RETROFITTING EXISTING MASS HOUSING FOR ENERGY EFFICINCY: A CASE STUDY IN GAZIEMIR EMLAK BANK HOUSING AREA, IZMIR, TURKEY

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ABSTRACT

RETROFITTING EXISTING MASS HOUSING FOR ENERGY EFFICIENCY: A CASE STUDY IN GAZIEMIR EMLAK BANK HOUSING AREA, IZMIR, TURKEY

Energy consumption in the extant residential building stock of Turkey is excessive owing to an inadequate regulative framework regarding energy-efficient retrofitting, application deficiency and failures in heating insulation detailing regulated by TS 825 Thermal Insulation in Buildings. Mechanical systems through the operation period of buildings are out of inspection and occupant profile pays attention to size rather than the quality of construction. In the framework of research concerning harmonization with the EU, the building regulations of Turkey have been adapted to the EU Directives promoting energy efficiency and reduction of energy demand in existing buildings. The Turkish Energy Efficiency Law, launched in 2007 in this framework, is the most noteworthy step. In the light of retrofitted housing examples from 11 EU countries, the thesis presents effective and case-specific retrofitting scenarios for a selected residential block in Gaziemir Emlak Bank Mass Housing Area in Izmir, Turkey. The objective is to draw attention to the enormous potential for reducing energy consumption in existing mass housing areas through implementation of energy-efficient retrofitting applications. The thesis discusses scenarios to decrease the energy demand for heating and evaluates the effects of predefined scenarios on cooling loads of selected apartment block. The building energy analysis software, Ecotect v5.50, has been used for the assessment of heating and cooling energy loads based on the current and improved conditions of the building. The thesis demonstrates that it is possible to save almost half of the annual energy consumption of the residential block in Gaziemir Emlak Bank Mass Housing Area by applying appropriate retrofitting scenarios.

ÖZET

MEVCUT TOPLU KONUTLARIN ENERJİ VERİMLİ YENİLENMESİ: GAZİEMİR EMLAK BANKASI KONUT ALANINDA BİR ÇALIŞMA, İZMİR, TÜRKİYE

Enerji verimli yenileme konusunda yetersiz kanuni çerçeve, TS 825 Binalarda Isı Yalıtımı Standardı'nda tanımlanmış ısı yalıtımı detaylarının uygulama eksiklik ve yanlışlıkları, ısıtma ve soğutma sistemlerinin bina kullanımı süresince hiç denetlenmemesi ve bina kalitesinden çok bina büyüklüğüne önem veren kullanıcı profili nedeniyle, Türkiye'deki mevcut konut stokunda enerji tüketimi gereğinden çok daha fazladır. Avrupa Birliği'ne uyum çalışmaları kapsamında Türkiye'deki yapı yönetmelikleri, mevcut binalarda enerji verimliliğini ve enerji tüketiminin azaltılmasını teşvik eden Avrupa Birliği yönergeleri ile uyumlu hale getirilmeye çalışılmaktadır. Bu kapsamda 2007'de yayınlanan Türkiye Enerji Verimliliği Kanunu en dikkate değer adımdır. Tez, İzmir Gaziemir Emlak Bankası Toplu Konut Alanı'ndan seçilmiş bir apartman bloğu için, Avrupa Birliği üyesi 11 ülkede gerçekleştirilmiş konut yenileme örnekleri ışığında belirlenmiş etkin ve yere özel enerji etkin yenileme senaryoları sunmaktadır. Tezin amacı, mevcut toplu konut alanlarında enerji tüketiminin, etkin enerji yenileme uygulamaları ile azaltılma potansiyeline dikkat çekmektir. Tez, seçilen apartman bloğunun ısıtma enerjisi yükünü azaltıcı senaryoları araştırmakta ve belirlenen senaryoların soğutma yükü üzerindeki etkilerini değerlendirmektedir. Mevcut ve iyileştirilmiş yapının ısıtma ve soğutma yükü, Ecotect v 5.50 bina enerji analiz programı kullanılarak hesaplanmıştır. Sonuç olarak bu tezde, İzmir Gaziemir Emlak Bankası Toplu Konut Alanındaki bir apartmanda uygun enerji yenileme senaryoları uygulanarak, mevcut yıllık enerji tüketiminin hemen hemen yarısı oranında azaltılabileceği kanıtlanmıştır.

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LIST OF ABBREVIATIONS

ADEME	Agence de I'Environment et de la Maitrise de I'Energie (French Environment and Energy Management Agency)
AMMS	Adnan Menderes Meteorological Station
CDD	Cooling Degree Day
CHP	Combined Heat and Power
Council	The Council of Europe
DOSİDER	Doğal Gaz Cihazları Sanayicileri ve İş Adamları Derneği (Natural Gas Equipment Manufacturers and Businessmen Association)
DPT	Devlet Planlama Teşkilatı (Republic of Turkey Prime Ministry State Planning Organization)
EC	European Community
EIE	Elektrik İşleri Etüd Dairesi (General Directorate of Electrical Power Resources Survey and Development Administration)
EPA-ED	Energy Performance Assessment of Existing Dwellings
EPBD	Energy Performance of Buildings Directive
EPS	Expanded Polystyrene
EU	European Union
EU-EDUCATION	European Union-Energy Intelligent Education
EURIMA	European Insulation Manufacturers Association
EuroACE	The European Alliance for Companies for Energy Efficiency in Buildings
FIEC	Fédération de I'Industrie Européenne de la Construction (European Construction Industry Federation)
HDD	Heating Degree Day
HVAC	Heating, Ventilation and Air-Conditioning
IEA	International Energy Agency
ITO	İstanbul Ticaret Odası (Istanbul Chamber of Commerce)
IBPSA	International Building Performance Simulation Association

IZODER	Isı Su Ses ve Yangın Yalıtımcıları Derneği (Association of Thermal Insulation, Waterproofing, Sound Insulation and Material Producers, Suppliers and Applicators)
İTÜ	Istanbul Technical University
İYTE	Izmir Institute of Technology
MENR	Ministry of Energy and Natural Resources
MTOE	Million Tons of Oil Equivalent
NECC	National Energy Conservation Center
NOVEM	Netherlands Environment and Energy Management Agency
OECD	Organization for Economic Co-Operation and Development
OED	Oxford English Dictionary
OPEC	Organization of Petroleum Exporting Countries
OTB	Onderzoeksinstituut (Research Institute for Housing, Urban and Mobility Studies)
TGNA	The Grand National Assembly of Turkey
TOE	Tons of Oil Equivalent
TOKI	Toplu Konut İdaresi Başkanlığı (Housing Development Administration of Turkey)
TÜBİTAK	Türkiye Bilimsel ve Teknik Araştırma Kurumu (The Scientific and Technical Research Council of Turkey)
TÜSİAD	Türk Sanayiceleri ve İş Adamları Derneği (Turkish Industrialists' and Businessmen's Association)
TS	Turkish Standards
TSE	Turkish Standards Institute
U	The Measure of the Rate of Heat Loss through a Material
USA	United States of America
XPS	Extruded Polystyrene
λ	Thermal Conductivity of a Material

CHAPTER 1

INTRODUCTION

1.1. Aim of the Study

Today, energy is an economically and politically valuable and strategic issue for many countries, especially those that are dependent on foreign resources owing to their limited capability of gas and oil production. The First World War made up the first international arena where energy became a prominent issue defining relations among countries (Tuncay, 2005). Its importance was secondly realized by the oil crises of 1973 when the OPEC raised the oil prices by more than 475% after the first shock wave. Then, in 1979, oil prices were increased by another 134% (Hitiris, 1998). These series of price hikes caused most countries to recognize the necessity of consuming energy efficiently and were attended by the growing awareness that energy henceforward increasingly would become subject of policy-making. As a result, countries throughout the world, but especially in what at the time was the EC, developed energy precaution schemes for current and potential energy crises. In other words, they launched energy policies in order to diminish dependency of national economies on imported energy (Tuncay, 2005).

At any point in time, there is inevitable increase in energy demand in the world: the institution of Energy Information Administration states that the total energy consumed in the world is expected to increase by 57% from 447 quadrillion BTU by 2004 to 702 quadrillion BTU by 2030 (International Energy Outlook, 2007). This means that consumption will increase annually by 2%. By far the highest increase in total energy consumed is predicted to be from fossil fuels which release CO_2. Large concentrations of CO_2 in the atmosphere cause global warming. In brief, because of increasing dependence on oil as the main energy resource and its inevitable outcome—the problem of global warming—available energy resources must be used more efficiently.

Since the beginning of the 1980s, Turkey's energy demand has started to increase owing to a dynamic economic development and rapid population growth (Çelebi, 2006). This rapidly increasing energy need of the nation has been met so far by imported oil and gas because of ineffective energy policies that disregard the promotion of energy efficiency in all aspects of life (Fidan, 2006). Main sectors dominating the increase in energy demand of Turkey are industry, building, transportation, and agriculture. The energy reports of 2001 compiled by TÜBİTAK (2003) show that the building sector is the second sector demanding the most energy with 19.793 MTOE, and its demand will reach 33.69 MTOE by 2010. The main reason for the rapid growth may be the noteworthy acceleration in the demand for new buildings. Another reason may be related to the poor quality of the existing residential building stock due to uncontrolled urbanization and building activity. For instance, 88% of the windows in residential buildings nationwide are made of single glass. In addition, there is no roof insulation in 90% of residential buildings. 96.4% of the buildings have little or no thermal insulation measures (DPT, 2006). Besides, according to Kayıkçı (2004), there are 2.5 million unregistered dwellings today in Turkey and no measures whatsoever for energy efficiency are under consideration for these buildings. Until now, the increasing energy demand in the building sector has been covered by increasing the energy supply. Yet, one of the common ways applied by developed countries to reduce energy consumption in the building sector is the policy of energy efficiency. Thus it may be maintained that energy efficiency ought to become the main policy for the existing building sector in Turkey. In other words, more energy can be saved in a short period of time by applying effective and case-specific retrofitting scenarios to existing buildings.

The OED defines the term 'retrofit' as, "modifying so as to incorporate changes made in later products of the same type or model." The retrofitting of an existing building may thus provide permanent reductions in energy consumption. Pedrini (2002) summarizes the following major benefits of energy efficient retrofitting:

1. Increasing building operation performance as a result of decreasing energy consumption and energy cost.
2. Increasing building value.
3. Increasing benefits of homeowner by higher tenant rent.
4. Developing thermal comfort.

5. Creating local jobs.
6. Reducing energy consumption of existing building stock in a short time.

There are several measures to achieve energy reduction by retrofitting. For example, the building envelope can be improved by the addition of insulation. The use of double glazing with special types of window glass and PVC frames can halt the energy loss by conduction and radiation. The heating and cooling system can regularly be upgraded to improve energy efficiency. Else, energy consumption can be diminished by replacing an old hot-water plumbing system. The combination of these measures may be set to constitute effective and case-specific retrofitting scenarios for energy efficiency. The scenarios are changeable, i.e. case-specific, based on the existing building's features. Thus the retrofitting of existing buildings should start by analyzing the existing conditions of a building in terms of thermal features with construction type and materials, insulation type, and location, window features with size, glazing and framing type and total energy load for heating and cooling as well as the orientation of the existing building. The other significant point is the site analysis for examining the utilization of passive heating and cooling measures in the building.

It is likely that in the literature on retrofitting of existing buildings one may come across terms like 'renovation' and 'refurbishment' that are sometimes used synonymously with 'retrofitting'. In fact, these terms are related to different aspects of buildings and do not, in themselves, designate the entire areas of activity met by 'retrofitting'. For example, as per the OED, the term 'refurbish' indicates "to furbish anew; to repolish, do up again." Again according to the OED, the term 'renovate' implies "to renew materially; to repair; to restore by replacing lost or damaged parts; to create anew." In brief, 'renovation' and 'refurbishment' are usually used in relation to the conversion of old buildings to their previous original conditions. Especially 'refurbishment' may be defined as the reinforcement of buildings. 'Retrofitting', on the other hand, may be the renewal or reparation of old buildings to improve current conditions by adding new equipment.

The research on retrofitting for energy efficiency in the world focuses mostly on the determination of retrofitting scenarios, regarding financial issues and cost-effective solutions for particular types of buildings, i.e. residential and office buildings. Al-Ragon (2002) has shown that energy saving in old residential buildings in Kuwait is possible on the national level by implementing effective retrofitting scenarios. The study introduces the simulation results of fifteen different types of retrofitting scenarios including wall and roof insulation and modification of glazing. Al-Ragon maintains that it is possible to save 3.25 million MWh energy by implementing the most effective retrofitting scenario in Kuwait. In the study by Santamouris and Dascalaki (2002), ten office buildings selected from around Europe were retrofitted to improve energy performance and indoor working conditions. The main objective of the study was "to develop global retrofitting strategies, tools and design guidelines in order to promote successful and cost-effective implementation of passive solar and energy efficient retrofitting measures to office buildings" (p. 575). Within this study, the energy saving potential of proposed retrofitting scenarios for each office building has been briefly evaluated. The study by Hestnes and Kofoed (2002) is based on the development of a detailed set of retrofitting strategies for office buildings in Denmark, England, France, Germany, Greece, Italy, Norway, Sweden, and Switzerland by applying both passive solar and energy conscious measures. The authors propose the addition of thermal insulation, replacement of windows, use of solar shading system, diminishment of air change rate, development of heating and cooling equipment, improvement of lighting system and use of passive cooling strategies to improve energy performance of office buildings and to obtain a healthy indoor environment. Papadopoulos, Theodosiou & Karatzas (2002) concentrated on two main scenarios: the improvement of central heating system and building envelope. Their research mainly evaluates the potential of retrofitting scenarios and the feasibility of these scenarios under changing economic conditions by using different types of sample buildings including residential, public and private enterprises, educational buildings, banks, and hospitals in Northern Greece.

In the EU, the concept of retrofitting for energy efficiency in existing buildings became an important issue with the publication of the Directive of Energy Performance of Buildings (2002/91/EC) which was accepted on 16 December 2002 and brought into force on 4 January 2003. It is now the most powerful instrument for the building sector in the member states. The directive covers labeling of products in terms of energy consumption, energy certification of buildings, calculation procedure of energy performance in buildings, energy efficiency standards, and energy services (Kemper, 2003). The member states are required to adopt it to their national laws as the essential regulation tool. Numerous countries in the EU are still carrying on work to complete the adaptation process. Turkey with its candidate status does not stand under the obligation to perform the directive at the moment. Yet, it is expected to adapt it in the near future. The Turkish Energy Efficiency Law, published in 2007, represents the first official attempt taken through the harmonization activities in the field of energy.

In Turkey, there is no adequate regulation to promote the retrofitting of existing buildings compared to the EU. Indeed, the scope of current legislations and By-laws concerning new and existing buildings are not sufficient to contribute to energy efficiency. The most important By-law is TS 825-Thermal Insulation in Buildings, which is related to the limitation of energy demand for heating in new buildings. To achieve this, TS 825 limits the U value of main building components like external wall, floor and ceiling to halt heat loss through conduction. However, it does not cover any measures about energy demand of buildings for cooling. Some cities such as Izmir, Adana and Mersin even consume more energy for cooling than heating. The other problems related to energy efficiency are the lack of public awareness concerning direct financial contribution to tenants for the improvement of existing buildings, insufficient information concerning energy efficiency, implementation failures in the construction phase, and lack of programs and campaigns for the promotion of energy efficient retrofitting. The most recent official study conducted in the scope of the harmonization of Turkish legislation with that of the EU is the publication of ‘Energy Efficiency Law’ on 2 May 2007, Official Gazette No: 5627. This law’s main aim is to develop efficiency in use of energy resources in order to reduce energy consumption, avoid waste, ease the burden of energy costs on the economy, and protect the environment. Yet there is still urgent need for more regulations for limiting the cooling and lighting energy demand and the inspection of boilers. As a result, one may argue that more energy is consumed because of the lack in the legislative framework concerning retrofitting for energy efficiency. This means that if the retrofitting of those existing residential buildings with poor quality becomes a building policy in Turkey, more energy can be saved in the short-run by applying case-specific retrofitting scenarios. It is a fact that even though designing new public and office buildings that are more energy efficient is an essential need for Turkey, these buildings will not be so influential in reduction of energy demand of the building sector in as short a period of time. Instead, the improvement of existing residential buildings for energy efficiency may prove to be a more effective and sustainable strategy to cope with the energy problem.

The objective of the present thesis is to demonstrate the possibilities of reducing energy consumption for heating in existing residential buildings by developing effective and case-specific retrofitting scenarios defined in view of the retrofitted housing examples in eleven EU countries. Lastly, among the various scenarios, the thesis searches for the most effective retrofitting scenarios to reduce energy consumption by eliminating the cost-benefit factor.

To achieve this aim, it was assumed that mass housing areas had enormous potential for energy-efficient retrofitting with their repeating types of similar building blocks. Here, any case-specific retrofitting scenario is applicable to any other housing block having similar features as the specific block examined, and thus more energy can be feasibly saved on the basis of the research. In this context, an extant apartment block was selected in Gaziemir Emlak Bank Mass Housing Area in Izmir, Turkey. The primary reason for the selection of the Gaziemir Emlak Bank Mass Housing Area as the case area were the physical conditions of the neighborhood with its mediocre level of construction quality and an occupant profile composed of middle-class citizens. It is one of the well-known mass housing areas of Izmir, located on the southern development axis of the city, which is easy to study and access. The second motivating reason was the date of construction of the housing blocks, which was between 1993 and 1998, before which the implementation of TS 825-Thermal Insulation in Buildings did not become compulsory. Lastly, there is a condensation problem on the inner surfaces of external walls because of the thermal insulation layer on the same surface, which rendered the buildings particularly worthy of improvement efforts.

1.2. Limitations and Method of the Study

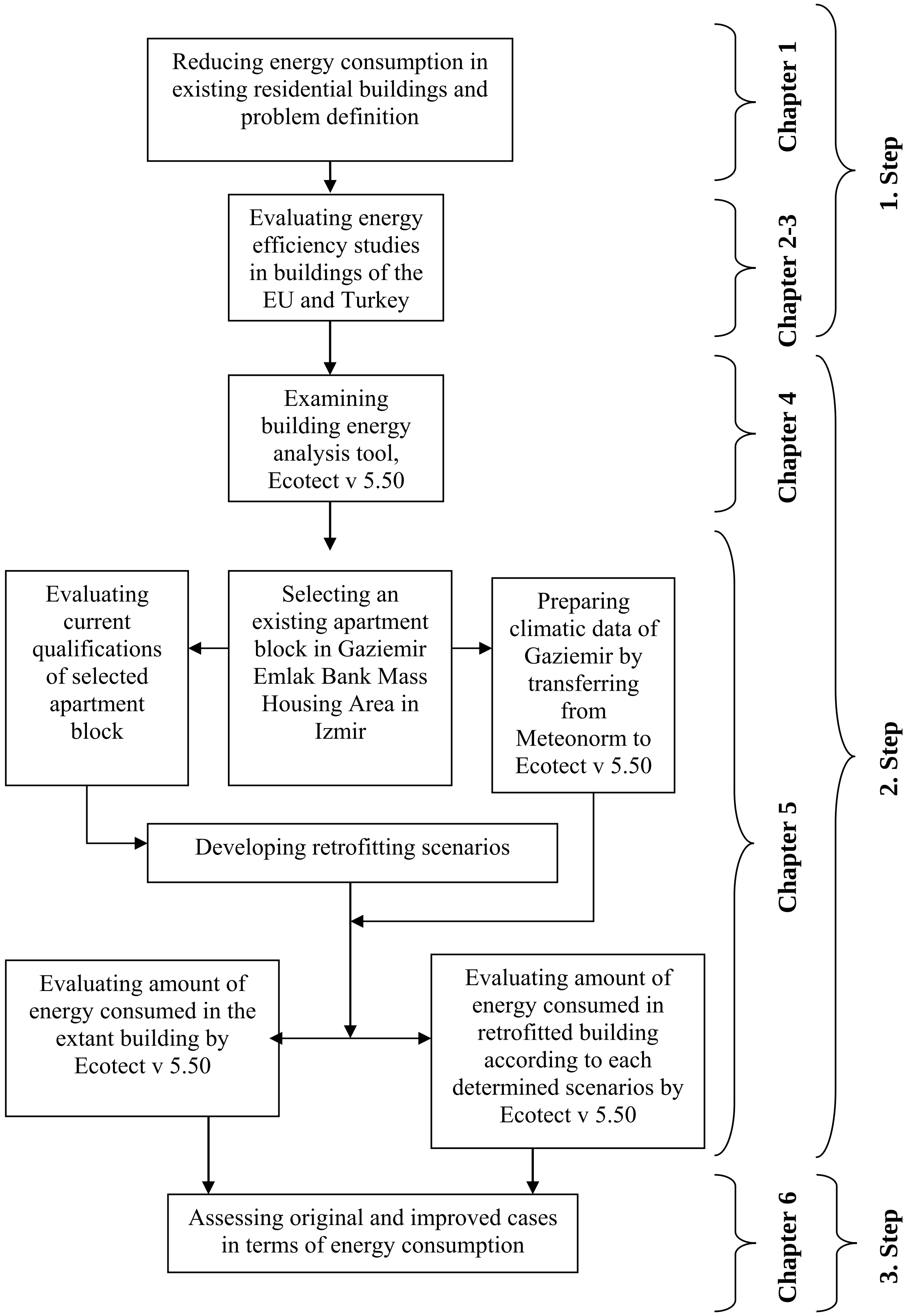
The methodology of this thesis is derived and adapted from Al-Ragon (2003) who has studied retrofitting of old residential buildings in Kuwait by applying cost-effective energy conservation measures. In this study, fifteen retrofitting scenarios were evaluated and a simple payback method was used to analyze the cost-benefit balance of the determined retrofitting scenarios. Then energy saving ratios of each retrofitting scenario and the payback period were combined to observe their effects. As a difference with the method of Al-Ragon's study, the present thesis does not assess the cost-effectiveness of the retrofitting scenarios as the final target of this thesis is limited to presenting the most effective, case-specific scenarios in terms of reducing energy demand for heating. The study of cost-control is subject to further examination requiring comprehensive research in the areas of economics, mathematics and management. In order to develop a general viewpoint about the cost factor of proposed retrofitting measures, Appendix A offers a simple calculation of cost about the building envelope and openings for heating and cooling periods.

This thesis utilized the building energy analysis tool Ecotect v 5.50 to simulate and compare the proposed retrofitting scenarios with the existing conditions. It excluded the real time monitoring of inner temperature and humidity in the apartment block. The goal of the thesis is not to predict the accurate changes in temperature and humidity, or to validate the outcomes of Ecotect v 5.50 software. The thesis hypothetically evaluates the current and improved situations with the simulation software Ecotect v 5.50 which is one of the most developed and frequently used softwares in similar studies, as e.g., it was used to evaluate thermal comfort conditions of a traditional Turkish house in Safranbolu by Harputlugil and Çetintürk in 2005.

The thesis concentrates on the reduction of heating loads and monitors the effects of retrofitting scenarios on cooling loads. Thus specific scenarios are not considered for decreasing cooling loads.

In this context, the structure of the study may be summarized on three levels as shown in Table 1.1. The first step indicates brief information about issues of energy efficiency in buildings in the EU and in Turkey. In this context, chapter 2 starts with basic energy efficiency studies in terms of buildings that explain EU polices and programs related to energy efficiency starting with the 1973 oil crises. It discusses various articles directly concerning energy efficiency in buildings of the Energy Performance of Buildings Directive (2002/91/EC), which is evaluated in detail. Lastly, retrofitted housing examples built between 1925 and 1980 from 11 EU countries, comprising Denmark, Sweden, The Netherlands, Germany, Austria, Bulgaria, Slovenia, The United Kingdom, Hungary, Latvia, and Greece, are examined in order to assess common retrofitting scenarios used in the EU. These examples are selected from Altaner, EI-EDUCATION, and EuroACE. Altaner and EI-EDUCATION are among

Table 1.1. Structure of the research method



programs implemented for achieving energy efficiency in the EU. Altaner mainly focuses on the promotion of renewable energy sources. EI-EDUCATION provides information about retrofitting extant social housing in Europe. EuroACE is an association including Europe's leading companies active in manufacture, distribution, and installation of a variety of energy saving goods and services. Its main objective is to help establish more sustainable energy use in buildings in the EU.

Chapter 3 summarizes energy efficiency studies in buildings in Turkey. It starts by providing brief information about energy use in the national building sector and continues with a discussion of the institutional structures from the perspectives of current energy efficiency regulations. Then, regulations related to energy efficiency studies in buildings conducted by the government from 1970 to the present are analyzed. In this regard, sources that provide information about recent work on energy efficiency have been found to be exceedingly scarce. Thus the majority of relevant information has been gathered through interviews conducted with Hakkı Buyruk, Commissioner of the Department of Energy Efficiency in Building and Transportation of the General Directorate of Electrical Power Resources Survey and Development Administration. In addition, relevant information has also been obtained from the report on the Energy Efficiency Strategy for Turkey providing an extensive source about the most recent advance studies in the country.

The second step has been the simulation phase of the selected apartment block in the Gaziemir Emlak Bank Mass Housing Area in Izmir, Turkey. Brief information on Ecotect v 5.50 building energy analysis software is introduced in Chapter 4. The kind of data used in the simulation process in Ecotect v 5.50 is defined in conjunction the thermal modeling steps of a building. Chapter 5 is that part of the thesis that demonstrates the relevant retrofitting process of the selected apartment block. In this context, the current condition of the case area is analyzed. This part of the investigation included several visits to the apartment block which took place in July of 2006 and 2007, and in February and May of 2008. In the first trip, photos of the façades of the apartment block were taken. Then data about the selected apartment block including data concerned with its physical condition, were gathered mostly by interviews with users, the doorkeeper of the block, and experts at the Turkish Emlak Bank's Izmir Office, and by personal observations on the site. The thermal performance of the selected apartment block was evaluated by using the simple software based on TS 825 norms and thermal images taken by a thermal camera (FLIR Therma CAM) to visualize energy losses through the external wall. To take thermal images of the selected apartment block, the building was visited on March 16, 2008 at 20.00 pm.

Secondly, the climatic features of Gaziemir were presented with a detailed analysis of main climatic parameters such as mean air temperature, relative humidity, rainfall, HDD, and CDD among four meteorological stations located in Izmir. The master theses of Zeynep Peker, "Energy Efficient Urban Design" (1998), and Ercan Kılınç's thesis "İzmir'in Rüzgar Özellikleri" (1996) [Wind Features of Izmir], and "İzmir İli 2004 Yılı Çevre Durum Raporu" [Official Report on Environmental Conditions in Izmir, 2004], are foremost among the scarce studies of climatic conditions in Izmir. Gaziemir region of Izmir was analyzed on the basis of the climate data taken from the AMMS located at Adnan Menderes International Airport in Gaziemir. These parameters comprise the average of the last 19 years, i.e. the period of 1987-2006. The data obtained about the climatic conditions of Gaziemir are highly accurate as the meteorological station at Adnan Mendres International Airport is located, in bird's eye-view, 3.4 km to the southeast of the case area. Yet, this data could not be utilized as the weather data of Ecotect v 5.50 software since the periods of climate data taken from AMMS and periods of data necessitated by the present study did not regularly overlap. Therefore, the climatic data of Gaziemir, derived from the Meteonorm global meteorological database, has been utilized in the simulation phase. The comparison of climatic data, particularly the mean air temperature and relative humidity, obtained from AMMS and Meteonorm, is presented in Appendix B.

After this step, the thermal modeling of the selected apartment block has been prepared by vertically dividing it into three major zones as ground, middle, and top floors in order to assess the zones' different thermal performance. Later, these three zones were divided again into sub-zones based on the function of the spaces such as living room, WC, etc. Then, retrofitting scenarios, derived from the 13 projects conducted in the scope of Altaner, EI-EDUCATION, and EuroACE programmes in the EU countries, were simulated for ground, middle, and top floors. A total of 18 scenarios were examined by the Ecotect v 5.50: 15 of them were structured as a single parameter, i.e. single retrofitting scenario, under four main retrofitting options: the improvement on the building envelope with thermal insulation, the improvement on the openings with energy efficient windows, the change in air infiltration rate, and the change in set point temperature. The remaining three retrofitting scenarios were set as the various combinations of four main retrofitting options to investigate the range of potential energy reductions. However, issues of energy consumption optimization and cost-effective solutions were not considered while determining the retrofitting scenarios in the thesis.

In the simulation, assessment of heating and cooling loads of the retrofitting scenarios was conducted for a typical year defined from 1 January to 31 December. It must be pointed out as a most important aspect of this study that energy consumption results may vary widely according to where they were based on real data on a hypothetical situation. However, the results obtained by hypothetical data are necessary for understanding the level of importance of the respective retrofitting scenarios. Results give information about only heating and cooling loads. They do not concern the energy consumption because energy consumption is changeable based on the efficiency of a heating and cooling system used in buildings. For example, an inefficient system can consume more energy for heating and cooling than an efficient one under the same conditions.

Results of the retrofitting scenarios are presented for both heating and cooling periods and shown separately in the form of excel sheets. The energy consumption for heating or cooling has been tabulated for both the actual condition and proposed scenarios on the same excel sheet. In the third step, effects of all retrofitting scenarios were evaluated in terms of the energy demand of the selected apartment block.

CHAPTER 2

ISSUES OF ENERGY EFFICIENCY IN THE EU

This chapter discusses the activities in, and efforts on, establishing and implementing the energy efficiency of residential buildings in the EU. For, Turkey is currently required to adopt its own legislation in conjunction with the EU norms. Indeed, Turkey should equally examine and evaluate other advanced international norms. As the scope of this thesis, however, targets fitting Turkey’s current policies against EU norms, this chapter is limited to a survey of the latter. The objective of this chapter is thus to analyze EU legislative directives and standards. The current chapter focuses on the analysis of legislative directives and applications related to the retrofitting of residential buildings in order to demonstrate the differences between EU and Turkey concerning energy efficiency legislations in terms of buildings. The chapter starts by describing legal instruments applied in the EU, and proceeds to explain the main energy efficiency programs and directives. The most important articles in the *Energy Performance of Buildings Directive* are evaluated in detail. The last part of the chapter informs about best housing retrofitting practices in the EU. To this end, thirteen practices were selected from EI-EDUCATION, which is an EU project to promote retrofitting of existing residential buildings, Altener, which is a kind of Community programme focusing on the promotion of renewable energy sources, and EuroACE, which is an association related to thermal insulation manufacturers in the EU.

2.1. Basic Energy Efficiency Studies in terms of Buildings

The EU launched policies and programs related to energy efficiency starting with the 1973 oil crises. Before that time, there were a few directives such as those concerned with appliance labeling and these were implemented poorly by the member states (EuroACE, 2004a). Today, however, the EU has developed a systematic, comprehensive conceptual system for constituting basic legal instruments to be implemented in the EU comprising the following:

1. Regulations: these are obligatory for all member states,
2. Directives: these are obligatory and they have to be adapted into the national legal framework,
3. Decisions: these are obligatory,
4. Recommendations and opinions: these are not obligatory and constitute a kind of proclamation (Energy Charter Secretariat, 2007).

The entire legal system related to energy efficiency in the EU is constituted in view of the main objectives of Europe’s energy policy; the security of supplies, competitiveness and sustainability (Green Paper, 2006). In order to make real these policies, the EU prepares various programs with limited periods granted to countries for implementation. These kinds of programs and plans, supported by the EU, are intended for the promotion of energy efficiency in buildings. These are explained in the following chronological order, proceeding from oldest to most recent:

1. JOULE/THERMIE Programme
2. Save Programme
3. Communication on Energy Efficiency Programme
4. Action Plan to Improve Energy Efficiency in the European Community
5. The European Climate Change Programme
6. Intelligent Energy Europe Programme

The **JOULE/THERMIE Programme**, implemented between 1994 and 1998, was a research program. It developed components of the specific programs for generating non-nuclear energy and innovative technologies. The program especially focused on developing the security of energy supplies, protecting the environment and encouraging the rational use of energy. It was implemented in two separate sub-programs as JOULE and THERMIE. While JOULE covered energy technologies still requiring development and distributed training grants, the THERMIE project administered demonstration projects with themes closer to the concerns of commerce. THERMIE was a kind of high profile and budget demonstration program that assigned high priority to energy efficiency. Its goals were developing energy efficiency in the demand and supply sectors, encouraging use of renewable energy resources, promoting use of clean coal and other solid fuels, and better use of the EU’s oil and gas resources.

After the JOULE/THERMIE Programme, the **SAVE Programme** became EU's major program concerning energy efficiency. Generally it focused on the non-technical actions relating to energy efficiency such as establishment of local and regional energy management agencies, pilot actions and studies, and policy measures. Moreover, the program has developed energy efficiency and promoted energy-saving behaviors in industry, commerce, domestic and transport sectors (Energy Framework Programme, n.d.). The SAVE Programme consisted of two steps: in the first step, SAVE I was launched by the Council in October 1991 and closed in 1995. It was generated in order to ratify three main aims: encouraging limiting of CO_2 emissions, decreasing use of imported fuels, and evaluating non-technical visions of energy efficiency by implementing programs dependent on technology (The SAVE Programme, 2000). Another SAVE II was launched in December 1996 for a 5-year period running to 2000 (The SAVE Programme, n.d.). Its goal was to improve the intensity of the final energy consumption. SAVE II covered the following sectors (European Commission, 2005):

- Buildings: rational use of energy in buildings is a crucial sector for the SAVE Programme because it accounts for 40% of EU energy demand;
- Transport: transport is a priority area for energy efficiency since it accounts for 30% of total energy consumption. Furthermore, carbon dioxide emissions from transport are expected to increase compared to the 1990 level by 39% by 2010;
- Households; households are an important target as the end-consumers who have a crucial role to play in promoting and adopting energy-saving behavior. The dissemination of information is therefore a priority. SAVE stimulates the dissemination of results and good practice from successful projects, pilot actions and studies in co-operation with member states;
- Industry: industry is an important end-user of energy and at the other hand indispensable when it comes down to making consumer appliances more efficient. Labeling and energy-efficiency targets as part of negotiated agreements are important instruments to improve the performance. The combined heat and power sector is included in this sector;
- Other: this is the rest category containing projects with a broad audience, Energy agencies related projects, and projects are difficult to classify in this typology (p. 19).

The legal structure of the SAVE Programme relevant to energy efficiency in buildings included three directives: the boilers directive (92/42/EEC), directive to limit carbon dioxide emissions by improving energy efficiency (93/76EEC), and the construction products directive (89/106/EEC). Briefly, the program improved particular measures to provide energy-efficient heating and cooling systems as well as hot water systems, insulation of building components such as wall, roof, and the use of special glazing systems in the member states when buildings were renovated (The SAVE Programme, n.d.). Lastly, the SAVE Programme was incorporated into the Energy

Framework Programme from 1998 to 2002. Then the commission integrated it into the Intelligent Energy Europe Programme, where it currently still is.

At the same time, the program of **Communication on Energy Efficiency** was implemented for regulating the general aims of the European energy efficiency strategy in 1998. This program regulated priorities for actions that were concerned with energy-efficient buildings; comprised a review of the Council Directive 93/76/EEC to limit carbon dioxide emissions; regulated energy-efficient households appliances and other end-use equipment; encouraged wider use of negotiated and long-term agreements on minimum energy efficiency requirements; increased dissemination of information, third-party financing, guarantee of results and other creative financing schemes; provided for energy efficiency in the electricity and gas sectors and combined heat and power, as well as for energy management and public and cooperative technology procurement (Commission of the European Communities, 1998).

