Energy Consumption and Thermal Performance of Typical Residential Buildings in Turkey

DISSERTATION

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ABSTRACT

Turkey has a large energy potential for reducing CO2 emissions by energy consumption in residential buildings, applying sustainable design strategies and renewable energies. Two critical elements of building energy consumption are climate and building energy standards, thus, a new detailed climate analysis of Turkey was prepared by using the classification methods in ASHRAE transactions 4610-4611. A review of building energy standards for selected countries allows for comparison with Turkey regarding standard updates or preparation. Four typical residential building types from Turkey were selected and analysed as to their energy consumption and thermal comfort, using the TRNSYS simulation program. Three of the building types are pre-fabricated and one is realised in a traditional building technology, which represents a significant number of dwellings in Turkey. The thermal simulation of the building types was carried out for three different climatic zones of Turkey: Hot, Moderate and Cold. The variation of design parameters shows, that high energy savings can be achieved by basic design strategies, including ventilation, orientation of large window areas with respect to solar heat gain, thermal insulation of building envelope, and utilization of thermal mass. It is shown in a systematic approach, how the thermal comfort and the energy performance for typical building s and climatic zones of Turkey can be improved to a level, which is comparable with advanced European standards of high comfort and low energy buildings. The remaining energy demand can partly be provided by integrating renewable energy technologies in the building such as solar thermal or photovoltaic panels.

Ümit Esiyok, September 2006

1. Introduction

Energy consumption, energy conservation and energy efficiency in buildings have been important research areas for countries due to increasing energy demand, lack of the natural sources caused by utilization of fossil fuel based energy sources and environmental issues like the greenhouse effect, acid rain and ozone depletion. Energy consumption is partly dependent on the weather, for example, in a cold year more energy is consumed to maintain comfortable internal temperature than in a warmer year. However not only climate characteristics but also buildings themselves have influence on energy use. A building with a weak envelope doesn't perform as well as a building with an energy efficient envelope regarding energy use.

Energy consumption is the amount of fossil fuels, renewable fuels and electricity consumed by end use sectors; industrial, residential, transport and service. One of the largest sectors that consume a significant amount of total energy in the world is the residential sector. For instance, in Europe the household and service sectors share 41% of total energy consumption; transport and industry follow with 30% and 29% of total demand respectively. In Turkey, the residential sector, placed in first place regarding energy consumption, represented almost one third of total energy consumption in 1990 (28, 98 %-15358 Ktoe). In 2001 it decreased by 21,62 %,-18541 Ktoe, making the residential sector second after the industrial sector, according to the statistics presented by the Ministry of Energy and Natural Sources.[1].

The contribution of building to environmental problems is increasing significantly. A considerable amount of energy is being used for the heating and cooling of a building to maintain its resident's thermal comfort. Due to this known fact scientists, organizations and academicians are looking for new solutions to decrease the energy consumption of buildings by using advanced design strategies, which perform to keep inhabitants thermal comfort within acceptable limits as well.

The building's envelope, which consists of everything that separates the indoor environment from the outdoor environment, including the basement slab, external walls and roof, plays an essential role in the energy demand of buildings. As a result, the design of energy efficient housing can be obtained by using more industrialized methods in production and construction processes and can provide improved indoor comfort, reduced drafts, moisture and improved air quality.

This work claims that pre-fabricated construction systems can be an adequate choice for energy efficient building envelopes since industrialized production and construction processes yield higher quality components that shape the building envelope (for example high quality in thermal insulation, the most important element of the energy efficient building) and flexible design that can affect solar heat gain and thermal mass (pre-fabricated shutters, portable wall units, etc.) compared to the conventional construction system. Pre-fabricated construction offers a dense, uniform, continuous air barrier with fewer thermal bridges, thanks to its high quality insulation. Another reason to choose pre-fabricated building technologies for simulation purposes is that these systems will dominate the building sector in the future due to their advantages with respect to its time saving, economic and quality advantages.

The components in pre-fabricated systems work together, not as an individual part. For example, the practice of gluing the components together in addition to the conventional fastenings in some examples makes pre-fabricated systems tighter than conventional systems. In conventional construction systems, work quality also depends on the ability of workers; therefore, construction quality will not be the same as in pre-fabricated systems. Because of these reasons the thesis asserts that pre-fabricated systems are better than conventional systems with regards to thermal behavior and energy consumption. Due to the reduced waste during the production and construction process pre-fabricated systems are considered to be environmentally friendly systems. Beside those advantages, choice of materials and design details are important factors for thermal performance.

In addition to all of those assessments mentioned above, energy sources, climate and geographical characteristics of Turkey are the starting point of this work.

Along with these evaluations, this study examines energy consumption and thermal performance in residential buildings, mainly in pre-fabricated residential buildings, in Turkey.

1.1. Objectives of The Work

This thesis deals with energy standards of residential buildings. Building energy standards for different countries from different regions and continents have been shortly examined and both prescriptive and performance requirements for residential building envelopes are illustrated.

The first objective of this study is to define and examine energy and energy consumption matter in Turkey in general terms and the policies carried out by the government. Accordingly importance of building energy standards is investigated. Standards in Turkey and in some developed countries, such as the European Union (Sweden, Norway, and Denmark as the countries that represent the best building energy standards in the world), Germany, USA and other countries which have competitive standard applications, are briefly explained and compared to each other. With regard to Turkey's application for EU membership, requirements for the candidate countries on the energy performance of buildings are main targets and following routes for Turkey in the light of "Directive 2002/91/EC of the European Parliament and of the Council of 16 December on the Energy Performance of Buildings", which explains and indicates requirements for buildings and should be applied by member countries by 2006. In October 2005, Turkey was accepted to start negotiations for EU membership; this fact encourages Turkey to reach EU standards in general and specifically in the energy field.

Climate classification is an important element for setting energy standards. As a result in this work different climate classifications are assessed. A new climate classification for Turkey was prepared according to the ASHRAE Transactions 4610 and 4611, which describe the development of a new climate classification for use in characterizing the performance of energy efficiency measures for buildings.

Following the simulations of selected systems, some comparisons are made between pre-fabricated construction systems and traditional construction systems to see whether the developments in the former pre-fabricated housing construction systems, which are expected to be in high quality, are efficient regarding energy consumption and their thermal performance, otherwise the systems need to be re-evaluated. One of the sample building systems selected for thermal simulation is a reinforced concrete system that is a compound of reinforced columns, beams and lightweight hollow bricks, representing most of the residential building technology in Turkey

This work also aims at introducing new pre-fabricated residential building systems based on the proven performance of the buildings that were tested by the companies in developed countries, as regards energy consumption and thermal comfort.

Pre-fabricated buildings are manufactured through an industrialized process improvement in quality brings many advantages in energy consumption and thermal comfort. One example for this system will be the Sekishui housing system developed by Sekishui Housing Business in Japan. The system includes completely finished units built in a covered area (Factory). Therefore, testing those units will be as easy as testing other factory made products that means each unit's quality, the energy performance of each, will be equal. Then those units are connected and put together on the site by using industrialized techniques. The applications were not examined in just Japan, but also, in other countries such as Sweden, Canada and the USA, where the combination of energy efficient building and prefabrication is an important concern of residential building,

Energy efficient and passive housing approaches were defined and examined briefly. Integration of the renewable energies in the residential buildings is an essential step to reduce CO_2 emission, thus, some samples of PV (Photovoltaic) architectural integrations in the Netherlands, the USA, Germany and some other countries were illustrated. In addition, judgment of applicability and adaptability of those systems in Turkey was subsequently discussed.

Another goal is to encourage the institutions related with energy (builders, building product manufacturers, industry organizations, academics, researchers and government) to focus on innovative technologies in energy and the pre-fabricated building sector by introducing new components, systems developed in industrialized countries and by providing a correlation between them to stress the importance of the energy efficiency in buildings, particularly in residential buildings.

The main tasks in this work are,

- Introduction of a new climate classification of Turkey, for the cities in the METEONORM databank (over 50 cities), according to the ASHRAE Transactions 4610 and 4611

- a short energy regulation review of some countries in the world from different continents, regions with respect to building envelope and energy consumption requirements

- determination, examination of the current situation of the selected residential buildings, which exemplify most of the housing types in Turkey and are made of different materials, both in pre-fabricated and conventional systems

- analysis of overall energy consumption (heating, cooling) and thermal performance of residential buildings in different climate regions by using scientific methods, simulation program TRNSYS

- comparisons between pre-fabricated and conventional systems regarding their energy efficiency performance

- lastly, recommendations for general targets of overall energy consumption and appropriate measures for housing in Turkey

1.2. Structure and Methodology

- Methodology:

Methods used for energy the analysis of the sample residential buildings in different regions are literature review, simulation programs, physical observations and the measurements done by other scientists. Much of the literature, related to the energy, pre-fabricated residential building technologies in the universities, on the Internet, from companies and institutions was examined. Selected buildings systems could be investigated by using various simulation programs such as TRNSYS, DOE 2, and ENERGY PLUS etc. TRNSYS, a transient simulation program developed by Wisconsin University in the USA, is used for a simulation of the selected building systems. The components of TRNSYS are written in FORTRAN language. TRNSYS consists of the

TRNSHELL, ISIBAT, PRESIM sub programs. Building envelope and some strategies of simulation are described in PREBID; the building model component. All weather data are provided from METEONORM.

- Structure:

After a brief introduction **in chapter one,** geographical characteristics of the country, energy sources and their potentials (especially renewable energy potential) in Turkey are analyzed **in the second chapter.**

In the third chapter, climate characteristics of Turkey according to different scientists and climate classification methods are examined. In addition, the new climate classification of Turkey is introduced by using the classification method described in ASHRAE Transaction 4610 and 4611climate. Building energy performance standards in different countries around the world are investigated **in the fourth chapter**. Some recommendations are made with respect to improving Turkish energy standards.

The fifth chapter aims at indicating energy efficient and passive housing approaches, new pre-fabricated building systems, integration of renewable energy sources, specifically integration of photovoltaic in residential buildings (PV) in developed countries such as Germany, USA, Japan and Scandinavian countries. Some residential building systems in Turkey were described as inputs for simulations.

The simulation program TRNSYS, assumptions and strategies used for simulations and an energy analysis of four residential building systems are explained in **the sixth chapter.** In addition, climate characteristics of the three selected cities are assessed. Design strategies and assumptions are graphically detailed. The results are analyzed with respect to four different conditions: heating-cooling energy demand, zone temperatures higher than 26°C, zone temperatures on the hottest day of year and different design strategies, including ventilation, glazing variables, thermal mass internal walls, shading, orientation variables and insulation. In this chapter the economic efficiency of the insulation thickness applied to a traditional system is graphically illustrated and assessed.

In conclusion, after reviewing all results derived from the study, the importance of the energy consumption, energy efficient design and factory made residential buildings is underlined. General recommendations for targets of overall energy consumption and appropriate measures for housing in Turkey are given in the last chapter.

In this thesis, the factors influencing energy demands of a building are classified into two main classes: climate and regulations. Improved building energy regulations, which are presented and formulated by using climate data, decrease energy consumption, since the main target is to reach or exceed required values of standards.

Several research projects were carried out regarding energy efficient residential buildings in Turkey. One of them is a research project that funded by TUBITAK – The Scientific and Technical Research Council of Turkey- and carried out by four scientists in 1997. The research project is entitled "Developing Energy Efficient External Envelope by Retrofitting in Rehabilitation of Existing Residential Buildings". The main objective of this research project was to develop applicable economic and energy efficient retrofitting systems for the external envelope of existing residential buildings in Istanbul. A five story reinforced concrete building block was selected as a model. Improvements were classified with regards to building area, dimensions (width/length) and physical properties. The DOE-2.1E computer program was used for the simulations. [43].

Obviously, that research project was done just for Istanbul and applied only for reinforced concrete systems. In addition, ventilation variables were not investigated, however their influence on energy loss were explained. Energy losses with regards to different variables (insulation thickness, glazing types, orientation and number of floors) were investigated. Some of the results of this research are as follows:

- increasing thickness of the thermal insulation material results in increased energy savings
- replacing single glazing with energy efficient glazing has longest payback period if applied with improved opaque elements

This thesis can also be considered as supplementary work to complete that research work by taking different cities and different residential building systems into account, since it is important to examine and investigate different cities and building technologies for a comparison.

2. Energy Sources in Turkey

2.1. Geographical Characteristics of Turkey

Turkey is one of the largest countries in Europe and Middle East with its 779452 km² total area (23764 km² on the European side, 755688 km² on the Asian side). The country lies between 36-42 north latitude and 26-45 east longitude (roughly rectangular in shape) and situated between two continents - Europe and Asia (Figure 2.1).

It is surrounded by three seas with a total of 8372 km total coastline; the Aegean with 2805 km, the Mediterranean with 1577 km, the Black Sea with 1695 km and the inner sea Marmara with 972 km. The Marmara connects the Black Sea and the Aegean via two straits: Istanbul and Canakkale straits. The country has seven geographical regions: Marmara, Aegean, Mediterranean, Southeast Anatolia, East Anatolia, Black Sea and Central Anatolia. The neighboring countries are Greece and Bulgaria to the northwest, Armenia and Georgia to the northeast, Iraq and Iran to the southeast and Syria to the south (Figure 2.2). The highest mountain in Turkey is Mount Ararat (5165 m) and biggest lake is Lake Van: both are located in eastern Anatolia.

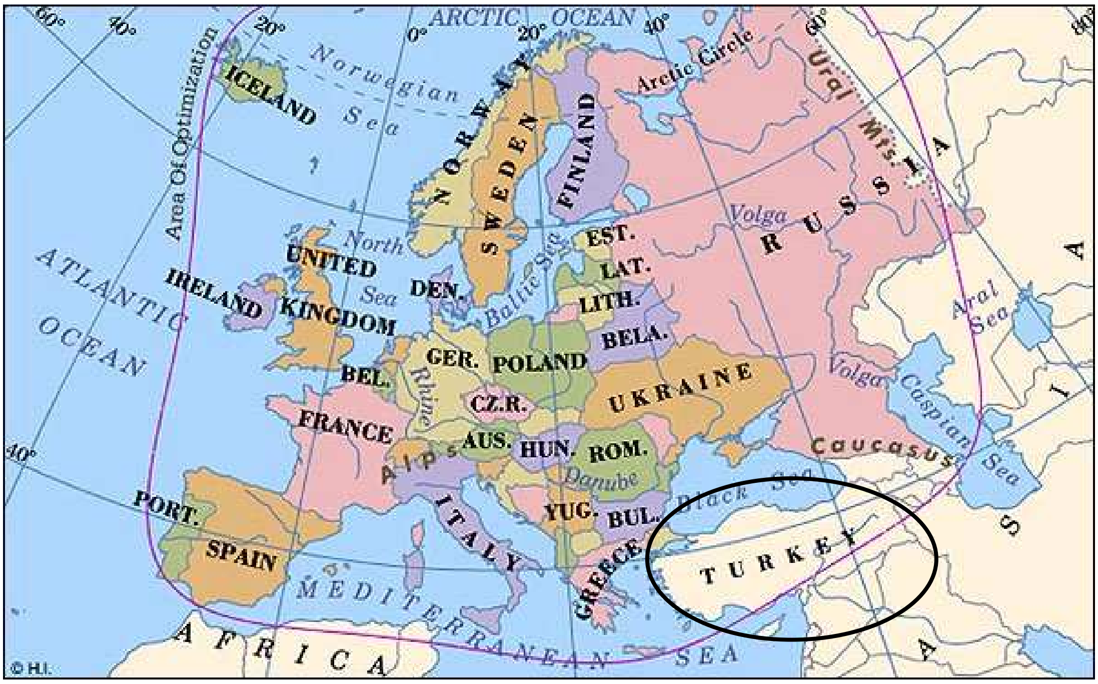


Figure 2.1: Turkey’s location between Europe and Asia (Source: www.Worldpress.org)

Turkey is the fifteenth most populated country in the world with approximately 73 million inhabitants. Istanbul houses almost 15 million of these inhabitants, making the city one of the most populated cities in the world *(2005 World Population Data Sheet, www.prb.org)*

Figure 2.2: Geographical map of Turkey (Source: www.Worldpress.org)

2.2. Energy Sources and Problems in Turkey

As a developing country an in conjunction with its fast growing economy and population - a population increase of almost one million inhabitants per year - Turkey's energy consumption has increased rapidly between 1996 and 2004. While total primary energy consumption in 1996 was 70.77 Mtoe, in 2004 it raised 87.78 Mtoe. On the other hand, total energy production in 1996 was 28.29 and 24.17 in 2004 (Figure 2.3).

The industrial sector accounted for 36% of total energy consumption, while residential and commercial sectors represented 35% in 1997. In recent years, the difference between the industrial and residential sectors has increased much more than in former years, according to the MENR (Ministry of Energy and Natural Resources) statistics. Among the EU candidate countries, Turkey has the second largest energy consumption, 50.1 Mtoe, after Poland, 58.4 Mtoe, according to the European Commission Yearbook "*Statistical yearbook on candidate countries*" in 2003.

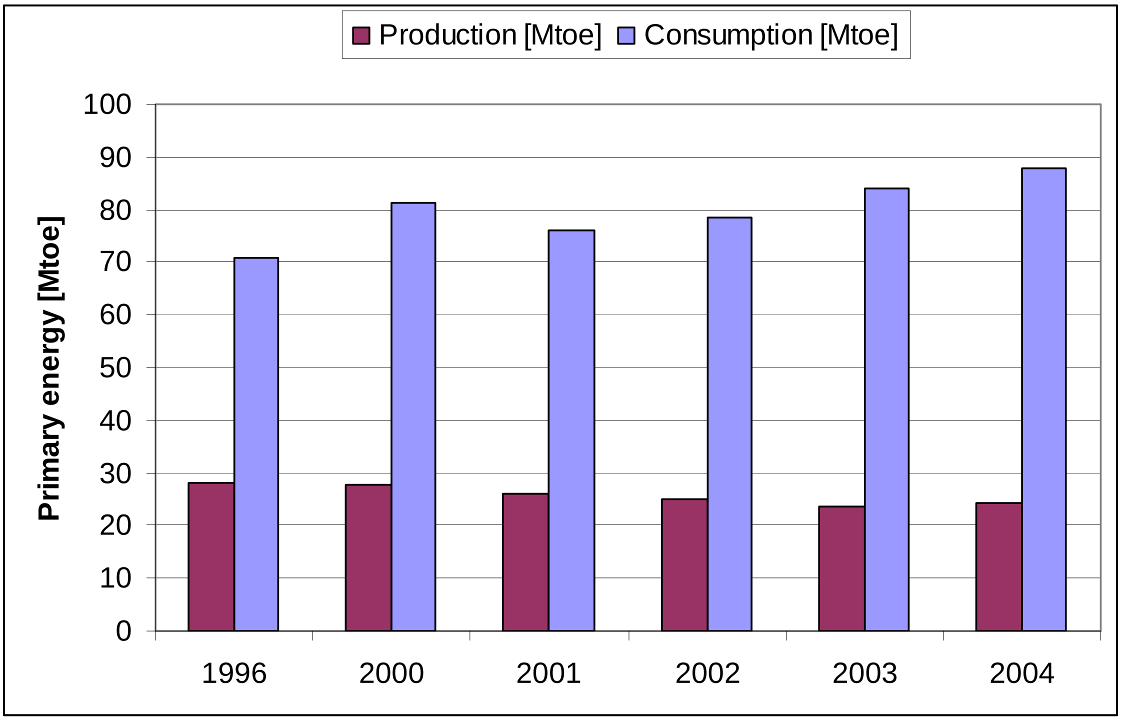


Figure 2.3: Energy production and consumption in Turkey

As it can be seen, Turkey is an energy importing country and dependent on the imported energy sources. Furthermore this trend seems to be continuing in the future. Although it has a wide variety of energy sources, the quality and quantity of most of the sources are not sufficient to produce energy. Some of the energy sources in Turkey are hard coal, lignite, asphalt, oil, natural gas, hydropower, geothermal, wood, animal and plant wastes (bio mass), solar and wind energy (Table 2.1). The proven reserves of lignite, the most abundant domestic energy source, is 7300 million ton and found in almost all of the country's regions. Lignite has the largest percentage in total energy production with its 42.5 percent share. After lignite, wood has the greatest share in total energy production with its 20% and oil accounts for 13%, 12.4% hydro and the final 15% includes animal wastes, solar, hard coal, natural gas, geothermal electricity and geothermal heat.

Table 2.1: Primary energy sources in Turkey (Source: MENR)

Source	Apparent	Probable	Possible	Total
Hard Coal (million tons)	428	449	249	1126
Lignite (million tons)	7339	626	110	8075
Asphaltite (million tons)	45	29	8	82
Bituminous schist (million tons)	555	1086		1641
Hydropower (MW/year)	35.045	-	-	35.045
Oil (million tons)	48,4	-	-	48,4
Natural gas (billion tons)	8,8	-	-	8,8
Nuclear (tons)				
Uranium	9129	-	-	9129
Thorium	380.000	-	-	380.000
Geothermal (MW/year)				
Electric	200	-	4300	4500
Thermal	2250	-	28.850	31.100
Solar (Mtoe/year)				
Electric	-	-	-	8,8
Heat	-	-	-	26,4

Turkey’s various renewable energy sources represent its second largest energy source after coal. Biomass and animal waste account 67.3 %, hydropower 29.5 %, geothermal 2 % and wind and solar account for 1.2 % each of total renewable energy production

There are many rivers in Turkey, thus water sources are one of the most important energy sources. 19 % of electricity generation was provided by hydropower in 2001, and it increased to 26 % in 2002. Turkey’s largest hydroelectric power plant is the Atatürk Power Plant, which has the 6th largest capacity in the world, with the capacity of 2400 MWe Karakaya with 1800 MWe Keban 1330 MWe Thirty four hydro plants are under construction, and 329 more hydro power plants are projected. The largest hydro power project in Turkey is the Southeastern Anatolia Project (GAP), which covers 74000 km2 of the country. Upon competition, GAP will have an installed capacity of 7476 MW 22% of Turkey’s total estimated economic potential [1] [2].

In spite of its high energy productivity benefits the power plants cause major environmental and social problems such as migration of residences, loss of valuable agriculturally productive alluvial bottomland, alteration of ecosystem.

In addition to water sources, Turkey has significant reserves of other renewable energy sources such as wind, solar, biogas and geothermal energy. **Wind energy:** western, northern and southeastern Anatolia is favorable for wind power generations, as annual wind speed is around 2.5 m/second (Figure 2.4). The first wind power facility which has 12 wind turbines for a capacity of 7.2 Mwe, was commissioned in 1998 in Izmir. In addition to this build-operate-transfer power station, 17 more were approved in 2001 and more applications are under evaluation by the Ministry of Environment and Natural Resources. Turkey had a total installed capacity of 18.9 MW in 2002.

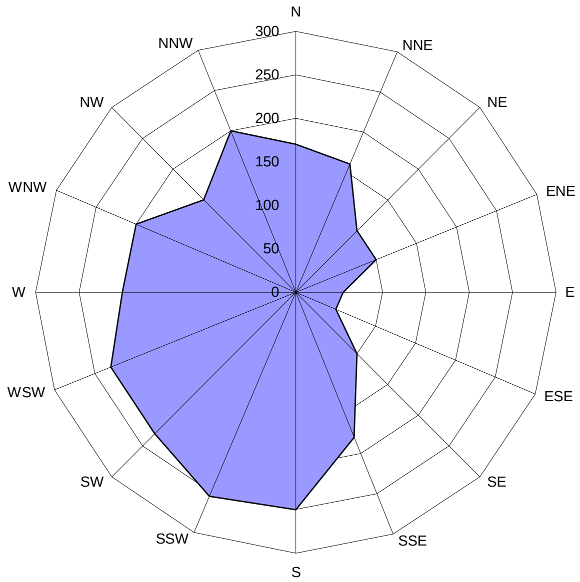


Figure 2.4: Turkey's wind direction

Another renewable energy source for which Turkey has significant potential is the **geothermal energy source**, which represents one eighth of the world's total geothermal potential. Much of this potential does not have a high quality, which is required to produce electricity. Thus it mainly is used for heating purposes. By the end of 2001 geothermal energy potential of electricity and thermal was predicted to be 4500 MW/y and 31100 MW/s respectively. The total installed capacity for heating was 820 MWth, all of which provided heating for 51600 residences. Geothermal districts which have temperatures above 40 °C are around the West, Northwest and Middle Anatolia. It has been expected that five million houses will be heated by using geothermal energy sources. The country's geothermal energy potential is determined by the fact that Turkey lies on the Alpine Himalayan organic belt [2].

Solar energy use in Turkey has increased dramatically in recent years, mostly for water heating purposes. Turkey's average annual sunshine duration is 2640 h (7.2 hours/day) and average solar intensity 3.6 kWh/m² day (Table 2.2). The main solar energy utilization in Turkey comes from flat plate collectors in the domestic hot water systems. Flat plate solar collectors can be seen at the top of a residential building's roof with a water tank almost in every region especially in the southern and western regions even in the villages. [3]

Table 2.2: Turkey's monthly solar energy and sunshine duration (Source: MENR)

MONTHS	MONTHLY TOTAL SOLAR ENERGY		SUNSHINE DURATION
	(Kcal/cm2-month)	(kWh/m2-month)	(hours /month)
January	4.45	51.75	103
February	5.44	63.27	115
March	8.31	96.65	165
April	10.51	122.23	197
May	13.23	153.86	273
June	14.51	168.75	325
July	15.08	175.38	365
August	13.62	158.4	343
September	10.6	123.28	280
October	7.73	89.9	214
November	5.23	60.82	157
December	4.03	46.87	103
TOTAL	112.74	1311	2640
AVERAGE	308,0 cal/cm2-day	3,6 kWh/m2-day	7,2 hours/day

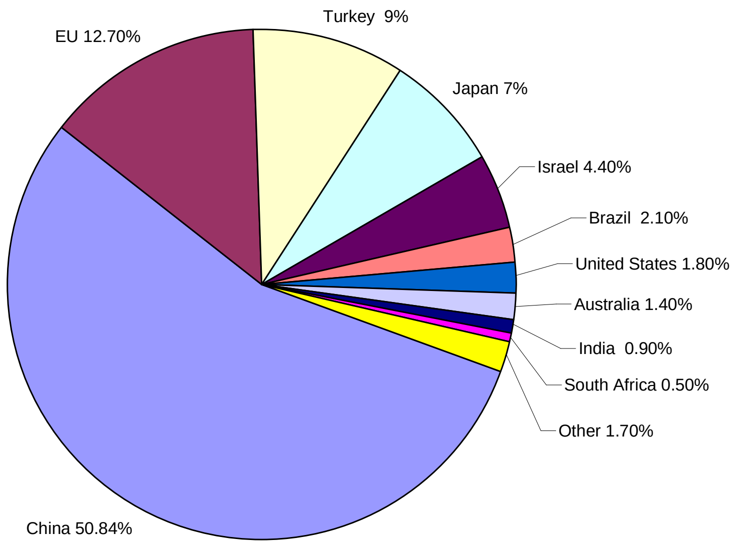


Figure 2.5: Share of existing solar hot water/heating capacity in the World (*Source: Renewable 2005 Global Status Report*)

Turkey is one of the leading countries in the world for total installed capacity with a total of collector area 8.2 million m² as of 2002. After China and the European Union, Turkey has the third largest solar hot water/heating capacity with 9% (Figure 2.5). [4]. Total energy production in 1998 was 210000 TOE it increased to 290000 TOE in 2001. There are almost 100 solar energy companies with the 750000 m2 of annual manufacturing capacity. Photovoltaic systems are used rarely in Turkey, since they are limited by the applications of governmental works such as telecom stations, forest fire observation towers and highway emergencies.

Turkey's solar energy potential has been estimated to be 26.4 million tons as thermal and 8.8 million tons as electricity. On the other hand, new preparations of solar energy source potential statistics are being prepared by MENR. Southeastern Anatolia has the highest sunshine duration (2993 hours/year) and is followed by the Mediterranean region (2956 hours/year), the East Anatolia (2664 hours/year) and the Aegean region (2738 hours/year) (Figure 2.6)

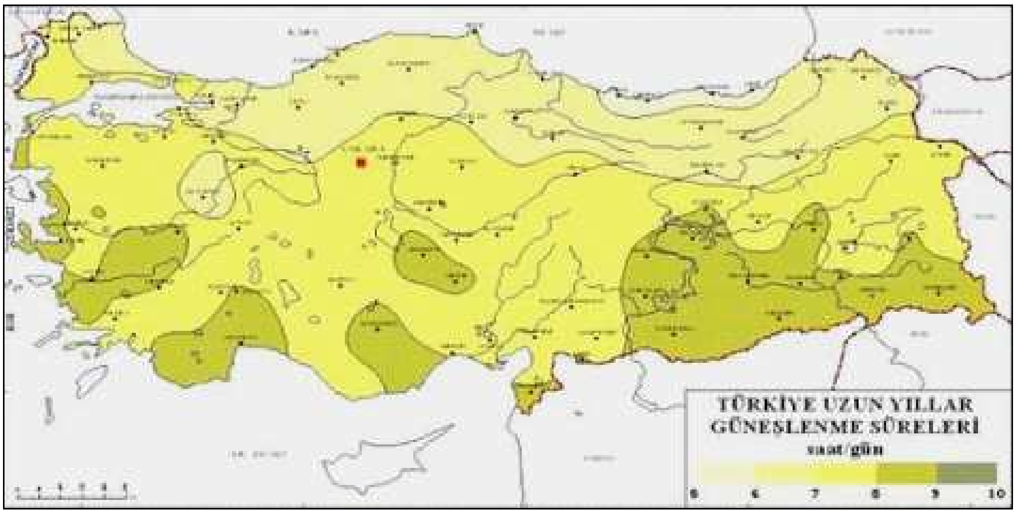


Figure 2.6: Sunshine duration hours of Turkey (Source: MENR)

Turkey uses a substantial amount of **bio energy** resources, including animal and plant wastes. For instance in 1997 animal and plant wastes accounted for nearly 6% of (6575 Ttoe) total energy production, but this number declined to 5790 Ttoe in 2001 and is expected to decline even more in the future. Turkey's biogas potential was identified as 3-4 bcm (1.5-2 million tons of oil equivalents, Mtoe) per year. In 2001, the quantity of raw material available was 4739 million tons as animal dung and 1790 million tons as wood residues. These sources are mainly used for heating purposes in rural regions.

Turkey's CO^2 emissions have increased parallel with its energy consumption. Turkey was ranked third among IEA member countries regarding the CO_2 emissions increase rate between 1990 and 1995, when it increased from 138.50 Mt to 160.50 Mt, and it has been expected that it will increase to 308.20 Mt in 2005 and to 424.50 Mt in 2010. Since 1990 Turkey's energy-related carbon emissions have increased from almost 138.50 Mt/year to 210.46 Mt/year. In contrast, the share of the residential sector was 16% in 1990, and it remained at 16% in 2000. In Turkey, total CO_2 emission per year from dwellings is 25.948 million tons, which at 5.3% ranks Turkey seventh among twenty European countries, according to the survey prepared by EURIMA (European Insulation Manufacturers Association) in 2001. [5]

According to the European Commission Yearbook "*Statistical yearbook on candidate countries*" in 2003 Turkey had the highest (227 Mt, 3.4 tons per capita) total CO_2 emissions among the EU candidate countries (Figure 2.7).

Even though Turkey became a member of UNFCCC (United Nations Framework Convention on Climate Change) on May 24, 2004, Turkey is not a party to Kyoto Protocol, but it is placed in Annex-1 countries which were defined in Marrakech in 2001.

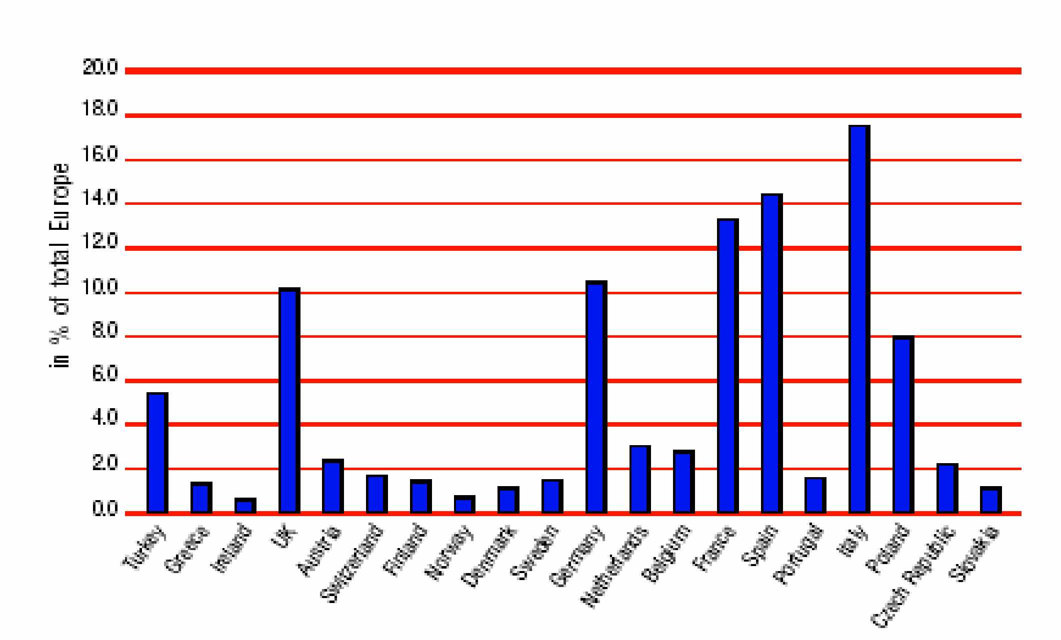


Figure 2.7: Total CO2 emissions per year from dwellings (Source EURIMA)

3. Climate and Climate Classifications

Climate is defined in the *Oxford Dictionary* as “the general weather conditions prevailing in an area over a long period”. Another detailed definition made in the intergovernmental panel on climate change report in 2001 is:

“Climate in a narrow sense is usually defined as the “average weather”, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system” [6]

Among other variables such as building envelope, heating system, type of use, etc., climate is the most important element and has the greatest influence on the energy consumption of buildings. Building envelopes are mainly shaped by climate characteristics of the surrounding environment where they are built. Therefore, analyzing the climatic conditions of buildings or places is one of the essential phases of design, which focuses on providing comfortable and energy efficient living spaces. Although a building may have a very good envelope construction, it still consumes more heating energy in a cold climate than that in hot climate. As a result, climate considered design plays a vital role for designers, engineers and architects, who should consider climate elements that influence both human comfort and a building’s thermal performance.

Some climatic elements considered in building design are:

-air temperature

-radiation, diffuse and beam radiation, or long wave short wave.

-wind speed

-relative humidity

-sky conditions

-rainfall

-air movement [7]

Climate classification becomes an essential matter at this point due to the determination and selection of the design strategies and material choices, since most energy performance standards are established by referring to regional climate classifications. The “Degree Day Method” is used in determining new generation climate classifications. They are used for calculating heat losses as well.

- **Degree Days**

Degree days are originally used to evaluate energy demand and energy consumption. They represent energy demand of a place and are an essential indicator for estimating energy needs. In many standards such as ASHRAE, TS 825, degree days are taken into account in order to calculate energy demands and energy losses**.** Once the climate classifications are made with the help of degree days, reference values of energy consumptions for each climate class are determined and used in calculations of energy demands.

- ***Heating Degree Day (HDD)***

The heating Degree Day can be defined as the sum of the differences between average ambient temperature and the lowest reference temperature. Degree days can be calculated weekly, monthly or yearly. Internal base temperature is specified according to climate regions and buildings. For example in the USA the base temperature for heating degree day is generally defined as 65 °F (18. 3 °C), while in the UK base temperature is 15.5°C. We choose 18°C, above which the building is assumed not to need heating. If the daily average temperature is lower than the 18 °C reference temperature, the difference between those temperatures gives heating degree days.

Heating Degree Days (HDD) $Gt = \sum_{n=1}^{Z} (\theta im - \theta am, n)[k.d / a]$ (1)

Where θim : Reference temperature for heating

θam : Average ambient temperature

- ***Cooling Degree Day (CDD)***

The cooling Degree Day is the sum of the difference between average ambient temperature and the upper reference temperature. The internal base temperature may be determined according to the building structure. In this work we choose the base temperature of 10°C referring ASHRAE transactions 4610-4611.

