Passive Solar Design Strategies for Buildings: A Case Study on Improvement of an Existing Residential Building's Thermal Performance By Passive Solar Design Tools

By

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**A Dissertation Submitted to the
Graduate School in Partial Fulfillment of the
Requirements for the Degree of**

MASTER OF ARCHITECTURE

Department: Architecture
Major : Architecture

İzmir Institute of Technology
İzmir, Turkey

September, 2003

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ACKNOWLEDGEMENTS

I would like to thank my supervisor Assist. Prof. Dr. H. Murat Günaydın firstly for his advices, critics and supports during the study. His patiently guidance puting forward valuable ideas allowed me to accomplish this thesis.

I must thank Prof. Dr. Gürbüz Atagündüz who is a well known scientist on the subject for his great efforts and contributions, his courses made me more informed and interested on this subject. The help of my friends Zeynep Durmuş, Zeynep Peker, and Berkan Erdoğmuş has invaluable support for this study. They have made great contributions towards solution of my problems especially about the method of the study. I want to thank Dr. Fikret Okutucu for his special advices for the development of the subject. Having the knowlegde of the subject well, he has helped me to consider the matter from the point of field applications. I am indebted to him for his special contributions.

Finally I wish to express my special thanks to my family for their supports and encouragement throughout my life and for always motivating me towards success.

S B

ABSTRACT

This thesis investigates the potentials of the use of Passive Solar Design strategies in existing low-rise residential buildings in the context of energy-efficient building design. Among the ways of developing energy-efficient building design, there are mainly active and passive systems to consider and the thesis focuses on passive ones which require integration of architectural characteristics and energy-efficiency strategies, which can likely be cost-effective and thermally comfortable as a result of that integration.

In order to achieve the objective of the study, a methodology has been developed. Fist a thorough literature survey is conducted. Then examples related to subject are investigated. Finally an existing residential building is selected and analysed as the case study. Current thermal performance and improved thermal performance of this building are analysed by the help of a software called Energy-10. Results of both original and improved projects are interpreted accordingly.

In buildings, Passive Solar Design strategies can provide fundamental comfort conditions related to heating, cooling for thermal and natural lighting for visual comfort or help building's conventional mechanical systems achieve these conditions requiring less amount of energy. Some of the Passive Solar Desgin strategies are seem in traditional architecture from harsh cold to hot humid climate, they have been in harmony with their environment and provide comfort conditions adjusting the outdoor climatic features by climatic design strategies and they are called as climate-responsive buildings. Solar orientation, solar apertures, thermal mass, solar chimneys, wind captures, lattice brise-soleils or mushrabiyas are the Passive Solar Design elements which have been used in traditional buildings, now abandoned, running by means of natural air currents.

To achieve a low-energy building, thermal insulation ought to be considered as the main energy-efficiency feature. Turkish thermal insulation standarts 'TS 825' is

deficient for designing low-energy buildings and there is no regulations that make the designers feel the desire to utilize low-energy concepts for their designs. Besides, the building's morphological organisation should be involved with respect to climatic and environmental data. One of the most important criterion in designing an energy-efficient building is incoprating properties of microclimate of the site that the building is to be placed. Using environmental (climatic, geographic, etc.) data well in building designs can lead to energy efficiency. Solar geometry, latitude, altitude, wind patterns, vegetation, hills and neighbor buildings are the determinants of microclimate of a site.

The findings of the study indicate that with the energy-efficiency design strategies by passive solar components having the additional cost of about 9% of the total building cost, it is possible to save the total annual energy used in this specific residential building by 18%. There are three types of energy need for the space conditioning and visual comfort (i. e., heating, cooling and lighting), the maximum energy saving is achieved in heating energy use by 61% decrease, lighting energy use is also decreased by 40%. However, in cooling energy need, there is an increase of 34%. This amount is overshadowed by passive solar gains in other energy savings (i. e., heating and lighting) and when the cooling strategies of the building (i. e., natural ventilation and stack effect ventilation) are considered, the building might be said to perform well in terms of thermaly in annual operation.

ÖZ

Bu tez enerji etkin yapı tasarımı çerçevesinde Edilgen-Pasif Güneş Tasarım ilkelerinin mevcut, az katlı konut binalarında kullanım olanaklarını araştırır. Enerji etkin yapı tasarımı gerçekleştirebilmek için ‘etken’ ve ‘edilgen’ çözümler söz konusudur. Tez, bu sistemler arasında mimari karakter ile enerji etkinliği stratejilerini daha sıkı bir biçimde entegre edebilen, bu yüzden de daha ucuz, uygulanabilir, ısıl konfor sağlamada etkili ve mimarlık pratiği ile daha yakın etkileşim içinde olabilen edilgen/pasif çözümler üzerinde yoğunlaşmaktadır.

Çalışmanın amacı doğrultusunda oluşturulan yöntem öncelikle geniş bir literatür araştırması, ardından konu ile ilgili örneklerin bulunup özetlenmesi, mevcut bir konut yapısının geliştirilecek proje olarak seçilmesi ve Energy-10 isimli termal analiz programı yardımı ile tamamlanan çalışma sonuçlarının yorumlanmasını kapsamaktadır.

Binalarda kullanılan Edilgen Güneş Tasarım ilkeleri, ısıtma, soğutma ve aydınlatma ile ilgili temel konfor şartlarının sağlanmasını yada binaların konvansiyonel mekanik sistemlerine bu koşulların oluşturulmasında yardımcı olarak daha az enerji tüketmelerini sağlarlar. Vernaküler mimaride Edilgen Güneş Tasarımı ilkelerinden bazıları sert, soğuk iklimlerden nemli, sıcak iklimlere kadar çeşitli, yöresel çözümlerle enerji etkinliği ilkelerini içerecek şekilde kullanılmıştır. Güneşe yönelim, direk kazanım açıklıkları, ısıl kütleler, güneş bacaları, rüzgar tutucular, kafes güneş kırıcılar geleneksel mimaride kullanılan ve çevresel, doğal iklim dinamiklerinin oluşturduğu hava hareketleri ile çalışan Edilgen Güneş Tasarımı stratejileri ve bileşenleridir.

Düşük enerjili yapı tasarımında, ısı yalıtımı öncelik verilmesi gereken bir konudur. Türkiye’de uygulanan ‘TS 825’ mevcut ısı yalıtım yönetmeliği enerji etkin tasarım konsepti anlayışında yapı yapmaya uygun olmadığı gibi kayda değer bir özendiriciliği ve teşvik ediciliği de yoktur. Diğer bir faktör de, binanın mekansal, yapısal ve malzeme özelliklerinin iklimle dengeli bir yapı tasarımı anlayışı içinde ele alınmasıdır. Binanın yapılacağı alanın mikro kliması, enerji etkinliğini etkileyecek en

önemli faktörlerden biri olacaktır. Alanın güneşlenme durumu, enlemi, yüksekliği, rüzgar koşulları, bitki örtüsü, fiziki yapısı ve çevre yapıları alana özgü mikro iklimi oluşturan çevresel verilerdir.

Bu çalışmanın sonunda elde edilen bulgular, edilgen güneş tasarımı ilkeleri ve bileşenleri ile sağlanacak enerji-etkin yapı tasarımı uygulamaları ile, seçilen mevcut konut yapısında yapılan ve bina maliyetinin yaklaşık %9'u oranındaki iyileştirme sonucunda mevcut haline kıyasla toplam enerji ihtiyacında %18'lik bir kazanç sağlanabileceğini göstermektedir. Mekanın ısıl ve görsel olarak şartlandırılmasında temel olarak üç tip enerji ihtiyacı söz konusudur (ısıtma, soğutma ve aydınlatma). Kazanımlar arasında en büyük payı %61 ile ısıtma enerjisi ve %40 ile aydınlatma enerjisindeki düşüş sağlamıştır. Ancak binanın soğutma yüklerinde %34'lük bir artış gözlenmiştir. Termal performansın, soğutma ihtiyacı açısından düşük çıkması kullanılan programın bazı yetersizliklerinden kaynaklanmaktadır ve binanın Enerji-10 isimli programında hesaplamada yetersiz kaldığı havalandırma stratejileri gözönüne alındığında binanın yıl boyunca konfor düzeyinde ısıl ve görsel performans sergileyeceği söylenebilir.