The EU Commission was invited to prepare an **Action Plan for Improving Energy Efficiency** by the Council on 7th December 1998. The Action Plan published in 2000 was very essential for the removal of barriers, which prevented energy-efficiency actions, to implement them in the member states. The objectives of the Action Plan (Commission of the European Community, 2000a) can be summarized as in the following:

- To refocus attention on promoting energy efficiency and to activate stakeholders;
- To present for endorsement common and co-ordinated policies and actions to be undertaken in the light of the Kyoto Agreement to contribute to the reduction of greenhouse gas emissions by 8% by the period 2008-2012, and to achieve other Community energy and environmental goals including those set forth in the European Climate Change Programme;
- To clarify the roles, related costs and to suggest timetables for the Community and the member states;
- To realize the available economic potential for improving energy efficiency in line with the proposed target for reduced energy intensity of one percentage point per year, compared to a business-as-usual trend which is estimated now to be close to zero. Meeting this target would realize two-thirds of the estimated savings potential of 18% by the year 2010. This would result in avoided energy consumption of over 100 Mtoe, and avoided CO_2 emissions of nearly 200 Mt/year or around 40% of the EU Kyoto commitment. Meeting the Community-wide target of doubling the use of cogeneration to 18% of the EU electricity production by 2010 is estimated to result in additional avoided CO_2 emissions of more than 65 Mt CO_2/year by the year 2010.
- To increase awareness of the fact that, although a target of 1% per year improvement is ambitious, it can be exceeded if additional resources are made available.
- To establish the foundation for a continuous and long-term improvement in energy efficiency through the use of market forces and market transformation, with accelerated development and diffusion of new energy-efficient technologies (p. 4).

According to the EU Commission, buildings have a large potential for the most cost-effective measures concerning energy efficiency more than the industry or the transport sector. However, the Action Plan does not attach adequate importance to cost-effective ways to improve energy saving when existing buildings come under comprehensive renovation (FIEC, 2007). In addition, it focuses on optimum energy performance necessities for new and renovated buildings, and design of passive houses is more important because its energy demand is very low (Zeuthen, n.d.). In brief, actions described as related to buildings in the Action Plan for Energy Efficiency consist of the developing insulation of extant buildings linking with incentives, energy certification of buildings, inspection of heating and cooling systems, and insulation of new buildings. The action plan covers also an EU Green Light Programme to encourage energy efficient lighting in public and commercial buildings (Commission of the European Communities, 2000a).

The European Commission has taken largest number of initiatives concerning the climate since 1991. Within this framework, the first **European Climate Change Programme** was launched to constitute effective and environmentally responsive policies and measures for decreasing green house gas emissions for the period between 2000 and 2004 (Delbeke, 2002). After closing of the first program, the second European Climate Change Programme started with a stakeholder conference in Brussels in 24 October 2005 and it still continues. The objective of the program is to explore cost-effective ways to reduce green house gas emissions with synergy across the EU (European Commission, 2006). It consists of six crucial areas aiming to attain Kyoto targets. One of them, related to buildings, concerns the development of energy efficiency in industry, households, and service sectors (European Commission, 2001). The program accepts that the building sector has a special effect in the reduction of CO_2 emission.

In the EU, there are various opportunities to improve energy efficiency and promote use of renewable energy sources. However, market conditions do not encourage these improvements in every case. Therefore, the **Intelligent Energy Europe Programme** was launched in 2003 to remove barriers preventing the attainment of a more energy-intelligent Europe. One of the significant features of the program was to encourage new and best performing technologies and projects with necessary investments (Competitiveness & Innovation Framework Programme, n.d.). In this context, the program consisted of five fields including transport, renewable energy, developing countries, energy efficiency, and horizontal, cross-cutting projects. Energy efficiency in social housing was provided for by assessment under energy efficiency in the program. Within this title, ongoing and completed projects are AVASH (Advanced Ventilation Approaches for Social Housing), EPI-SoHo (Energy performance Integration in Social Housing), ECOLISH (Energy Exploitation and Performance Contracting for Low Income and Social Housing), EPEE (European fuel Powerty and Energy Efficiency), R-REROFIT-KIT (Tool-kit for passive house retrofit), ESAM (Energy Strategic Asset Management in Social Housing Operators in Europe), InfoFin (Innovative Financing of Social Housing Refurbishment in Enlarged Europe), FACTOR 4 (Programme of actions Factor 4 in existing social housing in Europe), ISSES (Improving the Social Dialogue for Energy Efficient Social Housing), NIRSEPES (New Integrated Renovation Strategy to Improve Energy Performance of Social Housing), ROSH (Development and marketing of integrated concepts for energy efficenct and sustainable retrofitting of social housing), SHARE (Social Housing Action to Reduce Energy Consumption), TACKOBST (Tackling Obstacles in Socail Housing), RESHAPE (Retrofitting Social Housing and Active Preparation for EPBD), SuRE-Fit (Sustainable Roof Extension Retrofit for High-Rise Social Housing in Europe), TREES (Training for Renovated Energy Efficient Social Housing), and EI-Education (Energy Intelligent Education for Retrofitting of Social Houses).

2.2. Energy Performance of Buildings Directive (2002/91/EC)

Generally, directives and standards in the EU are generated and updated according to previous experiences obtained from legal obligations. In this context, the most important directive directly concerned with buildings is *Energy Performance of Buildings Directive (2002/91/EC)*. In addition, previous directives concerning energy efficiency in buildings are shown in Appendix C.

The Energy Performance of Buildings Directive (2002/91/EC) is the main legal instrument of the EU for energy efficiency in buildings since 4 January 2003. It aims to generate a common sensibility aiming at improving the energy performance of buildings among the EU countries. The directive proposed an adaptation period, which ended in January 2006, in order for each country to prepare its own legislation concerning the energy performance of buildings. There were two main key drivers to the directive: first was the environment including preserving, protecting and development of environmental conditions, logical use of natural resources, protection of human health applying necessary measures to deal with environmental problems within regional and worldwide levels (Heydt, 2004). The second driver was relevant to the energy supply condition of the EU which was directly related to increasing energy demand regularly. Therefore, the directive promotes the reduction of energy demand in the EU by energy saving measures in building and transport sectors (Green Paper, 2000).

The Energy Performance of Buildings Directive consists of 16 articles summarized in Appendix D (Council Directive 2002/91/EC, 2002). Four of them are related to the retrofitting of existing buildings:

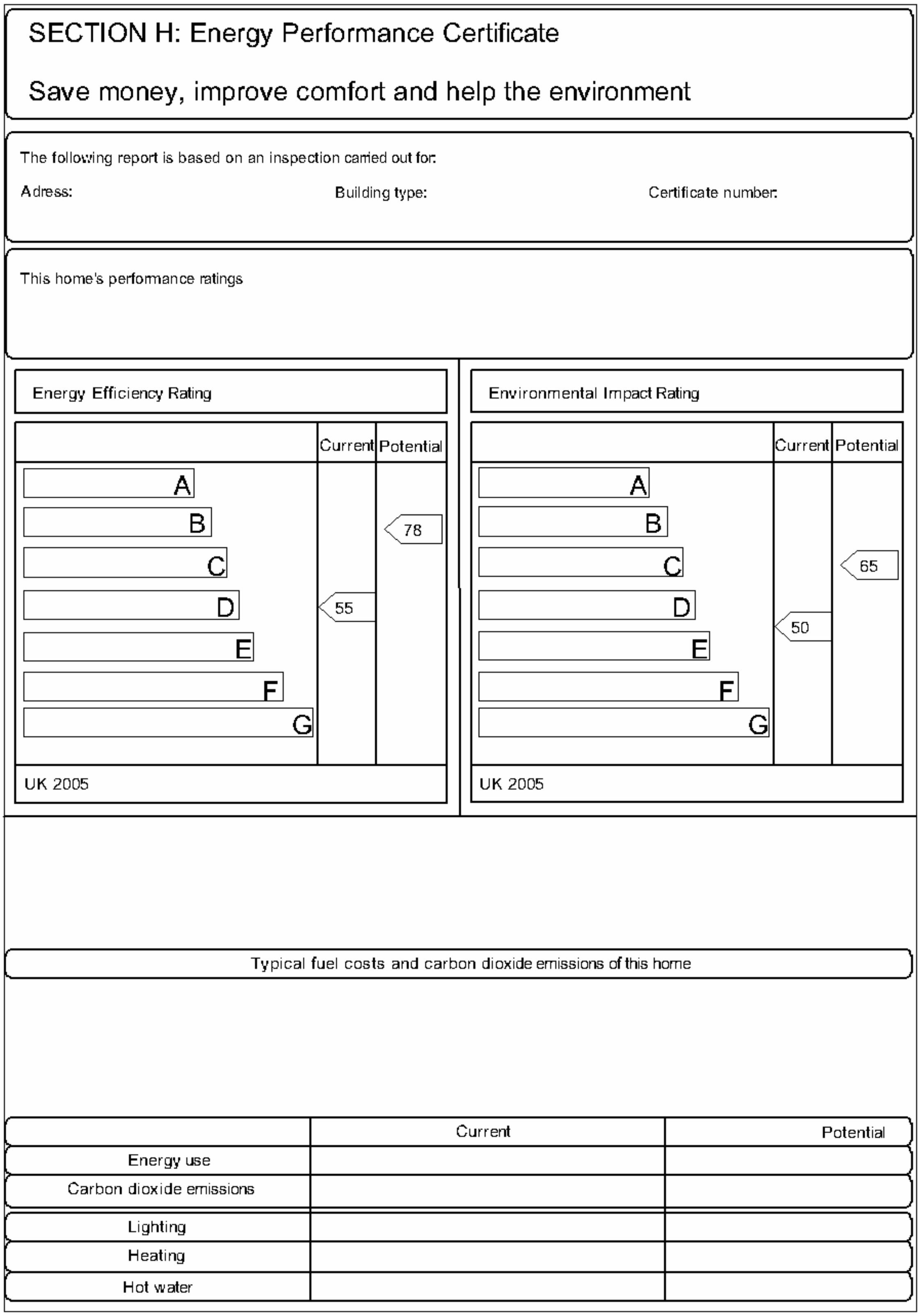
The first relevant article, no. 6, describes the minimum energy performance requirements which should be provided by existing buildings that exceed a total useful floor area of 1000 m^2 and are under major renovation. The energy performances of existing buildings are required to be upgraded to reach minimum requirements based on a specific calculation methodology. The methodology, in turn, should cover general indoor conditions like optimum ventilation. Requirements can vary between new and existing buildings and determined requirements have to be updated every five years based on obtained technical experience. They should also become technically, functionally and economically feasible. The requirements can be applied for the whole building or its renovated systems or components. These possible requirements for existing buildings can, "include installation of the building shell; improving technical systems in heating, cooling, and/or ventilation of the building; installation of energy supply systems using renewable energy resources (solar, biomass, […]); and/or improving the quality of the energy consumption system(s) of the building (e.g. lighting, […])" (EPA-ED, 2004a, p. 9).

Energy Performance Certificate no. 7 is the second article regulating the energy certification of existing and new buildings in the EU. It briefly presents the energy consumption ratio of buildings and its environmental impact. The certificate is essential for the evaluation of the energy consumption amount of an existing building when the building is constructed, sold or rented. The certificate must be obtained by the owner, prospective buyer or tenant (Figure 2.1 and Figure 2.2). It is required that the certificate be hung in a visible place in all buildings. A large building development consisting of multiple blocks with a common heating system can share a single certificate prepared for a representative block within the development. In addition, the certificate can provide extra information about energy saving measures, the energy performance potential of different types of buildings or a group of buildings or a building stock in a member state (EPA-ED, 2004b). Furthermore, cost-effective suggestions for the development of the energy performance of buildings can be added to the certificate if necessary. Lastly, the certificate is valid for only 10 years, after which period it must be updated.

The third article, no. 8, concerning the Inspection of Boilers, defines the rules of inspection for the energy-efficient use of boilers. Nonrenewable liquid or solid fuels of an effective rated output of 20 kW to 100 kW boilers require regular control. The inspection period should be at least two years for boilers of an effective rated output of more than 100 kW and is to be extended to four years for gas boilers. However, if a boiler is larger than 20 kW and more than 15 years old, an EU country is required to determine appropriate measures such as boiler size and evaluation of the boiler effectiveness in order to establish a one-off inspection of the heating system. Suggestions for replacement of the boiler, other modifications and solutions shall be provided to the users by experts.

The Inspection of Air-Conditioning Systems, no. 9, is the fourth article and defines an inspection process for air-conditioning systems in buildings. In other words, member states are hereby required to prepare the necessary regulations to establish a regular control mechanism of air-conditioning systems of an effective rated output of more than 12 kW. Inspections include assessment of air-conditioning efficiency and size.

As a result, the directive has positive impacts on, and provides different motivations for, energy efficiency in buildings for owners, operators, developers, designers, housing associations, architects, providers of building appliances, installation companies, building experts, tenants and essentially all energy consumers in the EU (Bowie & Jahn, 2003). All of this entails the possibility that, by 2010, 45 million tons of CO_2 can be saved the environment by applying EPBD in the EU. In addition, this reduction can be increased by upgrading the requirements and suggestions in the directives. To this end, the EU Commission has determined various improvements in the articles. For example, the Commission will suggest reducing the threshold for major retrofitting of existing buildings in 2009. Impact assessment of this projected alteration has been continuing on the basis of the estimated cost effective benefits of lowering the 1000 m^2 threshold in Article 6. Other improvement is related to energy efficiency. This


SECTION H: Energy Performance Certificate

Save money, improve comfort and help the environment

The following report is based on an inspection carried out for:

Adress: Building type: Certificate number:

This home's performance ratings

Energy Efficiency Rating

	Current	Potential
A		
B		78
C		
D	55	
E		
F		
G		

UK 2005

Environmental Impact Rating

	Current	Potential
A		
B		
C		65
D	50	
E		
F		
G		

UK 2005

Typical fuel costs and carbon dioxide emissions of this home

	Current	Potential
Energy use		
Carbon dioxide emissions		
Lighting		
Heating		
Hot water		

Figure 2.1. Page 1 of Energy performance certificate

(Source: Modified from the Department for Social Development, 2004)

Energy Performance Certificate

Report Section

Certificate number:	011111112430
Date issued:	25/12/2005
Name of Inspector:	Trainee Assessor

Summary of this home's energy performance related features

The following is an assesment of the key individual elements that have an impact on this home's performance rating.
Each element is .... the following scale: Very poor/Poor/Average/Good/Very good

Element	Decoription	Current performance
Main walls	Cavity wall, Insulation:As Built	Poor
Main roof	Pitched roof, Insulation at ....50 mm	Poor
Main floor	Sold Uninsulated face (assumed)	Very Poor
Windows	Single glazed windows	Very Poor
Main heating	Old large volume storage headers	Poor
Main heating controls	Manual charge control	Very Poor
Secondary heating	Electric portable electric headers Efficiency: 100.00 %	Poor
Hot water	Independent electric(immersion water heading systems,Single Immersion	Poor
Lighting	No low energy lighting	Very Poor

Current energy efficiency rating	O17
Current environmentalimpact rating	O18

Cost effective measures to improve this home's performance ratings

The improved energy ratings are cumulative,that is theyassume the improvements have been insulated in the order that they appear in the table.

	Lover cost meacures	Typical cavings	Performance ratings after improvement Energy efficiency	Environmential impact
1	Cavity wall insulation	£231 per year	F25	F27
2	Loft insulation top up to 250mm	£120 per year	F32	F33
3	Hot water tank and pipe work insulation	£53 per year	F35	F34
	Sub Total	£404 per year		
	Higher cost meacures			
4	Condensing boiler	£340 per year	D58	D57
	Total	£744 per year		

Potential energy efficiency rating	D68	
Potential enviromental Impact rating		D67

Figure 2.2. Page 2 of Energy performance certificate

(Source: Modified from the Department for Social Development, 2004) minimum energy performance standard will be developed for different types of new and retrofitted buildings in different European climate zones (Commission of the European Community, 2006). In brief, the necessary adaptation studies relevant to the directives have already been launched by all member states and the EU Commission. Yet completed regulations of EU countries based on EPBD documents are not available and not officially announced because of pending legislative issues except in Germany and Denmark. Thus, the directive is still not implemented by all member states.

2.3. Retrofitted Housing Examples in the EU

In the following part, selected housing examples retrofitted for energy efficiency from 11 EU countries, namely Denmark, Sweden, The Netherlands, Germany, Austria, Bulgaria, Slovenia, The United Kingdom, Hungary, Latvia, and Greece, are examined with respect to retrofitting. The building blocks in the examples were selected on the basis of function in that they were all residential. Energy consumption ratios before and after retrofitting, energy saving amount and project features are summarized briefly. The retrofitting examples are selected from the projects of EI-EDUCATION EuroACE, and Altener Programmes.[4] Detailed information about retrofitting projects is shown in Appendix E.

Retrofitting project 1 is the oldest project among the selected retrofitting examples in the EU. The existing apartment block was built in Oesterbro, Denmark in 1925 and it was retrofitted in 1994-1995 because of the high energy consumption the building had been displaying. The basic aim of the retrofitting was to reduce energy consumption for heating and constitute a low temperature district heating. Before the retrofitting, there was no mechanical ventilation system in the apartment block. The retrofitting installed sun spaces, glazed balconies, and low energy windows (U= 0.7 W/m^2K) as well as a heat recovery ventilation system. In addition, the solar heating system of the apartment block was improved, and extra insulation was added on

[4]EI-EDUCATION, conducted under Intelligent Energy Europe Programme, is an e-learning platform. It gives information about energy-intelligent retrofitting, technical, financial and social solutions, and best practices. EuroACE is an association including 20 of Europe's companies about manufacture, distribution and installation of a variety of energy saving goods. Goals of the association are helping the member states of the EU meet Kyoto Commitments and developing energy-efficient improvement measures for buildings. Ongoing between 1992 and 1997, Altaner is an EU Community program focusing on the promotion of renewable energy sources such as wind, water, solar power, and biomass.

external walls. To reduce energy demand for heating, a 178 m^2 solar wall was constructed by using transparent insulation. As a result, 51% of energy was saved (EI-EDUCATION Program, 2007).

Retrofitting project 2 involved the 10-storeyed apartment block constructed in Gaardsteen, Sweden, in 1970. To improve energy efficiency and integration of renewable energy systems for sustainable design, it was retrofitted in 2000. In the retrofitting process, an insulation layer was added on walls exposed to wind and on the roof. Solar collectors for pre-heating of domestic hot water and fresh air were installed. Existing windows were replaced with low-e glass and timber frame. By applying these measures, 44% of energy was saved (EI-EDUCATION Program, 2007).

The apartment block in the **retrofitting project 3** was built between 1963 and 1969 in Raamsdonk, The Netherlands. The retrofitting project in 2002 was developed to improve construction quality, living standards and to save energy. To achieve this objective, solar collectors were added. Extra insulation layers were used on façades and roof. Window glasses were exchanged with high energy effective glazing. Lastly, a heat recovery system based on ventilation air and boiler were installed. Since tenants resisted change in the building, a model of the retrofitted block was displayed in order to demonstrate the result of the retrofitting in terms of energy savings. With retrofitting measures, 70% of gas as the main heating source was saved (EI-EDUCATION Program, 2007).

In **Retrofitting project 4**, an apartment block located in The Hague, The Netherlands, of energy-saving potential was evaluated by efficiency measures. In 1987, a large retrofitting project was undertaken by applying high energy efficient windows and doors, extra insulation for wall, floor and roof, solar collectors, PV system, and new boilers. Almost 56% of energy savings were calculated (OTB, 2004).

Retrofitting project 5 included a 3-storey apartment block located in Ludwigshafen, Germany. The residence was built in 1960-1962. Low-income families had been living in the blocks by the stand of retrofitting. Following to the energy efficiency regulations of Germany; the apartment block was retrofitted in 2005 changing PV system, low temperature heating system, combined heat power equipment, high energy efficient glazing, and insulation for façade cellar, attic floors, and roof. As a result, almost 94% of energy was saved (EI-EDUCATION Program, 2007).

Retrofitting project 6 included an apartment block located in Neuhofen, Austria, which had been constructed in 1979. The building was retrofitted in 2004 in order to improve thermal comfort, appearance of the apartment and to reduce heating cost. The project was organized by the social housing association with an energy advisor. Prior to the retrofitting, tenants were alerted to noise and dust during the process. An energy efficient thermal insulation layer was added on the ground floor, façades and top ceiling. Glazing of windows was replaced with new one (U= 1.2 W/m^2K). After completion of the retrofitting, reactions of the tenants were very positive because of the reduction of heating cost: 45% of energy was saved (EI-EDUCATION Program, 2007).

Retrofitting project 7 involved an apartment block in Vienna, Austria, which had been constructed in the Second World War. Therefore, some windows of the building were 50 years old. Thus, they were exchanged with energy efficient ones. At the same time, the insulation level of the walls was very low. These were insulated. Because of the poor condition of the attic and roof, these were constructed for renting or selling with an intention to obtaining funds for retrofitting expenses. The energy saving ratio reached almost 30% (OTB, 2004).

Retrofitting project 8 involved an apartment block constructed in 1973, located in Olaine, Latvia. To provide for the reduction of the energy consumption for heating and meet increasing living standards and demand for building quality, it was retrofitted in 2005. In the retrofitting for energy efficiency, basement, ceiling, roof and external walls were insulated. In addition, the existing heating system of the apartment was improved. These appropriate measures were determined by calculating energy saving ratios. As a result, 35% of energy was saved (OTB, 2004).

Retrofitting project 9 concerned an apartment building in Ljubljana, Slovenia, which had been constructed in 1962. Before the retrofitting, the building was in poor state, had bad quality windows and non-aesthetical view of façades. At the same time, it consumed high amount of energy for heating. For that reason, it was retrofitted in 2005. The major aim was to develop the thermal properties of the apartment block and reduce energy demand. The following measures were used: insulation of façades and pipes, adding of heat consumption meters, and high energy efficient windows (U= 1.1 W/m^2K). As a result, 46% of energy was saved. The project succeeded with the co-operation and financial contribution of occupants and state subsidy (EI-EDUCATION Program, 2007).

Retrofitting project 10 involved a 22-storey block constructed in 1968 in London, United Kingdom, which was retrofitted in order to offer a model for saving energy in extant residential buildings. Therefore, during the retrofitting, all balconies were incorporated, by means of single-glazing, into the livable area of the apartment; low energy lighting systems were implemented; and the existing heating system was repaired to reduce energy consumption. To produce extra energy by nearly 5.500 kWh per annum, a Ropatec vertical axis wind turbine was added on the roof. By applying these measures, approximately 29% of energy was saved (EuroACE, 2006).

Retrofitting project 11 engaged a five-storey apartment block built in 1980 in Budapest, Hungary. To show the possibilities of energy saving with a holistic technical approach, a retrofitting project was prepared by which the external walls were improved by adding 80 mm polystyrene thermal insulation layer and the first floor and roof slab were fixed with insulating board. Windows and doors were fitted to seal. Lastly, the heating system was upgraded by using devices such as thermostatic radiator valves and automatic gas valves to limit energy consumption. As a result, the system came to consume 44% less energy (EuroACE, 2006).

Retrofitting project 12 involved an apartment block constructed in 1979 in Chalandri, Greece, whose main problem was high heating losses. Three scenarios were described to remedy the problem and each scenario was evaluated independently. The scenarios, which remained hypothetical, were the following with savings rates as indicated:

Scenario A: wall insulation, new boiler, insulation of heat distribution pipes and solar collectors (savings rate: 42%),

Scenario B: roof insulation, new boiler, insulation of heat distribution pipes and solar collectors (savings rate: 40%),

Scenario C: Double glazing, new boiler, insulation of heat distribution pipes and solar collectors (savings rate: 45%) (OTB, 2004).

Retrofitting project 13 engaged the building system of an apartment block constructed in 1980 in Radomir, Bulgaria, with prefabricated concrete panels. The block was retrofitted in 1997 to reduce energy consumption by applying thermal insulation for the basement ceiling. In addition, an extra thermal insulation layer was added on the external walls and roof. The existing heating system was improved; new boiler and electrical heaters were installed; the wooden windows were repaired. The energy savings rate obtained was 46%. In other words, the retrofitting project proved that important energy savings were achievable with implementation of simple technologies.

Other advantages of the project were better thermal comfort, better-quality windows, and less condensation (EI-EDUCATION Program, 2007).

The 13 projects briefly described possibilities of energy savings to be obtained in existing residential buildings by applying energy effective measures. An overview of all the projects and their retrofitting scenarios are presented in Table 2.1.

Each of the 13 projects presents the opportunity for the comparison of the energy consumption level of existing buildings before and after retrofitting. Table 2.1 shows that all selected retrofitted residential buildings were provided with a reduction in energy consumption at the minimum rate of 30%. In other words, a substantial amount of energy savings ensured, in the projects, a high decrease in fuel consumption and thus considerably lower emissions of CO_2. To achieve this, comprehensive retrofitting scenarios were implemented to the selected buildings. Retrofitting scenarios used in the examples included insulation of external walls, the ceiling, the ground floor (over unheated spaces) and the roof. Replacement of the poor quality windows with energy efficient glazing and frames equally proved profitable. In addition, the efficiency of active systems like boiler and air-conditioning in buildings were controlled and improved regularly. In order to obtain extra energy, the wind tribune, PV systems and solar collectors were used in the above-discussed projects.

In most cases among the projects, the main reasons tenants undertook to retrofit an existing building were the reduction of the energy consumption and improvement of the appearance of the building. Other reasons were the increasing of the economic value of the building, the living quality, and the thermal comfort of the spaces. They also sought to lower the heating and cooling costs and aimed the use of natural resources. Because of the lack of adequate financial support for these kinds of projects, the number of the retrofitting examples is limited. This means that, the difficulty of obtaining funding is a major barrier in accelerating the retrofitting of existing buildings. Most of the examples above were supported financially by EU programs and the local national institutions of countries. To increase the number of retrofitting projects, homeowners can be informed about the appropriate retrofitting scenarios and their respective effects on energy consumption. Governments can establish institutional structures, coordinated programs, and private financing systems.

Table 2.1. Summary table of retrofitting examples

Project No	Project description			Retrofitting scenarios											
	Location	Construction year	Retrofitting year	Savings rate %	Sun space	Glazed balcony	Energy efficient window	Thermal insulation	Solar wall	PV system	Set point temperature	Improved heating and cooling system	Solar collector	Wind tribune	Energy efficient lighting
1	Denmark	1925	1995	51	x	x	x	x	x			x			
2	Sweden	1970	2000	44	x		x	x					x		
3	The Netherlands	1969	2002	70			x	x				x	x		
4	The Netherlands	1954	1987	46			x	x		x		x	x		x
5	Germany	1962	2005	94			x	x		x	x	x			
6	Austria	1979	2004	45			x	x				x			
7	Austria	1950	Hypothetical	30			x	x							
8	Latvia	1973	2005	35				x				x			
9	Slovenia	1962	2005	46			x	x				x			
10	UK	1968	2002	29								x		x	x
11	Hungary	1980	-	44			x	x				x			
12	Greece	1979	Hypothetical	45			x	x		x		x	x		x
13	Bulgaria	1980	1995	46			x	x				x			

CHAPTER 3

ISSUES OF ENERGY EFFICIENCY IN TURKEY

This chapter undertakes the discussion of activities and efforts on energy efficiency of buildings in Turkey. It is formulated in two complementary parts so as to evaluate the respective conditions before and after the period of harmonization of Turkish regulations with those of the EU. The chapter starts with brief definitions of energy efficiency, energy intensity, and energy saving. Then, energy use, regulations and standards related to the building sector in Turkey are explained in detail. The challenge in this chapter is to show the necessity for revisions and new legislations to promote energy efficiency and an auto control system to monitor implementation of energy-efficient measures.

3.1. Energy Efficiency as a Development Policy

The energy sector is seen as one of the indicators for economic growth of countries as well as the vital need for improving living conditions of their citizens. Especially after the 1973 oil crises, most countries have generated particular policies concerning the energy sector: one of them is ‘energy efficiency’.

Energy efficiency is defined as reducing energy consumption without causing any diminution in living standards and service quality in buildings as well as in the product quality and amount in the industrial sector (MENR, 2007). Kavak (2005) explains it as the notion which expresses the assessment of energy resources in all phases from production to consumption at utmost effectiveness. In addition to this, energy efficiency “refers to products or systems using less energy to do the same or better job than conventional products or systems. Energy efficiency saves energy, saves money on utility bills, and helps protect the environment by reducing the amount of electricity that needs to be generated” (Çalıkoğlu, 2006). As a result, it has become an important political issue for the energy sector worldwide as stated by Kavak (2005) who correlates its strategic importance with the following key factors influencing the energy sector:

- Lack of easy access to energy resources,
- Distribution of energy resources on particular regions,
- Higher prices required for energy investments,
- Increase in cost of energy products,
- Ecological problems (p. 7).

Energy efficiency has specific indicators to determine and compare the relative energy efficiency situation of different sectors such as industry, transport, and household (World Energy Council, 2007). Two of these are ‘energy intensity’ and ‘energy saving’ (Asia Pacific Energy Research Centre, 2001). The most common indicator, as stated by Haydaroğlu (2006), is the energy intensity, i.e. the amount of primary energy consumed per gross national income. “At the national level, energy intensity is the ratio of total domestic primary energy consumption or final energy consumption to gross domestic product or physical output” (European Environment Agency Glossary, n.d.).[1] In other words, if the energy intensity is less in a country, a product can be produced with less energy. It means that energy efficiency is achievable as well (DPT, 2006).

Energy intensity ratios mostly fluctuate because of increasing energy consumption based on high comfort conditions and developing living standards. Besides, the fluctuation may be interrelated with countries’ economic conditions. Thus, the level of energy intensity varies regarding the local factors in each country.

Table 3.1 elucidates that there are slight differences among countries irrelevant of their levels of economic growth and population. One of the most significant differences is observable between Turkey and Japan: the energy intensity rate of the former is 0.38 TOE/BIN $, while the latter is only 0.09 TOE/BIN $. It means that countries with developed economies like Japan, Germany, and the USA use less energy to produce any product in comparison with Turkey. In other words, Turkey consumes more energy than those countries to reach the same production level. Today, most countries tend to reduce the rate of energy intensity by improving energy efficiency policies. Especially after 1973, most northern countries launched specific programs for reducing energy intensity.

[1] “Primary energy is the energy embodied in natural resources prior to undergoing any human-made conversions or transformations” (Source: http://www.eoearth.org/article/Primary_energy); Final energy: “energy supplied that is available to the consumer to be converted into useful energy (e.g. electricity at the wall outlet)” (Source: http://glossary.eea.europa.eu/EEAGlossary/search_html).

Table 3.1. Energy intensity rate of some countries in 2001 (TOE/Bin $)
(Source: Adapted from EIA, 2003)

Countries	**Population (Million)**	**GNI per Capita (Milliard 95 $)**	**Energy Intensity (TOE/Bin $)**
Japan	127.2	5.647,7	0.09
Germany	82.3	2.703,3	0.13
Italy	57.9	1.225,3	0.14
France	60.9	1.804,9	0.15
Swedish	8.9	294,0	0.17
United Kingdom	58.8	1.334,8	0.18
Israel	6.4	105.5	0.20
Greece	11.0	144.8	0.20
Argentina	37.5	280.0	0.21
Brazil	172.4	798.8	0.23
USA	285.9	8.977,8	0.25
Australia	19.5	468.0	0.25
Canada	31.1	717.4	0.35
Turkey	**68.6**	**190.3**	**0.38**
Mexico	99.1	371.9	0.41
India	1.032,4	492.5	1.08

As a result, energy intensity rates have diminished since the beginning of 1980. This trend is visible in some of the EU countries as shown in Table 3.2. Between 1995 and 2002, most EU countries decreased the energy intensity ratios. In case of Turkey, the ratios were inconsistent because of actual economic problems, lack of policies and measures.

‘Energy saving’ as the second most important indicator of energy efficiency is to enable energy production and consumption with maximum efficiency and to keep energy losses at minimum level without affecting economic growth and living standards (Fidan, 2006). As stated in the definition, the most crucial concept is to minimize energy consumption by preventing energy losses.

Table 3.2. Annual energy intensity rate of some EU countries 1995-2002
(Source: European Environment Agency, 2007)

Countries	1995	1997	1999	2001	2002
Belgium	100	104.4	102.3	95.6	89.5
Denmark	100	99.7	90.0	85.9	83.6
Estonia	100	90.4	76.1	69.3	62.9
Finland	100	102.9	95.0	90.8	93.6
France	100	99.9	96.4	96.4	95.3
Germany	100	100.3	94.4	94.2	92.4
Greece	100	99.9	97.8	97	96.2
Italy	100	98.2	99.2	95.6	95.7
Malta	100	106.9	103.8	84.9	82.8
Poland	100	91.2	75.5	69.6	67.6
Portugal	100	98.3	104.3	102.7	107.3
Romania	100	99.1	85.3	82.2	76.2
Spain	100	97.4	99.3	99.3	100.1
Turkey	**100**	**99.5**	**101.3**	**103.2**	**100**
EU-25 average	100	98.6	93.7	91.9	90.6

3.2. Energy Use and Building Sector

The energy sector in Turkey is composed of the four major sub-sectors of industry, building, agriculture, and transportation. According to the energy statistics of 2001 (TÜBİTAK, 2003), 19.793 MTOE of energy was used by the building sector. Table 3.3 indicates that the building sector consumes more energy than others except for the industry sector. It is expected that the energy demand in all sectors will inevitably increase: the rate of energy use in buildings will rise to 33.69 MTOE by 2010 with nearly a 68% increase in a decade.

In brief, it is evident that the energy demand throughout the world grows constantly in all sectors, but the resources are decreasing as constantly. Specifically, buildings make a major contribution to energy use. Thus energy efficiency becomes essential today. Several reasons for urgently launching measures toward the efficient use of energy in the building sector in Turkey can be recognized. Firstly, the noteworthy rise in energy demand, shown in Tables 3.3 and 3.4, is one of the central reasons for the need to use energy efficiently in the building sector.

