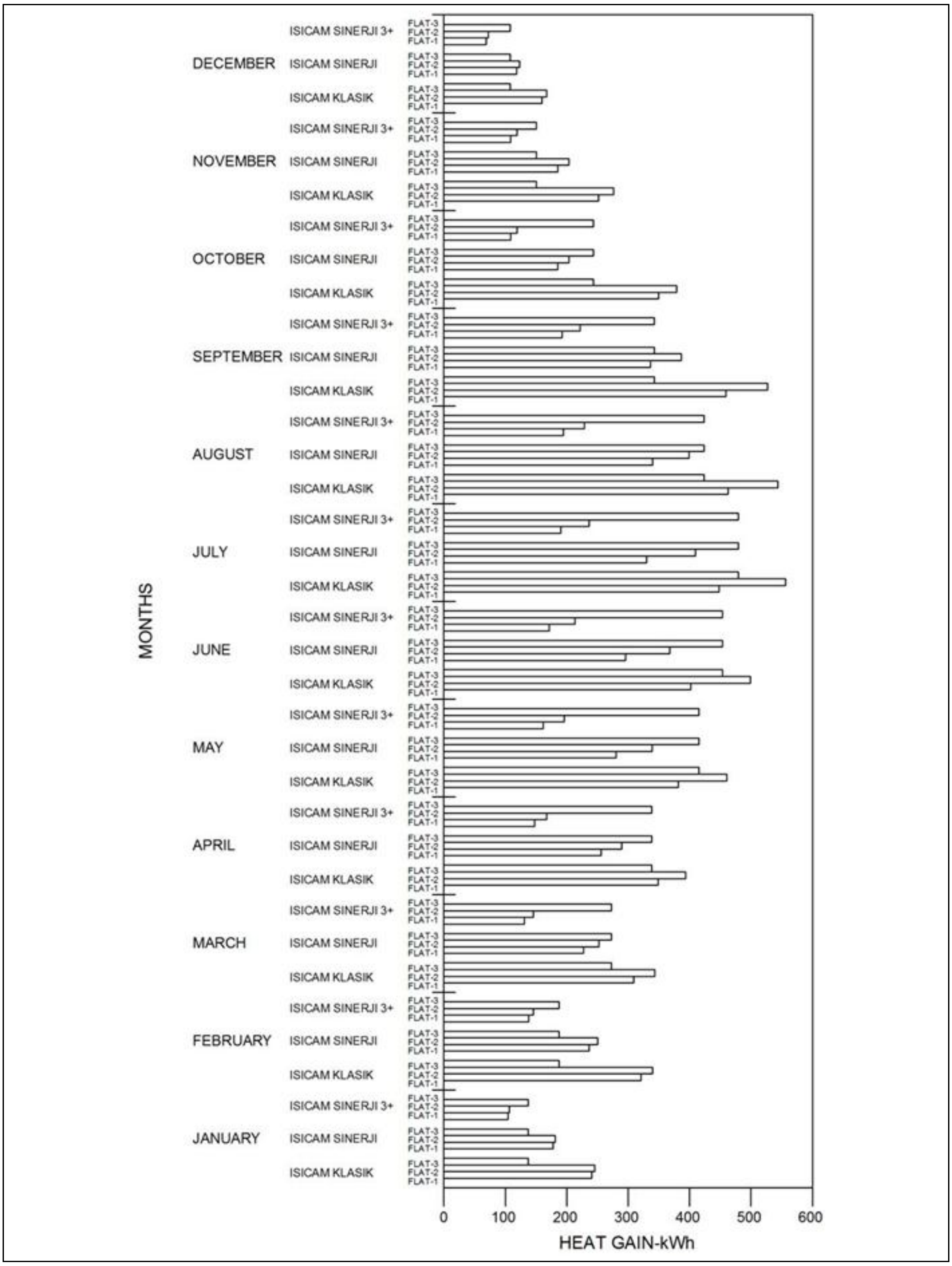

Figure 40 Monthly heat gains through the three window glazing alternatives in the investigated flat-1, flat-2, flat-3 kWh.

According to the simulation, the monthly heat gains for the three glazing window alternatives namely ISICAM KLASIK, ISICAM SINERJI and ISICAM SINERJI 3+ were similar for flat-3. This may be explained to the fact that this Northern facing flat-3 receives the least solar energy and thus the glazing windows have minimized reaction with the immediate exterior even though they were meant to react differently.

Another conclusion was that when the glazing alternatives namely ISICAM KLASIK, ISICAM SINERJI and ISICAM SINERJI 3+ were compared more heat gains were recorded for flats-2 when compared to flat-1. This may be explained due to the fact that the Southern-Eastern facing flat-2 is exposed to solar heat more than the Southern-Western facing flat-1.

In all the months, the performance of ISISCAM SINERJI 3+ in terms of heat gains for flat-1 and flat-2 was the least thus indicating its high performance. This is advantageous in the summer months since less heat gains are transmitted to the interiors. In the winter months this performance of ISICAM SINERJI 3+ indicates that even though less heat was gained to the interior from the exterior, at the same time less heat was lost from the interior to the exterior because of its high thermal performance.

4.2 Comparing Monthly Heat Load Production by the Heating System Through All the Different Wall Sections in Flat-1, Flat-2 and Flat-3

Figures 41, 42, and 43 shown below represent the monthly heat loads production by the heating system for the base case, 1A, 1B, 2A, 2B, 3A, 3B wall system sections of flat-1, flat-2 and flat-3. The numerical results obtained from the simulation could be seen in **APPENDIX WW.** The simulation provides heating load production throughout the entire months of the year, from January to December.

One conclusion that could be added is regarding the wall sections involving AAC blocks namely 1B, 1C and 1D, heavyweight concrete blocks namely 2B, 2C and 2D and lightweight concrete blocks namely 3B, 3C and 3D. According to the simulation these wall sections in each of their category perform almost similar with little numerical difference as could be seen in **APPENDIX WW** and figuratively as shown in **APPENDIX AAA.**

The severity of the winter months could be concluded from the simulation results. An increase of the heat load production by the heating system starts from October, to November and then to December and January which together produce the highest heat loads. From January to February and then to March the heating loads reduce gradually.

From the simulation program, the schedule of the heating system was selected as the winter (northern hemisphere). This schedule calculates the heating load production in the winter months from the beginning of October, throughout November, December, January, February and finally March. The other months from April, May, June, July, August and September are counted as the summer months where the heating system would be turned off and only natural ventilation would be used for cooling the interior spaces.

Another conclusion obtained from the simulation results for all the flats and for all the walls system sections which have no insulation, namely 1A, 2A and 3A, from the different types of blocks from Aerated Autoclaved Concrete Block, to heavyweight concrete blocks and to lightweight concrete blocks, the maximum heat loads are produced by the heating system. This indicates the importance of the presence of insulation in heat gain resistance in winter. The glass wool insulation implemented in the other wall system sections increase the thermal performance of the wall. This is due to the lower heat conductivity of glass wool with a value of 0.032 W/ m2.k. Thus lesser heat is gained to the interior and lesser heat loads are produced by the heating system by the other wall system sections other than 1A, 2A and 3A.

As could be seen from **APPENDIX AAA,** another conclusion obtained from the simulation results for the wall sections involving heavyweight concrete blocks namely 2A, 2B, 2C and 2D, the highest heat load production from the heating system was achieved when compared to the other heat load production resulted by the other wall sections involving AAC blocks namely 1A, 1B, 1C and 1D and lightweight concrete blocks namely 3A, 3B, 3C and 3D. This may be explained due to the fact that heavyweight concrete blocks have the highest heat conductivity value of 1.63 W / m2.k, when compared to that of AAC blocks and Lightweight concrete blocks which have the thermal conductivity of 0.11 W/ m2.k and 0.19 W / m2.k respectively. The difference in conductivity affects the heat transfer through the walls even though insulation is included. Thus higher heat transfer through the wall section occurs and higher heat load production is released by the heating system to maintain interior comfort. Therefore in a sequence, in order to provide the same interior comfort, according to the simulation results AAC blocks produce the best and least amount of heat load production by the heating system, followed by lightweight concrete blocks and then heavyweight concrete blocks.

When comparing the monthly total heat loads production by the heating system for the three flats 1, 2 and 3 under investigation, a similar pattern of thermal behavior was noticed from the winter to the summer months and vice versa. Heat load production decreased steadily from the winter months to the summer months and increased steadily from the summer months to the winter months but with a difference. This difference indicates that when considering the heat load production by the heating system the most energy was released by flat-3, followed by flat-1 and then by flat-2. This may be explained due to the fact that flat-3 which is the North facing flat received the least solar energy when compared to the other flats and thus more heat load production is required to achieve the needed interior thermal comfort. In addition, the least heat load production is achieved for flat-2 when compared to the other flats. This may be explained due to the fact that it received the maximum solar energy since it is the flat facing the South-East. This extra solar energy helps in the interior heat gain and thus in order to achieve the required interior comfort lesser heat load production in necessary by the heating system.

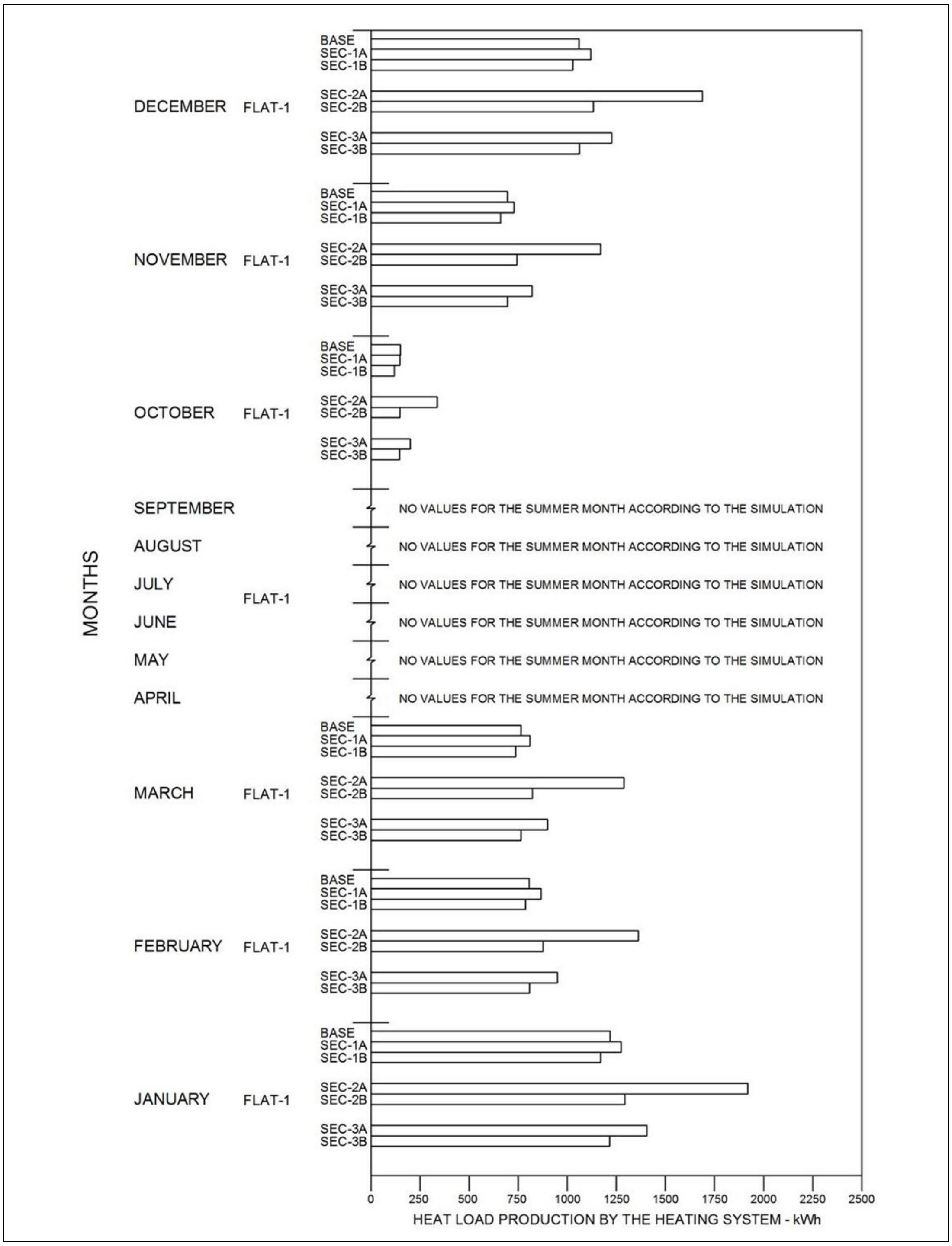

Figure 41 Monthly heat load production by the heating system for some Wall Sections in the investigated flat-1 kWh.

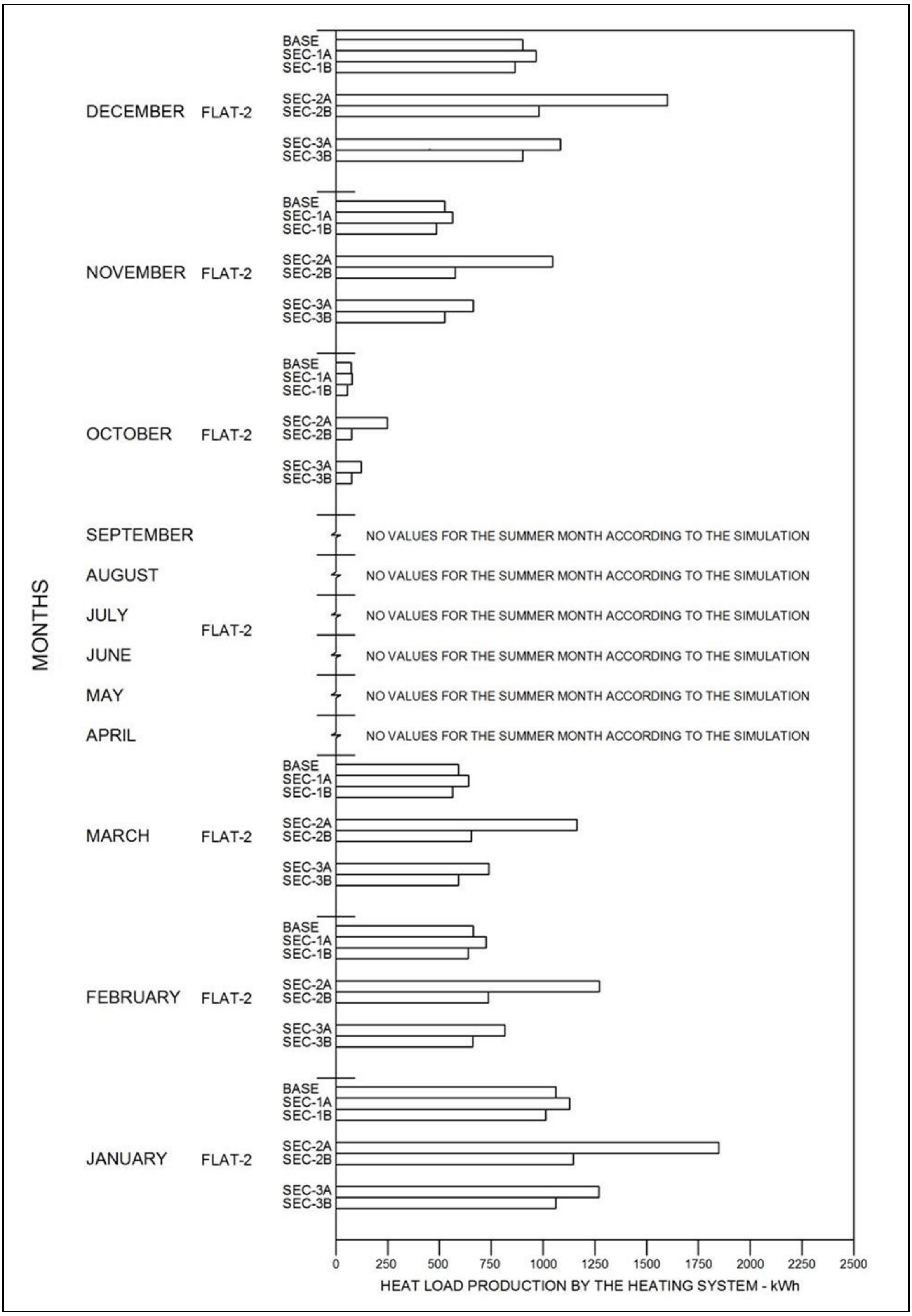

Figure 42 Monthly heat load production by the heating system for some Wall Sections in the investigated flat-2 kWh.

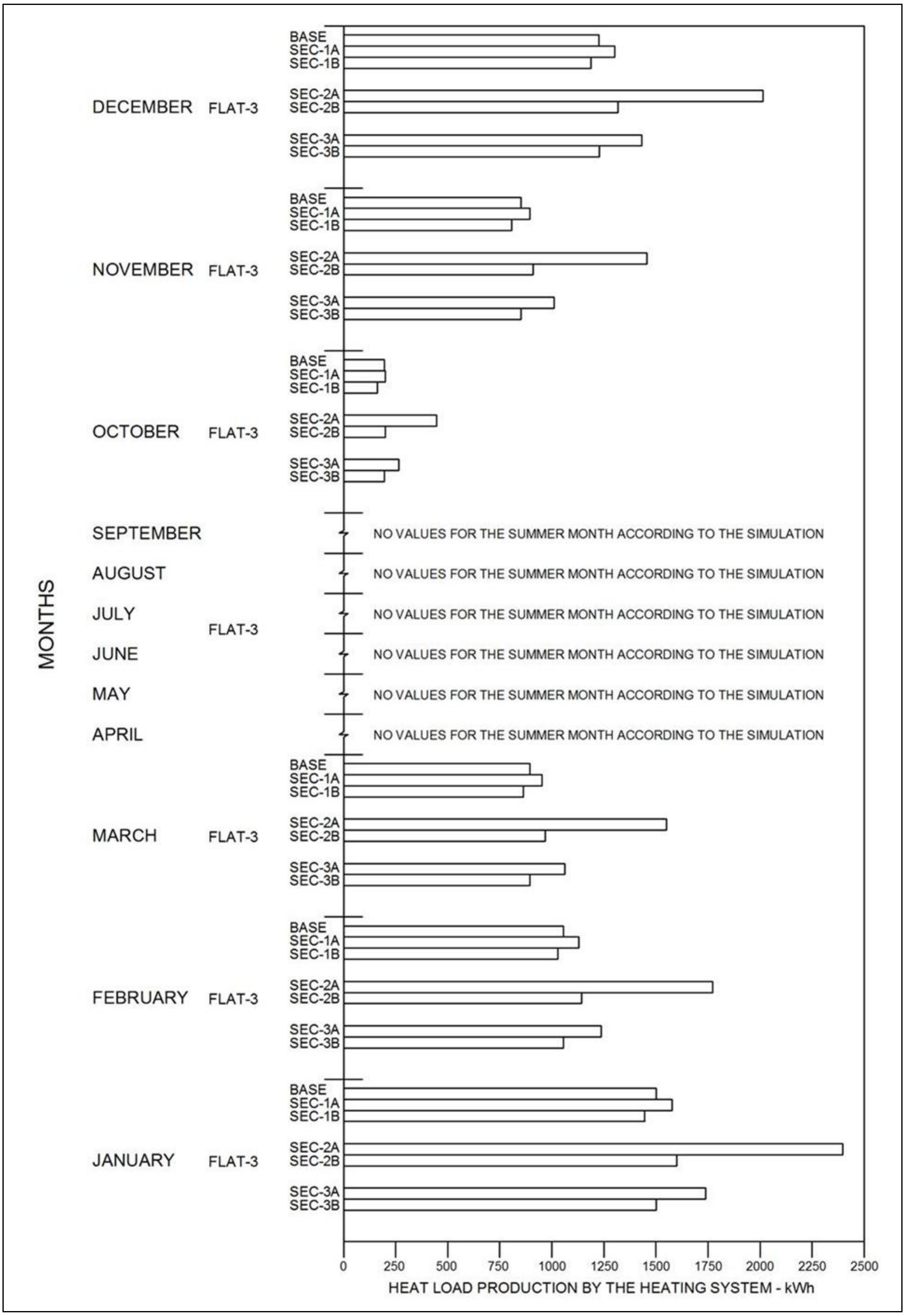

Figure 43 Monthly heat load production by the heating system for some Wall Sections in the investigated flat-3 kWh.

4.3 Comparing Yearly Heat Gains Through the Different Glazing Windows in Flat-1, Flat-2 and Flat-3

According to the simulation, the yearly heating loads transmitted to the interiors were determined by the usage of a heating gain measure by the glazings during the heating period. Figures 44 shows the yearly heating gains of the glazing window alternatives used in the respective study flats. The figure below indicates that for the three different glazing alternatives, those in flat-2 receive more solar heat when compared to flat-1. However, according to the simulation, the three different glazing alternatives in flat-3 perform similarly. This may be explained due to the fact that in this Northern facing flat little solar energy was received and since the high performance glazing performs well with the presence of solar energy the heat gain was minimized.

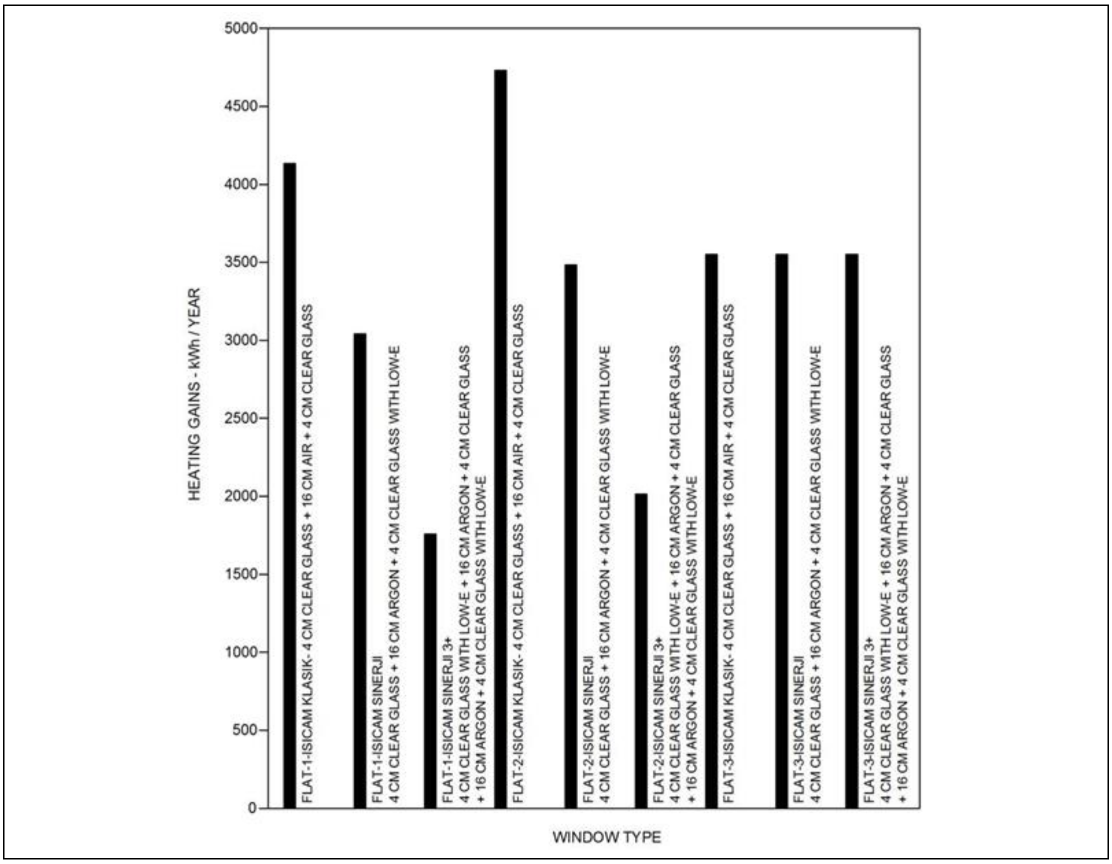

Figure 44 Yearly heating gains through the three window glazing alternatives in the investigated flat-1, flat-2 and flat-3- kWh/y.

4.4 Comparing Yearly Heat Load Production by the Heating System Through All the Different Wall Sections in Flat-1, Flat-2 and Flat-3

According to the simulation the annual heating loads are determined by the measure of the net load production of the heating system.

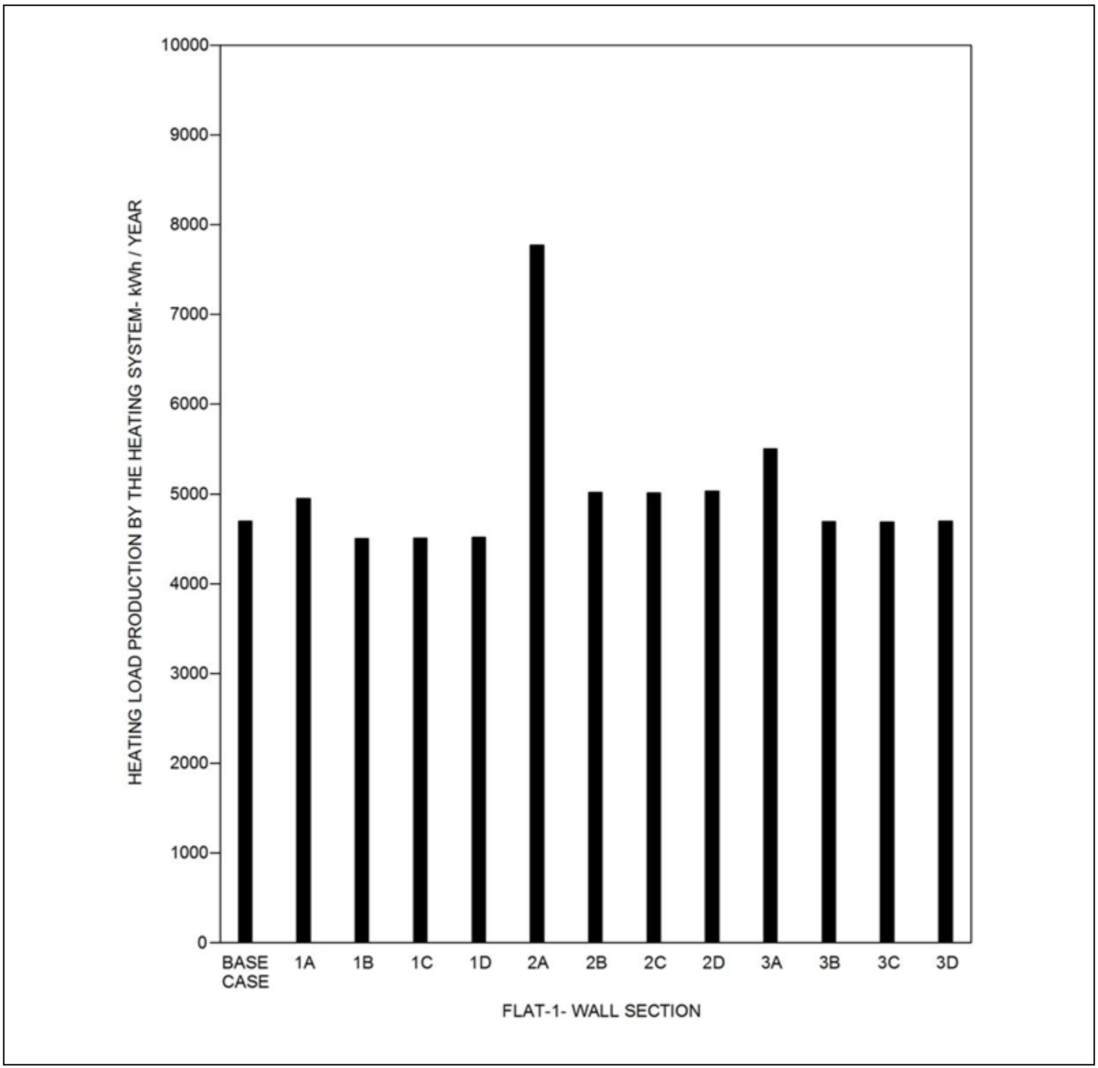

Figure 45 Yearly heating load production of the Wall Sections- Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D units in flat-1, kWh / year.

According to figures 45, 46, and 47, the yearly heating loads results obtained from the simulation show that in flat-1 the wall sections 1A, 1B, 1C and 1D involving Aerated Autoclaved Concrete Blocks produced the best performance of the heating system in terms of heating load production thus AAC blocks configuration provided the most heat energy saving in order to achieve the required interior comfort. This was followed by the wall sections 3A, 3B, 3C and 3D involving Lightweight Concrete Blocks, and then followed by the wall sections 2A, 2B, 2C and 2D involving Heavyweight Concrete Blocks.

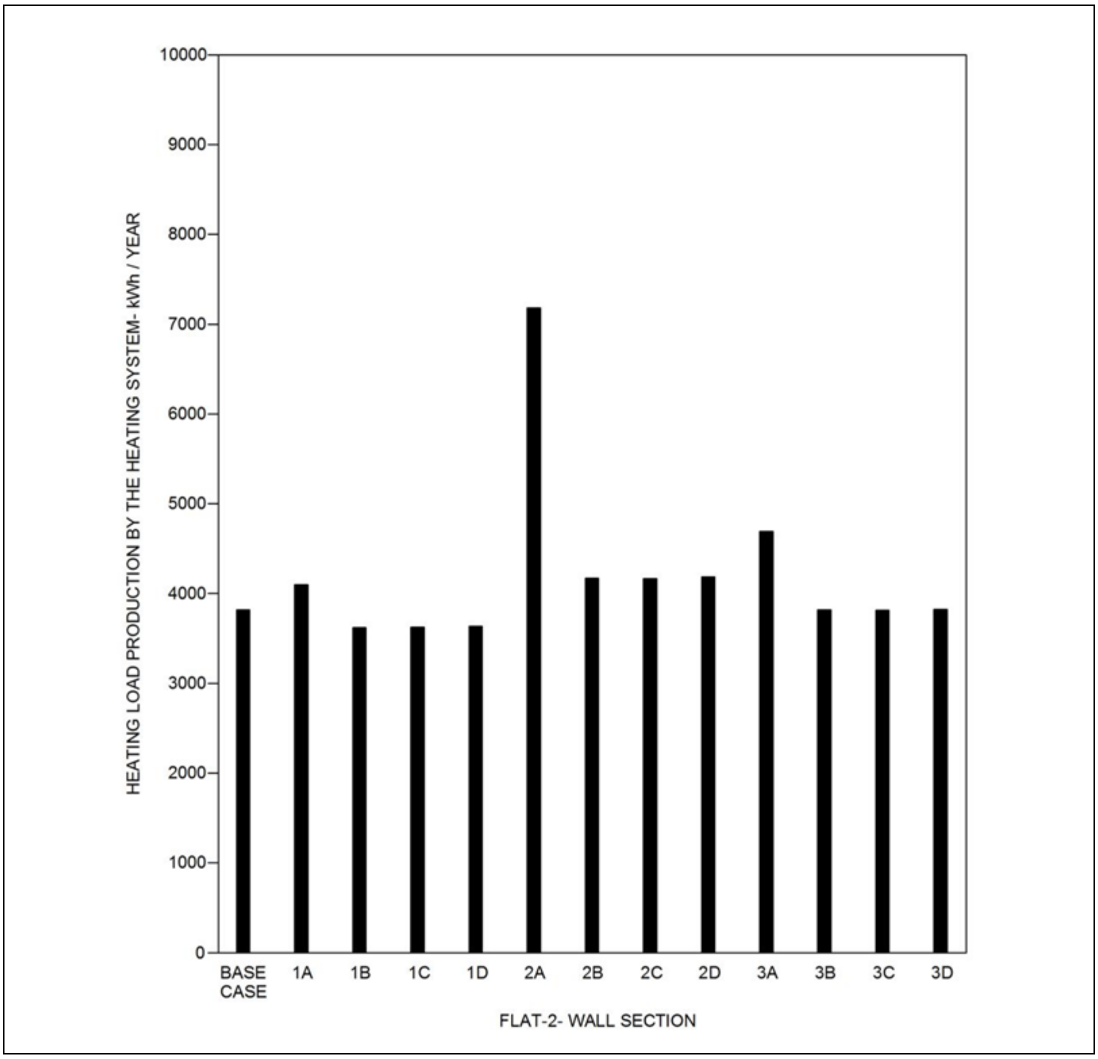

Figure 46 Yearly heating load production of the Wall Sections- Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D units in flat-2, kWh / year.