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Chapter 1

INTRODUCTION

1.1. Definition of the problem

Utilization of Solar energy in buildings has taken attention for decades and is getting more attention as a rising concept in building design (Yoo, et al., 1998; Hestnes, 2000; Hagan, 2001). The subject might have important effects on urban fabric and architectural environment (Tombazis, 2001). Climate-responsive design goes to ancient settlements and societies which developed their building techniques and design considerations according to regional physical factors beside the social and cultural ones (Buitti and Perlin, 1980). However, Farmer (1996) states that this issue has shifted to energy-efficient design and solar architecture today.

In the term in which modern architecture has come today, global environmental disasters, economical and social problems have given birth to tendency of establishing the settlements that can be constructed with recycled materials, have the ability to be paid up-assembled again and imply to the needs of energy in rationalist and cheap ways (Knowles, 2002). Sustainability is a general term incorporating all the natural, ecological, social, cultural and environmental protection for the future generations. Buchanan (1997) states that the basic principle here as having presence by conserving ecological balances that mankind has behaved unconsciously and without care of future or not damaging the natural environment with modern styles while meeting comfort needs, thus providing the same opportunities to subsequent life terms.

Nowadays the terms: ecological architecture and sustainable development are quite in our lives. They suggest people to design environments that are capable of meeting human needs and desires in ways which (Yeang, 1995):

► Use local resources, materials and existing energies.

► Maintain the integrity of eco-systems by maximizing the conservation of native plants and other life forms.

► Minimize the use of imported resources reducing dependence for them and use them if they are procured and processed in ways that are recyclable.

► Use renewable energies as maximum as possible for sustaining the life.

One of the stipulations for achievement of these goals is not relying on present natural sources by designing physical environments in utilitarian manners of renewable energy sources that are clean and not having harmful effects on the nature. According to Vale (1996), Solar energy is one of them and it has very effective ways to be used for conditioning of the buildings. The main concern to reduce negative environmental impacts due to buildings in terms of energy efficiency is optimisation of architectural forms for passive, active and hybrid solar technologies and intelligent systems to optimize energy used (Nicoletti and Simone, 1998).

It is a general factor that buildings account nearly half of total energy consumption in developed countries. The other consumers are transport and industry whose activities are related to buildings and their location as well (Wigginton and Harris, 2002). In Türkiye, there are only some solar buildings with real meaning of utilisation of renewable energies. Some of them are listed and interpreted in chapter 4. Existing building stock has to be taken into consideration if an improvement in energy consumption is going to be achieved. Generally, all buildings might be said that they will need to go under renovation in a certain time. In renovation process, there are some opportunities to apply energy efficiency strategies to buildings. Voss (2000) states that renovation of existing buildings will have the priority for global sustainability. And, as renovation makes the building status goes on for the future, energy consciousness ought to be an inherent part of it. In Türkiye, energy consumption for heating is considerably high as buildings are not insulated properly and some of energy saving strategies are not sufficient (Dilmac and Kesen, 2002). It is therefore important to consider low-energy design strategies not only for new buildings, but also energy saving and gaining strategies for refurbishment of existing buildings.

Contemporary architects and engineers have begun to use energy efficiency considerations and traditional Passive Design components with modified and technologically improved versions in their designs. Beforehand while the issue is seen in laboratory and residential buildings only, energy related approaches are now taken into consideration from single house buildings to mass housing, from institutional buildings to high-rise office buildings offering myriad solutions. Norman Foster’s Microelectronics Park building with the concept of Green Architecture and Double envelope strategies in Duisburg, Thomas Herzog’s Exibition Hall with energy-saving control systems cutting the cost of mechanical ventilation by half in Hanover, Nicholas Grimshaw's British Pavilion accomodating water walls with containers on the west and flowing system on the east creating cooling effect, solar panels on attractive louvres, Von Gerkan Marg's Glass Hall having passive environmental control strategies in Leipzig, Michael Hopkins' Inland Revenue Headquarters having developed environmental control strategy by natural ventilation and thermal mass are the samples of contemporary buildings of energy-related designs (Slessor, 1997).

1.2. Objectives of the study

Altough energy efficient design strategies related to active and passive use of solar energy are well known and used, they are even in building regulations in European countries' building practice, they are not considered in buildings as a design strategy or quality in Türkiye. The importance of the issue is understood well when the amount of energy consumed by buildings is taken into consideration. Dilmac and Kesen (2002) take attention to high energy consumption of residential buildings in Türkiye because of deficiency in insulation standards and energy-efficient design considerations. Okutucu (2002) emphasizes that residential buildings can save considerable amount of energy provided that being designed in the context of principles of passive solar design, and he concludes at the end of his study, it is possible to save energy by about 90% in terms of heating energy need with passive solar design considerations in residential buildings. This statement necessitates to consider also existing building stock having low standards of thermal performance and constituting a large amount of building existence.

When the geographical position of Türkiye is conceived being on east-west axis it has long insolation period, and being between latitudes of 36-42 degrees with the suitable atmospheric conditions it has high solar radiation of 30.000 kJ/m^2 (Dilmac and Kesen, 2002), and it can be said that buildings can have the opportunity of being as low-energy and even zero-energy buildings using active and passive solar components in Türkiye. Technological choices can make a building zero-energy or plus-energy one. For instance, photovoltaic technologies are used in building construction, but they are used with restricted limits because of cost issues. Transparent insulation has cost problems as well. They will possibly be cost-effective in the following years. However, Holloway (2002) emphasizes that passive solar components which are going to be explained in the following chapters can offer cost-effective and satisfying solutions to thermal needs of the buildings adding just 5-10% of total investment to the building costs. Okutucu (2002) in his study proves the cost and thermal-effectiveness of Passive Solar Design strategies discovering the value of additional cost of 11,6% od total building cost by Passive Solar components.

The main objective of this study is to investigate the possibilities of the use of Passive Solar Design strategies in existing low-rise residential buildings. In order to reach this objective, a case study is carried out by considering design criteria; from orientation to material choices; from space configurations to use of energy-efficiency tools (such as, thermal walls, trombe walls, sunspaces, solar apertures, and etc.).

The studies conducted in the light of this objective can be summarized as: to define the environmental problems caused by building industry and related results of using non-renewable sources as prime for conditioning of indoor environments, to discuss the effects of climate considerations in terms of environmental architecture, to explain the strategies for thermal improvements and their usage opportunities in building design giving detailed information on the systems, to reveal the possibilities of the use of Passive Solar Design strategies in residential buildings by sampling some projects from Türkiye and abroad, and to guide the designers for making good decisions about thermal characteristics of a building in early design phase. The last part of the whole study is very important as the stakeholders of the building industry have the lack of this part of the theme. With the knowledge of energy-efficiency strategies, one important barrier remains to make the issue being paid attention in practice is that designers and owners of the buildings are unwilling to make their buildings energy-conscious and tend to know how the decisions taken into consideration in pre-design phase will affect the buildng’s energy performances.

Showing the cases from all over the world that are in this intended scope and emphasizing the importance of energy-efficiency in buildings, it is aimed to make the issue wide spread in refurbishments of the existing residential buildings.