Table 3.3. Rates of energy use per sector in Turkey (2001)
(Source: TÜBİTAK, 2003)

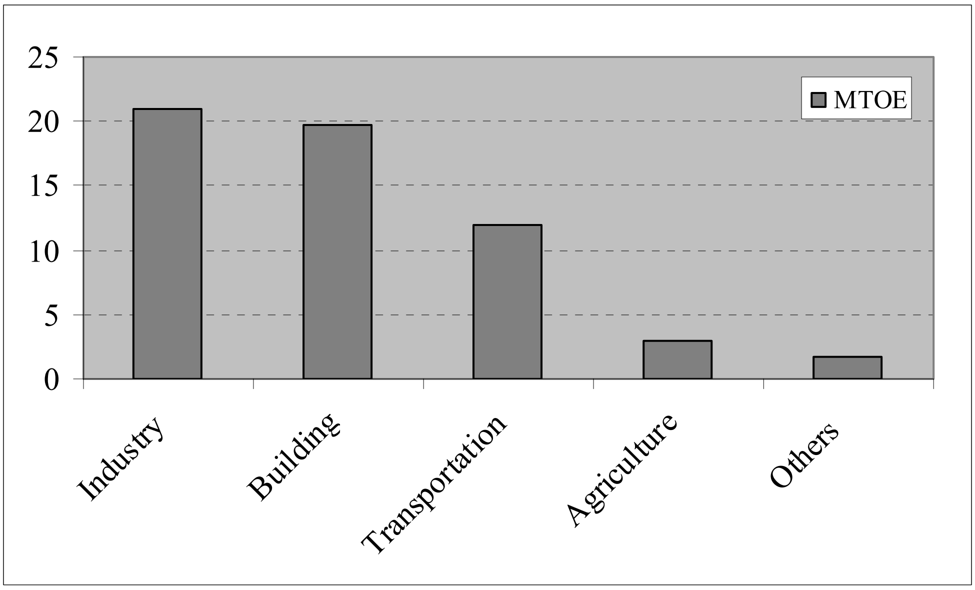
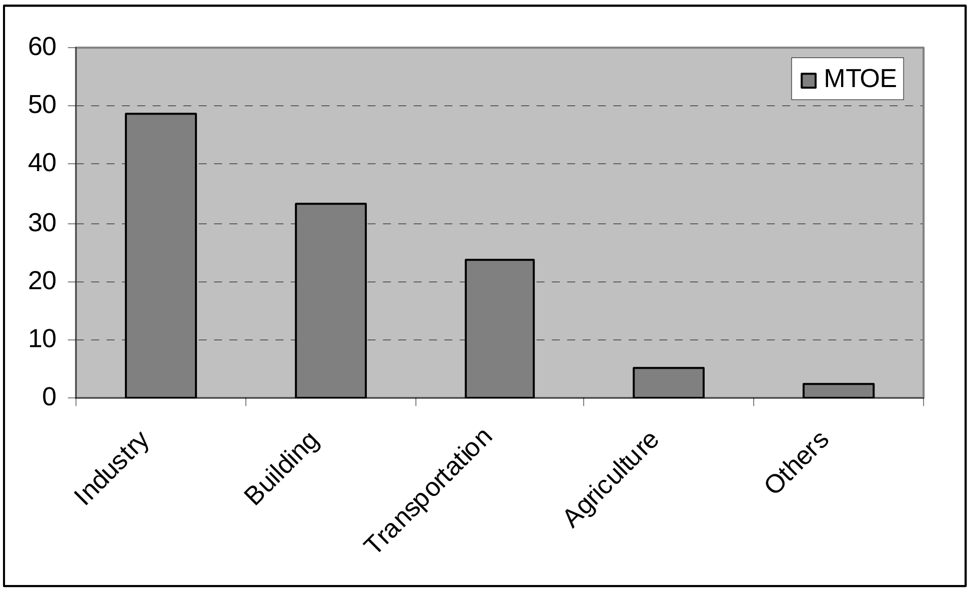


Table 3.4. Estimated rates of energy use per sector in Turkey (2010)
(Source: TÜBİTAK, 2003)



Another reason is evidently related to the poor quality of the existing residential building stock especially in cities. Uncontrolled urbanization and building activity together with new occupant profile who pays attention to size rather than quality of construction has come to the fore in the emergence of bulky stocks with all infrastructural, health and constructional problems (DPT, 2001). As a result, windows of 88% of residential buildings in Turkey are made of single glass. Only 12% of residential buildings have double and insulated glass, while this ratio is more than 50% in the EU countries. Roof insulation is used in merely 10% of the residential buildings, yet this ratio averages 40% in Europe. In brief, buildings in Turkey cause the consumption of more energy, particularly for the purpose of heating, compared to EU countries (DPT, 2006).

It is obvious that there are unregistered, i.e. illegal, houses in Turkey. The figures started with 80,000 in 1950; hit 240,000 in the beginning of the 1960s; and reached 600,000 in 1970. The latest statistics indicate that there were 2.5 million illegal houses in 2004; in other words, 12 million people were living in shanty towns (Kayıkçı, 2004). If these houses are incorporated in the legal residential building stock, the number of the buildings which do not have any measures for energy efficiency will inevitably increase.

Until now, increasing energy demand in Turkey has been atoned with increase in supply of energy. Yet, a part of this energy can be atoned by energy efficiency as seen in most countries which have introduced and applied regulations particular for energy saving. Research by TÜSİAD (1998) signifies that the potential of energy saving in the building sector of Turkey was 5.1 MTOE in 1997. Çalıkoğlu (2006) underlines that this potential is noteworthy, since thereby Turkey could halt importing the equivalent 1.4 milliard US$ worth tons of oil and natural gas, if the potential energy saving of 35% for heating and cooling costs of buildings and companies, and 15% for transportation were attained. Energy consumption rates are still high in Turkey compared to European countries because of insufficient measures taken for energy efficiency and weak institutional structure to reduce it.

3.3. Institutional Structure Concerning Energy Efficiency

There are three groups of stakeholders playing key roles in issues of energy efficiency in Turkey: intermediaries, policy makers and consumers (EIE, 2004). Among the stakeholders in Table 3.5, four governmental institutions mentioned are particularly entrusted with the development and implementation of national energy efficiency policies and activities related to buildings.

Table 3.5. List of stakeholders related to energy efficiency in Turkey
(Source: EIE, 2004)

Intermediaries	Policy Makers	Consumer groups
General Directorate of Electrical Power Resources Survey and Development Administration (EIE) / National Energy Conservation Centre (NECC)	Ministry of Energy and Natural Resources	Environmental Groups and Associations
TÜBİTAK	Ministry of Transport	Industrial Enterprises
Energy Market Regulatory Authority	Ministry of Reconstruction and Resettlements	Buildings (Residential and Commercial)
Turkish Standards Institution	Ministry of Finance	Commercial Services
Municipalities	Under-Secretariat of Treasury	Private and Public Transport
Industrial Branch Associations	State Planning Organization	Public Sector
Chambers of Industry and Commerce	Ministry of Environment and Forestry	
Universities	Ministry of Industry and Trade	
State Institution for Statistics		
Consumer Associations		

1. **Ministry of Energy and Natural Resources (MENR):** regulation of policies and control of their implementation within national energy policies.
2. **General Directorate of Electrical Power Resources Survey and Development Administration / National Energy Conservation Center (EIE/NECC):** application and coordination of every energy efficiency program, execution of training, energy auditing, drafting of legislation and public awareness encouragement activities to improve energy efficiency in every sector, administration of energy efficiency projects associated with

international organizations like WB, EU and JICA, carrying out energy saving and efficiency studies which are conducive to environmental protection by means of efficient use of energy resources, development of renewable and alternative energy resources.

3. **Ministry of Reconstruction and Resettlement:** evaluation and determination of the requirements of public organizations regarding buildings and other facilities such as providing support in the formulation of draft regulations and terms of references.
4. **Turkish Standards Institution:** preparation of necessary standards related to buildings and other sectors and conducting necessary research about standards. For instance, TS 825-Thermal Insulation in Buildings was prepared and published by this institution.

Two of the above institutions are the major ones responsible directly for energy efficiency activities in Turkey: EIE/NECC and MENR. All actions and regulations on energy efficiency in buildings have been executed or organized by these institutions. EIE/NECC is the primary institution conducting basic activities related to energy efficiency in Turkey. These activities consist of training in the explanation of energy-saving measures and increasing consumers' awareness of energy efficiency, the publishing of books, periodicals, magazines, etc. about energy efficiency for all sectors, offering consulting services on formulation of energy-efficient measures in the industrial and building sectors, and generating energy-management databases and energy-consumption statistics for industrial and public buildings.

MENR is responsible for policy making and monitoring implementation of regulations. One of the most problematic issues in energy efficiency studies on the institutional scale concerns budgeting. Since on the political plane, energy efficiency is not considered as the prime target, the share of budget for activities on energy-efficiency is quite insufficient. For instance, while the total budget of EIE/NECC was US$ 0.6 million in 2003, the budget of only one project, e.g. 'Energy Performance Integration in Social Housing - A Strategic Approach for Portfolio Management' in the EU is around €1,5 million (Intelligent Energy Europe Programme, 2006).

3.4. Extant Regulations for Energy Efficiency in the Building Sector of Turkey

Annual total energy losses in residential buildings nationwide are 5.3%. This rate is quite high when compared with most of EU countries' such as 3.0% in The Netherlands, 2.9% in Belgium, 1.7% in Finland, 1.3% in Greece, 0.7% in Norway, and 0.4% in Ireland (EURIMA, n.d.). This fact points to an urgent need for instituting comprehensive regulation for energy efficiency in the residential building sector and a strict control system in the implementation phase.

The first regulation entitled 'Protection rules from heat effects in buildings' was published in February 1970. Other regulation dates back to 1972 and was published by the Ministry of Energy and Natural Resources. It was more related to the facts and problems of the 70s, i.e reducing air pollution based on heating facilities in cities and achieving savings in fuel consumption. The respective energy saving rules and regulations are summarized in Table 3.6.

Table 3.6. List of extant regulations for energy efficiency in Turkey
(Source: ITO, 1999 & Özdemir, 2005)

Name of the Regulation	Publishing Date	Official Paper No	Publication Institution
Rules of Protection from Heat Effects in Buildings	February 1970	-	-
By-Law for Provision of Saving in Fuel Consumption and Reduction of Air Pollution Born of Heating Facilities in Cities	19.09.1972	14311	Ministry of Energy and Natural Resources of Turkey
By-Law for Provision of Saving in Fuel Consumption of Heating and Steam Facilities and Reduction of Air Pollution	03.10.1977	16102	Ministry of Energy and Natural Resources of Turkey
By-Law for Change in Development Plan of Some Municipalities and Addition of New Articles	30.10.1981	17499	Ministry of Reconstruction and Settlement

(Cont. on next page)

Table 3.6. (Cont.) List of extant regulations for energy efficiency in Turkey
(Source: ITO, 1999 & Özdemir, 2005)

By-Law for Provision of Fuel Saving Through Thermal Insulation in Existing Buildings and Reduction of Air Pollution	19.11.1984	18580	Ministry of Energy and Natural Resources of Turkey
By-Law for Change in Development Plan of Some Municipalities and Addition New Articles (Revision)	16.01.1985	18637	Ministry of Reconstruction and Settlement
TS 825-Standard for Thermal insulation in buildings	March, 1989	-	Turkish Standards Institution
TS 825-Standard for Thermal Insulation in Buildings (Renewed and developed)	April, 1998	-	Turkish Standards Institution
By-law for Thermal Insulation in Buildings	08.05.2000	24043	Ministry of Reconstruction and Settlement
TS 825-Standard for Thermal Insulation in Buildings (became obligatory)	14.06.2000	-	Turkish Standards Institution
Energy Efficiency Law	02.05.2007	26510	The Grand National Assembly of Turkey

Regulatory aspect of energy in Turkey strategically focuses on a prime target, i.e. minimizing 'heating' energy consumption in buildings. It is mainly interested in the use of thermal insulation while disregarding energy consumption for cooling. The most comprehensive regulation in use related to energy efficiency up to now is 'TS 825-Thermal Insulation in Buildings' regulated for new buildings. This standard basically consists of a kind of calculation procedure that concerns annual heating requirements for buildings and determines maximum annual energy values for heating. It was first launched in 1989, then revised and developed in 1998 and 2000. The basic changes were made in 1998 in TS 825. For example, firstly, Turkey is divided into four climatic zones. A method is generated to calculate annual energy demand for heating. Annual energy need (Q) is determined separately for four climatic zones. Lastly, calculation method of steam diffusion is determined.

The most recent version of TS 825 targets limiting energy use for heating in buildings, enhancing energy saving, determining the standard calculation method, determining ideal design option, providing optimum energy performance, determining energy consumption for heating in the existing buildings, determining energy saving potential before application of retrofitting project on existing building, and estimating future energy demand in buildings.

The types of buildings in which TS 825 must be implemented are listed as residential buildings, office and administrative buildings, theater, congress and concert halls, cultural centers, education buildings, library, sports facilities, dormitories, hospitals, rest homes, nursing homes, maternity hospitals, kindergartens, prison and barracks buildings, accommodation facilities, shopping centers, office blocks, bank and stock markets, and offices heated at a minimum of 15 °C (Karakoç, 2001).

TS 825 put into practice an official document, the Identity Certificate of Heat Need, indicating the amount of energy consumed per new building. With this certificate publicized on the entrance of an apartment block, tenants are simply informed about the total energy consumption of their building, and may compare it easily with others'. As part of the documents for obtaining official permission of building use, this certificate is signed by the mechanical engineer and the person responsible for instituting the thermal insulation project, and then confirmed by the municipality or governorship.

The implementation of TS 825 in the building sector became obligatory by June 14th, 2000, i.e. two years after its declaration. Together with the 'Regulation for Thermal Insulation in Buildings', it provides an essential amount of energy saving by limiting heat losses which thereby decrease by half, i.e. 100-150 kWh/m^2.

Today, there is a need for the comprehensive revision of TS 825 within the framework of harmonization with the energy directives of the EU. In fact, a commission under EIE was assigned to conduct the revision study. The draft versions of revision are now in circulation to pick up the opinions of central, public and private parts.

The last version of the revised draft conveys that the calculation procedure of the net heating need does not change. Yet, additional calculation methods and tables including city and borough's monthly mean humidity ratios are added. Besides, the limits of energy need are improved. Other proposals introduced by the revision study are the following:

1. Monthly mean outside temperatures are renewed with meteorological data of the preceding 20 years.
2. In TS 825, the analysis of vapor transmission was based on German standards (DIN 4108). With this draft, it is conducted by TS EN ISO 1378. Annual analysis and stable temperature, humidity, condensation and evaporation periods, which were used in Germany, were abolished. Instead, data like monthly mean air temperatures and humidity obtained from the climatic data of Turkey were used. Sample calculations are generated according to new methods.
3. It becomes obligatory to set the inner surface temperatures of all building materials in contact with the outside as at maximum 3°C less than the interior temperature of that space.
4. Special energy limitations are brought for the curtain wall. The use of coated double glazing becomes compulsory in all degree-day zones.
5. The thermal resistance of the floor is set as 0.80 m^2 K/W in buildings where there is no central heating system and where the tenant has controlled over the individual heating and boiler.
6. DIN 4148-4:2002 including calculation values of construction and insulation materials are adapted in TS 825 (İZODER, 2006).

To sum up, TS 825 is very essential for all new and existing buildings in Turkey. Its main target is to decrease energy consumption arising from heating. Thus, its implementation should be inspected and monitored during the construction process of buildings. There are two ways of inspecting in Turkey. The first is specific for public buildings constructed under the charge of The Ministry of Construction and Settlements. These buildings are controlled and monitored in accordance with regulations which are carried out by the provincial directorates of the Ministry under the supervision of the governors. Another way is for private buildings under Buildings Inspection Agencies whose functions are overseen by the Municipalities (Turkish Standard Institute, 2000).

3.5. Energy Issues in the Harmonization Process with the EU

The reorganization of Turkish legislation on energy issues in the scope of the harmonization process with EU directives is still an ongoing process. There are two fundamental Council directives on the energy efficiency of buildings that should first be adapted by the governmental bodies of Turkey. The starting Council directive relating to buildings is 93/76/EEC ("Omnibus Directive") to limit carbon dioxide emissions by improving energy efficiency (SAVE) in buildings. This directive demands preparation and application of programs for harmonization in the following fields (MENR, 2004a):

1. Energy certification of buildings to provide prospective users with information on a building's energy characteristics;
2. The billing of heating and hot water costs on the basis of actual consumption, to enable the costs of such services to be apportioned fairly among the users of a building;
3. Third party financing (including auditing, installation, operation and maintenance services) for energy efficiency investments in the public sector;
4. Thermal insulation of new buildings;
5. Regular inspection of boilers with an effective rated output of more than 15 kW;
6. Energy audits of undertakings with high energy consumption (p. 45).

Another important Directive, 2002/91/EC, which has been explained in detail in Chapter 2 on the energy performance of buildings, has been in force since the beginning of January 2003 and all EU member countries had had to put it into practice by 2006. It proposes a comprehensive methodology including calculation of the energy performance of buildings, application of optimum energy necessity on new and existing (under major renovation) buildings, regular control of air-conditioning systems and boilers and certification of buildings (Council Directive 2002/91/EC, 2002). The Ministry of Reconstruction and Resettlements is the responsible governmental institution about the implementation of this directive in Turkey. The necessary adoption studies have yet to be completed.

Only very limited regulations could be adopted in Turkish legislation with TS 825-Thermal Insulation in Buildings in Turkey. TS 825 is related to the limitation of energy requirements for heating in new buildings. Other regulations mentioned above in European directives have not been applied in their entirety and there is no comprehensive approach for the necessary implementation in the governmental institutions. Currently, a new By-law proposal is prepared by the Ministry of Public Works and Settlement, Ministry of Energy and Natural Resources, Ministry of Industry and Trade, Ministry of Environment and Forestry and related associations within the adaptation process of the energy performance of buildings directives. The proposal consists of ten main articles:

Article 1: Objective, definitions and scope.

Article 2: Energy efficiency, renewable energy and passive architecture practices in the architectural design process.

Article 3: Thermal insulation project.

Article 4: Ventilation, minimum ventilation and degree-days.

Article 5: Lighting and electric systems.

Article 6: Network systems and hot water plumbing.

Article 7: Certification of buildings.

Article 8: Central heating systems, auto control, boiler house and chimneys.

Article 9: Annual energy requirements.

Article 10: Hardware for registration of consumption, shares of outcomes in transfer of heat, shares of outcomes in special conditions ("EIE", n.d. b).

In addition, a few technical assistance projects have been conducted with the cooperation of international institutions such as the World Bank, EU organizations, Japan International Association Agency and German Technical Assistance Institution in Turkey (Secretariat General for EU Affairs, 2003). One of them was the project of 'Support to Energy Efficiency in Residential Buildings in the Municipality of Erzurum' launched in November 2002. The project was carried out by the cooperation of the German Technical Assistance Institution and Erzurum Municipality, Ministry of Energy and Natural Resources, and General Directorate of Electrical Power Resources Survey and Development. The project was formulated on the following objectives: enhancement of energy management ability in the Municipality of Erzurum, decrease in the energy consumption of secondary legislation in residential buildings, capacity-building in technical, legal and methodological subjects to perform an energy management system in the Municipality of Erzurum, and establishment of the training center for energy managers ("Erzurum Metropolitan Municipality", n.d.).

The scope and actions of the project were quite comprehensive: they covered both municipal and national scales like improving mission and studies in terms of energy efficiency of the National Energy Conservation Center, generating a national energy management system in Erzurum, training staff to dispense technical information for public buildings about their energy-efficient use, improving training facilities and program for energy manager, preparing proposals to develop the regulations about energy efficiency and thermal insulation in buildings, retrofitting selected existing buildings, and increasing consciousness of people about energy efficiency (Buyruk, 2005).

The comprehensive assessment of the existing energy efficiency situation in Turkey requires first the analysis of the current status of related legislation, administrative structure, and the national energy policy. Thus, a strategy report entitled 'Energy Efficiency Strategy for Turkey' has been prepared to improve energy efficiency activities in view of the best practices in the EU. It was prepared by the support of the EU-originated foreign agency, MVV Consultants and Engineers from Berlin. The report was published in June 2004 by MENR. This is the most comprehensive report on Turkey for, it summarizes the current relevant state of Turkey, missing aspects of energy efficiency studies, necessary implementation and schedule of the strategy linked with their reasons. In addition, the report clearly conveys that a study of energy efficiency and policies for energy-efficient building has not attained a satisfactory level. The general reason may be the lack of capacity in the building sector and insufficient financial resources. The other reasons are that there is no comprehensive approach to energy efficiency in buildings yet. Control and monitoring of thermal insulation in buildings is not sufficient. Policies developed by the governmental organizations could not be implemented on the local level as expected, depending on the limited capabilities of local actors. There are insufficient activities in the different target groups (EIE, 2004). All problems and reasons in terms of buildings are summarized in detail in Table 3.7.

In addition, the Report on Energy Efficiency Strategy for Turkey (EIE, 2004) proposes five solutions with necessary actions to develop energy efficiency and thermal comfort and to reduce heating cost in new and existing buildings. Solution one is the enhancing adaptation of construction standards. Its necessary actions are the developing insulation for existing buildings, energy certification for buildings to give information about a building's energy features, and generating capacity in municipalities to control construction standards.

Table 3.7. Problems and reasons in terms of energy efficiency in Turkey
(Source: EIE, 2004)

No	Problems	Reasons
1	Heat losses in buildings	▪ Lack of control about thermal insulation norms ▪ Insufficient financial capacity of owners for rehabilitation of buildings
2	High emissions from infertile boiler systems	▪ Use of low efficient boiler systems ▪ Insufficient cleaning of chimneys and inspection of boiler systems ▪ Insufficient natural gas distribution
3	Lack of awareness of consumer on energy efficiency	▪ Illegal electric usage ▪ Lack of information about simple energy saving techniques and methods
4	Lack of energy management in buildings	▪ Lack of information and support for implementation ▪ Lack of financial support for consumers

The second solution is to support rehabilitation of existing buildings in terms of energy supply facilities. To achieve this, use of natural gas instead of coal in buildings should be encouraged with building loan if buildings are constructed according to necessary norms. The third solution is related to generating energy management in buildings by implementing identification of energy management and further technology, training of building operators on energy efficiency, supporting municipality's attempts concerning energy management, generating compulsory energy management plans for buildings exceeding a given size, and supporting public supply programs for energy-efficient equipment. In addition, people should be informed about the best cost effective technologies and applications as well as about applying the efficient heating system for local climatic conditions, training for architects and engineers on application of energy-efficient technologies, changing oil boilers with natural gas boilers, and improving awareness of owners about low cost measures to decrease energy consumption. The last solution, generating financial system for energy efficiency projects, is exceedingly important because every action is based on improving the financial support system for new and especially existing buildings to apply energy-efficient measures.

Subsequent to this report, the twinning project was launched for the enhancement of energy efficiency studies for two years by July 2005. The partners of the project are the General Directorate of Electrical Power Resources Survey and Development Administration from Turkey, the 'Environment and Energy Management'

(ADEME) from France and 'Energy and Environment' (NOVEM) from The Netherlands. The project consists of two main groups of tasks and their sub-tasks:

1. Reinforcing the legal and institutional frame:
   - Advising to conduct a suitable legal frame with the EU after assessing existing regulations.
   - Preparing a guide in view of the best applications in the EU and aim of the energy efficiency strategies to perform implementations cooperation with related institutions.
   - Checking EIE's capacity formation and working procedures of human resources and making suggestions to improve them.
   - Showing affects of energy efficiency programs applied in the EU, and its adaptation for Turkey's conditions, design and application of integrated energy efficiency programs.
   - Improving awareness of people and giving necessary information on energy-efficient technologies.
   - Training and organizing of local stakeholders about energy efficiency and providing support to enhance and follow energy saving programs.
   - Preparing education activities for EIE's staff on necessary specific subjects.
   - Determining demonstration projects and rules to select them.
2. Assessing energy saving potential:
   - Improving various cost scenarios to determinate economic energy efficiency measures according to electric, gas and other energy resources and different consumer groups.
   - Checking existing studies and results of audit.
   - Giving education for specialist staff.
   - Generating working groups to gather necessary data in industry, buildings, transportation and their sub-sectors.
   - Generating database that serves as a benchmark for energy-efficient technologies, know-how and their cost.
   - Determining cost effective measures connecting with benchmarking database in sub-sectors ("EIE", n.d. a).

The Energy Efficiency Law which was put into practice on 22 February 2007 is the most important study on the content after the start of the adaptation process with the EU. It was prepared by MENR to generate a framework for enhancing and implementing the strategy for energy efficiency in all sectors. The law concentrates mainly on two topics: efficient use of energy and resources to reduce energy consumption and to protect the environment. In addition, Korucu (2005) summarizes the main targets of law as raising awareness on energy efficiency, developing institutional framework for energy efficiency services, and encouraging use of renewable energy resources including biofuels. Other policies and measures (IEA, 2005) brought by the law are that, "energy manager obligation will be extended to non-industrial establishments, including public and commercial buildings exceeding to a certain size. Industrial buildings and public organizations whose energy consumption or size exceeds a certain threshold must report their energy consumption annually to the EIE/NECC to facilitate its preparation of analysis on energy efficiency and forecasts." In addition, "public awareness will be increased through the channels described above and companies of electricity and natural gas distribution will be obliged to provide more informative invoices for the consumers as well as information on energy efficiency organizations." Furthermore, "tax incentives, subsidies and soft loans will be given to industry for energy-efficient investments." Lastly, "VAT exemptions will be provided for energy-efficient household appliances and equipment used in buildings, and subsidies will be provided for biomass-based co-generation" (p. 56).

3.6. Evaluation

It is evident that Turkey did not revise current legislation through energy efficiency as expected within the framework of harmonization with the EU. TS-825 Thermal Insulation in Buildings responds only to particular parts of the *Energy Performance of Buildings Directive (2002/91/EC)* and that is related to the limitation of the energy consumption for heating in buildings. Cooling, however, is as important as heating in Turkey and sometimes more energy is necessary for the former than for heating in the southern region of the country. However, there is no specific standard to calculate and limit the cooling demand in buildings. This brings about extra energy consumption. For that reason, a draft law (Energy Performance of Buildings for Turkey) mentioned in the previous part was prepared in coordination with a commission (Özgür, 2005). Now, it is under review. In addition, TS 825-Thernal Insulation in Buildings is valid merely for buildings which have been built after June 14th, 2000. However, Turkey has already a massive building stock, and most of its elements do not even cover the most necessary measures, e.g. thermal insulation. As a result, almost 95% of 8.5 million buildings are beyond the control of the TS 825 standard. Moreover, the consumption of energy for heating or cooling cannot be evaluated as a mere issue of operation and maintenance of a building during its life cycle. For one, the building has consumed energy already during the construction process, and in the demolition of a building at the end of its useful life. Therefore, energy efficiency is an inevitable policy to minimize the consumption in each phase and the cost of heating, cooling and lighting in buildings. Consequently, retrofitting of the existing residential buildings in Turkey, linking with design and implementation of guidelines and suitable financing system such as soft loans concerning consumers are essential. By retrofitting the existing residential buildings, more energy can be saved in a short period of time at national level. To calculate the energy savings rate as a result of the retrofitting at national level, statistical information concerning buildings has strategic importance as this information will be background of retrofitting projects in the decision processes. However, Turkey does not have enough and comprehensive statistical information about the number of buildings and their construction features such as the insulation level of existing buildings. The most recent research entitled 'Energy Consumption in Residences' was prepared in 1998 by the Turkish Statistical Institute (1998). It serves a database about the number of buildings, types of buildings, heating types, and materials used for insulation, energy consumption for heating, lighting, appliances and transportation in nine cities selected: Istanbul, Kocaeli, Izmir, Antalya, Ankara, Konya, Samsun, Erzurum, and Gaziantep.

There is no distinction in the evaluation process of residential buildings and public buildings in Turkey except what is outlined in the circular entitled, "Measures for Public Buildings to Reduce Energy Consumption," published by the Prime Ministry in 1997. This document declared that by 1998, the annual energy consumption of public buildings should be reported annually every May. However, it is a fact that the total building stock in the EU is classified distinctly as public buildings, residential buildings, high-rise residential buildings, and schools. Therefore, specific projects and policies are generated to increase energy efficiency for each class of building in the EU.

The Energy Efficiency Law of 2007 is the first initiative to fulfill EU regulations in the building sector in the harmonization process. Yet it is insufficient in detail in that it draws only a general framework without introducing any regulatory By-laws.

CHAPTER 4

OVERVIEW OF ECOTECT v 5.50, BUILDING ENERGY ANALYSIS SOFTWARE

Today, simulation is increasingly used in the design of buildings in order to perform a variety of performance analyses such as the study of energy consumption, thermal comfort, lighting, acoustic, cost-effective design, etc. This thesis utilizes one of the most commonly used energy analysis softwares, Ecotect v 5.50, to predict the annual energy consumption of the residential building according to different retrofitting scenarios. This chapter presents a detailed explanation and assessment of Ecotect v 5.50 software. Correspondingly, a number of questions find their answer below, such as: which kind of data is necessary to start the thermal modeling of a building, including site data and weather data? Which mechanical systems for heating and cooling can be defined by using the Ecotect v 5.50? Lastly, how to make a thermal model with Ecotect v 5.50?

4.1. Building Energy Analysis Software and Ecotect v 5.50

The assessment of the energy consumption of buildings is one of the most popular research topics by simulating the buildings in real-life conditions presently. To achieve this in buildings, more user-friendly analysis software is needed (Zhu, 2006). In other words, global requirements in the more sustainable improvements have resulted in an increasing number of new design technologies and strategies aimed basically at the development of buildings with respect to energy use, cost-effective solutions, thermal comfort and environmental impact (Holst, 2003). As a result, in the design process of energy efficient buildings, the uses of energy analysis softwares are increasingly used today.

Generally, energy analysis softwares can be divided into two such categories as the zonal approach and computational fluid dynamics. The zonal approach has two other sub-categories, i.e. the steady state and the dynamic approach. The zonal approach reduces computation time and complexity. Thus, softwares based on this method usually are preferred over others. Basic examples of energy analysis softwares based on the zonal approach are Energy Plus, Ecotect, Energy-10, eQuest, Design advisor, TAS, ESPr and DOE. The other type is the computational fluid dynamic approach. This system is related to the quantitative process of modeling fluid flows. The most important advantages of this approach include that real-life conditions can be identified more accurately than in the zonal approach (Mourshed & Keane, 2003).

Ecotect, the version v 5.50, is the comprehensive energy-efficient building design and environmental analysis software package (Marsh, 2006a). The main reason for the selection is that Ecotect v 5.50 provides fast and comprehensive modeling interface to generate the most complex building shape and the model is editable. With this feature of the software, resizing of the construction components such as walls and windows, manipulating complex curve, re-arrangement of the zones and adding or deleting surfaces are possible during the simulation process. The entrance of variables on thermal properties of buildings makes Ecotect v 5.50 more accurate as an overall simulation tool compared to other energy simulation engines.

Main users of Ecotect v 5.50 are usually architects, because the tool has been designed and written for use especially by architects. It provides architects with a simple and overall 3D modeling interface with various analytic functions including shadow and reflections, shading design, energy performance, solar analysis, lighting design, acoustic analysis, ventilation and air flow, and resource management (Marsh, 2006b).

To evaluate the energy performance of an existing building, firstly the current building geometry should be drawn in three dimensions by using planes or volumes to represent floors, walls and roofs. After drawing the main shape, windows, doors, and openings into the original planes or volumes are inserted on the model. Intended materials or assemblies for each entity of the completed model are then defined. These can be left to default materials until more information is available. In this step, real climatic conditions are necessary for calculation of energy performance of the building. Thus, geographic location is defined and the appropriate weather data file is applied in the simulation. Then, to oversee any incorrect model description, inter-zonal adjacency and over-shadowing calculations, the software is run. If there is any mistake, the model is developed through geometric, material or schedule changes. After all, results related to the energy performance of the buildings can be readily obtained by using the analysis section of Ecotect v 5.50.

4.2. Design Variables in Ecotect v5.50

Before starting the modeling of the building, a base design is essential in order accurately to predict its energy performance in Ecotect v 5.50. The first base design is related to ‘site characteristics’ and includes the specification of elevation, orientation, ground cover, building exposure rate, latitude, time zone, detailed schedule such as holidays and daylight saving period. Another is ‘weather data’. Ecotect v 5.50 uses the binary file format and other internationally implemented ASCII formats such as TMY Climate Data (TMY), TMY2 Climate Data (TM2), TRNSYS TMY Variant (TRY), Aus. BOM Hourly Data (LST), CSIRO Weather Data (DAT), NatHERS Climate Data, and ASHRAE WYEC2 Data. These weather data should contain dry bulb temperature (month of the year, day of the year, hour of the year), absolute humidity (g/kg), average wind speed (km/h), wind direction (degrees clockwise), global horizontal radiation (Wh), diffuse horizontal radiation (Wh), direct beam radiation (Wh), cloudiness (%) and rainfall (mm) to enable correct prediction. Besides, Ecotect v 5.50 has a weather tool offering a wide range of display options including 2D-3D graphs, wind roses and sun path diagrams. These features are very usable in assessing climatic conditions of selected locations. In addition, the user of Ecotect v 5.50 can determine the range of inside temperature (comfort band), number of people and their mean heat output, values based on lighting and small power loads per unit floor area, and the air exchange rate between the zone and the outside. In terms of ‘building fabric’, the user can specify all construction materials, construction composition of internal and external elements, material density, absorptivity of inward facing, specific heat, conductivity, transparency, color, emissivity, thermal lag and decrement, and solar absorption. Two types of materials can be assigned on all objects in Ecotect v 5.50 as primary and alternate materials. If one object does not overlap with another object such as wall, floor and ceiling, these objects are taken as using primary material. However, if there is one object positioned right next to or on top of another, it is taken as using alternate material (Figure 4.1).

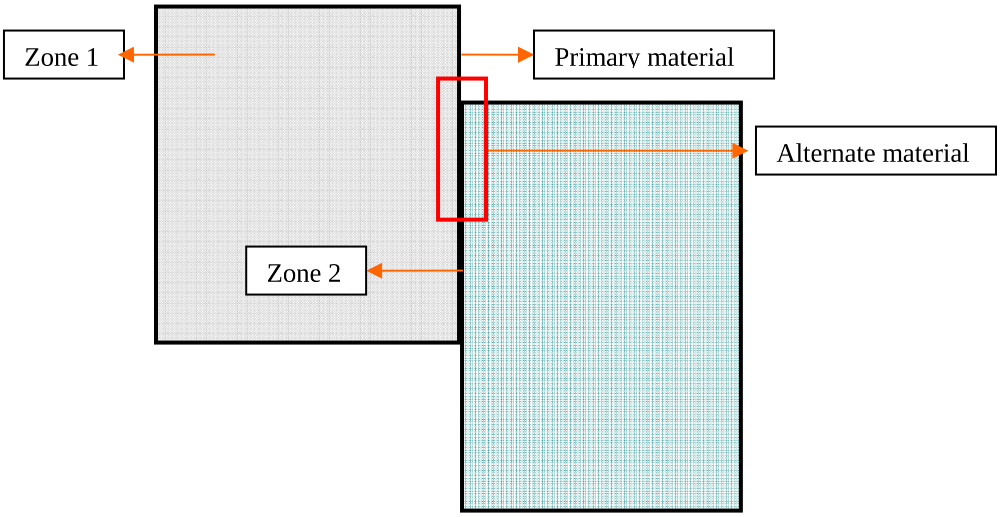


Figure 4.1. Primary and alternate materials in Ecotect v 5.50

In Ecotect v 5.50, there are several options for simulation of mechanical systems. The HVAC simulation engine of Ecotect v 5.50 enables the simulation of variable cases such as the Non- HVAC system mode. In this mode, all windows and doors are accepted as closed. In other words, occupants are assumed to ignore internal thermal comfort completely. Another mode is that of natural ventilation. This means that when the outside climatic conditions are closer to the described comfort conditions than the inside conditions, the occupants will open the windows. Thus, the air change rate during the operational period will be bigger than described conditions. Mixed-Mode is a combination of air-conditioning and natural ventilation. If the outside climatic conditions are within the described thermostat range, the HVAC system shuts down automatically. In full Air-Conditioning mode, if the air temperature is between the thermostat settings, the HVAC system runs during the operational time. Heating mode has the same function as the full air-conditioning mode with the difference that only heating loads are calculated in this process. Last is the cooling mode. This mode has the same function as full air-conditioning again, but only cooling loads are calculated.

4.3. Thermal Modeling Concept of Ecotect v 5.50

In Ecotect v 5.50, the building model consists of various thermal and non-thermal zones. A thermal zone can be described as a homogenous enclosed volume of air. All thermal zones must be enclosed geometrically. These zones are necessary for calculating all thermal conditions of buildings. A non-thermal zone is an ineffective object in the calculation process of Ecotect v 5.50. They are usually used to define shading devices, construction lines and other non-participatory data. Here it is essential that suitable rooms, which have the same thermal characteristics, should be grouped into a single zone. For example, a large room having north, east, west and south outer façades may be subdivided into multiple zones. In addition, each zone should be drawn as a complete three-dimensional prism, with planar surfaces on all sides. The separate thermal zones can be created if necessary. Thus Ecotect v 5.50 allows for creating unlimited thermal zones in the model. If the two zones are next to another, inter-zonal adjacency should be used to control common elements and geometry of the thermal zones. The element types for floor, windows, void and partition are very important, since these elements can be used only with their reference surfaces in the thermal model. If necessary, external shading components should be placed in the non-thermal zone because they do not affect thermal mass or solar radiation in each zone (Marsh, 2006).