Cooling Degree Days *Gt, K* = $\sum_{n=1}^{Z}(\theta im - \theta am, n)[k.d/a]$ (2)

Where θim : Reference temperature for cooling

θam : Average ambient temperature. [8]

In some cases, the Degree-hours (DH) method is used. Degree-hours are the result of the mean ambient temperature compared to an inside reference temperature. They help to monitor energy consumption of a house, as well as to detect possible anomalies. Degree hours together with the calculation of the thermal energy index are the two components of the energy signature of a building. Degree hours are not only a representative indication of the heating and cooling energy consumption but also it is an indication of energy saved for cooling and natural ventilation.[9] [15]

Heating and cooling degree days for the selected cities - Antalya, Istanbul and Erzurum - are illustrated in Figure 3.1. Degree days are calculated by referring to ASHRAE Transactions 4610 and 4611 which describe climate classification methods for ASHRAE standards. Heating degree days and cooling degree days are calculated by taking the base temperatures of 18°C and 10°C respectively. However, it seems that the cooling degree day's base temperature can be increased to 18 °C or 20 °C after reviewing the simulation results that we gained in this work. For instance, average ambient temperature doesn't exceed 20°C in Erzurum due to that reason it can be estimated and a higher base temperature may be used for calculating cooling degree days.

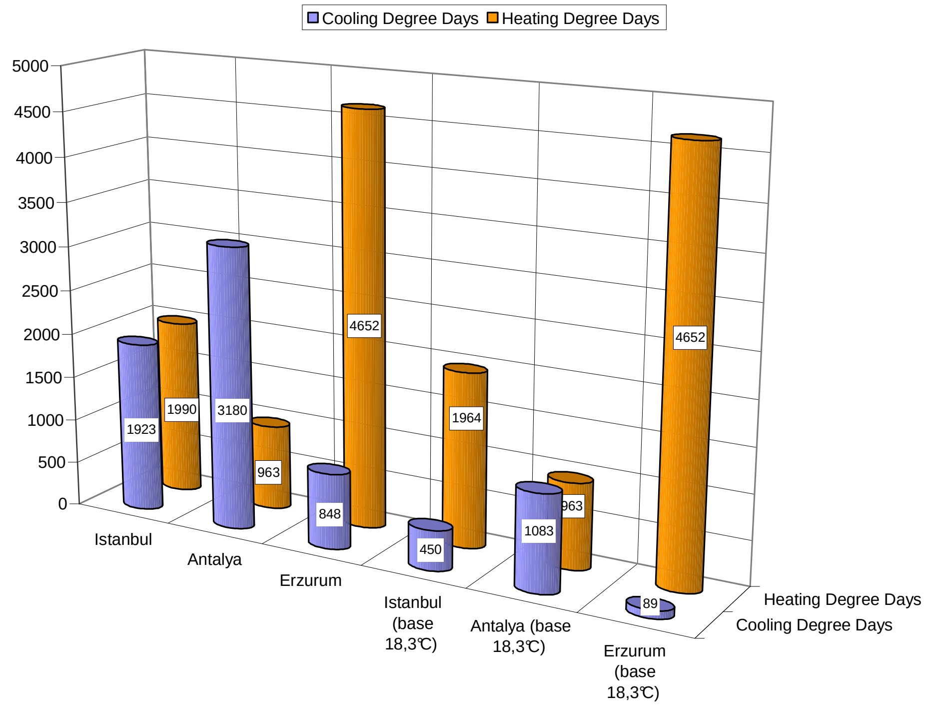


Figure 3.1: Heating and cooling degree days of selected cities (ASHRAE Method and CDD -18.3°C base)

The relation between degree days and energy consumption can also give prior approximate information before construction starts. In the research work done by A. Matzarakis and C. Balafoutis, it is concluded that a residential building in Florina (Greece), which has 1784.4 HDDs, spends almost nine times more energy to enjoy the same heating comfort than on the island of Rhodes (Greece), while the HDD ratio between those cities are approximately nine fold as well. Along with the degree days calculated for this work, the relation between degree days and energy consumption is also graphically illustrated. [10]

The Figures 3.2a and 3.2b represent the relations between energy demand and HDD and CDD for Antalya, Erzurum and Istanbul. It gives some information about climate as well and answers the question of how cold or hot the cities are. After examining the relation between degree days and energy consumption, we concluded that there is an almost linear relation between them. Heating and cooling degree days, heating and cooling energy demands of selected cities indicated in (Figure 3.2a, 3.2b), for instance the heating energy demand for Erzurum is almost 7 times that in Antalya. The heating degree day number of those cities shows almost the same relation for traditional construction. In addition, the ratio between cooling energy demand and cooling degree days is almost 1:2. However, the correlation between degree days and energy consumption depends on construction features as well.

As it is illustrated in the Figure 3.2a and 3.2b, four different construction systems in three different climate regions are investigated with regards to degree days and their energy consumption before improvements are made for the simulations. The linear regression method is used to evaluate the relation between two variables energy consumption and degree days for three cities Istanbul, Antalya and Erzurum. The energy consumption of the reference cases for each building types in these cities were obtained through the energy simulations by TRNSYS. The linear regression line of traditional building system differs from other systems because of its worst cooling energy performance in Antalya. In addition, only three cities were investigated, more data can provide appropriate regression line. The intersection points of energy consumption and degree days represent the performance of the different systems, for instance, if we investigate energy consumption of the traditional system in another city out of three cities that have cooling degree days of 1500, it can be estimated that the cooling consumption of this traditional building in selected city would be around 15 kWh/m²a The energy consumption values are taken from simulation results of the selected three cities in the reference case.

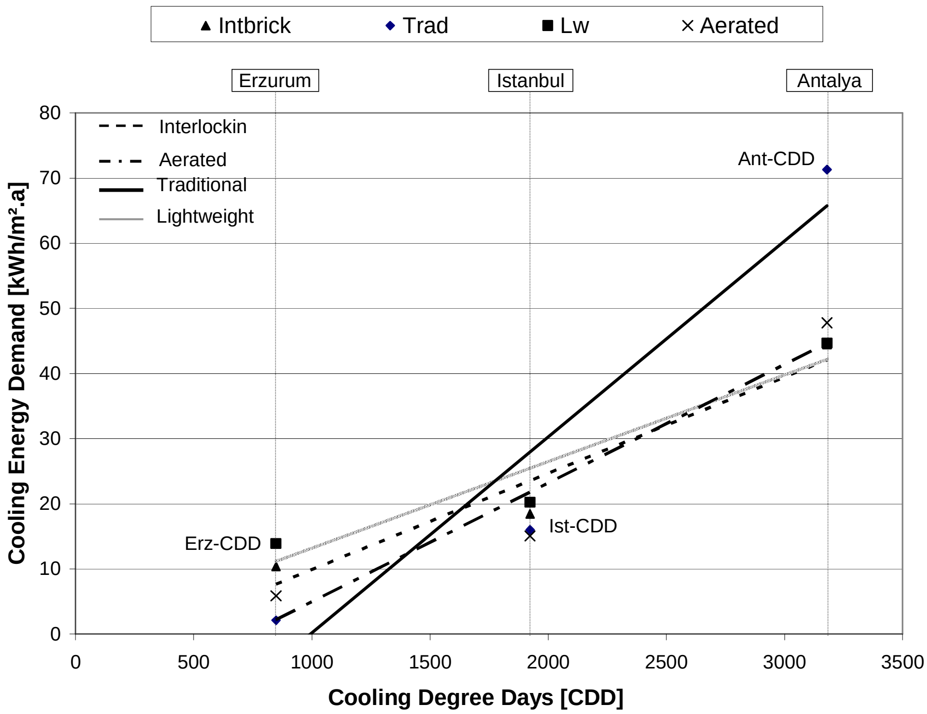


Figure 3.2a: The relation between cooling energy demand and degree days

Each residential building system represents different relations between degree days and heating/cooling energy consumption. For example, both systems with insulation have higher cooling degree days in a cold climate, while they perform better in hot climates with regards to cooling energy.

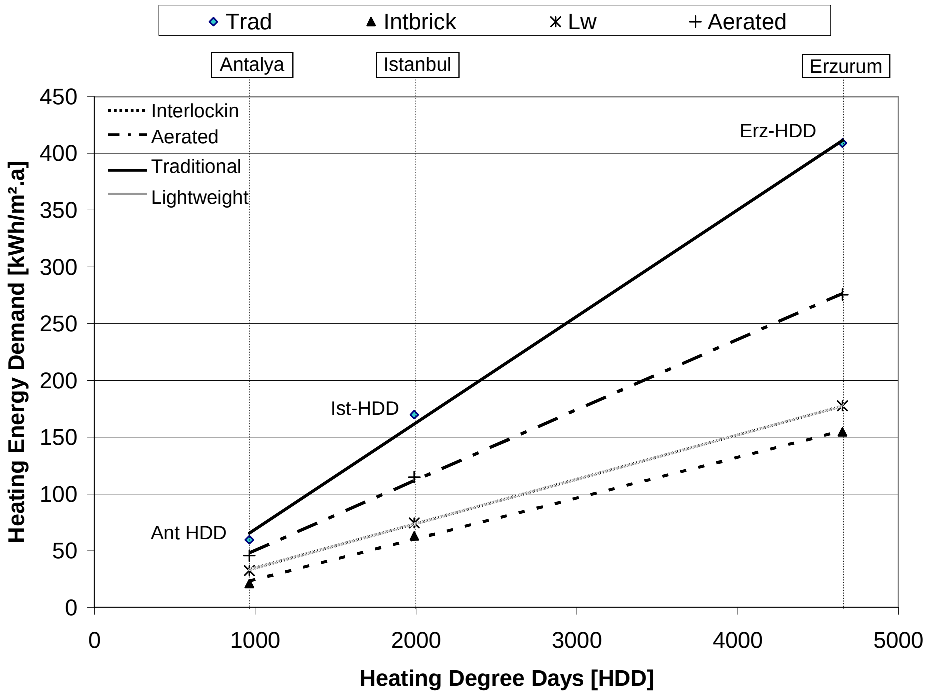


Figure 3.2b: The relation between heating energy demand and degree days

3.1. Climate Characteristics of Turkey

The world is divided into five main climatic zones according to *Köppen Classification*: tropical, arid, temperate, continental and polar climates. [44] Turkey is situated in the temperate Mediterranean climatic and geographical zone. The country has three main climatic zones: the Black Sea region is mild and generally rainy throughout the year with the temperature neither very low in winter nor very high in summer. The southern and western coastlines have a typical Mediterranean climate with mild winters and hot, dry summers. The Interior parts of Anatolia, with high land plains and a mountainous region east of Anatolia are marked by cold and snowy winters, hot and dry summers.

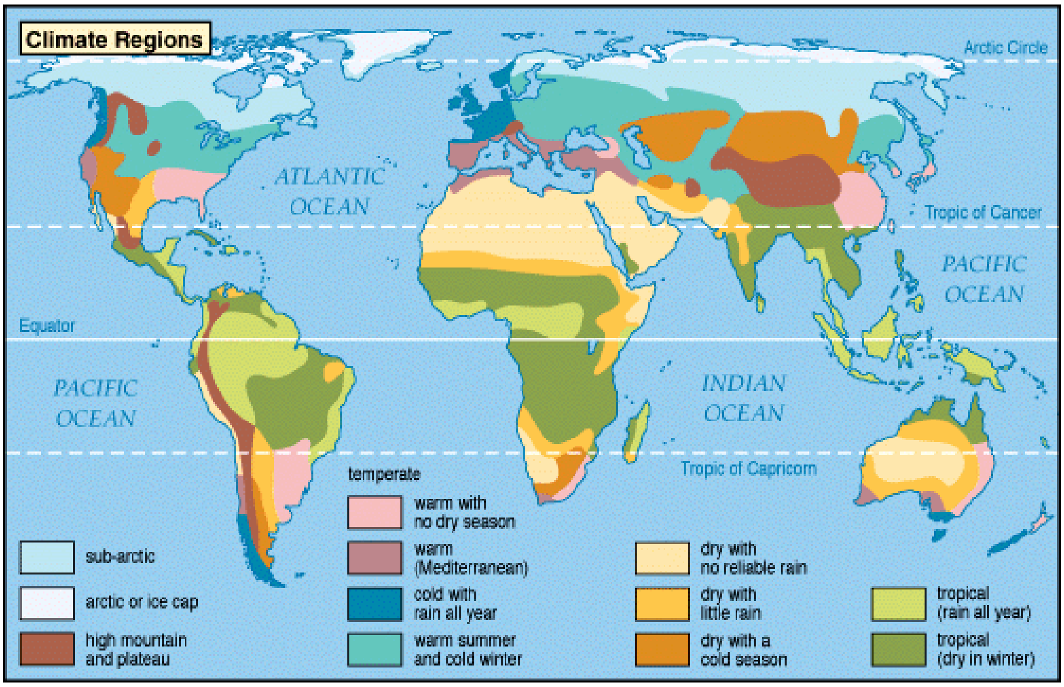


Figure 3.3: World climate zones (Source: http://encyclopedia.farlex.com)

Although the country has three main climate zones, the climate shows different characteristics and can be grouped into five climate groups (according to the scientists) because of their different geographical characteristics. For example in the Mediterranean region, mountains (Taurus Mountains) run parallel to the coasts and prevent the clouds from passing over into the interior parts of the country therefore the coastal side of the region receives more rainfall than the other part of the region. In conclusion it can be concluded that Turkey shows both continental climate and subtropical climate characteristics.

In the "*Turkey Baseline Report on Climate Change*" Turkey is divided into five climate zones [11].

- The Mediterranean climate

Characteristic of the Mediterranean climate are hot, moderately dry summers and mild, rainy winters. This climatic region represents all Mediterranean and a big part of the Aegean geographical regions. The highest annual average temperature reaches 20 °C on the eastern parts of the coast. The Mediterranean climate is classified into two classes:

- Humid Mediterranean climate,

- Semi-humid Mediterranean climate.

- Humid Mediterranean climate

Mean January temperature changes between 8 °C and 10°C, average temperature in July and August, the hottest months, reaches 28°C. Annual average precipitation is 1060mm mostly in winters, in January 240mm, in December 250mm.

- Semi-humid Mediterranean climate

Mean temperature varies between 5°C and 8°C in the coldest month, January. In the winters short term frost can be seen more than in the humid Mediterranean climate region. The rain season is in the winter. The annual mean precipitation is 650mm-850 mm. Particularly in summers, evaporation is high.

- The Black Sea climate

The Black Sea climate region receives the highest amount of rainfall throughout the year in Turkey. The eastern part of the Black Sea region has 2200mm annual average precipitation some years it even reaches 2300mm. The Black Sea Climate region covers all Black Sea coasts and includes the northern part of the Marmara region. Average temperature is 8°C-12°C. The region receives most of the rainfall in autumn and winter. The percentage of the rainy days in the summer is the highest.

- The Semi-humid Marmara climate

This climate zone includes the entire Marmara region except The Black Sea coasts of the region and a small part of the western cities of the Marmara which are influenced by eastern Europe’s climate. The climate is moderate. Annual average temperature is 14°C. The hottest months of the region, July and August, have an average temperature of 23°C. The highest recorded temperature for those months is 37 °C. The coldest month is January with a 5°C average temperature. Annual precipitation varies between 500mm-700mm. The share of summer rainfall is %10-%15.

- Steppe climate

Central Anatolia, the Lake District, the Midwest Anatolia, Southeastern Anatolia, part of the west Marmara region and the interior regions of the Black Sea region are the regions affected by the steppe climate. It is divided into two groups:

- The Semi - arid Central Anatolia climate

- The Semi-arid Southeastern Anatolia climate

- The Semi- arid Central Anatolia climate

Winters are cold, intensity increases towards the northeastern part of Central Anatolia. Mean temperature in the coldest month, January, fluctuates between –3°C and 0°C. In August it is 20°C-22°C. Average annual precipitation varies between 350mm and 500mm.

- The Semi-arid Southeastern Anatolia climate

Summers are very hot; the average temperature is greater than 30°C in the hottest months, July and August. January and February are the coldest months with temperatures of 3°C and 4°C respectively. Summers are dry and long lasting. Amount of annual rainfall is 350mm- 800mm. This climate region is the most arid region of Turkey.

- The Continental Eastern Anatolia climate

The continental Eastern Anatolia climate has the coldest weather in Turkey. Mean temperature is –8°C - 10°C in the winter. The hottest months do not exceed 20°C. Due to its high mountains, this region sometimes referred to as Turkey's roof [11]

3.2. Climate Classifications for Building Energy Standards

3.2.1. Climate Classification Used for TS-825 (Turkish Standard-825)

The Turkish State Meteorological Service and TSE (Turkish Standards Institution) classified Turkish climate regions as "*Thermal Insulation Regions*" by using a degree-day method which was developed by the Turkish State Meteorological Service. The classification, the number of temperature over 10 °C which is derived from 236 stations between 1981 and 2001, has been calculated as follows:

Effective Total Temperature (Degree Days) = $(M - 10) * N$ ***(3)***

M: Monthly mean temperature,
N: Number of days in the month [12]

Degree days for all cities and some towns are listed by using monthly mean temperatures in the equation. Degree days are not classified as heating and cooling degree days like it was mentioned in the ASHRAE classification. According to this classification Turkey is divided into four insulation regions: this was used for the Turkish Standard 825 (thermal insulation in buildings) to determine consumption values and insulation requirements. (Appendix A) The Climate classification of Turkey is made also by scientists but not used for standards.

- Classifications Created by Different Scientists

Different climate classifications for Turkey have been formulated by scientists. They have classified the climate according to the drought coefficients of the cities. These climate classifications differ in calculating water balances. The long range average weather data were used for classification. Some of the classifications are the Aydeniz classification, the Erinc classification and the Thornthwaite classification. The Aydeniz classification is illustrated in the Figure 3.4. As shown in the figure climate is divided according to the drought coefficient from very dry to wet [10].

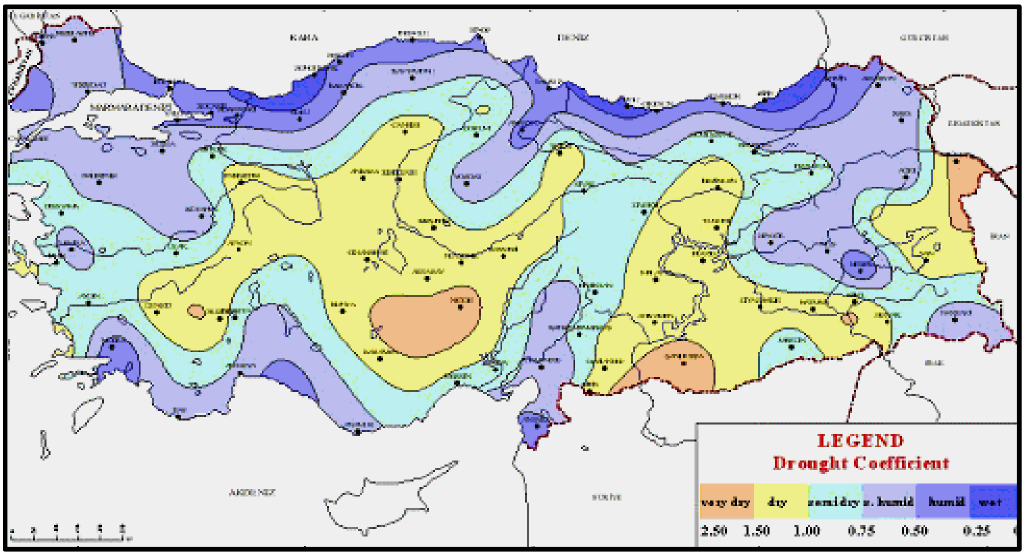


Figure 3.4: Classification of climate zones in Turkey according to the Aydeniz formula (Source:MENR)

3.2.2. Climate Classification Used for ASHRAE Standards (ASHRAE Transactions 4610-4611)

The climate classification was developed to be used in the implementation of building energy codes, standards, design guidelines and building energy analyses in the Unites States.

Compared to the climate classification used for the Turkish Standard TS-825, ASHRAE Transactions 4610 and 4611 are more detailed than the Turkish classification. The classification in the ASHRAE Transactions was made in two phases:

Firstly, climate regions were divided into three main groups, and each group has its own definition: marine definition, dry definition and humid definition. These definitions were made according to the some criteria for the locations, for instance; locations meeting the following criteria are defined as Marine definition;

- Mean temperature of coldest month between -3°C and 18°C and
- Warmest month mean temperature < 22°C and
- At least four months with mean temperature over 10°C and
- Dry season in summer.

Dry definition;

- Not marine and <2.0 * (T_c+7) where

  $P_{cm:}$ annual precipitation in cm, T_c: annual mean temperature in degrees Celsius

Humid definition;

- Not marine and P_{cm} = 2.0 * (Tc+7) (Appendix B)

Having those major climate definitions, the next step is thermal zone definition by using cooling degree day and heating degree day reference temperatures with the help of the *Köppen Classification* (Appendix C). The USA is divided into 8 climate zones. With sub-climate zone definitions, seventeen climate zones are explained with regards to thermal criteria and their names in the *Köppen Classification*. At the end of this research some of the cities around the world are classified as well. [13]

The zone boundaries of the CDD and HDD temperatures are selected according to the conditions in the USA, but from previous experience in other countries it can be said that CDD and HDD reference temperatures will be different for other countries, for instance for Europe.

3.2.3. New Turkish Climate Classification According to the ASHRAE Method

In this chapter Turkey's new climate classification has been made by using the climate classification method used for the ASHRAE standards. All definitions in ASHRAE 4610 and 4611 for zone and thermal classifications were integrated in Microsoft Excel and the weather data were taken from METEONORM for each city. For that classification purpose precipitation and monthly mean temperature data are needed. The method is applied to 51 cities in Turkey. Hourly weather data, including average temperature and precipitation over 10 years, are used for classification purposes. One problem with using this classification for Turkey and Europe could be the determination of base temperatures for CDD and the boundary of climate classification, since the parameters mainly reflect the United States of America. The reason to reclassify Turkey's climate regions according to ASHRAE classification is to compare it to the old climate classification of the country and to show the way to present and prepare classifications, especially since the classification that used by TS 825 is not sufficiently detailed

Some similarities can be seen among some cities when we compare two climate classification maps of Turkey used for energy standards. These two maps show the classification mentioned in TS-825, “Insulation regions in Turkey”, and the classification done by using the ASHRAE Transaction 4610-4611 method. Especially the cities by the sea show the same properties in both climate maps. The interior regions are divided into more divisions in the ASHRAE 4610-4611 classification than in the TS-825 classification mainly due to specific geographical characteristics of the cities. The Mediterranean, Aegean, Marmara and some parts of the Black Sea regions showed similar characteristics in two classifications. In the new classification some cities which have extreme climates can be easily seen. (Figure 3.6)

The new classification made for Antalya, Istanbul and Erzurum indicated that the classification of these cities seems to be at the right climate zones. Antalya, Istanbul and Erzurum found places in warm, mixed and cold climate zones respectively, reflecting the city’s climate characteristics more accurately (Figure 3.5).

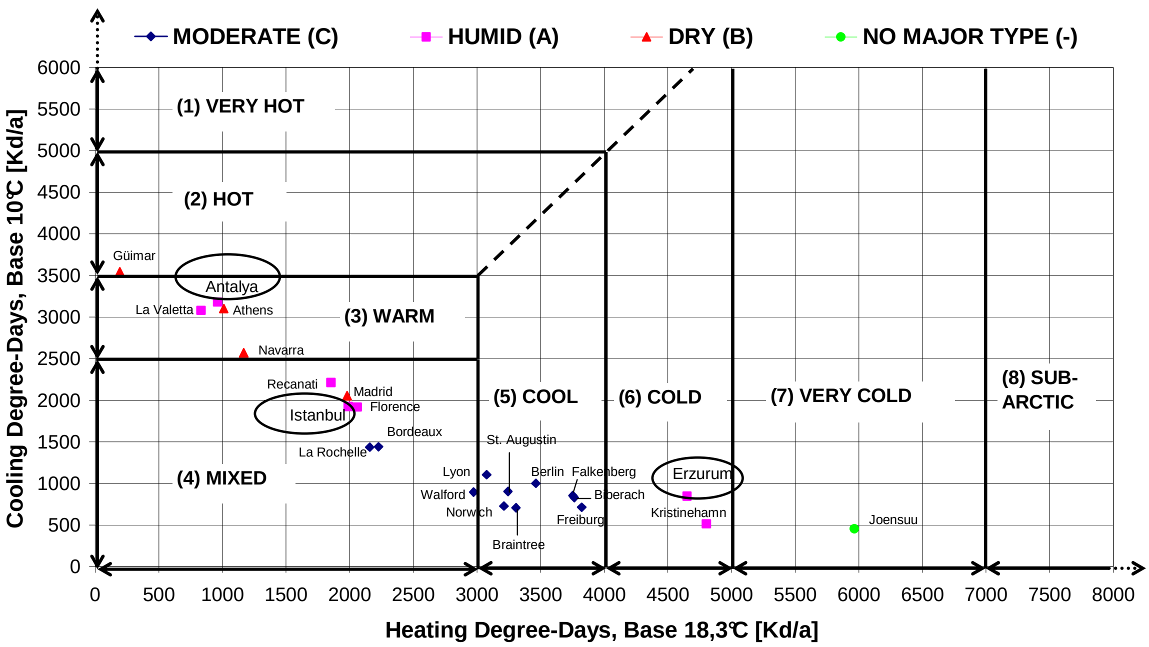
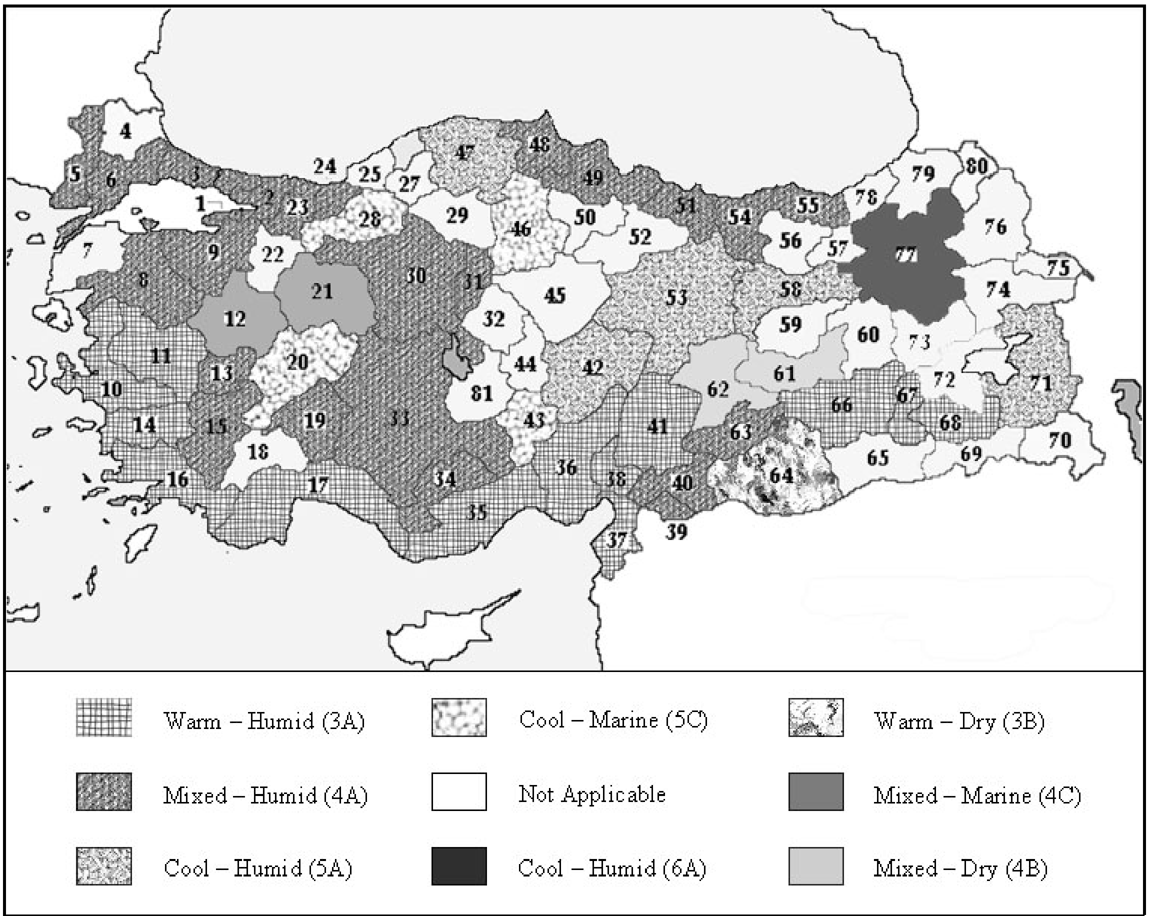


Figure 3.5: ASHRAE climate classification of three selected cities with some European cities.



1 Yalova	**15** Denizli	**29** Cankiri	**43** Nigde	**57** Bayburt	**71** Van
2 Kocaeli	**16** Mugla	**30** Ankara	**44** Nevsehir	**58** Erzincan	**72** Bitlis
3 Istanbul	**17** Antakya	**31** Kirikkale	**45** Yozgat	**59** Tunceli	**73** Mus
4 Kirklareli	**18** Burdur	**32** Kirsehir	**46** Corum	**60** Bingol	**74** Agri
5 Edirne	**19** Isparta	**33** Konya	**47** Kastamonu	**61** Elazig	**75** Igdir
6 Tekirdag	**20** Afyon	**34** Karaman	**48** Sinop	**62** Malatya	**76** Kars
7 Canakkale	**21** Eskisehir	**35** Mersin	**49** Samsun	**63** Adiyaman	**77** Erzurum
8 Balikesir	**22** Bilecik	**36** Adana	**50** Amasya	**64** Urfa	**78** Rize
9 Bursa	**23** Sakarya	**37** Hatay	**51** Ordu	**65** Mardin	**79** Artvin
10 Izmir	**24** Duzce	**38** Osmaniye	**52** Tokat	**66** Diyarbakir	**80** Ardahan
11 Manisa	**25** Zonguldak	**39** Kilis	**53** Sivas	**67** Batman	**81** Aksaary
12 Kutahya	**26** Bartin	**40** Gaziantep	**54** Giresun	**68** Siirt	
13 Usak	**27** Karabuk	**41** K.Maras	**55** Trabzon	**69** Sirnak	
14 Aydin	**28** Bolu	**42** Kayseri	**56** Gumushane	**70** Hakari	

Figure 3.6: New Turkish climate classification according to the classification methods used for ASHRAE Standards

Sun path (stereographic) diagrams of three selected cities help us to evaluate sun shine time, solar radiation on the surfaces and sun declination according to the seasons. As it can be seen, sun declination is lower during the winter seasons and higher in the summer seasons due to Turkey’s geographical situation. Regarding all those variations, design improvements - for instance shading devices, solar heat gains through windows, walls and roofs - can be formulated easier. For example; the sun shines almost at a 90° angle in June in Antalya, accordingly solar heat gain should be mostly received on roofs and the south exterior wall of a given building, thus, the construction design and strategies for the roof and the south wall construction become more important issues. Another important reference derived from sun path diagrams is the decision for orientation of a building. Designers can orientate the situation of exterior walls according to the heat gain and loss parameters.

In case of cold climates (Erzurum), the south surface should be designed carefully with regards to the maximum solar energy gain during the winter, even sometimes during the summer. Due to this reason the window area on the south surface determines the amount of solar heat gain through the windows, and in summer the windows may be shaded to prevent overheating. (Appendices D, E and F)

4. Building Energy Standards

The building envelope is responsible for most of the heating and cooling energy loads that mainly depend on the structure of the building elements (walls, roofs, windows, etc.). In order to minimize those effects on energy use, it is essential to develop or improve building energy standards which are composed of requirements, maximum and minimum thermal transmittance values of building envelope elements and energy efficient strategies for building envelopes in different climate regions. A large amount of energy savings can be achieved by applying energy efficient standards, as it has been shown in many simulations and improvements of envelopes.

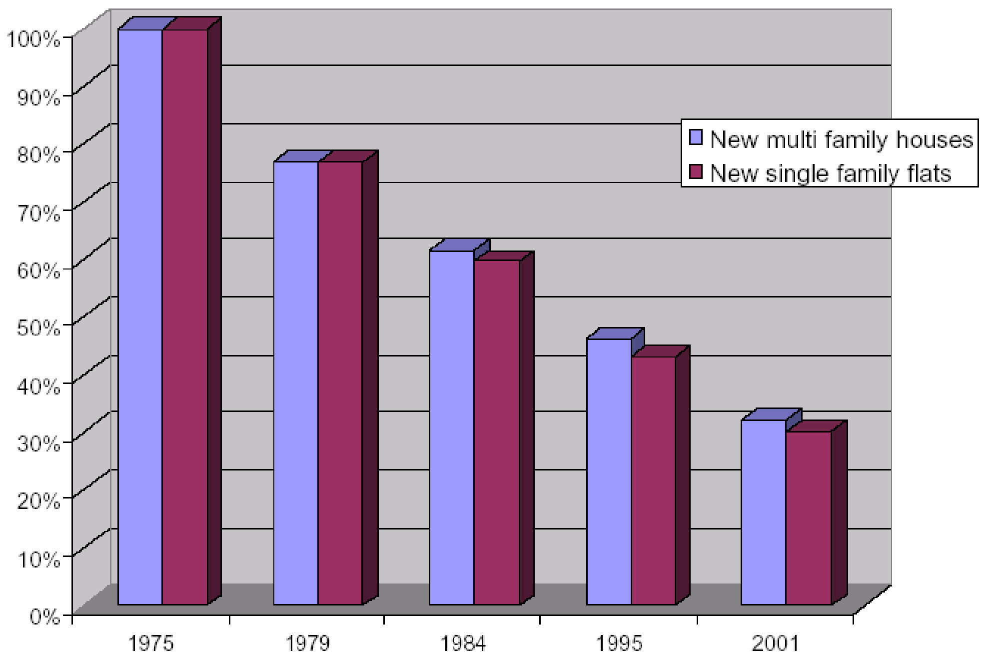


Figure 4.1: Impact of thermal building code improvements between 1975 and 2000 in Germany (Source: Franunhofer Institute)

As an example, Figure 4.1 above shows energy load reduction after updating thermal insulation codes between 1975 and 2001 in Germany. In Germany a new residential building in 2001 consumes approximately 30 % of a residential building in 1975, according to the research done by the Fraunhofer Institute. [14]

In a significant number of countries, energy standards have not yet been successfully enforced, and many countries do not even have any energy regulations at all. Considering the number of the countries that do not have any energy regulations, the net energy loss in the World is very high. Having looked at the general energy regulation circumstances of the World, it can be mentioned that some of the countries became aware of the importance of building energy regulations very late, except Sweden, Denmark, North America, Europe and some other countries from different regions. The regulations either are not mandatory or are just for non-residential buildings. (Figure 4.2) [15]

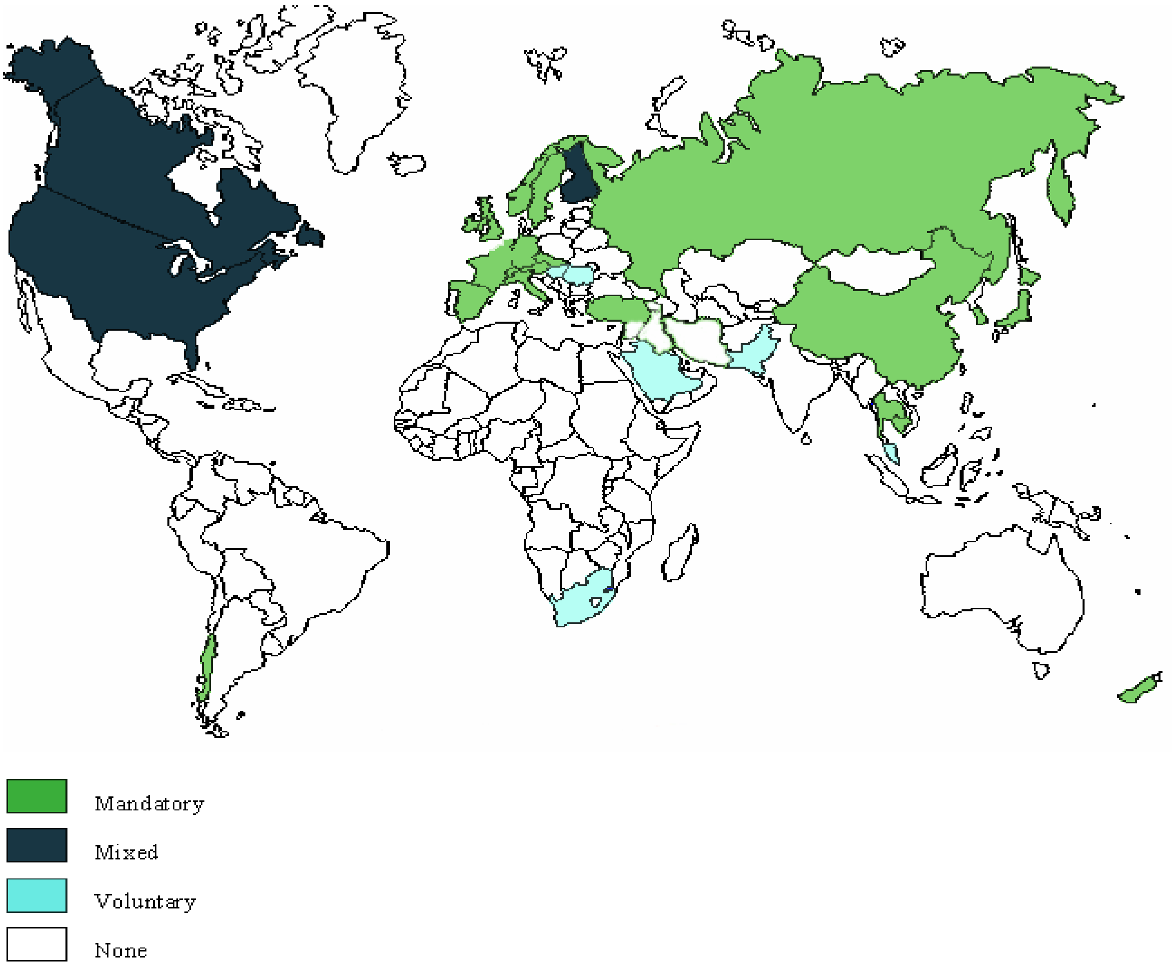


Figure 4.2: Status of building energy standards in the World (Source: www.deringergroup.com)

4.1. Building Energy Regulations in Turkey

In this chapter, the regulations with respect to energy performance of buildings and energy efficiency in heating and cooling energy consumption will be discussed. Regulations regarding energy conservation and saving issues are not sufficient or detailed in Turkey.