Chapter 2

METHODOLOGY

2.1. Method of the Study

To achieve the objectives defined in chapter 1, the following methodology has been developed. Figure 2.1 shows the methodology of the thesis. Following steps are followed:

1. Problem definition.
2. Discussing the energy considerations in architectural practice in terms of climate-responsive design.
3. Literature review on Passive Solar Design strategies.
4. Surveying the building examples from Türkiye and different countries.
5. Surveying the cases analysed thermaly.
6. Investigation of available building energy analysis softwares.
7. Selecting an existing residential building.
8. Evaluating the current thermal performance of the selected building.
9. Refurbishing the existing building by integrating passive solar design components.
10. Preparing the climatic data for the software.
11. Evaluating the thermal performance of both the original and the improved building.
12. Comparing the results of both buildings.
13. Evaluating the solar design strategies for existing buildings and discussion.

In the following section, the studies mentioned above in list to accomplish the thesis will be showed in a scheme and explained briefly.

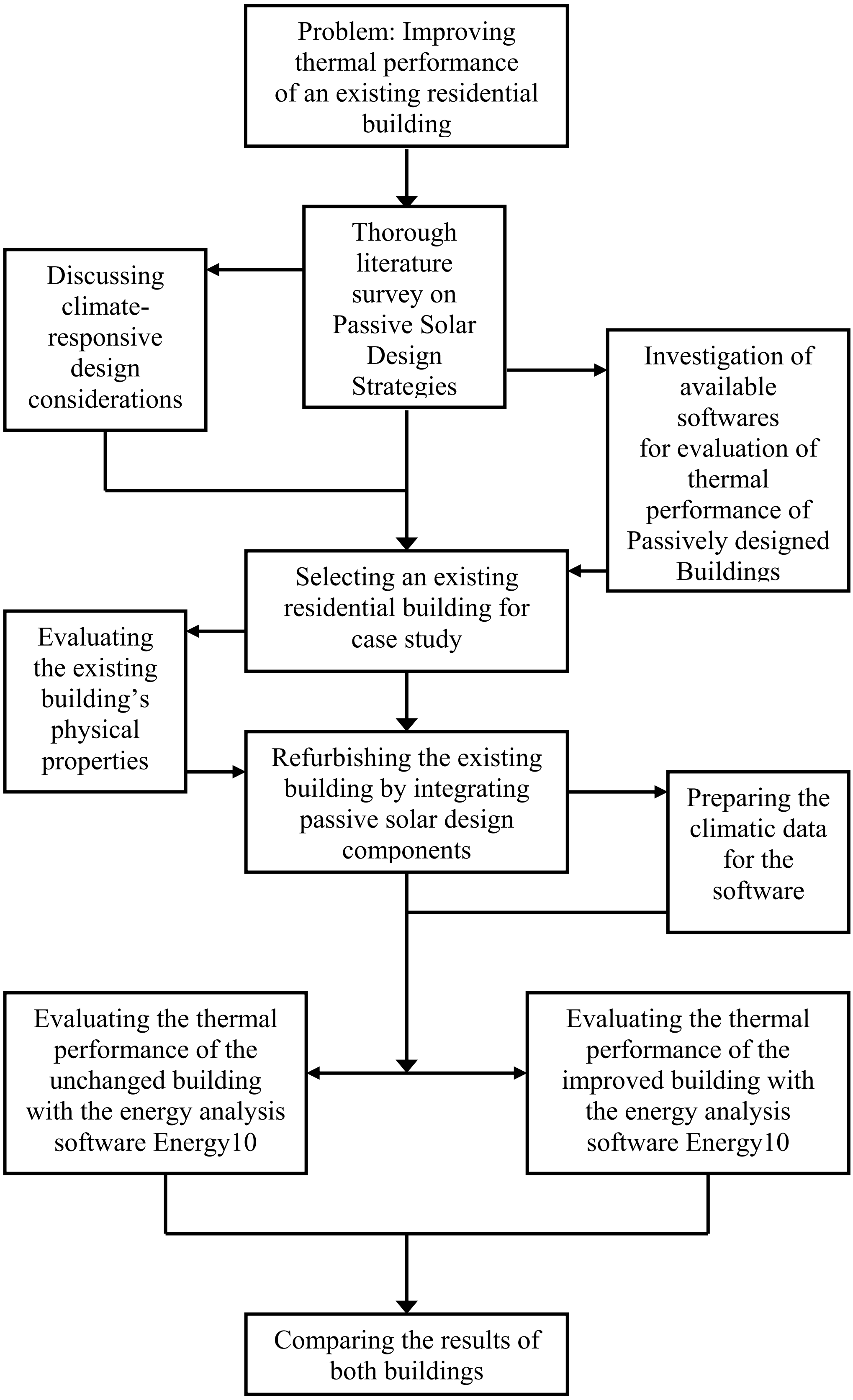


Figure 2.1. Structure of the research method.

In the context of objectives mentioned in chapter 1 following studies have been conducted. Firstly, reasons for defining the problem are realized in the context of environmental considerations being a crucial issue of the recent. These considerations are seen in the contemporary buildings as a design concept and used by contemporary designers. In this point, the subject requires evaluation of traditional building activity and contemporary building activity in terms of climate considerations and comfort conditions. It is important to reveal how the traditional architecture has behaved to providing thermal comfort with the viewpoint of climate-responsive design and how the contemporary architecture is behaving and will treat this issue.

To constitute the structure of the thesis, energy related solutions seen in the buildings are investigated. To understand and discuss the effects of the types of use of solar energy strategies regarding the relationship between building design and energy design, solar design systems used in buildings are investigated in detail. After revealing the components of solar energy design in buildings, the ones which require integration of architectural design and solar design strategies are expanded in more detail illustrating the systems in figures. With this investigation, examples in which solar design strategies were used are surveyed. The examples are limited in terms of size so that they can include all the systems as far as possible. As it will be discussed later, the natural phenomenon of heat flow is vital for passive Solar Design. For this constraint, the choice of the building is limited in size.

To go further, some studies done with the aim of thermal analysis of the buildings by using energy analysis tools are surveyed. In this part of the study, the cases found from the literature are evaluated in terms of their architectural properties and results of thermal analysis. The ways of studying the thermal analysis of the buildings are investigated among the selected cases, and one of the effective way is observed as the software-simulated thermal analysis of the buildings in terms of estimating the buildings' energy use annualy.

In the final stage of the study, an analiytical case has been done revealing and discussing the Passive and Active Solar Design strategies that can be applied to existing buildings. For the analysis, one of energy analysis softwaers is used to make selections of Solar Design Strategies effectively on the existing building in the design phase of the refurbishment project.

2.2. The Role of Energy Analysis Tools in Designating the Building's Energy Performance

In the process of designing a building, one of the most important and difficult subject to decide is making suggestion and estimation of thermal performance for the running period of the buildings. This difficulty leads the designers to ignore thermal analysis process in designing stage for more suitable conditions of human comfort and further more efficiency of energy use in operating period and ultimate cost-effectiveness and minimum environmental effect.

There are many currently available softwares developed in various institutions. These programs take on a special being associated with different types of buildings. So, the important point of choice of such softwares is to determine the type of the building. For instance, if it is aimed to analyse a residential building, an appropriate software needs to be chosen, if an office building is selected another one will be required or in terms of mechanical systems, a building with passive solar design strategies and suitable HVAC system or lighting analysis accordingly. Utkutuğ (2002) describes energy simulation programs that can analyse a building thermally with all active and passive features. She adds, with the informations provided by the help of such softwares, the alternative systems that will affect the consumption of the building's energy use (building's envelope, opening's sizes, lighting, and HVAC, etc.) can be analysed one by one to find optimum solution.