This may be explained due to the difference in the conductivities of different construction block used, where Aerated Autoclaved Concrete Blocks have the least conductivity of 0.11 W / m2 . K followed by Lightweight Concrete Blocks with a conductivity of 0.19 W / m2 . K and then Heavyweight Concrete Blocks with a conductivity of 1.63 W / m2 . K. The difference in conductivity affects the heat transfer through the walls even though insulation is used. The higher the conductivity of the material, the higher the heat is transferred through the wall section.

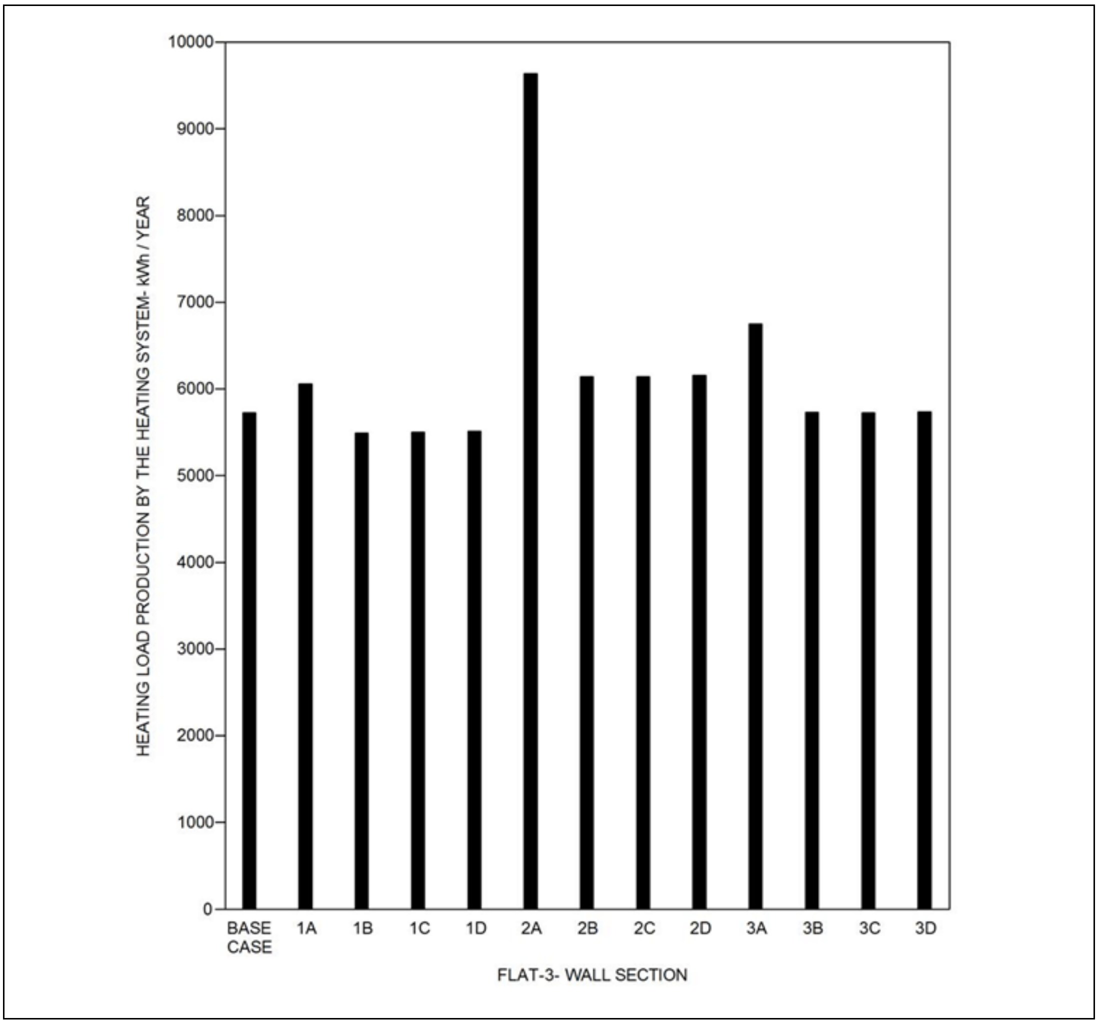

Figure 47 Yearly heating load production of the Wall Sections- Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D units in flat-3, kWh / year.

The thermal behavior pattern in flat-1 is repeated in the other flat-2 and flat-3, however to different extents. According to the simulation, flat-2 produced the least results in heat load performance followed by flat-1, and then followed by flat-3. This may be explained by the fact that the Southern Eastern facing flat-2 received the most solar energy which when added to the interior heating system lesser heating load is required to achieve interior thermal comfort in winter. The yearly energy expenditure obtained from the simulation results are used to calculate the operation costs which is further added to the initial investment cost. It is important to mention that the initial investment and operation costs value for the window glazing options is first calculated and then that for the different wall sections is also calculated.

4.5 Percentages (%) of Heat Gains and Losses Through the Window Glazings in Flat-1, Flat-2, Flat-3

According to Maçka and Yalçın in 2011 the heat losses and gains are considered to be as follows:

> "Heat losses occur through glazings, walls, floors, roofs, doors and ventilation, external infiltration, and external ventilation, while heat gains occur through general lighting, miscellaneous systems, occupancy, domestic hot water, heat generation, solar gains from exterior windows, room electricity, and computer and equipment in building." (Maçka and Yalçın, 2011).

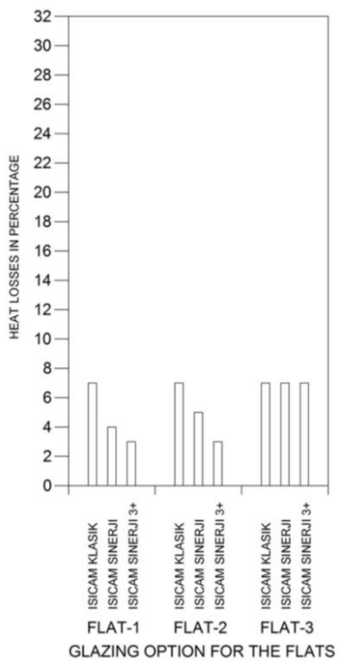

Figure 48 Heat losses (%) through the three window glazing alternatives in flat-1, flat-2 and flat-3 obtained from the simulation results.

From figure 48, 7% of the heat losses in flat-1 occur by ISICAM KLASIK glazing, 4% of the heat losses occur by ISICAM SINERJI and 3% of the heat losses occur by ISICAM SINERJI 3+. Therefore heat energy savings of 3% and 4% were obtained by ISICAM SINERJI and ISICAM SINERJI 3+ glazings respectively when compared to the ISICAM KLASIK glazing.

From figure 48, 7% of the heat losses in flat-2 occur by ISICAM KLASIK glazing, 5% of the heat losses occur by ISICAM SINERJI and 3% of the heat losses occur by ISICAM SINERJI 3+. Therefore heat energy savings of 2% and 4% were obtained by ISICAM SINERJI and ISICAM SINERJI 3+ glazings respectively when compared to the ISICAM KLASIK glazing.

From figure 48, 7% of the heat losses in flat-3 occur by ISICAM KLASIK, ISICAM SINERJI and ISICAM SINERJI 3+ glazings. This indicates similar thermal behavior of the glazing alternatives for flat-3. As mentioned earlier, this may be explained to the fact that little solar energy is received by the North facing flat-3.

From figure 49, 30% of the heat gains in flat-1 occur by ISICAM KLASIK glazing, 24% of the heat gains occur by ISICAM SINERJI glazing and 16% of the heat gains occur by ISICAM SINERJI 3+ glazing. Therefore heat energy savings of 6% and 14% were obtained by ISICAM SINERJI and ISICAM SINERJI 3+ glazings respectively when compared to the ISICAM KLASIK glazing.

From figure 49, 31% of the heat gains in flat-2 occur by ISICAM KLASIK glazing, 27% of the heat gains occur by ISICAM SINERJI glazing and 17% of the heat gains occur by ISICAM SINERJI 3+ glazing. Therefore heat energy savings of 4% and 14% were obtained by ISICAM SINERJI and ISICAM SINERJI 3+ glazings respectively when compared to the ISICAM KLASIK glazing.

From figure 49, 20% of the heat gains in flat-3 occur by ISICAM KLASIK, ISICAM SINERJI and ISICAM SINERJI 3+ glazings. This indicates similar thermal behavior of the glazing alternatives for flat-3. As mentioned earlier, this may be explained to the fact that little solar energy is received by the north facing flat-3.

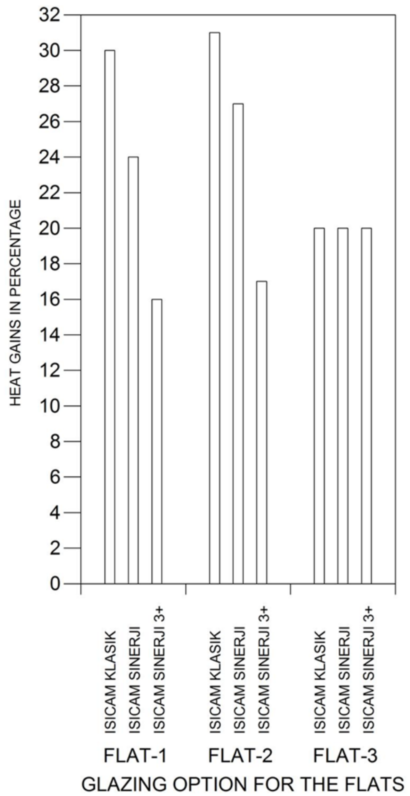

Figure 49 Heat gains (%) through the three window glazing alternatives in flat-1, flat-2 and flat-3 obtained from the simulation results.

4.6 Percentages (%) of Heat Losses through the Wall Sections in Flat-1, Flat-2, Flat-3

Heat losses occur through glazings, walls, floors, roofs, doors and ventilation, external infiltration, and external ventilation (Maçka and Yalçın, 2011).

From figure 50 below, the heat losses through all the wall system sections of flat-1 were shown. From the figure, 4% of the total heat losses in flat-1 occur by the base case wall section. A heat energy loss of 2% was obtained by wall section 1A. Similar heat energy losses were obtained by 1B, 1C, and 1D wall sections when compared to the base wall section. A further heat energy loss of 14% is obtained by 2A wall section when compared to the base wall section and further heat energy losses of 2% were obtained by 2B, 2C, and 2D wall sections. A further heat energy loss of 4% was obtained by 3A wall section when compared to the base wall section and further heat energy losses of 2% were obtained by 3B, 3C, and 3D wall sections when compared to the base case wall section.

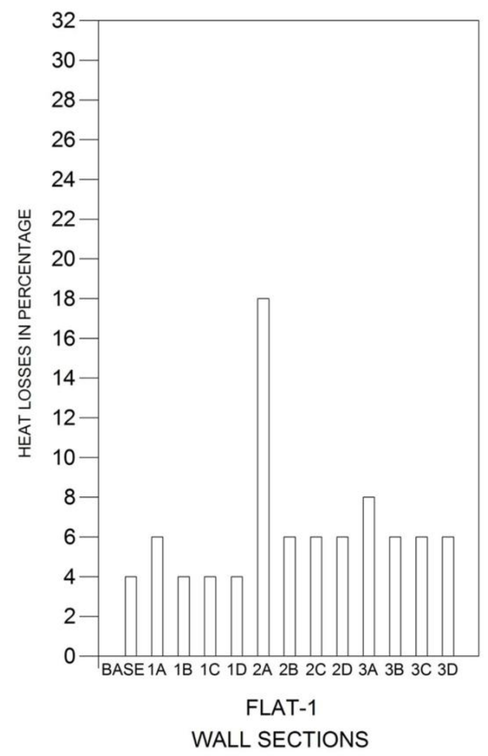

Figure 50 Heat losses (%) through all the Wall System Sections in flat-1 obtained from the simulation results.

The above results indicate that the AAC Blocks wall system sections produced the least energy losses, thus making it the most efficient in preserving heat load produced by the heating system. As mentioned earlier, this may be explained due to fact that AAC blocks have the least heat conductivity value thus reducing the amount of heat losses to the exterior. According to the heat loss results, wall system sections involving heavyweight concrete blocks behave similarly to wall sections involving Lightweight concrete Blocks with the exception of the wall section 2A and 3A.

These wall sections have no insulation and so were prompt to lose more heat to the exterior and thus increase the load on the heating system. The heat loss percentage values of these wall systems could be seen from **APPENDIX XX**.

From figure 51 below, the heat losses through all the wall system sections of flat-2 were shown. From the figure 4% of the total heat losses in flat-2 occur by the base case wall section. A heat energy loss of 2% was obtained by wall section 1A. Similar heat energy losses were obtained by 1B, 1C, and 1D wall sections when compared to the base wall section. A further heat energy loss of 15% was obtained by 2A wall section when compared to the base wall section and further heat energy losses of 2% were obtained by 2B, 2C, and 2D wall sections. A further heat energy loss of 4% is obtained by 3A wall section when compared to the base wall section and further heat energy loss of 2% were obtained by 3B, 3C, and 3D wall sections when compared to the base case wall section.

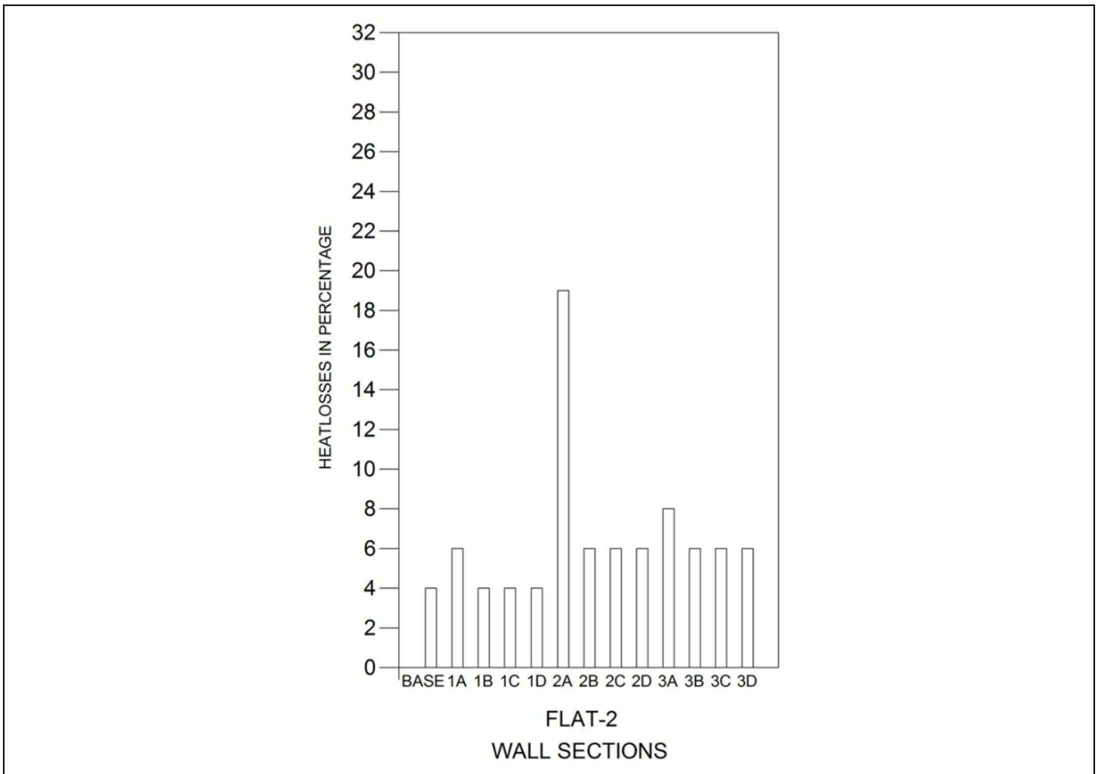

Figure 51 Heat losses (%) through all the Wall System Sections in flat-2 obtained from the simulation results.

The above results indicate that the AAC Blocks wall sections produce the least energy losses, thus making it the most efficient in preserving heat load produced by the heating system. As mentioned earlier, this may be explained due to fact that AAC blocks have the least heat conductivity value thus reducing the amount of heat losses to the exterior. According to the heat loss results wall sections involving heavyweight concrete blocks behave similarly to wall sections involving Lightweight concrete Blocks with the exception of the wall section 2A and 3A. These wall sections have no insulation and so are prompt to lose more heat to the exterior and thus increase the load on the heating system. The heat loss percentage values of these wall systems could be seen from **APPENDIX XX**.

From figure 52 below, the heat losses through all the wall sections of flat-3 are shown. From the figure 4% of the total heat losses in flat-3 occurs by the base case wall section. A heat energy loss of 2% is obtained by wall section 1A. Further heat energy gains of 1% were obtained by 1B, 1C, and 1D wall sections when compared to the base wall section. A further heat energy loss of 15% is obtained by 2A wall section when compared to the base wall section and further heat energy losses of 2% were obtained by 2B, 2C, and 2D wall sections. A further heat energy loss of 4% was obtained by 3A wall section when compared to the base wall section and similar heat energy losses were obtained by 3B, 3C, and 3D wall sections when compared to the base case wall section.

The above results indicate that the AAC Blocks wall sections produce the least energy losses, thus making the heat load production demand by the heating system the most in these sections. The reduction in heat energy by wall sections 1B, 1C and 1D was due the north facing flat-3 which receives the least solar energy and together with the low conductivity of AAC blocks lesser heat losses were produced by these wall sections. This is also applicable to wall sections 3B**,** 3C and 3D which also produce lesser heat losses for flat-3 when compared to those results of flat-1 and flat-2. As mentioned earlier, this may be explained due to the fact that lightweight concrete blocks have low heat conductivity values thus reducing the amount of heat loss to the exterior. According to the heat loss results, wall sections involving heavyweight concrete blocks lose heat more than the wall sections involving lightweight concrete blocks due to the difference in conductivity with the exception of the wall section 2A and 3A. These sections have no insulation and so are prompt to lose more heat to the exterior and thus increase the load on the heating system Wall sections. The heat loss percentage values of these wall systems sections could be seen from **APPENDIX XX**.

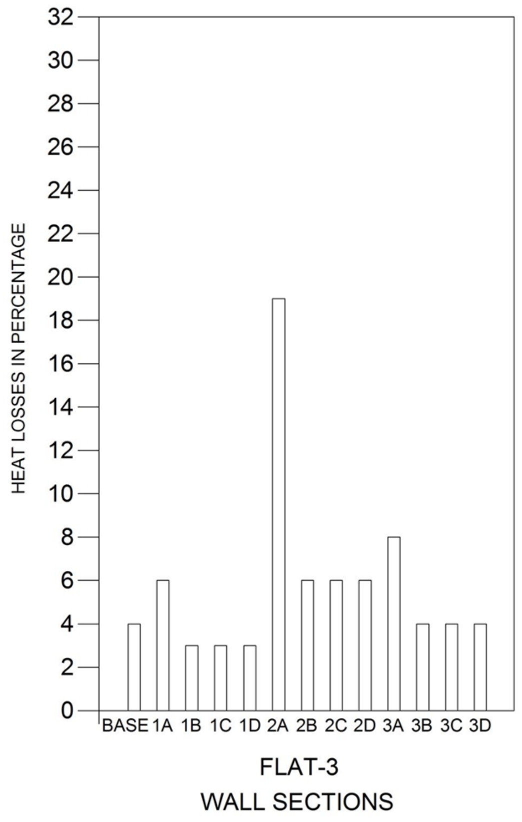

Figure 52 Heat losses (%) through all the Wall System Sections in flat-3 obtained from the simulation results

4.7 Initial capital investment calculation

The square-meter unit prices of the three alternative glazing units in this study were obtained from distributers that deal with (Trakya Cam Sanayii A.S.) (http://www.trakyacam.com.tr/, Last Accessed 18 / 03 / 2014) which is a company in Trakya (Turkey) that produces many quality architectural window glazing products that are common in the market. Since there were three window glazing alternatives, three initial capital investments and operation costs were calculated and tabulated. While table 12 shows the square-meter unit prices of the glazing units, table 20 shows the total initial capital investment for the glazing units in the flats. A sample calculation for the initial cost of a glazing unit could be seen in **APPENDIX ZZ**. The unit cost includes the price of the glazing, frame and labor cost for fixing.

Again it is important to mention that in this thesis only the initial capital investment and operation costs were investigated.

Table 12 The Three Window Alternatives Under Investigation Square-Meter Unit Costs (http://www.trakyacam.com.tr/, Last Accessed 18 / 03 / 2014)

	Window Type	U-Value W/m2.k	Glazing Costs TL + KDV / m2
ISICAM KLASIK	4 + 16 + 4 4 (cm) Pane Thickness + 16 (cm) Cavity Thickness + 4 (cm) Pane Thickness +	Air- 2.715	225
ISICAM SINERJI	4 + 16 + *4 4 (cm) Pane Thickness + 16 (cm) Cavity Thickness + 4 (cm) Pane Thickness +	Argon- 1.548	235
ISICAM SINERJI 3+	4* + 16 + 4 + 16 + *4 4 (cm) Pane Thickness + 16 (cm) Cavity Thickness + 4 (cm) Pane Thickness + 16 (cm) Cavity Thickness + 4 (cm) Pane Thickness +	Argon- 0.778	335

* The location of low-e Coating (Trakya Cam Sanayii A.Ş.)

The unit costs in this thesis in terms of the different wall system sections were based on the manufacturer. For the Base case 0.20 x 0.20 x 0.135 bricks and 0.20 x 0.20 x 0.085 bricks the manufacturer was Çorum Blok Tuğla. For the Aerated Autoclaved Concrete the manufacturer was Akggazbeton. While for heavyweight concrete blocks and lightweight concrete blocks the manufacturer was Expanded Shale, Clay, and Slate institute. For the exterior, sandwiched and interior insulation products the manufacturer was İzocam Ticaret ve Sanayii A.Ş. Tables 13, 14, 15, 16, 17 and 18 document the total costs of the wall system sections of the three different block units including the insulation.

Table 13 Flat-1 Total Block Costs (http://www.corumbloktugla.com/,(Last Accessed 20 / 03 / 2014) (www.akggazbeton.com, Last Accessed 05 / 03 / 2014), (http://www.escsi.org/, Last Accessed 23 / 03 / 2014).

Section	**Type of Block**	**Dimensions (W x D x L) / m**	**Total Area/m2**	**Unit Cost TL / m2**	**Total Cost /TL**
BASE	BRICKS	0.20 x 0.20 x 0.135	31.015	50.000	1550.75
BASE	BRICKS	0.20 x 0.20 x 0.085	31.015	37.500	1163.06
1A	AAC Blocks	0.20 x 0.25 x 0.60	31.015	130.000	4032.00
1B	AAC Blocks	0.20 x 0.25 x 0.60	31.015	130.000	4032.00
1C	AAC Blocks	0.10 x 0.25 x 0.60	62.030	75.000	4652.00
1D	AAC Blocks	0.20 x 0.25 x 0.60	31.015	130.000	4032.00
2A	Heavy Weight Blocks	0.20 x 0.20 x 0.40	31.015	32.200	999.00
2B	Heavy Weight Blocks	0.20 x 0.20 x 0.40	31.015	32.200	999.00
2C	Heavy Weight Blocks	0.10 x 0.20 x 0.40	62.030	28.325	1757.00
2D	Heavy Weight Blocks	0.20 x 0.20 x 0.40	31.015	32.200	999.00
3A	Light Weight Blocks	0.20 x 0.20 x 0.40	31.015	49.750	1543.00
3B	Light Weight Blocks	0.20 x 0.20 x 0.40	31.015	49.750	1543.00
3C	Light Weight Blocks	0.10 x 0.20 x 0.40	62.030	43.750	2714.00
3D	Light Weight Blocks	0.20 x 0.20 x 0.40	31.015	49.750	1543.00

Table 14 Flat-2 Total Block Costs (http://www.corumbloktugla.com/,(Last Accessed 20 / 03 / 2014) (www.akggazbeton.com, Last Accessed 05 / 03 / 2014), (http://www.escsi.org/, Last Accessed 23 / 03 / 2014).

Section	Type of Block	Dimensions (W x D x L) / m	Total Area m2	Unit Cost TL / m2	Total Cost/TL
BASE	BRICKS	0.20 x 0.20 x 0.135	31.015	50.000	1550.75
BASE	RRICKS	0.20 x 0.20 x 0.085	31.015	37.500	1163.06
1A	AAC Blocks	0.20 x 0.25 x 0.60	31.015	130.000	4032.00
1B	AAC Blocks	0.20 x 0.25 x 0.60	31.015	130.000	4032.00
1C	AAC Blocks	0.10 x 0.25 x 0.60	62.030	75.000	4652.00
1D	AAC Blocks	0.20 x 0.25 x 0.60	31.015	130.000	4032.00
2A	Heavy Weight Blocks	0.20 x 0.20 x 0.40	31.015	32.200	999.00
2B	Heavy Weight Blocks	0.20 x 0.20 x 0.40	31.015	32.200	999.00
2C	Heavy Weight Blocks	0.10 x 0.20 x 0.40	62.030	28.325	1757.00
2D	Heavy Weight Blocks	0.20 x 0.20 x 0.40	31.015	32.200	999.00
3A	Light Weight Blocks	0.20 x 0.20 x 0.40	31.015	49.750	1543.00
3B	Light Weight Blocks	0.20 x 0.20 x 0.40	31.015	49.750	1543.00
3C	Light Weight Blocks	0.10 x 0.20 x 0.40	62.030	43.750	2714.00
3D	Light Weight Blocks	0.20 x 0.20 x 0.40	31.015	49.750	1543.00

Table 15 Flat-3 Total Block Costs (http://www.corumbloktugla.com/,(Last Accessed 20 / 03 / 2014) (www.akggazbeton.com, Last Accessed 05 / 03 / 2014), (http://www.escsi.org/, Last Accessed 23 / 03 / 2014)

Section	**Type of Block**	**Dimensions (W x D x L) / m**	**Total Area m2**	**Unit Cost TL / m2**	**Total Cost/TL**
BASE	BRICKS	0.20 x 0.20 x 0.135	44.685	50.000	2234.25
BASE	RRICKS	0.20 x 0.20 x 0.085	44.685	37.500	1675.69
1A	AAC Blocks	0.20 x 0.25 x 0.60	44.685	130.000	5809.00
1B	AAC Blocks	0.20 x 0.25 x 0.60	44.685	130.000	5809.00
1C	AAC Blocks	0.10 x 0.25 x 0.60	89.370	75.000	6703.00
1D	AAC Blocks	0.20 x 0.25 x 0.60	44.685	130.000	5809.00
2A	Heavy Weight Blocks	0.20 x 0.20 x 0.40	44.685	32.200	1439.00
2B	Heavy Weight Blocks	0.20 x 0.20 x 0.40	44.685	32.200	1439.00
2C	Heavy Weight Blocks	0.10 x 0.20 x 0.40	89.370	28.325	2531.00
2D	Heavy Weight Blocks	0.20 x 0.20 x 0.40	44.685	32.200	1439.00
3A	Light Weight Blocks	0.20 x 0.20 x 0.40	44.685	49.750	2223.00
3B	Light Weight Blocks	0.20 x 0.20 x 0.40	44.685	49.750	2223.00
3C	Light Weight Blocks	0.10 x 0.20 x 0.40	89.370	43.750	3910.00
3D	Light Weight Blocks	0.20 x 0.20 x 0.40	44.685	49.750	2223.00

Table 16 Flat-1 Total Insulation Costs (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)

Section	Type of Insulation	Thickness / m	Total Area m2	Unit Cost TL / m2	Total Cost/TL
BASE	Extruded Polystyrene (XPS)	0.05	31.015	13.50	418.70
BASE	Expanded Polystyrene (EPS)	0.05	31.015	7.85	243.47
1A	No Insulation	0.00	0.00	0.00	0.00
1B	Exterior Insulation (Cephepan)	0.05	31.015	6.000	186.00
1C	Mid-Insulation (Wall Board)	0.05	31.015	2.880	90.00
1D	Interior Insulation (Optimum Wall)	0.05	31.015	2.880	90.00
2A	No Insulation	0.00	0.00	0.00	0.00
2B	Exterior Insulation (Cephepan)	0.05	31.015	6.000	186.00
2C	Mid-Insulation (Wall Board)	0.05	31.015	2.880	90.00
2D	Interior Insulation (Optimum Wall)	0.05	31.015	2.880	90.00
3A	No Insulation	0.00	0.00	0.00	0.00
3B	Exterior Insulation (Cephepan)	0.05	31.015	6.000	186.00
3C	Mid-Insulation (Wall Board)	0.05	31.015	2.880	90.00
3D	Interior Insulation (Optimum Wall)	0.05	31.015	2.880	90.00

Table 17 Flat-2 Total Insulation Costs (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)

Section	Type of Insulation	Thickness / m	Total Area m2	Unit Cost TL / m2	Total Cost TL
BASE	Extruded Polystyrene (XPS)	0.05	31.015	13.50	418.70
BASE	Expanded Polystyrene (EPS)	0.05	31.015	7.85	243.47
1A	No Insulation	0.00	0.00	0.00	0.00
1B	Exterior Insulation (Cephepan)	0.05	31.015	6.000	186.00
1C	Mid-Insulation (Wall Board)	0.05	31.015	2.880	90.00
1D	Interior Insulation (Optimum Wall)	0.05	31.015	2.880	90.00
2A	No Insulation	0.00	0.00	0.00	0.00
2B	Exterior Insulation (Cephepan)	0.05	31.015	6.000	186.00
2C	Mid-Insulation (Wall Board)	0.05	31.015	2.880	90.00
2D	Interior Insulation (Optimum Wall)	0.05	31.015	2.880	90.00
3A	No Insulation	0.00	0.00	0.00	0.00
3B	Exterior Insulation (Cephepan)	0.05	31.015	6.000	186.00
3C	Mid-Insulation (Wall Board)	0.05	31.015	2.880	90.00
3D	Interior Insulation (Optimum Wall)	0.05	31.015	2.880	90.00

Table 18 Flat-3 Total Insulation Costs (http://www.izocam.com.tr, Last Accessed 15 / 03 / 2014)

Section	**Type of Insulation**	**Thickness / m**	**Total Area m2**	**Unit Cost TL / m2**	**Total Cost TL**
BASE	Extruded Polystyrene (XPS)	0.05	44.685	13.50	603.25
BASE	Expanded Polystyrene (EPS)	0.05	44.685	7.85	350.78
1A	No Insulation	0.00	0.00	0.00	0.00
1B	Exterior Insulation (Cephepan)	0.05	44.685	6.000	268.00
1C	Mid-Insulation (Wall Board)	0.05	44.685	2.880	129.00
1D	Interior Insulation (Optimum Wall)	0.05	44.685	2.880	129.00
2A	No Insulation	0.00	0.00	0.00	0.00
2B	Exterior Insulation (Cephepan)	0.05	44.685	6.000	268.00
2C	Mid-Insulation (Wall Board)	0.05	44.685	2.880	129.00
2D	Interior Insulation (Optimum Wall)	0.05	44.685	2.880	129.00
3A	No Insulation	0.00	0.00	0.00	0.00
3B	Exterior Insulation (Cephepan)	0.05	44.685	6.000	268.00
3C	Mid-Insulation (Wall Board)	0.05	44.685	2.880	129.00
3D	Interior Insulation (Optimum Wall)	0.05	44.685	2.880	129.00

Table 19 The Glazing Areas of The Three Alternatives Under Investigation (m2)

Type of Glazing	Total Glazing Area-m2		
	Flat-1	Flat-2	Flat-3
Isicam Klasik	14.66	14.66	14.43
Isicam Sinerji	14.66	14.66	14.43
Isicam Sinerji 3+	14.66	14.66	14.43

Table 20 The total initial capital investment for the glazing units in the flats (TL)

Type of Glazing	Initial Capital Investment (TL)		
	Flat-1	Flat-2	Flat-3
Isicam Klasik	3299	3299	3247
Isicam Sinerji	3445	3445	3391
Isicam Sinerji 3+	4911	4911	4834

Table 21 The total initial capital investment for the Wall Sections in the flats (TL)

Type of Wall Section	Initial Capital Investment (TL)		
	Flat-1	Flat-2	Flat-3
Base Case	15,022	15,022	16,510
1A	11,124	11,124	12,901
1B	11,310	11,310	13,169
1C	17,350	17,350	19,440
1D	11,214	11,214	13,030
2A	9,107	9,107	9,547
2B	9,293	9,293	9,815
2C	15,857	15,857	16,670
2D	9,197	9,197	9,676
3A	8,569	8,569	9,249
3B	8,755	8,755	9,517
3C	17,772	17,772	17,007
3D	8,659	8,659	9,378

Table 19 shows the glazing areas in the three flats. While tables 20 and 21 show the initial capital investment of the glazing units and wall system sections investigated in the three flats. A sample calculation of the initial investment costs could be seen in **APPENDIX ZZ**.