Due to Turkey's application for EU membership, in recent years the country has reviewed and followed EU regulations and directives for member countries. Many legislative actions and energy directives are going to be harmonized and adapted from EU rules about energy efficiency in buildings [16].

TS-825 "Thermal Insulation in Buildings", which became mandatory in June 2000, is the most important and detailed standard related to energy conservation and heating energy consumption in buildings.

- **Thermal Insulation Standards in Buildings, TS-825**

TS-825 defines the rules of calculation of heating energy demand in buildings and gives the reference and permeable values for heating energy. However, these rules are not defined for the buildings which include passive solar energy systems. In addition, cooling energy demands of the buildings are calculated by using international standard PrEn ISO 13791. The TS-825 standard was prepared by adapting ISO 9164² and EN 832 standards to Turkey's condition [3].

Energy performance of the different types of buildings, the calculation method of annual heating energy demand, thermal transmittance "U" values (for walls, floors, windows, glazing and ground floor) for each region, which is defined by using the "degree day method" in TS-825, and the maximum heating demand values according to regions were described. Both prescriptive and performance based requirements were given (Table 4.1). The main objectives of the standard are;

- to limit heating energy loads in Turkey in order to increase energy saving performance
- to indicate and determine the calculation methods and their values
- to determine the heating energy consumption of existing buildings
- to indicate energy retrofit performance before the renovation of a building

Table 4.1: “U” values for building envelope in TS-825 standard

Regions defined in TS-825	Walls U_D (W/m²K)	Ground floor U_T (W/m²K)	Floor U_t (W/m²K)	Windows U_P (W/m²K)
1.Region	0.80	0.50	0.80	2.80
2.Region	0.60	0.40	0.60	2.80
3.Region	0.50	0.30	0.45	2.80
4.Region	0.40	0.25	0.40	2.80

The monthly outdoor temperature and solar radiation, which were taken into consideration in this standard to calculate heating loads of buildings, are classified separately according to each region and month. In addition, maximum heating loads were given according to the A/V (Area/Volume) rates of buildings for each region in terms of area and volume (Table 4.2). Having seen the insulation regions in Turkey and the A/V rates for each region, the heating load requirements (reference values of heating loads) for the three cities, selected for simulation in this work, are as follows:

for the A/V value smaller than 0.2: **Istanbul** which is in the second region 48 kWh/m² **Antalya,** which is in the first region 27 kWh/m², and **Erzurum,** which is in the fourth region 104 kWh/m². [17]

Table 4.2: Heating energy demands for each region according to TS 825 for lowest and highest A/V rate

	for A/V ≤ 0.2	for A/V ≥ 1.05	Unit
Q'_{1REG}	27	66	kWh/m²
	8.5	21	kWh/m³
Q'_{2REG}	48	104	kWh/m²
	14.7	33	kWh/m³
Q'_{3REG}	64	121	kWh/m²
	20.4	39	kWh/m³
Q'_{4REG}	104	175	kWh/m²
	33.4	56	kWh/m³

4.2. Regulations in Developed Countries

Many countries in the World have formulated building energy standards by referencing other detailed standards mostly from neighbor countries and ASHRAE fundamentals. Some countries adapted the rules for developed standards for their climatic conditions and construction types. For instance Canada, ASEAN countries and many other countries used USA standards as a reference. [18]

Turkey has reviewed EU directives and standards, ISO standards and DIN standards and adapted them to its conditions. Along with those adaptations of mostly European standards, some other standards in the World may have given interesting ideas about the preparation and measures of energy standards for Turkey, thus, in this work energy efficiency standards will be investigated in various countries in the World. Generally the prescriptive requirements (maximum thermal transmittance of the building envelope elements) will be introduced for most of the selected countries.

4.2.1. European Union (EU)

Energy regulations within the European Union (EU) vary according to the climate and geographic features of the countries. In most of the European countries, energy regulations are mandatory for both residential and commercial buildings. Many countries adapt their energy regulations according to the EU directives. One of the important directives concerning building energy is the “EU Building Energy Performance Directive”.

4.2.1.1. EU Building Energy Performance Directive

The European Union (EU) prepared a directive for all member and candidate countries entitled “Directive 2002/91/EC of the European Parliament and of the Council of 16 December on the Energy Performance of Buildings” which was adopted in November 2002 and published in the Official Journal of the European Communities. This Directive is important because it obliges all EU member and candidate countries to implement various measures in the field of energy efficiency of buildings. [19]

Directive 2002/91/EC of the European Parliament and of the Council of 16 December on the Energy Performance of Buildings:

The objective of this directive is to promote improvements in the energy performance of buildings within the European Union community, taking into account outdoor climate and local conditions, as well as indoor climate requirements and cost-effectiveness (*Directive 2002/91/EC of the European Parliament and of the Council of 16 December on the energy performance of buildings, January 2003*). According to the requirements indicated by the directive member countries must:

- define a building energy performance calculation methodology, which takes national or regional conditions into account
- apply minimum requirements for new buildings
- apply minimum requirements for large existing buildings that will be renovated
- administer energy performance certification of buildings when they sold or rented
- and implement regular inspection of boiler and air-conditioning

According to the directive the building energy performance calculation methodology should include the following aspects:

- thermal characteristics of the building (envelope and internal partitions)
- heating installation and hot water supply, including their insulation characteristics
- air-conditioning installation
- ventilation
- built-in lighting installation
- position and orientation of buildings, including outdoor climate
- passive solar systems and solar protection
- natural ventilation

- indoor climate conditions, including designed indoor climate, in addition building types should be classified [20]

4.2.1.2. German Regulations

Germany has detailed regulations, named DIN. Germany adopted its first thermal insulation ordinance in 1977 and reviewed it several times. In 2001, ENEV (Energiesparverordnung), a law for energy saving, was released, and in 2004 some changes were made. The requirements for thermal insulation and heating systems for major renovations and new buildings are detailed in this law. It lists both elemental and system requirements. This energy ordinance saves almost 60% more heating energy than the old ordinance in 1977. (Table 4.3) [21]

Table 4.3: Maximum values of the heat transition coefficients during first renovation, replacement and renewal of construction units

Line	Elements	According to	Buildings according to §1Sect. 1Nr.1	Buildings according to §1Sect. 1Nr.2
			Maximum Thermal Transmittance U_{max} (W/m²K)	
	1	2	3	4
1a	External Walls	General	0.45	0.75
b		Nr.1 b, d and e	0.35	0.75
2a	Windows Glass doors Skylights	Nr. 2 a	1.7	2.8
b	Glazing	Nr. 2c	1.5	No requirement
c	Curtain walls	General	1.9	3
3a	Windows Glass doors Skylights with special glazing	Nr. 2a and b	2	2.8
b	Special glazing	Nr. 2c	1.6	No requirement
c	Curtain walls with special glazing	Nr. 6 Sent 2	2.3	3
4a	Ceilings, roofs and pitched roof area	Nr. 4.1	0.3	0.4
b	Roofs	Nr. 4.2	0.25	0.4
5a	Ceilings and walls near to unheated rooms	Nr. 5b and e	0.4	No requirement
b	Or ground	Nr. 5a,c, d and f	0.5	No requirement

According to the new energy regulations, there is no requirement for thermal transmittance (U-W/m².K) values for the new buildings; however, systems performance requirements are given according to annual primary energy consumptions with respect to A/V value (Appendix G). This new approach for buildings energy performance sets the requirements for new and old buildings. Thermal insulation requirements are explained for two seasons, in winter and in summer. [22] Turkey adopted some of the DIN regulations in developing its own standards

4.2.1.3. Swedish, Norwegian and Danish Regulations

Sweden is known for having high quality regulations with respect to housing standards. Almost 50 years ago Sweden implemented a thermal insulation standard for buildings. Norway followed shortly thereafter and Denmark after fifty years, and both adopted the Swedish standards to their own. In “Building Regulations-BBR” the mandatory requirements and general recommendations for energy were published under the ninth chapter (Energy Economy and Heat Retention). In this chapter the building envelope requirements were given with regards to thermal insulation and transmission losses, air tightness, ventilation, production and distribution of heat. The reason for concentrating on the thermal loses is the cold climate of Sweden. The Swedish housing requirements for new apartments were defined as follows (BFS 2002). [23]

Table 4.4: Maximum “U” values defined in Swedish and Norwegian standards

Elements	Sweden	Norway
	Maximum transmission coefficient (U-W/m²K)	
External Walls	0.18	0.22
Ceilings Under Roofs	0.2	0.15
Floors next to ground	0.2	0.22
Windows	1.5	1.6

Table 4.5: Maximum "U" values defined in Danish standards

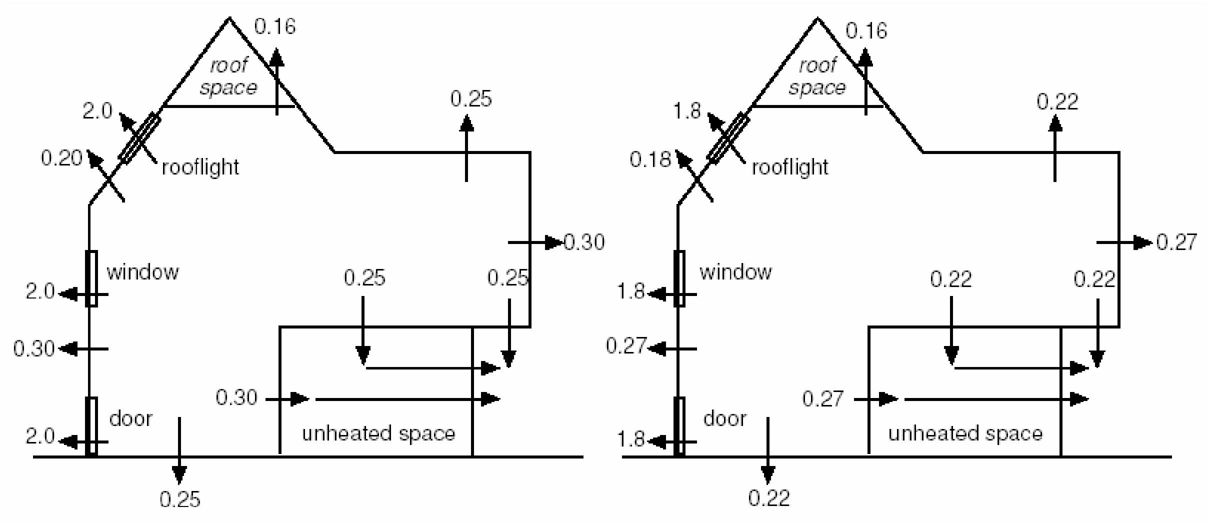
Element	Maximum transmission coefficient (U-W/m^2K)
External Walls	0.2 (timber frame) 0.3 for brick/block construction
	0.3 for brick/block
Ceilings with voids above	0.15
Attic type roofs	0.2
Ground floors	0.2 (timber frame)
	0.3 (brick/block)
Windows and Outer Doors Including Skylights	1.8

4.2.1.4. UK Regulations

In the UK the standard for the thermal performance of buildings is called "Conservation of Fuel and Power". In this regulation there are three different methods to investigate energy consumption requirements and envelope requirements. These are:

- Elemental Method
- Target U-value Method
- Carbon Index Method

The Elemental Method indicates maximum U-values of the building elements for two different heating systems. Types of heating systems mentioned in this standard are "Gas or oil central heating with boiler" and "Other gas or oil central heating, or any electric heating system or solid fuel central heating or undecided". Thermal transmittance values of each building envelope include the wall between unheated and heated spaces, roof attics, walls and flat roofs [24]. (Figure 4.3)



a) Gas or oil central heating with boiler

b) Other gas or oil central heating, or any electric heating system or solid fuel central heating or undecided

Figure 4.3: Maximum U-values using the Elemental Method in the UK standard.

4.2.2. USA (ASHRAE Standards)

ASHRAE (*The American Society of Heating, Refrigerating and Air-Conditioning Engineers*) was founded in 1894 in New York City. ASHRAE publishes standards, handbooks, transactions and journals. Having compared it to other standards in the World, it can be easily concluded that ASHRAE is the most detailed building energy standard in the World. Thus, many countries referenced ASHRAE standards in the process of preparing their own standards regarding the field of heating, ventilation, air-conditioning and refrigeration. Many laboratories, researchers and government organizations have contributed to the preparation process of ASHRAE. The standards are periodically reviewed, revised and published.

ASHRAE Standard 90.2-2001: Energy-efficient design of low rise residential buildings

One of the standards reviewed for this work is the ASHRAE Standard 90.2-2001, entitled "*Energy-Efficient Design of Low Rise Residential Buildings*". Purpose of this standard is to provide minimum requirement for the energy efficient design of low-rise residential buildings. This standard provides three different methods by which compliance can be determined for low-rise residential buildings: the prescriptive method, performance path method and annual energy cost method. In the prescriptive path method, minimum R-values of elements of the building envelope, the maximum U-factors and maximum SHGC-values for fenestration have been specified. The performance path method indicates the maximum U-value of the building envelope and the SHGC value of glass openings. [25] (Appendix H)

Some states in the USA have their own standards, which are more detailed and localized than ASHRAE. For example California, Oregon and Florida all have very advanced standards which were developed by using computer based methods. After the energy crisis in California in recent years, the state reviewed the 2001 standards and released the "*2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*" which came into effect in October 2005. The ASHRAE Standard 90 series are used as a reference for those states and other countries.

4.2.3. Japan and Korea Regulations

• Japan

The Japan Energy Conservation Center (ECCJ) has published the guidelines "*Design and Construction Guidelines on the Rationalization of the Energy Use for Houses*" and "*Criteria for Clients on the Rationalization of Energy Use for Buildings*", which were reviewed in 1999. Japan is classified into six climate regions. The guideline is divided into these sub-sections:

- standards related to the heat-insulation performance of building frames: standards for heat coefficient and standards for heat resistance of heat-insulation materials are given and illustrated according to the different residential building construction types (wooden, reinforced concrete and other houses) in this sub-section
- standards for the heat-insulation performance, etc., of openings
- standards for ventilation plans
- standards for heating and cooling and hot water supply plans
- standards for airflow plans

Maximum values of heating and cooling loads are also illustrated and their calculation methods described. For example according to the standard, heating shall be performed by setting the room temperature at 18°C or higher and the outdoor temperature at 15°C or below. (ECCJ) For the cooling load calculation, the room temperature is set at 27°C or below and relative humidity at 60% or below. [26]

- **Korea**

Korea implemented mandatory building energy standards in June 1992 and referenced ASHRAE and Japanese building energy standards. [18] Korea is divided into three thermal regions. The thermal insulation requirements were specified for each region with respect to building envelopes, thermal transmittance, "U-value" and thickness of the insulation [27].

4.2.4. Other Countries

Nowadays many other countries are becoming aware of the need to set energy efficient standards after seeing its benefits for the environment, economy and other benefits. In this sub-section two countries with hot climates, Egypt and Dubai, are shortly examined. Both countries are situated in North Africa and the Middle East, where the use of air-conditioning is very important due to high cooling loads.

Especially the preparation and methodology of the energy standards proposal for Egypt, which was prepared by a team of scientists and researchers who had many years experience in the development of building energy standards in the USA and other countries, can be a reference for the countries lying in the same region and for the countries that don't have detailed standards. The preparation process includes surveys of existing buildings physical and energy use and the use of computer simulations to analyze building energy performance. A key component of the development of these codes was the use of the DOE-2 hourly energy program. The information obtained from a survey of building energy use is very useful for defining prototypical buildings for use in computer analysis. In the conclusion a very detailed standard for Egypt is proposed [28].

The municipality of Dubai has developed the "*Regulations of Technical specifications for Thermal Insulation Systems and Control of Energy Consumption for Air-conditioned Buildings in the Emirate of Dubai*", which became mandatory in 2003. It is adopted from the ASHRAE standards, since ASHRAE is often used as a reference. This regulation contains three chapters, chapter one defines requirements of building envelope elements (roof, wall, glass openings.), the calculation of heat load and the design of air-conditioning systems. Chapter two includes specifications of thermal insulation materials and their installation. Chapter three gives general information about the regulations. In defining requirements for the building envelope, the overall transmission coefficient value "U" and, in addition, for glass openings the shading coefficient "SC" was used. The thermal transmittance U-value should not exceed the values shown in *Table 4.6*. Dry bulb temperature, wet bulb temperature, relative humidity and other variables were indicated for heating load calculation. [29]

Table 4.6: Building envelope requirements for Dubai

Building Elements	Maximum transmission coefficient (U-W/m²K)	Shading Coefficient (SC)
Roof	0.44	-
Wall	0.57	-
Windows	3.28	0.4

4.3. Conclusions and Discussions

Having a brief review of energy standards of the different countries from different regions in the world, the impact of building energy standards on energy consumption can be judged from their experience of standards over several years. Some research findings and figures for energy consumption in buildings show that building energy standards are an essential part of the energy saving issue. For instance the EU investigation into the implementation of a common building code for Europe in 2000 indicates that if the Danish building codes had been adopted to all EU member countries as a model, a large amount of energy could have been saved (for some countries more than 50%, such as for Portugal and Italy which are situated in Mediterranean region) (Figure 4.4) [30].

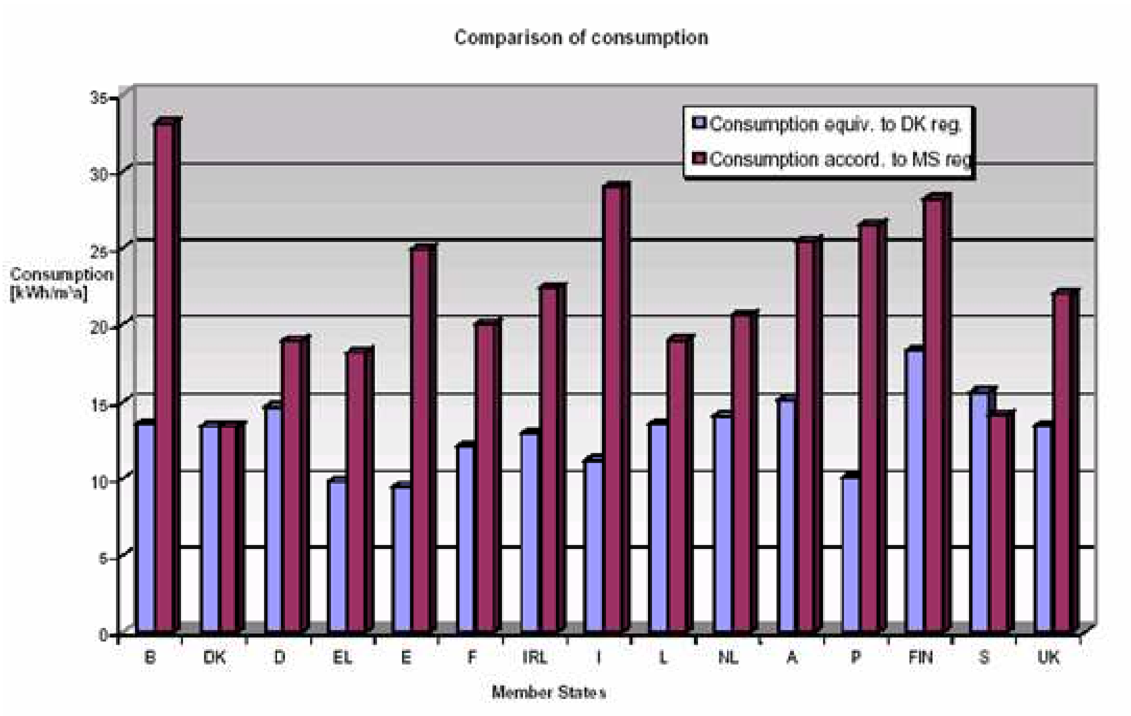


Figure 4.4: Energy consumption in EU countries after adjusting the Danish regulations as a model. (Source: http://europa.eu.int/comm/energy/library)

Although Turkey prepared its standards by reviewing European standards, there are some other standards which can be examined and referenced. Comparing the thermal insulation standard (TS-825) to some European countries, the thermal transmittance coefficient (U-value) requirements for new dwellings in TS-825 for building envelope elements are high, which results in waste of energy. For example in Sweden, Denmark and Germany thermal transmittance coefficient U-values for exterior walls are 0.18 W/m²K, 0.20 W/m²K and

0.35 W/m²K respectively, while they are 0.80 W/m²K for the hottest region and 0.40 W/m²K for the coldest region in Turkey. Similar comparisons for glazing, which is a very important element of the building envelope, can be a good illustration of seeing the differences between standards. The thermal transmittance "U value" requirement for windows is 2.8 W/m²K, while under DIN standards it is just 1.7 W/m²K. Those short comparisons indicate that the thermal transmittance "U values" of building envelope elements should be reviewed and updated to reasonable values. In addition, there is no requirement about cooling loads of buildings in T 825; it gives Pr EN ISO 13791 as a reference regarding the calculation of cooling energy load, the most important energy consumption variable for the southeastern and Mediterranean parts of Turkey. An overview of the regulations in Turkey and the other countries examined is illustrated in Table 4.7. One of the results of this work indicates that applying insulation leads not only to a decrease in heating energy decrease but also to a reduction in cooling demand in hot climates as well.

In standard TS 825, the calculation of degree days, which is used for determining thermal insulation region classification, was not illustrated. In contrast, the climate classification method, for example, is explained very detailed in ASHRAE Transactions 4610 and 4611.

Energy conservation and rational energy use are Turkey's main problem areas for the household sector. Because of the quality of the dwellings in Turkey, people consume more energy to reach and maintain the comfort level. In order to minimize the problems in these areas, the legislation side of those issues should be prepared carefully. In 2005, Turkey published the "*Energy conservation Law*" in the light of the "*EU Energy Performance of the Buildings Directive*". After adapting this law, every building will have energy certification. Private engineering offices determined and controlled by the Energy Ministry of the country, will be responsible for giving energy certifications. Energy certification will provide an essential amount of energy savings if the control mechanism of private engineering offices works properly. This is due to the fact that, if the standards were not mandatory in Turkey and would not be attached to any penalties, then most of the users would not be aware of possible savings. On the other hand after some years during the utilization, due to the energy prices they would face, they would be forced to spend a large amount of money for renovations. In order to apply the energy certification law, similar programs in some developed countries should be examined, for instance Energy Star Home

(USA), R-2000 Certification (Canada), Klima Haus (Switzerland), Casa Clima (Italy) and Energie Pass (Germany). Some of those programs are mandatory energy labeling programs and is expected to be enforced in some of the countries, like Germany and Italy, by 2006. Energy labels are usually given for industrial products and household appliances to show their energy efficiency level, but buildings were also classified as products. For instance in Switzerland they were given European labels from “A” to “G”. Buildings are labeled and rated according to their annual energy consumption; letters represent each class.

Energy labeling can be utilized for pre-fabricated (factory made) buildings elements, such as wall, roof and window by treating those elements as factory made products. Labeling may be prepared in terms of thermal transmittance “U values”.

Even if Turkey has a thermal regulation standard, new standards can be developed by using energy simulation tools for different representative buildings of the country in different climates. This different process in preparing new energy codes can give more significant and detailed results that are close to reality. One of the samples is the Egypt energy code proposal. In developing energy codes for this country energy simulation tools were used by experienced researchers. This standard developing process can be run following these steps:

- new climate classification, more detailed variables, the ASHRAE standard for climate classification can be a reference,

- energy survey of buildings; this step is based on the information regarding energy use in buildings (shape, orientation, climate zone, number of residences, heating cooling equipment, structure, insulation status, etc)

- utilization of energy simulation tools; after collecting of the data from the surveys a simulation process close to reality could be achieved by using competitive simulation programs

- having the simulation results, the public should be informed with respect to rational energy utilization, energy conservation and the standards for a trail period

- Turkish regulations mostly advocate administrative regulations; methods should also be investigated and examined

Table 4.7: Overview of the building energy regulations in selected countries

Countries	Building Envelope Elements				Building Energy Demand		
	Transparent			Opaque	Heating	Cooling	Total Energy Demand
	U Value	SC (Shading Coefficient)	SHGC (g-Value)	U Value	Q_h	Q_c	Q_T
Turkey	X			X	X		
Germany	X			X	X		
United Kingdom	X			X			X
Sweden	X			X	X		
Denmark	X			X			
Norway	X			X			
Japan	X		X	X			X
Korea	X			X			
USA	X		X	X	X	X	X
UAE (Dubai)	X	X		X			

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5. Prefabricated Residential Building Systems in Some Developed Countries and Description of Selected Residential Building Systems in Turkey

Two different types of housing construction systems were selected for simulation purposes. One is a traditional system, which represents most of the dwellings in Turkey and has a high amount of energy saving potential if it is properly constructed or renovated. The second consists of , three pre-fabricated housing systems, chosen as the representatives of new generation housing systems, which are going to dominate building systems in the future because of their advantages with respect to time, economy and flexibility. Each system utilizes different building materials. These three systems are:

- Interlocking brick system,
- Lightweight steel structure system,
- Aerated concrete system.

In this chapter, after explaining pre-fabricated residential building systems, energy efficient and passive housing approaches in developed countries, the selected systems in Turkey are evaluated with regards to their structure and materials, which are going to be used as "reference cases" in simulations. The retrofitted cases of building systems are explained in the next sub-chapters. For "base case" simulation window types of four systems are assumed to be single pane.

5.1. Prefabricated Residential Building Technologies, Passive and Energy Efficient Housing in Developed Countries

5.1.1. Energy Efficient and Passive Housing Approach

Energy efficiency and passive housing are new terms for Turkey, where people generally look for mechanical solutions for their energy needs. It will be informative to investigate a passive house in this work for a Turkish energy society in order to introduce passive house applications in Germany and in Sweden, where climates are colder and the number of passive houses higher than those of in Turkey. The second reason is to encourage Turkish construction, society and organizations by focusing on Turkey's passive home design potential as a result of its climate. A passive house is a house that provides comfortable indoor climates without using any mechanical heating and cooling.

The definition from the *Passive Haus Institute* in Germany is;

"*Passive houses are buildings, whose yearly heating heat requirement is so small that without an active heating system can be heated, for example small heating requirement can be supplied by supply air*."

A passive house is also called as "zero energy house" or as "house without heating" Passive houses are defined by a standard (functional requirements), not by a building method.

Criteria for passive houses are defined as follows:

- maximum constant energy load 10 W/m^2k
- maximum annual space energy requirement 15 W/m^2a
- maximum annual total amount of energy load 42 W/m^2a

In addition to the general requirement of energy consumption, envelope thermal transmittance values for passive houses are also regulated, but these are not mentioned as mandatory requirements due to the flexibility in architectural design. According to the Passive Energy Institute in Germany, thermal transmittance values (U value) of opaque and transparent building envelope elements (windows) should be smaller than 15 W/m^2K and 0.8 W/m^2K respectively.

Some of the key elements of passive houses can be classified as follows:

- Super insulation

Passive houses should have effective, continuous insulation within envelope without thermal bridges

- Air tightness

Another essential approach for passive house design is tightness of the building envelope due to heat loss through air change. In Germany, the requirements for air tightness of passive houses are defined by the Passive Haus Institute. For passive houses, the value should be smaller than $0.6h^{-1}$.

- Heat recovery from exchange air

- Maximum solar heat gain. [36]

Finally, design should be done carefully in order to receive maximum solar heat during the winter and to block direct solar heat during the summer, preventing overheating. This is done by reviewing and determining the amount of heating demand. Thus, the minimization of heat loss by reducing uncontrolled air change via tight structure and building envelope enrichment should be considered during the design phase.

5.1.2. Prefabricated Residential Buildings

The construction has become more industrialized year by year due to the importance of time, economy and quality aspects of buildings. Builders do not desire to be dependent on weather. Accordingly, most of the construction process has being carried from the construction site to the factory. The percentage of the factory process (production) determines pre-fabrication rate of a construction. Building envelope plays an essential role in estimating energy performance of the buildings; thus, quality and applications of materials have significant influences. This can be achieved by using industrialized methods during the production process in a covered area, a factory.

Pre-fabricated homes can be classified into four classes: manufactured homes, factory made homes, modular homes and panelized homes. Prefabricated construction brings the following advantages;

- a rational production process, assembly line automation like a commodity (for example: car production)
- time independency, fast production and installation, weather independency

- all elements of the construction system are produced in a covered area along with the materials used; this results in high quality
- for mass production it is economic
- prefabricated homes require less heat energy due to a high level of insulation applied in walls and roof

in addition to these advantages in production process, components can be supervised with regards to energy efficiency and performance. [37]

This section will briefly illustrate different kinds of prefabricated housing techniques, which represents the last level in prefabricated housing and some advanced housing techniques, from some countries. Some pre-fabricated housing companies and applications of panelized systems and unit systems, which represent most of the modern prefabricated housing around the world, will be described and evaluated in this chapter.

5.1.3. Prefabricated Residential Buildings in Some Developed Countries

The production process of a factory made home is similar to other industrialized goods, like a car production, which follows a pre-defined production process. A significant part of new prefabricated housing can be divided into main types: panelized housing and modular housing.

Prefabricated housing, so-called factory made housing, can be an important way of producing new temporary and permanent residential buildings, especially for a country like Turkey, which experiences high temporarily housing demand after natural disasters and permanent energy efficient housing demand in general. In this section of the work permanent prefabricated homes in some countries are investigated with respect to their energy performance, production process and level of prefabrication. These sample systems are chosen from different regions of the world; Germany, USA, Sweden, Japan and Canada.

5.1.3.1. Germany

In Germany, prefabricated housing builders mainly concentrate on the energy efficiency of residential buildings.

Company Wolf has a panelized system with wall panels consisting of 28 cm thickness sizes with thermal transmittance (U-value) of a 0.20 W/m²K. Another prefabricated building company, **HAAS Fertigbau** has an envelope system that consists of walls that have U-values of 0.155 W/m²K, a roof with 0.13 W/m²K and windows with three layer glazing with U-values of 0.8 W/m²K. Both companies use a panelized system.

Baufritz in Germany developed an ecological external wall panel that consists of wood shavings as insulation and roof panels as well. This innovative wall system, 40 cm thickness, has a U value of 0.13 – 0.16 (W/m²K). The panels are carried to the construction site and assembled there.

A research project from the Technical University of Munich focuses on a prefabricated building that can be built in 24 hours, thanks to fast connectors developed by a research team in Germany [40].

One of the interesting housing systems in Germany is the LBS System house which is built by using prefabricated brick elements and modules. This system uses small traditional materials like brick but the production process of wall units and modules takes place in factory not on site. [41]

5.1.3.2. Japan

Japan has one of the most advanced prefabricated home sectors in the world, especially with respect to the factory production process; they use robots to achieve the most rational, advanced techniques and apply them to produce panels or units of dwellings:

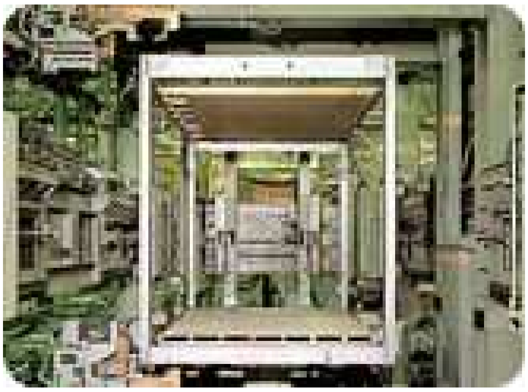
Sekisiu Corp., is one of the companies, that represents this housing production strategy. The company has two methods of home construction. Both systems are both made of box-shaped prefabricated units. The production process is illustrated in *Figure 5.1*.

One of the systems is called “Unit Housing”, in which living spaces are formed by using prefabricated unit boxes. The boxes are made of a steel frame structure covered by three kinds of cladding material compound panels of aluminium plate and gypsum boards, Synthelite (a compound board made of cement and wood chips) and press-attached porcelain tiles. Both systems have an 80% factory completion ratio. The company has 14 kinds of basic structural units, with cut units, large space units, functional units and over-hung units: there are more than 80 kinds of units. After transportation of ten to fifteen units from the factory to the construction site, a crew of six to seven workers and a crane install the units in approximately four hours.

The units are tested in the factory in an artificial weather room with respect to heat insulation, sound insulation, floor vibration, sweat resistance and water proof performance. This advantage indicates a significant quality difference between prefabricated and traditional construction techniques.

a - Assembly line in a factory

b - Utilization of the robots in production



c,d - Construction of a Unit box

e – Attaching the wall to unit

f – installation of units at site

Figure 5.1: Production and installation process of Sekisiu (Japan) home (a – e)

5.1.3.3. Scandinavian, Ireland

Housing companies in Scandinavian countries are renowned as the most energy efficient and, the prefabricated housing builders are concerned about energy efficient design and standards, two essential factors of construction because of the climate characteristics in Scandinavia. This defines Swedish attitude toward a residential building, energy efficiency is important for consumers as well as builders. The origins of the prefabricated housing industry, had origins date back to the 18th century, so that this type of housing now represents 90% percent of the dwellings in Sweden. There are no big quality differences between manufacturers of homes, since the building regulations and standards are stringent in the country. The factory production process allows continuity of construction in Sweden, where the winter lasts six months, which is why duration construction on site is not possible.

Reviewing some Swedish housing manufacturers, two types of factory made housing systems are available; panelized and modular systems representing 76% and 24% of housing construction respectively.

Top Housing AB is a Swedish company that applies international projects. After we investigated their pre-fabricated home system, it was obvious that the most important element of the building envelope in Sweden is insulation. The wall and roof insulation sizes are 12 cm and 14.5 cm respectively, the system has an insulation layer which separates the foundation and ground floor as well. It helps to protect cold air flow from the ground.

An Irish company, Scandinavian Homes LTD., is a company that combines energy efficiency, Swedish tradition and factory made housing approaches together. They build insulation fitted walls and roof for wood frame dwellings.

5.1.3.4. Canada, USA

In Canada and the USA there is a significant number of prefabricated housing companies representing different kinds of pre-fabrication levels, from big or small modular homes to panel homes. In the USA some organizations have been working on advanced housing technologies. One of them is PATH (Partnership for Advancing Technology in Housing), a public-private organization that aims to accelerate the use of new technology to improve quality, energy efficiency, durability environmental performance and affordability of housing in the USA.

Clayton Homes Inc. is a manufacturer of pre-fabricated homes; their home as a single unit in the factory. For this system, transportation and the distance between factory and construction site are main issues that must be solved. On the other hand the factory completion ratio increases the quality of the homes which are built as ENERGY STAR homes.

Les Industries Bonneville, a Canadian company, produces module boxes and panels, which are connected on site according to the plans, for instance a one-story house consist of two units and a two story home has four units.

Another building system, called “Quad-lock System”, is an Insulating Concrete Form System made of Expanded Polystyrene (EPS) tied by High Density Polyethylene (HDPE) and developed in Canada. Although the Quad-lock system is not a totally pre-fabricated system, the energy performance of its building envelope makes the system competitive, with 3 different structures and “U values” of 0.28 -0.20- 0.15 W/m²K respectively.

5.1.4. Integration of the Renewable Energies to Residential Buildings

After reducing energy use through the application of energy efficient design strategies, the rest of the energy demand can be provided by renewable energy sources such as solar panels, photovoltaic and small sized wind tribunes. As explained in the second chapter of this work, Turkey has the third largest installation of solar water /heat capacity in the world. However, the architectural integration of renewable energies, such as solar panels, is not successful enough, with regards to solar potential. The next planned work after this will be the integration of renewable energies to reduce energy use in residential buildings starting from the design phase. Combining this idea with the pre-fabrication approach will be the future of home technology, for which construction time, profitability and advanced passive design strategies are the most important features.