Architects and designers usually prefer using visual data. This process can be achieved easily in the result section concerning the energy performance data of buildings with five basic types of graphical display screens found in Ecotect v 5.50 (Figure 4.2).

The first screen yields ‘hourly temperature’ that shows the internal temperature of all visible thermal zones in the model over a 24-hour period. The ‘hourly heat gain’ screen is related to the size of all different heat flow paths of all visible thermal zones in the model. The third screen, ‘monthly space loads/discomfort’, defines total heat and cooling loads for each thermal zone. Another, ‘annual temperature distribution’ screen, basically shows a statistical range of internal temperatures or heat loads over an entire year. The last screen, ‘annual load distribution’, shows the maximum and minimum heating and cooling loads per day and year. Moreover, Ecotect v 5.50 has the resource consumption display screen to calculate the consumption of electricity, water, gas, petrol, diesel and oils.

Ecotect v 5.50 uses 'the Chartered Institute of Building Services Engineers Admittance Method' to calculate the thermal performance analysis functions mentioned above. The method is very useful and has no further limitations for building geometry

Figure 4.2. Graphical display screen of Ecotect v 5.50

and number of thermal zones. For instance, it can obtain a wide range of useful design information with a few pre-calculations for shading and overshadowing by using this method. According to the Admittance Method, the internal temperature of any building tends to run close to the mean outdoor temperature. When any fluctuations in the outside temperature or solar loads occur, the internal temperature too is fluctuated in a similar way as based on thermal capacity and resistance of building fabrics until total heat losses become equal to the total of all gains. Then, internal temperature does not change.

The admittance method has some limitations, i.e. each energy analysis tool yields relative accuracy results. Thus, the results show relative change. The relative accuracy allows designers to hypothesize about necessary subjects. The other disadvantage of the method is that it is less suitable in some situations. For instance, when a large sudden change happens in parameters, the effect of Ecotect v 5.50 occurs instantly whereas in real life, effects of the real equipment would be observed over time. In addition, the method does not track solar radiation onto individual surfaces, once the radiation has entered the zone. Lastly, the method does not follow solar radiation on individual surfaces when it enters a zone and bulk air flow rates are determined between individual apertures (Marsh, 2006a).

CHAPTER 5

CASE STUDY

This chapter gives information about the case area located in Emlak Bank Mass Housing Area in Gaziemir, Izmir, Turkey, and compares the effects of single retrofitting scenarios with combination of these in terms of energy consumption. After a brief overview of the concept of mass housing in Turkey and the climatic features of Izmir, the chapter introduces the 15-year-old apartment block under investigation. Various retrofitting scenarios including the combinations of addition of extra thermal insulation, replacement of current window frames and glasses with energy efficient ones, reduction of air infiltration rate, and alteration of set point temperatures of zones, are then presented. Aside from the modeling, the effectiveness of retrofitting scenarios for energy efficiency is also investigated by using the Ecotect v 5.50 building energy analysis software on the basis of the energy load for heating and cooling it yielded. Typical climatic data for Izmir taken from Meteonorm, which is a global meteorological database for engineers, planners and for use in education, has been implemented in the modeling phase.

5.1. Concept of Mass Housing in Turkey

Housing has become an alarming problem stemming mainly from industrialization and urbanization attempts in southern countries. Existing urban housing stock has ceased to meet the rising demand in very numerous countries in the world, as a result of migratory movements from rural areas to cities in the course of industrialization. In this context, the concept of mass housing has come to the fore as a solution to the problem of shelter in Turkey (Taş, 2005).

Since 1970, governments of Turkey have given serious consideration to collective housing projects: mass housing has been proposed as the means to manage the low-cost housing deficit of large demographic segments living in urban sprawls (Özçelik, 1998). By 1984, the construction of mass housing was regulated by the 'Mass Housing Law' enacted on 3 March 1984 (Official Gazette no: 2985) in which social housing is described as affordable dwellings designed in accordance with living traditions and the social structure of the community, requiring minimum construction cost. The law proposes the establishment of a funding system serving both tenants of different income strata and contractors, and guarantees the provision of proper land for housing in the city (Baytın, 2000). It ought also be pointed out that mass housing dwellings in Turkey are owned by private tenants, thus buildings are not monitored by the government or government controlled private companies. Therefore, any retrofitting study must be afforded by the cooperation of tenants.

The current mass housing areas physically display the following typical features:

1. Residential area composed of high-rise buildings with multiple flats per storey and high residential density
2. Residential area in the periphery of the city
3. Buildings with type-plan organization
4. Buildings with reinforced concrete skeleton system and ordinary brick infill
5. Buildings in the residential complex including such service areas as playground areas, green areas, schools, commercial areas, healthcare and sports areas.

Bahçıvan (1994) offers an overview of the governmental and private institutions that seek to meet the national mass housing demand and lists them as, The Ministry of Reconstruction and Resettlements, Turkish Emlak Bank, TOKI, local governmental bodies, and private cooperatives. TOKI has been the main responsible governmental institution for the planning and construction of low-cost housing since 1990.

The case area selected for the thesis, Gaziemir Emlak Bank Mass Housing Area in Gaziemir, is one of the largest mass housing areas of Izmir located in the southern development axis of the city. The area was constructed in 1989-1995. The Turkish Emlak Bank, the initial title Emlak and Eytam, was first founded in 1926 as a governmental organization to support the development of capital in the real estate sector. It was transformed into The Turkish Emlak and Credit Bank in 1946. Özösken (1993) explains the basic tasks of Turkish Emlak Bank, defined by the law of Turkish Emlak Bank, as the establishment of the construction industry and development of the market for construction material, the supply and retail of low-cost residential buildings, the provision of credit with long period of payback, the establishment of insurance partnerships, and conducting bank activities. Among these objectives, Gaziemir Emlak Bank Mass Housing Area was constructed to provide adequate low-cost residential buildings for Izmir.

5.2. Climatic Features of the Case Area

The climate of Izmir is classified as Mediterranean with mild and semi-humid weather conditions: while winters are rainy and temperate, summers are hot and dry. The climatic data is collected in four meteorological stations located respectively in the city center and the east, north and south axes of the city (Table 5.1). The station in Güzelyalı has served Izmir as central meteorological station since 1938. The Bornova station on the campus at Ege University is usually utilized for scientific research of the university. The Çiğli Station is part of a military base. The last station, AMMS in Gaziemir, serves the International Adnan Menderes Airport. In the following part, climatic data including mean air temperature, relative humidity, and rainfall taken from AMMS is compared with climatic data taken from other three stations.

Table 5.1. Location and service time of meteorological stations in Izmir
(Source: İzmir Valiliği İl Çevre ve Orman Müdürlüğü, 2004)

Name of the Station	Service Time (Since)	Latitude	Longitude
Izmir (Guzelyalı)	01.01.1938	38º26'	27º10'
Bornova	01.01.1929	38º28'	27º13'
Çiğli	12.11.1949	38º30'	27º01'
AMMS	15.11.1987	38º16'	27º09'

5.2.1. Mean Air Temperature

The values of monthly mean air temperature remain above the annual averages between May and November. The average annual mean air temperature of Gaziemir is 16.5ºC (Table 5.2). Monthly mean air temperatures range from 6.7ºC to 27.9ºC. Lowest is in January and highest is in July. The second hottest month is August, with 27.8ºC. In addition, the observed highest temperature was in July 2000 with 42.6ºC. While the months of May, June, July, August, and September, whose total average temperature is

24.4 necessitate cooling alone, the months of January, February, March, April, October, November, and December necessitate heating alone and their total average temperature is 10.8ºC. This data indicates that the winter season in Gaziemir is not too cold. The observed lowest temperature was in January 1942 with -8.2ºC. The comparison of average monthly mean air temperature values in four districts indicates that Gaziemir is cooler in the winter season and warmer in the summer season than the others (Table 5.3).

Table 5.2. Average monthly mean air temperatures in AMMS based on climactic data 1987-2006

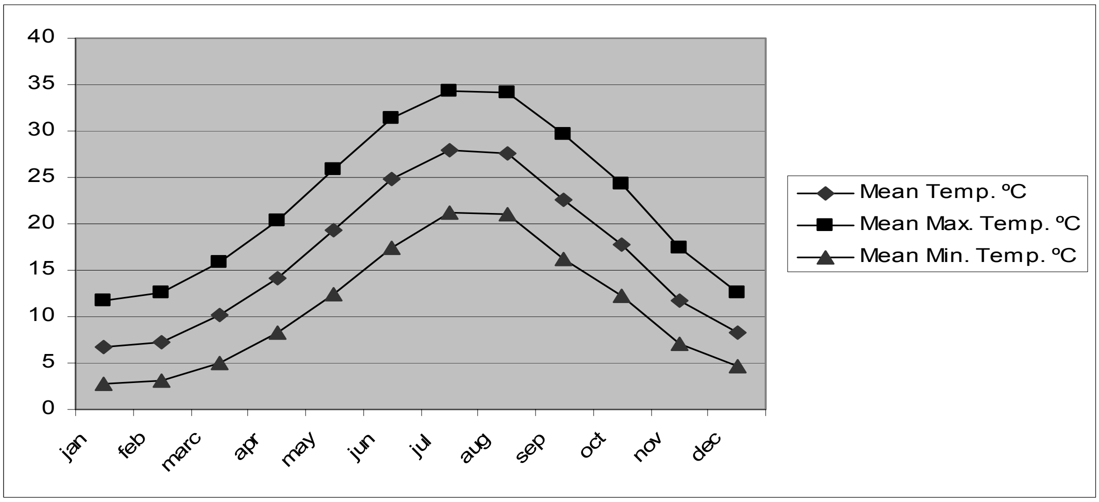
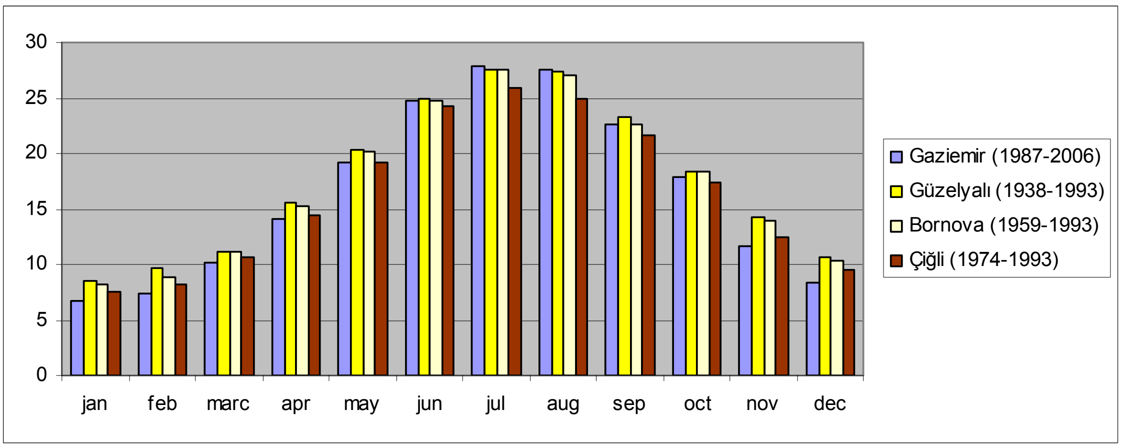


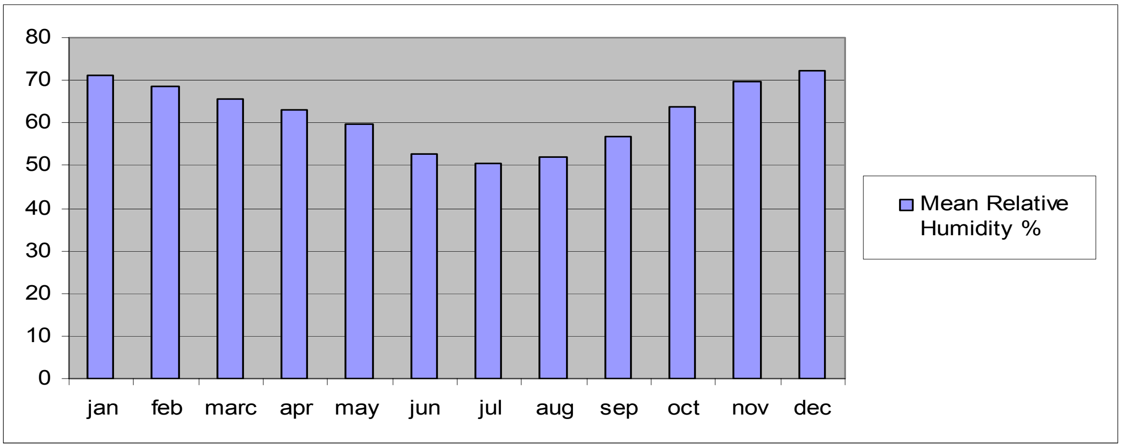
Table 5.3. Comparison of average monthly air temperature of Gaziemir, Güzelyalı, Bornova, and Çiğli



5.2.2. Relative Humidity

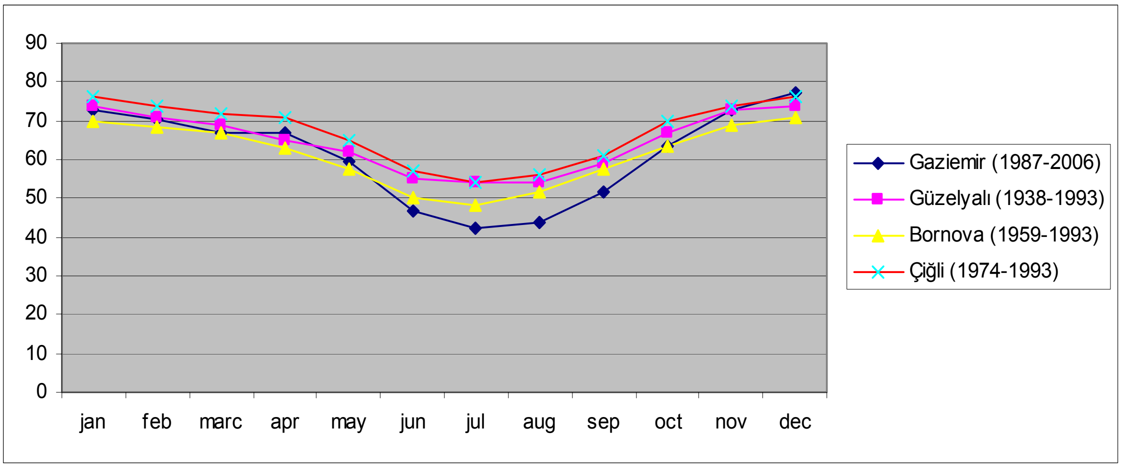
There is an inverse ratio between the values of relative humidity and mean air temperature. When the temperature becomes high, relative humidity is low. Thus the driest months are respectively July, August, and June with 42.2%, 43.9, and 46.7%, (Table 5.4). The average annual relative humidity is 65% in Gaziemir.

Table 5.4. Average monthly relative humidity values in AMMS, based on climactic data 1987-2006



The monthly average starts to increase by August and reaches 77% by December. The most humid months are respectively January and December measuring approximately 74% in Gaziemir. The comparison of average monthly relative humidity values of Gaziemir, Güzelyalı, Çiğli, and Bornova indicate that there are no big fluctuations among the four districts of Izmir (Table 5.5). The average relative humidity in July is 42.2% in Gaziemir, 48.1% in Bornova, and 54% in Güzelyalı and Çiğli.

Table 5.5. Comparison of average monthly relative humidity values of Gaziemir, Güzelyalı, Bornova and Çiğli



5.2.3. Rainfall

The average annual rainfall in Gaziemir is 56.3 mm and rainfall mainly occurs in the winter period. Winter months' rainfall annually averages 85%. December is the rainiest month of Gaziemir with 152 mm (Table 5.6). The summer is quite dry. The driest months are respectively June with 7 mm, July with 2.2 mm and August with 0.7 mm. In addition, Gaziemir is the rainiest district among the four districts of Izmir (Table 5.7).

Table 5.6. Average monthly rainfall in AMMS, based on climactic data 1987-2006

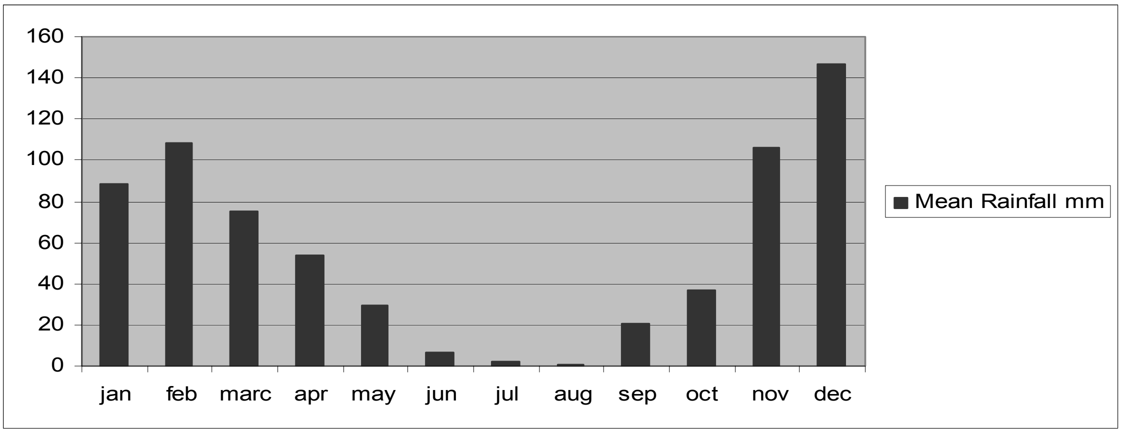
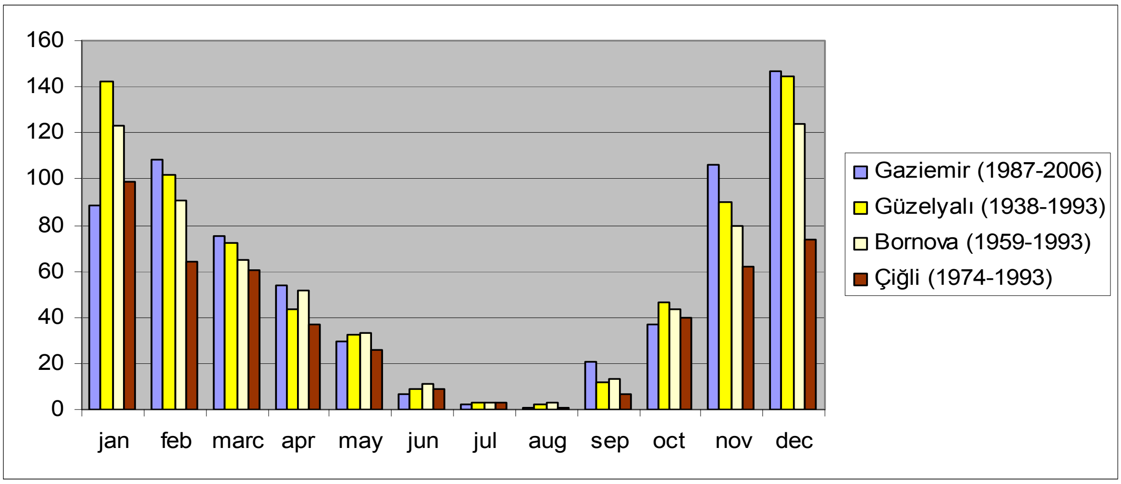


Table 5.7. Comparison of average monthly rainfall values of Gaziemir, Güzelyali, Bornova and Çiğli



5.2.4. Heating and Cooling Degree-Days

The degree-day method is used to calculate the annual energy demand of buildings (Bulut, Büyükalaca & Yılmaz, 2007). For heating, heating degree-days (HDD) can be calculated by applying the following formula:

$$HDD = (1\ day) \sum_{days} (Base\ temperature - Daily\ mean\ outdoor\ temperature)$$

For cooling, cooling degree-days (CDD) can be calculated in the same manner as that for heating degree-days:

$$CDD = (1\ day) \sum_{days} (Base\ temperature - Daily\ mean\ outdoor\ temperature)$$

Generally, 18°C is used as the base temperature for calculation of heating degree-days and 22°C for calculation of cooling degree-days. In this study, the heating and cooling degree-days for various districts of Izmir are determined by using the above formulas according to weather data between 1987 and 2006. Table 5.8 shows the total number of heating degree-days in Gaziemir (1167 HDD), Çiğli (1381 HDD), Bornova (1215 HDD) and Güzelyalı (1156 HDD) for each month. It is possible to observe that most energy for heating in Izmir is necessary for Çiğli.

Table 5.8. Comparison of monthly heating degree-days of Gaziemir, Güzelyali, Bornova and Çiğli

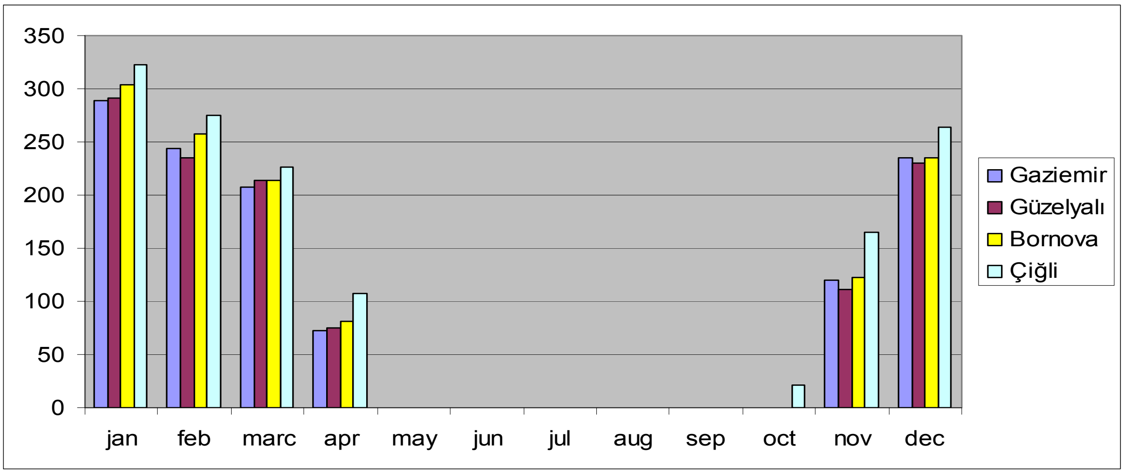
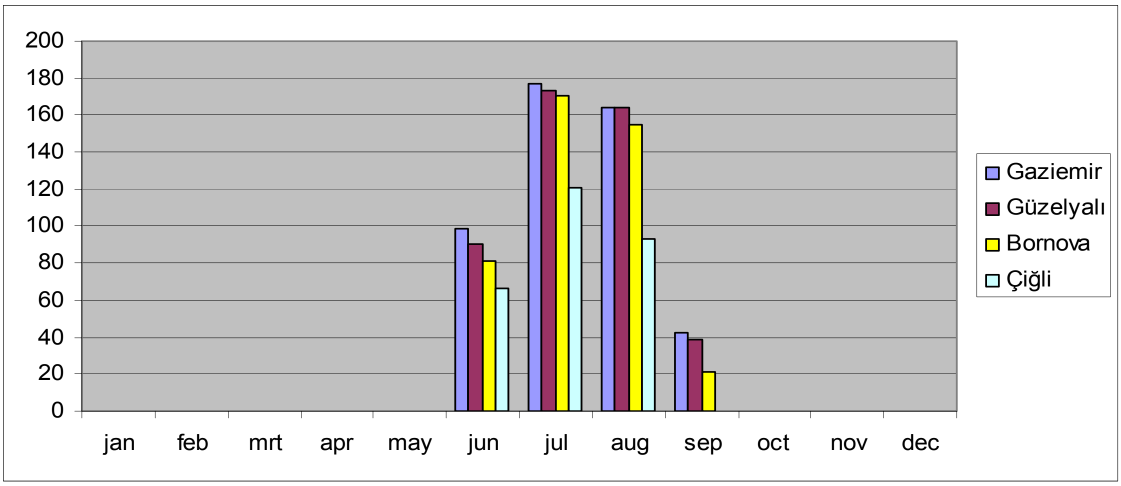


Table 5.9 indicates that outdoor temperature exceeds 22°C, the set point temperature in June, July, August and September. This fact implies that energy for cooling is necessary to reach thermal comfort in these months. It is very clear that Gaziemir consumes more energy for cooling than other districts of Izmir. Another important point is that energy for heating and cooling is not necessary in May and October except in Çiğli.

Table 5.9. Comparison of monthly cooling degree-days of Gaziemir, Güzelyalı, Bornova and Çiğli



5.3. Analysis of Emlak Bank Mass Housing Area

The Emlak Bank Housing is constructed as a mass housing complex in the municipality of Gaziemir in the southern development axis of Izmir almost 11.5 km from the city center (Figures 5.1, 5.2). The housing area is located in the south of Gaziemir, on the west side of the Izmir-Torbalı highway, and across from the Adnan Menderes International Airport. It is 97 m above sea level with a latitude of 38º18’ and longitude of 27º7’. The total surface area of the Emlak Bank Mass Housing area is 322,510 m^2. The area lies in the north-southerly direction. The Turkish Emlak Bank Mass Housing Project was planned for buildings in three steps between 1989 and 1995. It consists of apartment blocks, primary schools, trade centers, shops and one sports facility with swimming pool.

The first step was built on 134,464 m^2 of surface areas, which was started on 27 October 1989 and completed on 12 April 1991 spanning 18 months and consists of 2,347 apartment blocks, 12 shops, one primary education school, and trade center. There are three types of apartment blocks in this step. One of the types has one room with an area of 77-89 m^2. Another type has two rooms with an area of 100-113 m^2. Last type has three rooms with an area of 125-132 m^2.

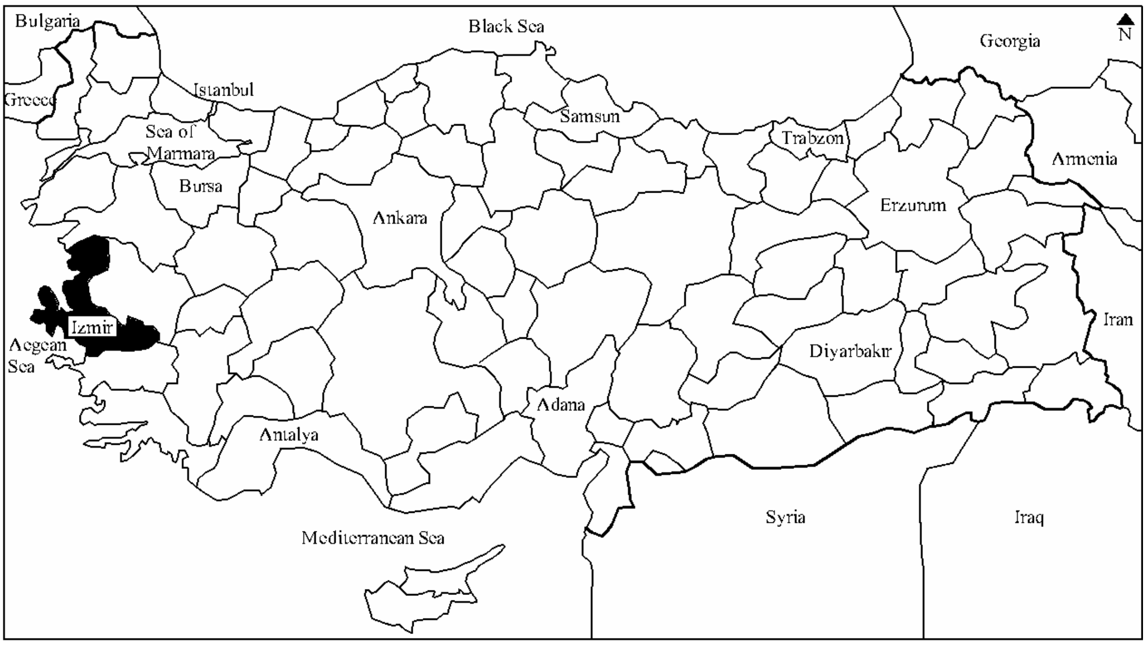


Figure 5.1. Location of Izmir on map of Turkey

Figure 5.2. Aerial view of Gaziemir Emlak Bank Housing Area
(Source: Google Earth)

Construction of the second stage started on 4 May 1993 and was completed on 28 February 1995 (138.443 m^2). This step consisted of 1.958 apartment blocks, one sports facility with swimming pool, kindergarten, one primary education school, and four trade centers. The apartment blocks were designed in three types: single-room with an area of 66-71 m^2; two-room apartment with an area of 80 m^2; three-room apartment with an area of 95 m^2.

The last stage was built on 49.603 m^2 surface areas between 1994 and 1995 within 15 months. It consists of only 960 apartment blocks designed in the three types: first type has one room with an area of 53-82 m^2; another type has two rooms with an area of 80 m^2; and third type has three rooms with an area of 95 m^2.

The apartment block with a building height of 17.74 m, located in the second step of development phase of the Gaziemir Emlak Bank Housing Area, was selected as the case study area. Designed by the architect Atilla Şenonca, the block carries five-storeys and ten flats with two flats/storey. The selected apartment block lies in the north-south axis, which allows for high solar exposure from east and west respectively in mornings and afternoons. Figure 5.3 indicates that the selected apartment block is a part of a housing group in Çağlar Sitesi, No. 6.

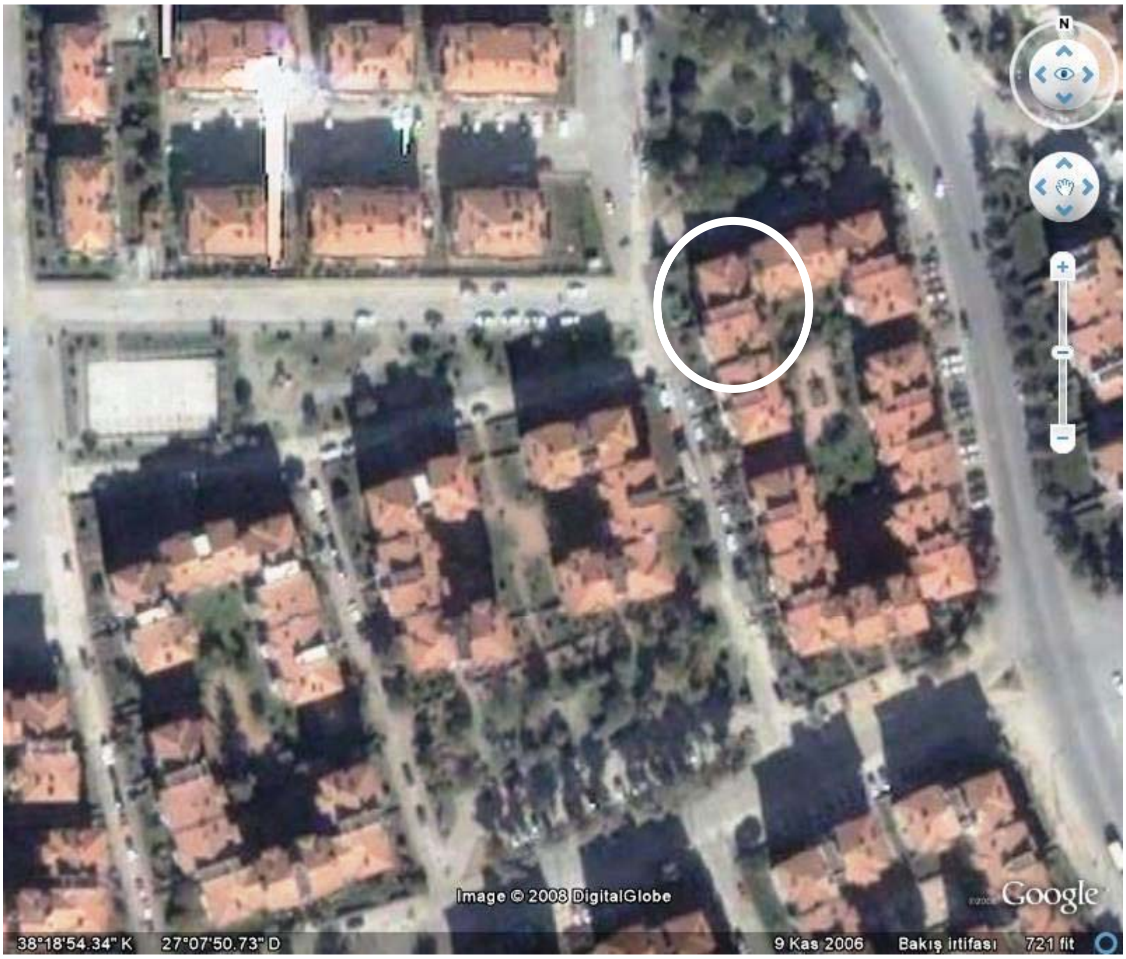


Figure 5.3. Aerial view of selected apartment block
(Source: Google Earth)

The sun path diagram of the case area indicates that the neighboring houses do not obstruct the sun exposures of the selected apartment block in the winter season (Figure 5.4). It means that the apartment block bears potential for taking greater advantages of the morning and afternoon sun throughout winter. However, this poses a disadvantage in the summer as solar radiation hits the apartment block directly. This causes overheating problems in all the zones of the building block.

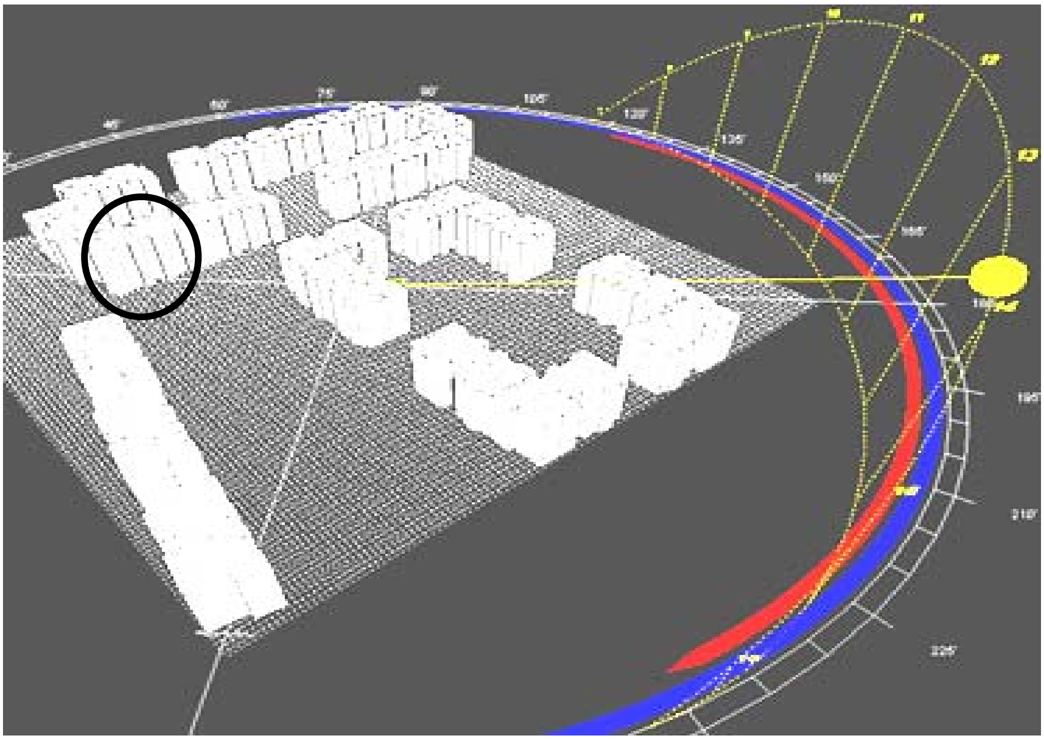


Figure 5.4. Sun path diagram of the case area with Ecotect v 5.50

The selected apartment block is constructed by tunnel formwork concrete construction system with a load transferring roof. The main structural parts are made of exposed reinforced concrete. The numerical information related to the apartment block is shown in Table 5.10. The apartment block consists of the basement and flat levels. The total area of flats is approximately 100 m^2. The basement contains the doorkeeper flat, shelters and storage space. Flats typically include a living room, kitchen, bathroom, WC and three bedrooms (Figure 5.5). Living room and kitchen, facing southwest, share a balcony providing shading in the summer time (Figure 5.6). The bathroom and bedroom on the northwest lie adjacent to the neighboring apartment block as may be observed in the detailed technical drawing of plans, sections and elevations of the apartment block shown in Appendix F (Figure 5.7). In addition, the bedrooms of the apartment block face the courtyard (Figure 5.8). The building is actively conditioned by the all-water central heating consuming coal and not cooling system.