Most of the energy analysis softwares use simulation process that means calculating the buildings energy need hour by hour using weather data recorded near the building site. By the help of these softwares, designers can predict how the building will operate through the entire year. As the case study consists of residential building's energy analysis, the names of some softwares which can do the task on residential ones will be given: 'Energy', 'SuncodePC', 'Energy-10', 'Ecotect', 'PowerDOE', 'Home Energy Saver (HES)', 'Energy Pro' are some of energy analysis softwares. A lot of environmental analysis softwares can be observed and some of them downloaded from the internet site, www.eere.energy.gov//buildings/tools_directory. In the following section, the softwares used in the projects that are summarised in chapter 4 will be explained in more detail.

Energy: This software can analyse the different design alternatives thermally in a building. It was first developed by Shaviv and Shaviv in the 70s and extended by Shaviv in the 80s. (Shaviv, 1998). The software 'Energy' is capable of calculating the heat transfer through external walls, it also takes the thermal mass of building materials into account. Additionaly, the software Energy can analyse illumination level. The program gives the total energy consumption of a building for heating, cooling, ventilation and artificial lighting for each month during the whole year.

Energy-10: Energy-10 is a software tool developed by National Renewable Energy Laboratory (NREL) for designing low-energy residential, small commercial and institutional buildings. It evaluates passive solar heating, natural ventilation and daylighting with energy efficient envelopes. It makes designer decide the best solution about energy efficiency in early design process without making a concession in comfort conditions. The software can analyse the buildings having a capacity of 10.000 square feet or less evaluating solar gains through the windows, heat flow through the walls and thermal storage of the materials. Energy-10 has passed the BESTEST procedure successfuly. The software brings an easiness of forseeing the thermal results of a building while there is no low energy one yet.

SuncodePC: The software SuncodePC is a general purpose thermal analysis program for residential and small commercial buildings. SuncodePC is a microcomputer version of SERIRES which was written under the guidance of Solar Energy Research Institute. The software can calculate the passive strategies in a building in terms of insulation, solar gain through apertures, trombe walls, water walls, green houses, and rockbin storages that are commonly used in passive buildings.

These are the tools that can facilitate the end decision on environmental (thermal, visual, accoustical) implementations in a building design. Architects have lack of close prediction of a building's thermal performance before construction though they have heard about the buildings that use half of the amount of energy of conventionaly designed ones. The tools that mentioned above can help get over this obstruction and eventually make architects interested in low-energy architecture. In this point, their reliableness on results of such tools is gaining importance. How can a designer rely on these software's accuracy? For this, there are some protocol which test such softwares in terms of their accuracy. For instance, BESTEST procedure developed by NREL (National Renewable Energy Laboratory) has been adopted by the U.S. Department of Energy (DOE) as basis to prove the reliance of such programs.

Chapter 3

HISTORY, DEFINITIONS AND SYSTEMS USED IN PASSIVE SOLAR ARCHITECTURE

3.1. Summary

In this chapter, history of solar architecture will be mentioned briefly and definitions of solar gain methods will be explained generally. In the contex of vernacular architecture, the relationships between climate and building design will be discussed considering the design criteria and construction techniques, then systems used in passive solar architecture will be introduced in more detail.

3.2. History and Evolution of Solar Architecture

Although energy was not a problem untill 1970s, some energy related approaches have been conducted in architectural design. To go past, traditional architecture has always guided us to design our buildings for better use of materials, more appropriate plan, and morphological organization and even better indoor conditions. Traditional architecture has had a lot of passive strategies to create thermal comfort in the buildings (Nahar, et al. 2003). Traditional architecture has been succesful in providing comfort conditions by offering regional solutions using neighbour opportunities.

Butti and Perlin (1980) explain that the use of the Sun's energy for climatic control goes to ancient settlements which used solar energy to accept warmth from the sun in winter while denying entrance to excessive sunshine in summer, but with one difference, they lacked glass for glazing their windows and so they were deprived of one of the modern designer's most valuable assets (Paul, 1979). The Greeks were the first that used solar energy to help heat their homes. The ancient Greeks were well interested in benefits of solar design, and built their houses by orienting them towards the South and used the thermal storage property of materials to keep the solar heat gain in the space. Greek cities such as Priene were planned on a grid plan with streets running east-west direction to allow the buildings to face South for accsess to the Sun (Vale, 1996). They prevented their spaces from high summer sun's effect via the porticos in front of rooms.

The Romans developed the Greece solar architecture inventing the clear material such as mica and glass to cover their openings. This provided the Romans to capture the Sun's beams through windows and keep them in the space for a longer time. They even used the term 'heliocaminus' to describe their south facing spaces.

Other use of the sun for space conditioning effectively appeared in the indigenous American architectural heritage, the 'sky city' of Acoma is one of the most sophisticated examples of American solar architecture (Butti and Perlin, 1980). They provided solar access to each building taking shape, orientation and height of the buildings into account. The Acomas built houses in a climate responsive manner. They used thick masonry, south facing walls to collect solar energy during the day of winters and row houses type for reducing the intense effect of summer sun's rays on east and west sides by adjacent houses (Knowles, 2002).

Solar energy strategies have been used for many years as it was observed. Orientation has been the most important criterion in traditional settlements. As there have been available and inexpensive fossil fuels, much of the knowledge of the past was left forgotten in the quest to adopt air conditioning as the throbbing heart of the modern buildings. And designers have ignored these knowledges of solar design up to now. Many contemporary architects have failed to remember, or never learned the basic common-sense aspects of natural controls. They have indulged themselves and saddled clients with buildings that cannot function independently of space-conditioning machinery. When power is interrupted, limited, or too costly, many modern buildings become uninhabitable (Wright and Andrejko, 1982).

Atagündüz (1989) states that one of the first modern applications of Passive Solar Design strategies is Trombe Walls which was put into practice by Prof. Trombe the director of solar energy research centre in Odelio in France. This system was then applied in architecture by Jacques Michel. Various solutions have been developed to realize the effective collection, storage and distribution of solar energy in buildings. This variation of solutions have taken effect on building's design so, they have caused forming of solar architecture as not a new concept but as a new option for modern architects and engineers with the new technologies (Atagündüz, 1989).

Now with the posibilities of being exhausted of fossil fuels, rised costs and present environmental damages, interest in energy efficient technologies has become important in architecture as in other fields. One of energy efficient treatments is to benefit from solar energy as ancient societies did. Developers and designers have not worried about the environmental pollution and long-term energy cost until now, and they have relied on machineries for environmental control of buildings.

Cofaigh et al. (1996) define that non-architects: politicians, environmentalists, and lay people offer three reasons for supporting the solar architecture and list them as political, economical and environmental concerns. In terms of politics, the reason for promoting it is to reduce dependence on oil. In terms of economy, it is to save money using 'free energy' from the Sun. In terms of environment, it is to prevent the nature and natural sources for other architecture. Knowles (2002) reminds us the concept of our production style with simple ungrammatical terms, we 'grow cheap' and 'maintain expensive'. And he emphasizes the necessity for a different way of evaluating the aesthetics of the buildings.

3.3. Definitions of Solar Design in terms of Climate-Responsive Design

There are generally two types of solar gain systems in buildings for reducing energy consumption without decreasing comfort level: Active systems and Passive systems. These will be explained in detail in the following subtitles. However, passive solar gain concept has the priority of expanding for long-term use of 2500 years of it (Butti and Perlin, 1980). Passive systems are defined as energy gaining and using method in any purposes by means of natural heat transfer phenomenon (convection, conduction, radiation). These systems have been used in architecture mostly as the fact that they can be adapted easily to the structure of the buildings and it is convenient to accomplish the thermal needs of the buildings. Use of these systems in building design can provide healthy and comfortable spaces decreasing the level of dependency on external fossil energies. Beyond these, the concept of solar design significantly contributes environmental protection as the systems let buildings to use less energy - making them energy conscious- than conventional design approach. The term 'solar design' means involving climatic considerations to take effect on shaping of the buildings (Nahar et al., 2003).