Photovoltaic (PV) integration will be briefly investigated in this subchapter. Roof and façade integrations represent most of the applications, along with some other solutions of integration for example: wall and balcony. The integration of PV elements can be divided into 5 classes:

- applied invisibly
- added to design
- adding to architectural image
- determining architectural image
- leading to a new architectural concept [38]

Some integration samples from different countries are illustrated pictorially. The countries that don't have as much solar energy potential as Turkey such as Sweden, Denmark or Germany, have more PV (photovoltaic) applications than Turkey. Thus the application pictures of renewable energy elements can give some ideas about architecturally integrated solar elements and encourage Turkish energy society, who is mostly dependent on fossil fuel energy sources.

	Canadian Solar Decathlon house. Concordia University and Université de Montréal Roof integration of PV.
	University of Michigan, Solar Decathlon house External envelope integration
	University of Maryland, Solar Decathlon houses
	The roof elements with the PV-modules have been prefabricated. The yearly solar electricity output from the 19 semi-detached houses with PV is expected to be 48000 kWh. Amersfoort - Netherland, Artes Architekten & Adviseurs, Jan Gizezen

	The PV-lamella system, yearly solar electricity output of all the PV-systems in the 'Waterwoningen - Gele Lis' sub-project is expected to be 9600 kWh. Amersfoort – Netherlands, Atelier Z., Zderek Z.
	Solgaarden-Kolding Apartments, Solgaarden - Kolding , Denmark, Roof- and facade integration. PV System Power**:** 107 Architect: Kjaer + Tichter A/S
	Breisach, Germany. Single family house, Grid connected. PV system power 5, 4. Type of application sunscreens. PV-integration in this project is facade integration as well as building element and sunscreen. Architect: Prof. Thomas Spiegelhalter
	Row houses IGA, Stuttgart, Germany and demonstration houses EXPO 2000, grid-connected, PV System Power: 5, 3, Type of application: sunscreens. Architect: Hegger - Lühnen, Schleiff

	Roof renovation, Rappaneck, Germany
	The PV-system is fitted on the roof, as well as high efficiency solar thermal collector, covered with transparent insulation. Transparent insulation is also used for the façade. Freiburg, Germany, residential building, PV system power 4.2, type of application roof, single crystalline silicon Architect: Hölker + Berghoff, D. Möller
	Haus der Zukunft, Wels, Austria, residential building, grid connected, 3, 47 kWp, facade + roof application. Architect: Sture Larsen
	Solar low energy house with PV, solar thermal collectors. Pietarsaari Solar House, Pietersaari, Finland, residential house, roof integrated PV, grid-connected, PV system power 2,2 , roof application, amorphous silicon

5.2. Prefabricated and Traditional Residential Building Systems in Turkey

The pre-fabricated residential buildings selected for this research are not totally pre-fabricated (factory made) systems. They are called pre-fabricated systems since the systems have some factory made components, pre-fabricated wall units, floor units, etc. the definition of the pre-fabrication level varies according to the system's construction. Each selected system represents a unique building envelope alternative (concrete interlocking bricks, steel skeleton with insulation and aerated concrete blocks).

5.2.1. Interlocking Brick System

The interlocking brick construction system consists of interlocking bricks for external and internal walls and pre-fabricated pre-stressed concrete hollow core panels for slabs (Figure 5.2).

Interlocking wall blocks, which are used for load-bearing walls and non load-bearing walls, are made of cement, fly ash and aggregates. They are produced in different size. Hollow core panels are used for flooring.

Wall units:

a) Load-bearing walls units; consist of concrete masonry blocks.
   Size; 19cm thickness, 39cm length, 19cm width
b) Non load-bearing wall units; are used for decorative purposes.
   Size; 9cm thickness, 39cm length, 19cm width

Floor units:

a) "Panelton"; is a pre-fabricated pre-stressed concrete hollow core panel. These panels can also be used as floor or wall panels but in this work, they are used as a floor unit. Size; 15cm thickness, 120cm width and the length of the panels can be determined according to the project by considering the load-bearing capacity.

In addition to above mentioned units, there are also reinforced horizontal and vertical bond beams, which are created by using special interlocking brick units as a permanent formwork. The size of the heat insulation that is used for walls varies between 6cm and 8cm and for the roof 10cm. [31]

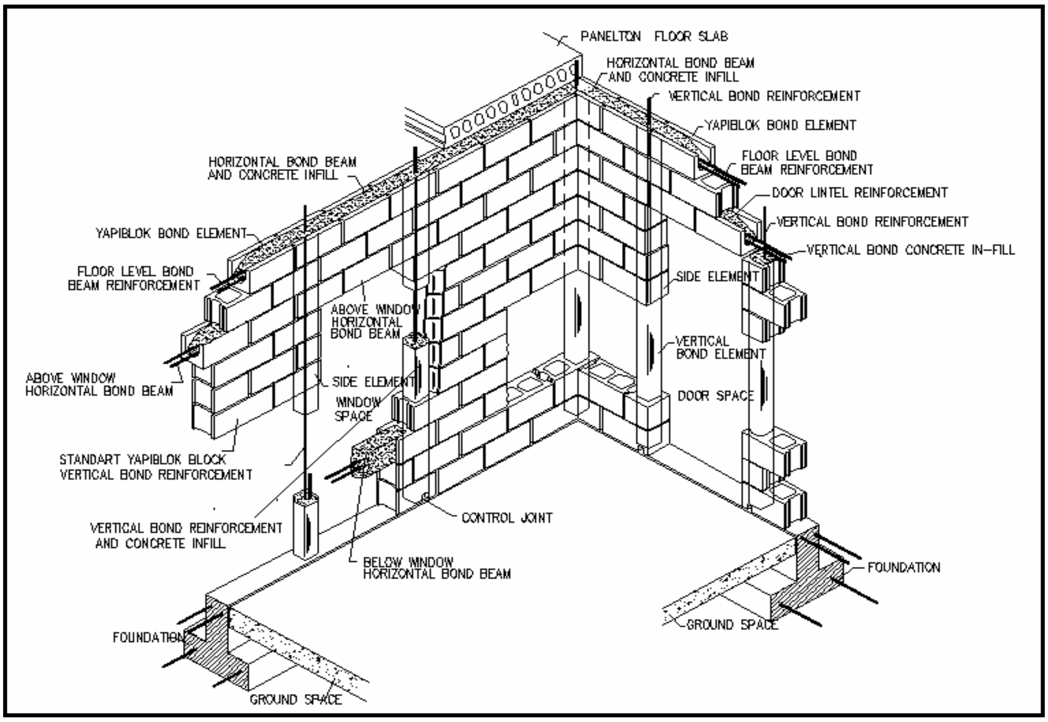


Figure 5.2: Interlocking brick system, a perspective. (Source: Yapi merkezi)

5.2.2. Lightweight Steel Framed System

The lightweight steel structure system is composed of a steel skeleton, which is constructed with lightweight cold-formed steel members, covered with OSB panels (Oriented Strand Board) from the exterior side of the wall and with plaster board from the interior side. The system is made up of sheets of 4cm polystyrene insulation applied on OSB panels and 16cm mineral wool insulation sandwiched between OSB panels and plaster boards; all installations are equipped between steel studs and those panels. The roofing structure is also the same as the wall structure, but with additional sheeting covered as a finishing layer. The floor structure is steel stud framing, on which OSB panels are layered. As with the wall wall and roof structure, insulation is placed between the OSB panel flooring and the plaster board ceiling. (Figure 5.3) The structures of selected building envelope elements are assumed like in Appendix I. [32]

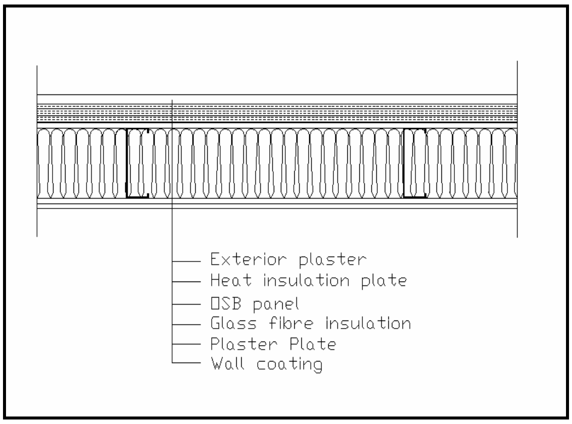
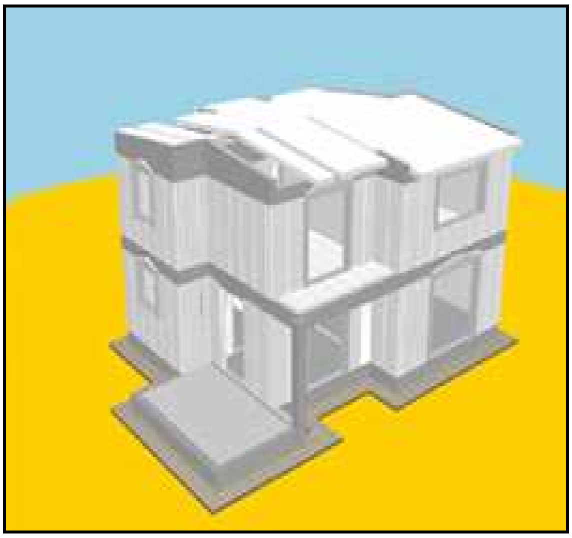


Figure 5.3: The lightweight steel system, a perspective. (Source: Kosk yapi)

5.2.3. Aerated Concrete System

The aerated concrete system is built by using gas concrete (aerated concrete blocks) units as wall, floor and in some cases roof elements. Since it has in-situ works, like columns, foundation and beams at the floor level, on top of which floor units are installed, the system is not totally pre-fabricated. (Figure 5.4) This system is made up of aerated concrete wall and roof blocks covered with cement mortar from the exterior and gypsum plaster from the interior face. Flooring consists of aerated concrete units with 15cm thickness as well. [33]



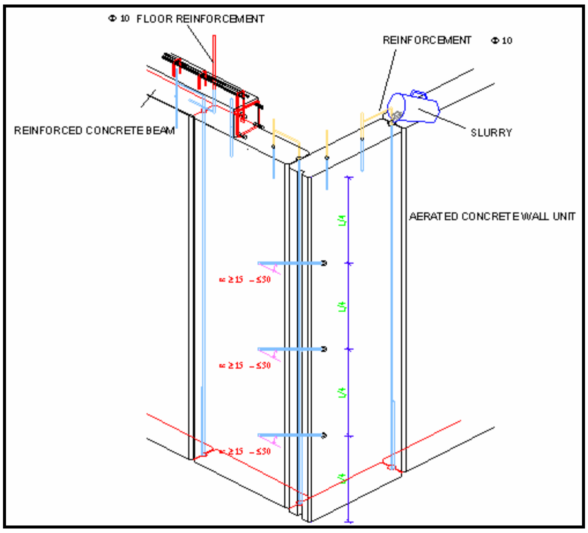


Figure 5.4: A perspective for the aerated concrete system. (Source: YTONGTURK)

5.2.4. Traditional (reinforced concrete) System

The traditional system chosen for simulation represents most of the dwelling structures in Turkey, the so-called, reinforced concrete structure system. This system consists of hollow clay brick external and internal walls and the load-bearing skeleton, composed of reinforced concrete floors, beams and columns. Both the external and internal walls are covered by cement plaster from both sides. Figure 5.4 illustrates an incomplete reinforced concrete system with its skeleton and walls but without finishing. The other detail is the typical detail of the floor and wall connection for the reinforced concrete system. Significant parts of the reinforced concrete dwellings in Turkey have no insulation. (Figure 5.5)

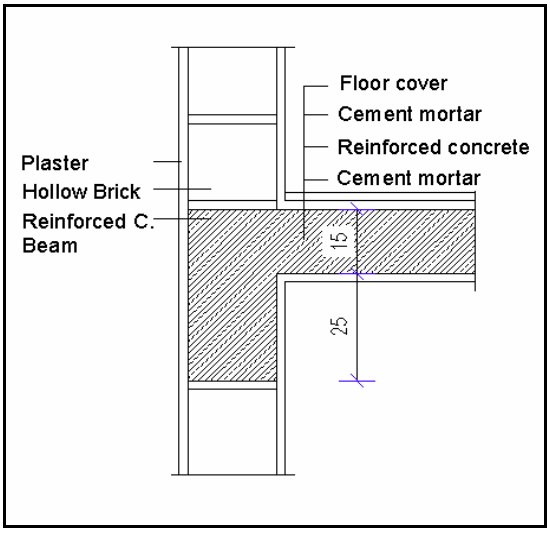


Figure 5.5: Typical reinforced concrete system in Turkey without plasters.

5.3. Conclusion and Recommendations

Energy efficiency and energy conservation are essential problem areas for Turkish housing stock. The quality of dwellings and their application without standards cause waste of energy, time, and natural artificial resources. Most of these problems are determined by their construction methods and materials, which is mainly the traditional construction (reinforced concrete) system in Turkey. Because of Turkey's quality housing demand in the future, pre-fabrication methods can be a solution for building healthy and energy efficient dwellings in a short amount of time. On the other hand, applications of prefabricated dwelling constructions are economic for mass housing. The passive housing approach, which uses natural resources for energy needs, should also be investigated and, likewise Turkey's potential analyzed: users of residential or commercial buildings are likely to use mechanical solutions even for the smallest energy needs without looking for natural solutions. As we saw in the simulations made for this work, natural solutions, so-called passive housing strategies reduce energy use dramatically, especially in extreme climates. Thus, common user ideas should be broken by recognizing these strategies which can create more economic and healthier living spaces. In addition, some new technologies like the shading system are equipped with sensors that schedule the shading devices which work according to (depend on) the solar radiation on the transparent surfaces or indoor temperature.

Pre-fabricated systems, investigated in this chapter from different developed countries, are good reference points. For instance, the system from Japan can be one with respect to production and assembly methods: the other systems, for which the energy efficiency aspect is most important, such as in Germany and Sweden, are also very competitive systems regarding their envelope properties, especially for cold climates. These sample building systems in Germany and Sweden have wall structures that give homes a very thick insulation layer: the optimum insulation thickness determined for there cities in this work can be the reference point for Turkey. The prefabricated systems for some countries and the systems that selected for this work in Turkey can be summarize regarding their degree of factory completion, energy efficient design, thermal transmittance values and insulation (Table 5.1).

Table 5.1: Properties of the prefabricated building systems for some countries

Countries and Building Systems		Degree of prefabrication (Factory completion)	Energy efficient design	Thermal transmittance "U" values (Wall) [W/m^2K]	Insulation
Turkey	Traditional	–	–	1,65	–
	Interlocking Brick	40%	X	0,31	X
	Lightweight	40%	X	0,17	X
	Aerated Concrete	50%	–	0,87	–
Germany	Panelized	70%	X	0,13-0,20	X
USA, Canada	Factory made	90%	X	NA	X
	Panelized	70%	X	NA	X
	Semi-prefabricated	50%	X	0,15-0,28	X
Scandinavian	Panelized	70%	X	NA	X
	Modular	70%	X	NA	X
Japan	Factory made	80%	X	NA	X

- Applicability of New Techniques in Turkey (discussion about the economy, climate and stability)

Applicability of new pre-fabricated systems mentioned in this chapter in Turkey can be successful, if the public is given information about pre-fabrication. Prefabricated housing has a negative stigma in the Turkish community due to a lack of information and bad applications after large earthquakes in Turkey. This introduction of pre-fabricated systems should include these aspects:

- Pre-fabrication is not always applied for temporary buildings, but also permanent and high quality buildings. The Izmit earthquake in 1999 was very bad advertisement for prefabricated homes, since those that were built after the earthquakes as temporary prefabricated dwellings were of poor quality and had a negative influence on the users and Turkish public opinion.

- definition of prefabrication,

- energy efficiency, energy efficient pre-fabricated homes

- economic efficiency

- technology level for the production process

Regarding integration of renewable energies, in the long term PV applications could also boom in Turkey like solar thermal panels if the prices of PV are affordable. It is very essential to investigate profitability of renewable energies in general and PV application specifically. This may be assessed by either different simulation programs or site measurements, choosing different climate regions of Turkey as prototypes.

- Some General Proposals of Prefabricated Energy Efficient Residential Buildings

Prefabrication is more open to innovations than traditional systems. Innovative solutions can be developed to minimize the energy loads of dwellings. For instance portable walls which work as a thermal mass or include some shading, ventilation ideas, prefabricated glazing units integrated with factory made panels or units, thick hollow brick wall panels, through which pipes runs to cool the buildings by circulating ground water and panel connectors - these are all very important for time saving and flexibility factors of the building construction.

Portable thermal mass walls: Pre-fabricated mobile thermal mass walls may be applied to store hot daytime temperature and for cold climates to release stored heat into the room at night. It can be called as “Mobile Tromble Wall”

Brick blocks for hot dry areas: Hollow brick block elements with a minimum thickness of 40 cm can be used for the building envelope and roof. Hollow brick performs well with regards to cooling loads. In addition, further cooling can be achieved by running pipes through these brick blocks through which ground water circulates.

Innovative connectors for panels: Some innovations are being made by different companies for quick pre-fabricated panel connectors.

New sandwich panels or boxes that contain all services: After assessing the energy performance of the envelopes, wall or unit elements can be proposed for every climate type.

6. Energy Analysis of The Sample Building Systems in Turkey

6.1. Methods

The dynamic Transient System Simulation program (TRNSYS), which was developed by University of Wisconsin, is used to simulate and analyze the thermal performance of the selected residential building systems. TRNSYS is a transient system simulation program with a modular structure where each component is described and written in FORTRAN language. Some of the utility programs of TRNSYS are PREBID (building description program), ISIBAT, TRNSED and TRNSHELL.

PREBID: building envelope definitions (wall, ground, roof, floor structure, orientation of the envelope and their size), part of the simulation strategies and orientation information, in short, all building descriptions are defined in this TRNSYS utility program. Firstly, the (*.BUI) file is one of the components of the building description, in which geometry and thermal properties of the building are created *(TRNSYS Manual).* This file is processed by the program BIDWIN, which uses information in the (*.BUI) file to generate two new files: (*.BLD) and (*.TRN). (*.BLD) is a file containing geometric information about building and the (*.TRN) file contains ASHRAE transfer functions for the walls. BIDWIN generates an information file (*.INF) which indicates inputs and outputs of a multi-zone building model (TYPE 56).

In the definition of building envelope materials, there is a material library in this multi-building zone component. New materials can also be defined when the user enters required values for materials. Ventilation, cooling, heating, infiltration and internal gains (number and activity of residents, electrical devices, appliances etc) are some of the variables that can be defined in this program. It takes the multi-zone building description and integrates it into the ISIBAT program as a component to run the simulation. There are significant numbers of outputs in PREBID program that are related to energy use, heat gain and loss, air temperature, relative humidity, etc.

ISIBAT is a general simulation environment program, which houses the TRNSYS simulation engine and most of the stand-alone utility programs. In this program a graphical interface is created by the user and contains inter-connected components to run the simulation. Some of those components used in this work are Type 9d (data reader which contains weather data), Type 16 (solar radiation processor; the orientation information, latitude and other inputs related to radiation are given in this component), Type 69 (fictive sky temperature for long-wave radiation exchange), Type 33 (dew point temperature and relative humidity), Type 56 (multi-zone building); printer and monitor components. More components can be added according to the simulation features. (Figure 6.1) [34]

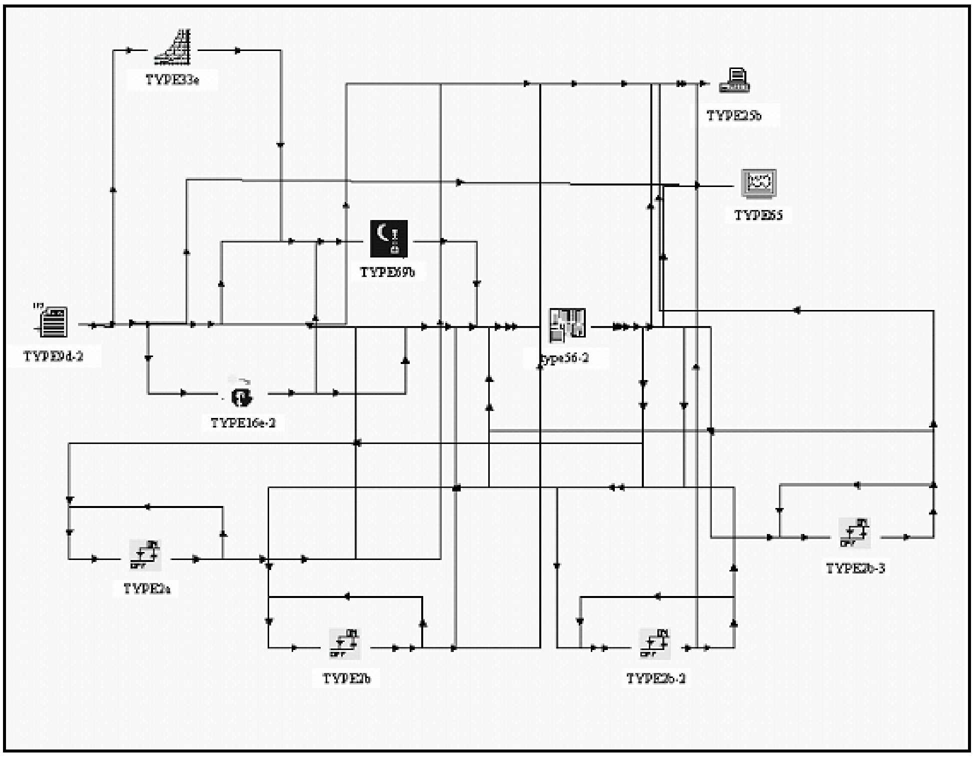


Figure 6.1: TRNSYS simulation window interconnected components (ISIBAT)

The weather data are obtained from METEONORM, a meteorological database for energy applications, which has over 7400 meteorological stations worldwide, including many cities in Turkey and the cities used for the simulations. METENORM can provide very detailed hourly (8760 hours in a year) data, from radiation to precipitation values, in different formats. The TRNSYS weather format is used for the simulation purposes and includes average data from a span of 10 years on solar radiation (global, beam radiation and diffuse radiation), relative humidity and ambient temperature.

6.2. Climate and Geographical Characteristics of the Selected Cities

Three cities - Antalya, Istanbul, Erzurum – each representing different climate zones in Turkey, are selected for the energy simulation of sample building systems. The hourly annual weather data is obtained from the METEONORM program as a component of the simulations; however, in this sub chapter general climate and geographical characteristics of the three cities are examined and illustrated graphically [35].

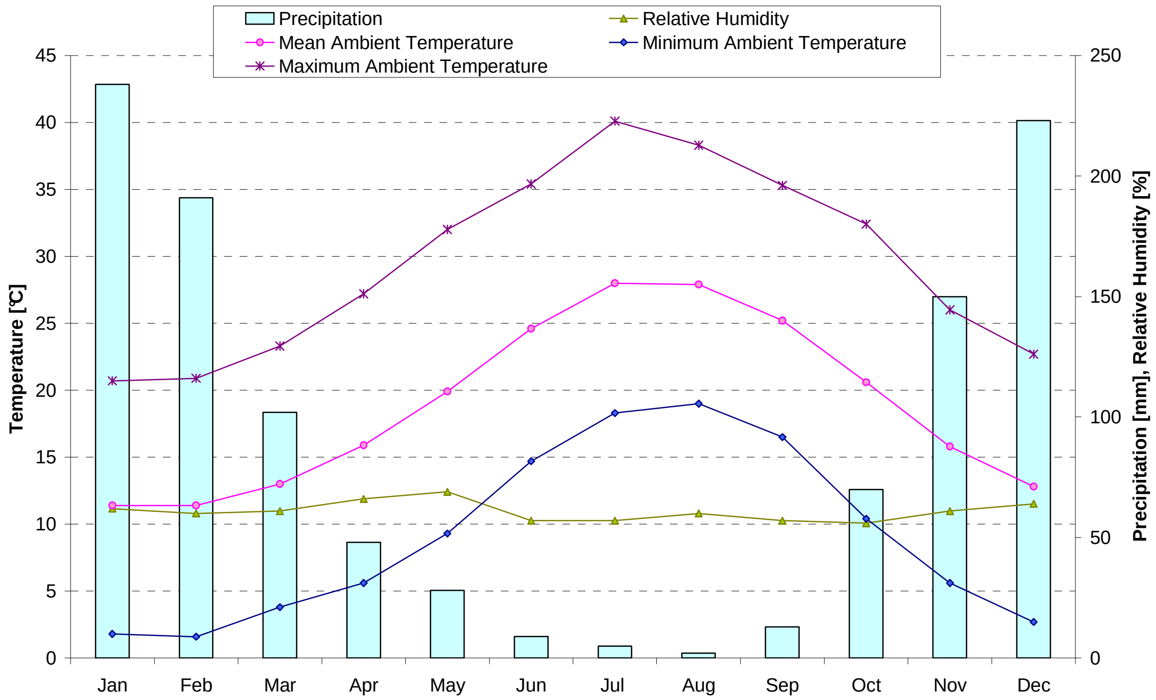


Figure 6.2: Climate characteristics of Antalya

Figure 6.2 above shows maximum, minimum and average ambient temperatures, relative humidity and precipitation for each month in Antalya. Both the Aegean and Mediterranean regions of Turkey have a typical Mediterranean climate: mild winters and hot summers. Antalya's rainy season is in the winter, from October to April. In the summer rainfall is quite low in contrast to the winter. The total amount of yearly rainfall reaches 1079 mm. The average mean temperature during the summer is 28 °C and in winter does not fall below 10 °C. The maximum temperature can increase to 40°C in the summer, and the difference between maximum and minimum ambient temperature is approximately 20°C. Relative humidity is generally around 55% and 60%.

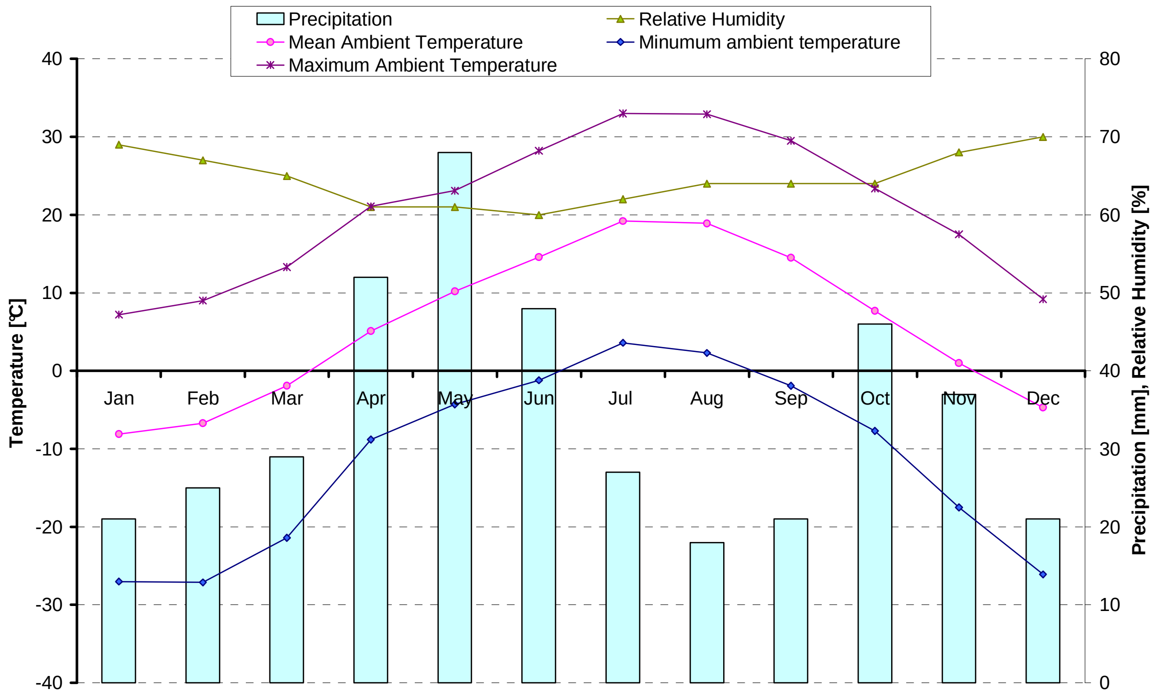


Figure 6.3: Climate characteristics of Erzurum

Erzurum is the one of the coldest city in Turkey because of its geographical characteristics. The city is located on a high plateau, with an altitude of 1823 m. The winters are very cold and rainy; the average winter temperature does not exceed 0 °C. The minimum winter temperature can drop to approximately -30°C, and even in the summer the minimum temperature is not over 5°C. Summers are mild with an average temperature of 20 °C. The city receives rainfall throughout the year, and the highest amount of rainfall is between April and June and reaches over 60 mm. August is the driest month of year. Relative humidity varies between 60% and 70% throughout the year (Figure 6.3).

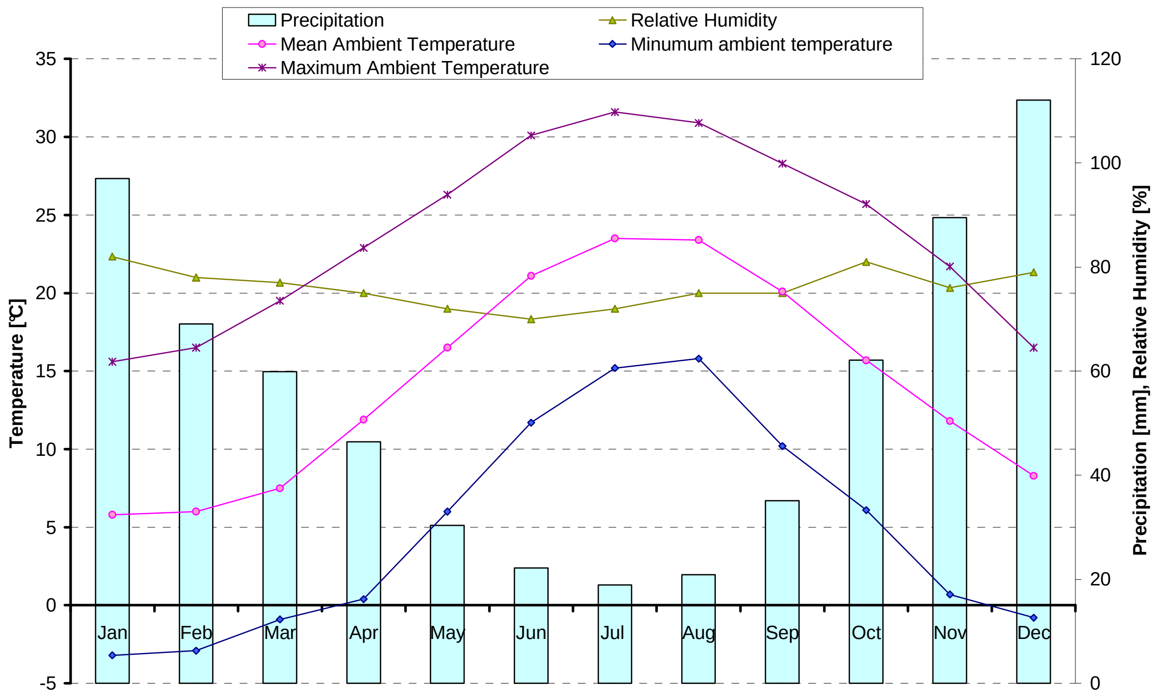


Figure 6.4: Climate characteristics of Istanbul

Istanbul receives rainfall mainly in winter but also throughout the year due to its geographical situation; it is surrounded by three seas and has a Black Sea coast. Generally, rainfall appears between September and April; the highest amount of rainfall is over 100 mm in the December. The driest season is summer, when monthly mean temperature doesn't exceed 25°C, and in winter the temperature is between 5°C-10°C. The difference between maximum and minimum ambient temperature is nearly 15°C. In winter the temperature can fall below 0°C but not less than -5°C. In addition, the climate is also influenced by the city's structure and planning (Figure 6.4).

Table 6.1: Altitude and geographical situation of the cities

Cities	Height above sea level [m]	Latitude	Longitude
Antalya	0	36.53 N	30.42 E
Erzurum	1823	39.57 N	41.17 E
Istanbul	2	41.02 N	28.57 E

Antalya lies in the Mediterranean region of Turkey and is surrounded by high mountains; however, the city is situated at an altitude of 0 m. Erzurum is situated at an altitude of 1823 m at the foot of Palandoken Mountain. The city is the largest city in the eastern Anatolian Region. Istanbul is one of the most populated cities in Europe, connecting Asia and Europe. The city is surrounded by the Black Sea and Marmara Sea and has an altitude of 2 m (Table 6.1).

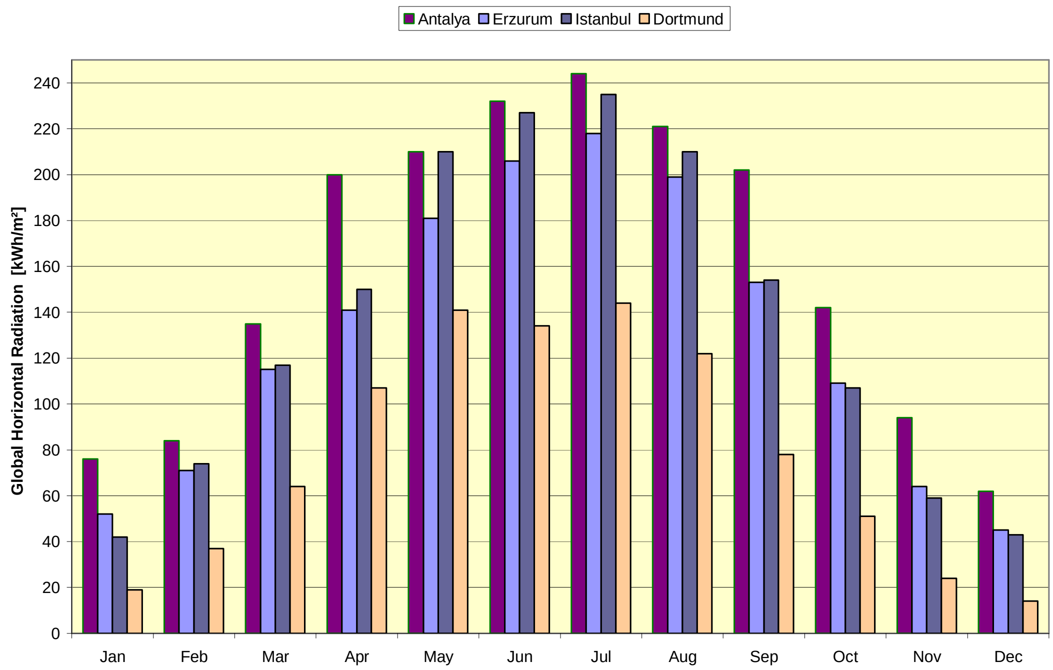


Figure 6.5: Global horizontal radiation in Antalya, Erzurum, Istanbul and Dortmund

Figure 6.5 above shows solar radiation intensities of the three cities in Turkey and Dortmund. All cities, including the coldest city in Turkey, have higher solar intensities than Dortmund. As seen in the graph, Antalya has the highest solar global horizontal radiation, thus, the primary goal of building design should be to lower solar heat gain, while using maximum solar heat gain as much as possible in Erzurum is the best solution for this heating dominated climate. In summer Istanbul has almost the same amount of solar intensity as Antalya. During the winter solar radiation is almost one-third of that in the summer for Antalya, however for the other cities Erzurum and Istanbul this ratio changes to 1/3 and 1/4 respectively.

6.3. Building Model

The model project is chosen as a two story multi-family building (Figure 6.5). Each story is divided into two thermal zones named Room first (RF), Room ground (RGR), Saloon first (SF), Saloon ground (SGR), due to their orientations, type of use and the amount of thermal mass internal walls. Both zones are separated by a common load bearing wall and have different usage: a daytime and a nighttime use. The long surfaces of the model building are faced northeast and southwest. Floor height is 2.80 m. Total internal wall area is 165.36 m², mostly within the RF and RGR zones. The dimensional properties of the model project are given in Table 6.2. Plan and elevations of model building is given in the Appendix L.

This prototype project is applied for all selected systems in order to accurately compare their thermal performance. In the simulation process, the materials of the envelope systems are varied according to the systems.

Figure 6.6: Floor plan of selected building model for simulations (Source: Yapi Merkezi)

Table 6.2: Some geometrical dimensions of the model building

Floor Area (m^2)	157.32
Volume (m^3)	440.5
A/V ratio	0.36
External Wall area (m^2)-without windows	189.85
o SE Wall	32.88
o SW Wall	63.12
o NE Wall	58.09
o NW Wall	35.76
Internal wall area (m^2)	165.36
Window Area (m^2)	15.12
o SE Windows	5.76
o SW Windows	0.72
o NE Windows	5.76
o NW Windows	2.88
Wall/Window ratio (%)	7.3
o SE	14.9
o SW	1.12
o NE	9.02
o NW	7.5
Roof Surface Area (m^2)	90.06
- NE	45.03
- SW	45.03

6.4. Strategies and Assumptions for the Simulations

Thermal modelings of four residential building systems were based on some assumptions. Simulations were performed in two phases, “Reference case” and “Improved case”. Firstly, the reference cases of systems were determined and simulations were carried out. In the second phase, all energy efficient design strategies and improvements were applied to compare and see energy saving performance of the systems between the reference case and the improved energy efficient case. Having the results of both simulation cases, two main comparisons were made: the cooling and heating energy demand of each building system in the three cities.