Table 5.10. Numerical information related to selected apartment block

Shape	Rectangular (almost 22.5 m × 11 m)
Height	Five storey (17.74 m)
Heated Volume	2751 m³
External wall area	866.142 m²
Roof area	205,9 m²
Floor area	190.8 m²
Window area	80 m²

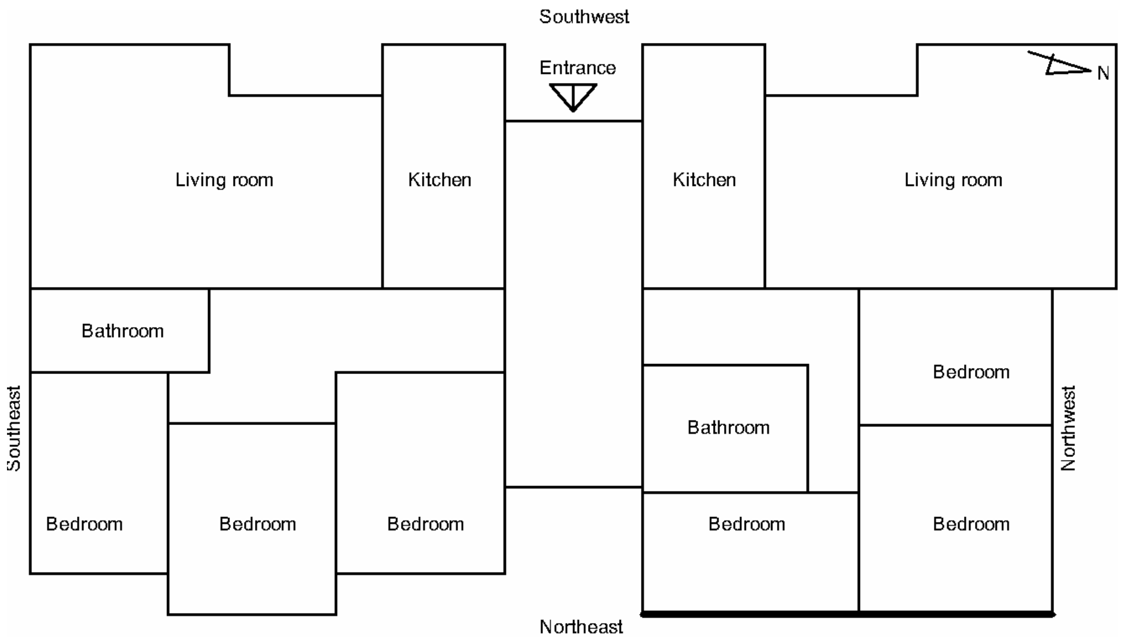


Figure 5.5. Distribution of spaces on floor plan

Figure 5.6. Southwest (entrance) façade of the apartment block

Figure 5.7. Diagonal view of southwest façade of the apartment block with perpendicular adjacent block to the northwest

Figure 5.8. Northeast façade of the apartment block facing the courtyard

It is essential to mention that in 1995 there was no regulation requiring the implementation of thermal insulation in buildings in Turkey. Nevertheless, the selected apartment block already had heating insulation in external walls, roof and ground floor (Table 5.11, 5.12, 5.13, 5.14, 5.15). For instance, external walls were, and still are internally insulated with styropor (EPS).

Table 5.11. Thermal properties of external wall

Layers of external wall	thickness (cm)	Thermal conductivity (W/m^2K)
Plaster stucco (inside)	0.5	0.300
Heraklit	0.5	0.120
Styropor	2	0.034
Heraklit	0.5	0.120
Reinforced concrete	13	1.8
U W/m^2K (existing)	1.1	
Proposed U W/m^2K (according to TS 825)	0.80	

Table 5.12. Thermal properties of attic floor

Layers of attic floor	thickness (cm)	Thermal conductivity (W/m^2K)
Whitewash (on the ceiling)	-	-
Reinforced concrete (floor)	14	1.8
Styropor	4	0.035
U W/m^2K (existing)	0.71	
Proposed U W/m^2K (according to TS 825)	0.50	

Table 5.13. Thermal properties of suspended floor over unheated spaces on the ground floor

Layers of suspended floor over unheated spaces the ground floor	thickness (cm)	Thermal conductivity (W/m^2K)
Plaster stucco (inside)	0.5	0.300
Heraklit	0.5	0.120
Styropor	2	0.034
Heraklit	0.5	0.120
Reinforced concrete	14	1.8
Levelling concrete	2	1.2
Topping coat	1	1.2
Mosaic tile	2	0.900
U W/m^2K (existing)	0.90	

Table 5.14. Thermal properties of slab on grade

Layers of slab on grade	thickness (cm)	Thermal conductivity (W/m^2K)
Mosaic tile	2	0.900
Levelling concrete	0.5	1.2
Water insulation	2	0.034
Reinforced concrete	14	1.8
U W/m^2K (existing)	1	
Proposed U W/m^2K (according to TS 825)	0.80	

Table 5.15. Thermal properties of suspended floor between flats

Layers of suspended floor between flats	thickness (cm)	Thermal conductivity (W/m^2K)
Carpeting	0.8	0.900
Levelling concrete	0.5	1.2
Reinforced concrete	14	1.8
Plaster stucco	0.5	0.300
U W/m^2K (existing)	0.50	

The thickness of insulation materials implemented in the selected apartment block is below the standards proposed by the TS 825-Thermal insulation in buildings. U values of building components for Izmir, for example, should be 0.80 for the outer wall, 0.50 for the attic floor, 0.80 for slab on grade, and 2.8 for windows. Therefore, the available insulation is inadequate to halt energy losses in the heating season. TS 825-Thermal insulation in buildings limits the consumed energy for heating in buildings by proposing adequate insulation thickness for building components. Briefly, the evaluation of the thermal performance of the selected apartment block in the winter season shows that the current insulation level is inadequate given its thickness. User-friendly software prepared by İZODER to facilitate the calculations required by TS 825 norms, is employed to calculate limited energy for heating demand based on TS 825 (see Appendix G). The results taken from İZODER's software indicate that the building with existing constructional features does not meet TS 825 norms. In other words, while limited energy for heating demand of the existing apartment block according to TS 825 norms is 50.29 kWh/m^2, calculated energy for heating need of the apartment block is 96.59 kWh/m^2.

The thermal images of the selected apartment block are a case in point (Figures 5.9, 5.10, 5.11). They visualize the surface temperature differences on the outer walls indicating briefly the location and distribution of places losing energy through surfaces. Thus the images enable a combination between surfaces with and without insulation in terms of energy losses. The yellowish colored surfaces on the thermal images show the higher surface temperatures. Figure 5.9 proves that there is excessive energy loss through walls in spite of the insulation by the inner surface.

The openings, especially windows, moreover, are essential with heat gains in the summer period and heat losses in the winter period. In the selected apartment block, windows are made of PVC frame with single clear glass whose U value is 4.30 W/m^{2}K.

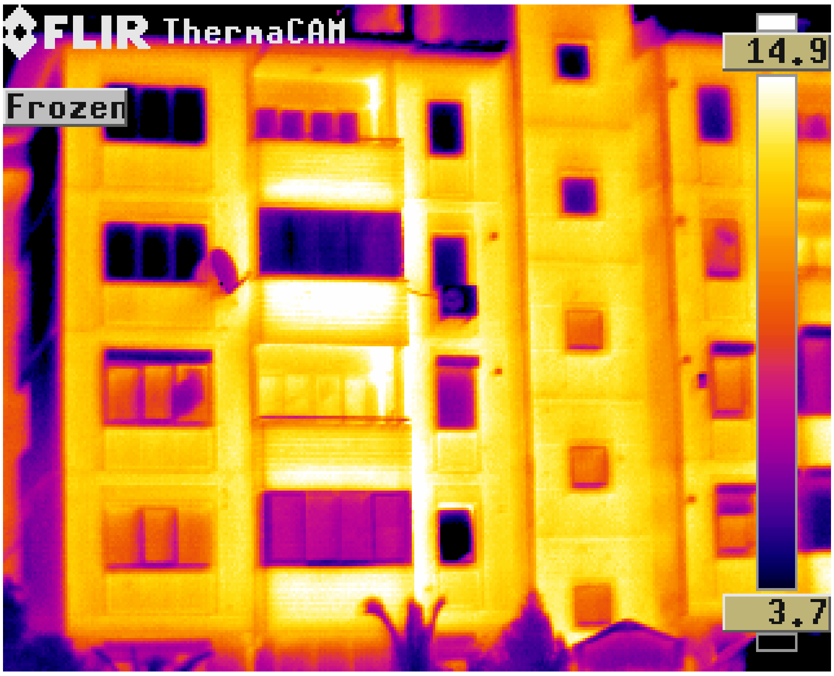


Figure 5.9. Thermal image: southwest (entrance) façade of the apartment block (16.03.2008)

Figure 5.10. Thermal image: northwest façade of the apartment block (16.03.2008)

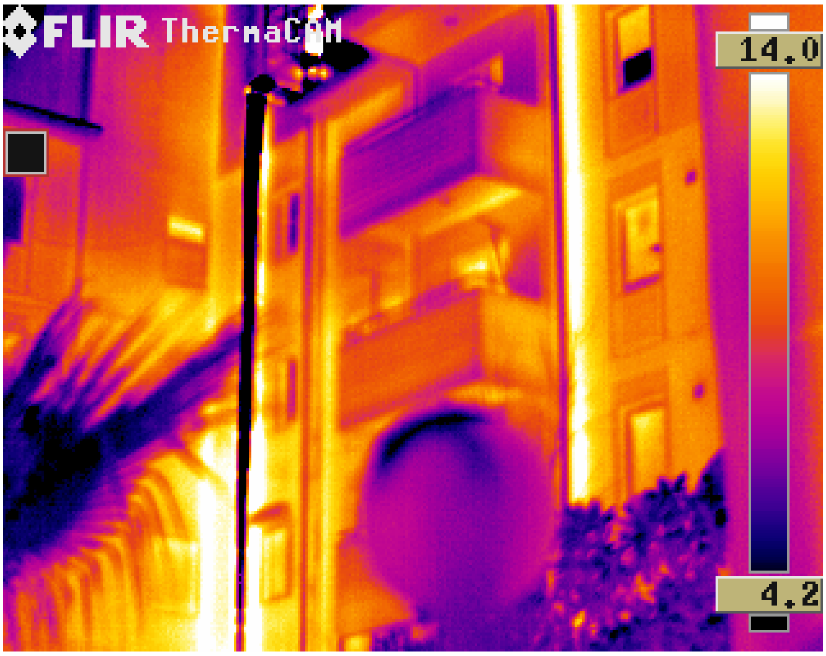


Figure 5.11. Thermal image: northeast façade facing courtyard of the apartment block (16.03.2008)

In each flat, there is a large living room window facing the southwest. There are no windows or any other kind of openings on the southeastern façade of the apartment block with the result that, each storey the flat lying on the southeast receives solar radiation through the southwest and northeast. There are no windows or any other openings on that section of the northeastern façade of the apartment block corresponding to the external wall of the flat lying on the northwest of a storey. These flats receive solar radiation through the northwest and southwest alone (Table 5.16). As the situation described above important to this research, let us observe the above once again in a diagram (Figure 5.5).

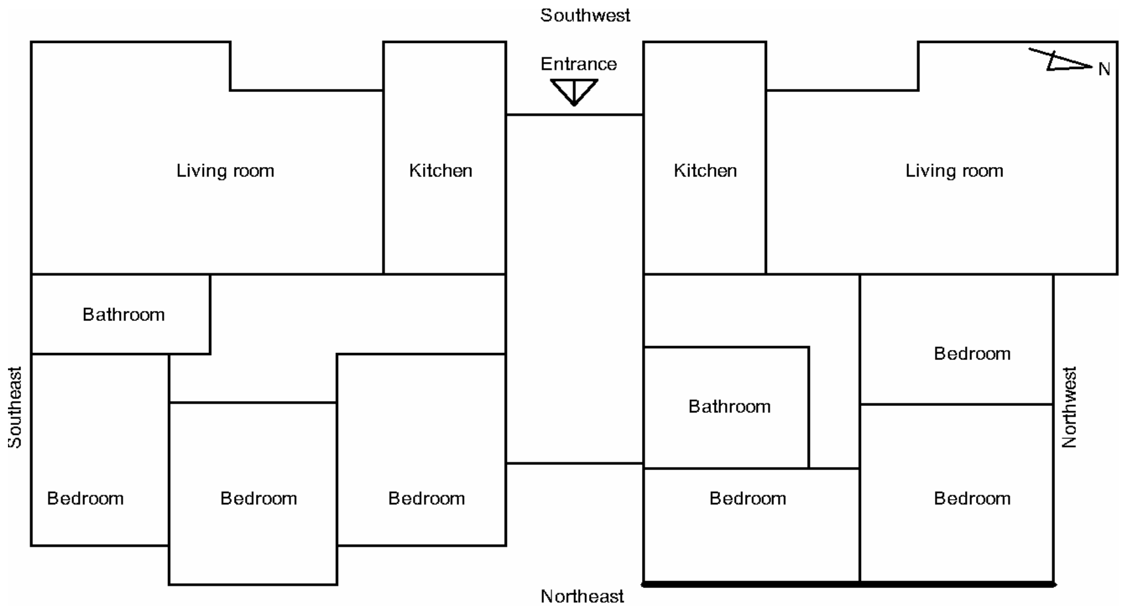


Figure 5.5. Distribution of spaces on floor plan

In addition, the bedrooms have small windows and every space within a flat has only one window. Glazing : floor area ratio per flat is approximately 8.5% in the apartment block. However, adequate glazing area is an essential parameter for passive use of solar gain for heating and daylight penetration for illumination of buildings. This ratio is low in the case building with 8.5%, while 12-15% is suitable for similar temperate climates (Bilgiç, 2003).

Table 5.16. Number and size of windows in the selected apartment block

Size / Orientation	0.90 x 1.25=1.125m^2	1.50 x 1.25=2.25m^2	2.25 x 1.25=2.81m^2
Southwest	2	-	2
Southeast	-	-	-
Northwest	-	1	-
Northeast	1	2	-
Total	3	3	2

5.4. Simulation of the Selected Apartment Block

The aim in simulating the selected apartment block is to show and evaluate effects of retrofitting scenarios on total energy consumption in the virtual environment. Therefore, the thermal performance interface of Ecotect v 5.50, building energy analysis software, has been prepared for the simulation of selected apartment block. This has made possible to assess the thermal performance of the apartment block before and after retrofitting.

The simulation process consisted of three steps. Firstly, two groups of data files, weather data of Gaziemir and the building design features of the apartment block were analyzed and adapted to Ecotect v 5.50. The following assumptions were made on the latter in order to obtain efficient and correct results from the software:

1. The projection on the second floor of the southwest façade has not been taken into consideration in the modeling phase owing to the fact that this very local projection comprised discontinuity on the exterior insulation. It could therefore not figured in the model.
2. The complex tilted and triangular surfaces of the roof are described as simple equivalent surfaces with their current orientation and tilt.
3. The fenestration components are described with their dimensional material disregarding the window frame.
4. Consideration of the internal load components such as people, lights and equipment was not included as specification of such for residences per one day or week in the kind of exactitude required by the software was not obtainable.
5. The U value of internal doors has a negligible influence on total energy consumption. Thus it was not considered.
6. The size and structure of the modeled building were kept as the same as before the retrofitting phase.

As a second step, the model of the existing situation was constructed by dividing the apartment block vertically into three major zones as ground, middle and top floors in order to observe different thermal behaviors of floors (Figure 5.12). It was assumed that additional losses occurred through the roof on the top floor and through the unheated spaces in the ground floor. These three major zones were then laterally divided into sub-zones according to function and location of spaces, e.g. as living room, WC, kitchen, etc. in any storey of the apartment block (Figure 5.13).

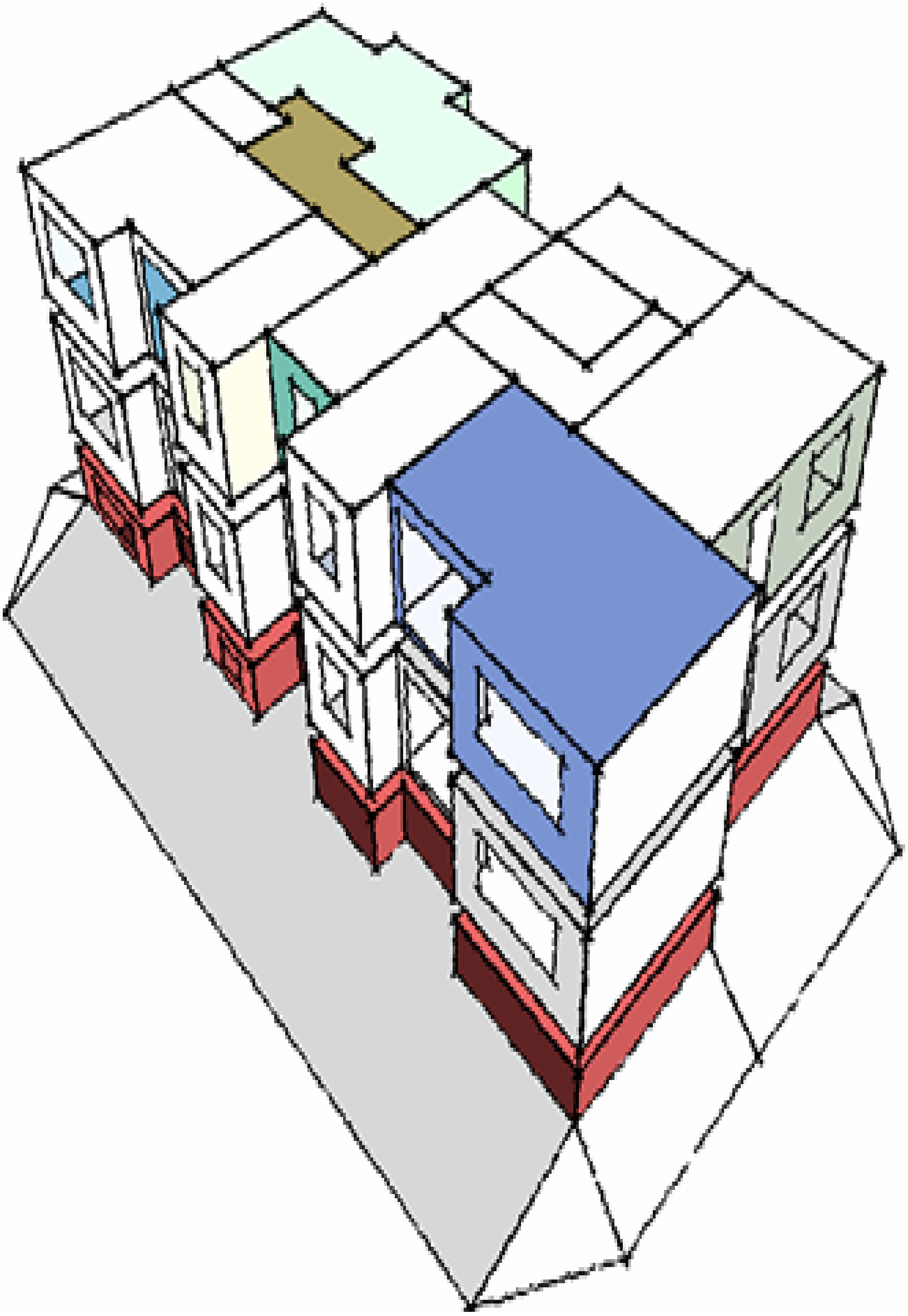


Figure 5.12. 3D major zone configuration of selected apartment block drawn in Ecotect v 5.50

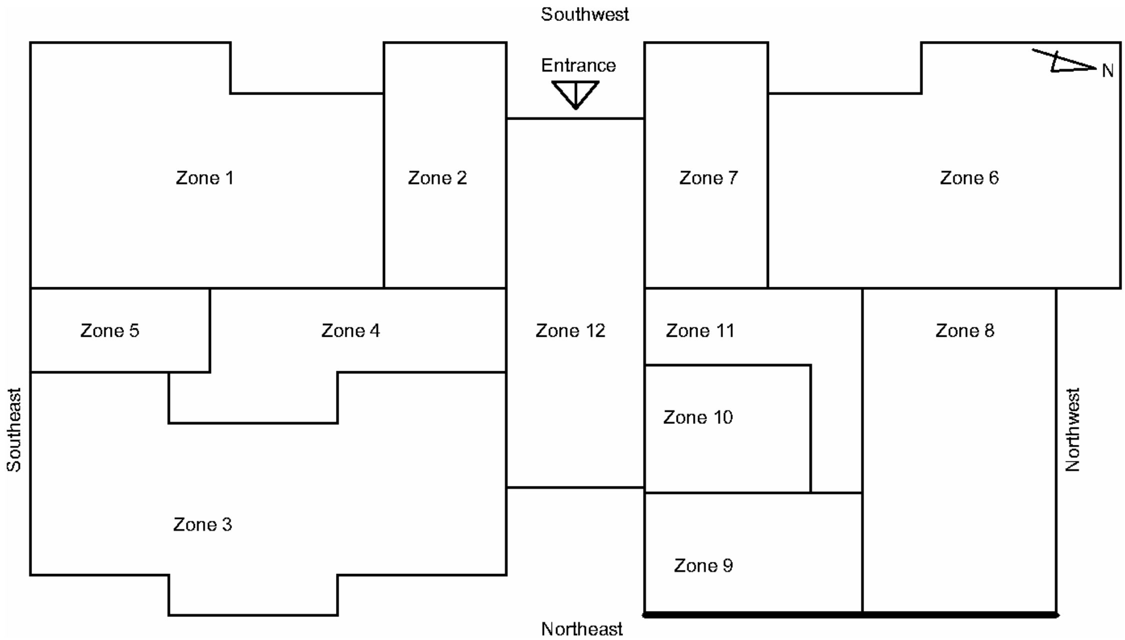


Figure 5.13. Distribution of zones in a storey of selected apartment block

The existing apartment block has a central heating system fueled by coal and private cooling applications. In other words, each lateral zone is regularly heated but randomly and rarely cooled. For that reason, it is accepted that regular cooling is necessary the zones 1, 3, 6, 8, and 9, since these zones make up places such as the living room and bedroom where the main portion of the interior life takes place. Set point temperature for heating and cooling are determined as 20ºC (running time: all day) and 26ºC (running time: 9am-12pm) linking with 55% relative humidity in simulation. According to the Local Environment Committee of the Governorship of Izmir (2006), set point temperature should be 20ºC for indoor heating in residential buildings but there is no limitation for humidity and cooling set point temperature.

Orientation, shape, thermal properties of building components, internal loads and internal climatic conditions affect the thermal performance of a building (Tavil, A., Sahal, N & Özkan, E, 1997). In this context, all properties of the selected building in Ecotect v5.50 are specified, with respect to the location of the apartment block, as latitude, longitude, time zone and orientation, the zone properties of the apartment block in terms of set point temperature, air infiltration rate, and humidity, the physical properties and orientation of the building, shading like balconies, and properties of the materials which are used in the building components.

Various retrofitting scenarios were defined. Main objectives of these scenarios were the following;

1. Reduction of heat loss through the building envelope by insulating the external walls, floors in unheated zones, and roof,
2. Reduction of heat loss through windows and doors by replacing these with energy efficient ones,
3. Reduction of infiltration rate,
4. Regulation of indoor set point temperature in different zones.

5.5. Simulation of Retrofitting Scenarios

The following part of this thesis introduces the simulation of retrofitting scenarios, derived from the 13 projects conducted in the scope of Altaner, EI-EDUCATION, and EuroACE programmes in the EU countries, as explained in Chapter 2. A total of 18 scenarios are examined by the Ecotect v 5.50: 15 of them are structured as a single parameter, i.e. single retrofitting scenario, under four main retrofitting options:

1. The improvement on the building envelope with thermal insulation,
2. The improvement on the openings with energy efficient window,
3. The change in air infiltration rate,
4. The change in set point temperature.

This simulation phase in the process of modeling is very significant for defining the scenarios that have the greatest potential for reducing the apartment block's energy demand. It is also useful for tenants and contractors to follow the effect of replacing or adding a single component. The rest of the retrofitting scenarios are set as the various combinations of four main retrofitting options to investigate the range of potential energy reductions. The retrofitting scenarios are simulated for both heating and cooling seasons, and presented separately in the form of excel sheets. Here the seasonal energy load (kWh/m^2), i.e. energy consumption for heating or cooling, is tabulated for both the actual condition and proposed scenarios in the same excel sheet.

5.5.1. Assessment of Retrofitting Option 1: The Improvement on the Building Envelope with Thermal Insulation

The envelope is the skin of the building reacting to indoor and outdoor climatic conditions (Givoni, 1976). Its thermo-physical properties are determinant in heating gains and losses (Kutlu, 1999). The amount of heat gain and loss depends on conductivity, surface conductance, temperature differences between outdoor and indoor, and thickness of materials (Gut & Ackerknecht, 1993). The total heat transmitted through warmer to cooler spaces is represented with U value.

In this phase, various retrofitting scenarios are developed to reduce heat losses from the external wall, roof and floor over unheated spaces. In other words, U values of these building components are reduced by adding an extra thermal insulation layer. The external walls of the selected apartment block are already insulated on the inner surface. Yet the insulation is more than 10 years old and displays condensation, and thus a fungus problem, because the interior insulation performs as a damp barrier. The condensation problem is usually seen on walls insulated on the inner surface and when the latter is implemented without vapor barrier. Therefore, condensation analysis was made for the external walls using TS 825 software taken from İZODER. As a result of the analysis, it was demonstrated that condensation occurred between insulation material and wall surface as shown in Figure 5.14. For that reason, it is assumed that the external wall requires simple improvements in the building envelope. To prevent this problem, vapor barrier should be applied on the warm side of the wall. Another means of prevention would be by applying a layer on the cold side. However, this solution may be applied only during the initial construction of the building when applying thermal insulation on the wall. Thus, the condensation problem for our apartment block can be solved by applying extra insulation on the wall. When extra insulation is, the condensation problem is found to disappear. For that reason, it is assumed that simple improvements in the building envelope are required (Figure 5.15).

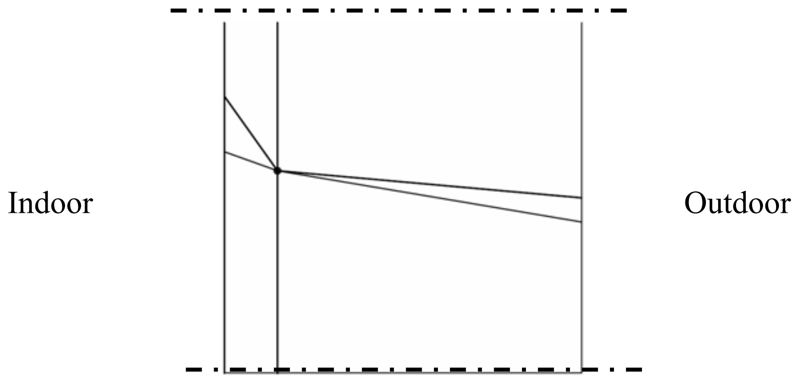


Figure 5.14. Condensation graph for actual condition
(source: TS 825 software)

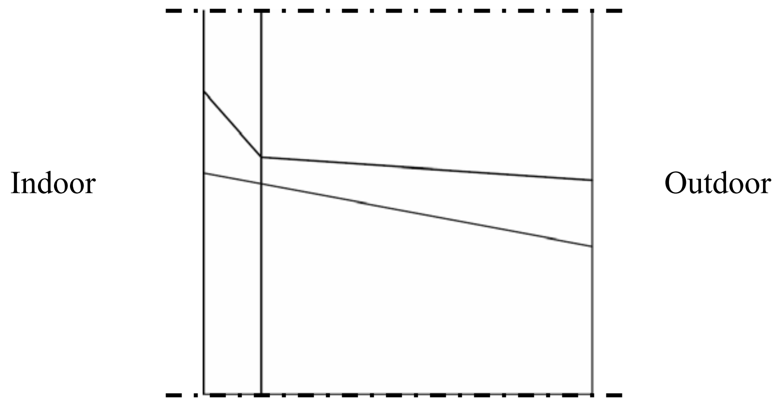


Figure 5.15. Condensation graph after application of extra insulation
(source: TS 825 software)

The insulation material selected was Extruded Polystyrene (XPS). It is the most commonly used insulation material after mineral wool and expanded polystyrene (EPS) in Turkey (Society of Polystyrene Manufacturers, nd.). Its technical properties are presented in Table 5.17.

Table 5.17. Technical properties of XPS
(Source: TS 825 & Akıncı, 2007)

Density (kg/m^3) TS 825	>20
Thermal Conductivity (W/m^2K) TS 825	0.031
Compression Strength at 10% deformation (kg/cm^2) (DIN 53121)	0.15-3
Water Absorption Capacity (%)	0.1
Water Vapor Diffusion Resistance Coefficient (DIN 52615) (μ)	80/150-100/200
Building Material Classification (DIN 4102)	B1 (Hardly Flammable)

As can be seen in Table 5.17, thermal conductivity of XPS is 0.031 W/m^2K (>20kg/m^3) in TS 825. Therefore, this value is accepted during the entire calculation process. For walls, 30, 50 or 80 mm external insulation layer (XPS) is added as these dimensions comprise the measure to protect from condensation on walls. For roof and floor over unheated spaces, 50, 80 or 100 mm insulation layers (XPS) were analyzed. The existing insulation layer (EPS) on the roof was replaced by new insulation. In addition, a new insulation layer was applied below the basement floor, replacing the existing one. Every improvement was evaluated separately for the ground floor, middle floor and top floor.

List of the scenarios relating to thermal insulation starting from the non-insulated condition of the apartment block are the following:

- Case 0.a: Ground floor—no insulation
- Case 0.b: Middle floor—no insulation
- Case 0.c: Top floor—no insulation
- Case 1.a: Ground—existing
- Case 1.b: Middle floor—existing
- Case 1.c: Top floor—existing
- Case 2.a: Ground floor—3 cm xps for wall
- Case 2.b: Middle floor—3 cm xps for wall
- Case 2.c: Top floor—3 cm xps for wall

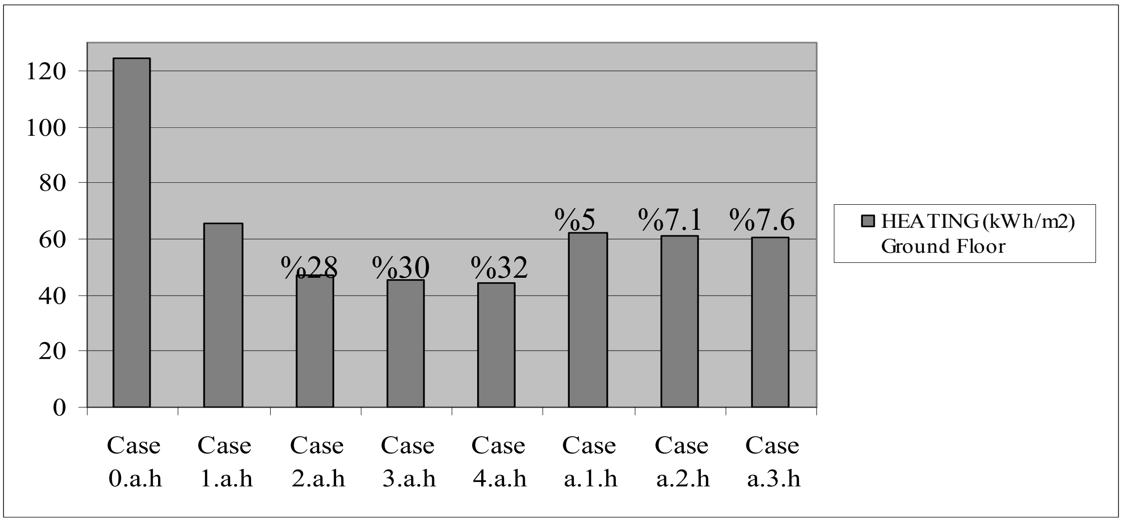
- Case 3.a: Ground floor—5 cm xps for wall
- Case 3.b: Middle floor—5 cm xps for wall
- Case 3.c: Top floor—5 cm xps for wall
- Case 4.a: Ground floor—8 cm xps for wall
- Case 4.b: Middle floor—8 cm xps for wall
- Case 4.c: Top floor—8 cm xps for wall
- Case a.1: Basement floor—5 cm xps for unheated surface
- Case a.2: Basement floor—8 cm xps for unheated surface
- Case a.3: Basement floor—10 cm xps for unheated surface
- Case c.1: Top floor—5 cm xps for roof
- Case c.2: Top floor—8 cm xps for roof
- Case c.3: Top floor—10cm xps for roof

In the flowing part, results of the determined scenarios are presented.

Heating Consumption on the Ground Floor

By the application of extra insulation on the external walls of the ground floor, it is possible to save annually 28.95% energy with case 2.a.h; 30.80% energy with case 3.a.h, and 32.30% energy with case 4.a.h compared to actual condition 1.a.h (Table 5.18). With another application of insulation over unheated spaces of the ground floor, it is possible to save annually 5.22% energy with case a.1.h; 7.11% energy with case a.2.h, and 7.68% energy with case a.3.h compared to actual condition1.a.h. As a result, the energy saving value of applying insulation over unheated spaces is lower than that of walls. However, almost 6% annual energy reduction was achieved by adding thermal insulation over unheated surface.

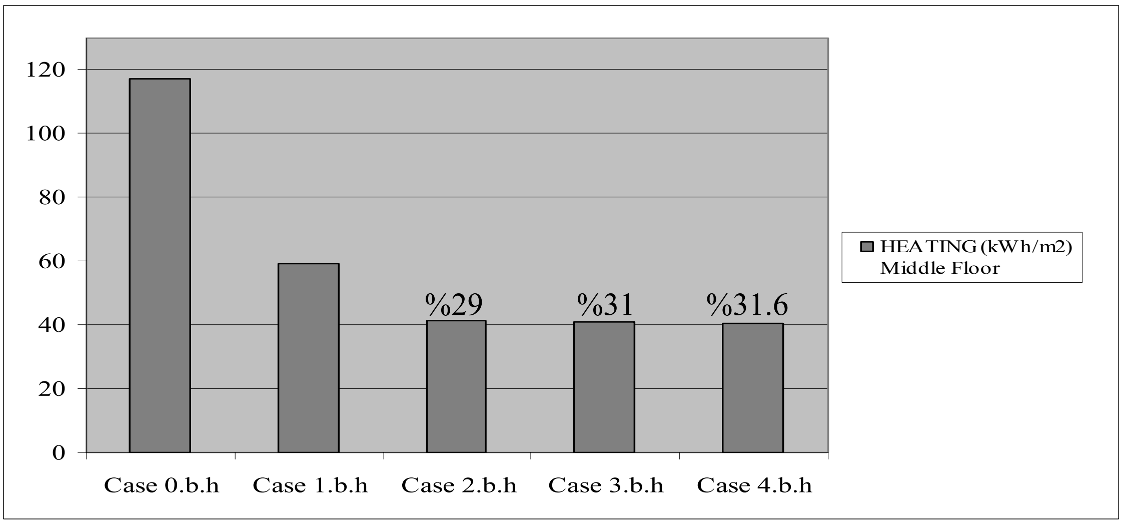
Table 5.18. Heating consumption on the ground floor



Heating Consumption on the Middle Floor

By the application of extra insulation on the external walls of the middle floor, it is possible to save annually 29.74% energy with case 2.b.h; 31.06% energy with case 3.b.h, and 31.60% energy with case 4.b.h compared to actual condition 1.b.h (Table 5.19).