4.8 Operation cost calculation

To calculate the operation costs of the building, the yearly heating energy costs are multiplied by unit cost of the fuel, natural gas, used to run the heating system multiplied by the study period. The yearly energy costs of the glazing units and wall sections used in the study flats are given in table 22 and table 23. A sample calculation of the operation cost for both the glazing window alternative and the different wall sections could be seen in **APPENDIX ZZ**.

Table 22 Annual energy prices of the glazings of the case study flats (TL).

	Isicam Klasik / TL	Isicam Sinerji / TL	Isicam Sinerji 3+ / TL
Flat-1	359.12	264.23	152.66
Flat-2	410.99	302.49	174.94
Flat-3	308.56	308.56	308.56

Table 23 Annual energy prices of the wall sections of the case study flats (TL)

	Base	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Flat-1	408	430	391	392	393	675	436	436	437	478	408	407	408
Flat-2	332	356	315	315	316	624	362	362	364	408	332	331	332
Flat-3	497	526	477	478	479	837	534	533	535	587	498	497	498

4.9 Comparing the Initial Investment and Operation Costs of Glazing Units in Flat-1, Flat-2, Flat-3

The fact that the lowest value would be the most economically efficient alternative was accepted in the evaluation of initial investment and operation cost for the study period (thirty years). Tables 24, 25 and 26 and figure 53 below show the sum of the total initial investment and operation costs of the glazing alternatives. A sample calculation for the total sum of the initial investigation and the operation costs could be seen in **APPENDIX ZZ**.

Table 24 Initial Investment and Operation Costs of Flat-1 Glazing Alternatives (TL)

	Isicam Klasik	Isicam Sinerji	Isicam Sinerji 3+
Flat-1 Initial Investment Cost / TL	3299	3445	4911
Operations Cost / TL	359.12 x 30 = 10,774	264.23 x 30 = 7,927	152.66 x 30 = 4,580
Total Initial Investment and Operation Costs	14,073	11,372	9,491

Table 25 Initial Investment and Operation Costs of Flat-2 Glazing Alternatives (TL)

	Isicam Klasik	Isicam Sinerji	Isicam Sinerji 3+
Flat-2 Initial Investment Cost / TL	3299	3445	4911
Operations Cost / TL	410.99 x 30 = 12,330	302.49 x 30 = 9,075	174.94 x 30 = 5,248
Total Initial Investment and Operation Costs	15,629	12,520	10,159

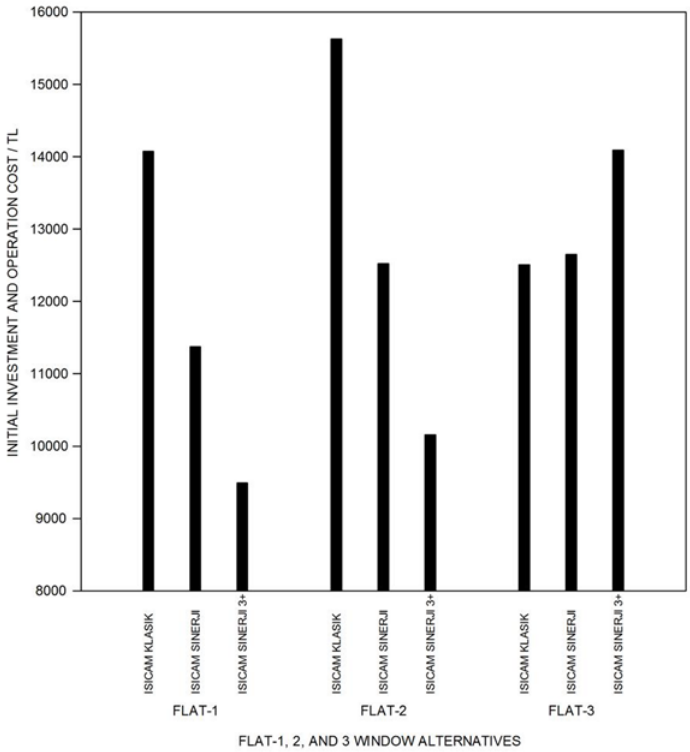

Figure 53 The summation of initial investment and operation costs of the investigated three window glazing units in Flat-1, Flat-2, Flat-3 (TL)

Table 26 Initial Investment and Operation Costs of Flat-3 Glazing Alternatives (TL)

	Isicam Klasik	Isicam Sinerji	Isicam Sinerji 3+
Flat-3 Initial Investment Cost / TL	3247	3391	4834
Operations Cost / TL	308.56 x 30 = 9256.8	308.56 x 30 = 9256.8	308.56 x 30 = 9256.8
Total Initial Investment and Operation Costs	12,504	12,648	14,091

4.10 Comparing the Initial Investment and Operation Costs of the Wall Sections in Flat-1, Flat-2, Flat-3

The fact that the lowest value would be the most economically efficient wall system sections was accepted in the evaluation of initial investment and operation cost for the study period. Tables 27, 28, 29, 30, 31, 32, 33, 34, 35 and figures 54, 55, 56 show the total initial investment and operation costs of the wall system sections.

Table 27 Initial Investment and Operation Costs of Flat-1 Wall Sections Base, 1A, 1B, 1C, and 1D (TL)

Flat-1	**BASE**	**1A**	**1B**	**1C**	**1D**
Initial Investment Cost / TL	15,022	11,124	11,310	17,350	11,214
Operations Cost / TL	408 x 30 = 12,240	430 x 30 = 12,900	391 x 30 = 11,730	392 x 30 = 11,760	393 x 30 = 11,790
Total Initial Investment and Operation Costs	27,262	24,024	23,040	29,110	23,004

Table 28 Initial Investment and Operation Costs of Flat-1 Wall Sections 2A, 2B, 2C, and 2D (TL)

Flat-1	**2A**	**2B**	**2C**	**2D**
Initial Investment Cost / TL	9,107	9,293	15,857	9,197
Operations Cost / TL	675 x 30 = 20,250	436 x 30 = 13,080	436 x 30 = 13,080	437 x 30 = 13,110
Total Initial Investment and Operation Costs	29,357	22,373	28,937	22,307

Table 29 Initial Investment and Operation Costs of Flat-1 Wall Sections 3A, 3B, 3C, and 3D (TL)

Flat-1	**3A**	**3B**	**3C**	**3D**
Initial Investment Cost / TL	8,569	8,755	15,772	8,659
Operations Cost / TL	478 x 30 = 14,340	408 x 30 = 12,240	407 x 30 = 12,210	408 x 30 = 12,240
Total Initial Investment and Operation Costs	22,909	20,995	27,982	20,899

Table 30 Initial Investment and Operation Costs of Flat-2 Wall Sections Base, 1A, 1B, 1C, and 1D (TL)

Flat-2	**BASE**	**1A**	**1B**	**1C**	**1D**
Initial Investment Cost / TL	15,022	11,124	11,310	17,350	11,214
Operations Cost / TL	332 x 30 = 9,960	356 x 30 = 10,680	315 x 30 = 9,450	315 x 30 = 9,450	316 x 30 = 9,480
Total Initial Investment and Operation Costs	24,982	21,804	20,760	26,800	20,694

Table 31 Initial Investment and Operation Costs of Flat-2 Wall Sections 2A, 2B, 2C, and 2D (TL)

Flat-2	**2A**	**2B**	**2C**	**2D**
Initial Investment Cost / TL	9,107	9,293	15,857	9,197
Operations Cost / TL	624 x 30 = 18,720	362 x 30 = 10,860	362 x 30 = 10,860	364 x 30 = 10,920
Total Initial Investment and Operation Costs	27,827	20,153	26,717	20,117

Table 32 Initial Investment and Operation Costs of Flat-2 Wall Sections 3A, 3B, 3C, and 3D (TL)

Flat-2	**3A**	**3B**	**3C**	**3D**
Initial Investment Cost / TL	8,569	8,755	15,772	8,659
Operations Cost / TL	408 x 30 = 12,240	332 x 30 = 9,960	331 x 30 = 9,930	332 x 30 = 9,960
Total Initial Investment and Operation Costs	20,809	18,715	25,702	18,619

Table 33 Initial Investment and Operation Costs of Flat-3 Wall Sections Base, 1A, 1B, 1C, and 1D (TL)

Flat-3	**BASE**	**1A**	**1B**	**1C**	**1D**
Initial Investment Cost / TL	16,510	12,901	13,169	19,440	13,030
Operations Cost / TL	497 x 30 = 14,910	526 x 30 = 15,780	477 x 30 = 14,310	478 x 30 = 14,340	479 x 30 = 14,370
Total Initial Investment and Operation Costs	31,420	28,681	27,479	33,780	27,400

Table 34 Initial Investment and Operation Costs of Flat-3 Wall Sections 2A, 2B, 2C, and 2D (TL)

Flat-3	**2A**	**2B**	**2C**	**2D**
Initial Investment Cost / TL	9,547	9,815	16,670	9,676
Operations Cost / TL	837 x 30 = 25,110	534 x 30 = 16,020	533 x 30 = 15,990	535 x 30 = 16,050
Total Initial Investment and Operation Costs	34,657	25,835	32,660	25,726

Table 35 Initial Investment and Operation Costs of Flat-3 Wall Sections 3A, 3B, 3C, and 3D (TL)

Flat-3	**3A**	**3B**	**3C**	**3D**
Initial Investment Cost / TL	9,249	9,517	17,007	9,378
Operations Cost / TL	587 x 30 = 17,610	498 x 30 = 14,940	497 x 30 = 14,910	498 x 30 = 14,940
Total Initial Investment and Operation Costs	26,859	24,457	31,917	24,318

In figures 54, 55 and 56 below, the initial investment costs for 1C, 2C and 3C influences the economy efficiency primarily when compared to the initial investment of the other wall sections namely 1B, 2B and 3B as well as 1D, 2D and 3D. This is due to the fact that wall sections 1C, 2C and 3C consist of a double layer of building blocks with a sandwiched insulation. The presence of this double layer increases both the walls prices since more blocks are used in their construction as well as the production cost represented by the monetary expense by the masons, used in their construction.

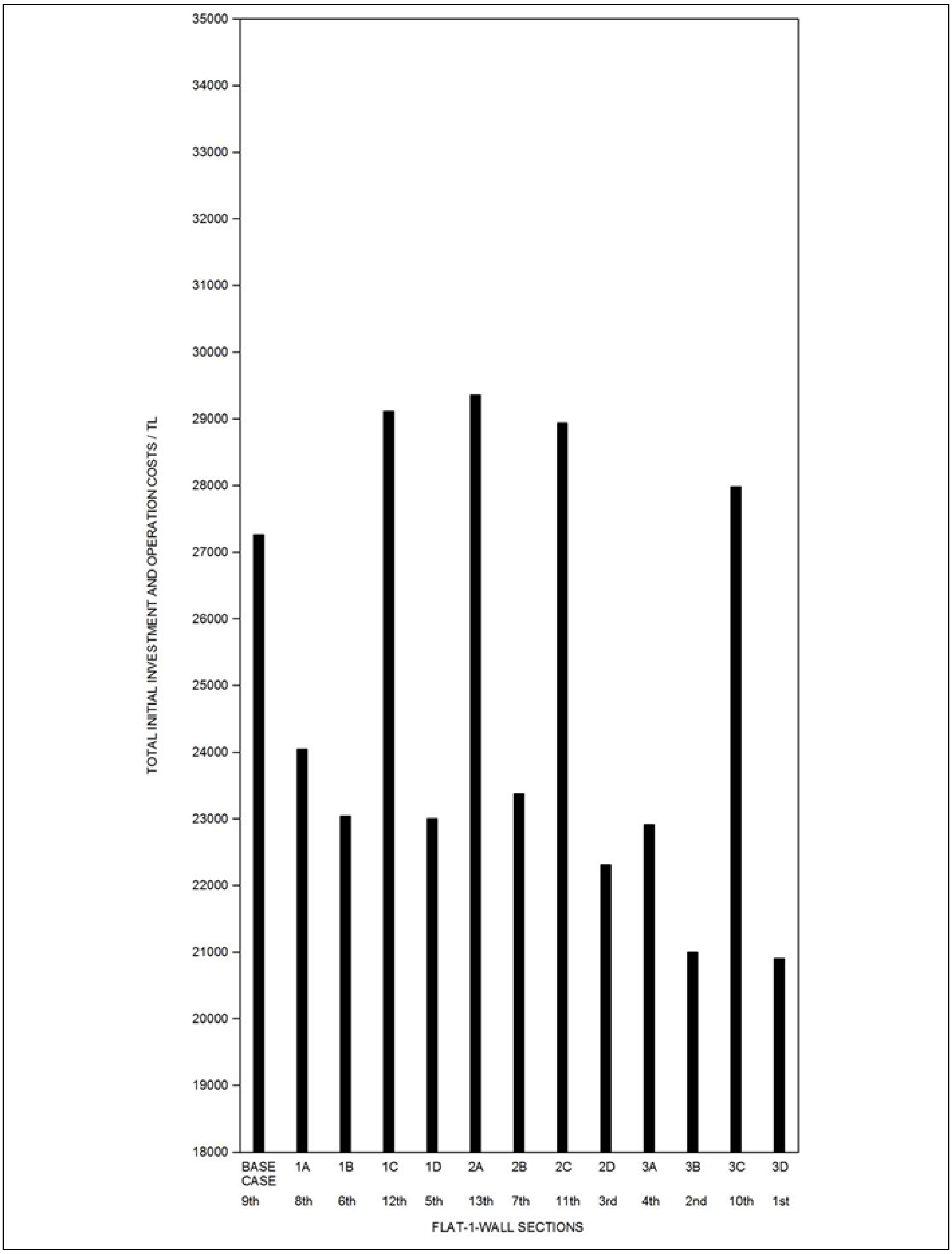

Figure 54 Total initial investment and operation costs of the investigated wall sections Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D in Flat-1 (TL)

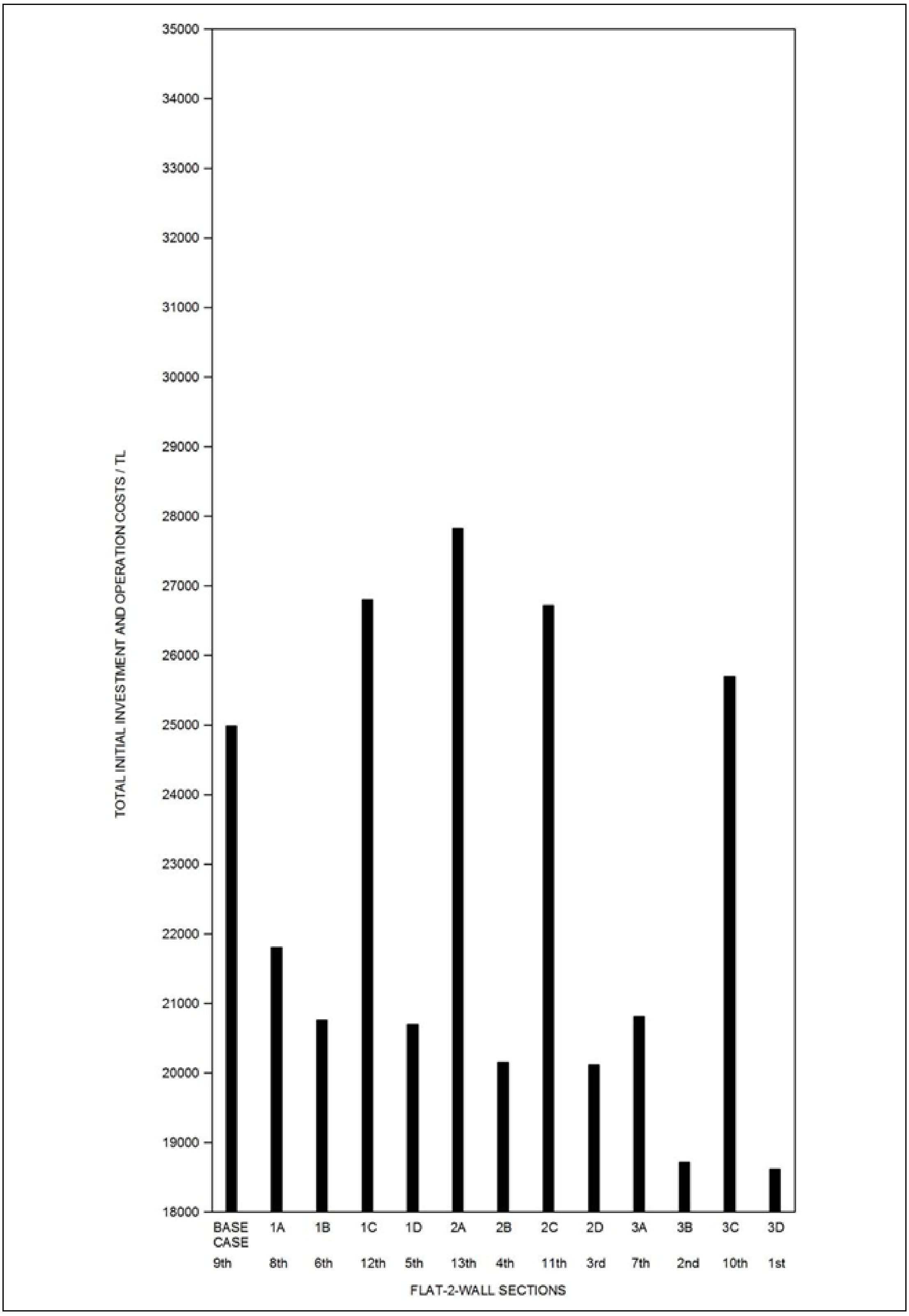

Figure 55 Total initial investment and operation costs of the investigated wall sections Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D in Flat-2 (TL)

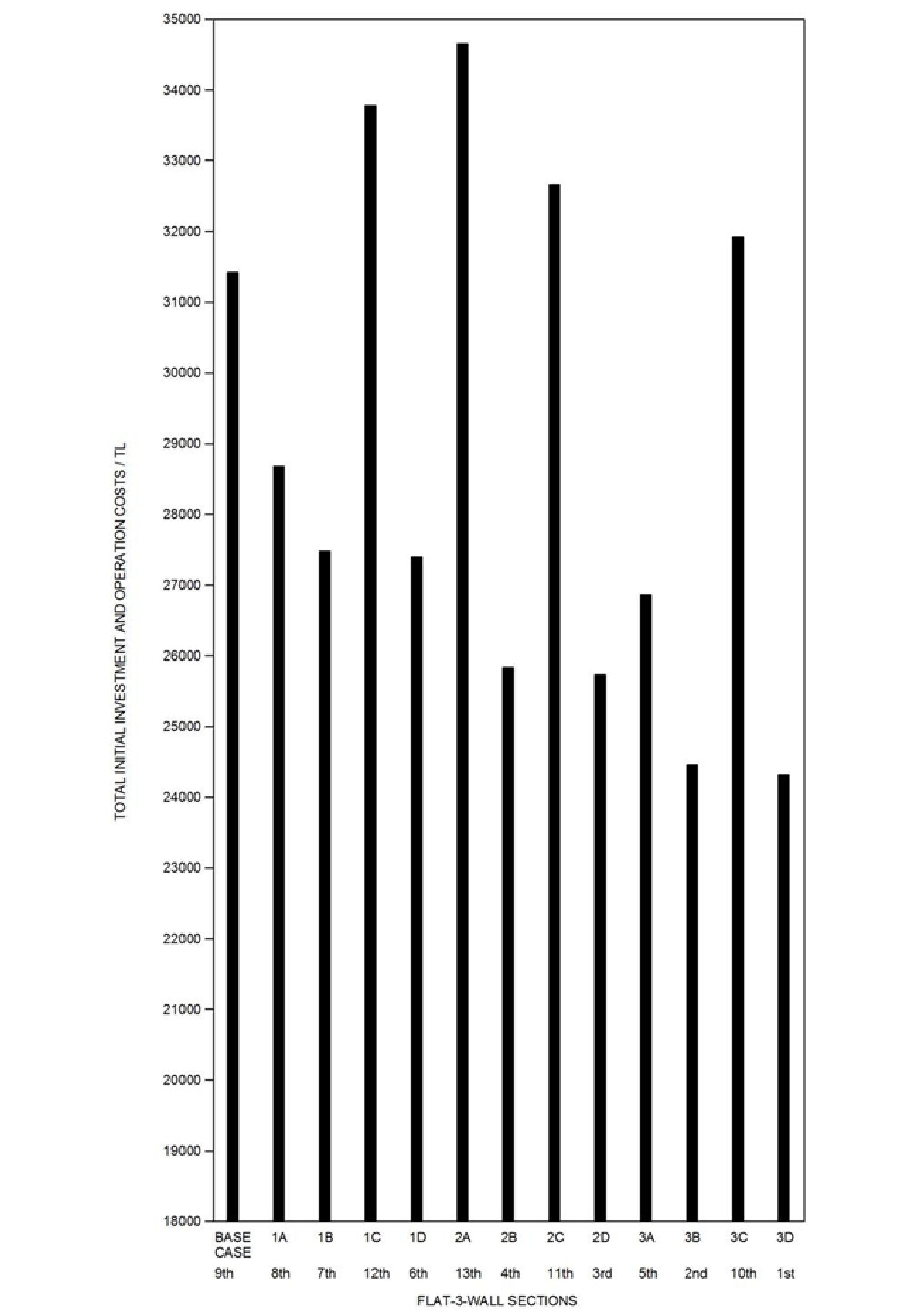

Figure 56 Total initial investment and operation costs of the investigated wall sections Base, 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 3D in Flat-3 (TL)

In addition figure 54, 55 and 56 shown above also show the total initial investment and operation costs order of wall sections from the best represented by 1 to the worst represented by 13.

Table 36 A comparison of percentages (%) of total initial investment and operation costs of the glazing units according to Isicam Klasik in Flat-1, Flat-2 and Flat-3

	Isicam Klasik	Isicam Sinerji	Isicam Sinerji 3+
Flat-1	---	0.81	0.670
Flat-2	---	0.80	0.650
Flat-3	---	1.15	12.69

Table 37 A comparison of percentages (%) of total initial investment and operation costs of the wall sections according to the base section in Flat-1, Flat-2 and Flat-3

	Bas -e	Sec. 1A	Sec. 1B	Sec. 1C	Sec. 1D	Sec. 2A	Sec. 2B	Sec. 2C	Sec. 2D	Sec. 3A	Sec. 3B	Sec. 3C	Sec. 3D
Flat-1	---	0.88	0.85	6.78	0.84	7.68	0.82	6.14	0.82	0.84	0.77	2.64	0.77
Flat-2	---	0.87	0.83	7.28	0.83	11.4	0.81	6.95	0.81	0.83	0.75	2.88	0.75
Flat-3	---	0.91	0.87	7.51	0.87	10.3	0.82	3.95	0.82	0.85	0.78	1.58	0.77

Tables 36 and 37 show a comparison of percentages (%) of total initial investment and operation costs of the glazing units according to Isicam Klasik and those of the wall sections according to the base section in Flat-1, Flat-2 and Flat-3

CHAPTER 5

CONCLUSIONS

In this thesis, the energy and economy efficiency of three double-glazing units and thirteen different wall systems were used in three flats of the first floor of an apartment building. They were calculated from the simulation results for the cold climate of Ankara. From the simulation results, table 38 shows the energy and economy efficiencies of the case study wall sections. In sequence, the wall sections with minimum energy and economy efficiency performance produce the best alternative. The best wall section is ranked as one or 1 and is given the maximum points of 65. This ranking system from 1 to 13 and the point system from 65 to 5 is applied for all the thirteen wall systems to verify their energy and economic efficiency in a sequence from best to worst.

Table 38 A comparison of the energy efficiency and economy efficiency of the investigated wall sections

Wall Sec.	Flat-1				Flat-2				Flat-3				Total Energy Efficient Perfor-mance Points	Total Economy Efficient Perfor-mance Points	TOTAL Points
	Energy Efficient Perfor-mance		Economy Efficient Perfor-mance		Energy Efficient Perfor-mance		Economy Efficient Perfor-mance		Energy Efficient Perfor-mance		Economy Efficient Perfor-mance				
	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt			
Base	7	35	9	25	5	45	9	25	4	50	9	25	130	75	205
1A	8	30	8	30	8	30	8	30	8	30	8	30	90	90	180
1B	1	65	6	40	1	65	6	40	1	65	7	35	195	115	310
1C	2	60	12	10	2	60	12	10	2	60	12	10	180	30	210
1D	3	55	5	45	3	55	5	45	3	55	6	40	165	130	295
2A	13	5	13	5	13	5	13	5	13	5	13	5	15	15	30
2B	10	20	7	35	11	15	4	50	10	20	4	50	55	135	190
2C	9	25	11	15	10	20	11	15	9	25	11	15	70	45	115
2D	11	15	3	55	9	25	3	55	11	15	3	55	55	165	220
3A	12	10	4	50	12	10	7	35	12	10	5	45	30	130	160
3B	5	45	2	60	6	40	2	60	6	40	2	60	125	180	305
3C	4	50	10	20	4	50	10	20	5	45	10	20	145	60	205
3D	6	40	1	65	7	35	1	65	7	35	1	65	110	195	305

In terms of the total energy efficiency performance by rank from the above table 38, the best ranking from best to worst is as follows:

Table 39 Ranking by the total energy efficiency of the investigated wall sections for all the three flats

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13
Wall Sec.	1B	1C	1D	3C	Base	3B	3D	1A	2C	2D	2B	3A	2A

From table 39, it could be concluded that the wall section alternative 1B which includes Aerated Autoclaved Concrete with insulation facing the outside produces the best performance in terms of energy efficiency. When considering the best energy efficiency performance, the wall section 1B for all the three flats, it could be concluded that minimum heating loads in kWh is required from the heating system to achieve the required thermal comfort when compared to other wall sections. All the other wall sections require the heating system to produce more heating to achieve the same thermal comfort.

In addition, wall sections 1B, 1C and 1D which are the sections involving Aerated Autoclaved Concrete blocks produce the best performances when compared to sections including lightweight concrete blocks and heavyweight concrete blocks.

Also as could be concluded, wall sections 3C, 3B and 3D which involve lightweight concrete blocks follow 1B, 1C and 1D wall sections in energy performances. These were then followed by wall sections 2C, 2D and 2B which involve heavyweight concrete blocks.

A final conclusion that was noticed was that regarding the sections without insulation namely 3A and 2A. According to the energy efficiency ranking, they attain the last two places in the list respectively. This means that the highest energy was required to be produced by the heating system in order to achieve the required interior thermal comfort.

In terms of the total economy efficiency performance by rank from the above table 38, the best ranking from best to worst is as follows:

Table 40 Ranking by the total economy efficiency of the investigated wall sections for all the three flats

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13
Wall Sec.	3D	3B	2D	2B	1D	3A	1B	1A	Base	3C	2C	1C	2A

From table 40, it could be concluded that the wall sections 3D and 3B respectively are the most economically efficient in the long term of 30 years. This may be explained by the fact that the operation cost summed as a total of the three flats, is lesser than the operation costs for other wall sections. This economic efficiency is supported by the low initial investment of both the wall sections. So when both the operation and initial investment costs were added the results indicated that wall sections 3D and 3B respectively are the most economically efficient compared to the other wall sections. Similarly, when the initial investment and operation costs are calculated to wall sections 2D and 2B as well as 1D and 1B, the results showed that the wall sections 3D and 3B which involves lightweight concrete blocks produced the most economic efficiency in the 30 year study period. This was followed by wall sections 2D and 2B in then 1D and 1B.

From the economy point of view, the 3C, 2C and 1C wall sections which included sandwiched insulation and two wall block layers the initial investment increased due to the fact that double distance block construction costs and efforts were undertaken when compared to the single layer block construction efforts applied in the constructing the other wall sections (See **APPENDIX QQ** for explanation). Thus, more blocks and energy are used in these double wall configurations. In turn, this influences the initial investment cost by a considerable margin which makes the wall sections 3C, 2C and 1C wall sections economically less efficient.

A final conclusion could be noted about wall section 2A which is the least economically efficient. While the initial investment is reasonably similar to other wall sections' initial investments, the affecting factor here is the operation cost which is relatively higher than those for other wall sections. As mentioned earlier, the operation cost calculated for this wall section 1A, summed as a total of all the three flats is more than the operation costs calculated for all the other wall sections. Since this operation cost is high as could be seen in the initial investment and operation cost tables, this high operation cost factor influences the economy efficiency, thus making wall section 2A the worst economically efficient wall section.

In terms of the total energy and economy efficiency performance by rank from the above table, the best ranking from best to worst is as follows:

Table 41 Ranking by both the total energy efficiency and economy efficiency of the investigated wall sections for all the three flats

Rank	1	2	3	4	5	6	7	8	9	10	11	12	13
Wall Sec.	1B	3B	3D	1D	2D	1C	Base	3C	2B	1A	3A	2C	2A

Considering the coupled energy and economic efficiencies of the wall sections as shown in table 41, those wall sections with insulation on the exterior namely 1B and 3B which involve AAC blocks and lightweight concrete blocks respectively, represent the best options. These are followed by the wall sections facing the inside represented namely by 3D, 1D and 2D. From the table 41 it is reminded that 3D is the wall section involving lightweight concrete blocks, and 1D is the wall section involving AAC blocks while 2D is the wall section involving heavyweight concrete blocks.

From table 41, it could also be concluded that for the three types of blocks the options without insulation namely 1A, 3A and 2A perform the worst in terms on both energy and economic efficiency, with the absence of insulation being the major factor in deciding their worst ranking.

From the simulation results, table 42 shows the energy and economic efficiencies of the case study window glazing alternatives. In sequence the window alternatives with minimum energy and economy efficiency performance produce the best alternative. The best wall section is ranked as one or 1 and is given the maximum points of 30. This ranking system from 1 to 3 and the point system from 30 to 10 is applied for all the three window alternatives to verify their energy and economic efficiency in a sequence from best to worst.

Table 42 A comparison of the energy efficiency and economy efficiency of the investigated glazing units

Glazing Unit	Flat-1				Flat-2				Flat-3				Total Energy Efficient Perfor-mance Points	Total Economy Efficient Perfor-mance Points	TOTAL Points
	Energy Efficient Perfor-mance		Economy Efficient Perfor-mance		Energy Efficient Perfor-mance		Economy Efficient Perfor-mance		Energy Efficient Perfor-mance		Economy Efficient Perfor-mance				
	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt	Ra-nk	Poi-nt			
Isicam Klasik	3	10	3	10	3	10	3	10	1	30	1	30	50	50	100
Isicam Sinerji	2	20	2	20	2	20	2	20	1	30	2	20	70	60	130
Isicam Sinerji 3+	1	30	1	30	1	30	1	30	1	30	3	10	90	70	160

In terms of the total energy efficiency performance by rank from the above table 42 the best ranking from best to worst is as follows:

Table 43 Ranking by the total energy efficiency of the investigated glazing alternatives for all the three flats

Rank	1	2	3
Glazing Unit	Isicam Sinerji 3+	Isicam Sinerji	Isicam Klasik

In terms of the total economic efficiency performance by rank from the above table the best ranking from best to worst is as follows:

Table 44 Ranking by the total economic efficiency of the investigated glazing alternatives for all the three flats

Rank	1	2	3
Glazing Unit	Isicam Sinerji 3+	Isicam Sinerji	Isicam Klasik

In terms of the total energy and economic efficiency performance by rank from the above table the best ranking from best to worst are as follows:

Table 45 Ranking by both the total energy and economic efficiency of the investigated glazing alternatives for all the three flats

Rank	1	2	3
Glazing Unit	Isicam Sinerji 3+	Isicam Sinerji	Isicam Klasik

From table 43 for all the flats, the high performance glazing ISICAM SINERJI 3+ produces the best results first in terms of energy efficiency, then in terms of economy efficiency and then in terms of total energy and economy efficiency when compared to ISICAM KLASIK and ISICAM SINERJI.