During the period of the 1960s and well into the 1970s the use of forced air systems in heating, ventilating and air conditioning (HVAC) systems of buildings dramatically increased. These systems having closed circulation system of conditioned air have been applied to buildings of all sizes and all functions from single-family tracthouses, through high-rise office buildings, to specialized uses such as auditoriums (Cook, 1989). The thermal comfort conditions that the architect should provide in architectural design have been overcome by means of electronical and mechanical devices not depending on architectural design and fabric of the building. Use of such devices in buildings has mainly replaced the climatic considerations of the design process that had been taken in primitive and vernacular architecture (Hagan, 2001).

Roaf et al. (2001) take up the issue regarding climatic design strategies and define that lack of climatic considerations in building design that is often seen in modern architecture has caused many buildings to overheat in hot seasons or vice versa where such problems never existed in traditional architecture. The ways of building in ancient societies were highly influenced by climatic and regional conditions, Rapoport (1969) defines that primitive and vernacular buildings responded to climate very well although he doubts and investigates on its determining factor. He concludes that they were dependent on the climatic considerations as primitive and pre-industrial builders had lack of the technology to let them ignore climatic parameters in building design. According to Aran (2000), climate as a complementary factor has played the role of designating lots of physical characteristics of rural buildings. He samples his statement from various regions of Anatolia defining some building's elements that change in size, material kind, form and position according to climate.

Architecture, as built-up environment, has an impact on the natural environment because architectural and urban environments are created by changing the contours of the earth and in these processes, fossil energies are used coming from coal –used for producing electricity the most- and petroleum –used for transportation and heating of spaces the most- for increasing human comfort level. As the buildings use the fossil energy sources for heating, cooling and ventilating, the natural world is getting polluted from these supplies' harmful impacts due to emissions of detrimental gases. This takes the readers to the relationship between energy and environmental pollution. The earth has some energy supplies that can be used to produce industrial products and artificial environments, but these supplies have some gases that are harmful for the nature of the world. As long as the fossil fuels are used primarly, it is obvious that the world will come across to natural collapses. Any economical system that is based on petroleum and coal pollutes the environment significantly, and tend to come down in a very short time. The most important part of this pollution and damage occurs in the atmosphere of cities which use fossil energy supplies intensively. Peker (1998) emphisizes the principles of energy-efficient urban design in her study. In the urban scale, solar zoning is so cricucal for these priciples, it includes sun rights and solar access of urban blocks. In architectural scale, maximizing the building's exposure to the sun in cold and temperate climates, and minimizing in hot regions are the starting point of passive solar design considerations (Hagan, 2001).

Due to machines used for human comfort needs, any architectural environment has needed to use external energy not depending on opprotunities of architectural design. Therefore fossil energy usage has had the priority for CO_2 emission and the ultimate environmental pollution with the excessive use of them in building industry. Eryıldız (2003) points out that half of total energy is used by building industry in the world and most of them is comsumed in operation period of the buildings. These environmental problems and increase of fuel costs have caused architects and engineers to reconsider design priorities and to deal with economics of energy use in building industry. The need to use energy efficiently has brought about the beginning of energy-conscious architecture again. Cofaigh et all. (1996) define other terms that's much in common included within energy concept as energy efficient building, energy conscious design and bio-climatic architecture. This rational new architectural tendency is blessed with much more than fuel frugality (Wright and Andrejko, 1982). Altough the use of solar energy in architecture for conditioning the spaces is not new, architects and engineers now have an important duty in terms of assuring a sustainable future considering the solar concept more in their designs. When we take a look at our age, we see some approaches for energy needs.

Cook (1989) states that during the decade following the 1973 oil embargo, the building design strategy in all countries could be characterized in one of three ways from the point of energy concept as followings:

- ‘Continuation of indigeneous traditions, where building design and city planning followed patterns of long-established historical appropriatenes. Both native materials and local climate were primary determinants’.

- ‘Modernism introduced twentieth century industrial construction materials and methods that are usually associated with the international style of architecture. The common denominator of universally available materials and equally interchangeable reductive building design and city planning schemes were supported by often elaborate mechanical, environmental control systems that depended on external or parasitic energy’.

- ‘Bioclimatic designs that continued the principles of ‘design with climate’ were established using modern buildings technology internationally by the 1950s. Both native materials and methods were used. Both heating and cooling as well as lighting and ventilation needs were integrated within the architecture by informed design professionals’.

Virtually, every country of the world has examples of all three building design approaches. Among the historical concepts Nicoletti and Simone (1998) give special importance to having rational and friendly relations with the natural environment that deals with the physical parameters such as soil, vegetation, urban fabrics and pollution.

Wright and Andrejko (1982) determine that ‘Successful architecture has always been a celebration of logic and beauty. The logic involves function, structure, economy, planning and the myriad other aspects of the architectural art, the beauty includes strong relations between the above mentioned concepts. Inescapably neither logic nor beauty is complete without the other’. According to them, the thermal performance is as important as the esthetic and functional experience, and they state that mankind has always aspired to create buildings that fulfill the yearnings for these themes.

The examples of successful work always incorporate the environment’s natural energy flows. The use of solar energy in all its natural forms gave a unique quality to architectural style. Addition to this, passive solar design strategies have integrity of architectural art and engineering from the point of creating environment that is both exciting and satisfying to the inhabitants.

Knowing many systems of solar design, why they cannot be used in building design for more healthy environments and reduction in CO_2 emissions globally? Roaf et all. (2001) agree with Eryıldız and point out that the buildings emit almost more than half of total greenhouse gas and they state that the building sector is very large and can play an important role in contribution to low-energy use for thermal achievements of the buildings.

As it is observed, architecture plays a significant role for CO_2 emission to the atmosphere; the other part belongs to power plants, industry production and transportation. Additionally, this use of fossil fuels and fossil technologies make people dependent on external supplies because of in ways we dwell, travel, produce and consume. Architects and Engineers should involve in early design process to provide that the building will reduce environmental deterioration it gives. One of the most effective ways to sustain natural environment for future generations is to make buildings energy-conscious (Wigginton and Harris, 2002). It is undisputed that the urbanization and industrialization has occurred by means of the energies that can be obtained easily and cheap, but it is time to consider urbanization and industrialization from the point of energies that have endless supply (renewable energies) without harmful effects. To what extent fossil supplies can be utilized, they are getting run out as the fact that used in our all life style intensively, and they will keep damaging the world.

Architects, Urban designers and Engineers should consider not only structural, functional and esthetical features but also thermal and operational ones in designing a building or a city. Architecture has had some approaches related with energy use and buildings. But, we cannot see the efficient use of these approaches in considerable amounts and as social projects. Any modern architectural approach hasn't had attention to the environment in terms of energy consciousness as it is an energy consumer phenomenon (Göksu, 1992).

Passive Solar Design

Generally, Passive Solar Design is described as the use of form and fabric of the buildings to admit, store and distribute energies from renewable sources (solar, wind etc.) appropriate for buildings; primarily solar energy and fresh air by means of without mechanical or electronical devices for space heating, cooling and lighting (Holloway, 2002). Some of the processes of heat flow can be managed naturally through building design in a manner that helps heating and cooling of the buildings. The basic natural processes that are used in passive solar energy systems are the thermal energy flows associated with radiation, conduction, and natural convection.