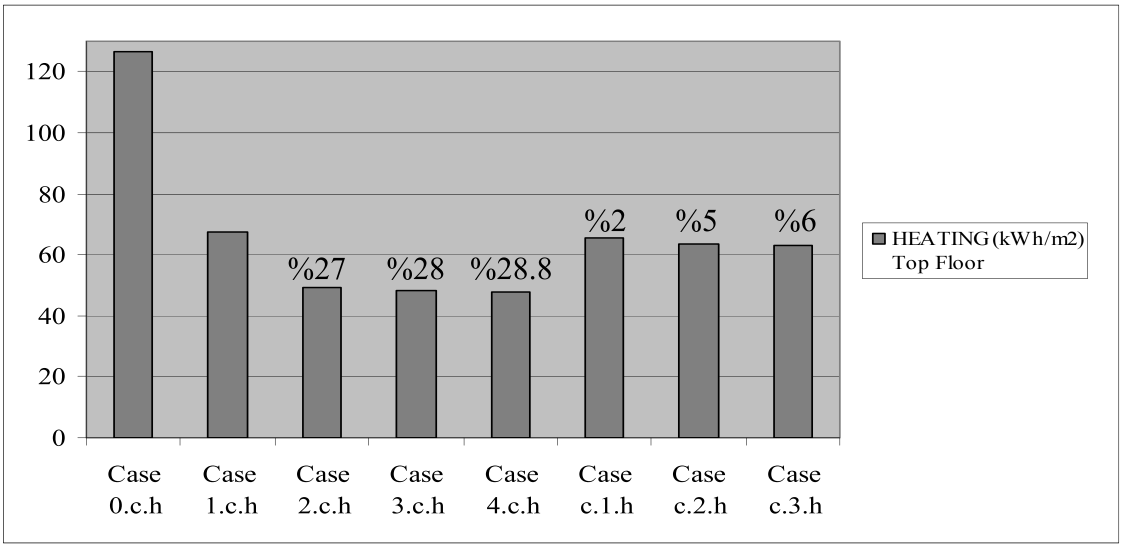
Table 5.19. Heating consumption on the middle floor



Heating Consumption on the Top Floor

By the application of extra insulation on the external wall of the top floor, it is possible to save annually 27.12% energy with case 2.c.h; 28.31% energy with case 3.c.h, and 28.83% energy with case 4.c.h compared to actual condition 1.c.h (Table 5.20). With another application of insulation on roof of the top floor, it is possible to save annually 2.91% energy with case c.1.h; 5.71% energy with case c.2.h, and 6.69% energy with case c.3.h compared to actual condition 1.a.h.

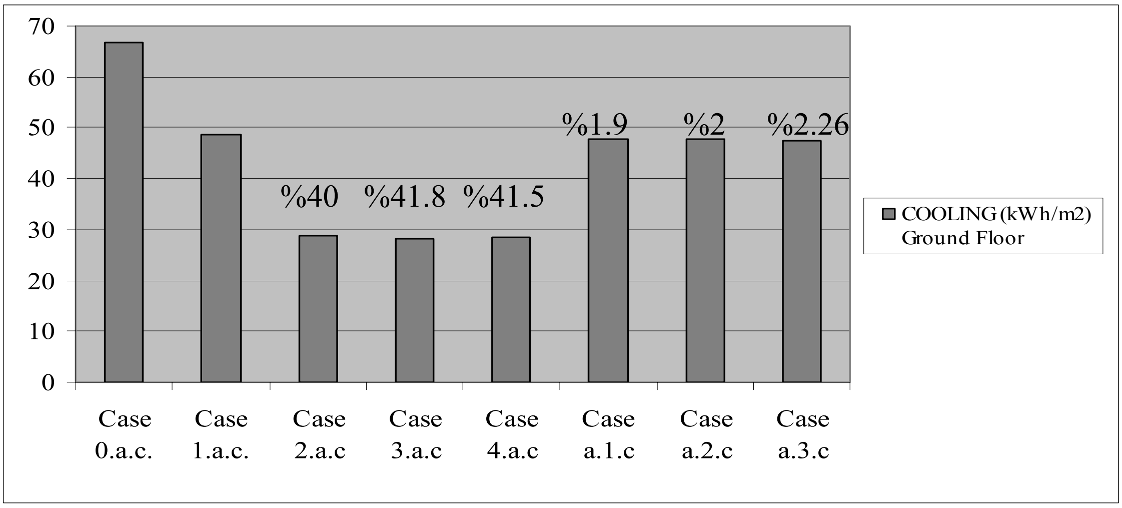
Table 5.20. Heating consumption on the top floor



Cooling Consumption on the Ground Floor

By the application of extra insulation on the external walls of the ground floor, it is possible to save annually 40.97% energy with case 2.a.c; 41.80% energy with case 3.a.c, and 41.67% energy with case 4.a.c compared to actual condition 1.c.h (Table 5.21). With another application of insulation over unheated spaces of the ground floor, it is possible to save 1.95% energy with case a.1.c; 2.05% energy with case a.2.c, and 2.26% energy with case a.3.c compared to actual condition 1.a.c.

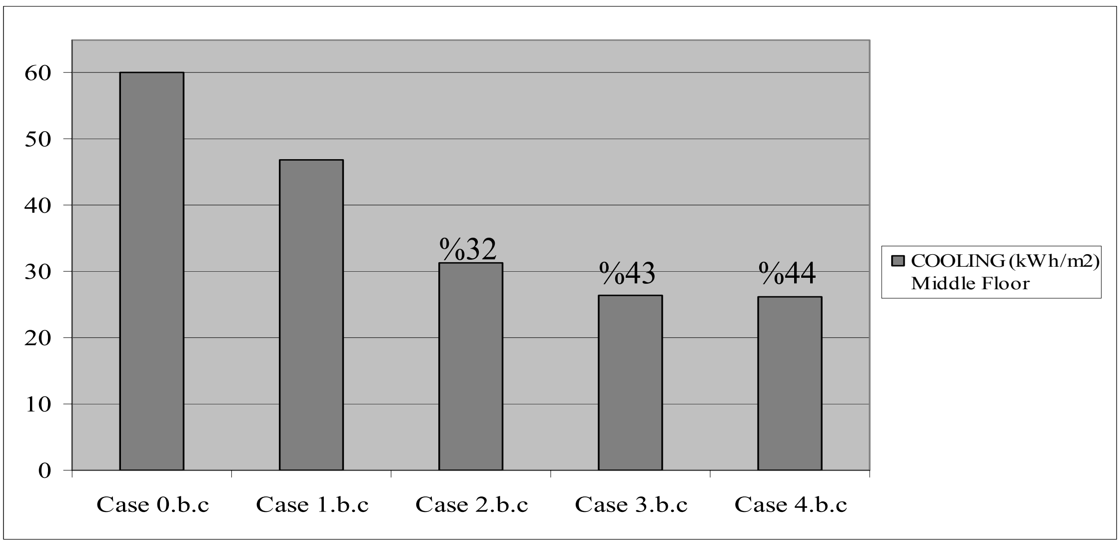
Table 5.21. Cooling consumption on the ground floor



Cooling Consumption on the Middle Floor

By the application of extra insulation on the external walls of the middle floor, it is possible to save annually 32.41% energy with case 2.b.c; 43.80% energy with case 3.b.c, and 44.18% energy with case 4.b.c compared to actual condition 1.b.c (Table 5.22).

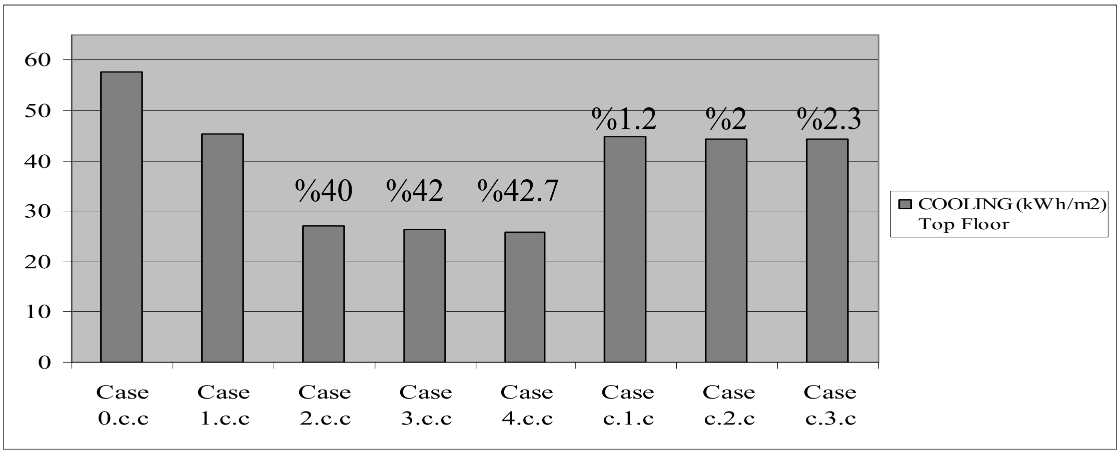
Table 5.22. Cooling consumption on the middle floor



Cooling Consumption on the Top Floor

By the application of extra insulation on the external walls of the top floor, it is possible to save annually 40.49% energy with case 2.c.c; 42.19% energy with case 3.c.c, and 42.76% energy with case 4.c.c compared to actual condition 1.c.h. With another application of insulation on the roof of the top floor, it is possible to save annually 1.23% energy with case c.1.c; 2.02% energy with case c.2.c, and 2.31% energy with case c.3.c compared to actual condition 1.c.c (Table 5.23). In addition, the effect of insulation thickness on cooling load of May and September is presented in Appendix H.

Table 5.23. Cooling consumption on the top floor



5.5.2. Assessment of Retrofitting Option 2: The Improvement on the Openings with Energy Efficient Windows

Windows have important functions such as providing visual and auditory contact between indoor and outdoor space, natural day lighting and ventilation to indoor spaces of buildings. In other words, they make up a kind of passive solar heating and cooling system (Givoni, 1998). According to size and type, they allow large heat gain and losses. For that reason, they affect directly the amount of energy consumption in buildings (Şenkal, 2005). As a result, the thermal resistance of windows is exceedingly important and can be improved to a maximum of energy saving function by applying energy-efficient glazing units such as low-e glass (Kaklauskas, Zavadskas, Raslanas, Ginevicius, Komka & Malinauskas, 2006). Another important point for windows is the selection of a suitable glazing type because heating and cooling loads in buildings are changeable based on climatic conditions and internal gains such as people, lighting, etc. For that reason, the definition of suitable criteria to evaluate thermal properties of windows is necessary. These criteria may be summarized as:

1. Thermal conductivity (U-value): quantity of heat transfer through conduction, convection, and radiation. When U-value decreases, rate of heat transfer is reduced.
2. Solar heat gain coefficient (SHGC): shows the heating gain from the sun. This value varies between 0 and 1. If it is closer to 0, heat gain from the sun decreases. In contrast, if it is closer to 1, heat gain from the sun increases.
3. Daylight index (D_x): ratio of the lighting transmittance in viewable range to the shading coefficient. Limit ratio for day lighting is 1.0 (Ayçam & Utkutuğ, 1999).

In view of the summarized criteria, properties of the selected glazing types are shown in Table 5.24. In addition, existing windows are made of PVC and single glass and also window frames are not changed with retrofitting scenarios.

Table 5.24. Thermal performance values of glazing used in simulation
(Source: Şişecam, 2005)

Glass Type	U-Value	SHGC	D_x	Thickness (mm)
Single Glass (actual condition)	5.1	0.94	1	6
Double Glass	2.8	0.69	0.78	6+12+6*
Double Glass with Special Coating	1.7	0.48	0.70	6+12+6**

*6 mm exterior pane + 12 mm air filled cavity + 6 mm clear glass interior pane
**heating and solar control coating on second surface of the 6 mm exterior pane

In Izmir, cooling is more important than heating due to climatic features. In other words, windows are exposed to more solar radiation during the cooling season. To block the negative effect of the sun in summer, SHGC ratio of glazing should be kept low. For that reason, double glass with special Coating, widely known in Turkey by the prominent manufacturer name of Isıcam Konfor, which has small heat gain ratio, has been assessed for the retrofitting scenario. At the same time this kind of double glass has very low U value compared with others. Thus, it is better for winter.

List of the cases relating to glazing are the following:

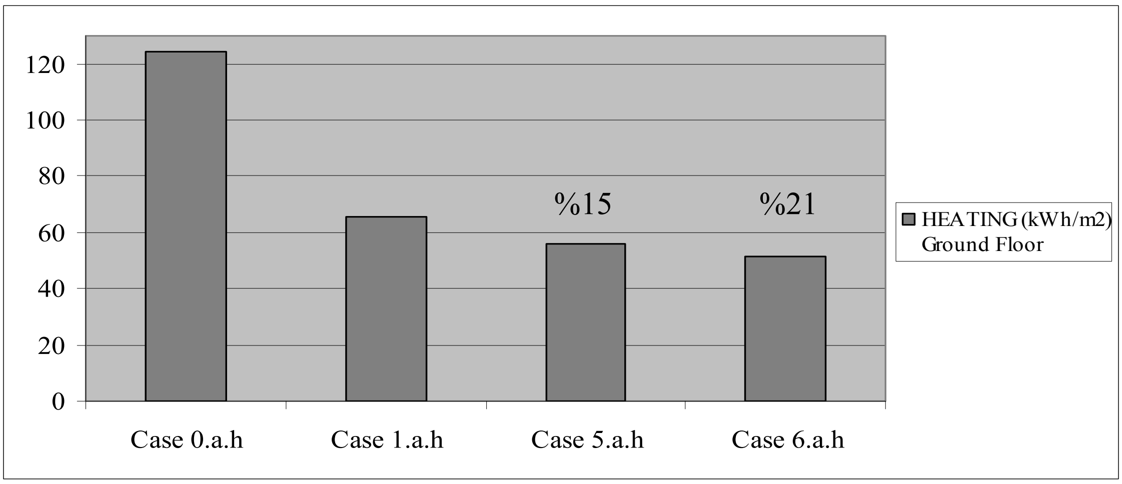
- Case 5.a: Ground floor—double glazing
- Case 5.b: Middle floor—double glazing
- Case 5.c: Top floor—double glazing
- Case 6.a: Ground floor—double glass with special coating
- Case 6.b: Middle floor—double glass with special coating
- Case 6.c: Top floor—double glass with special coating

In the flowing part, results of the determined scenarios are shown.

Heating Consumption on the Ground Floor

By replacing the existing glazing with double glass and double glass with special coating on the ground floor, it is possible to save annually 15.06% energy with case 5.a.h and 21.32% energy with case 6.a.h compared to actual condition 1.a.h (Table 5.25).

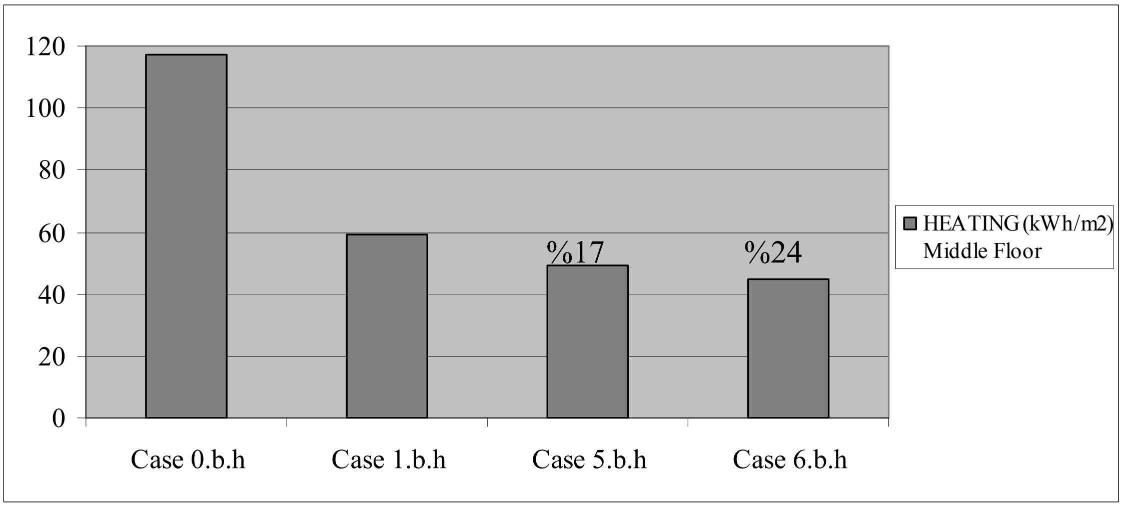
Table 5.25. Heating consumption on the ground floor



Heating Consumption on the Middle Floor

By replacing the existing glazing with double glass and double glass with special coating on the middle floor, it is possible to save annually 16.96% energy with case 5.b.h and 24.35% energy with case 6.b.h compared to actual condition 1.b.h (Table 5.26).

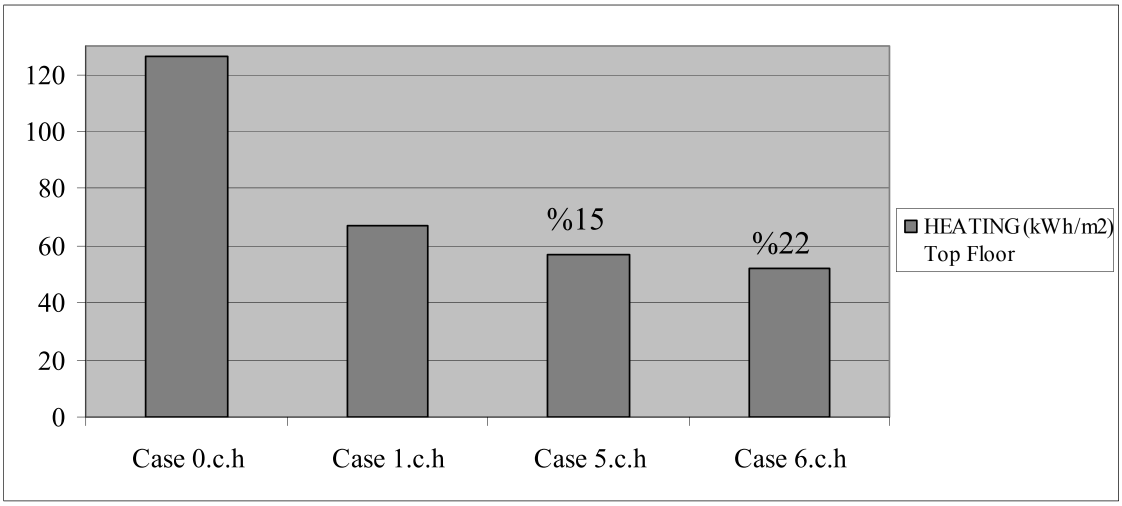
Table 5.26. Heating consumption on the middle floor



Heating Consumption on the Top Floor

By replacing the existing glazing with double glass and double glass with special coating on top floor, it is possible to save annually 15.44% energy with case 5.c.h and 22.24% energy with case 6.c.h compared to actual condition 1.c.h (Table 5.27).

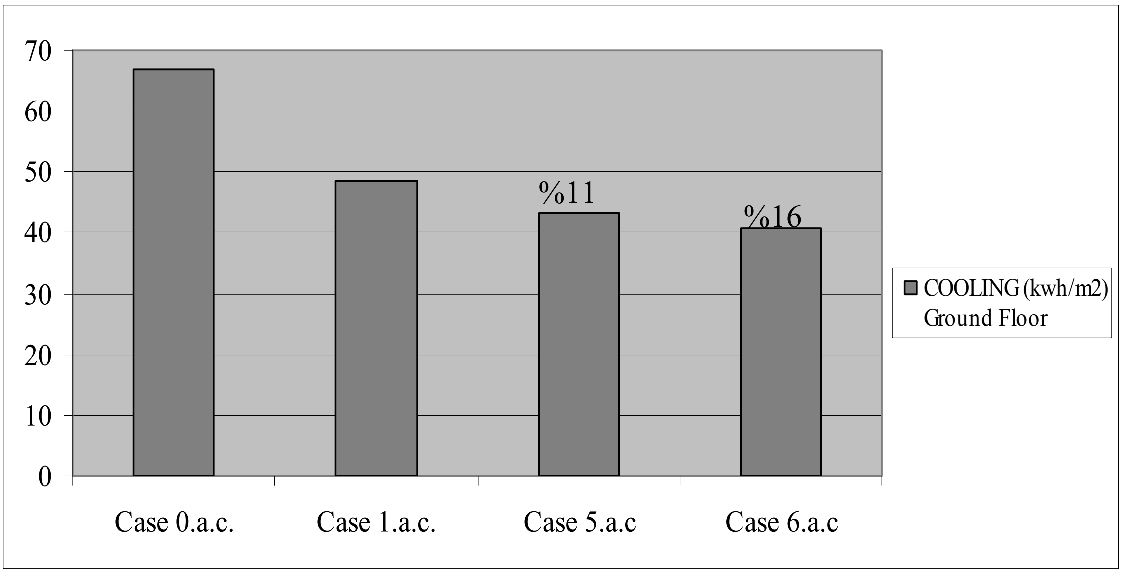
Table 5.27. Heating consumption on the top floor



Cooling Consumption on the Ground Floor

By replacing the existing glazing with double glass and double glass with special coating on the ground floor, it is possible to save annually 10.95% energy with case 5.a.c and 15.92% energy with case 6.a.c compared to actual condition 1.a.c (Table 5.28).

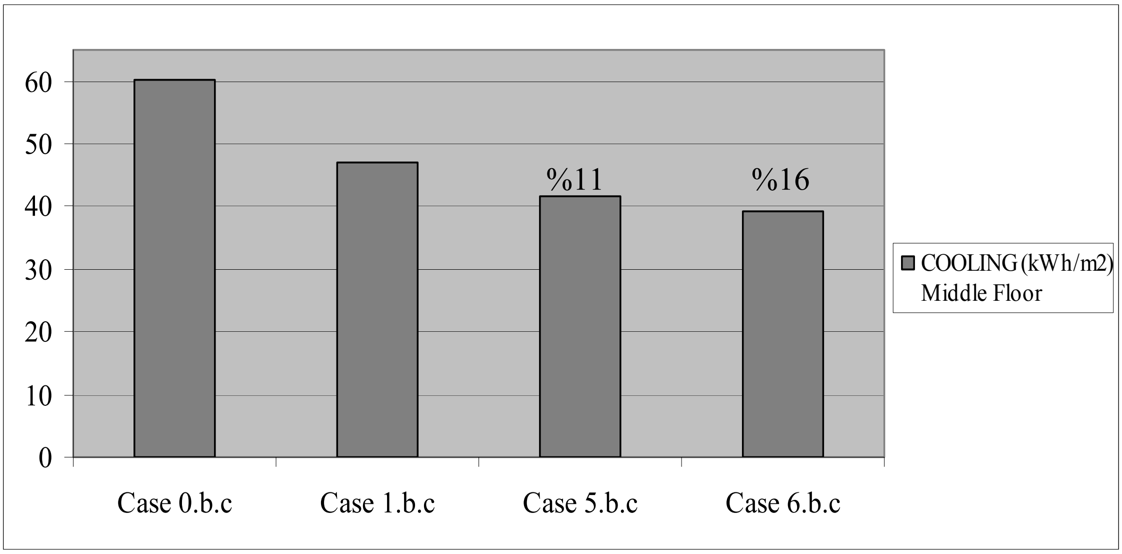
Table 5.28. Cooling consumption on the ground floor



Cooling Consumption on the Middle Floor

By replacing the existing glazing with double glass and double glass with special coating on the middle floor, it is possible to save annually 11.13% energy with case 5.b.c and 16.01% energy with case 6.b.c compared to actual condition 1.b.c (Table 5.29).

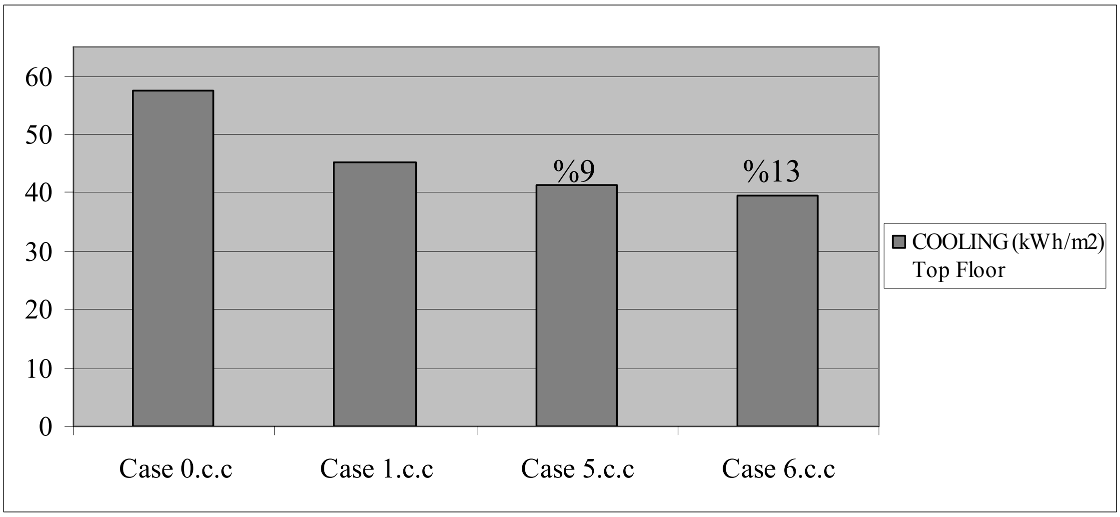
Table 5.29. Cooling consumption on the middle floor



Cooling Consumption on the Top Floor

By replacing the existing glazing with double glass and double glass with special coating on the top floor, it is possible to save annually 8.70% energy with case 5.c.c and 12.58% energy with case 6.c.c compared to actual condition 1.c.c (Table 5.30).

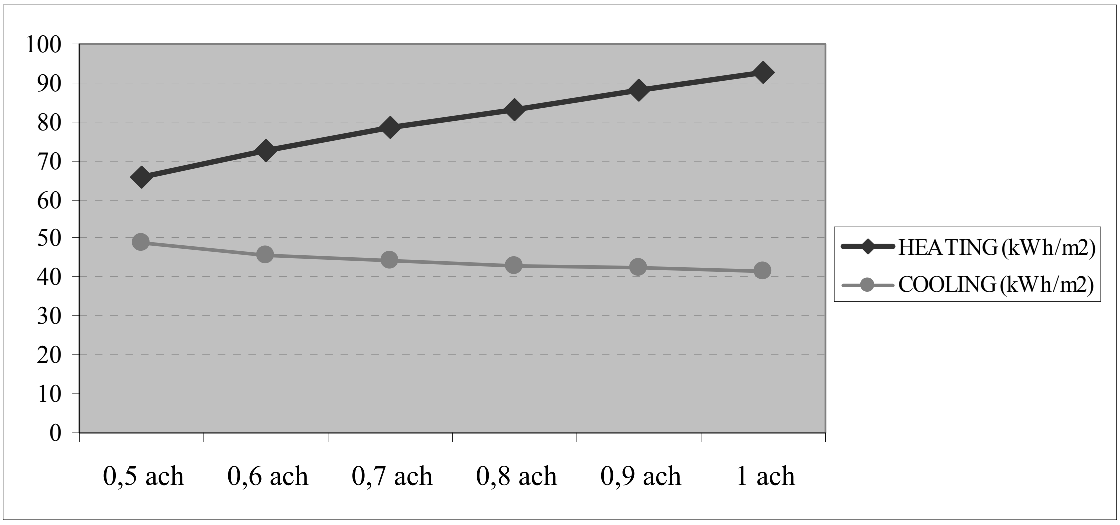
Table 5.30. Cooling consumption on the top floor



5.5.3 Assessment of Retrofitting Option 3: The Change in Air Infiltration Rate

Air exchange rate influences energy consumption in heated and cooled spaces. Air exchange occurs in two ways: intentional ventilation by opening windows, using an air conditioning system, etc. and undesired air infiltration (Lawrence Berkeley National Laboratory, 2006). Infiltration can be described as unplanned introduction of outdoor air based on wind, stack effect, or the action of exhaust fans. In addition, because of the undesired air infiltration, 50% of heat is lost in buildings that are poorly constructed with no weather stripping on windows and doors (Lechner, 1990). The effect of the reduction of the infiltration rate from 1 ach to 0.5 ach is calculated by using Ecotect v 5.50. Table 5.31 shows energy consumption change based on infiltration rate.

Table 5.31. Effect of change in air infiltration rate on energy consumption

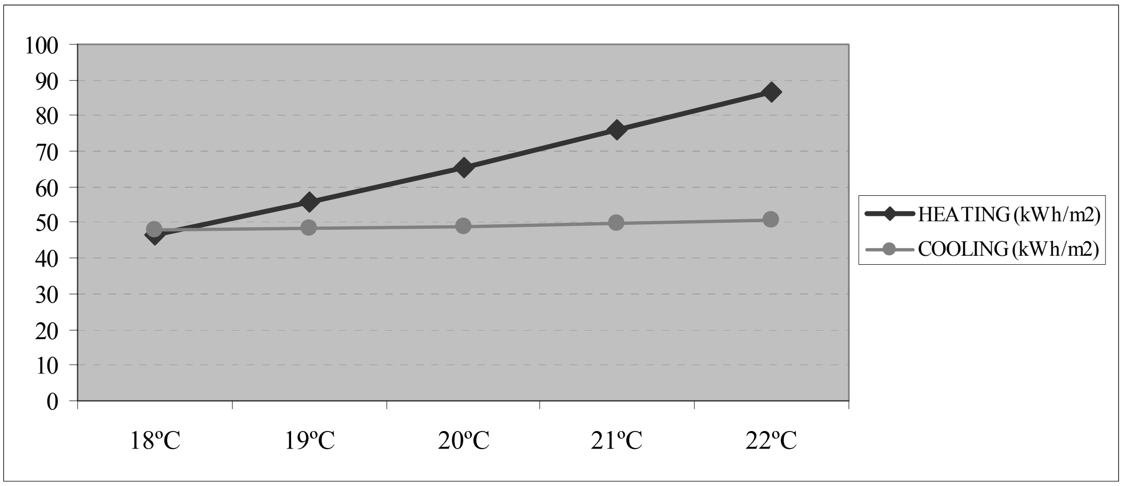


It is evident in Table 5.31 that energy consumption for heating increases or reduces almost by 6.8% in every one unit difference of air infiltration rate. At same time, this change approaches 2.3% in cooling.

5.5.4. Assessment of Retrofitting Option 4: The Change in Set Point Temperature

Change in set point temperature for heating can be applied by installing individual thermostats in buildings. Set point temperature can be regulated as 18ºC or 19ºC for more energy saving in spaces. This reduction is applied for all spaces except toilet and bathroom. In this way, energy saving quantity can be increased. According to Table 5.32, energy consumption for heating can be reduced almost by 18% by decreasing set point temperature only one degree.

Table 5.32. Effect of change in set point temperature on energy consumption



5.5.5. Combination of Single Retrofitting Options

The above section (5.6) described the benefits of single retrofitting scenarios in the same apartment block. This section shows the energy saving benefit of all appropriate retrofitting combinations. In other words, the scenarios were selected to present the range of potential energy reductions.

The same three retrofitting combinations were simulated by applying the scenarios to the ground, middle and top floors. In the discussion below, the following abbreviations are used:

- G: ground floor
- M: middle floor
- T: top floor

The following the retrofitting combinations were generated in order to identify possible energy saving rates:

1. G1, M1 and T1,
2. G2, M2 and T2,
3. G3, M3 and T3.

The combination was generated in order to identify first the minimum benefit scenario (G1, M1, and T1), which consist of 3cm insulation (XPS) to external wall, 5cm to ground floor over unheated spaces and roof, double glass to windows, 1ach selected as air infiltration rate and 20°C used as set point temperature.

The second combination (G2, M2, and T2) includes 5cm insulation (XPS) to external wall, ground floor over unheated spaces and roof, double glass with special coating to windows, 0,5ach selected as air infiltration rate and 20°C used as set point temperature.

The third combination (G3, M3, and T3) was generated in order to identify the maximum benefit scenario. It consists of 8cm insulation (XPS) to external wall, 10 cm to ground floor over unheated spaces and roof, double glass with special coating to windows, 0,5ach selected as air infiltration rate and 18°C used as set point temperature. The combinations of retrofitting options are summarized in Table 5.33. After simulating all retrofitting combinations, the total annual energy consumption for different scenarios is listed in Table 5.34.

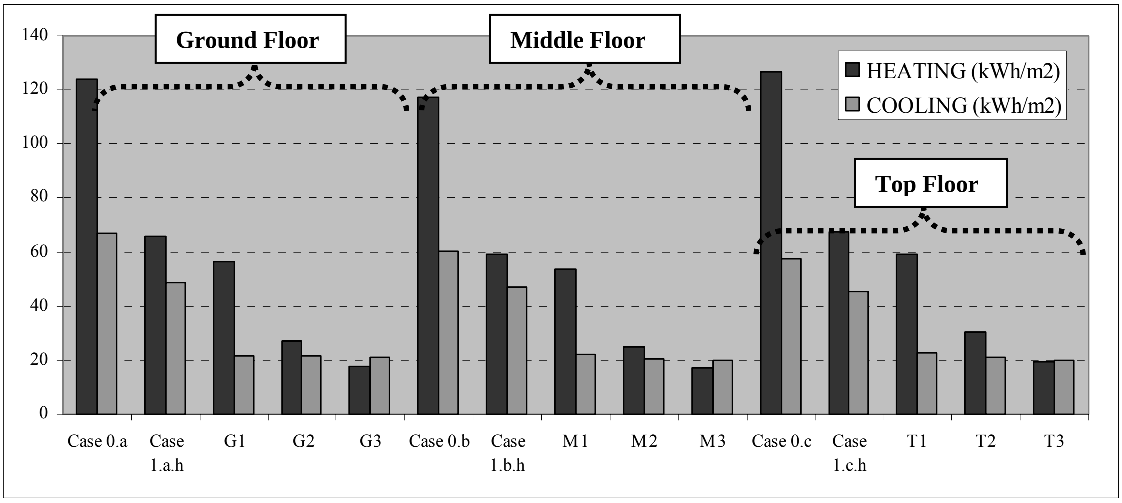
The simulation of each retrofitting scenario has shown that possible minimum annual energy saving is about 9% for heating and 50% for cooling. Maximum energy saving comes with scenarios G3, M3 and T3 almost to 70% for heating and 50% for cooling. It is clear that there are no big differences among levels of cooling savings. Another important point is that the energy used in the apartment block can be reduced easily by decreasing set point temperature and air infiltration rate. The details of the cost of the retrofitting scenarios and energy consumption are indicated in Appendix A.