The second comparison between the building systems is to indicate the exact temperature over 26 °C and for cold climates the exact temperature below 20 °C, along with ambient temperature, which gave us a picture to evaluate the performance of the building envelope of each system and the energy efficient design strategies. The design strategies are investigated one by one in order to show their influence on the energy saving performance of the building systems. The improvements of the systems for each city (climate) differ with respect to some strategies. For instance, in this work for Istanbul, Erzurum and Antalya different orientation strategies were used due to their climate characteristics. Those strategies are shortly defined by the following graphics. The improvements were applied for both in PREBID and ISIBAT according to the variables.

“Reference case” strategies: Heating and cooling reference temperatures are set at 20°C and 26°C respectively for all zones. Gains are considered as; four people use the zones in the given time schedule. The air-change rate is calculated/estimated as hygienic ventilation of 0.7^{-h} during the day and night, which is calculated according to the DIN 1946-T2 (30 m^3 per person). The ASHRAE 2001 fundamentals defined ventilation air requirement for houses, essentially 035^{-h} with at least 8L/s per occupant.

“Improved case” strategies: For improved cases the nighttime set up heating strategy was applied during the night between 24:00 and 08:00 hours. The heating temperature was set at 18°C (night) and 20°C (day), and the cooling reference temperature remained the same as in the reference case, 26°C. The most important goal of this thesis was to compare energy performance of the selected building systems. Accordingly due to that reason some internal gains from appliances, computers etc. that do not have a significant influence on energy use for such a model are not considered in the simulations.

In the improved case, window sizes are decreased from 1.44 m^2 to 1.2 m^2 for Erzurum in order to minimize heat loss through the transparent openings.

The user schedule is defined equally in both the reference and improved case as:

- for both RF and RGR zones: 4 people between 23:00 and 08:00
- for both SF and SGR zones: 2 people between 08:00 and 23:00

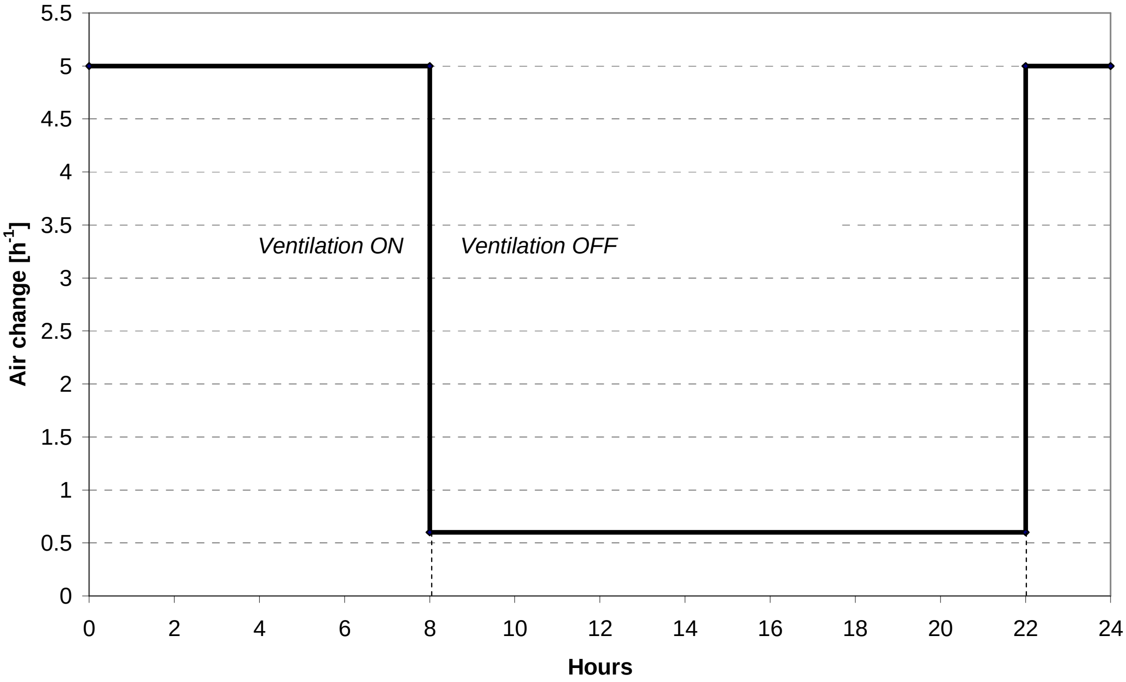


Figure 6.7: Ventilation strategy for Antalya in the improved case (Night Ventilation)

As seen in the Figure 6.7 the ventilation strategy for **Antalya** is set up as night ventilation to get cool-night ambient air inside by opening and closing the windows. It is assumed that the windows are opened during the night between 22:00 and 08:00 with an air-change rate of 5^{-h}, if the room temperature is greater than the ambient temperature and the ambient temperature is higher than 20°C. In addition, the ventilation rate remains constant during the day with a rate of 0.7^{-h} to supply hygienic air for residents. As it is illustrated in the graphic, between 08:00 and 22:00, only a hygienic air-change rate of 0.7^{-h} is applied. The reason for choosing night ventilation was the high daytime ambient temperatures in Antalya.

For both of the heating dominated cities, **Istanbul and Erzurum,** the same ventilation and infiltration strategies were assumed in the simulations. The strategy was considered as follows: if the room temperature is greater than the ambient temperature and over 25 °C, the building is ventilated by half-opened windows with an air change rate of 5^{-h}, otherwise, just the infiltration rate stays with the value of 0.7^{-h}.

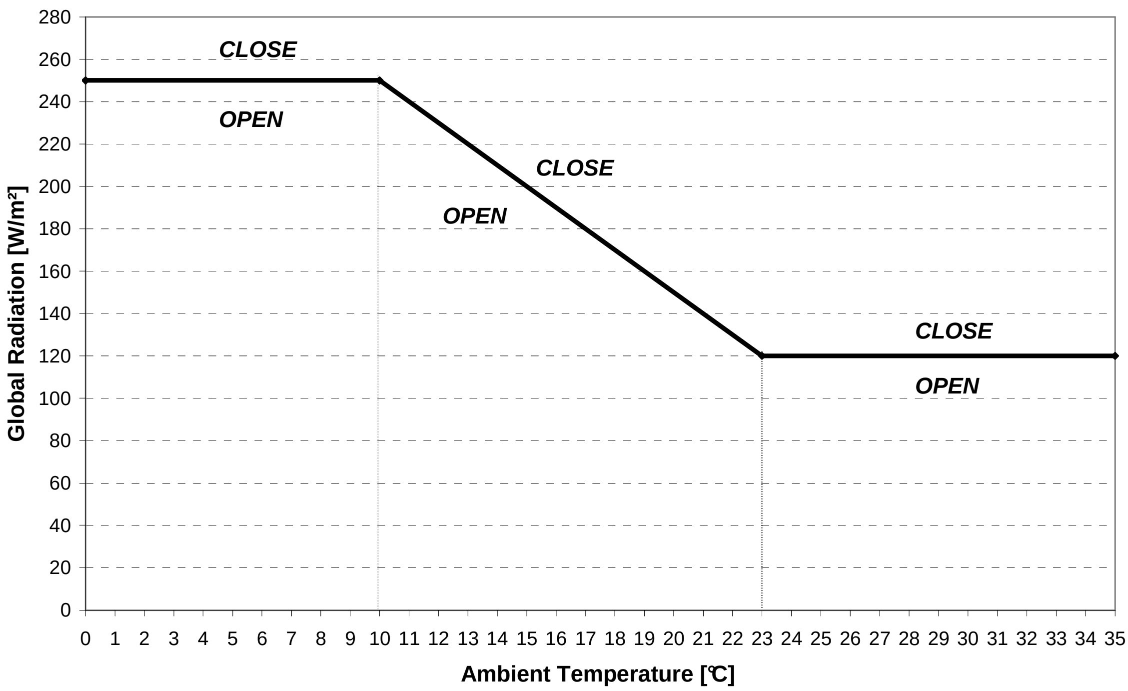


Figure 6.8: Shading strategy of the improved case for Antalya

In the regions with hot summers, a climate like Antalya and other southern regions, shading strategy is a very important energy saving element. The strategy chosen for Antalya depends on global radiation and ambient temperature, a mathematical equation representing the shading device is set up in the ISIBAT program. Boundary ambient temperatures were selected as 10° C and 23 °C and their match of global radiation values of 120 W/m² and 250 W/m² (Figure 6.8). Thus, if ambient temperature is between 0°C and 10 °C and global radiation is more than 250 W/m² the shading device will be closed. In the simulations that were carried out for Istanbul and Erzurum, no shading devices were applied because for those climates cooling loads were small in the reference case simulations.

Figure 32 shows heating and cooling strategies used in simulations for Antalya. Cooling is going to be applied after the room temperature reaches over 26°C, and heating is activated when the room temperature is under 18°C between 0:00-8:00 during the nighttime set up; during the day the heating reference temperature is set up as 20°C (Figure 6.9).

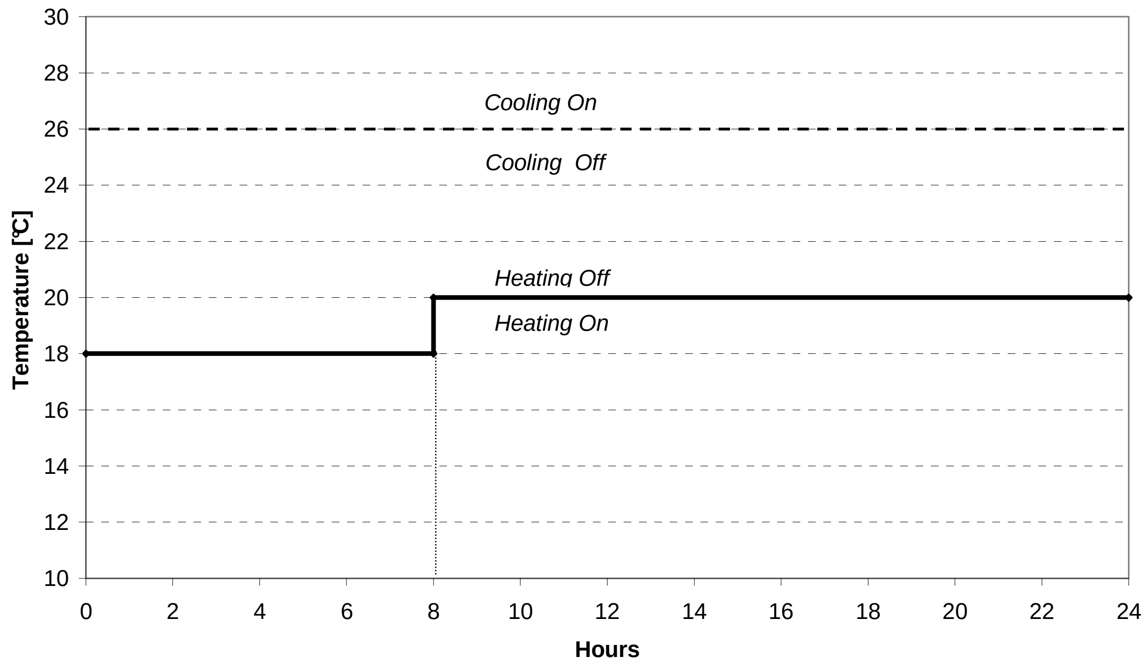


Figure 6.9: Heating and cooling strategy for Antalya in the improved case (with nighttime set up)

Heating and cooling strategies for Istanbul and Erzurum:

- cooling will be activated when the indoor operative temperature is higher than 26°C,
- the zones will be heated if indoor operative temperature is lower than 18°C

Constructional properties for each system before and after improvements are presented in Appendix J and K. The criteria for selection of the systems are;

- One of the thesis goals is to analyze energy performance of the prefabricated residential buildings in Turkey and compare it with reinforced concrete residential buildings. The yearly housing demand in Turkey is almost 300.000 according to the government report in 2002. Thus, the country needs fast, economic and energy efficient housing stock, prefabricated systems can supply these 3 requirements. Three prefabricated systems have many applications of new housing projects in Turkey; therefore it will be useful to investigate these systems regarding their energy consumption. In addition, among the prefabricated residential building systems these systems share first three places.

- A significant number of the residential buildings in Turkey is reinforced concrete buildings and not insulated. Thus, improvement of the reinforced concrete residential building systems is an essential task with respect to energy saving and conservation.

6.5. Analysis of the Simulation Results

The simulations of four different residential building systems were performed with respect to different aspects of energy use and thermal performance:

- Analyzing the results with regard to heating and cooling loads
- Analyzing the results with regard to number of zone temperatures over 26°C and below 20°C
- Analyzing the results with regard to building performance on the hottest day of year
- Analyzing the results with regard to different design strategies

The traditional System, which represents most of the residential buildings in Turkey and is generally built without insulation, shows the worst performance in both the hot region (Antalya) and the cold region (Erzurum): especially in Erzurum the heating requirement is almost two and a half times the maximum requirement in Turkish Standard-825. Other prefabricated systems perform better than traditional systems before and after the improvement of the systems.

Primary energy is calculated according to the DIN-4701. It is overall energy, including the energy used to generate the delivered energy (final energy) and to transport it to a building. The factor for multiplication with the delivered electricity is based on a country's energy mix for generation of electricity. Energy delivered to the building, like gas, oil or other fuel, electricity, district heat etc. Effective energy is the amount of energy which has to be provided by the technical systems in order to satisfy the needs of the rooms. [46] (Figure 6.10). The TRNSYS simulation results give building energy use. Primary energy source for heating is natural gas, for which primary energy factor (f_p) is 1.1, and the loss during the distribution of energy to the building is 15% of delivered energy (final energy). Primary energy source for cooling is electricity with primary energy factor of 2.9.

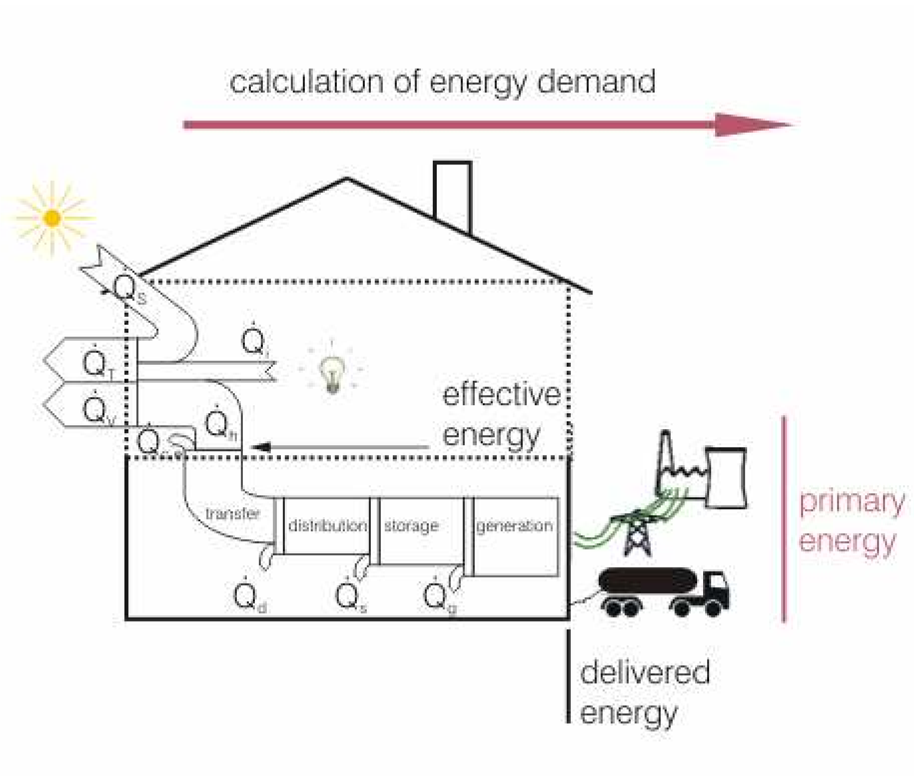


Figure 6.10: Primary, delivered and effective energy (Source: www.euleb.info)

6.5.1. Analysis of the Results with Regard to Heating and Cooling Energy Loads

In hot climates like Antalya, all systems have significant amounts of cooling loads. The reference simulation highlighted the interlocking brick system and lightweight steel skeleton system, which accommodate insulation and show better performance than the systems without insulation, the aerated concrete system and the traditional system. Although the most important issue for Antalya is cooling, heating demand for the traditional system exceeded the maximum required amount mentioned in TS-825 standard in the reference case simulation. Surprisingly, the lightweight system showed the second best cooling and heating energy performance after the interlocking system because of its lower thermal transmittance features, which result in a minimum heat gain and heat loss (Figure 6.11).

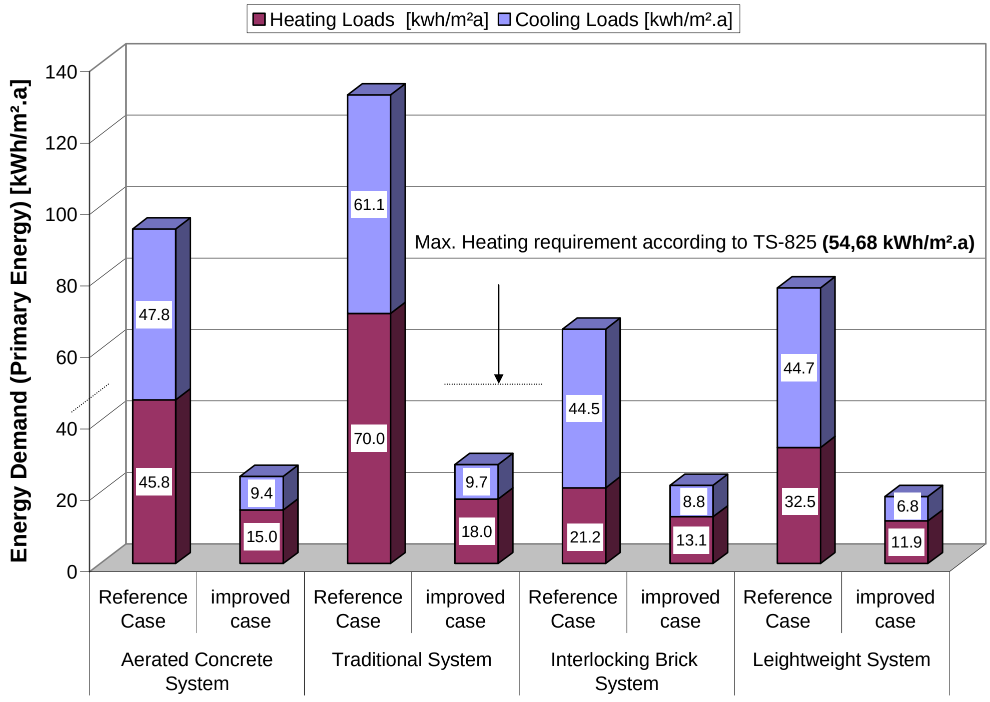


Figure 6.11: Energy loads (primary energy) in Antalya before and after the improvements

After applying energy efficient strategies - including ventilation, shading, insulation and different glazing types – the cooling and heating energy demands sank dramatically for all building systems. Improving reference systems indicated the highest energy use decrease in the traditional system and the aerated concrete system. The decreases in heating loads, due to the application of a 5 cm thick insulation in the improved case and some design strategies, are (from 70 kWh/m².a to 18 kWh/m².a) over 70% in the traditional system and over 60% in the aerated concrete system, which is under the required load required in the Turkish standards (54, 68 kWh/m².a). Energy use for the other two pre-fabricated systems, the interlocking brick and the lightweight system, is reduced by almost 50 % and had 60 % respectively.

Advanced design strategies are mainly applied to lower cooling demand for Antalya. In such a climate this is more important than heating demand, which is why design strategies resulted in large decreases in cooling demand for all systems, especially in traditional system with more than an 80% decrease. It can be concluded that thermal mass systems with a small insulation size can perform better performance with regards to cooling and heating loads without having any improvements. Not only applied design strategies have influence in decreasing energy use, but also thermal transmittance values of the building envelope limit heat loss and gain. Thus, the lightweight system indicates best performance even in a hot climate with the help of shading and high daytime ventilation, which blocks solar heat gain through the windows during the day and exhausts hot air during the night.

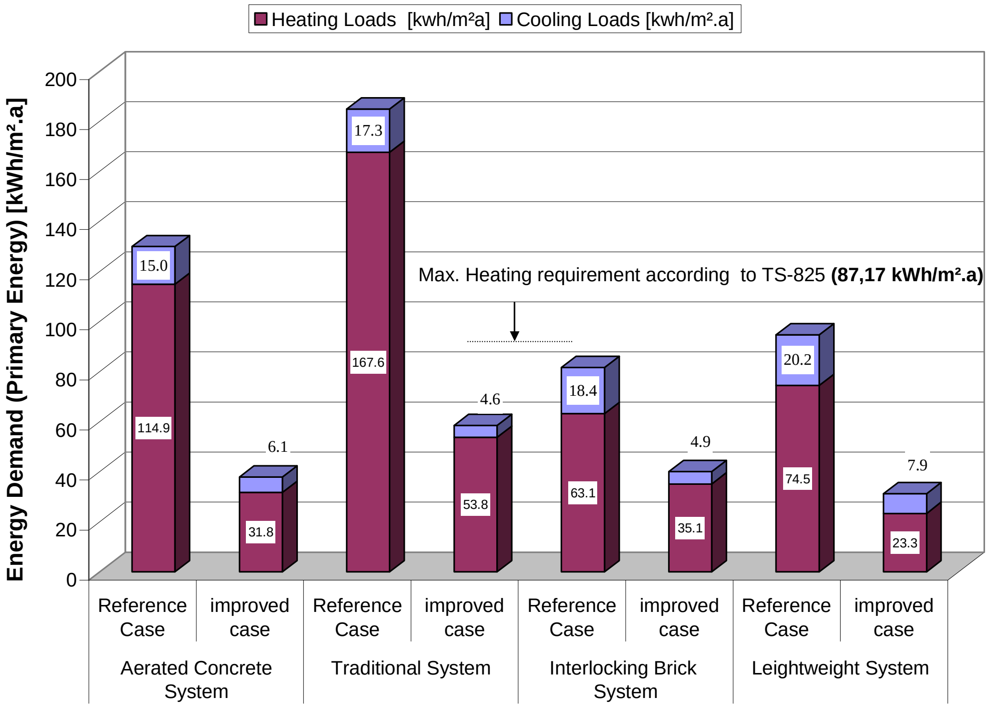


Figure 6.12: Energy loads (primary energy) in Istanbul before and after improvements

In moderate climates like Istanbul, due to the cold winters, heating loads are more important than cooling loads. In the reference case two systems, the interlocking brick and lightweight steel systems, show the best performances regarding heating energy, thanks to their insulation. The interlocking brick and the lightweight systems had heating energy savings of 57% and 68% respectively after modification of the reference building. The other two systems exceeded the maximum standard value of heating energy demand mentioned in standard TS-825. In the simulation process, installation of 5 cm insulation for both the aerated and the traditional systems resulted in a large heating demand decrease (from 167 kWh /m².a to 53 kWh /m².a). Heating energy savings of 70% for the aerated system and 67% for the traditional system were achieved. Especially applying small sized insulation to the aerated concrete resulted in significant energy savings. All systems achieved more than a 50% cooling load decrease; the traditional and interlocking brick systems had the lowest cooling loads out of the four systems (Figure 6.12).

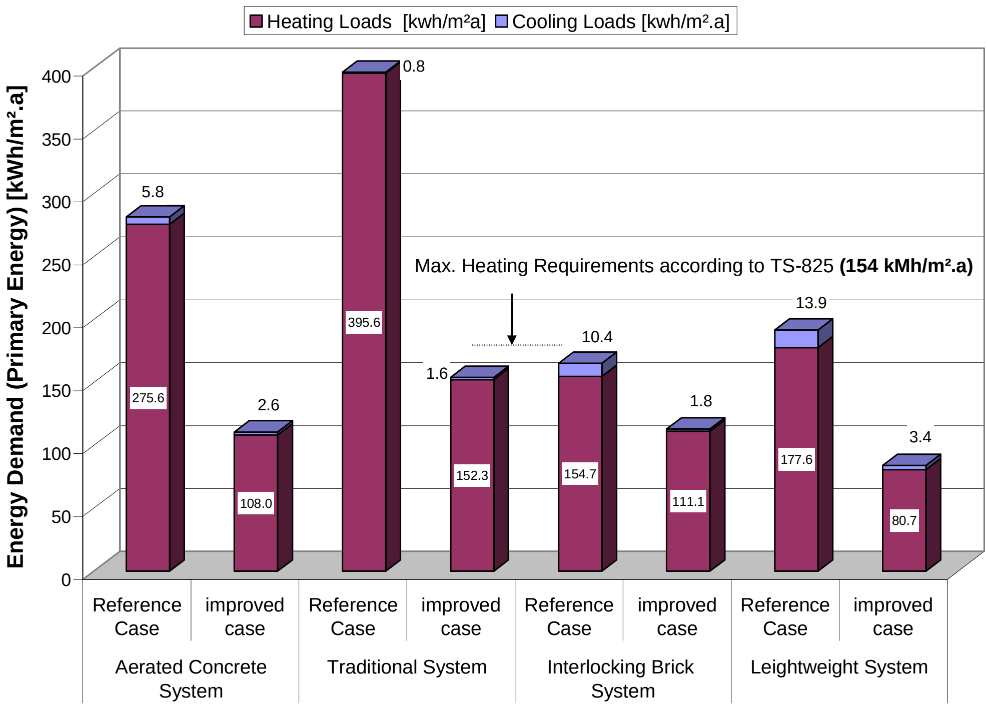


Figure 6.13: Energy loads (primary energy) in Erzurum before and after improvements

Erzurum, which is situated at an altitude of 1800 m, has a very cold climate. Accordingly, almost all systems, with the exception of the interlocking brick system, failed to meet the standards under the TS-825 heating energy requirement, which was defined for Erzurum in the reference case. Even in the improved case, the traditional system is close to the maximum reference heating demand. Although the city is too cold important heating energy savings are achieved close to 60%, by applying new design strategies; especially the impact of insulation on heating demand was significantly effective.

Heating loads sank almost to one-third of the reference case demand after improvements for all systems except the interlocking brick system, in which heating loads decreased just 50 kWh/m²a one-third of the heating load. Insulation for the traditional and aerated concrete systems has the greatest influence on the minimization of heating demand because of the climate conditions in Erzurum. Having regarded to very few cooling dominated days, the lightweight system shows the worst performance with regard to cooling demand.

This is a consequence of the transmittance properties of the building envelope, which is not thermal mass and has the smallest thermal transmittance value out of the four systems.

6.5.2. Analysis of the Results with Regard to Zone Temperatures Greater Than 26°C for Improved Systems

The second general evaluation of these systems was made by comparing the temperatures that exceeded 26°C for the three climates for cooling load evaluation. The results represent the temperatures without considering mechanical cooling or heating, so-called, free running temperatures. In addition, the systems can be compared with respect to temperature frequency higher than 26°C as a result the capacity of cooling systems can be deduced from those charts.

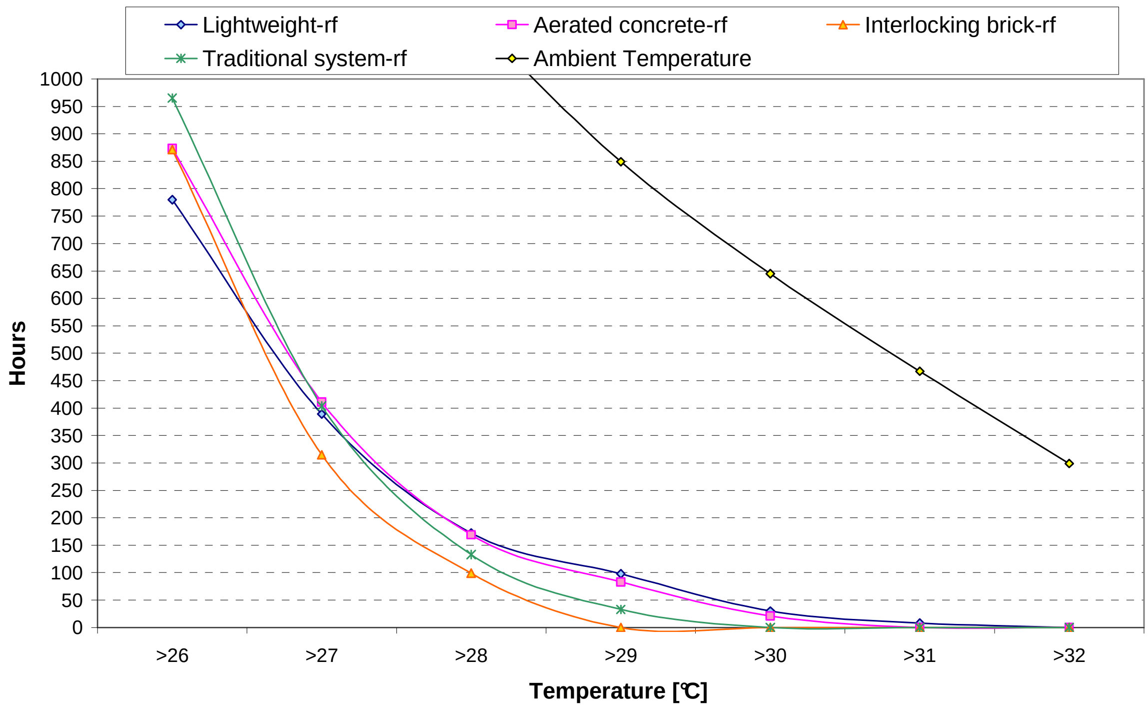


Figure 6.14: The RF-zone temperatures greater than 26°C in Antalya (after improvements)

In Antalya, the temperature range for the interlocking brick system and the traditional system, both thermal mass systems, is between 26°C and 29°C. The temperatures generally concentrated between 26°C and 27°C, which are close to the reference temperature for cooling. On the other hand the lightweight system and the aerated system have higher temperatures than those two thermal mass systems. Consequently, those systems need more cooling energy to reach the comfort level. As we see in the chart, the aerated concrete and lightweight systems have greater temperature fluctuations between 26°C and 31°C. The higher the temperature is, the higher the cooling energy it needs. (Figure 6.14)

After improvements, the difference between the ambient temperature and the indoor temperatures for the systems increased all systems showed better performance than in reference case.

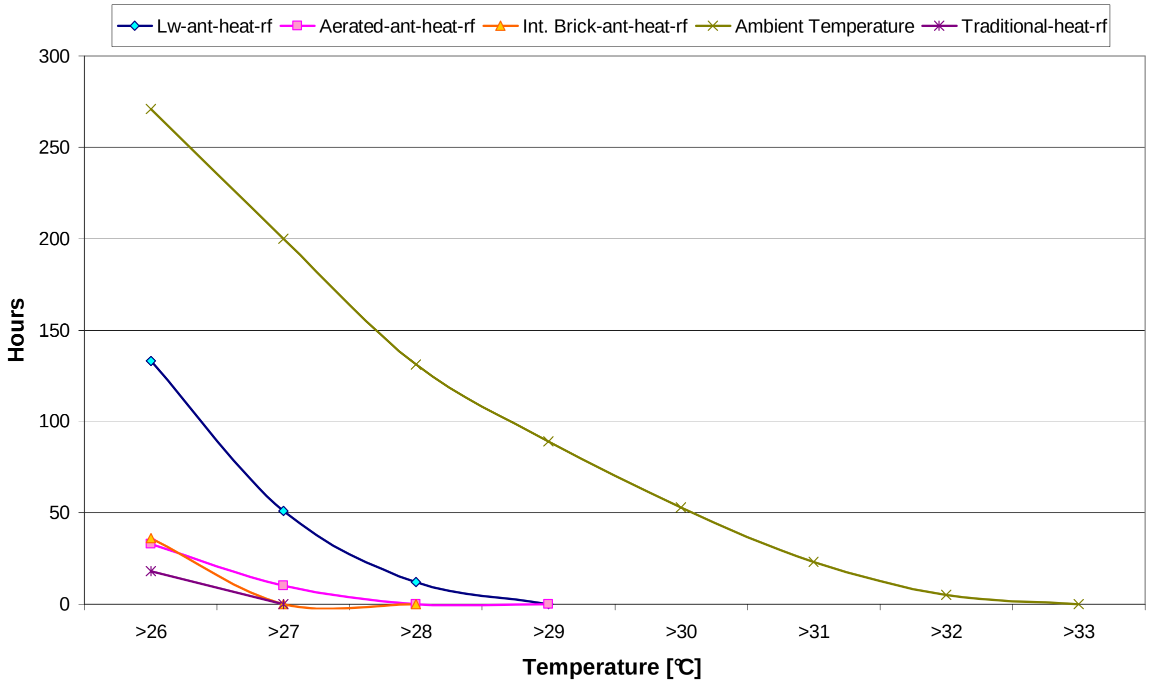


Figure 6.15: The RF-zone temperatures greater than 26°C in Erzurum

In Erzurum, the temperatures exceeding 26°C are not as high as in the other cities; however, the systems do have cooling demands for some days of the year. The lightweight system shows the worst performance regarding cooling loads in Erzurum, although just 140 hours in a year are over the 26°C reference temperature, while the other systems have fewer temperatures exceeding 26°C (Figure 6.15). In addition, the number of temperatures lower than 20°C can give significant information to asses how important the heating needs are.

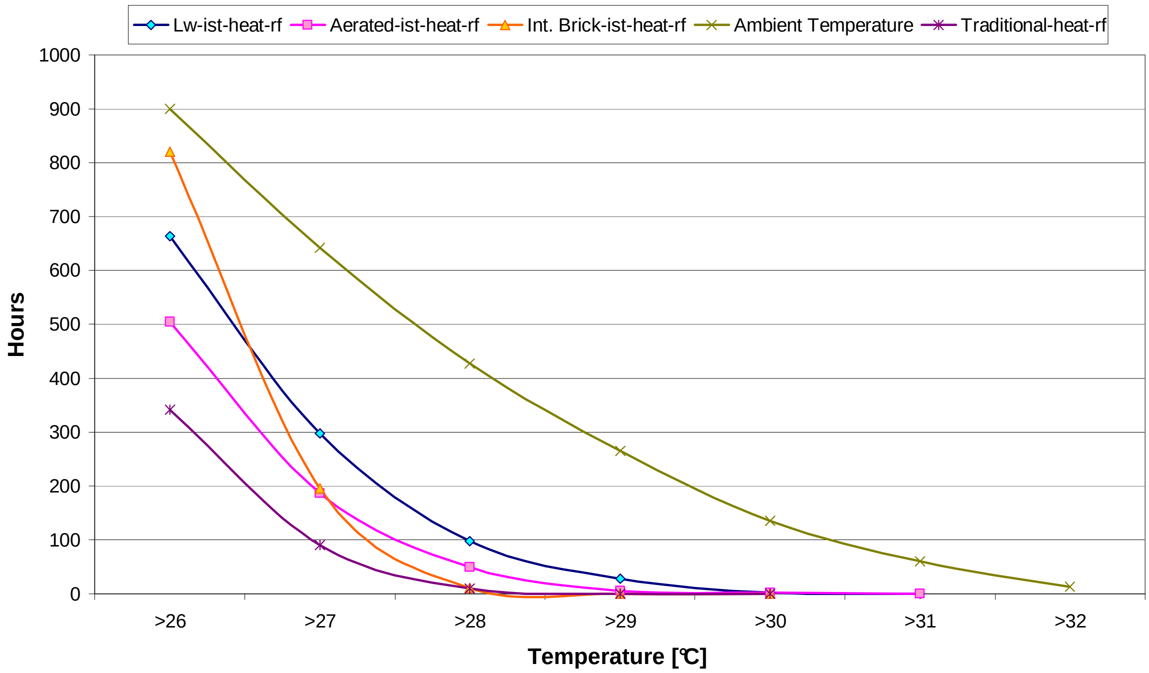


Figure 6.16: The RF-zone temperatures greater than 26°C in Istanbul

Istanbul lies in a moderate climate; differences between systems can be seen more clearly than that in the hot climates. The fluctuation of temperature does not change itself, but the temperatures exceeding 26°C are higher in the lightweight and aerated concrete systems than in the interlocking brick and traditional systems. The temperature range was mainly situated between 26°C and 28°C for the interlocking brick and traditional systems, while for the lightweight and aerated systems temperature fluctuates between 26°C and 30°C. Both the lightweight and aerated concrete systems have higher temperatures than the interlocking brick and traditional systems they were between 28°C and 30°C. This means more energy efficient improvements are needed for these systems in order to decrease the temperature to an adequate level (Figure 6.16).