However, when flat-3 was considered individually according to the simulation, all the glazing units tended to perform similarly. This may be explained due to the fact that little solar energy is received by the North facing flat-3 to the extent that the glazing units were not used to their maximum potential causing them to behave similarly.

As a result, another conclusion may be obtained regarding the economy efficiency. Since the glazing alternatives perform similarly for flat-3, the initial investment proves to be a burden leading to monetary wastage of the high performing expensive glazing alternative namely ISICAM SINERJI 3+. This is followed by ISICAM SINERJI. Since both ISICAM SINERJI 3+ and ISICAM SINERJI were prevented from performing their high performance intended function, ISICAM KLASIK becomes economically efficient for flat-3.

One of the conclusions and benefits that could be added from this investigation would be the possibility of reducing energy bills and rents. In terms of energy and economic efficiency flat-2 resulted in the least heating bills produced by the heating system during winter, followed by flat-1 and then flat-3. This was due to the flats different orientations. Flat-2 facing South East received the most solar energy during the winter followed by flat-1 facing South West and then flat-3 facing North. Therefore, the flats rents differ accordingly where flat-2 is allocated the highest rent followed by flat-1 and then flat-3.

In addition, the best wall section and glazing alternatives concluded from this study would help release the least amount of CO_2 which would have otherwise added to environmental pollution.

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APPENDIX A

QUESTIONNAIRES FLAT-1, FLAT-2 AND FLAT-3

QUESTIONNAIRE-FLAT-1

1) How many are your family members? Write applicable (Yes or No).

1) Father: __NA____
2) Mother: __NA____
3) Child-1: __NA____
4) Child-2: __NA____
5) Child-3: __NA____
6) Child-4: __NA____
7) Other: __Single Occupant___________________________________

2) How many boys and how many girls are your children? State the number.

1) Girls: __0____
2) Boys: __0____

3) Write down the number series of children by age and gender. Write applicable.
For example:- Child-1: Girl (10 years old)

1) Child-1: __0____
2) Child-2: __0____
3) Child-3: __0____
4) Child-4: __0____
5) Other: __0____

5) Which room belongs to child-1? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

6) Which room belongs to child-2? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

7) Which room belongs to child-3? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

8) Which room belongs to child-4? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

9) During the weekdays how is the M. Bedroom used? For example:

Between (23:00 pm – 07:00 am) the M. Bedroom is occupied, and.

Between (07:00 am – 18:00 pm) the M. Bedroom is not occupied.

1) Between which hours is it occupied:

   1:__24:00 pm – 08:00 am________________
   2:__NA_______________________________
   3:__NA_______________________________

2) Between which hours is it not occupied:

   1:__08:00 am – 24:00 pm________________
   2:__NA_______________________________
   3:__NA_______________________________

10) During the weekdays how is the Bedroom-1 used? For example:

Between (23:00 pm – 07:00 am) the Bedroom-1 is occupied, and

Between (07:00 am – 18:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

   1:__NA_______________________________
   2:__NA_______________________________
   3:__NA_______________________________

2) Between which hours is it not occupied:

   1:__NA_______________________________
   2:__NA_______________________________
   3:__NA_______________________________

11) During the weekdays how is the Bedroom-2 used? For example:

Between (23:00 pm – 07:00 am) the Bedroom-2 is occupied, and

Between (07:00 am – 18:00 pm) the Bedroom-2 is not occupied

1) Between which hours is it occupied:

1:__NA______________________________
2:__NA______________________________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__NA______________________________
2:__NA______________________________
3:__NA______________________________

12) During the weekdays how is the Saloon used? For example:

Between (18:00 pm – 23:00 pm) the Saloon is occupied, and

Between (23:00 pm – 18:00 pm) the Saloon is not occupied.

1) Between which hours is it occupied:

1:__20:00 pm – 24:00 pm _______________
2:__NA______________________________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__24:00 pm – 20:00 pm _______________
2:__NA______________________________
3:__NA______________________________

13) During the weekdays how is the kitchen used? For example:

Between (19:00 pm – 20:00 pm) the kitchen is occupied.

Between (20:00 pm – 19:00 pm) the kitchen is not occupied, and

1) Between which hours is it occupied:

1:__19:00 pm – 20:00 pm ______________
2:__NA______________________________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__20:00 pm – 19:00 pm ______________
2:__NA______________________________
3:__NA______________________________

14) During the weekdays how is the laundry used? For example:

On Wednesday Between (20:00 pm – 21:00 pm) the laundry is used, or

During the weekdays it is not used,

1) Between which hours is it occupied:

1:__NA______________________________
2:__NA______________________________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__NA______________________________
2:__NA______________________________
3:__NA______________________________

15) During the weekends how is the M. Bedroom used? For example:

Between (24:00 pm – 09:00 am) the M. Bedroom is occupied, and

Between (09:00 am – 24:00 pm) the M. Bedroom is not occupied.

1) Between which hours is it occupied:

1:__24:00 pm – 10:00 am ______________
2:__NA______________________________
3:__NA_____________________________

2) Between which hours is it not occupied:

1:__10:00 am – 24:00 pm ______________
2:__NA______________________________
3:__NA______________________________

16) During the weekends how is the Bedroom-1 used? For example:

Between (24:00 pm – 09:00 am) the Bedroom-1 is occupied, and

Between (09:00 am – 24:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

1:__NA________________________________
2:__NA________________________________
3:__NA________________________________

2) Between which hours is it not occupied:

1:__NA________________________________
2:__NA________________________________
3:__NA________________________________

17) During the weekends how is the Bedroom-2 used? For example:

Between (24:00 pm – 09:00 am) the Bedroom-2 is occupied.

Between (09:00 am – 24:00 pm) the Bedroom-2 is not occupied, and

1) Between which hours is it occupied:

1:__NA________________________________
2:__NA________________________________
3:__NA________________________________

2) Between which hours is it not occupied:

1:__NA________________________________
2:__NA________________________________
3:__NA________________________________

18) During the weekends how is the Saloon used? For example:

Between (09:00 am – 24:00 pm) the Saloon is occupied.

Between (24:00 pm – 09:00 am) the Saloon is not occupied, and

1) Between which hours is it occupied:

1:__11:00 am – 19:00 pm________________
2:__20:00 pm – 24:00 pm________________
3:__NA________________________________

2) Between which hours is it not occupied:

1:__24:00 pm – 11:00 am________________
2:__19:00 pm – 20:00 pm________________
3:__NA_______________________________

19) During the weekends how is the kitchen used? For example:

Between (19:00 pm – 20:00 pm) the kitchen is occupied, and

Between (11:00 am – 19:00 pm) the kitchen is not occupied, and

Between (10:00 am – 11:00 am) the kitchen is occupied, and

Between (20:00 pm – 10:00 am) the kitchen is not occupied,

1) Between which hours is it occupied:

1:__10:00 am – 11:00 am________________
2:__19:00 pm – 20:00 pm________________
3:__NA_______________________________

2) Between which hours is it not occupied:

1:__20:00 pm – 10:00 am________________
2:__11:00 am – 19:00 pm________________
3:__NA_______________________________

20) During the weekends how is the laundry used? For example:

On Wednesday Between (20:00 pm – 21:00 pm) the laundry is used, or

During the weekdays it is not used,

1) Between which hours is it occupied:

1:__10:00 am – 11:00 am________________
2:__NA_______________________________
3:__NA_______________________________

2) Between which hours is it not occupied:

1:__11:00 am – 10:00 am________________
2:__NA_______________________________
3:__NA_______________________________

21) What are the holidays of the year that you celebrate? State Yes and for how many days?

1) Ramadan days: __Yes, three days ______________________________
2) Pilgrimage days: __Yes, four days______________________________
3) New Year: __Yes, one day____________________________________
4) Independence day: __Yes, one day______________________________
5) Children day: __Yes, one day__________________________________
6) Workers day: __Yes, one day__________________________________
7) Summer holidays: __Yes, three month_________________________
8) Other: __NA____
9) Other: __NA____
10) Other: __NA____

22) Which holidays do you leave home and for how many days? For example:

Summer Holidays: 90 days

1) __Summer Holidays, for 90 days _______________________________
2) __Ramadan Holiday, for 3 days________________________________
3) __Haj Holidays, for 4 days____________________________________
4) __NA____
5) Other: __NA____
6) Other: __NA____
7) Other: __NA____

23) Do you have a water radiator heating system (Combi System) for heating in winter? State Yes or No? If **no** which other system do you use?

__Yes____

24) For how many months (during the winter) of the year do you use this heating system fully?

___Six Months (October, November, December, January, February, March) ____

25) For how many months (during the summer) of the year do you not use this heating system fully?

___Six Months (April, May, June, July, August, September) ________________

26) Approximately how much money do you use to buy natural gas or electricity for this heating system?

___3600 TL / One Year for heating purposes and water heating______________

27) Do you use any device (for example cooler or fan) to cool during the summer? State Yes or No. If yes describe the device and between which times it is used in summer.

__No____

____

28) Do you ventilate your house mechanically? State Yes or No. If yes describe the device and at what times it is used. For Example:

Split Unit (Used between 12:00 pm– 20:00 pm)

__No____

29) Do you ventilate your house naturally in summer? State Yes or No. If yes describe the times this is done. For example

(Windows are open between 12:00 pm – 20:00 pm).

__Yes, Open Windows (Opened Between 12:00 am – 20:00 pm)______________

____

30) Do you have computers in your house? State Yes or No. If yes, describe how many and where they are located in the house?

__Yes, One Laptop Computer. Located in the Saloon.________________________

____

____

31) Do you have office equipment (printer, fax, and etc)? State Yes or No. If yes, describe what they are, how many, and where they are located in the house?

__NA____

____

____

QUESTIONNAIRE – FLAT-2

1) How many are your family members? Write applicable (Yes or No).

1) Father: __Yes____
2) Mother: __Yes____
3) Child-1: __Yes____
4) Child-2: __NA____
5) Child-3: __NA____
6) Child-4: __NA____
7) Other: __NA____

2) How many boys and how many girls are your children? State the number.

1) Girls: __One Girl____
2) Boys: __NA____

3) Write down the number series of children by age and gender. Write applicable.
For example:- Child-1: Girl (10 years old)

1) Child-1: __Girl (3 years Old)__________________________________
2) Child-2: __NA____
3) Child-3: __NA____
4) Child-4: __NA____
5) Other: __NA____

5) Which room belongs to child-1? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __Yes____

6) Which room belongs to child-2? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

7) Which room belongs to child-3? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

8) Which room belongs to child-4? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

9) During the weekdays how is the M. Bedroom used? For example:

Between (23:00 pm – 07:00 am) the M. Bedroom is occupied, and.

Between (07:00 am – 18:00 pm) the M. Bedroom is not occupied.

1) Between which hours is it occupied:

1:__24:00 pm – 07:00 am_______________
2:__12:00 am – 14:00 pm_______________
3:__19:00 pm – 20:00 pm_______________

2) Between which hours is it not occupied:

1:__20:00 pm – 24:00 pm_______________
2:__07:00 am – 12:00 am_______________
3:__14:00 pm – 19:00 pm_______________

10) During the weekdays how is the Bedroom-1 used? For example:

Between (23:00 pm – 07:00 am) the Bedroom-1 is occupied, and

Between (07:00 am – 18:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

1:__09:00 am – 12:00 am_______________
2:__NA_______________________________
3:__NA_______________________________

2) Between which hours is it not occupied:

1:__12:00 am – 09:00 am_______________
2:__NA_______________________________
3:__NA_______________________________

11) During the weekdays how is the Bedroom-2 used? For example:

Between (23:00 pm – 07:00 am) the Bedroom-2 is occupied, and

Between (07:00 am – 18:00 pm) the Bedroom-2 is not occupied.

1) Between which hours is it occupied:

1:__22:00 pm – 07:00 am_______________
2:__13:00 pm – 15:00 pm_______________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__15:00 pm – 22:00 pm_______________
2:__07:00 am – 13:00 pm_______________
3:__NA______________________________

12) During the weekdays how is the Saloon used? For example:

Between (18:00 pm – 23:00 pm) the Saloon is occupied, and

Between (23:00 pm – 18:00 pm) the Saloon is not occupied.

.

1) Between which hours is it occupied:

1:__15:00 pm – 19:00 pm_______________
2:__21:00 pm – 24:00 pm_______________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__24:00 pm – 15:00 pm_______________
2:__19:00 pm – 21:00 pm_______________
3:__NA______________________________

13) During the weekdays how is the kitchen used? For example:

Between (19:00 pm – 20:00 pm) the kitchen is occupied.

Between (20:00 pm – 19:00 pm) the kitchen is not occupied, and

1) Between which hours is it occupied:

1:__07:00 am – 08:00 am_______________
2:__14:00 pm – 15:00 pm______________
3:__20:00 pm – 21:00 pm______________

2) Between which hours is it not occupied:

1:__21:00 pm – 07:00 am______________
2:__08:00 am – 14:00 pm______________
3:__15:00 pm – 20:00 pm______________

14) During the weekdays how is the laundry used? For example:

On Wednesday Between (20:00 pm – 21:00 pm) the laundry is used, or

During the weekdays it is not used,

1) Between which hours is it occupied:

   1:__10:00 am – 11:00 am_______________
   2:__NA______________________________
   3:__NA______________________________

2) Between which hours is it not occupied:

   1:__11:00 am – 10:00 am_______________
   2:__NA______________________________
   3:__NA______________________________

15) During the weekends how is the M. Bedroom used? For example:

Between (24:00 pm – 09:00 am) the M. Bedroom is occupied, and

Between (09:00 am – 24:00 pm) the M. Bedroom is not occupied.

1) Between which hours is it occupied:

   1:__24:00 pm – 10:00 am______________
   2:__17:00 pm – 18:00 pm______________
   3:__NA______________________________

2) Between which hours is it not occupied:

   1:__18:00 pm – 24:00 pm______________
   2:__10:00 am – 17:00 pm______________
   3:__NA_____________________________

16) During the weekends how is the Bedroom-1 used? For example:

Between (24:00 pm – 09:00 am) the Bedroom-1 is occupied, and

Between (09:00 am – 24:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

   1:__11:00 am – 12:00 am_______________
   2:__NA______________________________
   3:__NA______________________________

2) Between which hours is it not occupied:

1:__12:00 am – 11:00 am_______________
2:__NA______________________________
3:__NA______________________________

17) During the weekends how is the Bedroom-2 used? For example:

Between (24:00 pm – 09:00 am) the Bedroom-2 is occupied.

Between (09:00 am – 24:00 pm) the Bedroom-2 is not occupied, and

1) Between which hours is it occupied:

1:__22:00 pm – 07:00 am_______________
2:__15:00 pm – 17:00 pm_______________
3:__NA______________________________

2) Between which hours is it not occupied:

1:__17:00 pm – 22:00 pm_______________
2:__07:00 am – 15:00 pm_______________
3:__NA______________________________

18) During the weekends how is the Saloon used? For example:

Between (09:00 am – 24:00 pm) the Saloon is occupied.

Between (24:00 pm – 09:00 am) the Saloon is not occupied, and

1) Between which hours is it occupied:

1:__12:00 am – 15:00 pm______________
2:__18:00 pm – 20:00 pm______________
3:__21:00 pm – 24:00 pm______________

2) Between which hours is it not occupied:

1:__24:00 pm – 12:00 am___________
2:__15:00 pm – 18:00 pm___________
3:__20:00 pm – 21:00 pm___________

19) During the weekends how is the kitchen used? For example:

Between (19:00 pm – 20:00 pm) the kitchen is occupied, and

Between (11:00 am – 19:00 pm) the kitchen is not occupied, and

Between (10:00 am – 11:00 am) the kitchen is occupied, and

Between (20:00 pm – 10:00 am) the kitchen is not occupied,

1) Between which hours is it occupied:

   1:__10:00 am – 11:00 am________________
   2:__15:00 pm – 16:00 pm________________
   3:__20:00 pm – 21:00 pm________________

2) Between which hours is it not occupied:

   1:__21:00 pm – 10:00 am________________
   2:__11:00 am – 15:00 pm________________
   3:__16:00 pm – 20:00 pm________________

20) During the weekends how is the laundry used? For example:

On Wednesday Between (20:00 pm – 21:00 pm) the laundry is used, or

During the weekdays it is not used,

1) Between which hours is it occupied:

   1:__10:00 am – 11:00 am________________
   2:__NA_______________________________
   3:__NA_______________________________

2) Between which hours is it not occupied:

   1:__11:00 am – 10:00 am________________
   2:__NA_______________________________
   3:__NA_______________________________

21) What are the holidays of the year that you celebrate? State Yes and for how many days?

1) Ramadan days: __Yes, three days ________________________________
2) Pilgrimage days: __Yes, four days________________________________
3) New Year: __Yes, one day_______________________________________
4) Independence day: __Yes, one day_______________________________
5) Children day: __Yes, one day___________________________________
6) Workers day: __Yes, one day____________________________________

7) Summer holidays: __Yes, three month__________________________
8) Other: __NA____
9) Other: __NA____
10) Other: __NA____

22) Which holidays do you leave home and for how many days? For example:

Summer Holidays: 90 days

1) __Summer Holidays, for 90 days ________________________________
2) __Ramadan Holiday, for 3 days_________________________________
3) __Haj Holidays, for 4 days_____________________________________
4) __Children's Day, for 1 day____________________________________
5) Other: __NA____
6) Other: __NA____
7) Other: __NA____

23) Do you have a water radiator heating system (Combi System) for heating in winter? State Yes or No? If **no** which other system do you use?

__Yes____

24) For how many months (during the winter) of the year do you use this heating system fully?

___Six Months (October. November, December, January, February, March) ____

25) For how many months (during the summer) of the year do you not use this heating system fully?

___Six Months (April, May, June, July, August, September) ________________

26) Approximately how much money do you use to buy natural gas or electricity for this heating system?

___3600 TL / One Year for heating purposes and water heating_______________

27) Do you use any device (for example cooler or fan) to cool during the summer? State Yes or No. If yes describe the device and between which times it is used in summer.

__No____

____

28) Do you ventilate your house mechanically? State Yes or No. If yes describe the device and at what times it is used. For Example:

Split Unit (Used between 12:00 pm – 20:00 pm)

__No____

____

29) Do you ventilate your house naturally in summer? State Yes or No. If yes describe the times this is done. For example

(Windows are open between 12:00 pm – 20:00 pm)

__Yes, Open Windows (Opened Between 12:00 am – 20:00 pm)______________

____

30) Do you have computers in your house? State Yes or No. If yes, describe how many and where they are located in the house?

__ Yes, One Laptop Computer. Located in the Bedroom-1___________________

____

____

31) Do you have office equipment (printer, fax, and etc)? State Yes or No. If yes, describe what they are, how many, and where they are located in the house?

__NA____

____

____

QUESTIONNAIRE – FLAT- 3

1) How many are your family members? Write applicable (Yes or No).

1) Father: __Yes____
2) Mother:__Yes____
3) Child-1: __Yes____
4) Child-2: __Yes____
5) Child-3: __NA____
6) Child-4: __NA____
7) Other: __NA____

2) How many boys and how many girls are your children? State the number.

1) Girls: __Yes, two girls_____________________________________
2) Boys: __NA____

3) Write down the number series of children by age and gender. Write applicable.
For example:- Child-1: Girl (10 years old)

1) Child-1: __Girl (12 years Old)______________________________
2) Child-2: __Girl (8 years Old)_______________________________
3) Child-3: __NA____
4) Child-4: __NA____
5) Other: __NA____

5) Which room belongs to child-1? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __Yes, Room for Child-1_________________________

6) Which room belongs to child-2? Write (Yes or No or Not applicable).

1) Bedroom-1: __ Yes, Room for Child-2_________________________
2) Bedroom-2: __NA____

7) Which room belongs to child-3? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

8) Which room belongs to child-4? Write (Yes or No or Not applicable).

1) Bedroom-1: __NA____
2) Bedroom-2: __NA____

9) During the weekdays how is the M. Bedroom used? For example:

Between (23:00 pm – 07:00 am) the M. Bedroom is occupied, and.

Between (07:00 am – 18:00 pm) the M. Bedroom is not occupied.

1) Between which hours is it occupied:

1:__24:00 pm – 07:00 am______________
2:__12:00 am – 14:00 pm______________
3:__19:00 pm – 20:00 pm______________

2) Between which hours is it not occupied:

1:__20:00 pm – 24:00 pm______________
2:__07:00 am – 12:00 am______________
3:__14:00 pm – 19:00 pm______________

10) During the weekdays how is the Bedroom-1 used? For example:

Between (23:00 pm – 07:00 am) the Bedroom-1 is occupied, and

Between (07:00 am – 18:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

1:__24:00 pm – 07:00 am______________
2:__19:00 pm – 20:00 pm______________
3:__NA_____________________________

2) Between which hours is it not occupied:

1:__20:00 pm – 24:00 pm______________
2:__07:00 am – 19:00 pm______________
3:__NA_____________________________

11) During the weekdays how is the Bedroom-2 used? For example:

Between (23:00 pm – 07:00 am) the Bedroom-1 is occupied, and

Between (07:00 am – 18:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

1:__24:00 pm – 07:00 am______________
2:__19:00 pm – 20:00 pm______________
3:__NA____________________________

2) Between which hours is it not occupied:

1:__20:00 pm – 24:00 pm______________
2:__07:00 am – 19:00 pm______________
3:__NA____________________________

12) During the weekdays how is the Saloon used? For example:

Between (18:00 pm – 23:00 pm) the Saloon is occupied, and

Between (23:00 pm – 18:00 pm) the Saloon is not occupied.

1) Between which hours is it occupied:

1:__10:00 am – 14:00 pm______________
2:__15:00 pm – 19:00 pm______________
3:__21:00 pm – 24:00 pm______________

2) Between which hours is it not occupied:

1:__24:00 pm – 10:00 am___________
2:__14:00 pm – 16:00 pm___________
3:__20:00 pm – 21:00 pm___________

13) During the weekdays how is the kitchen used? For example:

Between (19:00 pm – 20:00 pm) the kitchen is occupied.

Between (20:00 pm – 19:00 pm) the kitchen is not occupied, and

1) Between which hours is it occupied:

1:__07:00 am – 08:00 am______________
2:__14:00 pm – 15:00 pm______________
3:__20:00 pm – 21:00 pm______________

2) Between which hours is it not occupied:

1:__21:00 pm – 07:00 am______________
2:__08:00 am – 14:00 pm______________
3:__15:00 pm – 20:00 pm______________

14) During the weekdays how is the laundry used? For example:

On Wednesday Between (20:00 pm – 21:00 pm) the laundry is used, or

During the weekdays it is not used,

1) Between which hours is it occupied:

   1:__10:00 am – 11:00 am________________
   2:__NA________________________________
   3:__NA________________________________

2) Between which hours is it not occupied:

   1:__11:00 am – 10:00 am________________
   2:__NA________________________________
   3:__NA________________________________

15) During the weekends how is the M. Bedroom used? For example:

Between (24:00 pm – 09:00 am) the M. Bedroom is occupied, and

Between (09:00 am – 24:00 pm) the M. Bedroom is not occupied.

1) Between which hours is it occupied:

   1:__24:00 pm – 10:00 am________________
   2:__17:00 pm – 18:00 pm________________
   3:__NA________________________________

2) Between which hours is it not occupied:

   1:__18:00 pm – 24:00 pm________________
   2:__10:00 am – 17:00 pm________________
   3:__NA________________________________

16) During the weekends how is the Bedroom-1 used? For example:

Between (24:00 pm – 09:00 am) the Bedroom-1 is occupied, and

Between (09:00 am – 24:00 pm) the Bedroom-1 is not occupied.

1) Between which hours is it occupied:

   1:__24:00 pm – 10:00 am________________
   2:__17:00 am – 18:00 pm________________
   3:__NA________________________________

2) Between which hours is it not occupied:

1:__18:00 pm – 24:00 pm________________
2:__10:00 am – 17:00 pm________________
3:__NA________________________________

17) During the weekends how is the Bedroom-2 used? For example:

Between (24:00 pm – 09:00 am) the Bedroom-2 is occupied.

Between (09:00 am – 24:00 pm) the Bedroom-2 is not occupied, and

1) Between which hours is it occupied:

1:__24:00 pm – 10:00 am________________
2:__17:00 pm – 18:00 pm________________
3:__NA________________________________

2) Between which hours is it not occupied:

1:__18:00 pm – 24:00 pm________________
2:__10:00 am – 17:00 pm________________
3:__NA________________________________

18) During the weekends how is the Saloon used? For example:

Between (09:00 am – 24:00 pm) the Saloon is occupied.

Between (24:00 pm – 09:00 am) the Saloon is not occupied, and

1) Between which hours is it occupied:

1:__11:00 am – 16:00 pm_______________
2:__18:00 pm – 20:00 pm_______________
3:__21:00 pm – 24:00 pm_______________

2) Between which hours is it not occupied:

1:__24:00 pm – 11:00 am_______________
2:__16:00 pm – 18:00 pm_______________
3:__20:00 pm – 21:00 pm_______________

19) During the weekends how is the kitchen used? For example:

Between (19:00 pm – 20:00 pm) the kitchen is occupied, and

Between (11:00 am – 19:00 pm) the kitchen is not occupied, and

Between (10:00 am – 11:00 am) the kitchen is occupied, and

Between (20:00 pm – 10:00 am) the kitchen is not occupied,

1) Between which hours is it occupied:
   1:__10:00 am – 11:00 am________________
   2:__16:00 pm – 17:00 pm________________
   3:__20:00 pm – 21:00 pm________________

2) Between which hours is it not occupied:
   1:__21:00 pm – 10:00 am________________
   2:__11:00 am – 16:00 pm________________
   3:__17:00 pm – 20:00 pm________________

20) During the weekends how is the laundry used? For example:

On Wednesday Between (20:00 pm – 21:00 pm) the laundry is used, or

During the weekdays it is not used,

1) Between which hours is it occupied:

   1:__10:00 am – 11:00 am________________
   2:__NA_______________________________
   3:__NA_______________________________

2) Between which hours is it not occupied:

   1:__11:00 am – 10:00 am________________
   2:__NA_______________________________
   3:__NA_______________________________

21) What are the holidays of the year that you celebrate? State Yes and for how many days?

1) Ramadan days: __Yes, three days ______________________________
2) Pilgrimage days: __Yes, four days______________________________
3) New Year: __Yes, one day___________________________________
4) Independence day: __Yes, one day_____________________________
5) Children day: __Yes, one day_________________________________
6) Workers day: __Yes, one day_________________________________
7) Summer holidays: __Yes, three month__________________________
8) Other: __NA____

9) Other: __NA____

10) Other: __NA____

22) Which holidays do you leave home and for how many days? For example:

Summer Holidays: 90 days

1) __Summer Holidays, for 90 days ____________________________
2) __Ramadan Holiday, for 3 days______________________________
3) __Haj Holidays, for 4 days__________________________________
4) __Children's Day, for 1 day_________________________________
5) Other: __NA____
6) Other: __NA____
7) Other: __NA____

23) Do you have a water radiator heating system (Combi System) for heating in winter? State Yes or No? If **no** which other system do you use?

__Yes____

24) For how many months (during the winter) of the year do you use this heating system fully?

___Six Months (October, November, December, January, February, March) ____

25) For how many months (during the summer) of the year do you not use this heating system fully?

___Six Months (April, May, June, July, August, September) ________________

26) Approximately how much money do you use to buy natural gas or electricity for this heating system?

___3600 TL / One Year for heating purposes and water heating_______________

27) Do you use any device (for example cooler or fan) to cool during the summer? State Yes or No. If yes describe the device and between which times it is used in summer.

__No____

____

28) Do you ventilate your house mechanically? State Yes or No. If yes describe the device and at what times it is used. For Example:

Split Unit (Used between 12:00 pm – 20:00 pm)

__No____

____

29) Do you ventilate your house naturally in summer? State Yes or No. If yes describe the times this is done. For example

(Windows are open between 12:00 pm – 20:00 pm)

__Yes, Open Windows (Opened Between 12:00 am – 20:00 pm)______________

____

30) Do you have computers in your house? State Yes or No. If yes, describe how many and where they are located in the house?

__ Yes, One Laptop Computer. Located in the Saloon________________________

____

31) Do you have office equipment (printer, fax, and etc)? State Yes or No. If yes, describe what they are, how many, and where they are located in the house?