Table 5.33. Combination of single retrofitting options

	Retrofitting option 1 (Wall-XPS-cm)			**Retrofitting option 1 (Ground and Roof -XPS-cm)**			**Retrofitting option 2 (Glazing)**		**Retrofitting option 3 (Set point Temperature -°C)**					**Retrofitting option 4 (Air Infiltration-ach)**						**Retrofitting Combinations**
	3	5	8	5	8	10	A*	B**	18	19	20	21	22	0.5	0.6	0.7	0.8	0.9	1	
Ground Floor	X			X			X				X								X	**G1**
		X		X				X			X			X						**G2**
			X			X		X	X					X						**G3**
Middle Floor	X						X				X								X	**M1**
		X						X			X			X						**M2**
			X					X	X					X						**M3**
Top Floor	X			X			X				X								X	**T1**
		X		X				X			X			X						**T2**
			X			X		X	X					X						**T3**

A* Double glazing
B** Double glass with special coating

Table 5.34. Energy saving rates of combined retrofitting options



CHAPTER 6

CONCLUSION

Retrofitting of existing residential buildings bears the important potential to reduce national energy consumption in the residential building stock of Turkey. This thesis has only considered the energy reduction potential based on heating for residential buildings. Similar savings potential can be achieved through retrofitting other building types such as office buildings. However, to determine effective retrofitting scenarios, more analysis is necessary.

This study has focused on retrofitting measures to reduce energy consumption for heating in extant residential buildings and improve their energy efficiency in view of the energy efficiency regulations in Turkey and EU. Current energy efficiency regulations for residential buildings in the EU and Turkey are respectively discussed in Chapters 2 and 3, followed by an overview of retrofitted housing examples from the EU, which are presented in terms of the low-energy retrofitting options. The subsequent chapter, Ecotect v5.50, used in the calculation of energy performance of buildings in the thesis research, is discussed in terms of its contribution to the present research.

Buildings should posses suitable conditions of temperature, humidity, wind, and lighting for occupants to live and work in comfort. Particular aspects of climate like temperature, humidity, wind, etc. are effective in determining indoor conditions in buildings. Taking into consideration all of these criteria, the climate of the Gaziemir region of Izmir was selected as the case area.

Then, an apartment block from Gaziemir Emlak Bank Housing Area was selected as the special case study in order to observe the effect of pre-defined retrofitting scenarios reducing energy consumption in extant buildings. After selecting the case building, its existing conditions like size, geometry, thermal features, and orientation were summarized, which analyses were necessary for defining the appropriate retrofitting scenarios for the test case. Thermal camera images were used toward assessment of the amount of energy losses from the existing envelope.

The case building already possessed thermal insulation on the interior surface of the walls, roof and floors over unheated spaces. However, the significant problem was condensation on the walls deriving from the nature of the interior insulation. This problem was determined by using the TS 825 software developed by İZODER. To solve it and reduce the energy consumption, an extra insulation was added on the external surface of the walls. XPS (U: 0.031 W/mK) was selected as insulation material. Different thicknesses of the XPS (3, 5 and 8 cm) were entered into simulation to trace the energy consumption rate by using the Ecotect v 5.50 energy analysis software. At the same time, XPS (5, 8 and 10 cm) was simulated for roof and ground floor. As a result of the simulation, it was found that by the application of XPS (3, 5 and 8 cm) only on the external walls of the ground, middle and top floors, it would be possible to save energy between 27% and 32% per m^2 for heating. Savings rate could be changed between 5% and 7% by applying only extra insulation on the floor over unheated space on the ground floor. If extra insulation is applied on the roof, this rate has been found to change between 3% and 6% for heating. With scenarios applied on walls, it is possible to save energy for cooling between 40% and 44%. In addition to this, the cooling savings rate can be decreased by another 2% by applying insulation on the roof and ground floor.

The actual case building has single glass (U: 5.1 W/m^2K) on windows. In the simulation, the extant panes were exchanged firstly with double glass (U: 2.8 W/m^2K) and, in a second step, with double glass with special coating (U: 1.7 W/m^2K). According to simulation results, 15% energy saving for heating was found to be possible while for cooling almost 10% was seen to be possible by applying double glazing. This rate could be increased to 22% for heating and 15% for cooling when the double glass with special coating is applied to the windows of the building block.

Change in air infiltration rate affects the energy consumption as positive or negative. To trace these positive and negative effects, air infiltration rate was analyzed by means of the simulation program. Results have shown that energy saving rates for heating can change 6.8% in every one unit difference of air infiltration rate. This change rate was positive for heating if air infiltration rate was low (0.5ach). For cooling, saving rates was 2.3% when air infiltration rate was very high (1 ach) but in this rate heating consumption proved too big.

Control of temperature or limit in the spaces is very important because unnecessary increases in heating temperature and decreases in cooling temperature cause big consumption in energy. According to simulation results, energy consumption for heating can be reduced almost by 18% by decreasing set temperature by only one degree.

Described retrofitting options may be grouped as for envelope (walls, roof attic and floors over unheated spaces), glazing, reducing infiltration rate and rearrangement of set point temperature. After analyzing savings rate of the individual retrofitting options, these were grouped and simulated to re-evaluate the range of potential energy reductions. As a result of the simulation, it was found that 70% in heating and 50% in cooling energy was saved by applying XPS (8 cm on walls, 10 cm on roof and floor over unheated spaces), double glass with special coating for window, 18ºC set temperature and 0,5ach air infiltration rate. With this combination, maximum energy savings rate was achieved. At the same time, minimum energy savings rates is obtained by implementing 3cm insulation (XPS) to external wall, 5cm to ground floor over unheated spaces and roof, double glass to windows, 1ach, air infiltration rate and 20°C, set point temperature.

This thesis has proven that it is possible to save energy for heating and cooling by applying suitable retrofitting scenarios, which are not too complicated, to existing residential buildings. In the above mentioned improvement in the apartment block, the following conclusions are accepted to be important:

1. Available energy efficient options can contribute to a reduction in the energy use in residential buildings. This reduction in energy consumption is more for heating than cooling.
2. Control systems in buildings for incorrect set point temperatures and ventilation can reduce energy use significantly.
3. Selection of glazing types based on climatic features of the location bear significant effect on energy use.
4. Improvement of indoor thermal comfort can be obtained.

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APPENDIX A

COST OF THE RETROFITTING MEASURES AND ENERGY CONSUMPTION

In this part, the cost of retrofitting measures and cost of the energy source consumed in the apartment block according to retrofitting scenarios is assessed. To calculate the cost of the retrofitting measures, different cost values were collected from three construction firms. After, their average is used as a final cost. The approximate costs of retrofitting measures are given below:

XPS-3cm……………………………………………………………………..33/m^2 YTL
XPS-5cm……………………………………………………………………..39/m^2 YTL
XPS-8cm……………………………………………………………………..45/m^2 YTL
XPS-10cm……………………………………………………………….………49/m^2 YTL
Double glass (4 mm + 9 mm + 4 mm)..……………………………….……….....149/m^2 YTL
Double Glass with Special Coating (4 mm + 9 mm + 4 mm)..…………..….199/m^2 YTL

Insulation of external wall:
XPS-3cm: 866.142 m^2……………………………….………….....…..28,582.69 YTL
XPS-5cm: 866.142 m^2………………………………...………….……33,779.54 YTL
XPS-8cm: 866.142 m^2………………………………...……..………...38,976.39 YTL
XPS-10cm: 866.142 m^2……………………...………………………...42,440.96 YTL

Insulation of suspended floor over unheated spaces at the ground floor level:
XPS-5cm: 121 m^2 ……….…..…………………….…………….....…………..4,719 YTL
XPS-8cm: 121m^2…………...…………………………………………...……..5,445 YTL
XPS-10cm: 121 m^2...…………..……………………………...……………5,929 YTL

Insulation of attic floor:

XPS-5cm: 180 m^2………..…………...………..….…………………………..7,020 YTL

XPS-8cm: 180m^2……………………...………....………………………..8,100 YTL

XPS-10cm: 180 m^2...……………………..…………...……………………8,820 YTL

Replacement of windows:

Double glass (4 mm + 9 mm + 4 mm) 80 m^2………………………………..11,920 YTL

Double Glass with Special Coating (4 mm + 9 mm + 4 mm) 80 m^2…......…..15,920 YTL

The approximate cost of the energy consumed in the ground, middle and top floors were determined by using the following formula:

Annual fuel cost = [Annual energy demand / (efficiency of system x thermal value of fuel type) x unit price of fuel]

The values used for calculation procedure of annual fuel cost are summarized in Table A.1 according to electric and coal as the most commonly used energy sources in the mass housing dwellings.

Table A.1. Values used to calculate annual fuel cost

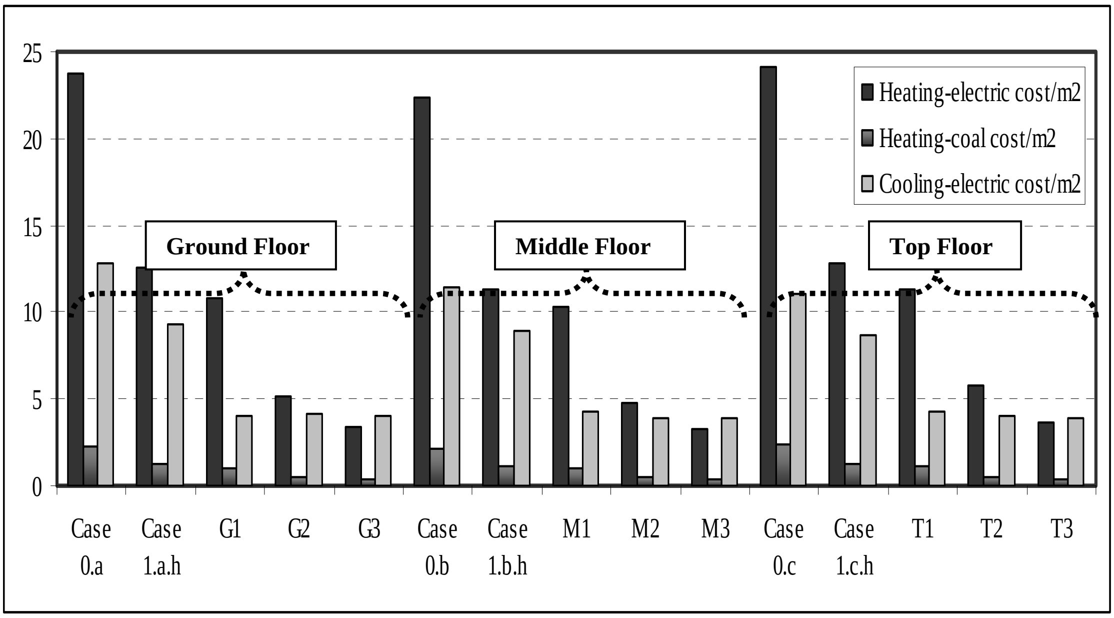
(Source: Energy & Environmental Technology Systems Magazine, 2008)

Values used in formula	Electric	Coal*
Thermal value of fuel	860 kcal/kWh	4640 kcal/kg
**Unit price of fuel (YTL)	0,188994	0,341020
Unit price of fuel (€***)	0,10	0,18
Mean efficiency	99%	65%

*Domestic lignite coal from Kısrakdere/Soma
**07 February 2008
***1€= 1,9472 YTL (Source: Central Bank of Republic of Turkey, 24.05.2008)

As a result of the calculation, it is seen that energy costs for heating can be reduced maximum by 75% with G3, M3 and T3 retrofitting scenarios (Table A.2). This reduction can be maximum by 55% for cooling by applying the same retrofitting scenarios. With application of G1, M1 and T1, the savings rate is 15% for heating. With the same scenarios for cooling, the saving rate is 50%. In other words, there are no big differences among the scenarios for cooling. With G2, M2 and T2, the savings rate can be almost 56% for heating. Another important point is that the cost is based on source of the energy used in buildings because of the thermal value of fuels.

Table A.2. Comparison of cost of the energy sources consumed in the ground, middle and top floors of the apartment block



APPENDIX B

COMPARISON OF CLIMATIC DATA OF AMMS AND METEONORM: MEAN AIR TEMPERATURE AND RELATIVE HUMIDITY

In this part, the monthly average, values of mean air temperature and relative humidity for the Gaziemir district obtained from AMMS and transferred from Meteonorm used in simulation program is compared in order to observe differences between them. While the climatic data taken from AMMS is the average of the period of 1987 and 2006, the Meteonorm's data is based on Test Reference Year. Table B.1 indicates that the mean air temperature is nearly identical, but the relative humidity data do not overlap (Table B.2).

Table B.1. Comparison of the monthly average air temperature of AMMS and Meteonorm for Gaziemir

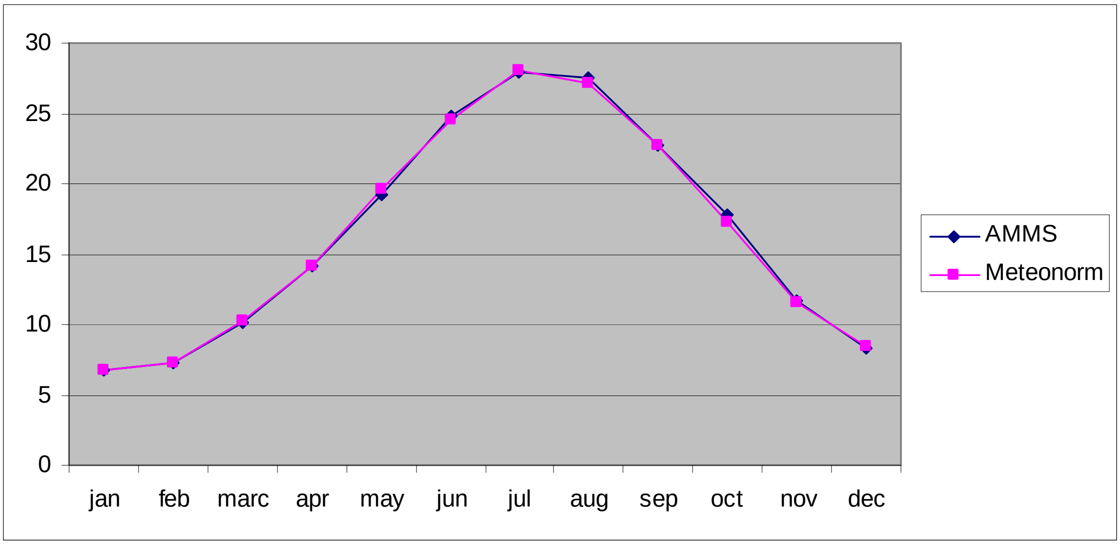
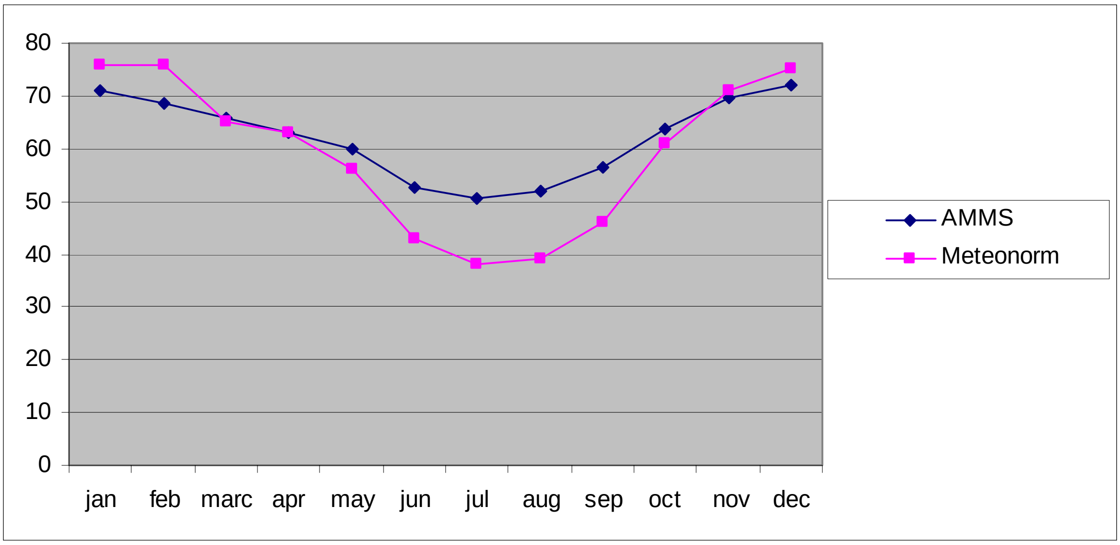


Table B.2. Comparison of the monthly average relative humidity of AMMS and Meteonorm for Gaziemir



APPENDIX C

ENERGY EFFICIENCY DIRECTIVES PUBLISHED BEFORE EPBD IN THE EU

1. Council Directive 92/42/EEC on “efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels.”
2. Council Directive 92/75/EEC on “the indication by labeling and standard product information of the consumption of energy and other resources by household appliances.”
3. Council Directive 93/76/EEC on “to limit carbon dioxide emissions by improving energy efficiency (SAVE).”
4. Commission Directive 94/2/EEC implementing Council Directive 92/75/EEC “with regard to energy labeling of domestic electric refrigerators, freezers and their combinations.”
5. Commission Directive 95/12/EC implementing Council Directive 92/75/EEC concerning energy labeling of clothes washers.
6. Commission Directive 95/13/EC implementing Council Directive 92/75/EEC concerning energy labeling of clothes dryers.
7. Council Directive 96/57/EC on energy efficiency requirements for household electric refrigerators, freezers and combinations thereof.
8. Commission Directive 96/6/EC implementing Council Directive 92/75/EEC concerning energy labeling of household dishwashers.
9. Commission Directive 91/17/EC of 16 April 1997 implementing Council Directive 92/75/EEC with regard to energy labeling of household dishwashers.
10. Commission Directive 98/11/EC implementing Council Directive 92/75/EEC concerning energy labeling of household lamps.
11. Directive 2000/55/EC of the European Parliament and of the Council of 18 September 2000 on energy efficiency requirements for ballasts for fluorescent lighting.
12. Commission Directive 2002/31/EC of 22 March 2002 implementing Council Directive 92/75/EEC with regard to energy labeling of household air-conditioners.

13. Commission Directive 2002/40/Ec of 8 May 2002 implementing Council Directive 92/75/EEC with regard to energy labeling of household electric ovens.
14. Commission Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings (EPA-ED, 2004a, p. 12).

APPENDIX D

ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE (2002/91/EC)

The directive consists of 16 articles:

Article 1: Objectives

The aim is to develop the energy performance of buildings by assuring:

1. A system for a methodology for calculating energy performance of buildings
2. Implementation of minimum energy requirements on new buildings
3. Implementation of minimum energy requirements on existing buildings exceeding 1000 m^2 and becoming under renovation.
4. Energy certification of buildings
5. Regular control and evaluation of boilers and air-conditioning systems.

Article 2: Definitions

'Building', the 'energy performance of a building', 'energy performance certificate of a building', 'combined heat and power (CHP)', 'air-conditioning system', 'boiler', 'effective rate output expressed in kW' and 'heat pump' was described.

Article 3: Adoption of a methodology

According to this article Member states have to determine a methodology for calculating of energy performance of buildings at national or regional level. The methodology shall be formulated for (Bowie & Jahn, 2003):

1. Installation
2. Heating
3. Hot water

4. Cooling
5. Ventilation
6. Built-in lighting
7. Heat recovery
8. Passive or renewable energy installations
9. Indoor climate
10. Position and orientation of the buildings.

In addition to this, building types should be divided into groups as (Warren, 2003);

1. Single-family houses of different types
2. Apartment blocks
3. Offices
4. Education buildings
5. Hospitals
6. Hotels and restaurants
7. Sport facilities
8. Wholesale and retail trade services buildings
9. Other types of energy-consuming buildings.

The methodology must be updated regularly and may include indicator relating to CO_2 emission.

Article 4: Setting of energy performance requirements

Optimum measures to provide minimum energy performance requirements should be taken for buildings accordance with the methodology based on Article 3. These energy performance requirements should be reviewed in each five years and updated if necessary. Member states can exclude following buildings not to apply energy performance requirements:

1. Buildings and monuments becoming under protection because of the specific architectural or historic merit
2. Buildings used for worship and religious practices
3. Temporary buildings used for two years or less
4. Industrial sites

5. Workshops and non-residential agricultural buildings needed low energy
6. Agricultural buildings used a sector having agreement on energy performance
7. Residential buildings to be designed to use less than four months of the year.
8. Stand-alone buildings having less than 50 m^2 floor area.

Article 5: New Buildings

Minimum energy performance requirements should be provided by new buildings. Before constructing the new buildings having a total useful floor area over 1000 m^2, Member states should encourage alternative systems like heat pumps**,** district or block heating and cooling**,** CHP**,** and decentralized energy providing system depends on renewable energy resource.

Article 6: Existing Buildings[1]

Article 7: Energy Performance Certificate

Article 8: Inspection of boilers

Article 9: Inspection of air-conditioning systems

Article 10: Independent experts

Qualified and/or accredited experts operating as sole traders or be employed by public or private bodies is necessary for inspection boilers and air-conditioning systems and certification of buildings.

[1] Articles whose content is not included in this Appendix may be found in Chapter 2 above.

Article 11: Review

Implementation and impacts of the directive should be evaluated by commission. Accordance with this assessment commission can make suggestion with respect to:

1. Energy performance requirements can be applied for buildings having a total useful area less than 1000 m^2
2. General incentives for further energy efficiency measures in buildings.

Article 12: Information

If the Member States need help the commission can give staging information campaigns by using Community programmes. Building users shall be informed to how to develop energy performance of the buildings.

Article 13: Adaptation of the framework

Parts 1 and 2 of the Annex should be reviewed regular intervals and at maximum every two years.

Article 14: Committee

A Committee has generated by Commission to control implementation of the Directive.

Article 15: Transposition

All Member States have to enter into force the Directive at least on 4 January 2006. However, member states can want to additional three years to implement Article 7-8 and 9 because of the lack of qualified and/or accredited experts but Member States should give information about this situation with a schedule to fully implement the Directive.

Article 16: Entry into force

It enters into force on the day of its publication in the official journal of the European Communities.

APPENDIX E

DESCRIPTION OF SELECTED RETROFITTED HOUSING EXAMPLES FROM 11 EU COUNTRIES

Table E.1. Description of selected retrofitted housing examples from 11 EU countries

Project No: 1 Project Name: Oesterbro, Denmark Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Oesterbro, Denmark	Urban	Mild	2,906	1925	1994-1995	Apartment block	Not known	9,896 m^2	Danish Housing Association	mean 1.78 million Euros	EU Thermie Programme, Danish Energy Authority	125 KhW/m^2 per year	61 KhW/m^2 per year
Project No: 2 Project Name: Gaardsteen, Sweden Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Gaardsteen, Sweden	Rocky landscape	Continental and cold	2,906	Beginning of 1970	2000	Apartment blocks	10 buildings consisting of 255 flats total	19,000 m^2 (heated floor area)	Gårdstensbostäder, Kastanjgården 3, 424 39 Angered, Sweden	mean 10,7 Million Euro	Gårdstenbostäder subsided by the EU	275 KhW/m^2 per year	165 KhW/m^2 per year

(Cont. on next page)

Table E.1. (Cont.) Description of selected retrofitted housing examples from 11 EU countries

Project No: 3 Project Name: Raamsdonk, The Netherlands Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Raamsdonk, The Netherlands	Open lowlands, close to rivers and close to city	Mild and humid	2,688	1963-1969	2000-2002	Row family houses	42 dwellings	3,.360 m^2	Volksbelang	39,900 Euro per dwelling	The owner and governmental subsidy	240 KhW/m^2 per year (gas only)	72 KhW/m^2 per year (gas only)
Project No: 4 Project Name: The Hague, The Netherlands Conducted under program ALTANER programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	The Hague, The Netherlands	Open green area, relatively low	Not known	Not known	1954	Hypothetical retrofitting scenario	Apartment block in four storeys	56 flats	3,770 m^2	Private owner	Not known	Not known	219,938.3 m^3 (natural gas)	67,500.6 m^3 (natural gas)

(Cont. on next page)

Table E.1. (Cont.) Description of selected retrofitted housing examples from 11 EU countries

Project No: 5 Project Name: Ludwigshafen, Germany Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Ludwigshafen, Germany	Low hilly landscape, central-west Germany	Continental	Not known	1960-1962	2005	Apartment blocks	24 flats	736 m^2	GAG Ludwigshafen am Rhein (housing association)	16,667 Euro per apartment	The owner and governmental subsidy	250 KhW/m^2 per year (space heating)	15 KhW/m^2 per year (space heating)

Project No: 6 Project Name: Neuhofen, Austria Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Neuhofen, Austria	Low hilly landscape, north of the country	Continental	3,672	1979	2004	Apartment block	25 flats	1,810.30 m^2	LAWOG (social housing association)	Approx. 565,000 Euro	Loan and reserves by LOWAG, subsidies from regional government	86 KhW/m^2	47 KhW/m^2

(Cont. on next page)

Table E.1. (Cont.) Description of selected retrofitted housing examples from 11 EU countries

Project No: 7 Project Name: Vienna, Austria Conducted under program ALTANER programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Vienna, Austria	High density urban area, heavy traffic	Not known	Not known	Second World War	Hypothetical retrofitting scenarios	Apartment Block in five storeys	13 flats and two shops	Not known	Private owner	Not known	Not known	37,046 m^3 (gas)	1,110 m^3 (gas)
Project No: 8 Project Name: Olaine, Latvia Conducted under program ALTANER programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Olaine, Latvia	Urban	Continental and cold	4,060	1973	2005	Apartment block	54 flats	2,000 m^2	Cooperative building	Approx. 74,000 Euro	Loan from commercial bank	147 KhW/m^2 (specific heat consumption)	95 KhW/m^2 (specific heat consumption)

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Table E.1. (Cont.) Description of selected retrofitted housing examples from 11 EU countries

Project No: 9 Project Name: Ljubljana, Slovenia Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Ljubljana, Slovenia	Urban	Sub-Alpine	3,300	1962	2005	Apartment block	40 flats	1,882 m^2	Private owner	167,000 Euro	The owner and state subsidy	151 KhW/m^2	100 KhW/m^2
Project No: 10 Project Name: London, United Kingdom Conducted under program EuroACE programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	London, United Kingdom	Urban	Moderate	Not known	1968	2002	Apartment block	160 flats in 22 storeys	Not known	Westminster City Council	14.48 million Euro	City West Homes	9,830 kWh/flat per year	7,000 kWh/flat per year

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Table E.1. (Cont.) Description of selected retrofitted housing examples from 11 EU countries

Project No: 11 Project Name: Budapest, Hungary Conducted under program EuroACE programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Budapest, Hungary	Urban	Moderate	Not known	1980	Not known	Apartment block in five storeys	56 flats	Not known	Private owner	Not known	Government	246 kWh/m2a (space heating)	137 kWh/m2a (space heating)

Project No: 12 Project Name: Chalandri, Greece Conducted under program ALTANER programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Chalandri, Greece	Open urban area, low traffic	Not known	Not known	1979	Hypothetical retrofitting scenario	Apartment block in four storey	12 flats	1,498 m^2	Private owner	Not known	Not known	127.1 KWh/m^2	57.6 KWh/m^2

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Table E.1. (Cont.) Description of selected retrofitted housing examples from 11 EU countries

Project No: 13 Project Name: Radomir, Bulgaria Conducted under EI-EDUCATION programme	Location	Surrounding	Climate	HDD	Construction year	Retrofitting year	Typology	Number of dwellings	Total floor area	Owner	Cost of the retrofitting	Financed by	Energy consumption before retrofitting	Energy consumption after retrofitting
	Radomir, Bulgaria	Municipality	Mild continental	2900 (mid-October to mid-April)	1980	1995	Apartment block	21 flats	4,557 m^2	Private owner	Loan pay-back period: 6 years	PHARE Funded Demonstration Project.	197.8 KhW/m^2	106.7 KhW/m^2

APPENDIX F

DRAWINGS OF PLANS, SECTIONS AND ELEVATIONS OF SELECTED APARTMENT BLOCK

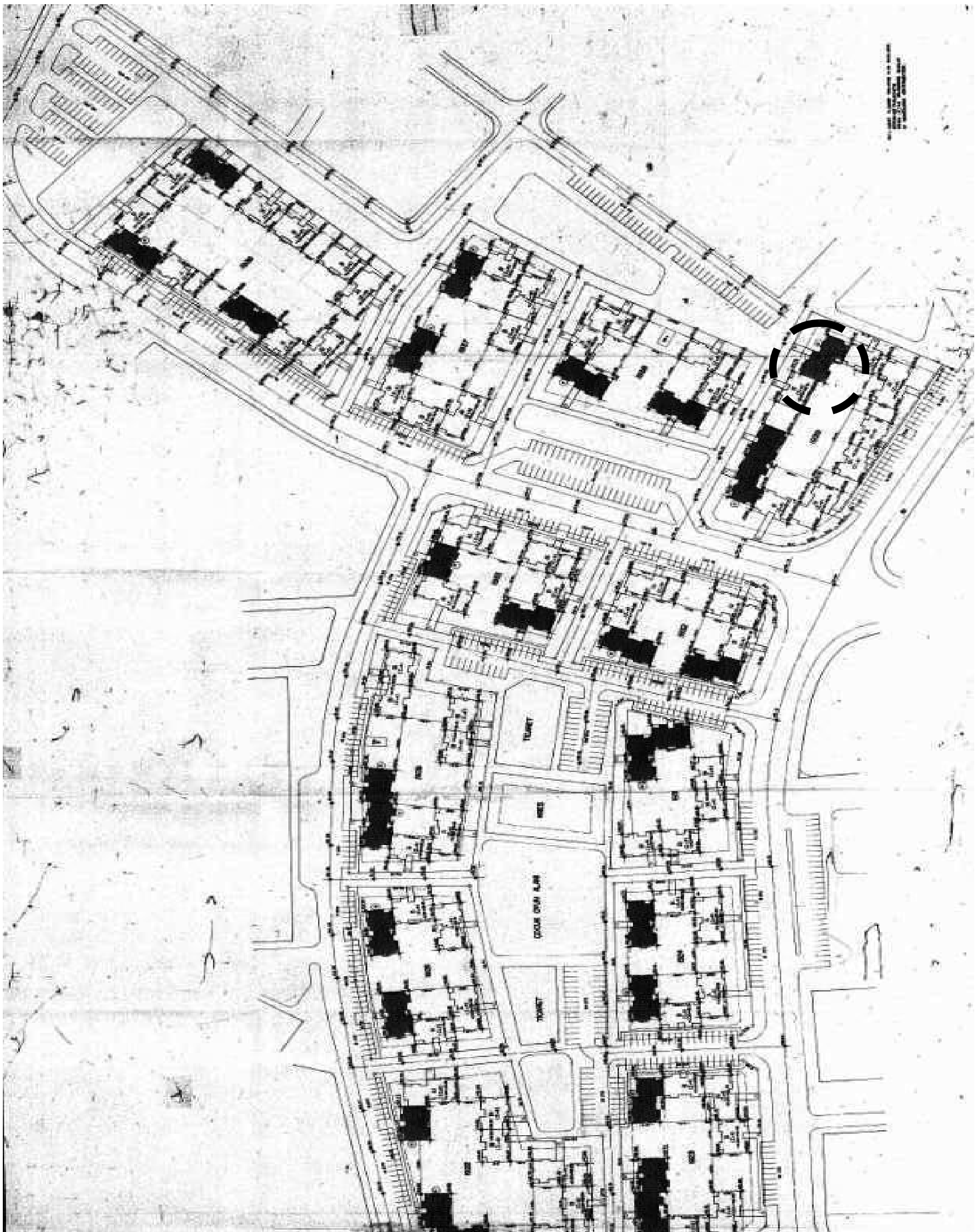

Figure F.1. Site plan of Gaziemir Emlak Bank Housing Area (Second Development Phase)