6.5.3. Analysis of the Results with Regard to Zone Temperatures for Improved Systems on the Hottest Two Days

- Hot Climate (Antalya)

Some of the general simulation results for a hot climate are as follows: the first floor is warmer than the ground floor. All systems exceeded the cooling reference temperature of 26°C in Antalya due to the high ambient temperature. During the night, temperature difference between the zones was lower than during the day because of the night ventilation until 8 o'clock. Consequently, the zone temperatures increased after 8:00 am. The zone temperatures do not follow the ambient temperature curve thanks to the shading strategy and the help of the thermal mass internal walls, which had a large influence on keeping the zone temperatures almost constant throughout the day. The zones that have more internal walls have a cooler indoor climate than the zones without any internal partitions.

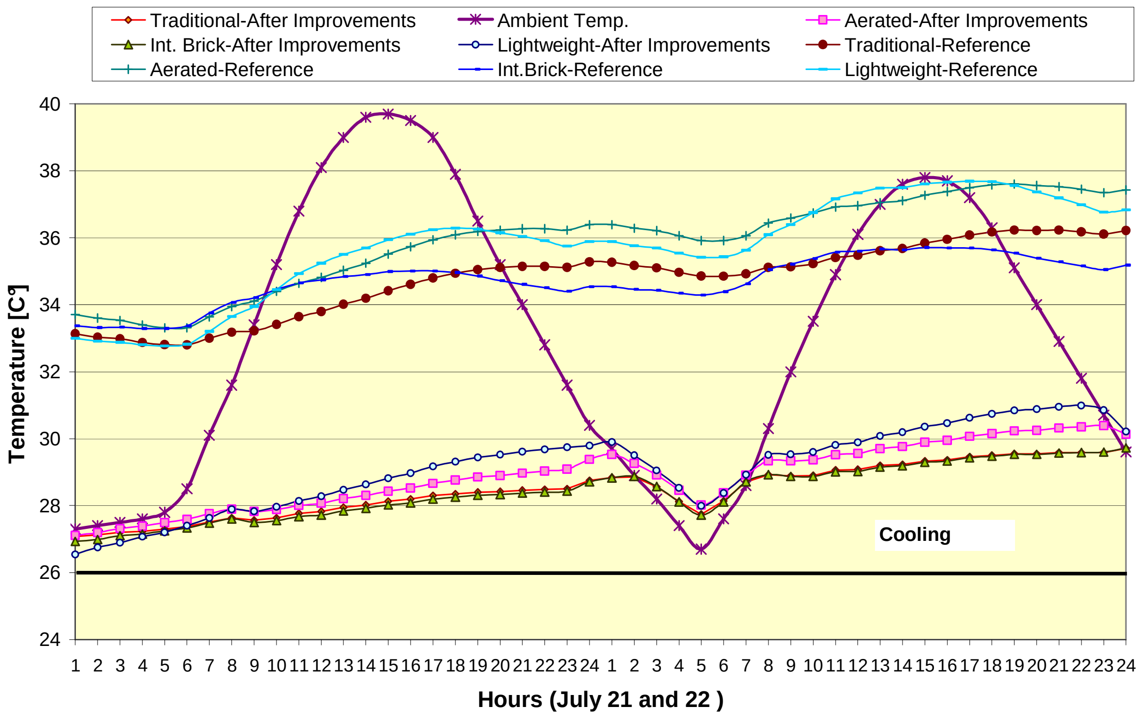


Figure 6.17: Temperature of the RF-zones (Room first floor) on the hottest day in Antalya for all building systems

Figure 6.17 illustrates the temperature comparison of the RF-zone (Room first zone) between the four residential systems on the hottest day of the year and on the following day (July 21 and 22) in Antalya. The interlocking brick and traditional systems reach their peak temperature value at night; mostly because of the heat storage capacity of the thermal mass construction. The solution for this problem can be clearly seen in the graphic night ventilation should be applied after 22:00. to cool down the rooms. During the daytime, the lightweight system has the highest temperature, followed by the aerated concrete system. However, the temperature difference between the systems is not as high as that in Istanbul. The impact of night ventilation on the zone temperature varies between 1°C - 3°C for the zones with thermal mass internal walls, while it varies between 2°C and 6°C for the zones without thermal mass internal walls. The maximum daily RF-zone temperatures do not exceed 30°C. The temperature difference between ambient temperature and the highest room temperature is approximately 10°C, when the ambient temperature is at the peak point of the day (14 o'clock).

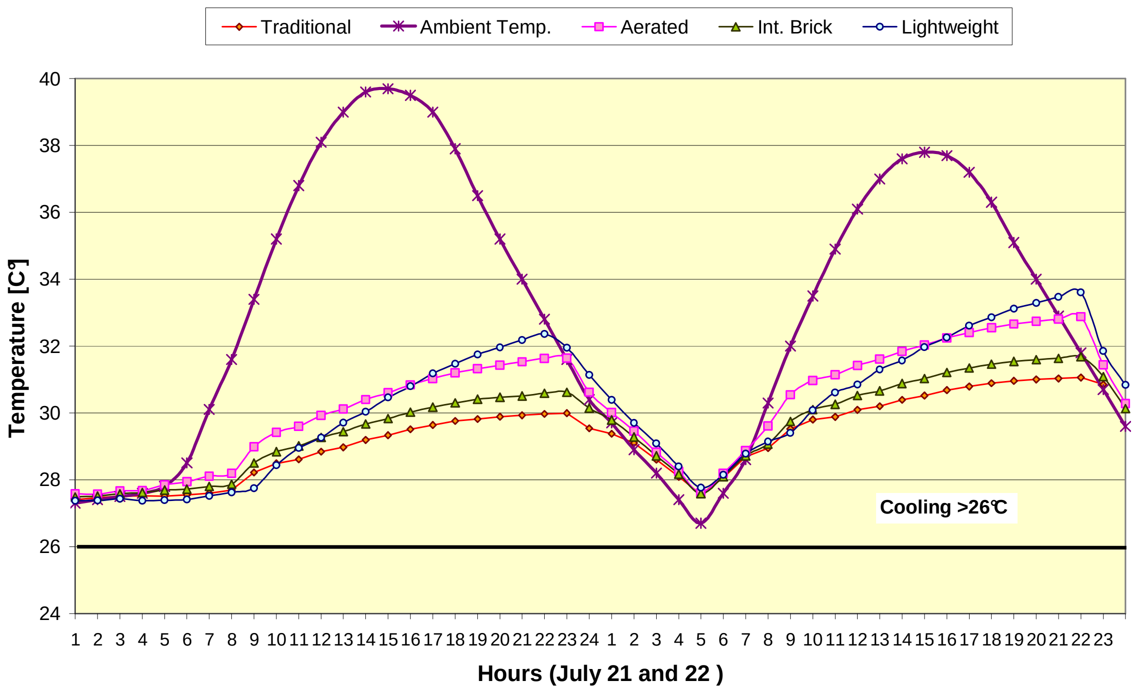


Figure 6.18: Temperature of the SALF-zones (Saloon first floor) on the hottest day in Antalya for all building systems

Figure 6.18 highlights the temperatures in the SALF-zones, which have no internal thermal mass partition walls like the RF-zone. Both the "SALF" and "SALGR" zones, which represent saloon zones in the first floor and ground floor, have higher temperatures than the room zones the smaller internal thermal mass partition walls lead to the higher daily temperature.

The lightweight system has higher temperatures than the other three systems because the system can not absorb the heat during the day as much as the thermal mass building systems. On the other hand it shows better performance at night. It is important to use heavyweight structures in such hot climates. The daily room temperatures vary between 34°C and 27°C for these two hot days, while during the night all four zone temperatures are almost equal to the ambient temperature.

The traditional system showed one of the best performances with regards to zone temperature, which lies 10°C under the ambient temperature. The zone temperatures vary within the limit of 4°C. The zone temperatures are between 29°C and 26°C, while the ambient temperature is at the peak point of 40°C at 15 o'clock

The zone temperatures of the aerated concrete system do not exceed 34°C, while the ambient temperature varies between 40°C and 38°C. As it can clearly be seen, due to the night ventilation the zone temperatures at night decrease drastically by the ambient temperature, which is also over 26°C, the cooling reference temperature at that time. The temperature difference between ambient and zone temperatures fluctuates between 8°C and 10°C.

- Moderate Climate (Istanbul)

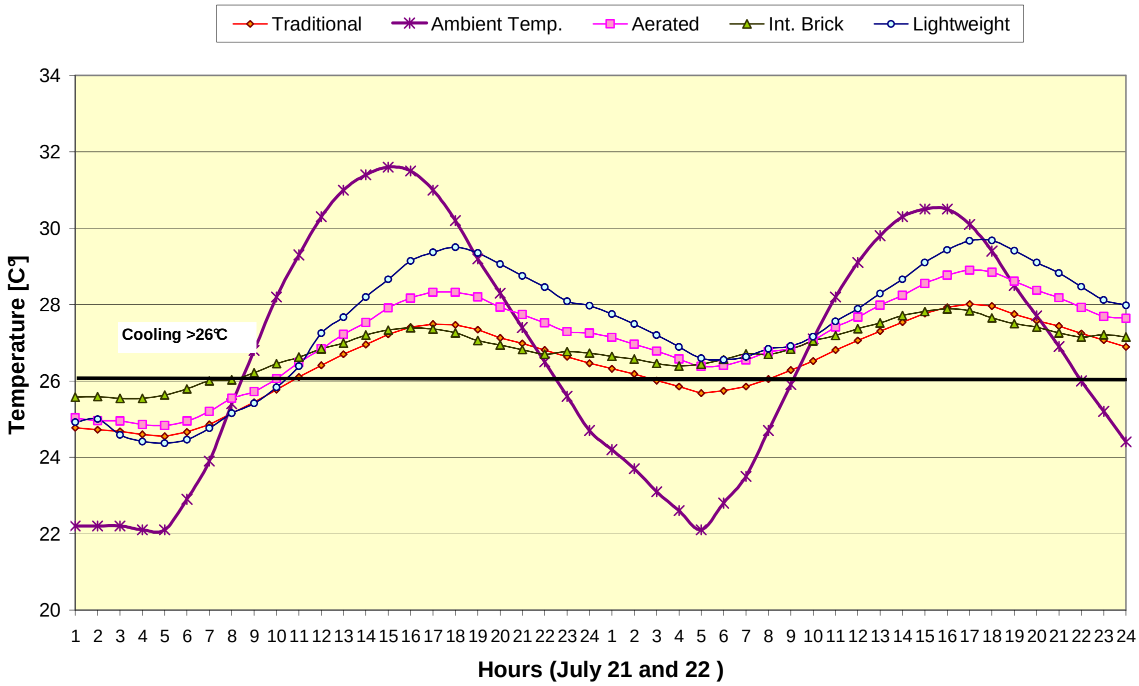


Figure 6.19: Temperature of the RF-zones (Room first floor) on the hottest day in Istanbul for all building systems

Although in simulations, there is no shading device considered for Istanbul, for some days it could be considered in order to lower solar heat gain through the windows. The day time temperatures of zones indicate that the heavyweight structure keeps the rooms cool. On the other hand, it lets the stored heat out into the rooms in the night, thus, the zone temperatures are higher than the ambient temperature. The RF-zone temperatures of the systems between during day and night vary between 3°C-5°C. The night ventilation strategy is not used for Istanbul, but rather formulated as follows: if the ambient temperature is lower than the zone temperature and the zone temperature is higher than 25°C, then the zone will be ventilated with 5^{-h}. Thus, the worst case of room temperatures will be equal to ambient temperature, and it will never be over ambient temperature. In this moderate climate of Istanbul, the RF-zone temperatures fluctuate in the context of 24°C and 30°C, while the difference between day and night ambient temperatures is 10°C. RF-zone temperature fluctuations of the four systems are lightweight 24°C-30°C, aerated concrete 25°C-28°C, interlocking brick 25.5°C-27°C and the traditional system 25°C-27°C. (Figure 6.19)

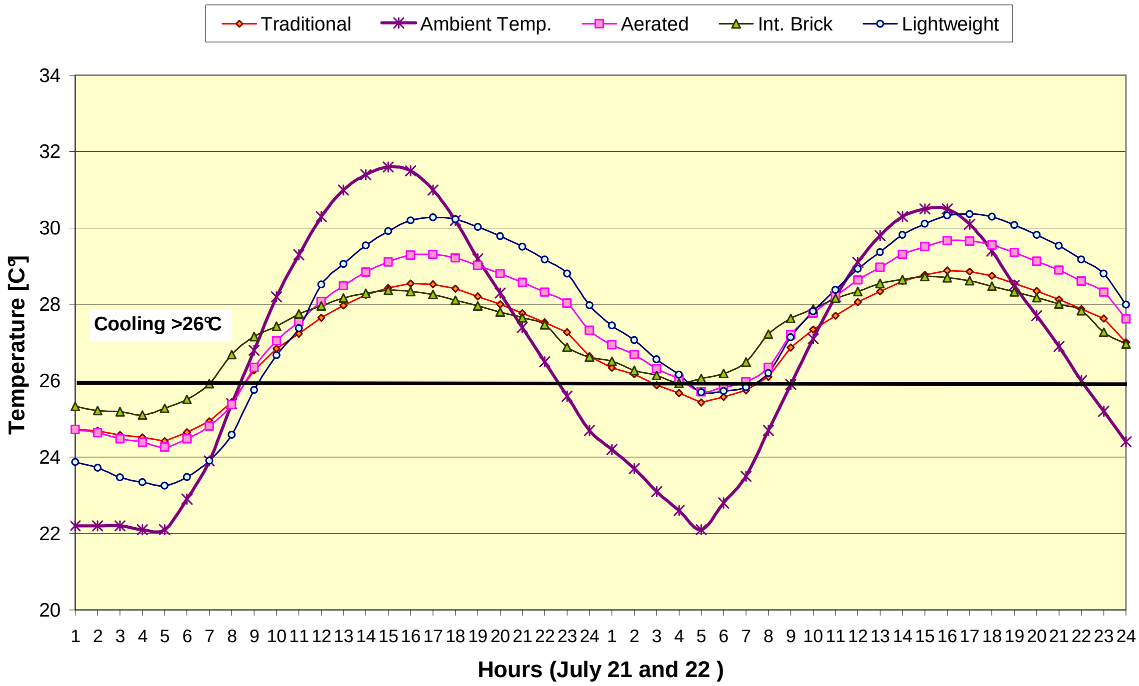


Figure 6.20: Temperature of the SALF-zones (Room first floor) on the hottest day in Istanbul for all building systems

The figure represents the hottest day in Istanbul: thus, daytime room temperatures are closer to the ambient temperature. Even if the lightweight structure does not have a large thermal capacity the zones RF and RGR have more internal partitions On these hottest days, the minimum night ventilation can help to provide more comfortable indoor spaces as seen in the graph. However, it is normally not necessary to use night ventilation in Istanbul.

The temperature difference between day and night fluctuates between 10°C and 8°C, the SALF-zone temperatures vary within the limits of 3°C and 7°C, generally below the cooling reference temperature of 26°C. The highest change is seen in the lightweight system.

The figure demonstrates how the reinforced concrete building can maintain comfortable indoor temperatures in Istanbul. In the morning and at night, the zone temperatures are lower than 26°C due to night ventilation. In the hot daytime, the windows are closed to prevent hot ambient air from entering the rooms. In addition, with the help of thermal mass walls the daily temperatures of the zones are approximately 2°C lower than the ambient temperature (Figure 6.20).

- Cold Climate (Erzurum)

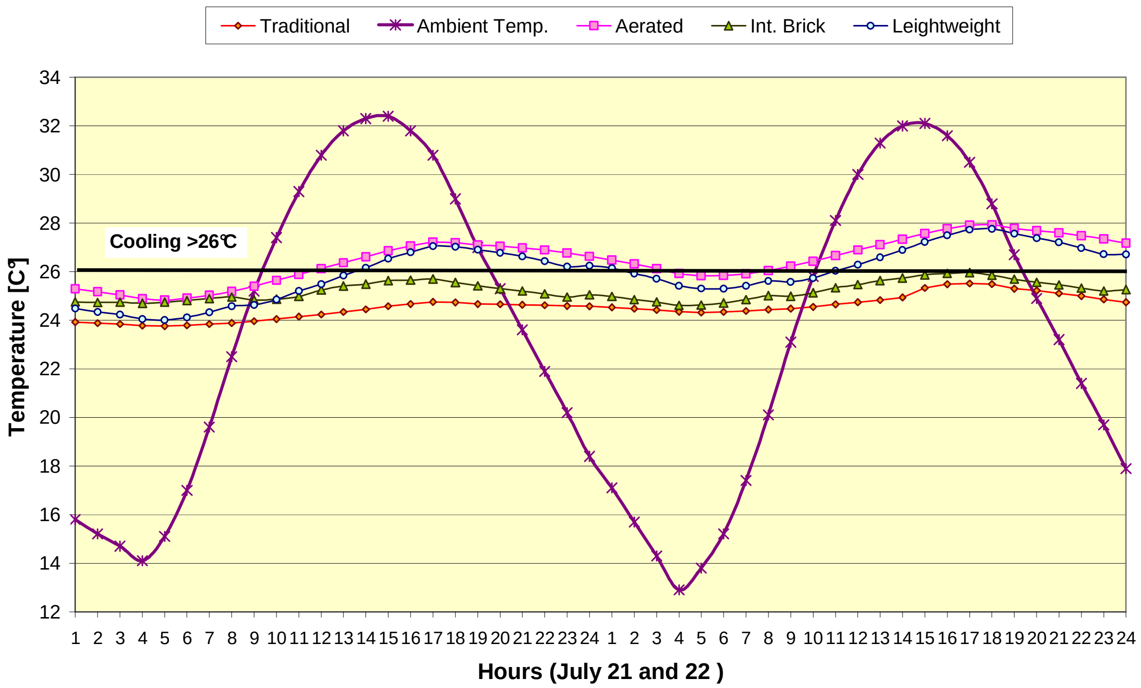


Figure 6.21: Temperature of the RF-zones (Room first floor) on the hottest day in Erzurum for all building systems

The RF zone temperatures of all systems in Erzurum show a constant trend during the two hottest days of the year. Despite that Erzurum has a large temperature difference between night and day, which can reach a difference of 20°C for some days, even on the hottest day. At night the room temperatures are under the cooling reference temperature, 26°C, determined for the simulations. Both the traditional system and the interlocking brick system show better performances than the aerated concrete and lightweight systems with regards to room temperature. The zone temperatures of both thermal mass systems do not exceed 26°C, while those of the aerated concrete and lightweight systems are over 26°C, except during the night. The ventilation rate of 1^{-h} eliminated the disadvantage of the thermal mass systems at night. (Figure 6.21)

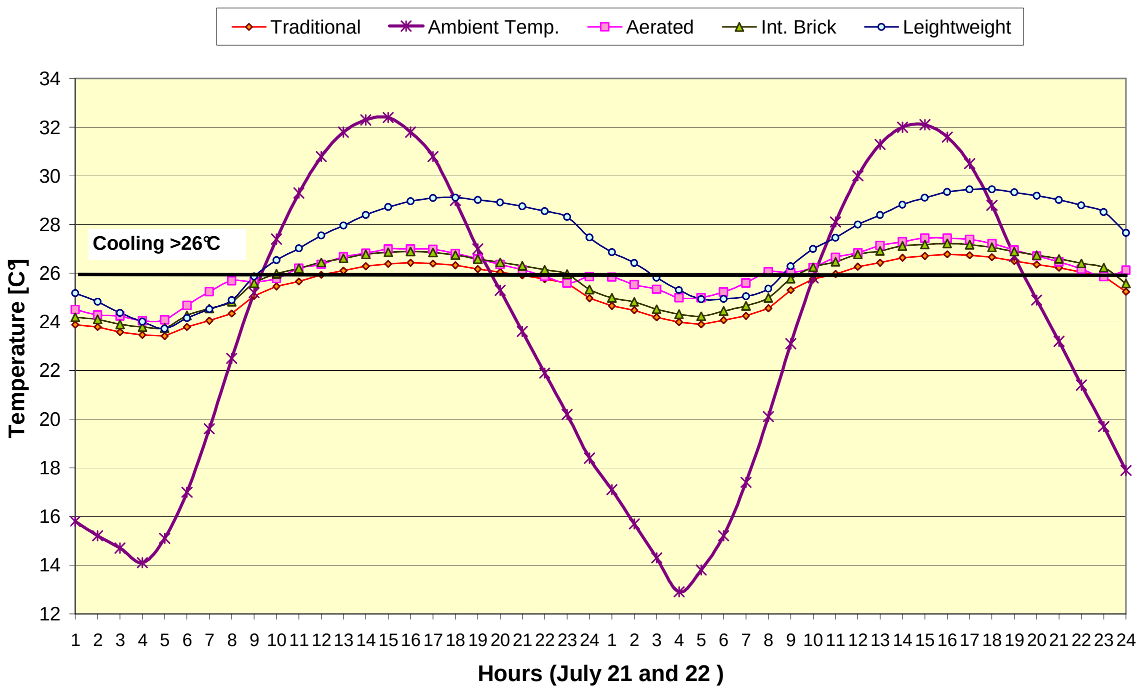


Figure 6.22: Temperature of the SALF-zones (Room first floor) on the hottest day in Erzurum for all building systems

Figure 6.25 indicates the SALF-zone temperatures of the selected building systems for Erzurum. The zone temperatures are generally under the cooling reference temperature of 26°C, even on this warmest day, on which ambient temperature decreases by approximately 12 °C against morning at 4:00. Nevertheless, the lightweight system has higher temperatures than the other systems. During the day the zones that have no internal walls have higher temperatures than those with thermal mass internal partitions. Although some days at night the ambient temperature can get as low as 12°C, the zone temperatures do not fall below 24°C, thanks to the insulated envelopes of the building system and the lowrate of ventilation.

6.5.4. Analysis of the Results with Regard to Different Design Strategies for Improved Systems

6.5.4.1. Ventilation

Ventilation strategy is one of the critical elements of the building energy use because of heat gain and loss through the air change. In this section, the influence of five air change rates (between 0^{-h} and 5^{-h}) on cooling loads are investigated for 4 buildings systems. The natural ventilation is applied by controlling the windows. The hygienic ventilation rate of 0.7^{-h}, which was calculated according to the DIN 1946, is used for the cold and moderate climates in order to provide a minimum healthy, clean and comfortable atmosphere for the occupants. On the other hand for the hot climate, high night ventilation rate of 5^{-h} is used to exhaust warm indoor temperature through the cool night ambient temperature. In addition, the hygienic ventilation rate of 0.7^{-h} is used during the day to minimize influence of warm ambient daily temperature. The natural ventilation depends on wind speed and the temperature difference between inside and outside air. The high ventilation rates can be achieved by using cross ventilation. Following air-change rates can be given as rough calculations [45]:

Table 6.3: Types of window openings and their air-change rates

Types of window openings	Air-change rate [-h]
Closed windows and doors	0 - 0.5
Tilted windows	0.3 - 1.5
Half-opened windows	5.0 - 10.0
Completely opened windows	10.0 - 15.0
Oppositely located windows	up to 40.0

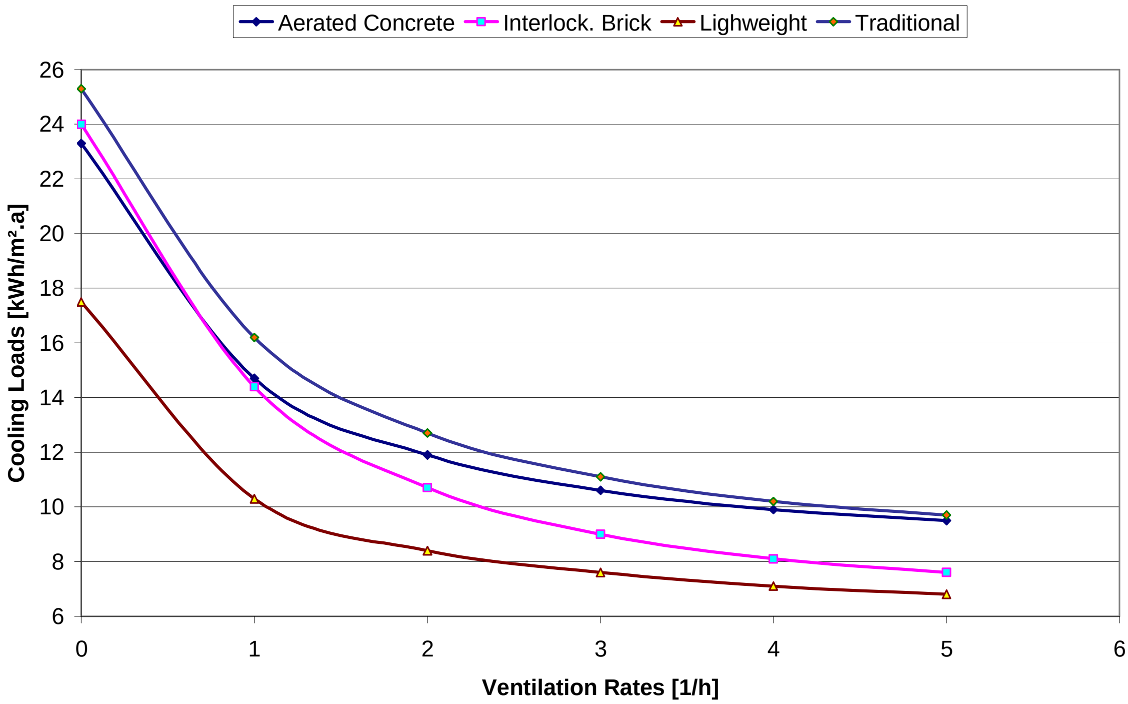


Figure 6.23: Influence of night ventilation on cooling loads (Primary Eenergy) for Antalya

The graphic shows the influence of the six different air-change values, from 0^{-h} to 5^{-h} on cooling loads of the four different systems in Antalya. The ventilation strategy is shown in this chapter graphically and can be summarized accordingly during the day (between 8:00 and 22:00) windows are closed, with a minimum hygienic air change value of 0.7^{-h} and during the night (between 22:00 and 8:00) windows are opened to reach a maximum air change of 5^{-h}. As seen in the graph increasing the air-change values results in significant reductions in the cooling loads of the four different construction systems in Antalya. The interlocking brick system and the traditional system indicate the best performances, with 70% and 60% of reductions in cooling loads when just hygienic air-change is applied and a 5^{-h} air-change value, which eliminates the disadvantage of the thermal mass structure during the night.

When applying just the hygienic air-change, the lightweight system has the lowest cooling load out of the four systems. Other heavyweight systems store more heat during the day than the lightweight building, and they let out the stored heat into the living spaces at night. Thus, if enough ventilation is not applied to sweep the hot air out of living spaces, they will be overheated even at night. Consequently greater air-change rates are applied; this resulted in a high cooling load difference between the interlocking brick and the lightweight structure, which is almost equal in the case of 5^{-h} air-change. Out of six different air-change rates, the significant improvement can be succeeded by applying 1^{-h}.

Cooling loads of the interlocking brick system drop from 24 kWh /m²a to almost 14 kWh /m².a, which is already a 60% of decrease, for the lightweight system from 17.4 kWh /m².a to almost 10 kWh /m².a, for the traditional system from 25 kWh /m²a to 15 kWh /m²a and for the aerated concrete system from 23 kWh /m²a to 9 kWh /m²a. In addition to these results, optimum air-change rates for those four systems can be determined by examining the graphic above for Antalya. It can be concluded that air-change values greater than 3^{-h} not have large influences on the cooling loads. Thus, the ventilation rates can be determined between 3^{-h} and 4^{-h} for traditional and aerated concrete buildings, 4^{-h} and 5^{-h} for interlocking brick and lightweight buildings (Figure 6.23).

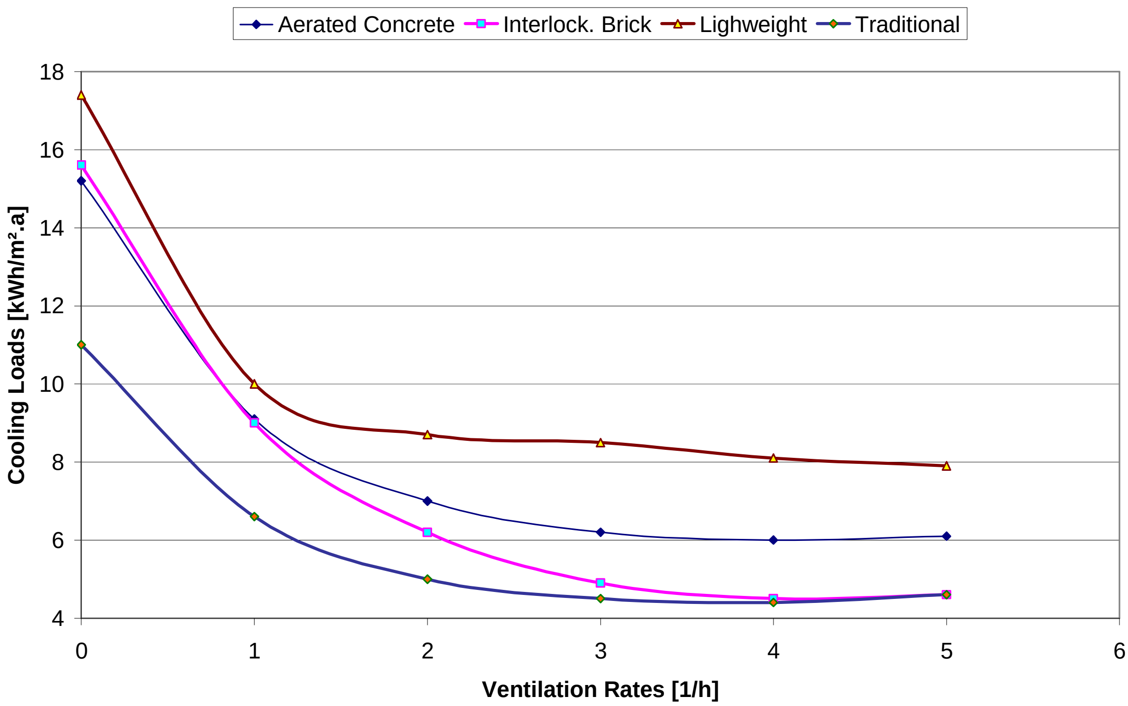


Figure 6.24: Influence of ventilation on cooling loads (Primary Energy) for Istanbul

Figure 6.24 above highlights the performance of the four different systems with regard to different ventilation rates in the moderate climate. The ventilation strategy in Istanbul can be defined shortly as follows if room temperature is over 25°C windows will be opened with 5^{-h} air-change and will decrease from 25°C, if room temperature drops under 22°C the ventilation will be off and only hygienic ventilation will be applied.

Traditional building has the lowest cooling load out of the four different building constructions, which ranked after the in the following order: interlocking brick, aerated concrete and lightweight buildings. In such a moderate climate, application of the high air-change values can result in an increase in the cooling demand. As seen in the graphic after applying 4^{-h} the cooling loads increase slightly. This can be caused by a high air-change of 5^{-h}, at which point the temperature fluctuation can be very high, thus, the ambient temperature can increase over the duration of an hour.

The graphic clearly indicates that the interlocking brick building can perform well, if it is supported by sufficient ventilation, which is not more than 4^{-h} in this moderate climate. The cooling loads of the lightweight building decreases sharply from 17 kWh/m².a to 10 kWh/m²a, representing 75 % of the total decrease, if only 1^{-h} air-change value applied. In contrast, the air-change rates, higher than 1^{-h}, do not greatly reduce the cooling loads. The air-change values more than 4^{-h} are also not adequate ventilation for aerated concrete. Optimum air-change rates can be proposed as 2^{-h} for the lightweight building systems and 3^{-h} for the rest of the building systems.

6.5.4.2. Glazing Variables

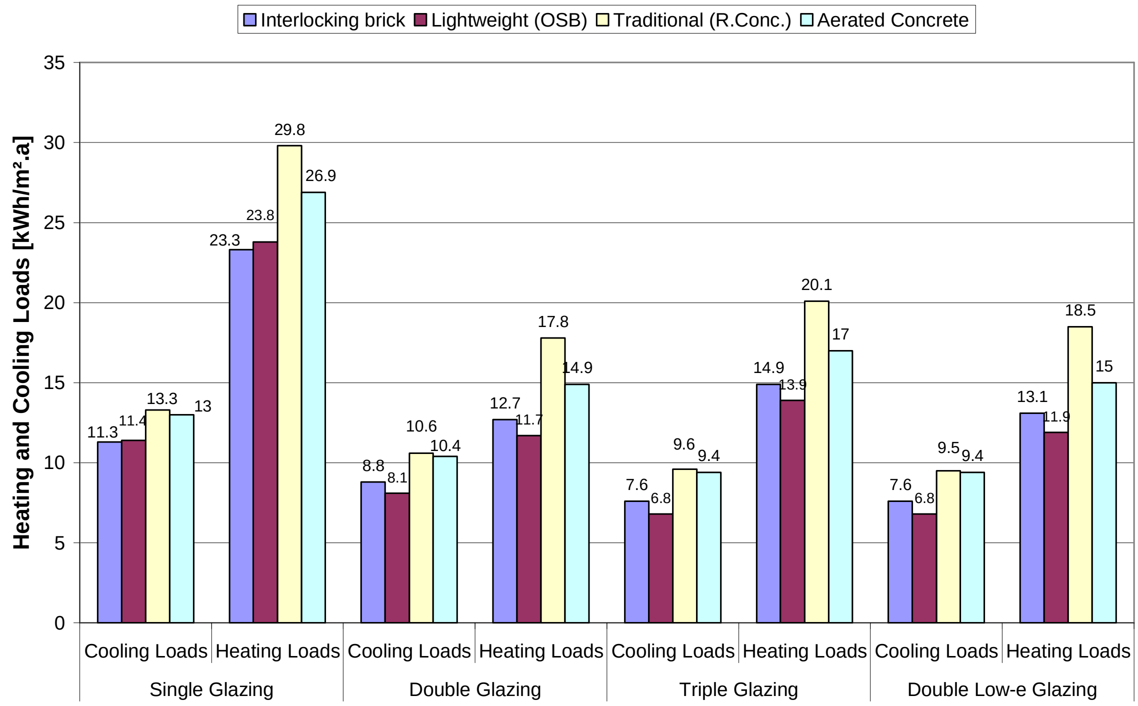


Figure 6.25: Heating-cooling energy (Primary Energy) performance of different glazing types for Antalya

Figure 6.25 shows the performance of four glazing types, including single glazing, double glazing, triple glazing and double low-e glazing for each building system in a hot climate region Antalya, with respect to heating and cooling loads. The simulated glazing types have the thermal transmittance “U-value” and solar heat gain coefficient values “g-value” as following:

Single glazing U-value: 5.8 W/m².K, g-value: 0.87

Double glazing U-value: 2.7 W/m².K, g-value: 0.777

Triple Glazing U-value: 1.8 W/m².K, g-value: 0.7

Double low-e U-value: 1.7 W/m².K, g-value: 0.597

Since the main concern is to reduce cooling loads in such a climate, the ranking of the glazing types from best to worst regarding cooling demand will be triple glazing, double low-e glazing, double glazing and single glazing respectively for all building types. On the other hand, when using triple glazing, the heating loads decrease in comparison to the single glazing case, but they have a higher heating energy use than the case of installing double glazing and double low-e glazing. Due to the solar thermal transmittance “g” value of 0.77, the building with double glazing shows one of the best cooling performances. The building with single glazing has the worst performance with regards to both cooling and heating loads with its higher “g-value” of 0.87; it describes a percent of transmitted solar heat gain through the windows and a higher “U-value” of 5.8 W/m²K. Consequently, when using single pane we have more overheated and more heating dominated thermal zones. Double low-e glazing is ideal for such cooling dominated climates because of its lower solar heat gain coefficient “g-value” of 0.59, compared to the four other glazing types.

Improving glazing types from single pane to the others resulted in high decreases in both the heating and cooling demand of the buildings in Antalya. If the lightweight building is protected against daytime solar radiation by means of different design strategies, it represents one of the best performances in Antalya. Once the system receives solar heat gain it is difficult to release this hot air without the help of shading and special windows.