__NA____

____

APPENDIX B

DIFFERENT CONSTRUCTION SYSTEM UNDER INVESTIGATION (BS EN ISO 6946)

Table 46 Different Construction System Under Investigation (BS EN ISO 6946)

Type of Wall Construction System	**Conductivity W/m2 x k**	**Specific Heat J/Kg x K**	**Density Kg/m3**
Existing Wall Construction System			
Red Brick Block 13.5 cm (Outer Leaf)	0.32	1000	600
Red Brick Block 8.5 cm (Inner Leaf)	0.32	1000	650
Wall Construction System Under Study			
Autoclaved Aerated Concrete (AAC)	0.11	896	2800
Concrete Block (Heavyweight)	1.63	1000	2300
Concrete Block (lightweight)	0.19	1000	600

APPENDIX C

DIFFERENT INSULATION MATERIALS UNDER INVESTIGATION (URALITA)

Table 47 Different Insulation Materials Under Investigation (Uralita)

Type of Wall Insulation System	Conductivity W/m2 x k	Specific Heat J/Kg x K	Density Kg/m3
Exiting Wall Insulation System			
Extruded Polystyrene Foam (CO2 Blown) XPS	0.034	1400	35
Expanded Polystyrene (Standard) EPS	0.040	1400	15
Proposed Wall Insulation System			
MW Glass Wool (High Performance Panels)	0.032	840	30

APPENDIX D

DIFFERENT WINDOW FRAMES UNDER INVESTIGATION
(BS EN ISO 6946)

Table 48 Different Window Frames Under Investigation

Type of Window Frame	**U-Value (W/m2 x k)**
Existing Window Frames	
Painted Wooden Window Frame	3.633
Proposed Window Frame	
Unplasticized Polyvinyl Chloride (UPVC) Window Frame	3.476

APPENDIX E

ORIGINAL EXTERNAL WALL SYSTEM (SECTION BASE CASE)

Table 49 Original External Wall System (Section Base Case)

Construction	
External Walls	
Number of Layers	6
Outermost Layer	0.030 M Gypsum Insulating Plaster
Second Layer	0.040 M XPS Extruded Polystyrene – Co2 Blowing
Third Layer	0.135 M Brick
Fourth Layer	0.030 M EPS Expanded Polystyrene (Standard)
Fifth Layer	0.085 M Brick
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX F

HVAC TEMPLATE (DESIGN BUILDER)

Table 50 HVAC Template (Design Builder)

Template	Hot Water Radiator Heating,Natural Ventilation
Mechanical Ventilation	
ON or OFF	Off
Auxiliary Energy	
Auxiliary Energy (kWh/m2)	3.26
Heating	
ON or OFF	On
Fuel	2-Natural Gas
Heating System CoP	0.65
Type	
Heating Type	1-Convective
Supply Air Condition	
Supply Air Temperature (°C)	15
Supply Air Humidity Ratio (g/g)	0.010
Operation	
Schedule	Winter (Northern Hemisphere)
Cooling	
ON or OFF	Off
DHW	
ON or OFF	On
DHW Template	Project DHW
Type	4- Instantaneous DHW only
DHW CoP	0.850
Fuel	2- Natural Gas
Water Temperatures	
Delivery Temperature (°C)	50
Mains Supply Temperature (°C)	10
Operation	
Schedule	On
Natural Ventilation	
ON or OFF	On
Outside Air Definition Method	1- By Zone
Outside Air (ac/h)	3.00
Schedule	Summer (Northern Hemisphere)
Air Temperature Distribution	
Distribution Mode	1- Mixed

APPENDIX G

LIGHTING TEMPLATE (DESIGN BUILDER)

Table 51 Lighting Template (Design Builder)

Lighting Template	
Template	Fluorescent
General Lighting	
ON or OFF	On
Light Energy (W / m2-100 lux)	4.60
Schedule	(According to zone usage)
Luminaire Type	1- Suspended
Radiant Fraction	0.420
Visible Fraction	0.180
Convective Fraction	0.400
Task and Display Lighting	
ON or OFF	Off
Exterior Lighting	
ON or OFF	Off
Lighting Control	
ON or OFF	Off

APPENDIX H

GLAZING TEMPLATE (DESIGN BUILDER) – PART-1

Table 52 Glazing Template (Design Builder) – Part-1

Glazing Template	
Template	Project Glazing Template
External Windows	
Glazing Type	Alternative 1, 2 or 3
Layout	No glazing
Dimension	
Type	0-None
Reveal	
Inside Reveal Depth (m)	0.00
Inside Sill Depth (m)	0.00
Frame Dividers	
ON or OFF (Has a Frame / Dividers)	On
Construction	UPVC Window Frame
Dividers	
Type	1- Divided Lite
Width (m)	0.020
Horizontal Dividers	1
Vertical Dividers	1
Outside Projection (m)	0.00
Inside Projection (m)	0.00
Glass Edge-Center Construction Ratio	1.00
Frame	
Frame Width (m)	0.040
Frame Inside Projection (m)	0.00
Frame Outside Projection (m)	0.00
Glass Edge-Center Construction Ratio	1.00
Shading	
ON or OFF (Window Shading)	Off
ON of OFF (Local Shading)	Off
Internal Windows	
Glazing Type	Project Internal Glazing
Layout	No Glazing

Table 52 (Continued) Glazing Template (Design Builder) – Part-2

Dimensions	
Type	0- None
Frame and Dividers	
ON or OFF (Has a frame / dividers)	Off
Operation	
% Glazing area opens	% 0
Operation Schedule	Off
Roof Windows / Skylight	
Glazing Type	Project Roof Glazing
Layout	No roof glazing
Dimensions	
Type	0-None
Frame and Dividers	
ON or OFF (Has a frame / dividers)	Off
Shading	
ON or OFF (Window Shading)	Off
Door	
External	
ON or OFF (Auto generate)	Off
Internal	
ON or OFF (Auto generate)	Off
Operation	
% Area Door Opens	0
% Time Door is Open	0
Operation Schedule	Off
Vents	
Internal	
ON or OFF (Auto generate)	Off
Operation	
Operation Schedule	Off

APPENDIX I

PROPOSED EXTERNAL WALL SYSTEM (SECTIONS 1A, 1B, 1C AND 1D)

Table 53 Proposed External Wall System (Section 1A, 1B, 1C and 1D)

Construction	
Proposed External Walls-1A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-1B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-1C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.10 M Aerated Autoclaved Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-1D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Aerated Autoclaved Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Interior Plaster

APPENDIX J

PROPOSED EXTERNAL WALL SYSTEM (SECTIONS 2A, 2B, 2C AND 2D)

Table 54 Proposed External Wall System (Sections 2A, 2B, 2C and 2D)

Construction	
Proposed External Walls-2A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-2B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-2C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.10 M Hollow Heavyweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-2D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Heavyweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Interior Plaster

APPENDIX K

PROPOSED EXTERNAL WALL SYSTEM (SECTIONS 3A, 3B, 3C AND 3D)

Table 55 Proposed External Wall System (Sections 3A, 3B, 3C and 3D)

Construction	
Proposed External Walls-3A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-3B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-3C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.10 M Hollow Lightweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed External Walls-3D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Lightweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Interior Plaster

APPENDIX L

ORIGINAL FLAT ROOF SYSTEM

Table 56 Original Flat Roof System

Construction	
Flat Roof	
Number of Layers	6
Outermost Layer	0.020 M Concrete Roofing Tiles
Second Layer	0.030 M Screed
Third Layer	0.002 M Pure Bitumen
Fourth Layer	0.080 M XPS Extruded Polystyrene – CO2 Blowing
Fifth Layer	0.120 M Reinforced Concrete with % 2 Steel
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX M

ORIGINAL AND PROPOSED PITCHED ROOF SYSTEM

Table 57 Original and Proposed Pitched Roof System

Construction	
Pitched Roof (Occupied)	Turkey Pitched Roof (Heavyweight)
Number of Layers	3
Outermost Layer	0.025 M Clay Tile (Roofing)
Second Layer	0.1523 MW Stone Wool (Rolls)
Innermost Layer	0.005 M Roofing Felt
Pitched Roof (Unoccupied)	Turkey Pitched Roof (Heavyweight)
Number of Layers	3
Outermost Layer	0.025 M Clay Tile (Roofing)
Second Layer	0.1523 MW Stone Wool (Rolls)
Innermost Layer	0.005 M Roofing Felt

APPENDIX N

ORIGINAL AND PROPOSED INTERNAL PARTITION SYSTEM

Table 58 Original and Proposed Internal Partition System

Construction	
Internal Partition	
Number of Layers	3
Outermost Layer	0.020 M Gypsum Insulating Plaster
Second Layer	0.100 M Brick
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX O

ORIGINAL SEMI-EXPOSED WALL SYSTEM (BASE CASE)

Table 59 Original Semi-Exposed Wall System (Base Case)

Construction	
Semi-exposed Wall-Base Case	
Number of Layers	6
Outermost Layer	0.030 M Gypsum Insulating Plaster
Second Layer	0.040 M XPS Extruded Polystyrene – Co2 Blowing
Third Layer	0.135 M Brick
Fourth Layer	0.030 M EPS Expanded Polystyrene (Standard)
Fifth Layer	0.085 M Brick
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX P

PROPOSED SEMI-EXPOSED WALL SYSTEM (SECTIONS 1A, 1B, 1C AND 1D)

Table 60 Proposed Semi-Exposed Wall System (Sections 1A, 1B, 1C and 1D)

Construction	
Proposed Semi-exposed Walls-1A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-1B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-1C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.10 M Aerated Autoclaved Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-1D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Aerated Autoclaved Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Interior Plaster

APPENDIX Q

PROPOSED SEMI-EXPOSED WALL SYSTEM (SECTIONS 2A, 2B, 2C AND 2D)

Table 61 Proposed Semi-Exposed Wall System (Sections 2A, 2B, 2C and 2D)

Construction	
Proposed Semi-exposed Walls-2A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-2B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-2C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.10 M Hollow Heavyweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-2D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Heavyweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Interior Plaster

APPENDIX R

PROPOSED SEMI-EXPOSED WALL SYSTEM (SECTIONS 3A, 3B, 3C AND 3D)

Table 62 Proposed Semi-Exposed Wall System (Sections 3A, 3B, 3C and 3D)

Construction	
Proposed Semi-exposed Walls-3A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-3B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-3C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.10 M Hollow Lightweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Interior Plaster
Proposed Semi-exposed Walls-3D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Exterior Plaster
Second Layer	0.20 M Hollow Lightweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Interior Plaster

APPENDIX S

ORIGINAL AND PROPOSED SEMI-EXPOSED CEILING SYSTEM

Table 63 Original and Proposed Semi-Exposed Ceiling System

Construction	
Semi-exposed Ceiling-Base Case	Turkey Semi-Exposed Ceiling (Heavyweight)
Number of Layers	4
Outermost Layer	0.01 M Plywood (Heavyweight)
Second Layer	0.1392 M MW Glass Wool (rolls)
Third Layer	0.10 M Cast Concrete
Innermost Layer	0.013 M Plaster Board

APPENDIX T

ORIGINAL AND PROPOSED SEMI-EXPOSED FLOOR SYSTEM

Table 64 Original and Proposed Semi-Exposed Floor System

Construction	
Semi-exposed Floor	
Number of Layers	5
Outermost Layer	0.030 Gypsum Insulating Plaster
Second Layer	0.040 M XPS Extruded Polystyrene – Co2 Blowing
Third Layer	0.120M Concrete, Reinforced (With 2% Steel)
Fourth Layer	0.030 M Screed
Innermost Layer	0.020 M Ceramic / Porcelain

APPENDIX U

ORIGINAL AND PROPOSED GROUND FLOOR SYSTEM

Table 65 Original and Proposed Ground Floor System

Construction	
Ground Floor	
Outermost Layer	5
Second Layer	0.030 M Gypsum Insulating Plaster
Third Layer	0.080 M XPS Extruded Polystyrene – CO2 Blowing
Fourth Layer	0.120 M Reinforced Concrete with % 2 Steel
Innermost Layer	0.030 M Screed
Outermost Layer	0.020 M Wooden Flooring

APPENDIX V

ORIGINAL AND PROPOSED EXTERNAL FLOOR SYSTEM

Table 66 Original and Proposed External Floor System

Construction	
External Floor	
Number of Layers	1
Single Layer	0.100 M Dense Cast Concrete

APPENDIX W

ORIGINAL AND PROPOSED INTERNAL FLOOR SYSTEM

Table 67 Original and Proposed Internal Floor System

Construction	
Internal Floor	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Plaster
Second Layer	0.120 M Reinforced Concrete with % 2 Steel
Third Layer	0.030 M Screed
Innermost Layer	0.020 M Wooden Flooring

APPENDIX X

ORIGINAL SUB-SURFACES WALL SYSTEM (BASE CASE)

Table 68 Original Sub-Surfaces Wall System (Base Case)

Construction	
Sub surface Wall-Base Case	
Number of Layers	6
Outermost Layer	0.030 M Gypsum Insulating Plaster
Second Layer	0.040 M XPS Extruded Polystyrene – Co2 Blowing
Third Layer	0.135 M Brick
Fourth Layer	0.030 M EPS Expanded Polystyrene (Standard)
Fifth Layer	0.085 M Brick
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX Y

ORIGINAL AND PROPOSED SUB-SURFACES INTERNAL WALL SYSTEM

Table 69 Original and Proposed Sub-Surfaces Internal Wall System

Construction	
Sub surfaces Internal Wall System	
Number of Layers	3
Outermost Layer	0.020 M Gypsum Insulating Plaster
Second Layer	0.100 M Brick
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX Z

ORIGINAL AND PROPOSED SUB-SURFACES ROOF SYSTEM

Table 70 Original and Proposed Sub-Surfaces Roof System

Construction	
Sub surface Roof System	
Number of Layers	3
Outermost Layer	0.020 M Gypsum Insulating Plaster
Second Layer	0.120 M Reinforced Concrete with % 2 Steel
Innermost Layer	0.020 M Gypsum Insulating Plaster

APPENDIX AA

PROPOSED SUB-SURFACES WALL SYSTEM (SECTIONS 1A, 1B, 1C AND 1D)

Table 71 Proposed Sub-Surfaces Wall System (Sections 1A, 1B, 1C and 1D)

Construction	
Proposed Sub surface Walls-1A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.20 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-1B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-1C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.10 M Aerated Autoclaved Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Aerated Autoclaved Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-1D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.20 M Aerated Autoclaved Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster

APPENDIX BB

PROPOSED SUB-SURFACES WALL SYSTEM (SECTIONS 2A, 2B, 2C AND 2D)

Table 72 Proposed Sub-Surfaces Wall System (Sections 2A, 2B, 2C and 2D)

Construction	
Proposed Sub surface Walls-1A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.20 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-1B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-1C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.10 M Hollow Heavyweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Hollow Heavyweight Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-1D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.20 M Hollow Heavyweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster

APPENDIX CC

PROPOSED SUB-SURFACES WALL SYSTEM (SECTIONS 3A, 3B, 3C AND 3D)

Table 73 Proposed Sub-Surfaces Wall System (Sections 3A, 3B, 3C and 3D)

Construction	
Proposed Sub surface Walls-3A	
Number of Layers	3
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.20 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-3B	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.050 M MW Glass Wool (High Performance Panel)
Third Layer	0.20 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-3C	
Number of Layers	5
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.10 M Hollow Lightweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Fourth Layer	0.10 M Hollow Lightweight Concrete Block
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster
Proposed Sub surface Walls-3D	
Number of Layers	4
Outermost Layer	0.030 M Gypsum Insulating Exterior Plaster
Second Layer	0.20 M Hollow Lightweight Concrete Block
Third Layer	0.050 M MW Glass Wool (High Performance Panel)
Innermost Layer	0.020 M Gypsum Insulating Interior Plaster

APPENDIX DD

ORIGINAL AND PROPOSED SUB-SURFACES EXTERNAL AND INTERNAL DOOR SYSTEMS

Table 74 Original and Proposed Sub-Surfaces External and Internal Door Systems

Construction	
Sub-Surfaces	
External Door	Wooden Door
Internal Door	Wooden Door

APPENDIX EE

ORIGINAL AND PROPOSED INTERNAL THERMAL MASS SYSTEMS

Table 75 Original and Proposed Internal Thermal Mass Systems

Construction	
Project Thermal Mass	0.10 M Cast Concrete Dense

APPENDIX FF

COMPONENT BLOCKS SHADING AND REFLECTION SYSTEMS

Table 76 Component Blocks Shading and Reflection Systems

Component Block	
Component block shades and reflects	
ON or OFF	off
Material	Material
Project component block material	
Maximum Transmittance	0.000
Transmittance Schedule	
ON or OFF	Off (All the time)

APPENDIX GG

AIR TIGHTNESS

Table 77 Air Tightness

Air Tightness	
Model Infiltration	
ON or OFF	On
Constant Rate (ac/h)	0.700

APPENDIX HH

WINDOW OPENING SYSTEM

Table 78 Window Opening System

External Windows	**Drawn**
Glazing Type	**Any Glazing Type Under Investigation**
Frame Type	**UPVC Frame**

APPENDIX II

DOOR OPENING SYSTEM

Table 79 Door Opening System

Doors	
External	
Auto generate	
ON or OFF	Off
Internal	
Auto generate	
ON or OFF	Off
Operation	
% Area door opens	
% Time door is open	
Operation Schedule	
ON or OFF	Off

APPENDIX JJ

INTERIOR WINDOW SYSTEM

Table 80 Interior Window System

Internal Windows	None

APPENDIX KK

ROOF WINDOW / SKYLIGHT SYSTEM

Table 81 Roof Window / Skylight System

Roof Windows / Skylights	None

APPENDIX LL

VENT OPENING SYSTEM

Table 82 Vent Opening System

Vents	
Internal	
Vent Type	Grille, small, light slats
Auto Generate	
ON or OFF	off
Operation	
ON or OFF	off

APPENDIX MM

OCCUPANCY SCHEDULES FOR FLATS-1, FLAT-2 AND FLAT-3

Table 83 Flat-1 Occupancy Schedule

Time (h)	Zones																	
	Saloon		M. Bed room		Bed room -1		Bed room -2		Kitchen		Bath room		WC		Bath		Laun-dry	
	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE
00:00-08:00	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08:00-09:00	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
09:00-10:00	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10:00-11:00	0	0	0	0	0	0	0	0	0	0.5	0	1	0	0	0	0	0	1
11:00-12:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:00-13:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:00-14:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14:00-15:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15:00-16:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16:00-17:00	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
17:00-18:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18:00-19:00	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:00-20:00	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
20:00-21.00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21:00-22:00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22:00-23:00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23:00-00:00	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Table 84 Flat-2 Occupancy Schedule

Time (h)	Zones																	
	Saloon		M. Bed room		Bed room -1		Bed room -2		Kitchen		Bath room		WC		Bath		Laun-dry	
	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE
00:00-07:00	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	1	0	0	0	0	0.5	0	0	0	1	1	1	1	0	0
08:00-09:00	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
09:00-10:00	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10:00-11:00	0	0	0	0	1	0	0	0	0	0.5	0	0	0	0	0	0	1	1
11:00-12:00	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
12:00-13:00	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:00-14:00	0	1	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0
14:00-15:00	0	1	0	0	0	0	1	0	0.5	0	1	1	0	0	0	0	0	0
15:00-16:00	1	0	0	0	0	0	0	1	0	0.5	0	0	0	0	1	1	0	0
16:00-17:00	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
17:00-18:00	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18:00-19:00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:00-20:00	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20:00-21.00	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
21:00-22:00	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0
22:00-23:00	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
23:00-00:00	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0

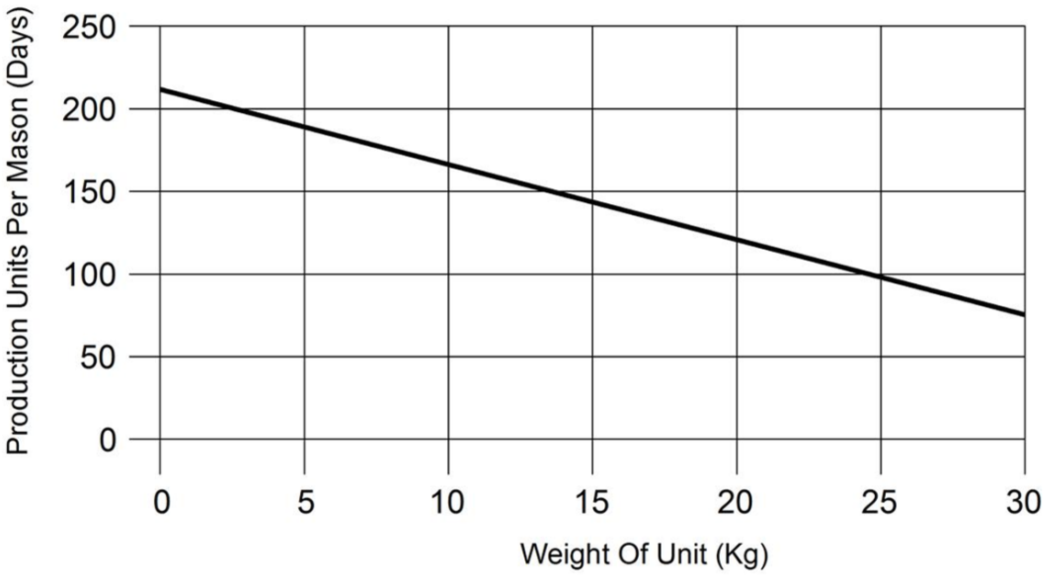
Table 85 Flat-3 Occupancy Schedule

Time (h)	Zones																	
	Saloon		M. Bed room		Bed room -1		Bed room -2		Kitchen		Bath room		WC		Bath		Laun-dry	
	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE	WD	WE
00:00-07:00	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	1	0	1	0	1	0.5	0	1	1	1	1	0	0	0	0
08:00-09:00	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
09:00-10:00	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
10:00-11:00	1	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	1	1
11:00-12:00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12:00-13:00	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13:00-14:00	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14:00-15:00	0	1	0	0	0	0	0	0	0.5	0	0	0	1	1	0	0	0	0
15:00-16:00	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
16:00-17:00	1	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
17:00-18:00	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
18:00-19:00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19:00-20:00	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
20:00-21.00	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0
21:00-22:00	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22:00-23:00	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
23:00-00:00	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

APPENDIX NN

PRODUCTION UNITS PER MASON ACCORDING TO BLOCK WEIGHT

Table 86 Production Units Per Mason According to Block Weight



Estimated production rates based on CMU weight. Reprinted with NCMA permission from Kolkoski, R.V., Masonry Estimating. Craftsman Book Company, 1988. Information is supported in NCMA TEK Note 4-1A: Productivity and Modular Coordination in Concrete Masonry Construction (2002), which states "concrete masonry unit weight greatly impacts masonry productivity, with lighter weight units resulting in higher productivity rates (other factors being equal).

APPENDIX OO

TYPE OF CONCRETE BLOCKS, DIMENSIONS, PRICES AND PRODUCTION DAYS IN TURKISH LIRAS

Table 87 Type of Concrete Blocks, Dimensions, Prices and Production Days in Turkish Liras

Type of Block of Concrete Blocks	Dimensions (W x D x L) / cm	Weight / kg	Cost / TL	Production / Days
13.50 cm Brick	13.50 x20 x 20	3.24	0.20	190.0
8.5 cm Brick	8.50 x 20 x 20	2.21	0.15	200.0
Aerated Autoclaved	20 x 25 x 60	12.000	16.250	160.0
Aerated Autoclaved	10 x 25 x 60	6.000	8.125	180.0
Heavy Weight	20 x 20 x 40	15.558	2.576	140.0
Heavy Weight	10 x 20 x 40	11.022	1.133	162.0
Light Weight	20 x 20 x 40	11.476	3.980	161.5
Light Weight	10 x 20 x 40	7.711	1.750	175.0

APPENDIX PP

SKILLED TECHNICAL STAFF (MASONS) AVERAGE MONTHLY PAY

Table 88 Skilled Technical Staff (Masons) Average Monthly Pay

Position	Average Monthly Pay (mean)
SKILLED TECHNICAL STAFF	1,576 TL

APPENDIX QQ

THE MASONS SALARY FOR THE CONSTRUCTION OF THE BUILDING ENVELOPE FOR ONE FLOOR INCLUDING FLATS-1, FLAT-2 AND FLAT-3

Table 89 The Masons Salary For the Construction of the Building Envelope for One Floor Including Flats 1, 2 and 3

Type of Block of Concrete Blocks	Dimensions (W x D x L) / m	Produc -tion Ratio days / days	No. of Mas -ons	Constrc -tion Period / month	Block Layers In wall	Masons Salary / TL	Total Salary / TL
13.5 cm Brick	**0.135 x 0.20 x 0.20**	**180 / 190 = 0.947**	**2**	**2**	**1**	**1,576x2x2 x1x0.947**	**5,972**
8.5 cm Brick	**0.085 x 0.20 x 0.20**	**180 / 200 = 0.900**	**2**	**2**	**1**	**1,576x2x2 x1x0.900**	**5,674**
Aerated Autoclaved	**0.20 x 0.25 x 0.60**	**180 / 160 = 1.125**	**2**	**2**	**1**	**1,576x2x2 x1x1.125**	**7,092**
Aerated Autoclaved	**0.10 x 0.25 x 0.60**	**180 / 180 = 1.000**	**2**	**2**	**2**	**1.576x2x2 x2x1.000**	**12,608**
Heavy Weight	**0.20 x 0.20 x 0.40**	**180 / 162 = 1.111**	**2**	**2**	**1**	**1,576x2x2 x1x1.286**	**8,108**
Heavy Weight	**0.10 x 0.20 x 0.40**	**180 / 140 = 1.286**	**2**	**2**	**2**	**1.576x2x2 x2x1.111**	**14,010**
Light Weight	**0.20 x 0.20 x 0.40**	**180 / 175 = 1.029**	**2**	**2**	**1**	**1,576x2x2 x1x1.115**	**7,026**
Light Weight	**0.10 x 0.20 x 0.40**	**180 / 161.5 = 1.115**	**2**	**2**	**2**	**1.576x2x2 x2x1.029**	**12,968**

Since the building which has a ground and three floors is constructed in two years, each floor is built and finished in six month or 180 days. This period is taken as the standard production period. From **APPENDIX NN** and **APPENDIX OO** the production units per mason according to block weight, dimension and cost are documented. Since there are three flats in one floor and since the exterior envelope of one floor is constructed in six month by two masons, the exterior envelope of each of the three flats is therefore constructed in **two month by two masons**. From these two month by two masons and the block layers the masons total salary could be calculated as shown in **APPENDIX QQ**.

APPENDIX RR

COMPARING ENERGY CONSUMPTIONS THROUGH GLAZING UNITS IN THE INVESTIGATED FLATS

The glazing units in the studied flats have different orientations and so it cannot be concluded that each glazing unit has the same linear proportionality in terms of total energy consumption.

Table 90 The energy consumption through the glazing units in the flat-1.

Flat-1 (103.5632 m2)			
Double Glazing Units	Total Glazing Area -m2	Yearly Total Energy Consumption-kWh	Net Energy Consumption For Glazing Area of 1 m2-kWh
Isicam Klasik	14.66	4134.40	282.02
Isicam Sinerji		3041.99	207.50
Isicam Sinerji 3+		1757.53	119.89

Table 91 The energy consumption through the glazing units in the flat-2.

Flat-2 (105.2381 m2)			
Double Glazing Units	Total Glazing Area -m2	Yearly Total Energy Consumption-kWh	Net Energy Consumption For Glazing Area of 1 m2-kWh
Isicam Klasik	14.66	4731.55	322.75
Isicam Sinerji		3482.47	237.55
Isicam Sinerji 3+		2014.05	137.38

Table 92 The energy consumption through the glazing units in the flat-3.

Flat-1 (107.0125m2)			
Double Glazing Units	Total Glazing Area -m2	Yearly Total Energy Consumption-kWh	Net Energy Consumption For Glazing Area of 1 m2-kWh
Isicam Klasik	14.43	3552.30	246.17
Isicam Sinerji		3552.30	246.17
Isicam Sinerji 3+		3552.30	246.17

APPENDIX SS

COMPARING ENERGY CONSUMPTIONS THROUGH THE WALL SECTIONS IN THE INVESTIGATED FLATS

Table 93 The energy consumption through the Wall Sections in the Flat-1.

Flat-1 (103.5632 m2)			
Wall Sections of Flat-1	Total Exterior Wall Area -m2	Yearly Total Energy Consumption- kWh	Net Energy Consumption For Glazing Area of 1 m2- kWh
Base Case	31.015	4698.61	151.49
1A		4950.15	159.61
1B		4503.75	145.21
1C		4509.15	145.39
1D		4517.81	145.67
2A		7770.12	250.53
2B		5018.61	161.81
2C		5013.98	161.66
2D		5031.04	162.21
3A		5501.98	177.40
3B		4693.17	151.32
3C		4688.88	151.18
3D		4694.81	151.37

Table 94 The energy consumption through the Wall Sections in the Flat-2.

Flat-2 (105.2381 m2)			
Wall Sections of Flat-2	Total Exterior Wall Area -m2	Yearly Total Energy Consumption- kWh	Net Energy Consumption For Glazing Area of 1 m2- kWh
Base Case	31.015	3817.97	123.10
1A		4098.68	132.15
1B		3620.56	116.74
1C		3625.15	116.88
1D		3636.33	117.24
2A		7178.76	231.46
2B		4168.56	134.40
2C		4167.16	134.36
2D		4186.24	134.97
1A		4693.57	151.33
1B		3819.41	123.15
1C		3816.02	123.04
1D		3822.80	123.26

Table 95 The energy consumption through the Wall Sections in the Flat-3.

Flat-1 (107.0125m2)			
Wall Sections of Flat-3	Total Exterior Wall Area -m2	Yearly Total Energy Consumption- kWh	Net Energy Consumption For Glazing Area of 1 m2- kWh
Base Case	44.685	5723.88	128.09
1A		6056.20	135.53
1B		5493.01	122.93
1C		5500.59	123.10
1D		5511.49	123.34
2A		9638.08	215.69
2B		6141.85	137.45
2C		6139.07	137.39
2D		6157.28	137.79
3A		6751.76	151.10
3B		5730.18	128.23
3C		5726.39	128.15
3D		5733.31	128.31

APPENDIX TT

PERCENTAGES (%) OF HEAT GAINS AND LOSSES THROUGH THE GLAZING ALTERNATIVES IN FLAT-1, FLAT-2 AND FLAT-3

Heat losses occur through glazings, walls, floors, roofs, doors and ventilation, external infiltration, and external ventilation, while heat gains occur through general lighting, miscellaneous systems, occupancy, domestic hot water, heat generation, solar gains from exterior windows, lighting, and chillers in building.

Table 96 The heat losses (kWh) through the three window options in Flat-1 obtained from the simulation results according to windows types.

Heat Losses – kWh (Flat-1)						
	Glazing	Walls	Floors	Door and Ventilation	External Infiltration	External Ventilation
Isicam Klasik	612	396	360	216	1404	6026.4
Isicam Sinerji	381.6	396	360	216	1404	6026.4
Isicam Sinerji 3+	223.2	396	360	216	1404	6026.4

Table 97 The heat losses (kWh) through the three window options in Flat-2 obtained from the simulation results according to windows types.

Heat Losses – kWh (Flat-2)						
	Glazing	Walls	Floors	Door and Ventilation	External Infiltration	External Ventilation
Isicam Klasik	676.8	396	367.2	129.6	1461.6	6271.2
Isicam Sinerji	417.6	396	367.2	129.6	1461.6	6271.2
Isicam Sinerji 3+	244.8	396	374.4	129.6	1461.6	6271.2

Table 98 The heat losses (kWh) through the three window options in Flat-3 obtained from the simulation results according to windows types.

Heat Losses – kWh (Flat-3)						
	Glazing	Walls	Floors	Door and Ventilation	External Infiltration	External Ventilation
Isicam Klasik	698.4	446.4	1281.6	93.6	1490.4	6393.6
Isicam Sinerji	698.4	446.4	1281.6	93.6	1490.4	6393.6
Isicam Sinerji 3+	698.4	446.4	1281.6	93.6	1490.4	6393.6

Table 99 The heat gains (kWh) through the three window options in Flat-1 obtained from the simulation results according to windows types.

Heat Gains – kWh (Flat-1)								
	General Lighting	Occup-ancy	Solar Gain Exterior Windows	DHW (Natural Gas)	Room Electri-city	System Misc.	Heat Genera-tion	Computer And Equipment
Isicam Klasik	1159.91	551.93	4134.40	10.42	419.53	291.24	7188.11	317.74
Isicam Sinerji	1159.91	554.15	3041.99	10.42	419.53	291.24	6683.29	317.74
Isicam Sinerji 3+	1159.91	556.83	1757.53	10.42	419.53	291.24	6458.25	317.74

Table 100 The heat gains (kWh) through the three window options in Flat-2 obtained from the simulation results according to windows types.

Heat Gains – kWh (Flat-2)								
	General Lighting	Occup-ancy	Solar Gain Exterior Windows	DHW (Natural Gas)	Room Electri-city	System Misc.	Heat Genera-tion	Computer And Equipment
Isicam Klasik	1567.90	1971.32	4731.55	50.23	417.84	302.99	5873.80	312.48
Isicam Sinerji	1567.90	1943.32	3482.47	50.23	417.84	302.99	4912.40	312.48
Isicam Sinerji 3+	1567.90	1978.72	2014.05	50.23	417.84	302.99	5026.69	312.48

Table 101 The heat gains (kWh) through the three window options in Flat-3 obtained from the simulation results according to windows types.

Heat Gains – kWh (Flat-3)								
	General Lighting	Occup-ancy	Solar Gain Exterior Windows	DHW (Natural Gas)	Room Electri-city	System Misc.	Heat Genera-tion	Computer And Equipment
Isicam Klasik	1859.10	3052.23	3552.30	59.44	616.45	309.13	8805.98	474.76
Isicam Sinerji	1859.10	3052.23	3552.30	59.44	616.45	309.13	8805.98	474.76
Isicam Sinerji 3+	1859.10	3052.23	3552.30	59.44	616.45	309.13	8805.98	474.76

APPENDIX UU

PERCENTAGES (%) OF HEAT GAINS AND LOSSES THROUGH THE WALL SECTIONS IN FLAT-1, FLAT-2 AND FLAT-3

Heat losses occur through glazings, walls, floors, roofs, doors and ventilation, external infiltration, and external ventilation, while heat gains occur through general lighting, miscellaneous systems, occupancy, domestic hot water, heat generation, solar gains from exterior windows, lighting, and chillers in building.