When the sunlight strikes a building, its materials can reflect, transmit, or absorb the solar radiation due to physical, locational and morphological properties of the materials and components of the buildings. Additionally, the heat produced by the sun causes air movement that can be predictable in designed spaces. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in fulfilling thermal requirements of a building. Passive systems are intimately integrated into the fabric of the building because they need to use some components of the building as inherent parts of passive systems. The term 'passive' in architecture means involving the building's form and fabric itself. The level of integration is essential if the proper flow of heat is to occur naturally without any or with little mechanical assistance that's an important feature for passive solar architecture.

When a building is considered with the concept of utilization of solar energy to be a low-energy one, it should be designed to be as 'self-sufficient' as possible in terms of providing thermal comfort needs. This state comes from characteristics of passive solar design. Tributsch (1995) compares function of solar buildings with living organisms whose outer skin regulates inner requirements in terms of self-helping. In a passive design approach, often the building is collector and heat storage system, and the elements of a passive solar building serve multiple purposes. Passive solar design approach is achieved by using the properties of materials and shape of the buildings, and ways of solar design will effect architectural language and also determine operational patterns of the buildings. Form, material, plan organisation and orientation are the main instruments in passive solar architecture, and they inform us in terms of every values of a building such as economy, aesthetic, functionality and also energy efficiency (Nicoletti and Simone, 1998).

In architecture, solar design means reducing demand rather than to substitute for fossil fuels, and solar energy acts to save energy used. Göksal (2003) attracts attention that inescapable results of use of energy that is unfitting from the point of ecological principles lie under the fundamental of environmental problems. Therefore, it is necessary to develop an energy system that is appropriate for a sustainable future in the scale of building and city. The probability of unobstructed environmental damage and running out of natural sources have forced the designers and investors to take measures for the buildings that will use renewable energy sources for creating comfortable environments while relying on fossil energies as little as possible.

Wright and Andrejko (1982) point out that during the past half-century, with the availability and intense use of fossil fuels, the building industry and its clients have taken maximum advantage of machines to control light, temperature and comfort level in their buildings. Tombazis and Preuss (2001) notice that control is a crucial issue for a building in fulfilling its thermal appropriateness, and they state that in a conventional (static) or non-climate responsive design approach, control usually means pushing a button to operate some machineries for lighting, heating, cooling and air conditioning etc., while the building's fabric remains the same. This state leads the designers to a dynamic approach between architecture and natural environment. Recently, the building's facades are defined as climate modifier that regulate inner conditions by changing its physical and optical properties in accordance with the outer climatic conditions.

The variability of building's envelope requires movable parts and improved technologies, which conflict with passive design concept. Cofaign et all. (1996) emphasize that the knowledge of climate response in building design and living ways was implicit varying from region to region. However, these knowledge of the past will no longer meet the needs of the works of today's architects who are confronted with new materials, building technologies and conditions of modern life style. According to Cofaign et all. (1996), these considerations must be relearned and modified to suit the requirements of today's buildings.

Contemporary deficiencies can be offset by contemporary methods, for instance: new energy saving materials, developed envelope systems like multi-layered facades. So, solar technologies and needs for efficiency in an energy conscious design approach will combine all the features of solar gain systems making active and passive strategies together. Hestnes (1999) states that the terms active and passive have no sense any more in architecture. This is in line with Cofain's statement. Because active and passive components are complementary for each other for the needs of today's buildings, the newer buildings may be both energy efficient, solar heated and cooled, and even photovoltaic powered, they are basically called "solar buildings".

Active Solar Design

Active solar design is distinguished from passive systems, which use the fabric of the building, in terms of collection of solar energy, storage of collected heat and distribution of heat to spaces. Active systems use components out of fabric of the building for collection, storage and funs or pumps for forced distribution of collected and stored heat.

While this may at first seem a relatively minor dinstinction, in fact, it implies major architectural design implications. Boyd (1994) describes the terms 'active' that means including the attached services and 'passive' that means including form and structure of the building itself. In the case of an active system, the design of the solar collection and heating system do not need to be integrated with the structure of the building. However, in passive systems, the components of the system are considered as architectural elements like walls, windows or roofs with little modifications to trombe walls, mass storage walls, double south glazing and sunspaces.

Atagündüz (1989) defines the active systems as heating water by solar collectors and sending heated water to current boiler preheating the system or heating the air by air collectors and blowing the heated air to the spaces to be heated. The various active solar components (storage, heating, distribution system, control system, and collectors) can be positioned in any remote location, connected by means of pipes or ducts with little or no direct effect on the building design or construction method, and operate satisfactorily.

For instance, thermal solar collectors with water or air that are commonly used on roofs of buildings can be used for eighter domestic hot water or space heating. They are completely separate units from building's morphology. They do not even use the inclination of the roofs. In this point, it is useful to mention high-efficiency conditions of collection units. The maximum efficiency is derived from the system during the whole year when the collectors are placed at latitude angle of the site. An air collector system constituting the roof of the solar house of Erciyes University is showed in figure 3.1.

Atagündüz (1989) defines how the radiation value changes according to different surface slopes for the whole year. For seasonal use of the systems, they should be adjusted to site latitude angle plus 15 degrees for winter use most, or site latitude angle minus 15 degrees for summer use most for the maximum seasonal efficiency. Apart from other active systems, solar walls can have an important effect on fabric of the building. They include building's wall surfaces an assembled metal sheet painted dark colour (outer face of the sheet) on the wall for example: aluminium or steel sheet and a transparent surface constituting an air gap of 20-25 cm between sheet element and transparent surface. These systems are commonly in use, figure 3.2 shows a solar wall system from sports building of Erciyes University. These buildings showed in figures 3.1 and 3.2 have active systems of solar design strategies.

Nowadays, almost all the active system components such as solar water heating and air collectors, photovoltaic panels, etc. can have multifunctional configuration to be used either for solar heating purposes or for constituting the building's envelope. The facades and roof of a building can be also great energy collectors besides being architectural elements. According to Hestnes (1999), in an energy-efficient or energy-conscious building approach, energy conservation technologies should be introduced first, passive solar technologies second and active solar technologies third. However, in order for solar buildings to be energy efficient in terms of environmental assesment and energy budget, all three technologies will be essential to be integrated into the elements of the buildings (Hestnes, 1999).

Figure 3.1: Solar house of Erciyes University, Kayseri, Türkiye. South facade of the building and the roof has active solar components. Trombe wall on facade, and air collector on the roof.

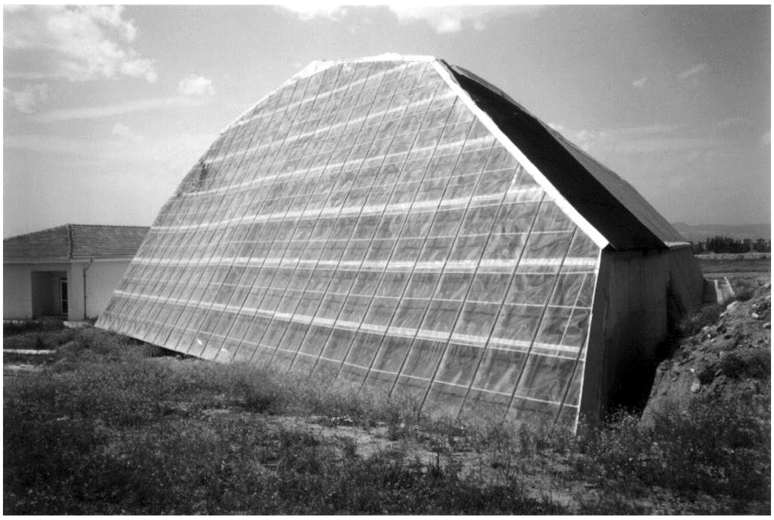


Figure 3.2: Sports building of Erciyes University, Kayseri, Türkiye. The solar wall or air collector constitutes the building’s wall element as well. The system has a storage unit of plastic bottles of water using the high thermal storage capacity of water material.