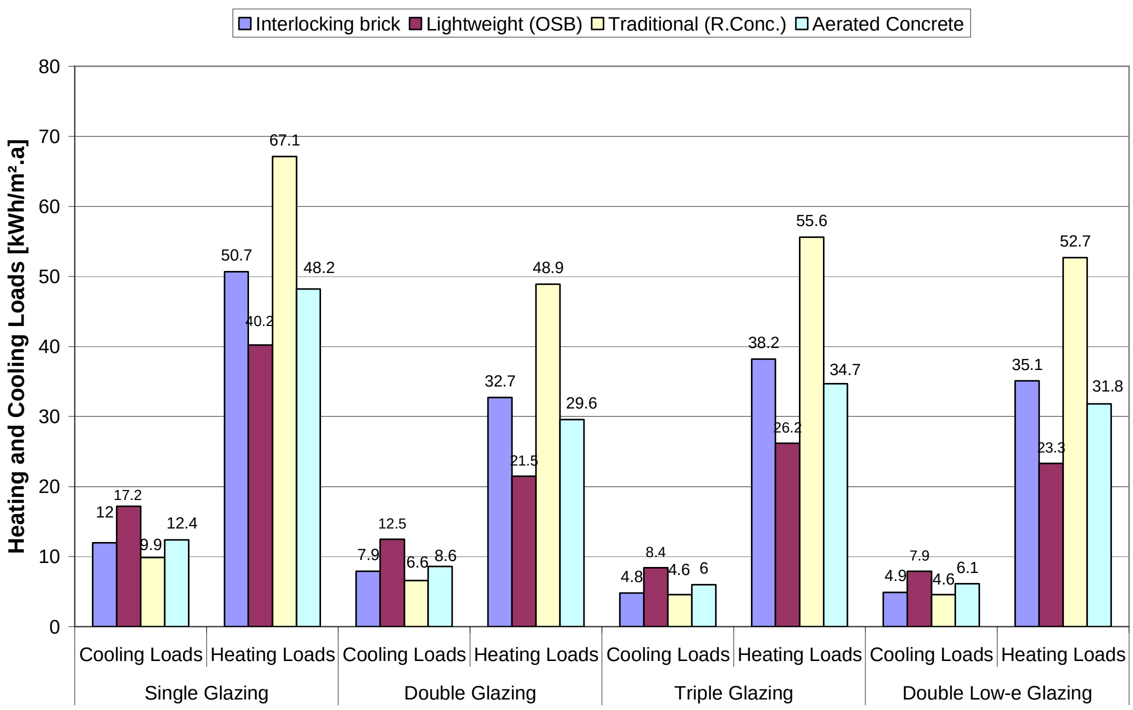


Figure 6.26: Heating-cooling energy (Primary Energy) performance of different glazing types for Istanbul

Double glazing with a “U-value” of 2.7 W/m².K and “g-value” of 0.777 has the lowest heating loads for all building types in the moderate climate, Istanbul. However cooling load performance of this glazing type represents the third out of four glazing types due to its higher “U-value” and “g-value”, which means the temperature flow between outside-inside is higher, and it has more solar heat gain through the windows . Triple glazing and double low-e glazing keep the buildings cooler than the other window types mostly due to their lower “g”-values of 0.7 and 0.597 respectively. In addition smaller thermal transmittance values of both glazing types keeps the indoor environment warmer than that in double glazing.

The lightweight building with double glazing performs better than other glazing types with regards to heating loads but has the second worst cooling performance. Traditional building has the highest heating demand for all types of glazing, while it performs best in cooling demand (Figure 6.26).

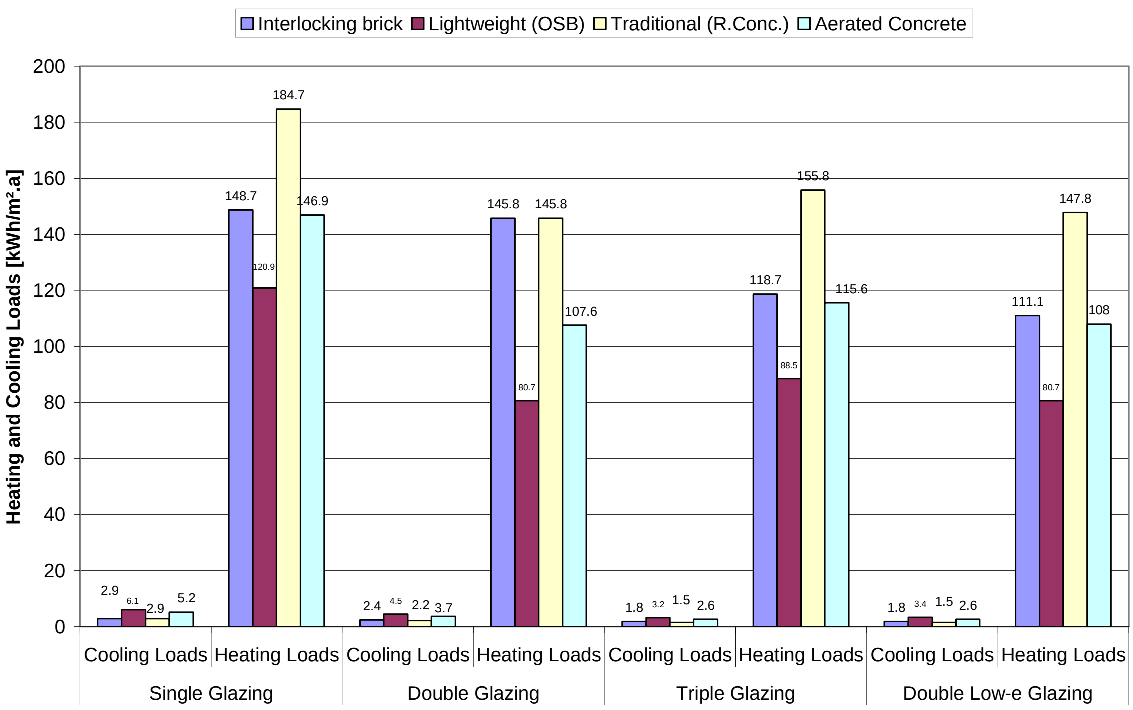


Figure 6.27: Heating-cooling energy (Primary Energy) performance of different glazing types for Erzurum

In Erzurum, where the buildings have almost no cooling demand due to its extreme cold climate, the main concern is to heat the building and keep the heated air in the living spaces with minimum hygienic ventilation. The glazing types with lower thermal transmittance values and a higher solar heat gain coefficient can be ideal for such climates, because of getting as much as solar heat gain even in summer and keeping the heat loss lower through the windows. The lightweight building performed better than the other three building types with respect to heating load largely due to its insulation thickness of almost 20 cm. Double glazing and double low-e glazing show nearly the same heating performance for each building system. Nevertheless double low-e glazing reduces cooling loads by more than 50% (Figure 6.27).

6.5.4.3. Thermal Mass Internal Walls

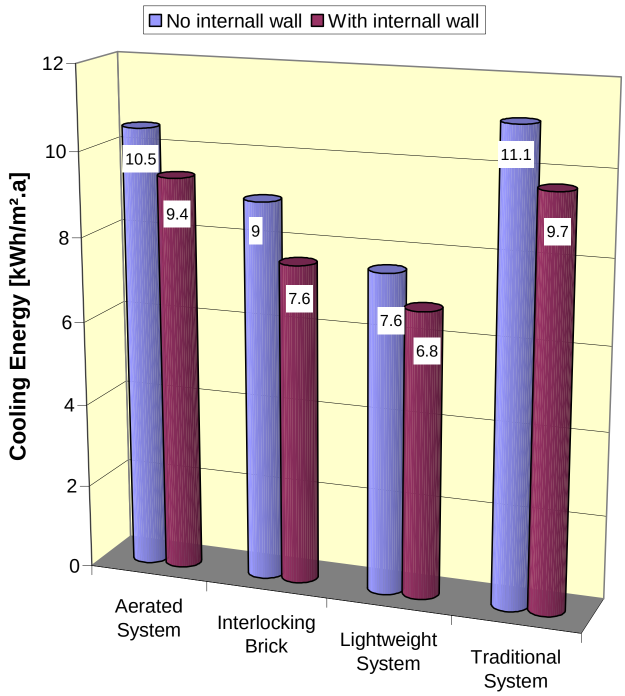


Figure 6.28: Influence of thermal mass internal walls on cooling energy loads (Primary Energy) in Antalya

There are no large temperature differences between day and night temperatures in Antalya, Thus, the systems with thermal mass internal walls with high heat storage capacity can overheat the room during the nighttime in the summer: however, it cools the room by emitting coming solar radiation during the day. As illustrated in Figure 6.28 thermal mass internal walls of the traditional, interlocking brick and aerated concrete buildings have a greater influence than the lightweight structure in Antalya when using maximum night ventilation in order to exhaust as much as released heat from the thermal mass walls. The traditional and interlocking brick systems show the two best two performances, with a reduction of 1.4 kWh/m²a cooling energy load, followed by the aerated concrete and lightweight systems, with a reduction of 1kWh/m²a and 0.8 kWh/m²a respectively. In the winter thermal mass walls reduce heating loads unless the daytime temperatures are not extremely cold (Figure 6.28).

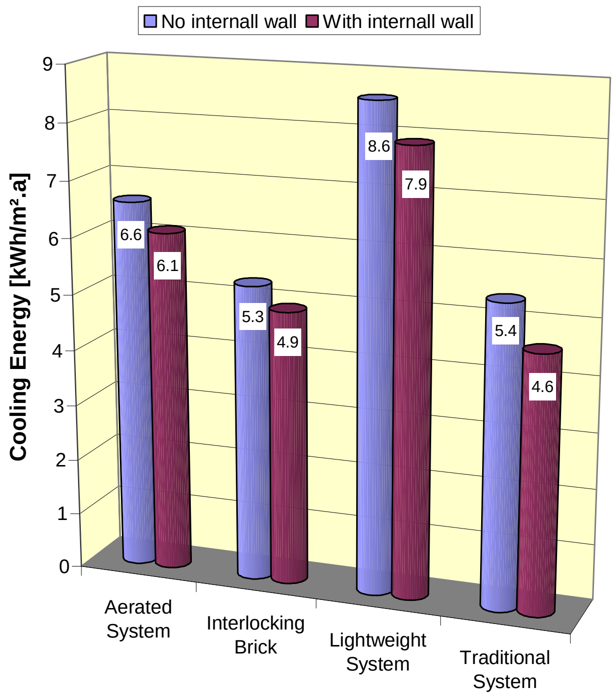


Figure 6.29: Influence of thermal mass internal walls on cooling energy loads (Primary Energy) in Istanbul

As indicated in Figure 6.29, the cooling energy demand of the four structures decreases slightly. Thus, in moderate climates the heat storage capacity of walls does not play an essential role as it does in hot climates due to lower solar heat gains. Nevertheless, only the influence of internal partition walls is simulated in order to see its impact on energy use.

Since the thermal mass walls are cooler, the heat is absorbed and conducted into these materials. If thermal mass walls are warmer than the temperature of the surrounding environment, it releases heat into the surroundings. Erzurum has extremely cold winters and cool summers: in addition, night temperatures even in summer do not exceede 15°C. Thus, thermal mass internal walls emit the heat from the surrounding area and decrease the room temperature.

6.5.4.4. Shading

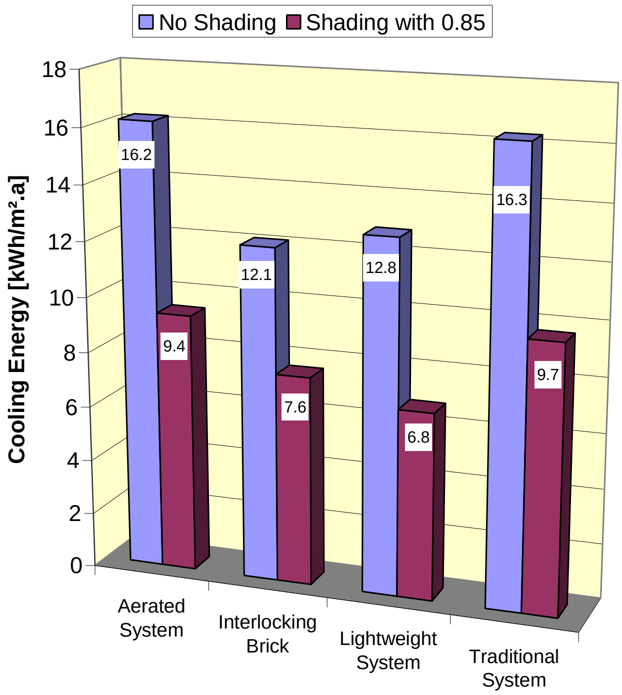


Figure 6.30: Influence of shading on cooling loads (Primary Energy) of the four systems in Antalya

Figure 6.29 displays the shading performances of the four different systems on cooling demand in a hot climate. The shading strategy is described according to the global solar radiation and ambient temperature. The shading factor is defined as the ratio of the non-transparent area of shading element to the whole transparent area. It is assumed to be 85% in the simulations. The transparent openings with shading result in 45% cooling savings compared to those without shading elements. The biggest percentage of saving is seen for the lightweight building out of the four systems, because non-thermal mass walls do not emit heat during the day as much as thermal mass walls, which let out emitted heat into the living space at night and, thus, increase cooling loads. The low thermal transmittance value of the lightweight building is another reason for lower cooling demand when using a shading element.

6.5.4.5. Orientation

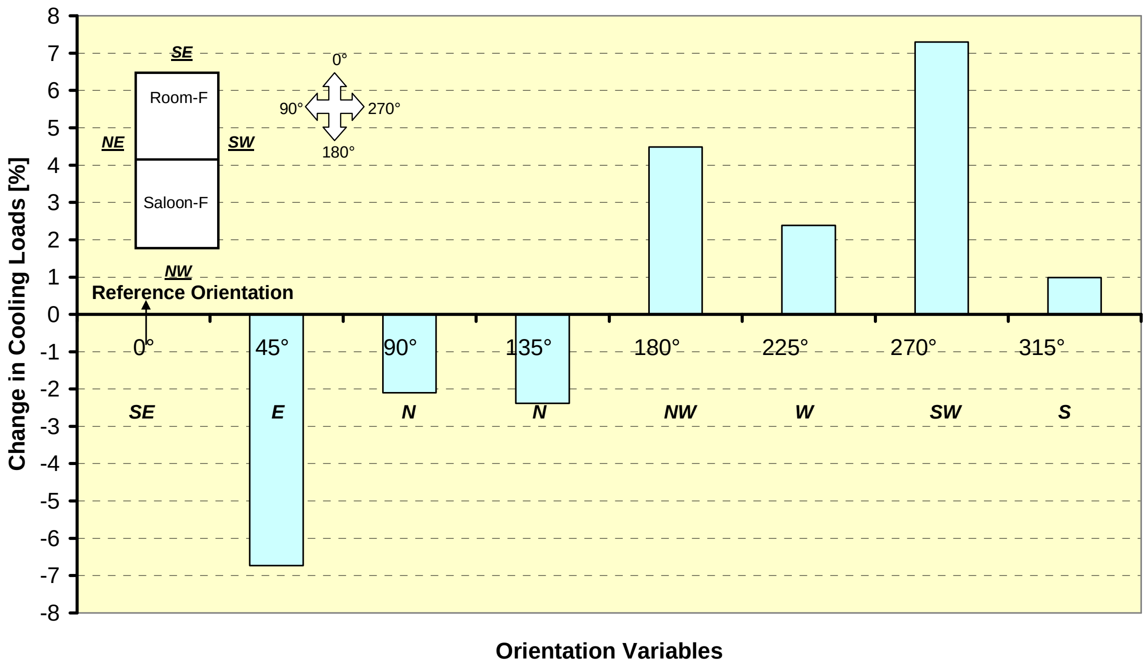


Figure 6.31: Influence of orientation variables for the traditional system in Antalya

The model building is situated as it is illustrated in Figure 6.31, with long external surfaces that face northeast (NE) and southwest (SW), and short building surfaces that face southeast (SE) and northwest (NW). The reference surface is southeast (SE) representing 0°in the graphic, and the model building is rotated every 45° counter-clockwise. The figure above shows the influence percentage of each orientation variable on cooling loads for Antalya from 0° to 315°. The greatest cooling energy saving can be made by rotating the model building 45° counter-clockwise. The reasons are that the southwest (SW) surface has no windows, and the short building surfaces face east and west. Thus, west and east surfaces of the building do not receive high solar radiation. The SW wall emits solar heat during the day, which keeps the indoor climate cool. The worst orientation variables are when the building is rotated 180°, 225° and 270°, due to higher solar heat gain from the large surfaces and windows.

In the improved case of simulations for Istanbul and Erzurum, the model building is rotated 225°, which gives it lowest heating demand according to the simulations and allows it to receive as much solar heat gain as possible, even sometimes in the summer for Erzurum.

6.5.4.6. Insulation

Insulation variables were simulated just for the traditional building, which represents a significant share of the residential building constructions in Turkey. The lightweight and interlocking brick systems have insulation in the wall and floors. Thus, insulation variables are not examined for these systems.

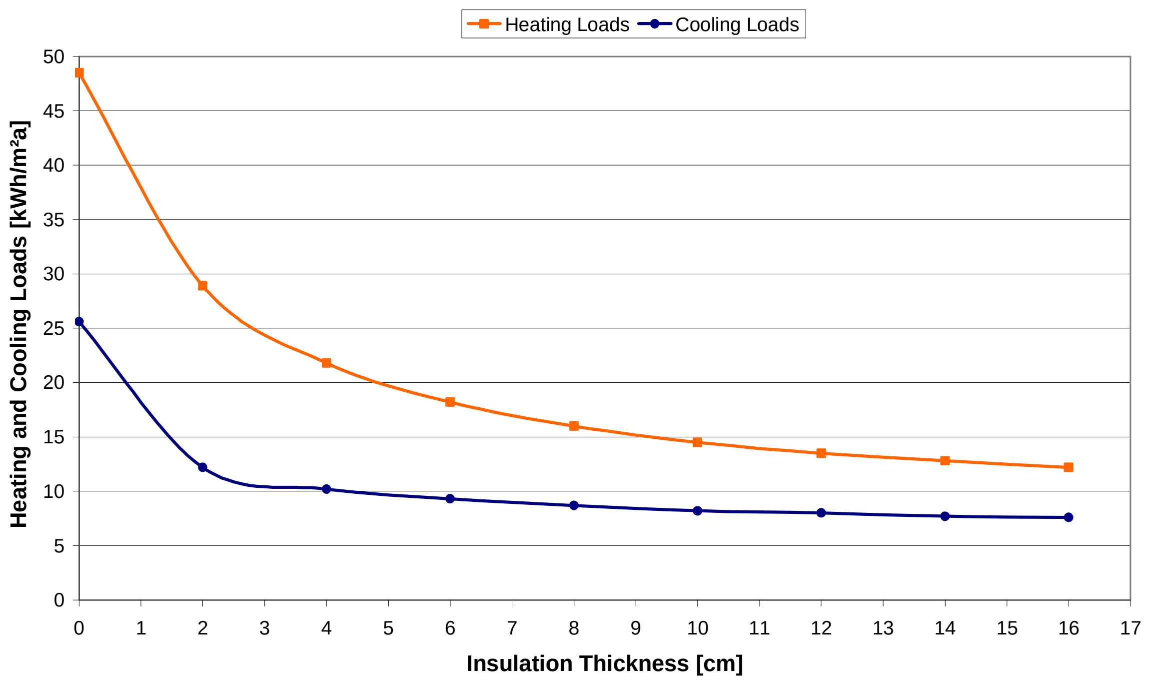


Figure 6.32: Influence of insulation thickness on heating and cooling loads (Primary Energy) for the Traditional System in Antalya

Figure 6.32 shows the influence of different insulation thicknesses on the heating and cooling demand for traditional building in hot climates. In other regions (temperate and cold regions), insulation was a very important element of energy savings since it decreased the heating energy demand, but it has no influence on the cooling energy demand in heating dominated regions. On the other hand, as seen in the chart, a small amount of insulation has a large influence on the cooling energy demand in hot climates. For instance, we applied just 2 cm of insulation to the external walls of the model building, and as a result we saved almost 50% of cooling loads.

An insulation thickness of more than 2 cm does not have a big impact on the cooling demand. It can be concluded that the small amount of insulation keeps the cool air within the building, and the external insulation prevents and lowers the heat gain through the walls into the building. The conclusion can be made for heating loads as well, but the difference is that insulation thickness of 8 cm can be beneficial to take heating loads down. Heating loads are reduced by more than 60 % by using 8 cm insulation for the external walls. A similar attempt to decreasing the cooling demand by combining a minimum internal heat gain and insulation use in warm climates is the ECOFYS report created for the European Insulation Manufacturers Association. The report concluded that a combination of lowering internal loads and improving insulation can save 85% of the cooling demand for a residential building sample in Madrid [42].

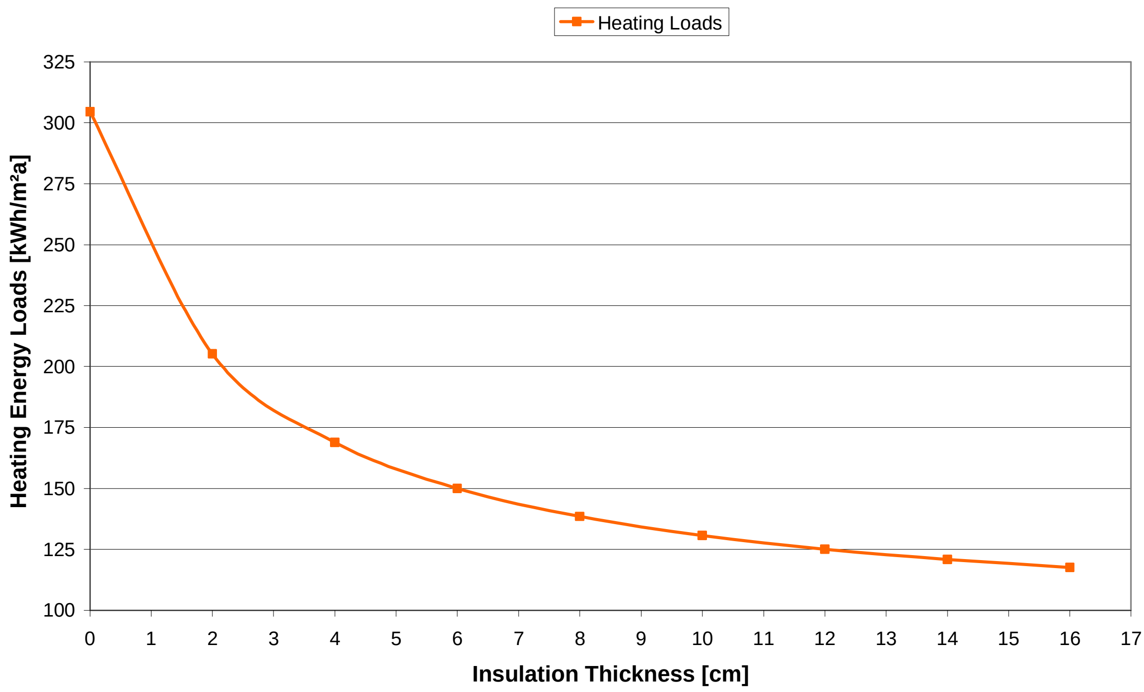


Figure 6.33: Influence of insulation thickness on heating energy load (Primary Energy) for the traditional System in Erzurum

It is clear that insulation plays an essential role in decreasing the heating demand of a building situated in a cold climate zone. Figure 6.33 above indicates the simulation result with different insulation thicknesses and their impacts on the heating demand Erzurum. Due to the cold climate in Erzurum, even 15 cm of insulation reduces the yearly heating demand of the city drastically, from 300 kWh/ m².a to almost 120 kWh/ m².a; more than 50% saving is achieved. It shows us that in such cold climate zones the thicknesses of the walls should be greater than 20 cm with insulation in order to drop the energy demand to reasonable values by enriching the building envelope and, thus, minimizing heat loss

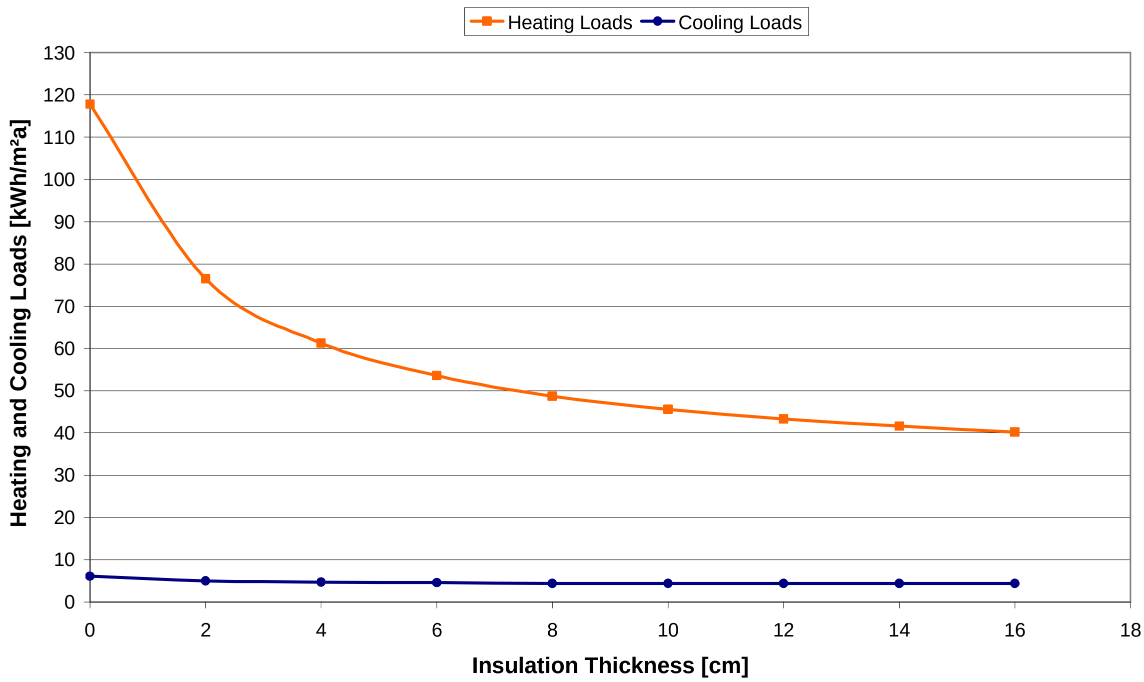


Figure 6.34: Influence of insulation thickness on heating and cooling loads (Primary Energy) for the Traditional System in Istanbul

The simulation results for Istanbul conclude that applying insulation can only have an influence on the heating demand and very little influence on the cooling demand for such temperate climates. The graph indicates an almost constant cooling energy demand when the thickness of the insulation is increased, while heating energy demand sinks by 40 kWh /m².a. In other words, even if there is some cooling demand in temperate climates, the thickness of the insulation does not have a big influence on it. Installing even 2 cm insulation only has a very small affect on cooling demand (Figure 6.34).

- Economic Profitability of the Insulation for the Reinforced Concrete System

To increase insulation thickness results in heating and cooling energy reduction. On the other hand, the initial costs of buildings will rise. Thus, an evaluation of the long-term payback period for different insulation thicknesses becomes a significant task. The actual cash value method (Barwert Method) is used in order to analyze the economic efficiency of different insulation thicknesses for Traditional building. Shortly, the actual value of investment after 50 years is monitored for each insulation thickness applied to external walls. Heating energy loads and cooling energy loads are taken into account in order to calculate the actual cash values of different insulation thicknesses. The yearly inflation rate is considered to be 5%. The initial costs of applying different insulation thicknesses are obtained from different companies and construction costs are determined by the construction ministry. The natural gas price is taken from the Istanbul Municipality gas company (IGDAS) tariffs 0.023 €/kWh as of 2005 and the electricity price 0.075 €/kWh, which is taken from the Turkish electricity distribution company (TEDAS) tariffs, as of 2005.

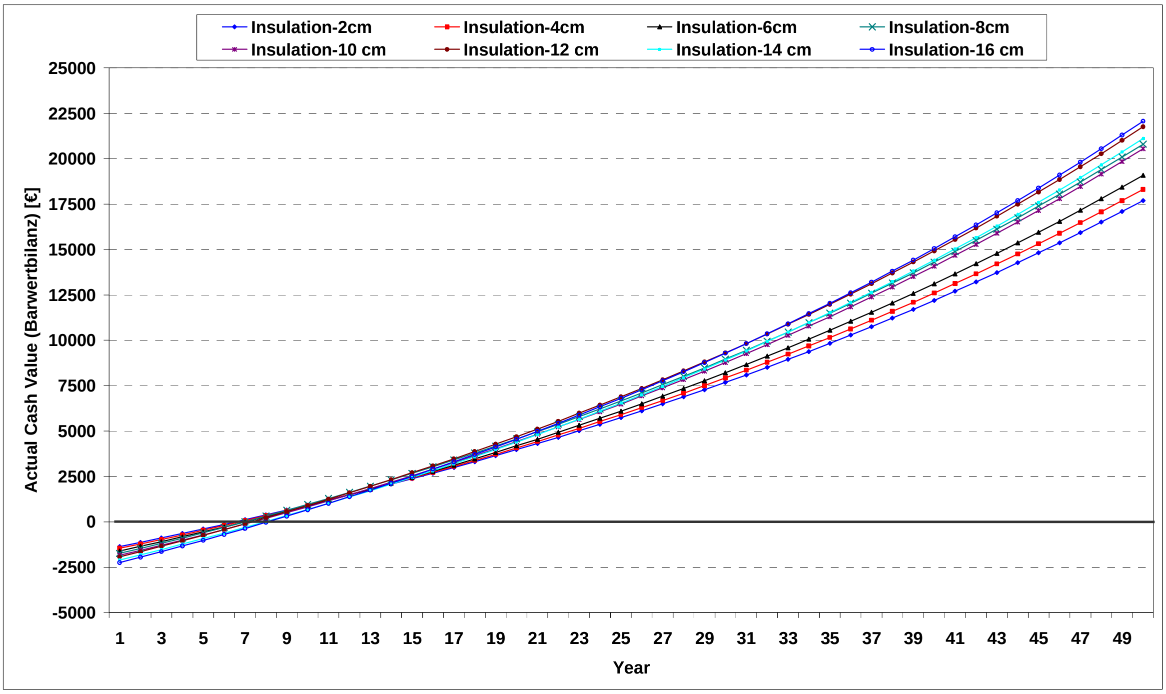


Figure 6.35: Insulation investment and payback period for the traditional system in Antalya

The graph indicates that the payback years buildings with different insulation thicknesses in Antalya vary between 7 and 8 years. An investment between 2000 € and 2500 € for external wall insulation of the simulated building model will bring 17500 € and 22500 € profit after 50 years mostly because of the cooling demand. Taking the graph into consideration, some assumptions can be made regarding the optimum thickness of the insulation for this climate. As seen in the graphic, after 50 years there is no much difference between the actual values of investment for the building in Antalya. Thus, even applying a small amount of insulation to external walls will be enough (Figure 6.35).

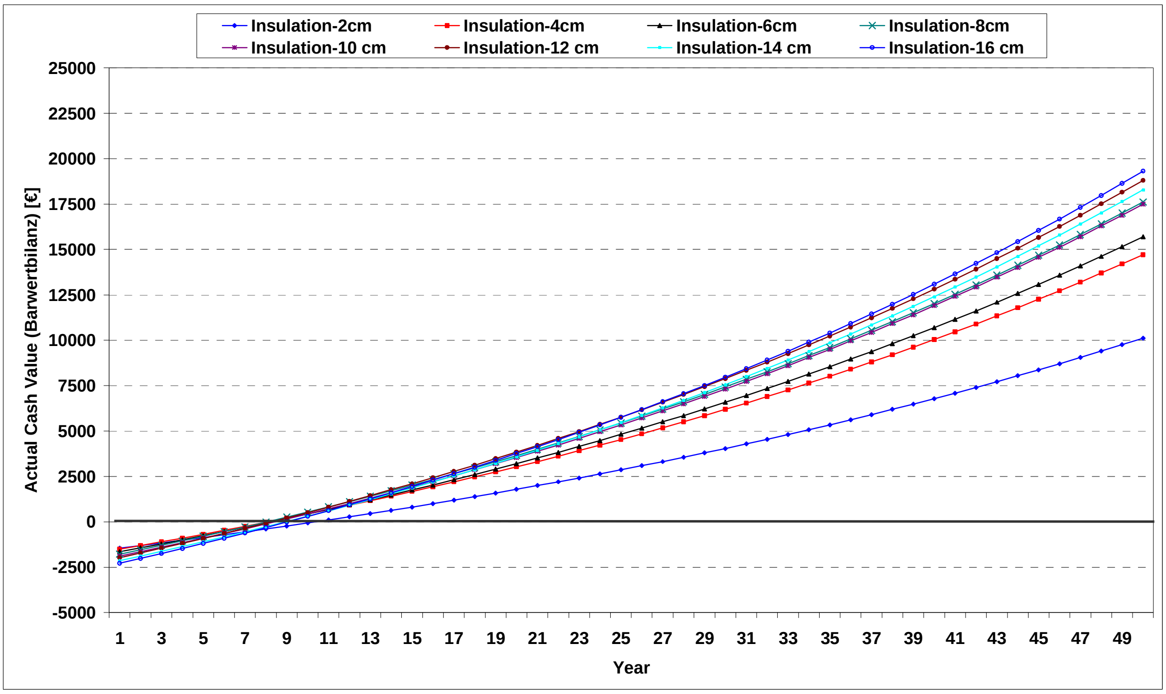


Figure 6.36: Insulation investment and payback period for the traditional system in Istanbul

Actual cash values of applying different insulation thicknesses for external walls in Istanbul differ in Antalya. The payback time varies between 8 and 10 years. After 50 years the differences between actual values of investments vary much more than in Antalya. Employing 2 cm insulation for external walls reflects the worst profit in comparison with other variables of insulation thickness regarding payback time and actual value of investment. Six thousand euros are gained just by increasing the insulation thickness to 4 cm. It can be estimated that the insulation between 6cm and 8 cm is an optimal thickness for such moderate climates (Figure 6.36).

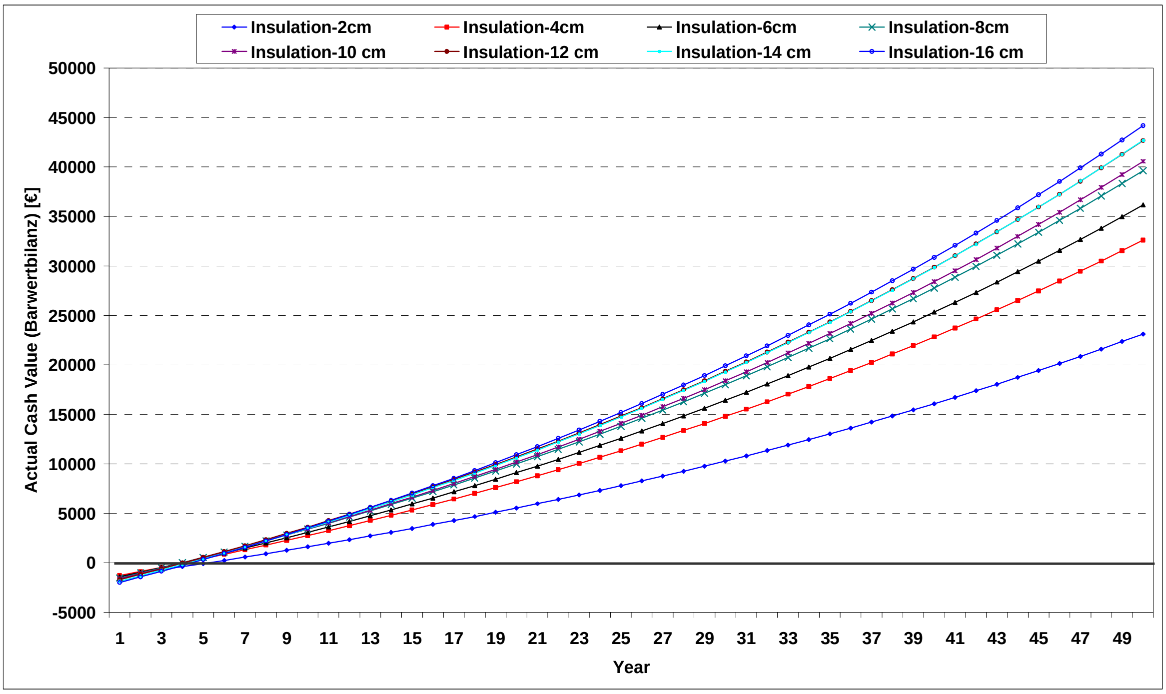


Figure 6.37: Insulation investment and payback period for the traditional system in Erzurum

Due to its extreme cold weather, applying insulation to a building in Erzurum is the most profitable improvement among the other strategies. Even applying 2 cm insulation is as profitable as applying 16 cm insulation in the moderate climate of Istanbul. The differences between actual values of investments after 50 years are very large. For instance, investing in the installation of 2 cm thickness after 50 years is 26000 €, while that of 16 cm insulation increases by 46000 €. Thus, payback years for these different insulation thickness applications is reduced by 3-4 years, which is mainly influenced by the heating loads (Figure 6.37).