Table 102 The heat losses (kWh) through the wall sections of Flat-1

Heat Losses – kWh (Flat-1)						
	Glazing	Walls	Floors	Door and Ventilation	External Infiltration	External Ventilation
Sect. Base	612	396	360	216	1404	6026.4
Section1A	612	518.4	352.8	216	1404	6026.4
Section1B	612	316.8	360	216	1404	6026.4
Section1C	612	324	360	216	1404	6026.4
Section1D	612	316.8	360	216	1404	6026.4
Section2A	597.6	1886.4	331.2	208.8	1404	6026.4
Section2B	612	547.2	352.8	216	1404	6026.4
Section2C	612	547.2	352.8	216	1404	6026.4
Section2D	612	547.2	352.8	216	1404	6026.4
Section3A	604.8	756	352.8	216	1404	6026.4
Section3B	612	396	360	216	1404	6026.4
Section3C	612	396	360	216	1404	6026.4
Section3D	612	396	360	216	1404	6026.4

Table 103 The heat losses (kWh) through the wall sections of Flat-2

Heat Losses – kWh (Flat-2)						
	Glazing	Walls	Floors	Door and Ventilation	External Infiltration	External Ventilation
Sect. Base	676.8	396	367.2	129.6	1461.6	6271.2
Section1A	669.6	532.8	367.2	129.6	1461.6	6271.2
Section1B	676.8	316.8	367.2	129.6	1461.6	6271.2
Section1C	676.8	316.8	367.2	129.6	1461.6	6271.2
Section1D	676.8	316.8	367.2	129.6	1461.6	6271.2
Section2A	655.2	2044.8	338.4	122.4	1461.6	6271.2
Section2B	669.6	561.6	367.2	129.6	1461.6	6271.2
Section2C	669.6	561.6	367.2	129.6	1461.6	6271.2
Section2D	669.6	561.6	367.2	129.6	1461.6	6271.2
Section3A	669.6	7992	360	129.6	1461.6	6271.2
Section3B	676.8	396	367.2	129.6	1461.6	6271.2
Section3C	676.8	396	367.2	129.6	1461.6	6271.2
Section3D	676.8	396	367.2	129.6	1461.6	6271.2

Table 104 The heat losses (kWh) through the wall sections of Flat-3

Heat Losses – kWh (Flat-3)						
	Glazing	Walls	Floors	Door and Ventilation	External Infiltration	External Ventilation
Sect. Base	698.4	446.4	1281.6	93.6	1490.4	6393.6
Section1A	691.2	597.6	1274.4	93.6	1490.4	6393.6
Section1B	698.4	352.8	1288.8	93.6	1490.4	6393.6
Section1C	698.4	352.8	1288.8	93.6	1490.4	6393.6
Section1D	698.4	352.8	1288.8	93.6	1490.4	6393.6
Section2A	676.8	2318.4	1209.6	86.4	1490.4	6393.6
Section2B	691.2	633.6	1274.4	93.6	1490.4	6393.6
Section2C	691.2	640.8	1274.4	93.6	1490.4	6393.6
Section2D	691.2	640.8	1274.4	93.6	1490.4	6393.6
Section3A	691.2	900	1260	93.6	1490.4	6393.6
Section3B	698.4	446.4	1281.6	93.6	1490.4	6393.6
Section3C	698.4	446.4	1281.6	93.6	1490.4	6393.6
Section3D	698.4	446.4	1281.6	93.6	1490.4	6393.6

Table 105 The heat gains (kWh) through the wall sections in Flat-1

Heat Gains – kWh (Flat-1)								
	General Lighting	Occup-ancy	Solar Gain Exterior Windows	DHW (Natural Gas)	Room Electri-city	System Misc.	Heat Genera-tion	Computer And Equipment
Sect. Base	1159.91	552.26	4134.40	10.42	360.23	291.24	7228.63	317.74
Section1A	1159.91	554.95	4134.40	10.42	360.23	291.24	7615.62	317.74
Section1B	1159.91	551.64	4134.40	10.42	360.23	291.24	6928.84	317.74
Section1C	1159.91	551.46	4134.40	10.42	360.23	291.24	6937.15	317.74
Section1D	1159.91	550.58	4134.40	10.42	360.23	291.24	6950.47	317.74
Section2A	1159.91	569.69	4134.40	10.42	360.23	291.24	11954.03	317.74
Section2B	1159.91	556.27	4134.40	10.42	360.23	291.24	7720.94	317.74
Section2C	1159.91	555.56	4134.40	10.42	360.23	291.24	7713.81	317.74
Section2D	1159.91	554.21	4134.40	10.42	360.23	291.24	7740.06	317.74
Section3A	1159.91	557.87	4134.40	10.42	360.23	291.24	8464.59	317.74
Section3B	1159.91	552.52	4134.40	10.42	360.23	291.24	7220.26	317.74
Section3C	1159.91	552.26	4134.40	10.42	360.23	291.24	7213.66	317.74
Section3D	1159.91	551.78	4134.40	10.42	360.23	291.24	7222.79	317.74

Table 106 The heat gains (kWh) through the wall sections in Flat-2

Heat Gains – kWh (Flat-2)								
	General Lighting	Occup-ancy	Solar Gain Exterior Windows	DHW (Natural Gas)	Room Electri-city	System Misc.	Heat Genera-tion	Computer And Equipment
Sect. Base	1567.90	1967.32	4731.55	50.23	417.84	302.99	5873.80	312.48
Section1A	1567.90	1976.22	4731.55	50.23	417.84	302.99	6305.66	312.48
Section1B	1567.90	1963.12	4731.55	50.23	417.84	302.99	5570.10	312.48
Section1C	1567.90	1962.65	4731.55	50.23	417.84	302.99	5577.16	312.48
Section1D	1567.90	1960.08	4731.55	50.23	417.84	302.99	5594.36	312.48
Section2A	1567.90	2039.85	4731.55	50.23	417.84	302.99	11044.3	312.48
Section2B	1567.90	1980.44	4731.55	50.23	417.84	302.99	6413.17	312.48
Section2C	1567.90	1978.85	4731.55	50.23	417.84	302.99	6411.01	312.48
Section2D	1567.90	1974.91	4731.55	50.23	417.84	302.99	6440.37	312.48
Section3A	1567.90	1989.70	4731.55	50.23	417.84	302.99	7220.88	312.48
Section3B	1567.90	1967.18	4731.55	50.23	417.84	302.99	5876.02	312.48
Section3C	1567.90	1966.57	4731.55	50.23	417.84	302.99	5870.80	312.48
Section3D	1567.90	1964.54	4731.55	50.23	417.84	302.99	5881.23	312.48

Table 107 The heat gains (kWh) through the wall sections in Flat-3

Heat Gains – kWh (Flat-3)								
	General Lighting	Occup-ancy	Solar Gain Exterior Windows	DHW (Natural Gas)	Room Electri-city	System Misc.	Heat Genera-tion	Computer And Equipment
Sect. Base	1859.10	3052.23	3552.30	59.44	616.45	309.13	8805.98	474.76
Section1A	1859.10	3064.62	3552.30	59.44	616.45	309.13	9317.23	474.76
Section1B	1859.10	3046.86	3552.30	59.44	616.45	309.13	8450.78	474.76
Section1C	1859.10	3046.08	3552.30	59.44	616.45	309.13	8462.44	474.76
Section1D	1859.10	3042.30	3552.30	59.44	616.45	309.13	8479.22	474.76
Section2A	1859.10	3147.46	3552.30	59.44	616.45	309.13	14827.8	474.76
Section2B	1859.10	3069.67	3552.30	59.44	616.45	309.13	9448.99	474.76
Section2C	1859.10	3067.77	3552.30	59.44	616.45	309.13	9444.73	474.76
Section2D	1859.10	3062.72	3552.30	59.44	616.45	309.13	9472.74	474.76
Section3A	1859.10	3083.52	3552.30	59.44	616.45	309.13	10387.3	474.76
Section3B	1859.10	3052.48	3552.30	59.44	616.45	309.13	8815.66	474.76
Section3C	1859.10	3051.76	3552.30	59.44	616.45	309.13	8809.53	474.76
Section3D	1859.10	3049.26	3552.30	59.44	616.45	309.13	8820.48	474.76

APPENDIX VV

MONTHLY HEAT GAINS TRANSMITTED THROUGH THE THREE GLAZING ALTERNATIVES IN FLAT-1, FLAT-2 AND FLAT-3

Table 108 The Monthly Heat Gains Transmitted Through the Three Glazing Alternatives in Flat-1

Flat1	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Tot**
ALT1	240.7	321.0	309.0	348.6	381.4	402.0	448.4	462.7	458.9	349.9	251.7	160.0	4134.4
ALT2	177.8	236.6	227.1	256.3	280.7	296.0	329.9	339.7	336.5	257.3	185.8	118.3	3042.0
ALT3	104.2	137.9	130.8	147.7	161.9	171.4	190.2	194.5	192.4	148.8	108.7	69.2	1757.5

Table 109 The Monthly Heat Gains Transmitted Through the Three Glazing Alternatives in Flat-2

Flat2	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Tot**
ALT1	245.5	339.9	343.3	393.8	460.5	499.1	556.5	543.4	526.9	379.0	276.4	167.2	4731.6
ALT2	181.4	250.5	252.4	289.7	339.1	367.7	409.7	399.2	386.7	278.7	203.9	123.5	3482.5
ALT3	106.3	145.9	145.5	167.2	196.1	213.2	236.8	228.9	221.6	161.2	119.1	72.4	2014.1

Table 110 The Monthly Heat Gains Transmitted Through the Three Glazing Alternatives in Flat-3

Flat3	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Tot**
ALT1	137.1	187.7	272.5	338.3	415.3	453.9	479.3	423.9	342.8	243.5	150.4	107.7	3552.3
ALT2	137.1	187.7	272.5	338.3	415.3	453.9	479.3	423.9	342.8	243.5	150.4	107.7	3552.3
ALT3	137.1	187.7	272.5	338.3	415.3	453.9	479.3	423.9	342.8	243.5	150.4	107.7	3552.3

APPENDIX WW

MONTHLY HEAT LOAD PRODUCTION OF THE HEATING SYSTEM IN FLAT-1, FLAT-2 AND FLAT-3 IN KWH

Table 111 The Monthly Heat Load Production of The Heating System in Flat-1

Flat1	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Tot**
Base	1219	806	764	0	0	0	0	0	0	151	697	1061	4699
1A	1275	866	811	0	0	0	0	0	0	149	729	1121	4950
1B	1171	788	737	0	0	0	0	0	0	120	660	1029	4504
1C	1173	785	735	0	0	0	0	0	0	124	663	1029	4509
1D	1175	786	736	0	0	0	0	0	0	130	663	1028	4518
2A	1920	1363	1290	0	0	0	0	0	0	338	1170	1689	7770
2B	1293	877	823	0	0	0	0	0	0	149	743	1134	5019
2C	1291	872	820	0	0	0	0	0	0	155	743	1132	5014
2D	1294	871	821	0	0	0	0	0	0	167	745	1133	5031
3A	1405	950	900	0	0	0	0	0	0	200	820	1226	5502
3B	1217	809	764	0	0	0	0	0	0	147	695	1062	4693
3C	1216	806	763	0	0	0	0	0	0	148	694	1061	4689
3D	1217	807	764	0	0	0	0	0	0	151	695	1061	4695

Table 112 The Monthly Heat Load Production of The Heating System in Flat-2

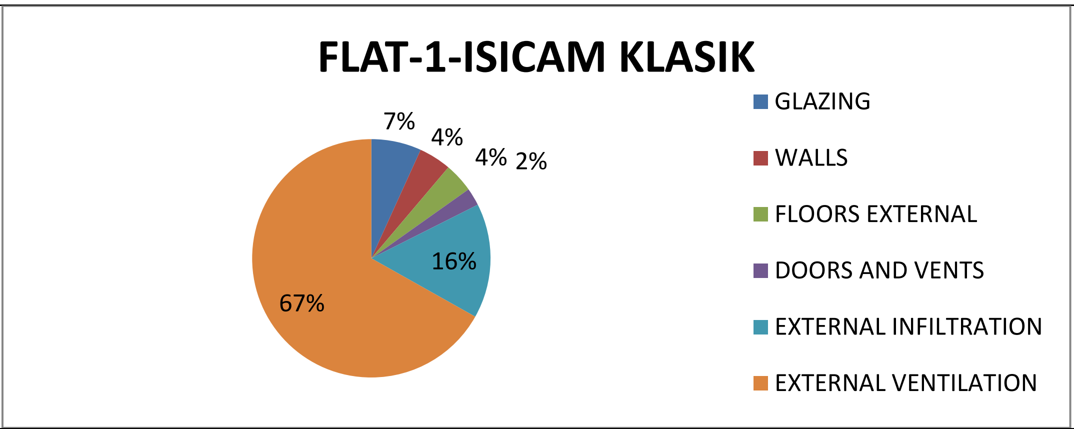
Flat2	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Tot**
Base	1062	662	593	0	0	0	0	0	0	74	525	902	3818
1A	1128	724	641	0	0	0	0	0	0	77	563	966	4099
1B	1013	639	564	0	0	0	0	0	0	55	486	865	3621
1C	1015	636	562	0	0	0	0	0	0	58	490	865	3625
1D	1016	637	565	0	0	0	0	0	0	62	492	865	3636
2A	1850	1272	1163	0	0	0	0	0	0	248	1046	1601	7179
2B	1146	736	654	0	0	0	0	0	0	76	576	981	4169
2C	1145	731	652	0	0	0	0	0	0	82	577	979	4167
2D	1147	730	654	0	0	0	0	0	0	93	581	980	4186
3A	1271	816	739	0	0	0	0	0	0	121	662	1084	4694
3B	1062	661	593	0	0	0	0	0	0	75	526	902	3819
3C	1062	659	592	0	0	0	0	0	0	76	526	901	3816
3D	1061	661	594	0	0	0	0	0	0	79	527	902	3823

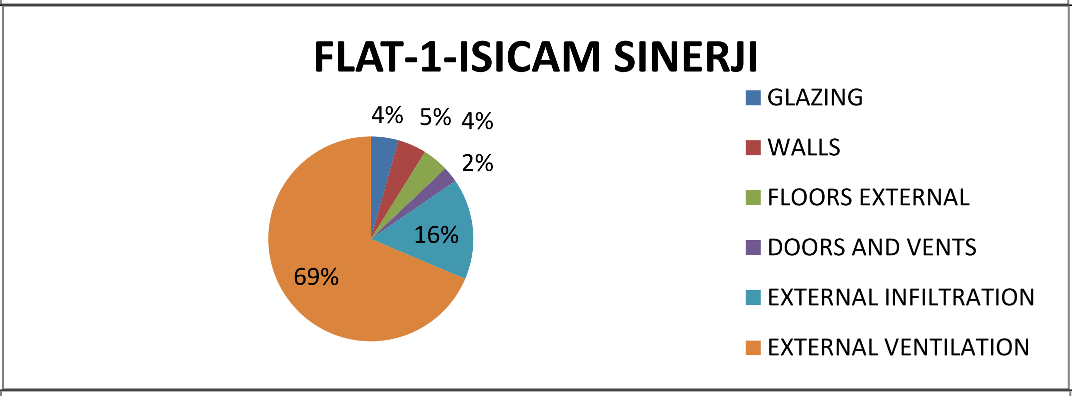
Table 113 The Monthly Heat Load Production of The Heating System in Flat-3

Flat3	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Tot**
Base	1501	1056	894	0	0	0	0	0	0	196	851	1227	5724
1A	1578	1130	953	0	0	0	0	0	0	200	894	1302	6057
1B	1445	1029	863	0	0	0	0	0	0	163	807	1187	5493
1C	1448	1026	861	0	0	0	0	0	0	168	810	1187	5501
1D	1449	1026	862	0	0	0	0	0	0	176	811	1187	5511
2A	2398	1772	1550	0	0	0	0	0	0	447	1457	2014	9638
2B	1600	1143	969	0	0	0	0	0	0	200	911	1319	6142
2C	1599	1139	965	0	0	0	0	0	0	209	912	1316	6139
2D	1600	1137	965	0	0	0	0	0	0	223	916	1316	6157
3A	1740	1238	1063	0	0	0	0	0	0	265	1012	1433	6752
3B	1502	1056	895	0	0	0	0	0	0	197	852	1228	5730
3C	1502	1054	894	0	0	0	0	0	0	199	852	1226	5726
3D	1502	1055	895	0	0	0	0	0	0	202	853	1227	5733

APPENDIX XX

PERCENTAGE HEAT LOSSES AND HEAT GAINS FOR THE GLAZING WINDOWS AND HEAT LOSSES THROUGH ALL WALL SECTIONS FOR FLAT-1, FLAT-2 AND FLAT-3





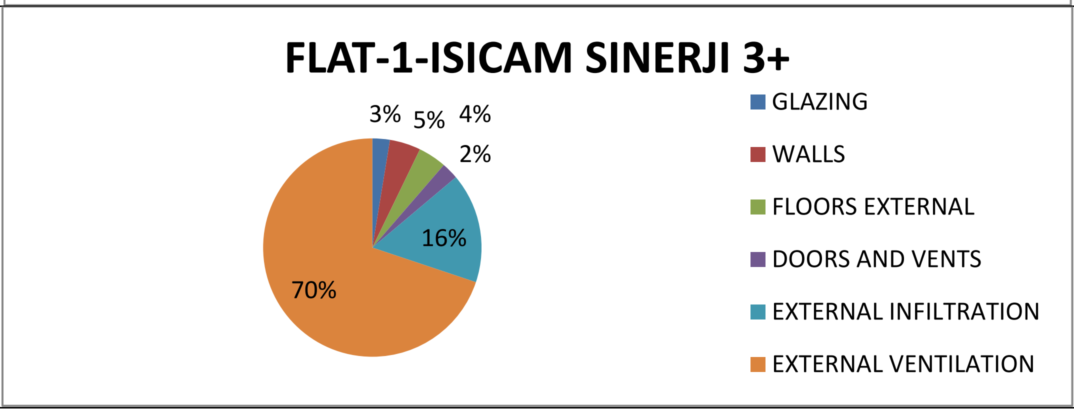


Figure 57 Heat losses (%) through the three window glazing options in flat-1 obtained from the simulation results

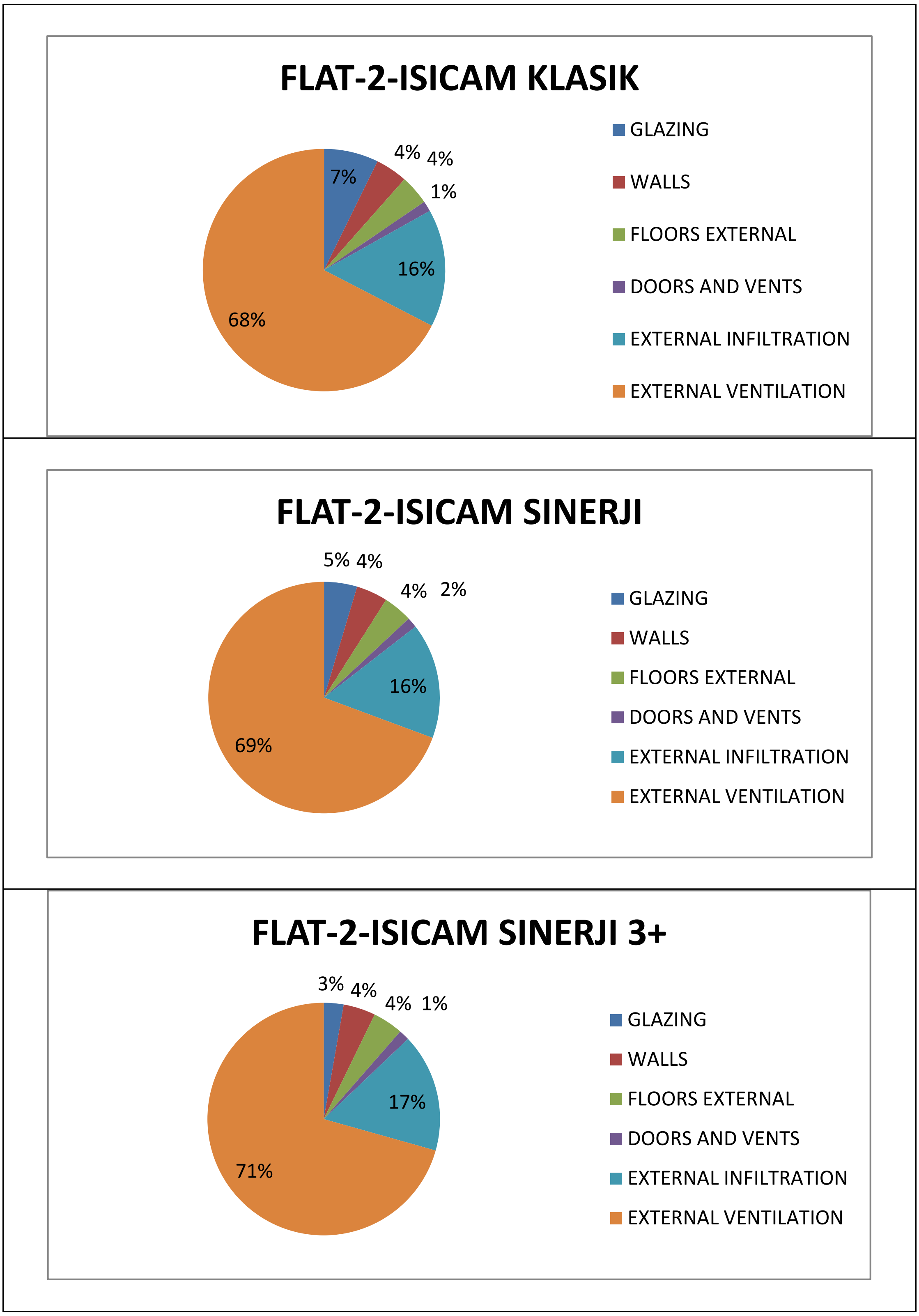


Figure 58 Heat losses (%) through the three window glazing options in flat-2 obtained from the simulation results

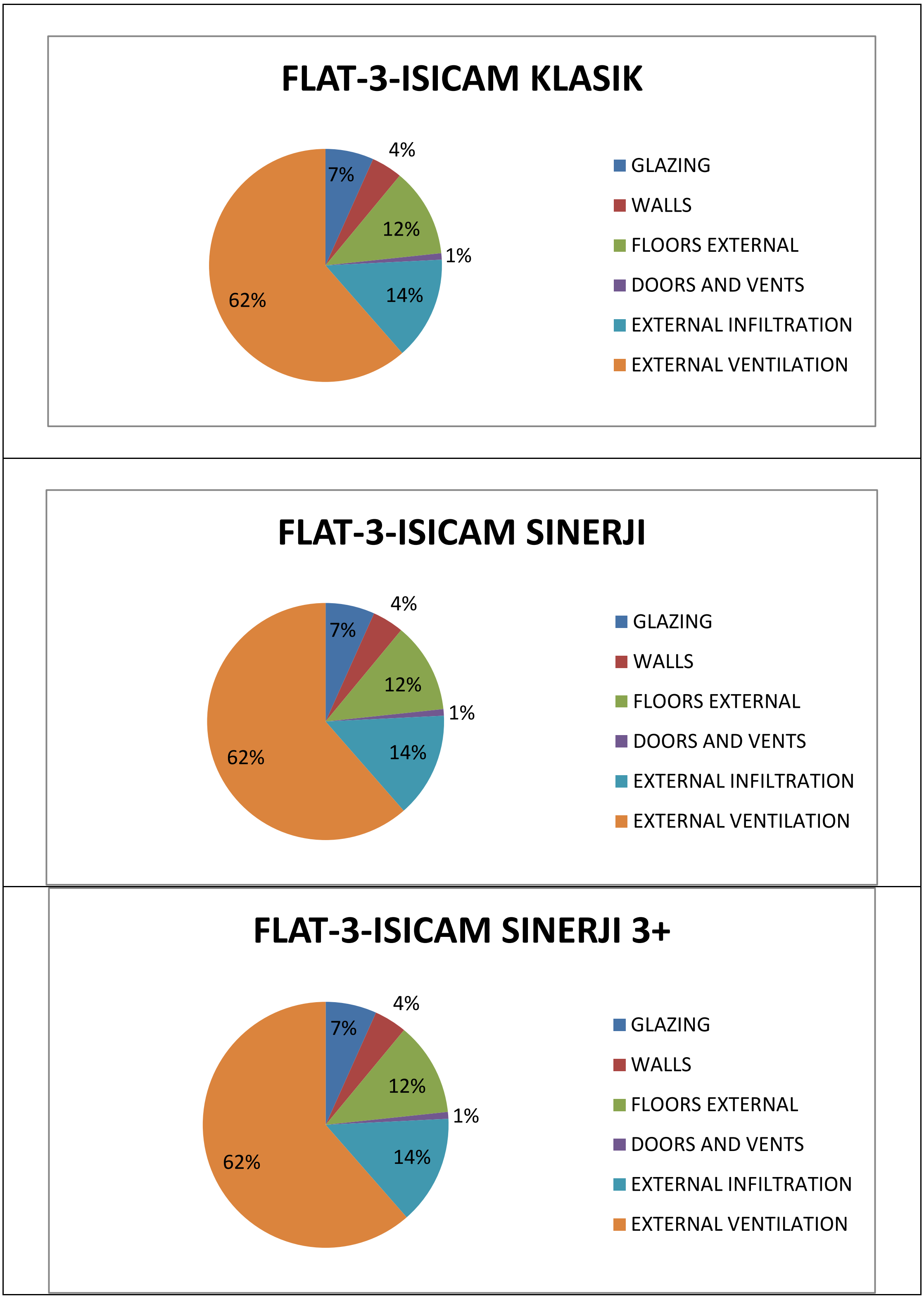


Figure 59 Heat losses (%) through the three window glazing options in flat-3 obtained from the simulation results

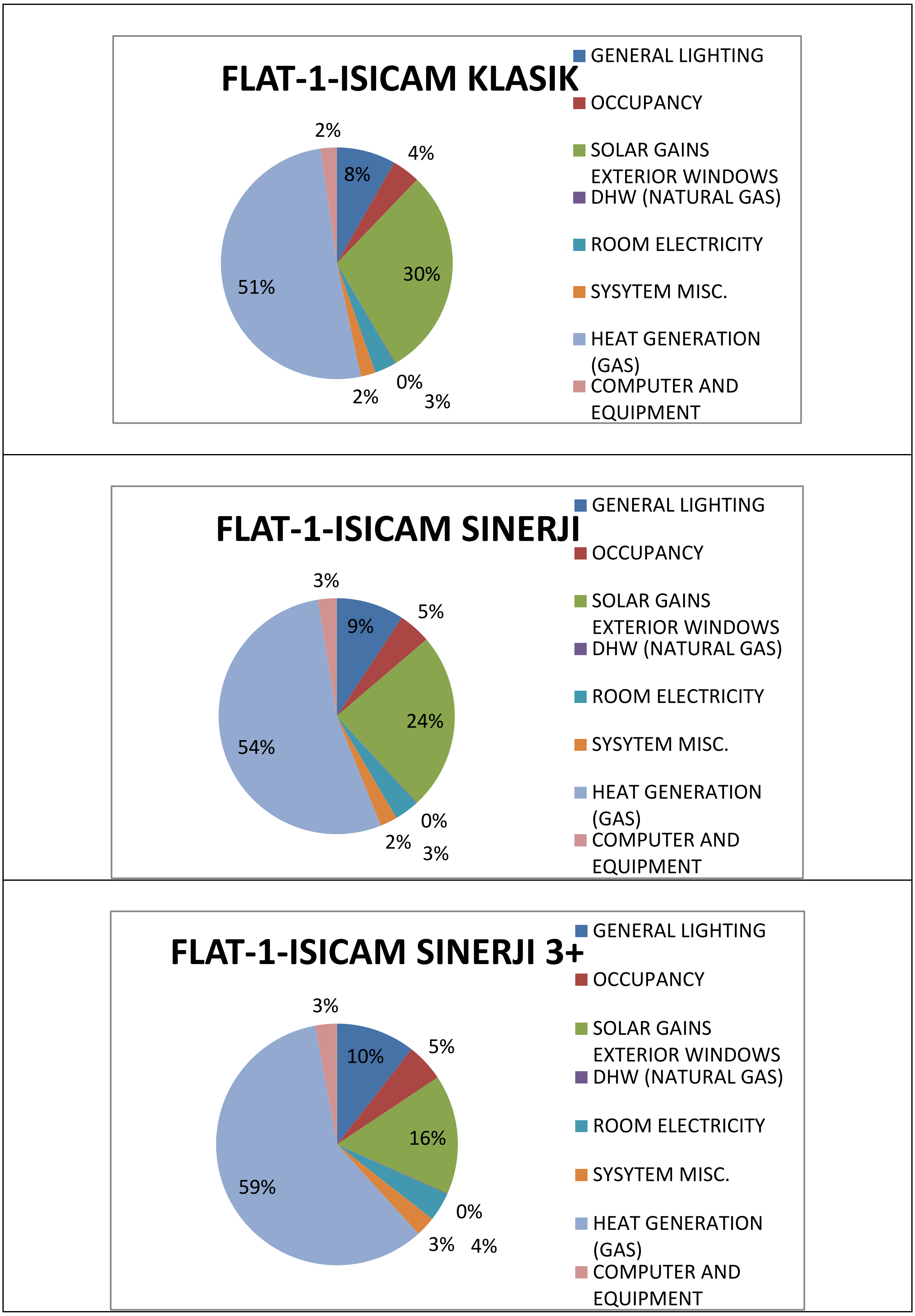


Figure 60 Heat Gains (%) through the three window glazing options in flat-1 obtained from the simulation results

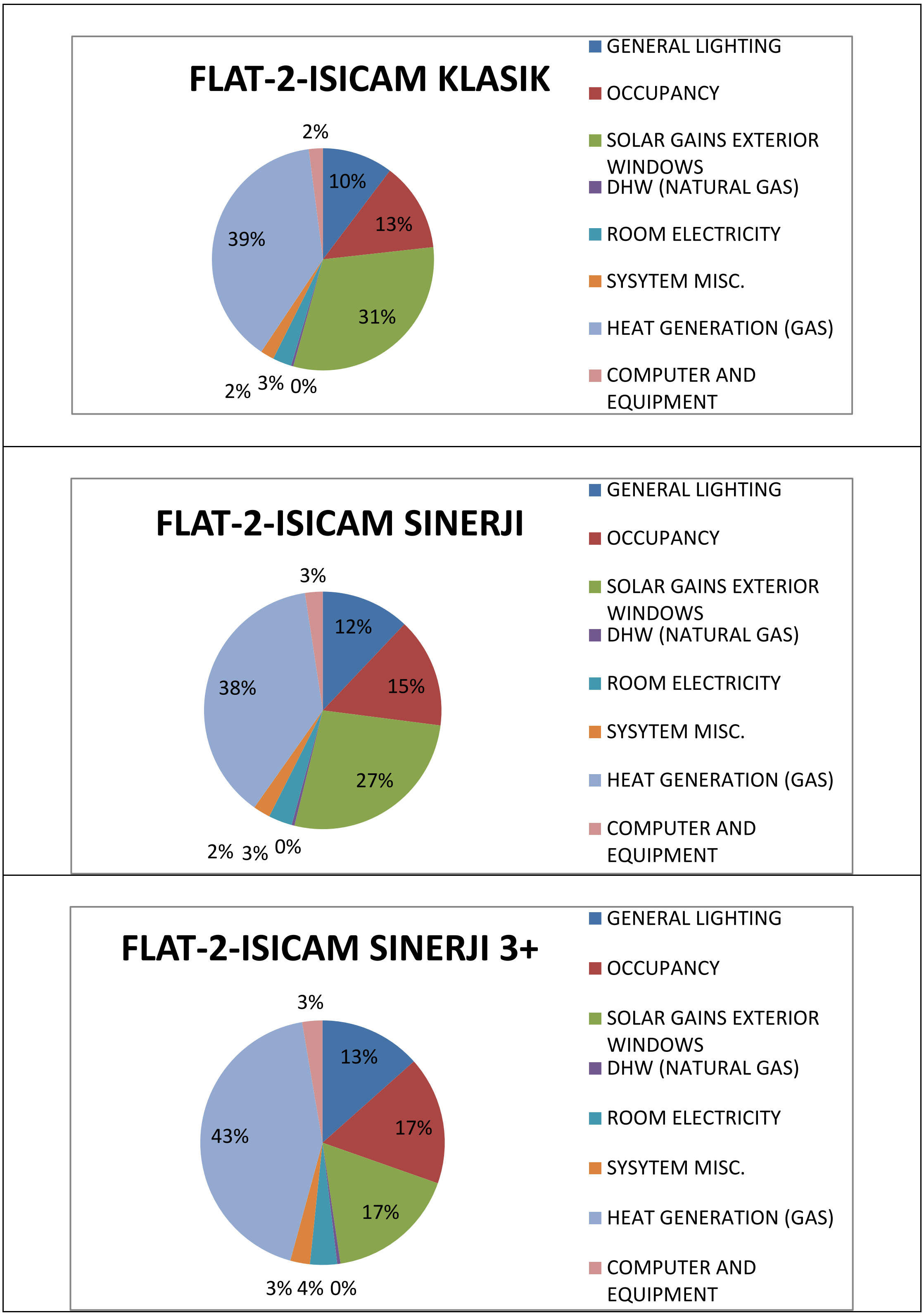


Figure 61 Heat Gains (%) through the three window glazing options in flat-2 obtained from the simulation results