Passive Cooling of Buildings

Normally in a building, the spaces are conditioned to supply a comfortable inner environment for the occupants. This process involves heating, cooling, humidifying, dehumidifying or ventilation. Cooling is an important element from the point of energy economy in developed countries, with air conditioning causing peaks in electricity use on summer days.

If solar energy can be utilized to cool the buildings, it will decrease the demand of electricity use for the cooling of buildings. Beyond this, with a combination of solar heating and cooling will be in most places more economical than heating or cooling alone and will be celebration of logic and beauty in terms of architectural design (Swartman, 1979). As a design strategy, in hot climates, using the passive solar heating may not sound good, avoiding from the Sun may be better for the whole year. Passive cooling techniques can be used to reduce, and in some cases eliminate, mechanical air conditioning requirements in areas where cooling is a dominant problem. Nahar et al. (2003) define 'passive cooling' as the extraction of heat from the building body by utilising the natural processes of heat flow to the ambient atmosphere. As with the design of passive solar buildings where heating is the main concern, the implementation of passive cooling techniques is a multilayered process inextricably linked with the architectural design of the building in its environment.

Shading devices, window lattices for control of solar radiation and daylight, wind catches (malkaf), wing walls for ventilation, cisterns with wind towers, moist clay jars on air inlet of wind towers, damp porous water jars in front of ventilation openings for evaporative cooling and earth bermed spaces for mass effective cooling are all Passive Cooling components and strategies that have been used in traditional architecture in hot climates. Passively cooled buildings will utilize the steady state condition of the earth, cooling effect of removing water mass from a surface and wind to cool the spaces even in case of deficiency in wind velocity creating sufficient wind effect by the Sun.

3.4. Passive Solar Design Strategies in Conditioning of Buildings

3.4.1. Passive Solar Heating Systems

In architecture, Passive Solar Heating Systems mean energy-consciousness of a building from the point of consuming energy to provide thermal comfort to its occupants rationally. This means that architectural design should attempt to conserve, save and if possible generate energy as an essential ingrediant of common-sense design. Energy conscious opportunities are possible in all phases of a building, namely; planning, construction, operation and maintenance. In general, it is preferable to integrate passive solar heating systems into the fabric and structure of the building, especially where a new building is being designed. The importance of these opportunities varies with the type and scale of a project (Wright and Andrejko, 1982).

Three basic heat-transfer processes provide efficient operation of passive solar systems: **conduction**, **convection**, and **radiation** as mentioned before. Since the system uses the three processes naturally (not conventionally), namely not depending on or conforming to any accepted mechanical treatments, the integration of system with the fabric of the building is very important in terms of distance between collection component and space to be conditioned. A good passive solar design can stimulate air movement in a building by natural convection without the use of fans. However, some part of mechanical solutions can be used to encourage the flow of the conditioned air. Wright and Andrejko (1982) state that Passive Solar Heating Systems can be classified according to their physical configuration dividing into the three generic categories:

► **Direct gain** - heat is collected and stored directly in the living space.

► **Indirect gain** - heat is collected and stored adjacent to the primary living spaces and thermally linked (not visually) to them.

► **Isolated gain** - heat is collected adjacent to or apart from the weather-skin and stored either apart from or in the living spaces.

The primary elements to consider with each category include solar collection surfaces, thermal storage materials, heat distribution, and control mechanisms which will then be explained.

Before expanding these systems, it is essential to mention another important design strategies in passive solar building design (locational features). How the elements of climate analysis, energy-conscious planning, and passive solar design are molded into the most suitable building solution lie under the locational features, where the building will be constructed and contours of the ground, climatic conditions, and landscaping all considerably affect the satisfaction of a passive solar building. As mentioned before, shape of the building has also effect on this satisfaction. Additionaly, as a design approach, passive solar buildings often have "open floor plans" to facilitate the "thermosiphoning" movement of solar heat from the south side through the rest of the building. Sometimes small fans are used to aid in warm air distribution in spaces with "closed floor plans".

Contours of the ground: One of the most important features for the design of solar buildings is optimization of the site for appropriate solar orientation and wind use. Carter and Villiers (1987) point out that the best site for a passive solar building has attributes like direct sunshine during the winter and coverage from cold winter winds. A site that slopes to the south in the northern hemisphere, or to the north in the southern hemisphere often makes it easier to satisfy the requirements for solar design considerations to be taken in an energy-efficient building design. The physical properties of the site should be analysed for the decisions of energy-efficient design, for instance: hills around the building to be constructed will affect the solar exposure of the building, wind pattern of the site is also crucial for either winter protection or summer cooling, site slope has importance for solar exposure again. These characteristics of a site outh to be taken into consideration for energy-efficiency in a building design.

Landscaping of the site: Landscaping involves the deliberate change of the contours of the earth, and the planting of trees and other vegetation. This is normally done for esthetical aspects of outer spaces, but it can also play a major role in protecting the building from cold winter winds and from the hot summer sun (Carter and Villiers, 1987). Plants can be used effectively around a building to reduce energy consumption. Givoni (1998) lists effects of the plants on thermal performance of a building as: they can provide shading effect on the outer walls of a building, plants has the ability to reduce the temperature of ambient air of the building site, ground cover by vegetation reduces the reflected solar radiation around a building, when planted on east and west sides of a building they can ensure good shading effect for summer.

Deciduous trees planted on the south side of a building will block the Sun's light during the hotter months and lose their leaves during the cooler months, allowing sunlight to penetrate into the spaces. Use of their positive effects in a design will enhance the thermal conditions of the architectural environment.

Effects of climate: According to Markus and Morris (1980) climate and built form interaction made the ancient settlements' architectural environment climate-responsive and therefore livable and comfortable without developments in construction materials and technologies. Carter and Villiers (1987) state that passive solar design has something to offer in nearly all climates, but obviously the requirements vary. The main sense here is the climate-responsive design principles. It means that providing thermal comfort for any architectural environment by using native materials and energy-conscious design strategies in any climatic conditions outside.

Givoni (1998) states that there are four climatic effects roughly, and he defines some of design criteria for passive solar design of the buildings. To summarize them: for hot-dry regions, these regions are characterized by their aridity, high temperatures of summer daytime and big diurnal temperature fluctuations being between the latitudes of 15 and 30 degrees. The strategies for this climate are compact layout of building for high level of insulation, internal and attached courtyards for shaded areas, small windows for protection against dense summer solar radiation, light colours of the outer walls to decrease the absorbtion level and vegetation near the bulding as a moderator of climate.

For hot-humid regions, they are characterized by high level of moisture, high temperatures of summer, low temperature fluctuations in a daily cycle. The important design considerations in hot-humid regions are spread out layout of the buildings for effective cross ventilation, maximizing the rate of night cooling for preparation of the building for daytime in a cool state, having courtyards enclosed or semi-enclosed, and minimizing the solar exposures of the openings for reducing the heat effect of high summer radiation (Givoni, 1998).

Cold climates have the characteristics of uncomfortable cold winters and comfortable summers. In such regions the main design consideration in buildings is to minimize heating energy need by using passive solar heating strategies. Building insulation is other main factor for such climates. Compact layout will provide insulation. Also the winds are detrimental to thermal performances of the buildings in winters, special care must be taken for this negative effect. Buffer zones on northern facades will be needed to modify the outdoor climate (Givoni, 1998).