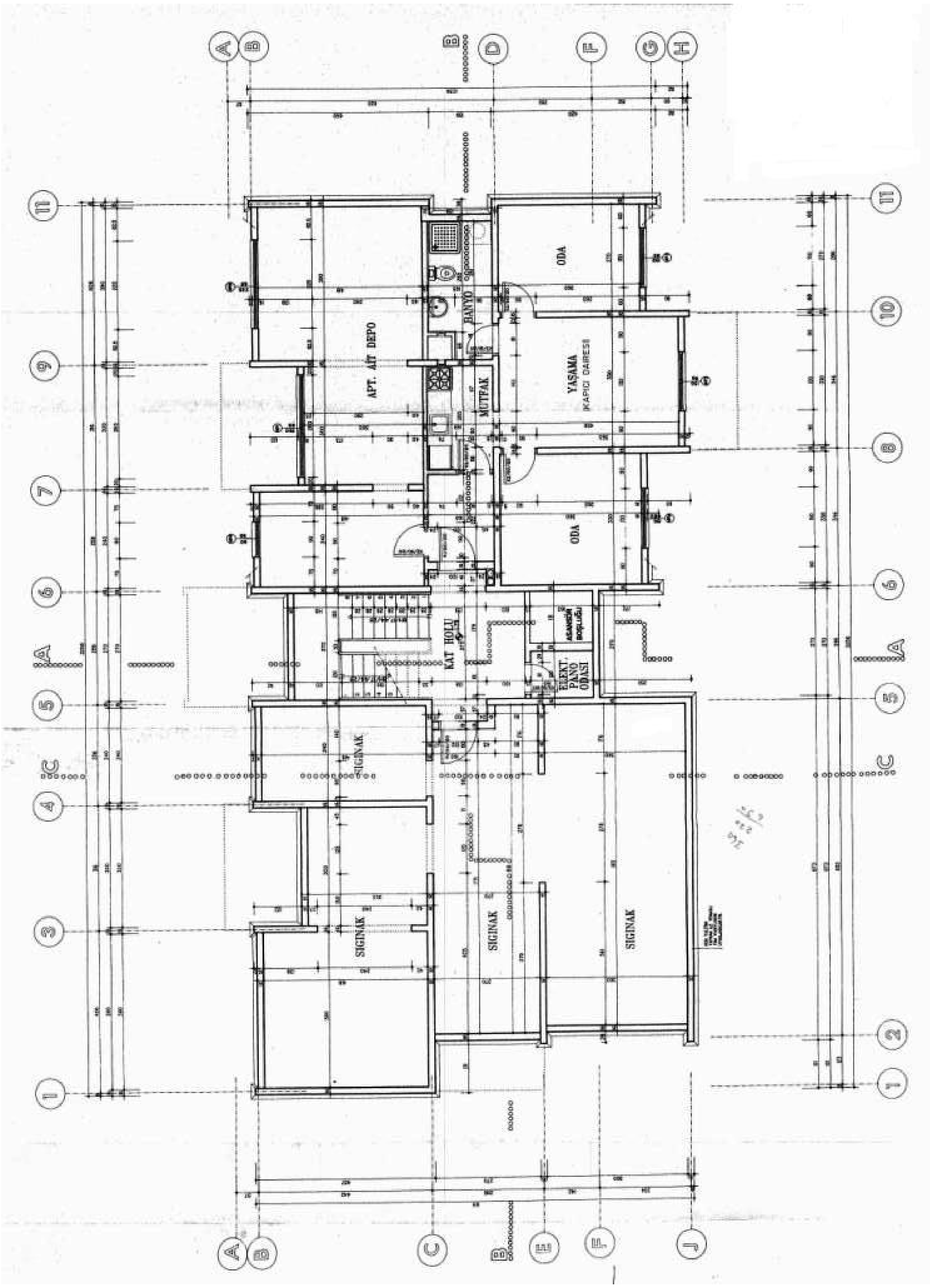

Figure F.2. Basement floor plan of selected apartment block

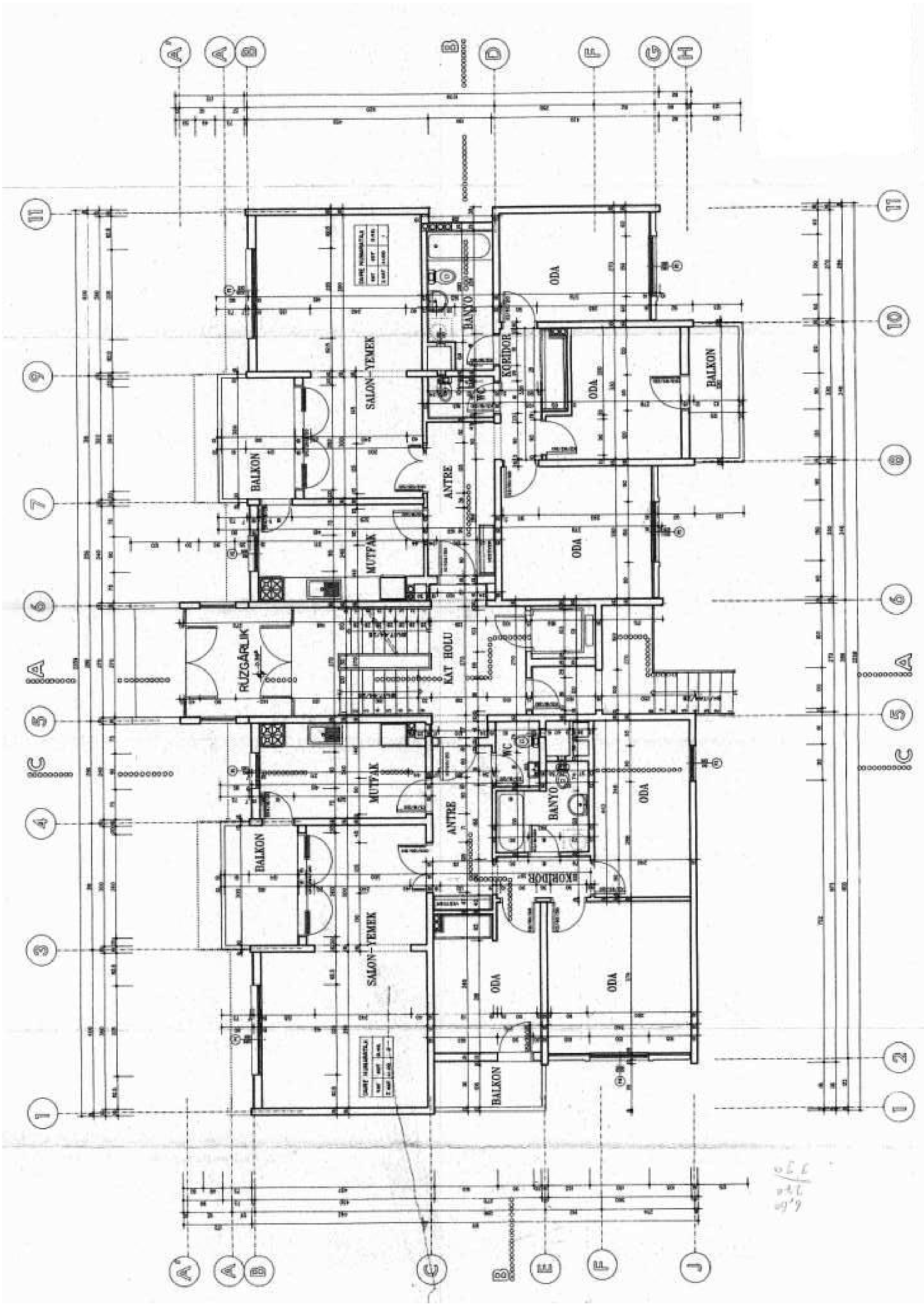

Figure F.3. Ground floor plan of selected apartment block

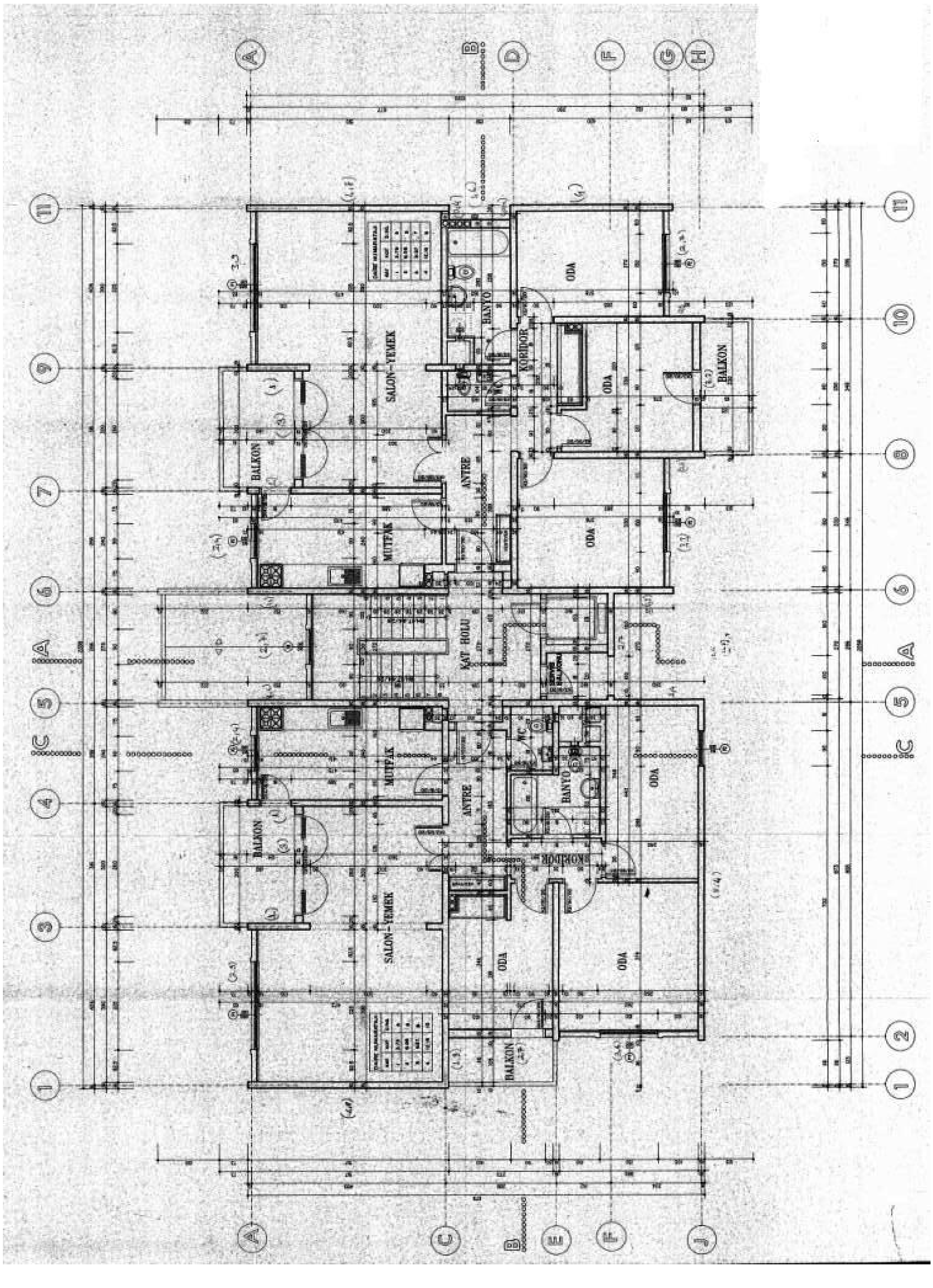

Figure F.4. Typical floor plan of selected apartment block

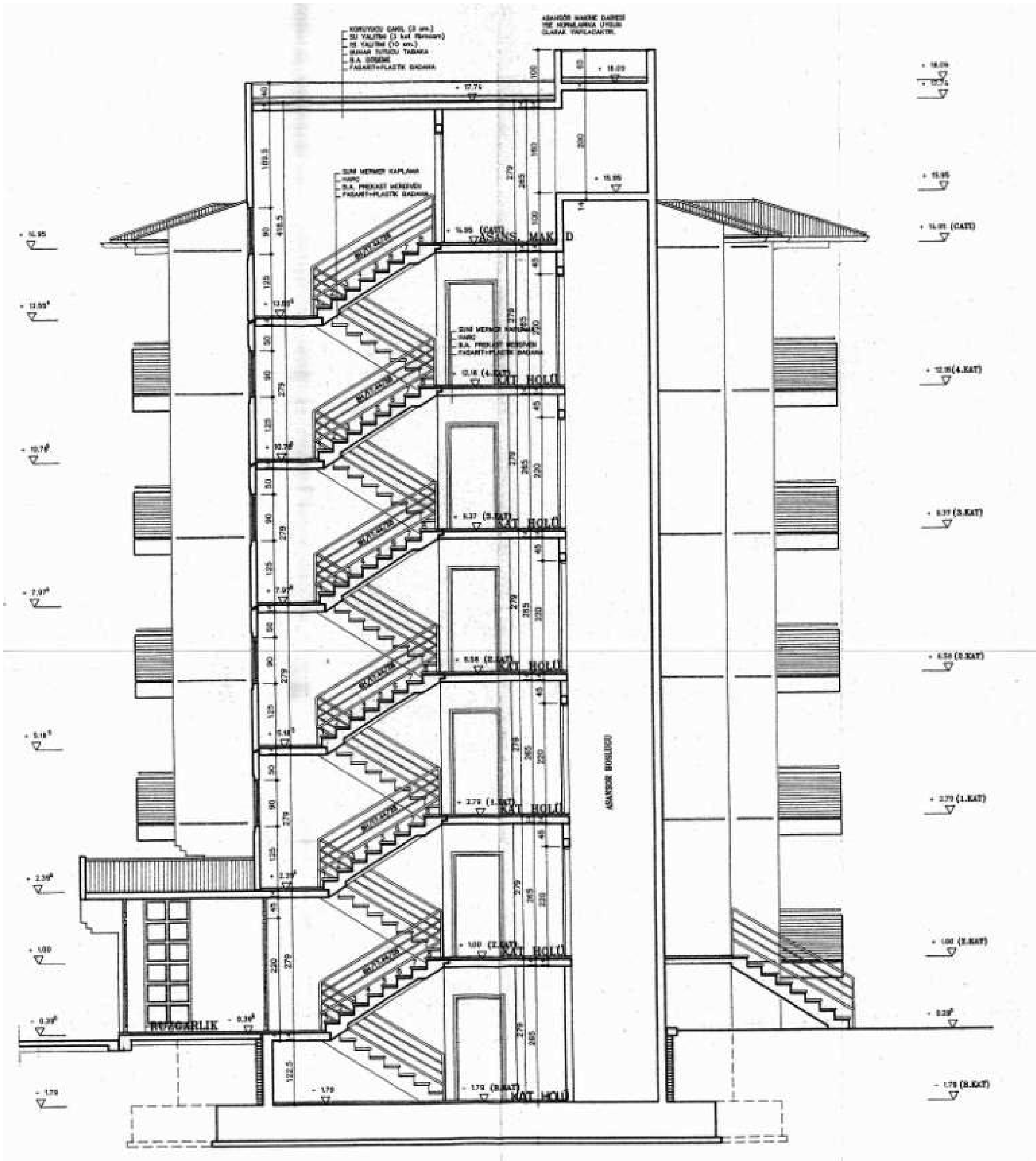

Figure F.5. Section AA of selected apartment block

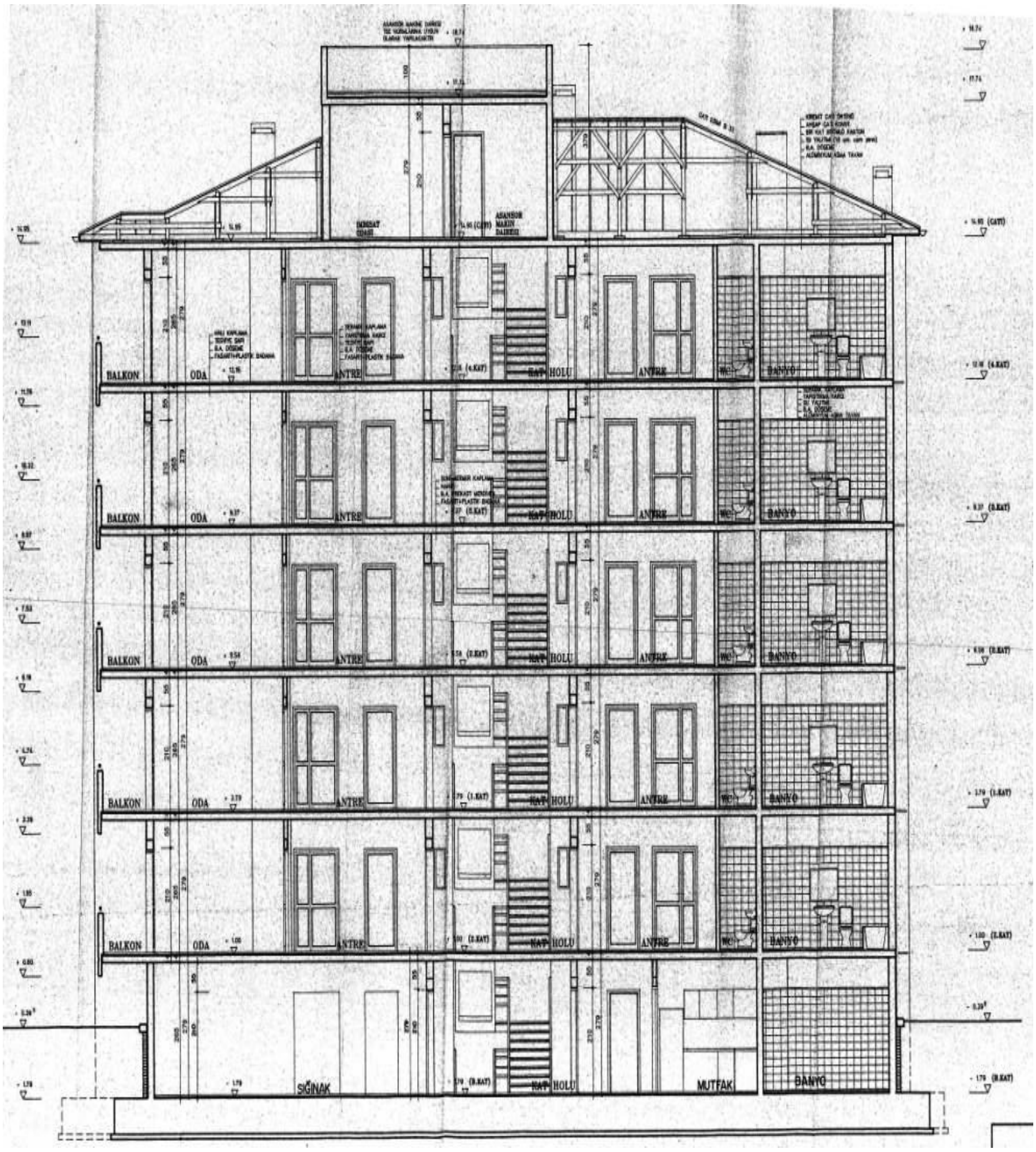

Figure F.6. Section BB of selected apartment block

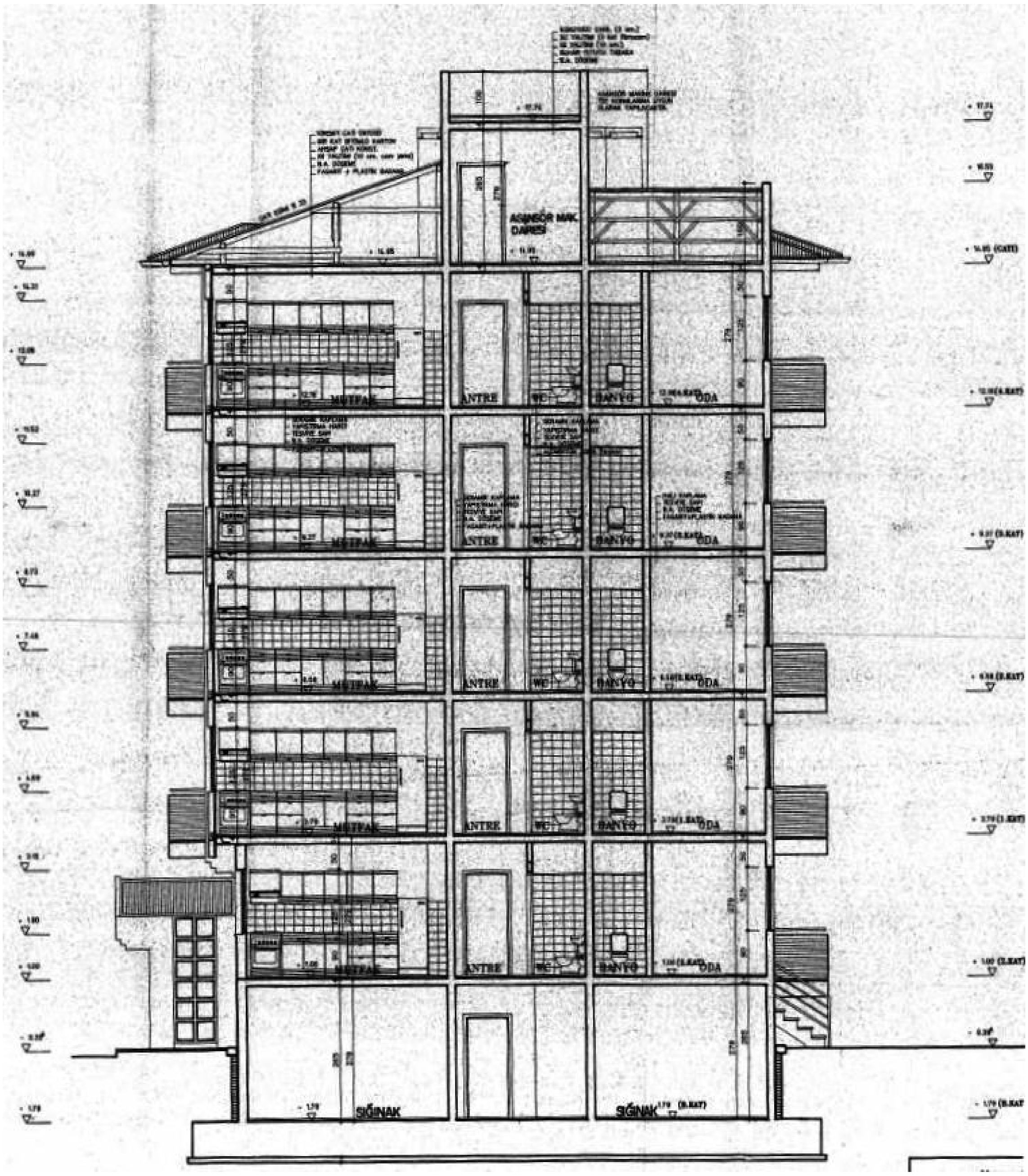

Figure F.7. Section CC of selected apartment block

Figure F.8. Southwest elevation of selected apartment block

Figure F.9. Northeast elevation of selected apartment block

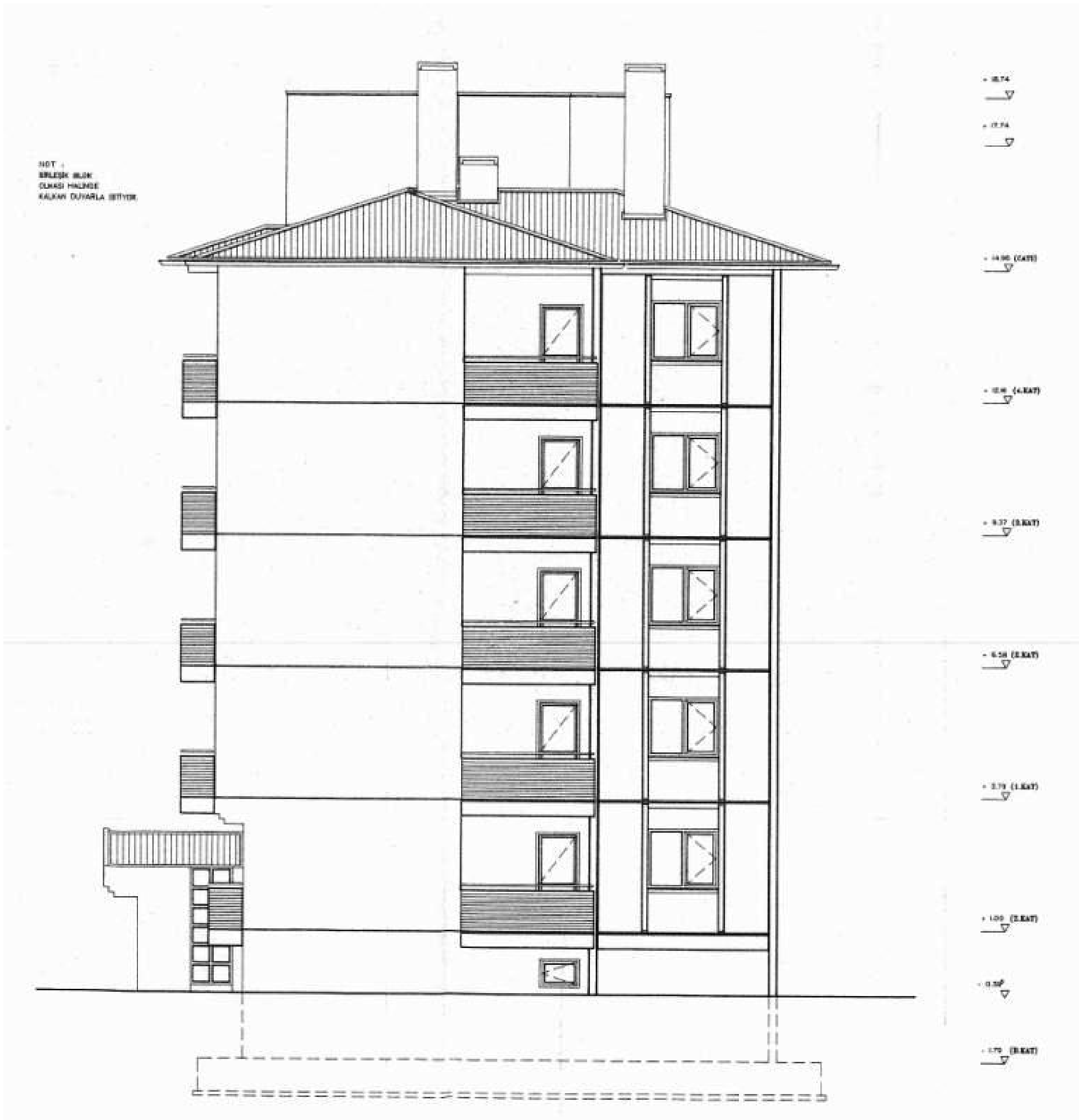

Figure F.10. Northwest elevation of selected apartment block

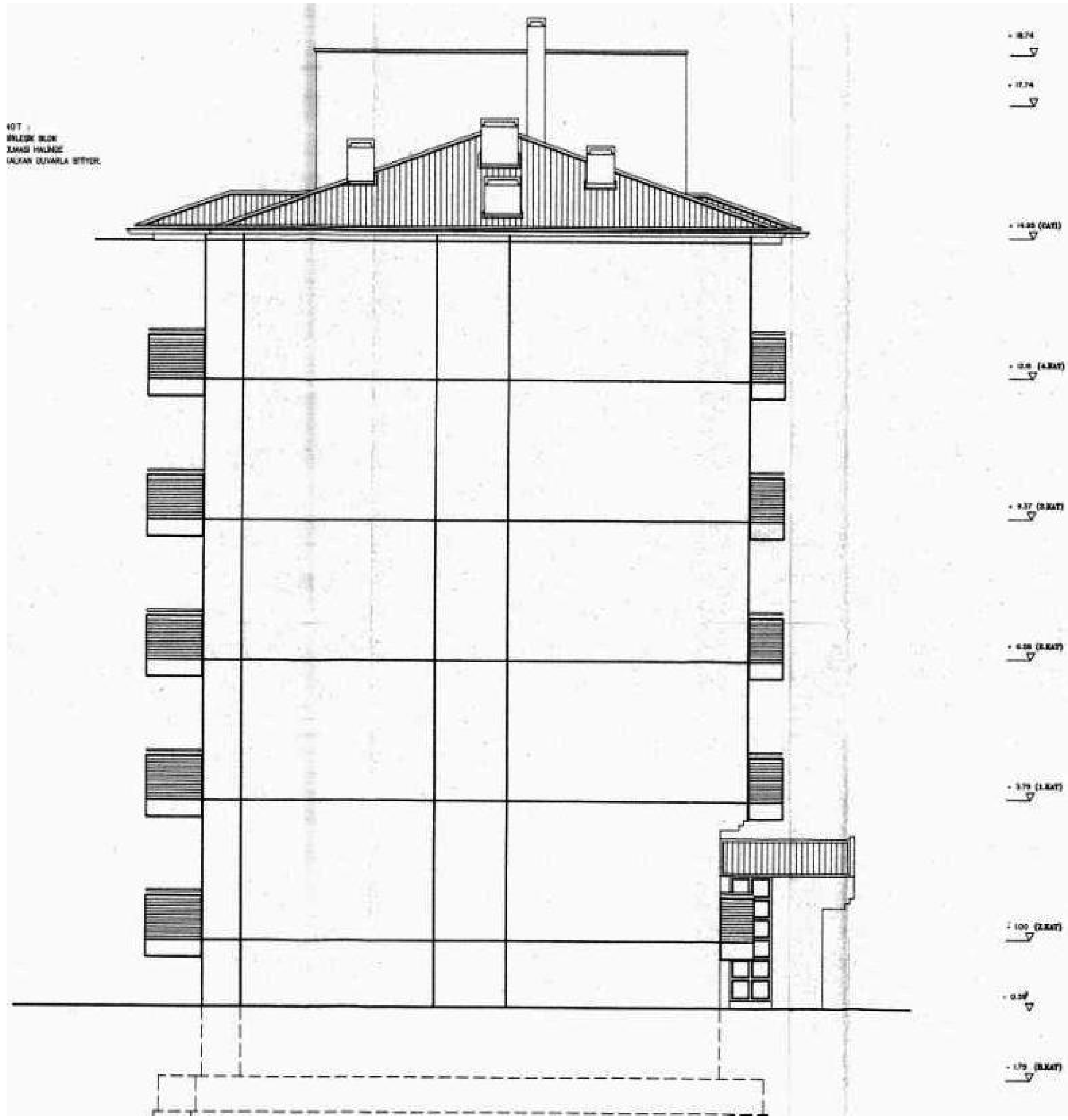

Figure F.11. Southeast elevation of selected apartment block

APPENDIX G

HEATING LOSS CALCULATION BASED ON TS 825-THERMAL INSULATION IN BUILDINGS

Table G.1. Specific heating loss calculation of building using İZODER software

BİNADAKİ YAPI ELEMANLARI			Yapı elemanının kalınlığı d (m)	Isıl iletkenlik hesap değeri λ_h (W/mK)	d/λ, $1/\alpha$ (m²K/W)	Isı iletkenlik katsayısı U (W/m²K)	Isı kaybedilen yüzey A m²	Isı kaybı A x U (W/K)
DUVAR (dış havaya açık) DUVAR/	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,13			
	4.4	Yalnız alçı kullanarak (agregasız) yapılmış sıva	0,005	0,300	0,017			
			0,005	0,120	0,042			
			0,020	0,034	0,588			
			0,005	0,300	0,017			
			0,160	1,800	0,089			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,04			
TOPLAM					0,92	1,084	1.045,41	1.133,23
DUVAR (düşük sıcaklıklı) DUVAR/	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,13			
			0,005	0,300	0,017			
			0,130	1,800	0,072			
			0,005	0,300	0,017			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,13			
TOPLAM					0,37	0,5 x 2,735	18,28	25,00
DUVAR (toprağa temas eden) DUVAR/	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,17			
			0,005	0,300	0,017			
			0,160	1,800	0,089			
	9.2.1	Mastik asfalt kaplama > 7 mm	0,007	0,700	0,010			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)						
TOPLAM					0,25	0,5 x 3,501	23,65	41,39
TAVAN (çatılı) TAVAN/	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,13			
			0,005	0,300	0,017			
			0,140	1,800	0,078			
			0,040	0,035	1,143			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,08			
TOPLAM					1,45	0,8 x 0,690	205,19	113,26
TABAN (ısıtılmayan iç ort. bitişik) TABAN/	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,17			
	9.1.4	Halı vb. kaplamalar	0,005	0,070	0,071			
	4.6	Çimento harçlı şap	0,005	1,400	0,004			
			0,140	1,800	0,078			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,17			
TOPLAM					0,45	0,5 x 2,029	145,38	147,49

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Table G.1. (Cont.) Specific heating loss calculation of building using İZODER software

BİNADAKİ YAPI ELEMANLARI	Yapı elemanının kalınlığı d (m)	Isıl iletkenlik hesap değeri λ_h (W/mK)	$d/\lambda, 1/\alpha$ (m^2K/W)	Isı iletkenlik katsayısı U (W/m^2K)	Isı kaybedilen yüzey A m^2	Isı kaybı A x U (W/K)
PENCERE				**5,200**	**76,36**	**397,10**
KAPI				**3,500**	**96,18**	**336,63**
Yapı elemanlarından iletim yoluyla gerçekleşen ısı kaybı toplamı :					**2.194,11**	**W/K**

H = Hi + Hh

Hi = 2.194,11 W/K

Hh = 602,0 W/K

H = 2.796,06 W/K

Table G.2. Calculation of annual energy requirement for heating by using İZODER software

Aylar	Isı kaybı: Özgül ısı kaybı H = Hi + Hh (W/K)	Isı kaybı: Sıcaklık farkı Ti-Td (K,C)	Isı kaybı: Isı kayıpları H(Ti-Td) (W)	Isı kazançları: İç ısı kazancı ϕ_i (W)	Isı kazançları: Güneş enerjisi kazancı ϕ_g (W)	Isı kazançları: Toplam $\phi_T = \phi_i + \phi_g$ (W)	KKO γ (-)	Kazanç kullanım faktörü η_{ay} (-)	Isıtma enerjisi ihtiyacı Qay (kJ)
OCAK	2.796,06	11,0	30.756	3.648	2.022	5.670	0,18	1,00	65.022.912
ŞUBAT		9,7	27.121		2.436	6.084	0,22	0,99	54.685.601
MART		7,5	20.970		2.879	6.527	0,31	0,96	38.112.975
NİSAN		3,3	9.226		2.758	6.406	0,69	0,77	11.128.440
MAYIS		0,0	0		3.151	6.799	0,00	0,00	0
HAZİRAN		0,0	0		3.279	6.927	0,00	0,00	0
TEMMUZ		0,0	0		3.203	6.851	0,00	0,00	0
AĞUSTOS		0,0	0		3.099	6.747	0,00	0,00	0
EYLÜL		0,0	0		2.794	6.442	0,00	0,00	0
EKİM		0,9	2.516		2.421	6.069	2,41	0,34	1.172.983
KASIM		5,7	15.937		1.908	5.556	0,35	0,94	27.771.621
ARALIK		9,6	26.842		1.784	5.432	0,20	0,99	55.635.517
							Qyıl = Σ Qay =		253.530.049

Qyıl = 0,278 x 1/1000 x 253.530.049 = 70.481 kWh

Bu bina için sınırlandırılan enerji ihtiyacı Q' = 50,29 kWh/m2

Bu bina için hesaplanmış olan ısı ihtiyacı Q = 96,59 kWh/m2

Q > Q' olduğundan bu bina için yapılmış olan ısı yalıtım projesi standarda uygun değildir.

APPENDIX H

EFFECT OF INSULATION THICKNESS ON INDOOR TEMPERATURE

To see effect of insulation thickness in external wall on indoor temperature in zone 6 of the middle floor for transition months of the year: 20 May and 23 September (Table H.1. and Table H.2).

Table H.1. Indoor air temperature of zone 6 of ground floor on 20 May when 3, 5, and 8 cm XPS applied on external walls.

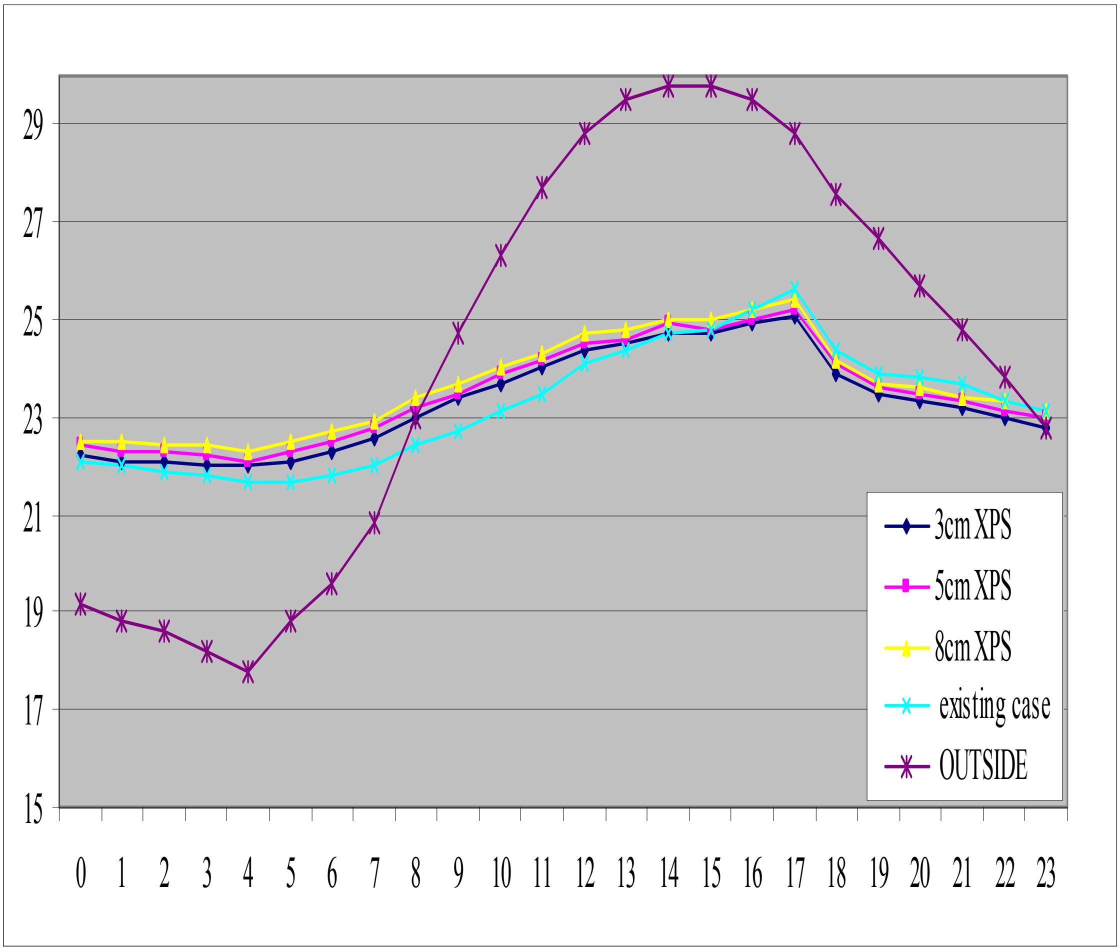

Table H.2. Indoor air temperature of zone 6 of ground floor on 23 September when 3, 5, and 8cm XPS applied on external walls.