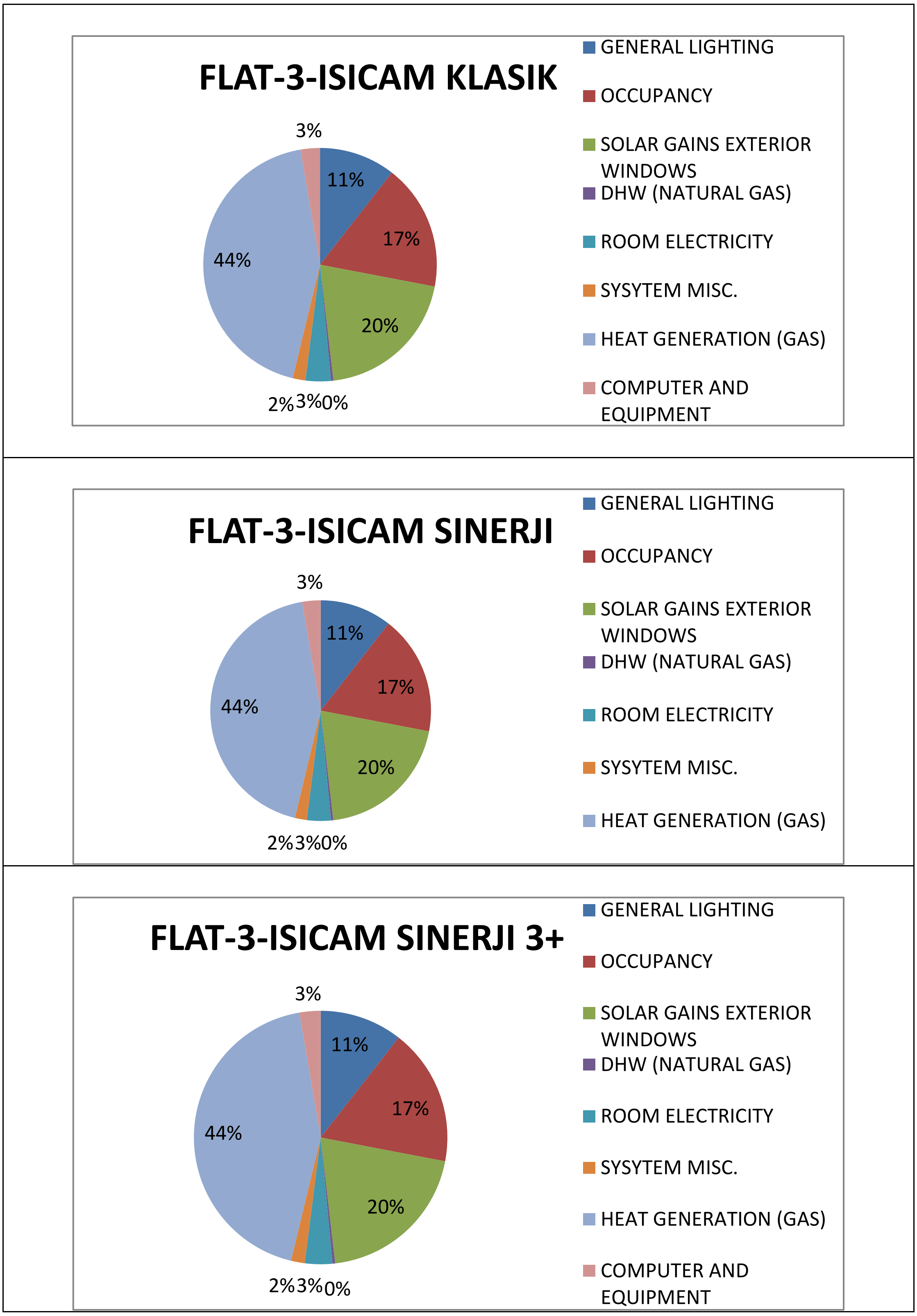
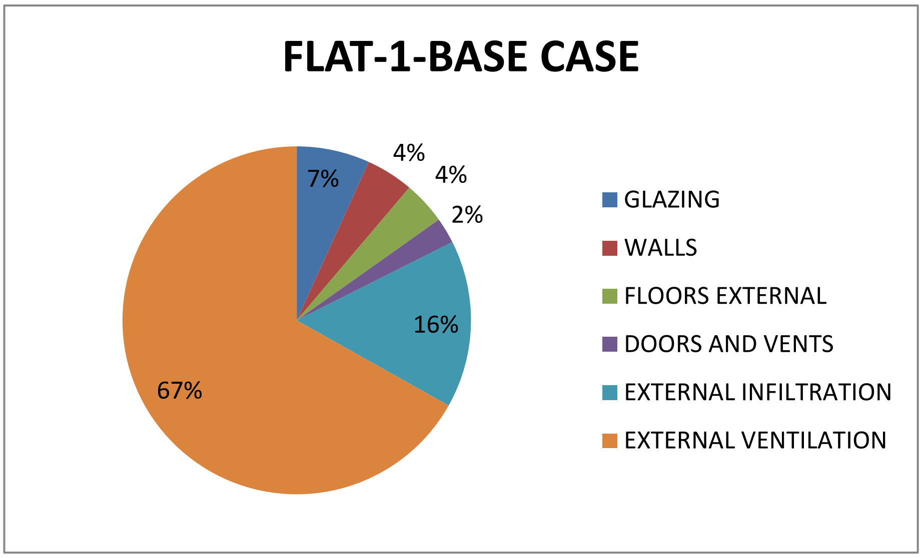


Figure 62 Heat Gains (%) through the three window glazing options in flat-3 obtained from the simulation results



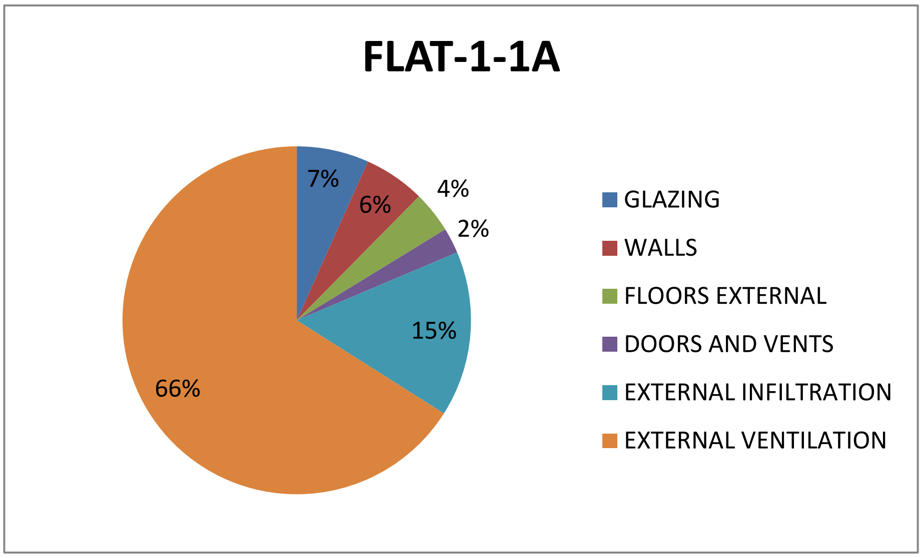
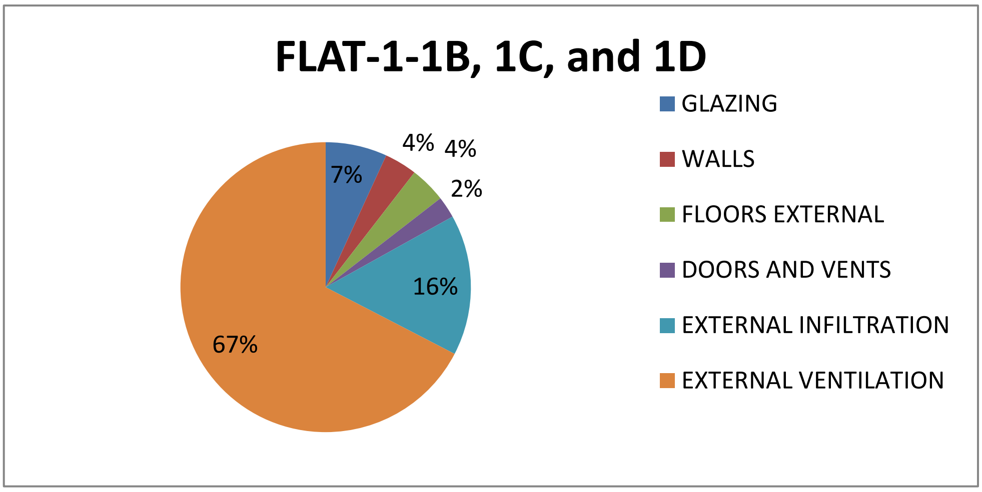
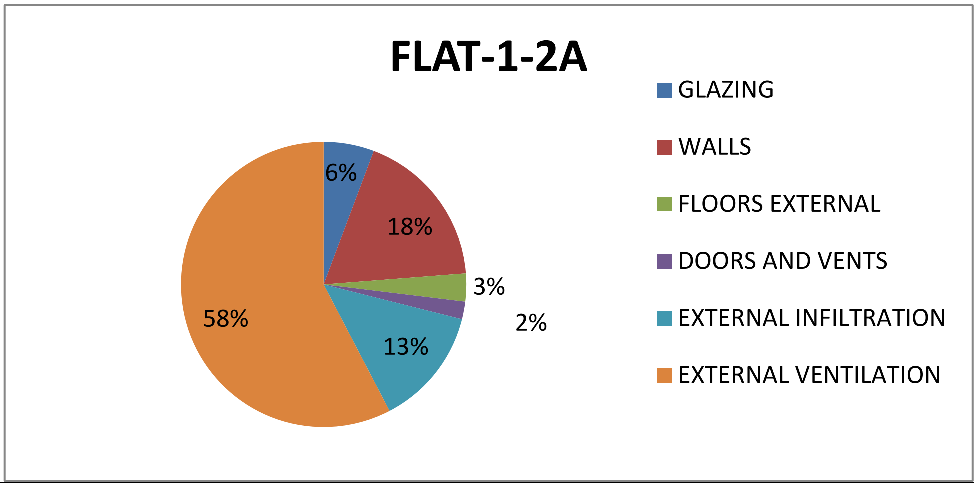


Figure 63 Heat losses (%) through the Wall Sections Base and 1A in flat-1 obtained from the simulation results





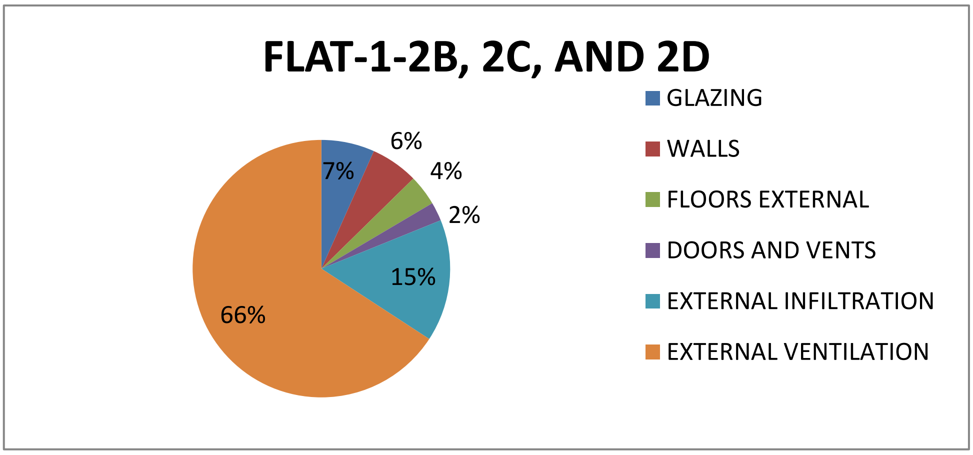
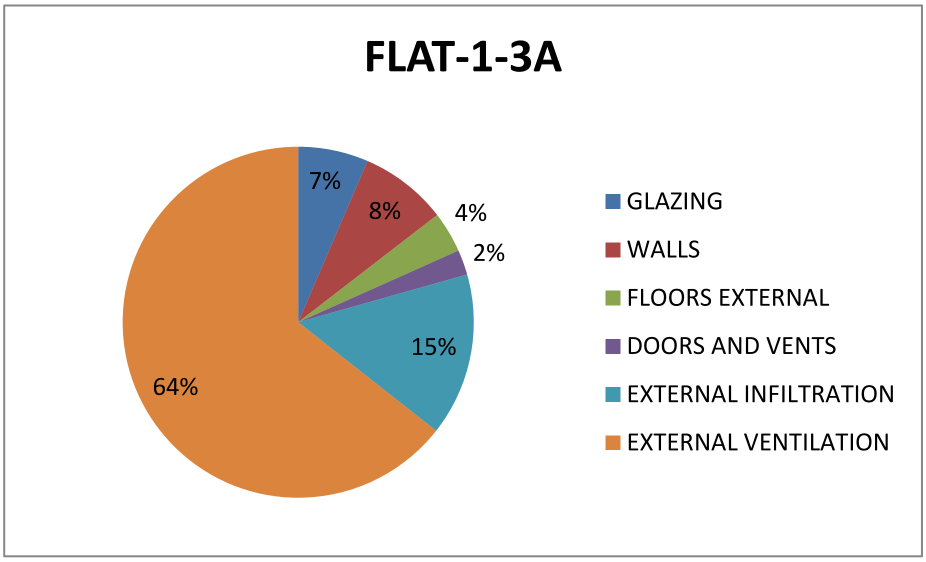


Figure 64 Heat losses (%) through the Wall Sections 1B, 1C, 1D, 2A, 2B, 2C, 2D in flat-1 obtained from the simulation results



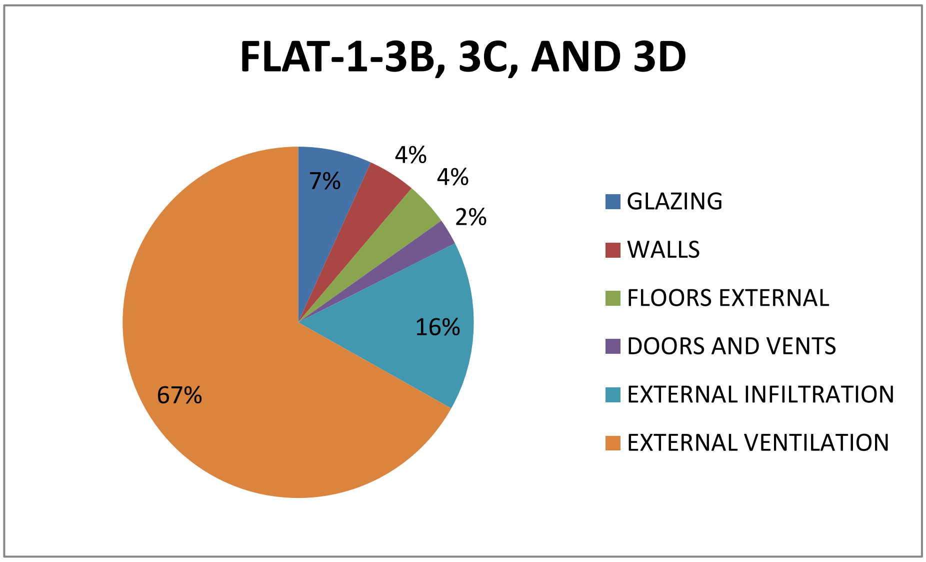
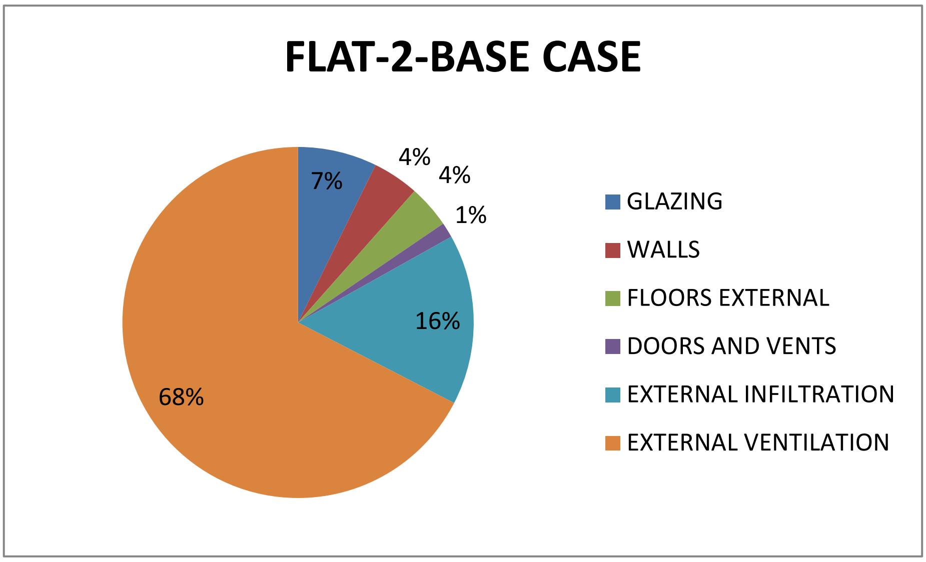


Figure 65 Heat losses (%) through the Wall Sections 3A, 3B, 3C and 3D in flat-1 obtained from the simulation results



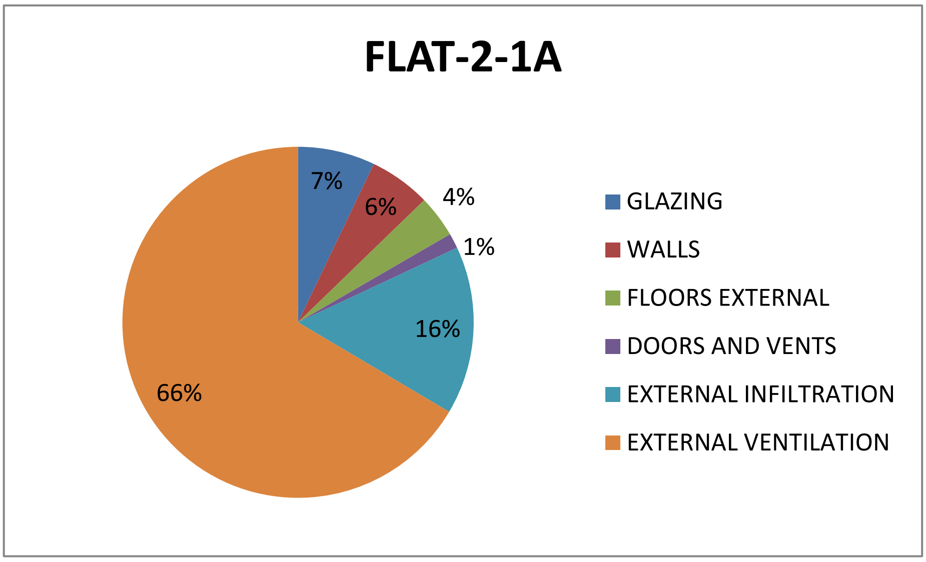


Figure 66 Heat losses (%) through the Wall Sections Base and 1A in flat-2 obtained from the simulation results

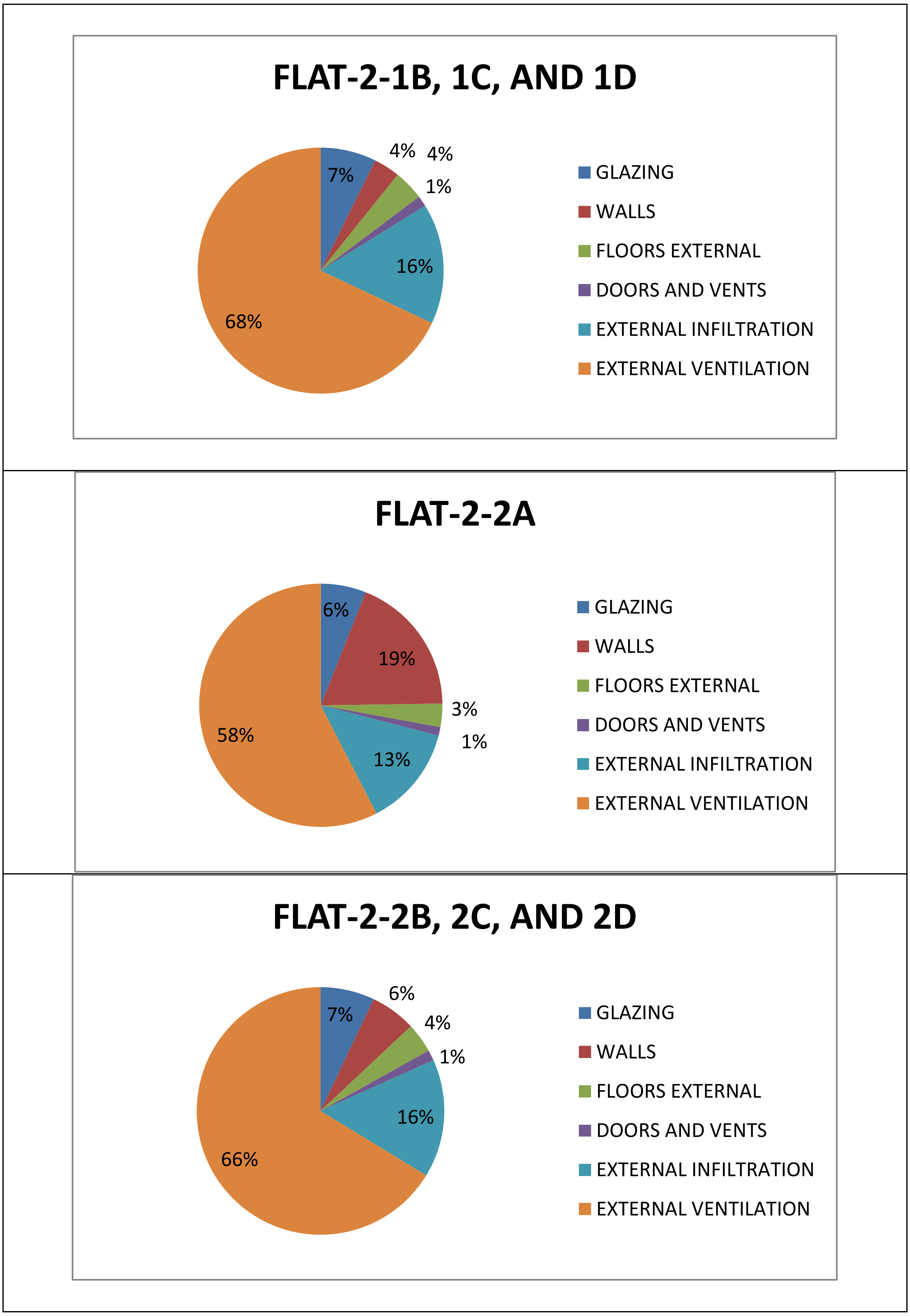


Figure 67 Heat losses (%) through the Wall Sections 1B, 1C, 1D, 2A, 2B, 2C, 2D in flat-2 obtained from the simulation results

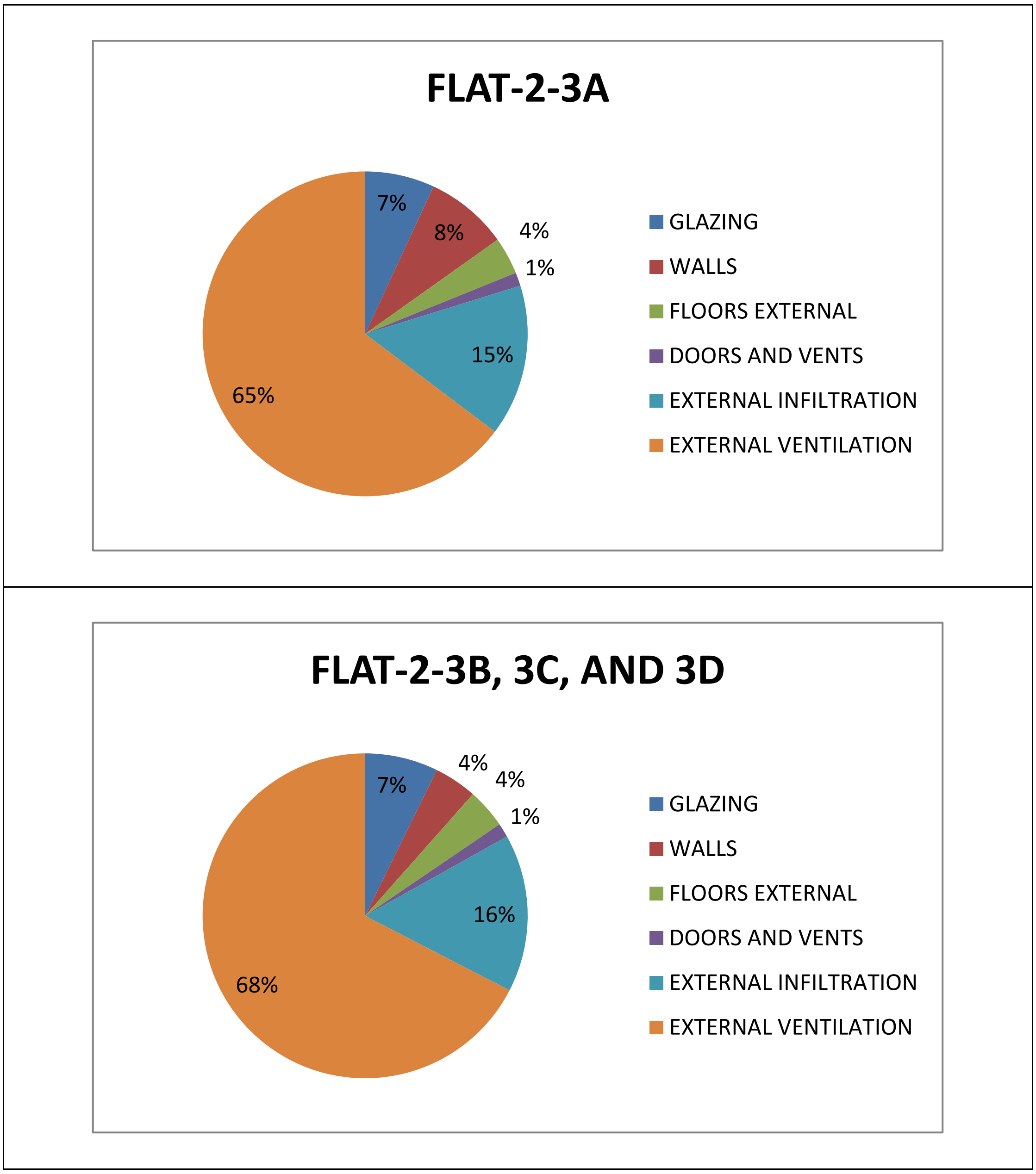
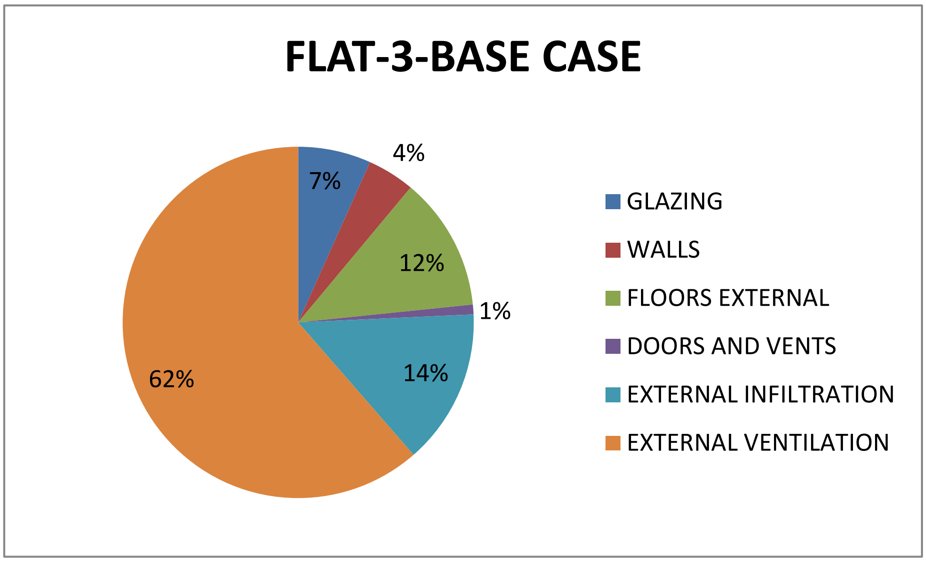


Figure 68 Heat losses (%) through the Wall Sections 3A, 3B, 3C and 3D in flat-2 obtained from the simulation results



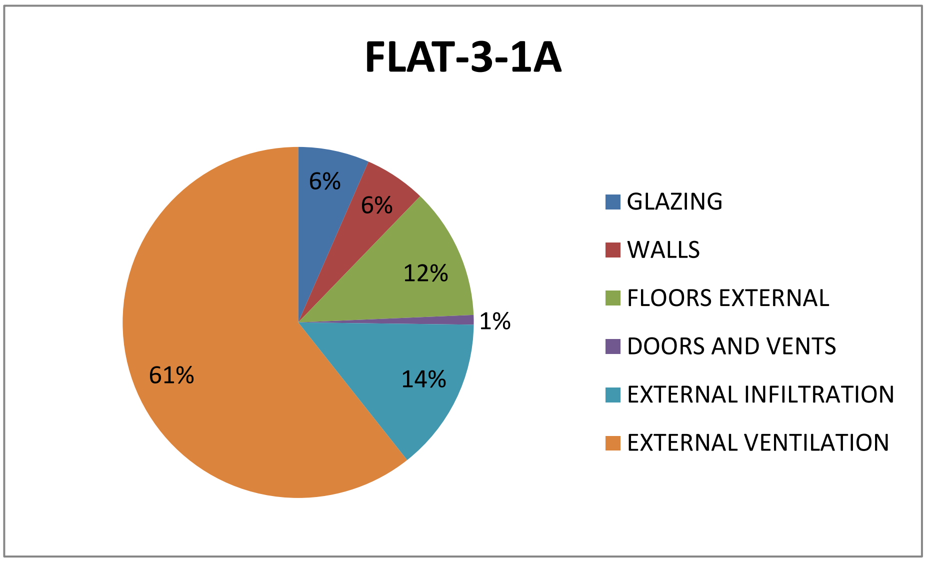


Figure 69 Heat losses (%) through the Wall Sections Base and 1A in flat-3 obtained from the simulation results

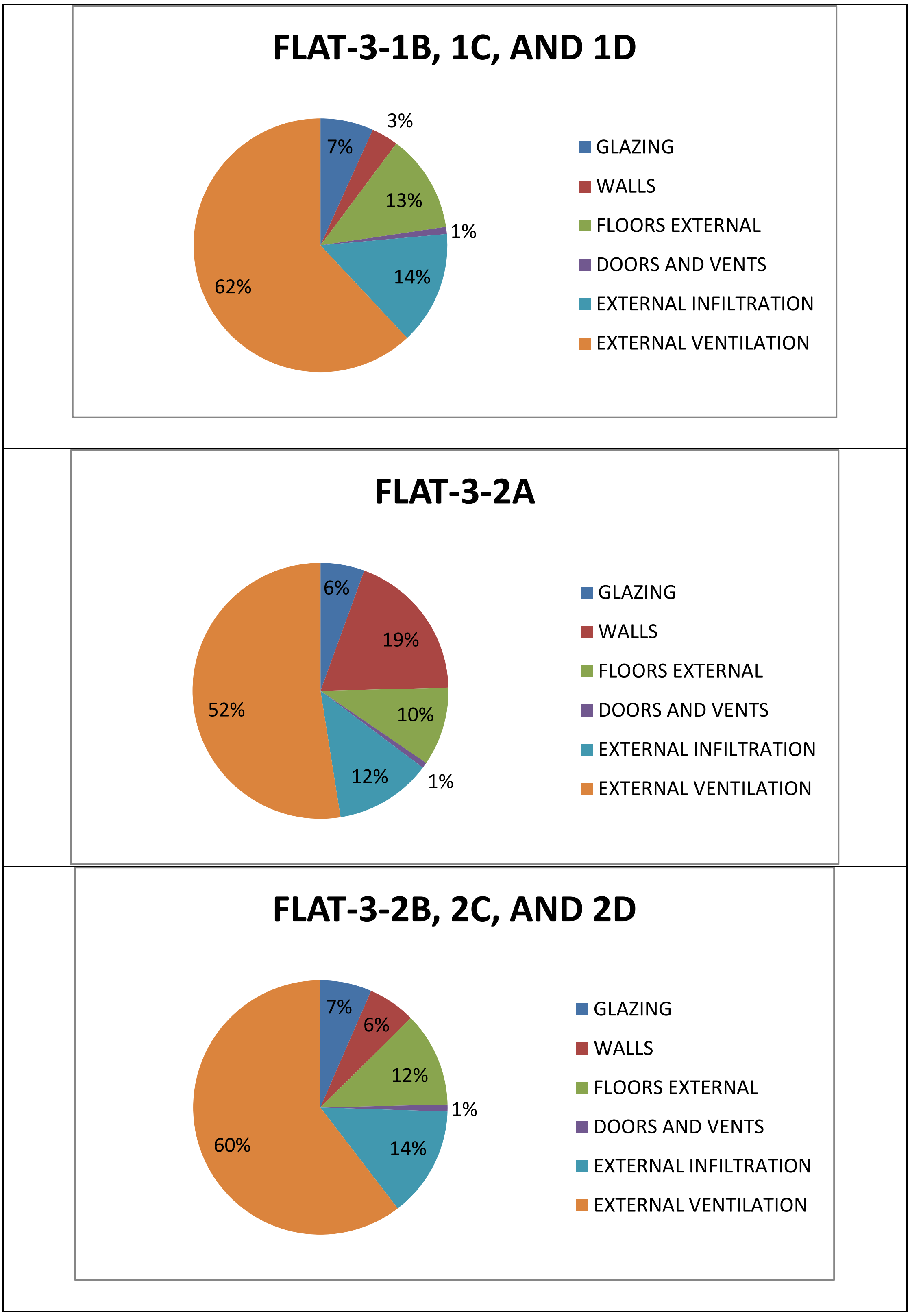


Figure 70 Heat losses (%) through the Wall Sections 1B, 1C, 1D, 2A, 2B, 2C, 2D in flat-3 obtained from the simulation results