6.6. Summary of simulation results

Cold climate	**Temperate Climate**	**Hot climate**
▪ Insulation is the most important element, for cold climate, optimal insulation thickness varies between 10 cm and 14 cm. ▪ Economic profitability of insulation thickness over 8 cm is very high because of huge heating energy decreases. ▪ Small ventilation rates of 1^{-h}, more compact structure. ▪ Lightweight materials for daily heat gain, heavy structure for nightly heat gain. The systems with good insulation features perform better. ▪ Glazing with smaller thermal transmittance “U-value” and higher solar heat gain “g-value”. ▪ Orientation east, west large surfaces for heat gain.	▪ Optimum ventilation rates varies for the selected building systems between 2-4 $_{h}$ ▪ Insulation thickness can be optimized as 6-8 cm. ▪ Heating is main concern, but also a part of summer overheating problems can be seen ▪ Aerated concrete system shows the best performance regarding heating energy demand ▪ Shading can be considered for several days in summer.	▪ Shading is very effective in order to balance daytime room temperature ▪ Maximum night ventilation decreases room temperature during the night. ▪ Thermal mass materials to cool indoor environment, traditional and interlocking block performed better regarding cooling demand. ▪ Insulation thickness of 2 cm is enough for such climates ▪ Orientation east, west short surfaces with minimum windows ▪ Glazing with small thermal transmittance “U-value” and solar heat gain “g-value”

7. Conclusions and recommendations

The thesis illustrated that Turkish residential building stock may attain great energy saving performance just by applying advanced design strategies. In addition to these strategies, as a future research work, renewable energy integration should be investigated. No mechanical solutions, except the integration of solar and PV panels, are suggested as a renewable energy solution to energy demands. The conclusions and discussions addition to Chapter 4 and Chapter 5 can be summarized as follows:

- The new climate classification done according to the ASHRAE transactions 4610-4611 showed that a precise classification is needed and degree day method can be used for estimating energy needs of each city. The relation between energy consumption and climate analysis through the degree day method can give some information of estimating energy consumption in the pre design phase. Although in this work we selected just three cities and four building systems, more cities, respectively climate zones can be investigated by energy institutions in Turkey in order to create a reference for architects and homeowners.

- Turkish energy standards should be updated after careful examination of the other standards in the World. Thermal transmittance values of the building components should be reviewed and updated. The preparation of the standards can be made by using new scientific methods, for instance; utilization of the simulation programs which is briefly explained in the Chapter. 4.

- After simulating the four different construction systems in three cities from different regions, improvements of the systems and application of new energy strategies save large amount of energy between 50-80% with respect to heating and cooling energy. The energy simulation of some residential buildings helped to optimize energy design strategies of each city we selected. This optimization should be made by Turkish energy, institutions regarding ventilation rate, insulation thickness, type of glazing, orientation of building, construction system, shading element and other variables, after defining residential building types in Turkey with the help of real measurements and simulation tools.

Applying energy efficient design strategies is the first step of energy efficient building; second step can be integration of the renewable energies to building envelope. Thus, future works will focus on integration of the renewable energy sources. Especially solar energy integration both in terms of photovoltaic and solar thermal applications should be carefully examined. In addition, because of Turkey’s large housing demand, the need for energy efficient, economic and permanent residential buildings can be supplied by prefabricated buildings. In the future renewable energy integrated prefabricated building systems will dominate residential building sector.

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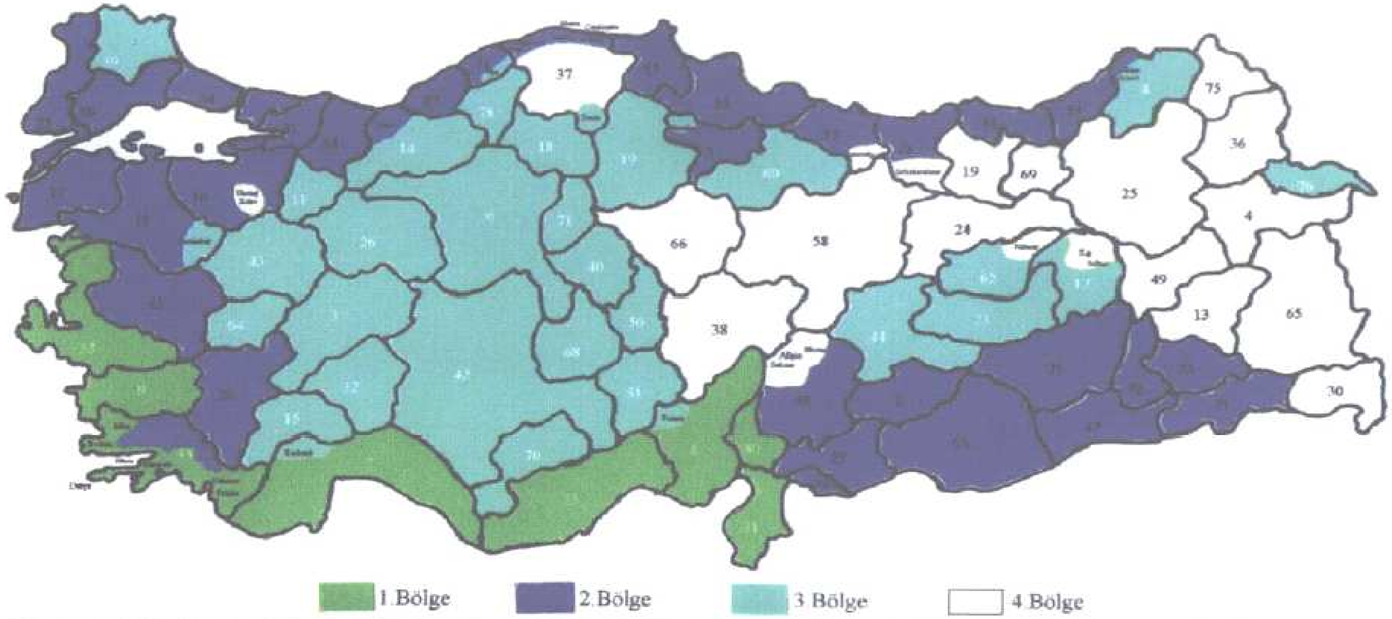
Appendix A: The classification used for TS-825 standard

Ek 10 - Derece Gün Bölgelerine Göre İllerimiz



1-ADANA	11-BİLECİK	21-DİYARBAKIR	31-HATAY	41-KOCAELİ	51-NİĞDE	61-TRABZON	71-KIRIKKALE
2-ADIYAMAN	12-BİNGÖL	22-EDİRNE	32-ISPARTA	42-KONYA	52-ORDU	62-TUNCELİ	72-BATMAN
3-AFYON	13-BİTLİS	23-ELAZIĞ	33-İÇEL	43-KÜTAHYA	53-RİZE	63-Ş.URFA	73-ŞIRNAK
4-AĞRI	14-BOLU	24-ERZİNCAN	34-İSTANBUL	44-MALATYA	54-SAKARYA	64-UŞAK	74-BARTIN
5-AMASYA	15-BURDUR	25-ERZURUM	35-İZMİR	45-MANİSA	55-SAMSUN	65-VAN	75-ARDAHAN
6-ANKARA	16-BURSA	26-ESKİŞEHİR	36-KARS	46-K.MARAŞ	56-SİİRT	66-YOZGAT	76-IĞDIR
7-ANTALYA	17-ÇANAKKALE	27-GAZİANTEP	37-KASTAMONU	47-MARDİN	57-SİNOP	67-ZONGULDAK	77-YALOVA
8-ARTVİN	18-ÇANKIRI	28-GİRESUN	38-KAYSERİ	48-MUĞLA	58-SİVAS	68-AKSARAY	78-KARABÜK
9-AYDIN	19-ÇORUM	29-GÜMÜŞHANE	39-KIRKLARELİ	49-MUŞ	59-TEKİRDAĞ	69-BAYBURT	79-KİLİS
10-BALIKESİR	20-DENİZLİ	30-HAKKARİ	40-KIRŞEHİR	50-NEVŞEHİR	60-TOKAT	70-KARAMAN	80-OSMANİYE

Appendix B: Climate classification methods used for ASHRAE standards. First step; Definition of the main zones

A. Major Climate Type Definitions [1]
I. Marine (C) Definition - Locations meeting the following criteria:
• mean temperature of coldest month between –3ºC (27ºF) and 18ºC (65ºF)[2] AND
• warmest month mean < 22ºC (72ºF)[3] AND
• at least four months with mean temperatures over 10ºC (50ºF)[4] AND
• dry season in summer[5]. The dry season in summer criterion is met when the month with the heaviest rainfall in the colder season has at least three times as much precipitation as the month in the warmer season with the least precipitation. The colder season is October, November, December, January, February, and March in the Northern Hemisphere and April, May, June, July, August, and September in the Southern Hemisphere. All other months are considered the warmer season, in their respective hemispheres.
II. Dry (B) Definition (SI) - Locations meeting the following criteria: Not Marine and $P_{cm} < 2.0 \times (T_C + 7)$ where: P_{cm} = annual precipitation in cm T_C = annual mean temperature in degrees Celsius
III. Humid (A) Definition (SI) - Locations meeting the following criteria: Not Marine and $P_{cm} \geq 2.0 \times (T_C + 7)$
Notes: 1. Humid, dry, and marine zone definitions are based on Strahler 1963, Plate 2, except as noted. 2. These criteria are necessary to exclude Köppen's (D) "snow" climates and (A) "tropical" climates. 3. This criterion excludes the (a) "hot in summer" climates, such as the South-eastern and Midwestern United States. 4. This criterion excludes some marine climates in high latitude locations, such as Alaska, Iceland, and Northern Norway, from special treatment as marine climates. 5. This "dry season in summer" definition is from Köppen 1931 (German text), p.129. The authors were unable to find in this text quantitative definitions for "colder season" and "warmer season," only an acknowledgement of the inherent difficulty in defining these seasons in a way that is effective for all world climates. The month-based definitions were created by the authors to make the climate definitions complete and computable. Under the variants of the Köppen system reviewed for this work, the dry in summer criterion was part of the Cs (Mediterranean) but not the Cb (Marine, Cool Summer) subdivision. We included it in the general Marine zone definition for use in the United States because dry summers are a characteristic attribute of the Pacific marine climates that we felt were necessary to recognize in the classification. It was also in excluding isolated locations in other parts of the country from meeting the Marine zone criteria. Specifically, sites at higher elevations in the Southern Appalachian Mountains (such as Asheville, NC) and medium elevations in the South-western United States (such as Albuquerque, NM) otherwise marginally met the marine criteria. Outside of the United States, such as in Northern Europe where marine influences extend far inland and summers are not as dry, this criterion may not be useful and could be dropped.

Appendix C: Climate classification methods used for ASHRAE standards. Second step; Thermal zone definition

B. Thermal Zone Definitions

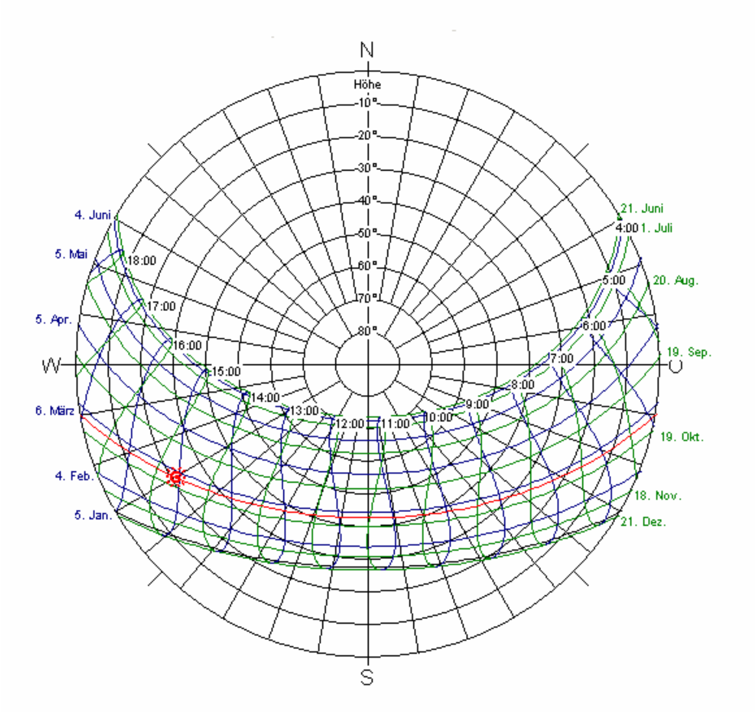
Zone No.	Climate Zone Name and Type [2]	Thermal Criteria [(1.3.8)]	Köppen Class.[5]	Köppen Classification Description [6]
1A	Very Hot – Humid	5000 < CDD10ºC	Aw	Tropical Wet-and-Dry
1B[7]	Very Hot – Dry	5000 < CDD10ºC	BWh	Tropical Desert
2A	Hot – Humid	3500 < CDD10ºC = 5000	Caf	Humid Subtropical (Warm Summer)
2B	Hot – Dry	3500 < CDD10ºC = 5000	BWh	Arid Subtropical
3A	Warm – Humid	2500 < CDD10ºC = 3500	Caf	Humid Subtropical (Warm Summer)
3B	Warm – Dry	2500 < CDD10ºC = 3500	BSk/BWh/H	Semiarid Middle Latitude/Arid Subtropical/Highlands
3C	Warm – Marine	HDD18ºC = 2000	Cs	Dry Summer Subtropical (Mediterranean)
4A	Mixed – Humid	CDD10ºC = 2500 AND HDD18ºC = 3000	Caf/Daf	Humid Subtropical/Humid Continental (Warm Summer)
4B	Mixed – Dry	CDD10ºC = 2500 AND HDD18ºC = 3000	BSk/BWh/H	Semiarid Middle Latitude/Arid Subtropical/Highlands
4C	Mixed – Marine	2000 < HDD18ºC = 3000	Cb	Marine (Cool Summer)
5A	Cool – Humid	3000 < HDD18ºC = 4000	Daf	Humid Continental (Warm Summer)
5B	Cool – Dry	3000 < HDD18ºC = 4000	BSk/H	Semiarid Middle Latitude/Highlands
5C[7]	Cool – Marine	3000 < HDD18ºC = 4000	Cfb	Marine (Cool Summer)
6A	Cold – Humid	4000 < HDD18ºC = 5000	Daf/Dbf	Humid Continental (Warm Summer/Cool Summer)
6B	Cold – Dry	4000 < HDD18ºC = 5000	BSk/H	Semiarid Middle Latitude/Highlands
7	Very Cold	5000 < HDD18ºC = 7000	Dbf	Humid Continental (Cool Summer)
8	Subarctic	7000 < HDD18ºC	Dcf	Subarctic

Notes:

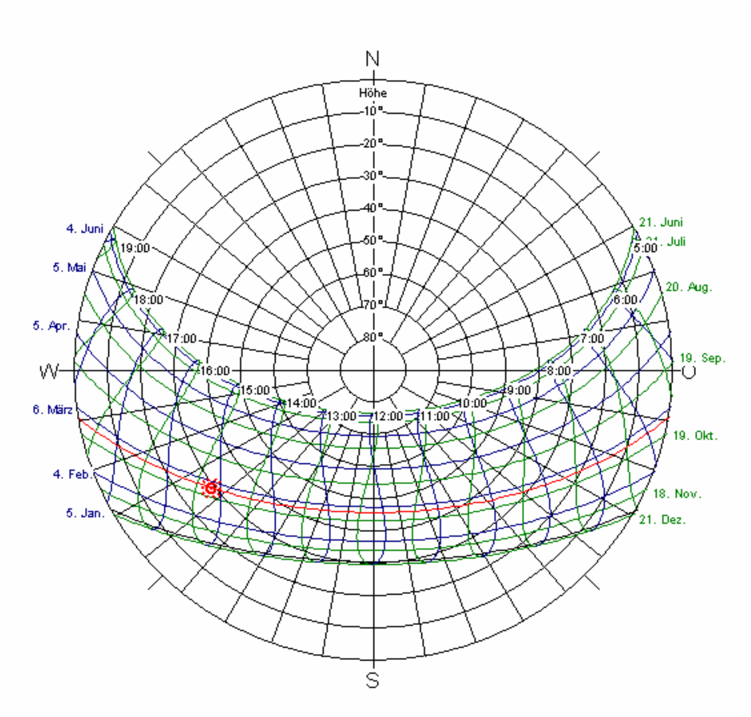
1. Column 1 contains alphanumeric designations for each zone. These designations are intended for use when the zones are referenced in the code. The numeric part of the designation relates to the thermal properties of the zone. The letter part indicates the major climatic group to which the zone belongs; A indicates humid, B indicates dry, and C indicates marine. The climatic group designation was dropped for Zones 7 and 8 because we did not anticipate any building design criteria sensitive to the humid/dry/marine distinction in very cold climates. Zones 1B and 5C have been defined but are not used for the United States. Zone 6C (Marine and HDD18ºC > 4000 (HDD65ºF > 7200) might appear to be necessary for consistency. However, very few locations in the world are both as mild as is required by the Marine zone definition and as cold as necessary to accumulate that many heating degree days. In addition, such sites do not appear climatically very different from sites in Zone 6A, which is where they are assigned in the absence of a Zone 6C..
2. Column 2 contains a descriptive name for each climate zone and the major climate type from Table 2A. The names can be used in place of the alphanumeric designations wherever a more descriptive designation is appropriate.
3. Column 3 contains definitions for the zone divisions based on degree-day cooling and/or heating criteria. The humid/dry/marine divisions must be determined first before these criteria are applied. The definitions in Table 2A and 2B contain logic capable of assigning a zone designation to any location with the necessary climate data anywhere in the world. However, the work to develop this classification focused on the 50 United States. Application of the classification to locations outside of the United States is untested.
4. Column 4 contains the name of a SAMSON station found to best represent the climate zone as a whole. See Section 4.3 for an explanation of how the representative cities were selected.
5. Column 5 lists the abbreviations for the climate groups based on a simplified version of the Köppen system (Finch et al. 1957). (see Figures 1 and 2). This information relates the climate zones to a widely-used world classification system, and may facilitate application outside of the United States.
6. Column 6 contains a verbal description derived from Köppen's work that serves to explain the two- and three-letter codes in the previous column.
7. Zones 1B and 5C do not occur in the United States, and no representative cities were selected for these zones due to data limitations. Climates meeting the listed criteria do exits in such locations as Saudi Arabia; British Columbia, Canada; and Northern Europe.
8. SI to I-P Conversions:

2500 CDD10ºC = 4500 CDD50ºF	3000 HDD18ºC = 5400 HDD65ºF
3500 CDD10ºC = 6300 CDD50ºF	4000 HDD18ºC = 7200 HDD65ºF
5000 CDD10ºC = 9000 CDD50ºF	5000 HDD18ºC = 9000 HDD65ºF
2000 HDD18ºC = 3600 HDD65ºF	7000 HDD18ºC = 12600 HDD65ºF

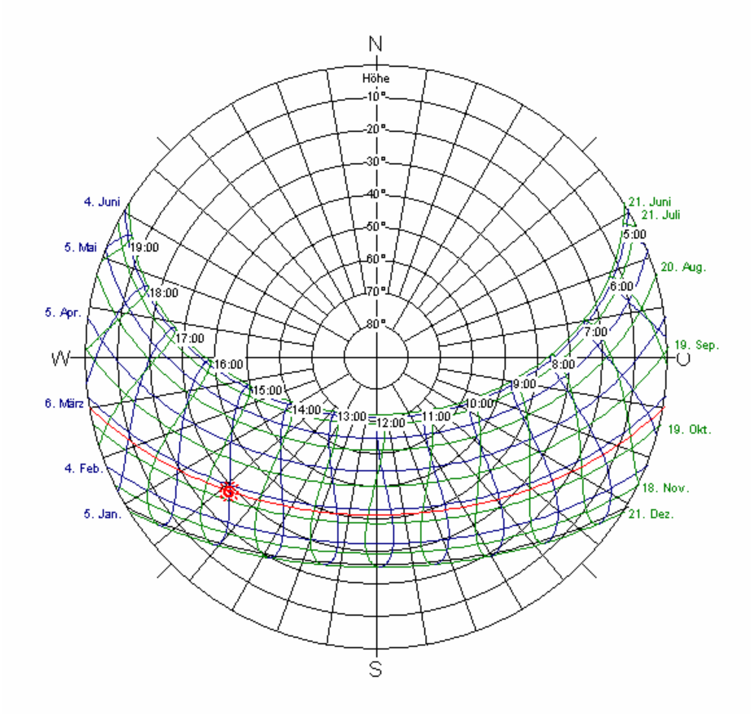
Appendix D: Sun path (Stereographic) diagram of Erzurum



Appendix E: Sun path (Stereographic) diagram of Antalya



Appendix F: Sun path (Stereographic) diagram of Istanbul



Appendix G: Maximum values of yearly primary energy consumption and specific transmission heat losses

According to ENEV (Energiesparverordnung) – *(Translated from ENEV)*

A/V_e Ratio	Annual Primary Energy Consumption			Specifically, transmission heat losses related heat-transferring encompassing area	
	Q_p in kWh/(m².a) related to the floor area		Q_p in kWh/(m³.a) related to the heated volume	H_T in W/(m²K)	
	Residential buildings (except the buildings defined by Column 3)	Residential buildings with predominant electrical water heating systems	Other buildings	Non-Residential buildings with the surface/windows area of ≤30% and residential buildings	Non-Residential buildings with the surface/windows area of >30%
1	2	3	4	5	6
≤ 0.2	66.00 +2600/100+A_N)	88.00	14.72	1.05	1.55
0.3	73.53 +2600/100+A_N)	95.53	17.13	0.80	1.15
0.4	81.06 +2600/100+A_N)	103.06	19.54	0.68	0.95
0.5	88.58 +2600/100+A_N)	110.58	21.95	0.60	0.83
0.6	96.11 +2600/100+A_N)	118.11	24.36	0.55	0.75
0.7	103.64 +2600/100+A_N)	125.64	26.77	0.51	0.69
0.8	111.17 +2600/100+A_N)	133.17	29.18	0.49	0.65
0.9	118.70 +2600/100+A_N)	140.70	31.59	0.47	0.62
1	126.23 +2600/100+A_N)	148.23	34.00	0.45	0.59
≥1.05	130.00 +2600/100+A_N)	152	35.4	0.44	0.58

Appendix H: Thermal transmittance "U" values of low-rise residential buildings for USA (Source: ASHRAE Standard 90.2-2001)

Climate zones	Ceilings				Walls											Floors					Doors	Fenestration			
	Attic Space		Without Attic Space		Above-Grade Frame		Frame Adjacent to Unconditioned Space		Above Gade Mass Exterior insulation	Above Gade Mass Interior insulation	Mass Adjacent to Unconditioned Space	Below Grade Exterior Insulation		Below Grade Interior Insulation	Unwented Crawl Space	Frame Over Exterior		Frame Over Unconditioned Space and Vented Crawl Space		Slab-on-Grade (Perimiter Insulation)	Non-Wood	Vertical Glazed Assemblies		Skylights	
	Wood	Steel	Wood	Steel	Wood	Steel	Wood	Steel					Depth Below Grade			Wood	Steel	Wood	Steel						
No.	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	R	U	U	SHGC	U	SHGC
1	0.20	0.22	0.36	0.48	0.51	0.67	1.56	2.51	1.48	1.48	1.39	3.59	H	3.58	2.34	0.34	0.51	0.37	0.51	0.00	2.21	3.80	2.10	9.08	2.27
2	0.20	0.22	0.23	0.48	0.47	0.51	1.56	2.51	1.48	1.48	1.39	3.59	H	3.58	2.34	0.29	0.51	0.37	0.51	0.00	2.21	3.80	2.10	5.96	2.27
3A,B	0.20	0.22	0.23	0.45	0.47	0.36	1.56	2.51	1.48	1.03	1.39	1.33	H	3.58	0.37	0.29	0.44	0.29	0.40	0.00	2.21	2.67	2.27	5.11	2.27
3C	0.20	0.22	0.23	0.45	0.47	0.36	1.56	2.51	1.48	1.03	1.39	1.33	H	3.58	0.37	0.29	0.44	0.29	0.40	0.00	2.21	2.67	2.27	5.11	NR
4	0.15	0.17	0.23	0.45	0.33	0.36	0.53	0.88	0.87	1.03	1.39	1.02	F	3.58	0.24	0.26	0.40	0.29	0.40	0.00	2.21	1.99	2.61	3.41	NR
5	0.13	0.15	0.23	0.40	0.33	0.27	0.46	0.88	0.87	1.03	1.39	0.81	F	3.58	0.18	0.22	0.40	0.22	0.36	0.00	2.21	1.99	2.61	3.41	NR
6	0.12	0.13	0.15	0.36	0.25	0.27	0.46	0.88	0.65	0.41	1.39	0.58	F	3.58	0.18	0.22	0.40	0.22	0.36	0.00	2.21	1.99	NR	3.41	NR
7	0.12	1.31	0.15	0.36	0.20	0.27	0.46	0.57	0.65	0.41	1.39	0.46	F	3.58	0.18	0.15	0.40	0.19	0.36	0.00	2.21	1.99	NR	3.41	NR
8	0.11	0.12	0.15	0.36	0.20	0.27	0.31	0.35	0.65	0.30	0.40	0.46	F	0.32	0.18	0.15	0.40	0.19	0.36	0.00	2.21	1.99	NR	3.41	NR

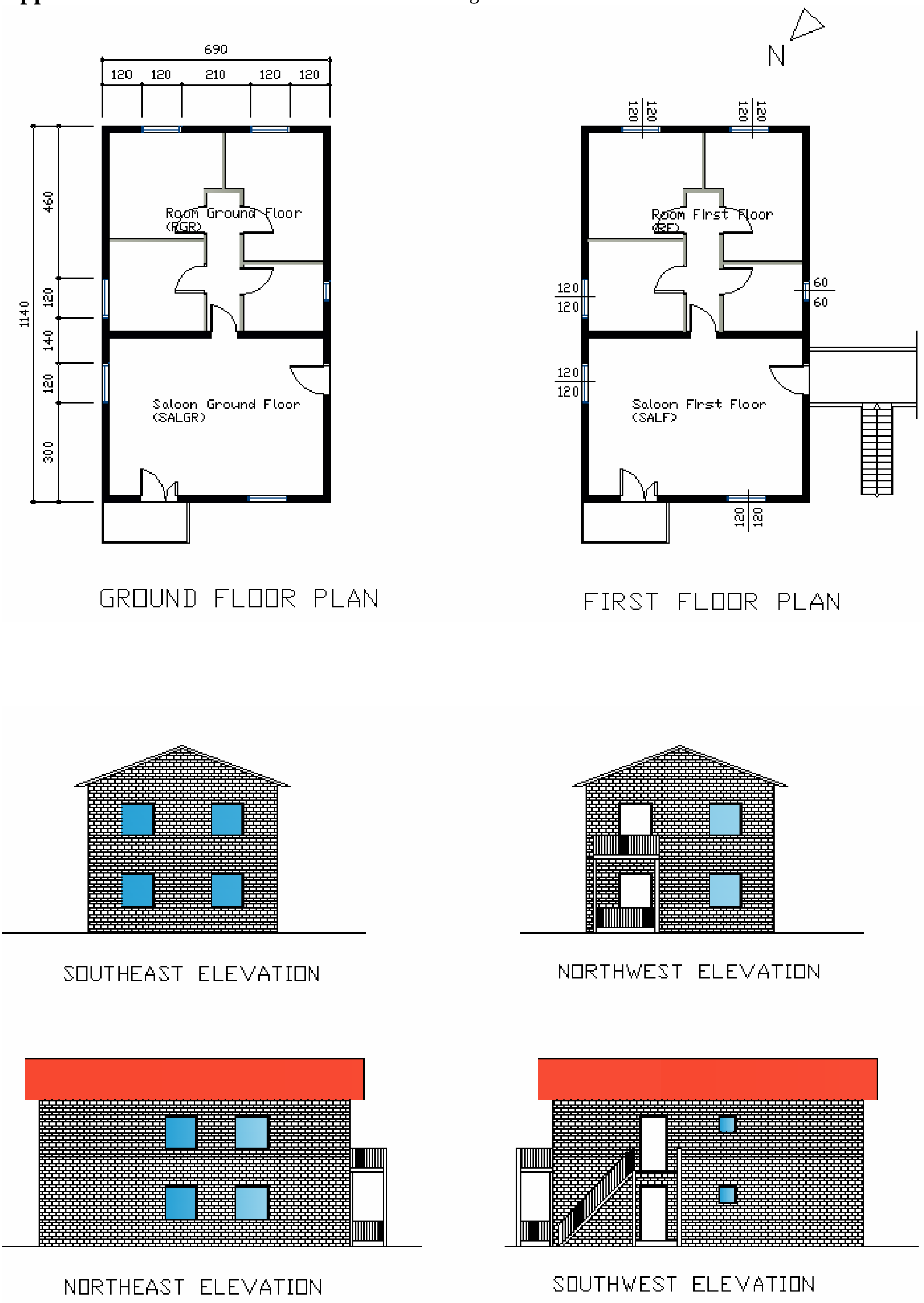
Appendix J: Constructional properties of the simulated systems after improvements

CONSTRUCTIONS OF SIMULATED BUILDINGS AFTER IMPROVEMENTS																		
Construction Types	Wall Structure			Floor Structure			Ground Structure			First Floor Ceiling			Roof			Internal Wall		
	Materials		U-value [W/m^2.K]	Materials		U-value [W/m^2.K]	Materials		U-value [W/m^2.K]	Materials		U-value [W/m^2.K]	Materials		U-value [W/m^2.K]	Materials		U-value [W/m^2.K]
Interlocking Brick	Gypsum Plaster Hollow Brick Polystren Air Space Hollow Brick	1 cm 19 cm 8 cm 10 cm	0.31	Gypsum Plaster Concrete Floor Panel Cement Mortar Particle Board	1 cm 15 cm 2 cm 2 cm	1.1	Particle Board Cement Mortar Polystren Cement Mortar Purnice Gravel	2 cm 2 cm 5 cm 5 cm 5 cm	0.39	Gypsum Plaster Concrete Floor Panel	1 cm 15 cm	2.3	Plywood Mineral Wool Plywood Bitumen Sealing Roof Tile	1 cm 8 cm 1 cm 0.5 cm 5 cm	0.4	Gypsum Plaster Hollow Brick Gypsum Plaster	1 cm 10 cm 0.5 cm	3.4
Lightweight Steel	Gypsum Plaster OSB Board Mineral Wool Plaster Board Polystren Cement Mortar	1 cm 1.3 cm 16 cm 1.1 cm 4 cm 3 cm	0.17	Gypsum Plaster Plaster Board Mineral Wool OSB Board Particle Board Floor	1 cm 1.8 cm 8 cm 1.3 cm 2 cm	0.37	Particle Board Polystren Cement Mortar Purnice Gravel	2 cm 5 cm 5 cm 5 cm	0.37	Gypsum Plaster Plaster Plate Minerall Wool OSB Panel	1 cm 1.3 cm 8 cm 1.3 cm	0.45	OSB Board Insulation OSB Board Bitumen Sealing Roof tile	1.3 cm 8 cm 1.1 cm 0.5 cm 5 cm	0.45	Gypsum Plaster Mineral Wool Plywood Gypsum Plaster	1 cm 8 cm 1,3 cm 1 cm	0.47
Aerated Concrete	Gypsum Plaster Aerated Conc. Block Polystren Cement Mortar	1 cm 20 cm 5 cm 3 cm	0.35	Gypsum Plaster Aerated Conc. Block Cement Mortar Particle Board	2 cm 15 cm 2cm 2 cm	0.72	Particle Board Cement Mortar Polystren Cement Mortar Purnice Gravel	2 cm 2 cm 5 cm 5 cm 5 cm	0.39	Gypsum Plaster Aerated Conc. Block	2 cm 15 cm	1.09	Plywood Mineral Wool Plywood Bitumen Sealing Roof Tile	1 cm 8 cm 1 cm 0.5 cm 5 cm	0.4	Gypsum Plaster Aerated Conc. Block Gypsum Plaster	2 cm 10 cm 2 cm cm cm	1.35
Traditional System	Cement Mortar Light Hollow Brick Polystren Cement Mortar	2 cm 20 cm 5 cm 3 cm	0.41	Cement Mortar Concrete Floor Cement Mortar Particle Board	2 cm 12 cm 2 cm 2 cm	1.38	Particle Board Cement Mortar Polystren Cement Mortar Purnice Gravel	2 cm 2 cm 5 cm 5 cm 5 cm	0.39	Cement Mortar Concrete Floor Cement Mortar	2 cm 12cm 2 cm	3.8	Plywood Mineral Wool Plywood Bitumen Sealing Roof Tile	1 cm 8 cm 1 cm 0.5 cm 5 cm	0.41	Cement Mortar Light Hollow Brick Cement Mortar	2 cm 10 cm 2 cm	2.1

Appendix K: Constructional properties of the simulated systems before improvements

CONSTRUCTIONS OF SIMULATED BUILDINGS BEFORE IMPROVEMENTS																		
Construction Types	**Wall Structure**			**Floor Structure**			**Ground Structure**			**First Floor Ceiling**			**Roof**			**Internal Wall**		
	Materials		U-value [W/m².K]	Materials		U-value [W/m².K]	Materials		U-value [W/m².K]	Materials		U-value [W/m².K]	Materials		U-value [W/m².K]	Materials		U-value [W/m².K]
Interlocking Brick	Gypsum Plaster Hollow Brick Polystren Air Space Hollow Brick	1 cm 19 cm 8 cm 10 cm	0.31	Gypsum Plaster Concrete Floor Panel Cement Mortar Particle Board	1 cm 15 cm 2 cm 2 cm	1.1	Particle Board Cement Mortar Purnice Gravel	2 cm 5 cm 5 cm	1.08	Gypsum Plaster Concrete Floor Panel	1 cm 15 cm	2.3	Plywood Bitumen Sealing Roof Tile	1 cm 0.5 cm 5 cm	0.4	Gypsum Plaster Hollow Brick Gypsum Plaster	1 cm 10 cm 0.5 cm	3.4
Lightweight Steel	Gypsum Plaster OSB Board Mineral Wool Plaster Board Polystren Cement Mortar	1 cm 1.3 cm 16 cm 1.1 cm 4 cm 3 cm	0.17	Gypsum Plaster Plaster Board Mineral Wool OSB Board Particle Board Floor	1 cm 1.8 cm 8 cm 1.3 cm 2 cm	0.37	Particle Board Cement Mortar Purnice Gravel	2 cm 5 cm 5 cm	1.08	Gypsum Plaster Plaster Plate Minerall Wool OSB Panel	1 cm 1.3 cm 8 cm 1.3 cm	0.45	OSB Board Insulation OSB Board Bitumen Sealing Roof tile	1.3 cm 8 cm 1.1 cm 0.5 cm 5 cm	0.45	Gypsum Plaster Mineral Wool Plywood Gypsum Plaster	1 cm 8 cm 1,3 cm 1 cm	0.47
Aerated Concrete	Gypsum Plaster Aerated Conc. Block Cement Mortar	1 cm 20 cm 3 cm	0.87	Gypsum Plaster Aerated Conc. Block Cement Mortar Particle Board	2 cm 15 cm 2cm 2 cm	0.72	Particle Board Cement Mortar Purnice Gravel	2 cm 5 cm 5 cm	1.08	Gypsum Plaster Aerated Conc. Block	2 cm 15 cm	1.09	Plywood Bitumen Sealing Roof Tile	1 cm 0.5 cm 5 cm	0.4	Gypsum Plaster Aerated Conc. Block Gypsum Plaster	2 cm 10 cm 2 cm	1.35
Traditional System	Cement Mortar Light Hollow Brick Cement Mortar	2 cm 20 cm 3 cm	1.65	Cement Mortar Concrete Floor Cement Mortar Particle Board	2 cm 12 cm 2 cm 2 cm	1.38	Particle Board Cement Mortar Purnice Gravel	2 cm 5 cm 5 cm	1.08	Cement Mortar Concrete Floor Cement Mortar	2 cm 12cm 2 cm	3.8	Plywood Bitumen Sealing Roof Tile	1 cm 0.5 cm 5 cm	2.6	Cement Mortar Light Hollow Brick Cement Mortar	2 cm 10 cm 2 cm	2.1

Appendix L: Plan and elevations of the model building



<u>Curriculum Vitae</u> :

Name	Umit Esiyok
Date of birth	19 January 1976
Place of birth	Elazig, Turkey
Education	
Since 2003	PHD at the University of Dortmund
1996 - 2000	MSc Arch. Degree: Istanbul Technical University, Turkey
1992 - 1996	Bachelor Degree in Architecture, University of Trakya, Turkey
1986 - 1992	High School, Yeni Levent High School
Work Experience	
April 2006 – Sept 2006	HPP architects, Duseldorf, Germany
Since 2004	As a research assistant for different projects and lectures at University of Dortmund, Chair for environmental Architecture.
July 1998 – June 1999	Morrison Construction Services in Istanbul, Renovation of US Consulate, Turkey
June 1997 – Sept. 1997	Yapi Organizasyon Ltd.