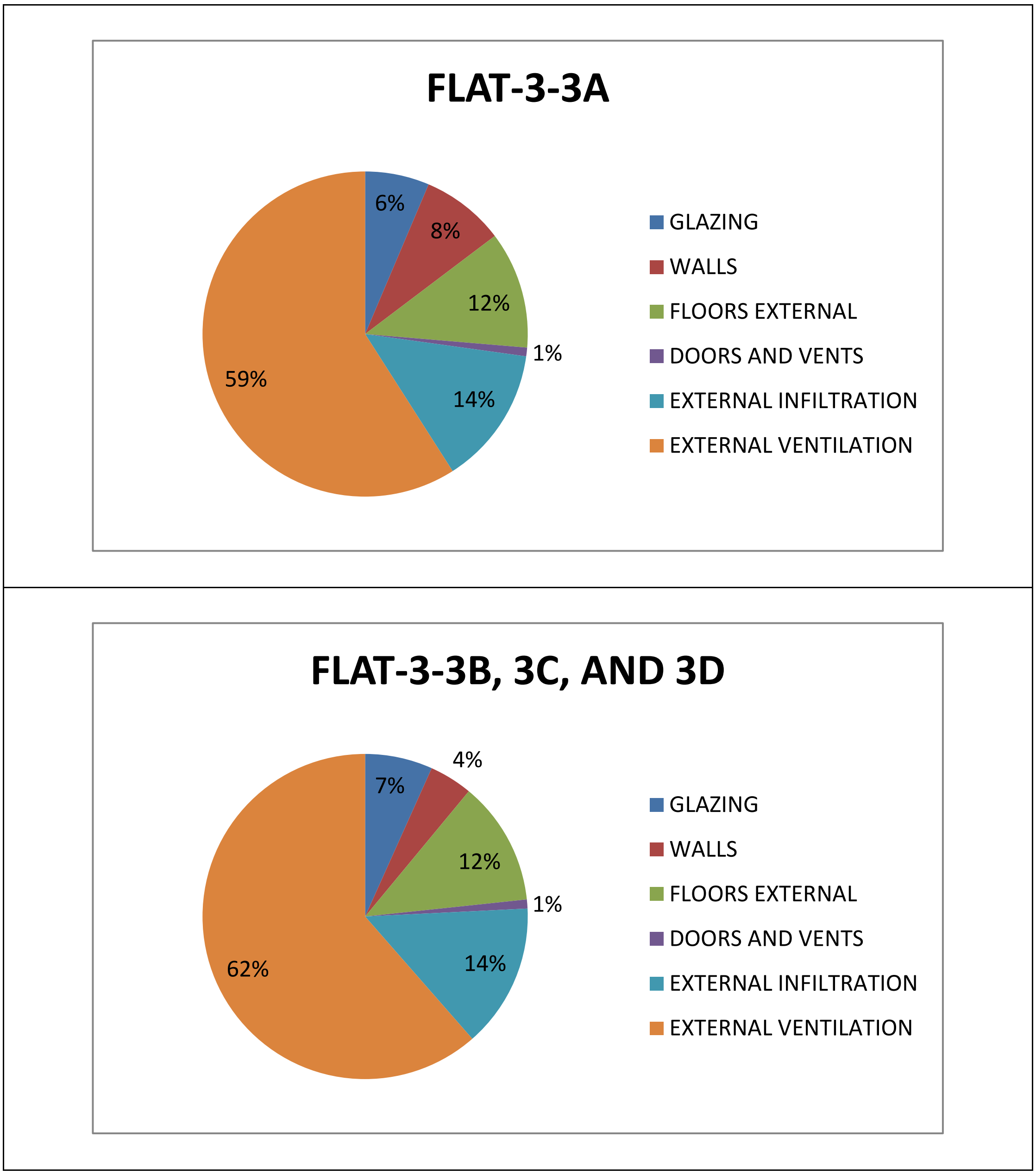
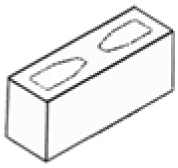
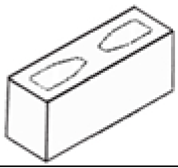
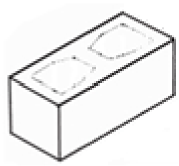
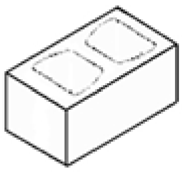
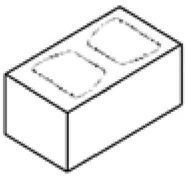


Figure 71 Heat losses (%) through the Wall Sections 3A, 3B, 3C and 3D in flat-3 obtained from the simulation results

APPENDIX YY

HOLLOW CMU CHARACTERISTICS

Table 114 The image, dimensions, density, weight, block per cube, fire ratings of a number of available hollow concrete masonry units (http://www.superiorblockcorp.com), Last Accessed 12 / 12 /2013)

Image	Nominal Size (cm)	Actual Size (cm)	Density	Weight (lbs)	Block Per Cube	Fire Rating (hrs)
	10x20x40 cm Hollow	9.675 x 19.675 x 39.675 cm	125	23.64	144	1 hr
			105	18.17	144	1 hr
			90	16.41	144	1 hr
	15x20x40 cm Hollow	14.675 x 19.675 x 39.675 cm	125	30.57	96	1 hr
			105	23.49	96	1 hr
			90	21.22	96	1 hr
	20x20x40 cm Hollow	19.675 x 19.675 x 39.675 cm	125	41.45	72	2 hrs
			105	31.85	72	2 hrs
			90	28.77	72	2 hrs 30mins
	25x20x40 cm Hollow	24.675 x 19.675 x 39.675 cm	125	52.32	60	2 hrs 30mins
			105	40.20	60	3 hrs
			90	36.31	60	3 hrs
	30x20x40 cm Hollow	29.675 x 19.675 x 39.675 cm	125	63.19	42	3 hrs
			105	48.55	42	3 hrs 30mins
			90	43.86	42	4 hrs

APPENDIX ZZ

SAMPLE CALCULATIONS

Sample Calculation -1

From table 12 the glazing cost and fixing cost of ISICAM SINERJI 3+ found in the market = 335 TL + KDV / m2

Therefore the Initial Investment is equal to:

From table 19 The Total Window Glazing Area in m2 = 14.66 m2

X From table 12 The ISICAM SINERJI 3+ Glazing Cost = 335 TL

= Initial investment = 4911 TL

Sample Calculation -2

From table 21 the cost of the Base Case Wall Section with its construction calculated from the market for flat-1 equals:

From table 13 the total unit cost of brick (0.20x0.20x0.135) m per m2

= Total Area x Unit Cost/m2 TL

= 31.015 x 50.00 TL

= 1550.75 TL

+

From table 13 the total unit cost of brick (0.20x0.20x0.085) m per m2

= Total Area x Unit Cost/m2 TL

= 31.015 x 37.50 TL

= 1163.00 TL

+

From table 16 the total unit cost of Extruded polystyrene (XPS) per m2

= Total Area x Unit Cost/m2 TL

= 31.015 x 13.50 TL

= 418.70 TL

+

From table 16 the total unit cost of Extruded polystyrene (XPS) per m2

= Total Area x Unit Cost/m2 TL

= 31.015 x 7.85 TL

= 243.47 TL

+

From Appendix QQ the total Mason Salary for Brick (0.20x0.20x0.135) m including insulation in TL

= 5,972 TL

+

From Appendix QQ the total Mason Salary for Brick (0.20x0.20x0.085) m including insulation in TL

= 5,674 TL

= Initial investment = 15,022 TL

Sample Calculation -3

The operation cost is calculated using a multiplication of the total yearly energy expenditure calculated from the simulation by the cost of natural gas per kWh which is the main energy heating supply. For the city of Ankara and according to table 11 this natural gas price equals:

= 0.08686175 TL / kWh

As shown in Appendix-RR the total yearly energy consumption for ISICAM KLASIK for Flat-1 equals:

= 4134.4 kWh

Therefore, the operation cost equals:

= Cost of natural Gas x Yearly energy expenditure for ISICAM KLASIK for Flat-1 kWh

= 0.08686175 x 4134.4 TL

= 359.12 TL

Sample Calculation -4

The operation cost is calculated using a multiplication of the total yearly energy expenditure calculated from the simulation by the cost of natural gas per kWh which is the main energy heating supply. For the city of Ankara and according to table 11 this natural gas price equals:

= 0.08686175 TL / kWh

As shown in Appendix-SS the total yearly energy consumption for the Base Case Wall Section for Flat-1 equals:

= 4698.61 kWh

Therefore, the operation cost equals:

= Cost of natural Gas x Yearly energy expenditure for the Base Case Wall Section for Flat-1 kWh

= 0.08686175 x 4698.61 TL

= 408.13 TL

Sample Calculation -5

Since there no owning, operating, maintaining, repairing, replacing and disposing of a building or a building system over a period of time considered, only the sum of the Initial Investment Cost and Operation Cost is included.

As seen from table 24 the initial investment and operation total cost of ISICAM KLASIK glazing for Flat-1 equals:

Initial Investment Cost = 3299 TL

+ Operation Cost x 30 = 359.12 x 30 = 10,774 TL

Initial Investment + Operation Costs = 14,073 TL

Sample Calculation -6

Since there no owning, operating, maintaining, repairing, replacing and disposing of a building or a building system over a period of time considered, only the sum of the Initial Investment Cost and Operation Cost is included.

As seen from table 27 the initial investment and operation total cost of the Base Case Wall Section for Flat-1 equals:

Initial Investment Cost = 15,022 TL

+ Operation Cost x 30 = 408.13 x 30 = 12,240 TL

Initial Investment + Operation Cost = 27,262 TL

APPENDIX AAA

ANKARA CLIMATE: 1) DRY BULB TEMPERATURE AND RELATIVE HUMIDITY; 2) SUN SHADING CHART (DECEMBER 21st TO JUNE 21st); SUN SHADING CHART (JUNE 21st TO DECEMBER 21st); WIND WHEEL

The dry bulb temperature and relative humidity for all the month of the year are documented. It could be inferred from the graph that relative humidity during the nights is higher than those values during the day. This is because the temperature is high during the day and hot air absorbs water more than cold air as shown in figure 72. As could be inferred from the graph the dry bulb temperatures are below the comfort level during the winter month and within the comfort limits during the summer.

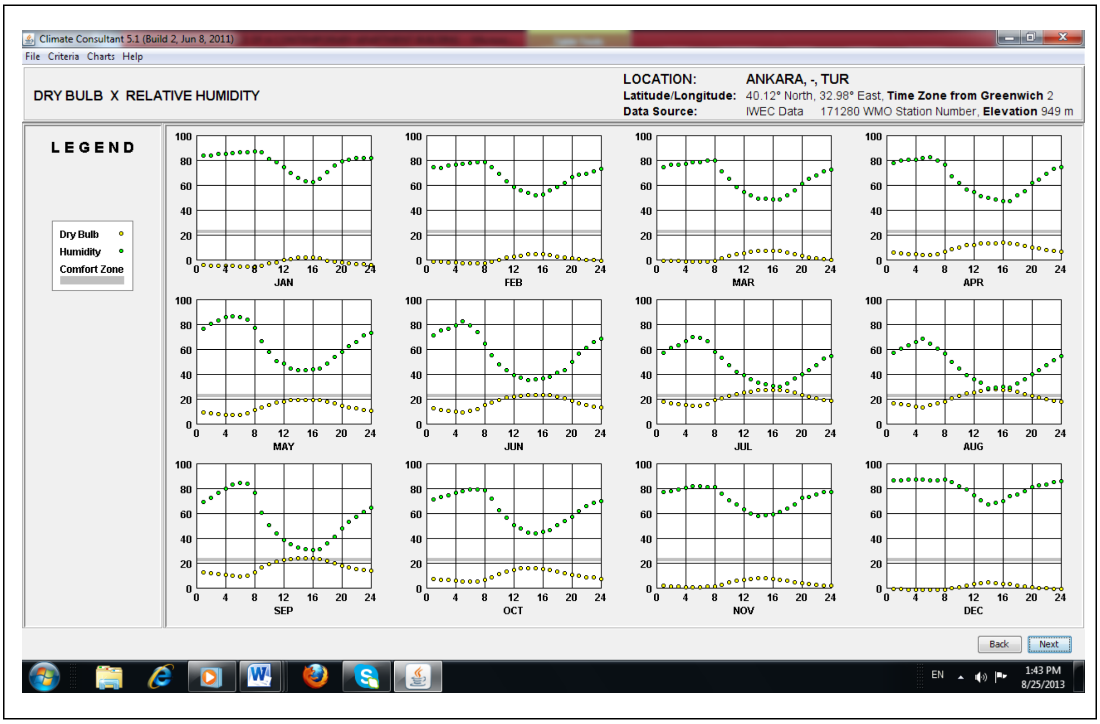


Figure 72 Dry Bulb Temperature and Relative Humidity Within Ankara According to Climate Consultant

The sun shading chart recording from December 21st to June 21st indicate the winter months mostly. The blue color indicates temperatures less than 21˚C , the yellow color indicates temperatures greater than 21˚C, while the red color indicates temperatures greater than 24˚C. From figure 73 above the blue color occurs for the months of December, January, February, March and April, while the yellow and red color is common to the month of May and June. As could be inferred from the chart the late morning, afternoon and evening hours display higher temperatures.

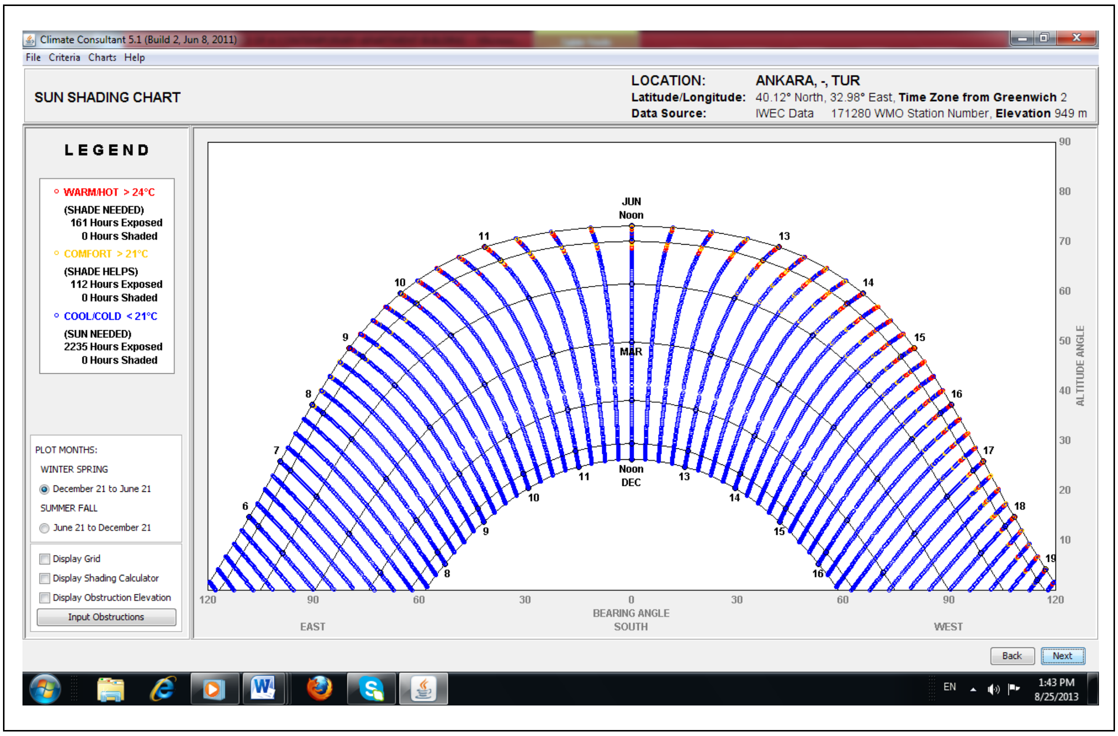


Figure 73 Sun Shading Chart (December 21st to June 21st) Within Ankara According to Climate Consultant

The sun shading chart recording June 21st to December 21st indicate the summer months mostly. The blue color indicates temperatures less than 21˚C, the yellow color indicates temperatures greater than 21˚C, while the red color indicates temperatures greater than 24˚C. From figure 42 below the yellow and red colors occurs for the months of June, July, August and September while the blue color is common to the month of October, November and December. As could be inferred from the chart the late morning afternoon and evening hours display higher temperatures as shown in figure 74.

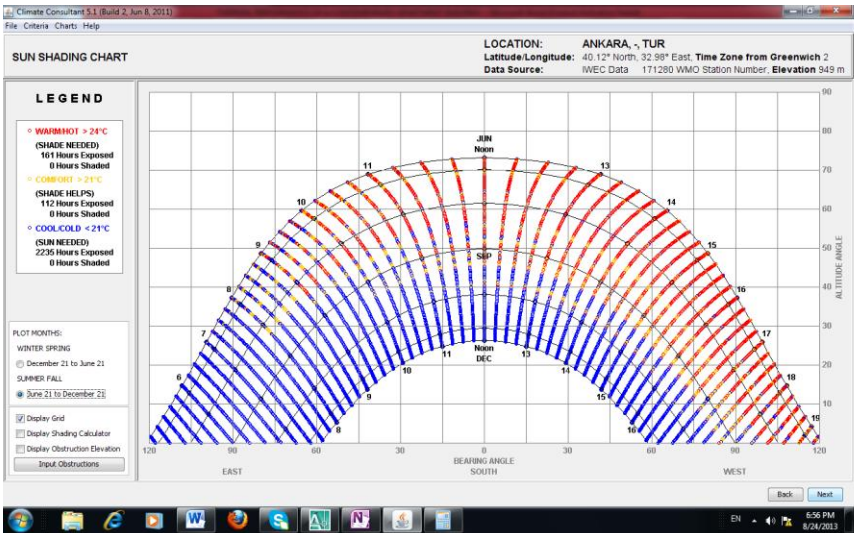


Figure 74 Sun Shading Chart (June 21st to December 21st) Within Ankara According to Climate Consultant

As seen from the wind wheel chart much of the wind blows from north and north-east direction as shown in figure 75.

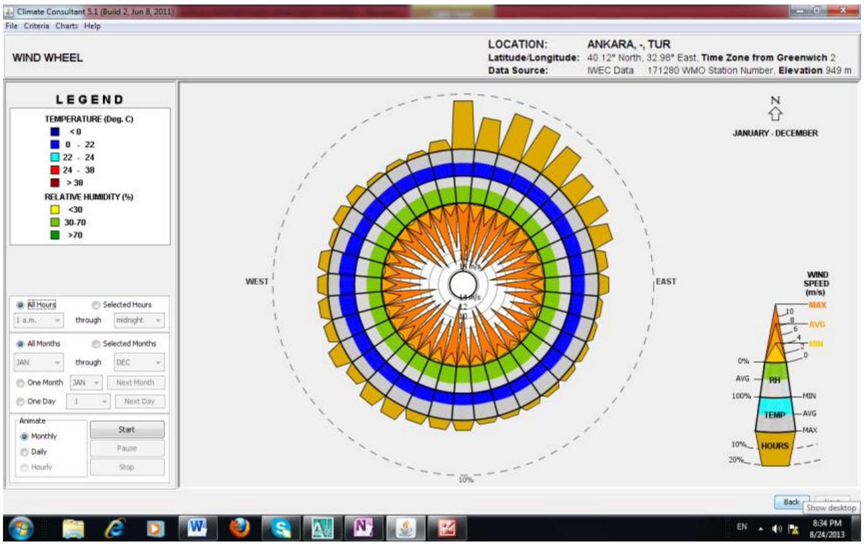


Figure 75 Wind Wheel Within Ankara According to Climate Consultant

APPENDIX BBB

MONTHLY HEAT LOAD PRODUCTION BY THE HEATING SYSTEM FOR ALL THE WALL SECTIONS IN THE INVESTIGATED FLAT-1, FLAT-2 AND FLAT-3 (KWH)

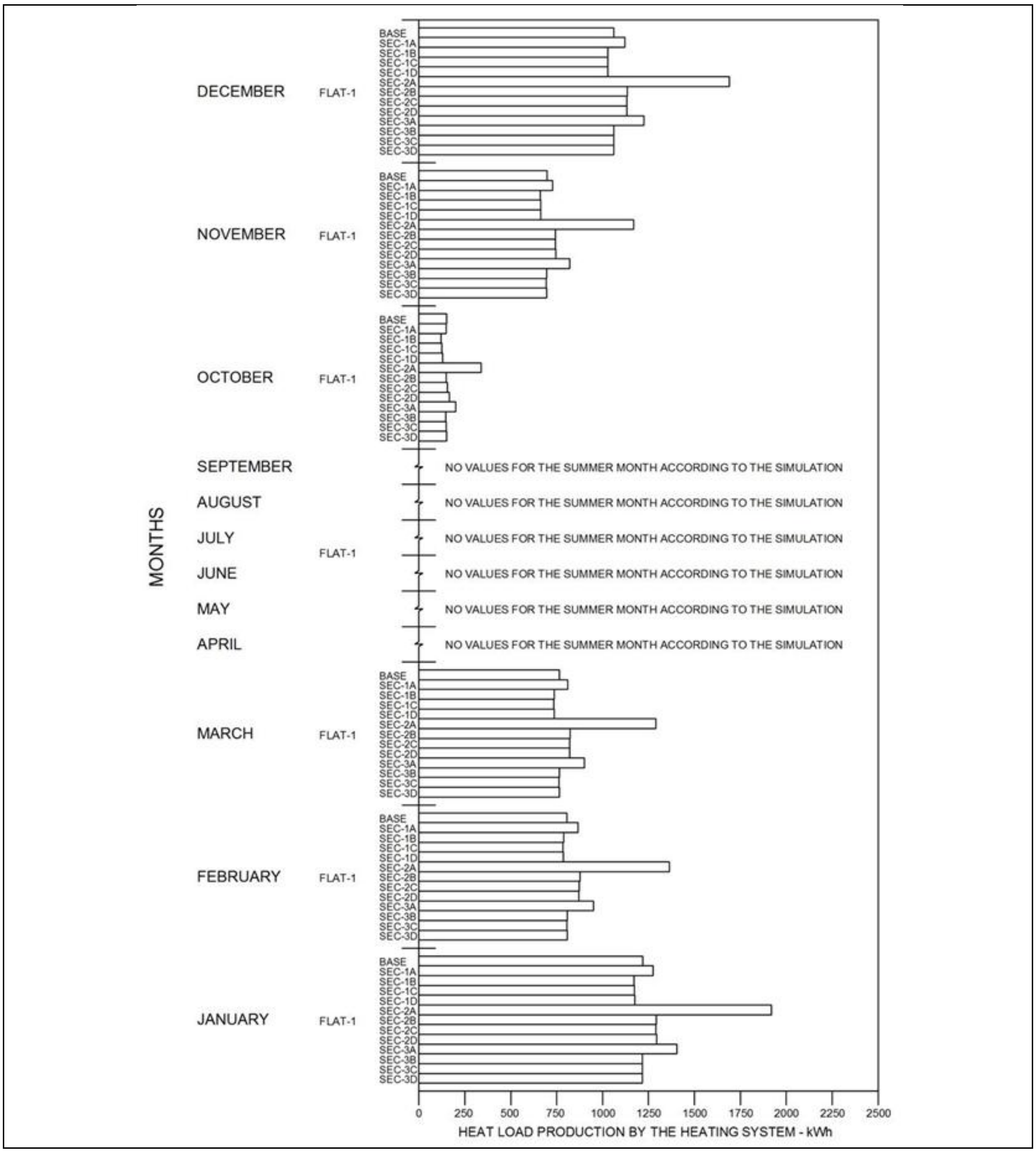


Figure 76 Monthly heat load production by the heating system for all the Wall Sections in the investigated flat-1 kWh.

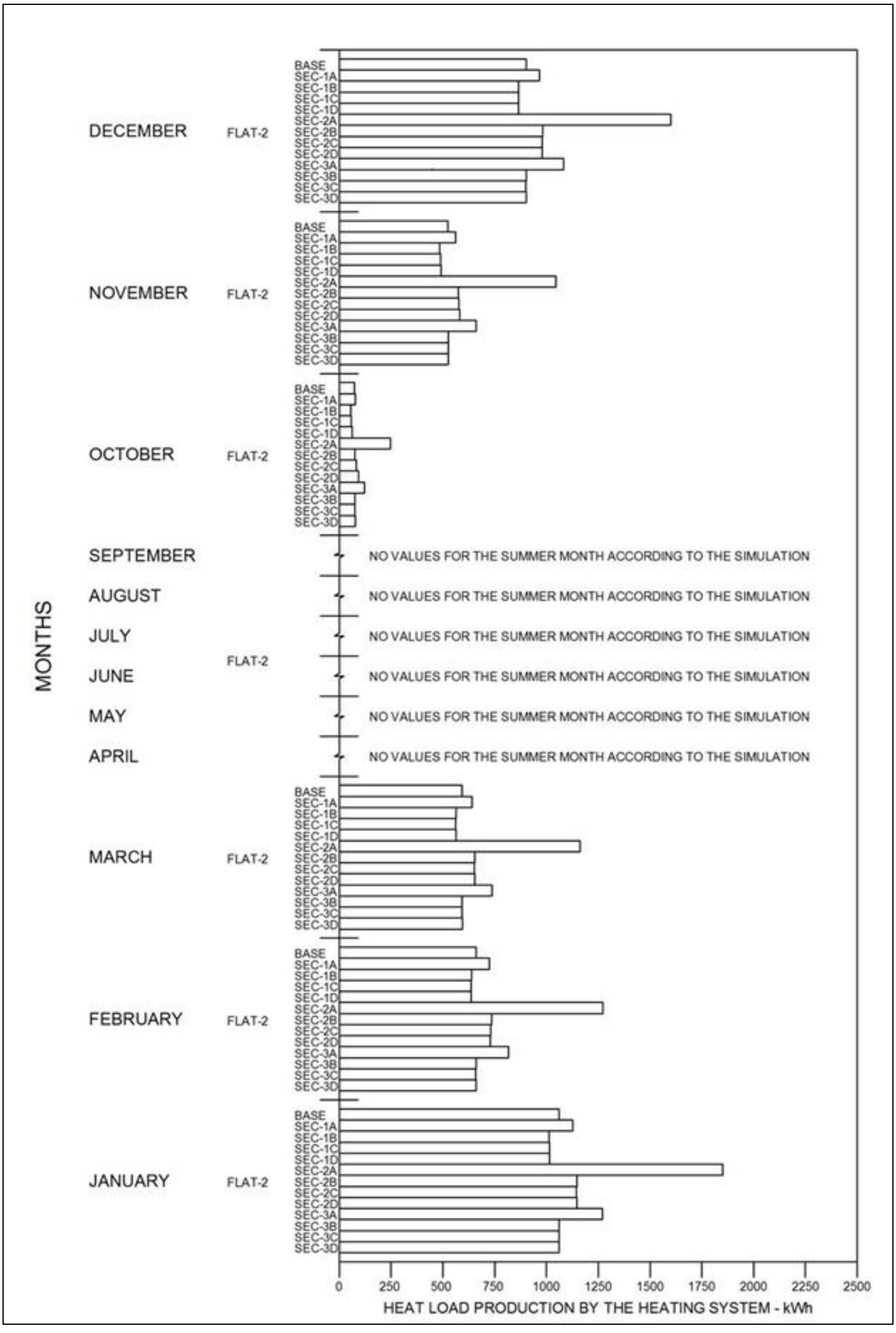


Figure 77 Monthly total heat loads produced by all the Wall Sections in the investigated flat-2 kWh.

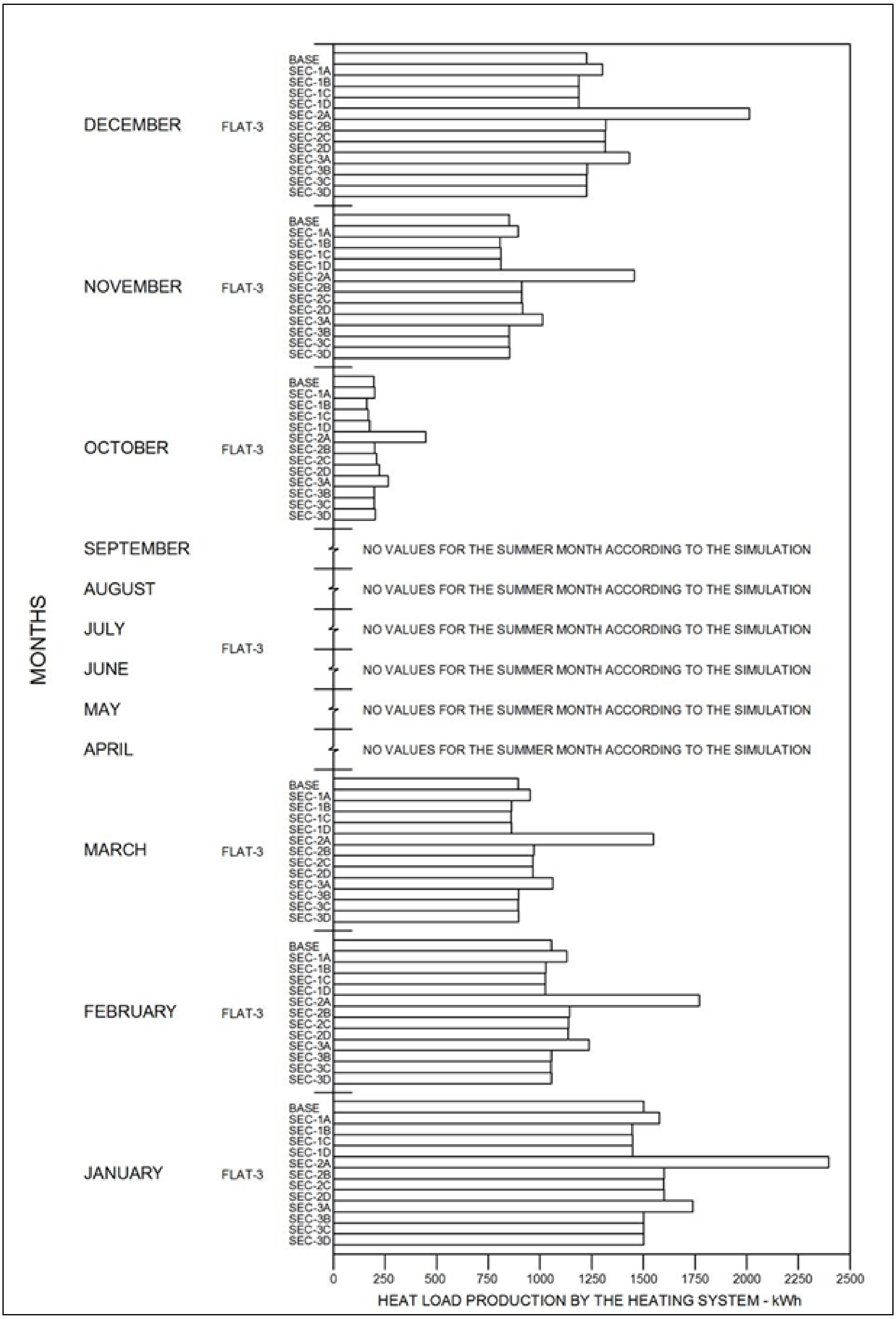


Figure 78 Monthly total heat loads produced by all the Wall Sections in the investigated flat-3 kWh.