Cold winters and hot-humid summers are seen mostly between latitudes of 30 and 45 degrees. Including either cold or hot-humid characteristics, these regions are quite hard to design for energy-efficiency. With cold winters, the buildings will need to be heated by passive solar energy whereas they will need to be protected from solar radiation in hot summers. So when all passive solar design strategies are used, thermal performance of the buildings will be moderated to comfort level (Givoni, 1998).

Shape of the building: This subject plays an important role in designing a passive solar building. The architect, who is concerned about environmentally sensitive design, should form the building shape by also concerning the relationship between energy losses or gains and building shape. Creating a compact building form can reduce heat losses through the building envelope. The smaller the area of outside wall per heated volume, the less energy will be required to operate the building. Markus and Morris (1980) show in figure 3.3 and table 3.1 how the surface areas to the volume ratio changes with the variation of shape in size while all shape's volumes are the same. The igloos' domes are the samples of consideration of relationship between form and climate. They have maximum volume with minimum surface area, with this configuration of the shelter, its inner thermal comfort has been provided with candles.

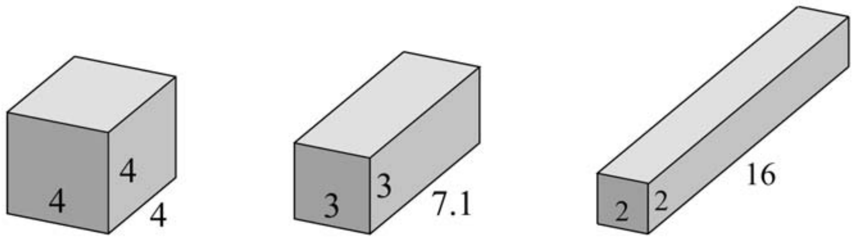


Figure 3.3: Different shapes with the same volume have different surface area to volume ratios (Adapted from Markus and Morris, 1980).

Solid shape type	Surface area	Volume	Surface / Volume ratio
a	96	64	1,5
b	103,2	64	1,61
c	136	64	2,13

Table 3.1: The more compact shape a building has the less surface area it will have (Adapted from Markus and Morris, 1980).

As a conceptual layout and thermal zoning of the building, unheated spaces should be placed on the northern sides as much as possible. For instance: storages, service areas, garages, and lower temperature requiring spaces such as bedrooms, staircases, entrances, and corridors are also possible to be placed on the non-solar direction (The European Passive Solar Handbook, 1992). Generally, there are some components that have vital importance to the passive systems. These are: Solar apertures and thermal storage materials.

Solar Aperture: They are the surfaces that solar beams can enter through. The building elements such as windows and skylights can be defined as solar apertures provided that they are oriented towards the Sun. As a result of orientation, solar beams are cought and used to provide heat by means of other solar components (thermal masses and storage units). In general, the larger the solar aperture provided that properly oriented the greater the solar gain. But larger is not necessarily better; too large a solar aperture can cause either overheating or a wasteful venting of collected solar heat. It can also increase heat loss at night due to high thermal conductivity of aperture materials.

Thermal Storage: Thermal mass is the amount of potential heat storage capacity available in a material. In a building, materials with a high thermal mass value include a concrete slab with a tiled floor, brick, stone or earthen walls, or even water tanks. When positioned correctly inside the house, thermal mass can store heat during the day in winter, and re-radiate it at nighttime. The components that can absorb, storage and then release the solar heat into the building are: masonry walls, brick walls, concrete floors, water containers that have dense-mass effect. They also have other important ability of stabilizing the interior heat. During the day, when there is excess solar heat, the thermal mass absorbs the excessive heat to prevent overheating. At night, the thermal mass releases the heat to keep the building warm. Thermal mass prevents the temperature fluctuations in the space during this daily cycle.

As it can be observed, virtualy, every building has some passive effect with their solar apertures and thermal mass materials. But to increase the efficiency of these systems, it is necessary to have some requirements mentioned before in a manner that they will contribute achievements of thermal comfort of the buildings. In the following section, passive solar design strategies: direct, indirect and isolated gain methods are going to be expanded in detail.

Direct Gain Systems

Direct gain Passive Solar Design has the meaning of no having visual obstruction between outside and inside of a space to be heated while admiting the Sun's beams through. The solar beams are allowed to penetrate into the building's inner surfaces by means of solar apertures, and then absorbed by the mass of inner surfaces lastly, distributed to occupied spaces by means of natural heat transfer phenomenon. In this system, the actual living space is a solar collector, heat absorber and distribution system. And the most important character of this system is that an occupant can experience all the processes of solar heating from collection to distribution of the solar heat. Figure 3.4 and 3.5 show working principle of direct gain systems in a winter day.

South facing windows admit solar energy into the house where it strikes directly and indirectly thermal mass materials in the house such as masonry, concrete and brick walls and floors. Paul (1979) mentions the components that are in direct gain systems as south facing glazed surfaces and thermal mass. Most direct gain buildings include: large, south-facing windows to admit winter sun, thermal mass inside to store and reduce temperature swings and distribute the gained heat by radiation and calculated overhangs above the south facing glass to shade the building in summer time preventing from overheating. He defines the spaces that have such passive direct components as a sort of 'live-in solar collector'.

In a direct gain system, sunlight is admitted directly to the interior through south-facing glazing. It strikes massive interior surfaces of occupied space, is absorbed and is converted to heat. Some of the heat from the surface is immediately released back into the room interior by convection and radiation. The remainder of heat absorbed is conducted into the thermal mass, which slowly warms up; later, at night, the stored heat is released back to the occupied space. As glass is opaque to the short-wave beams of the sun, this reradiated heat, which has long-wave beams, is trapped by the familiar greenhouse effect.

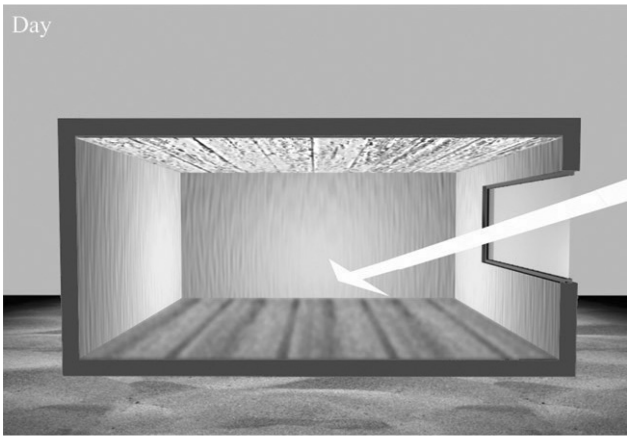


Figure 3.4: Thermal mass in the interior absorbs the solar radiation through the solar apertures during the winter day.

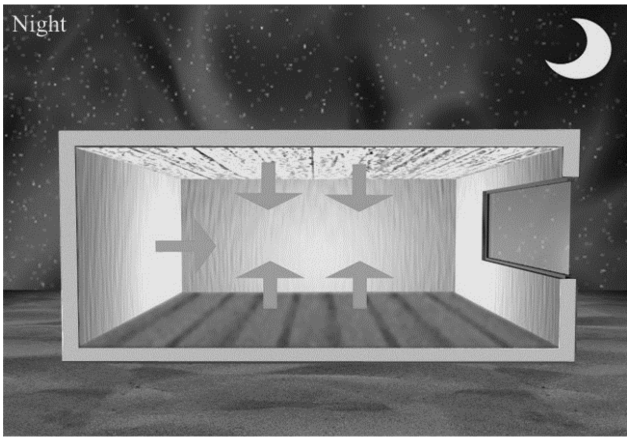


Figure 3.5: Thermal mass reradiates the collected heat to occupied space at night.

The thermal mass is crucial for an effective operation in direct gain systems. While the large amount of solar radiation admitted during the day, if only lightweight surfaces were available to absorb heat, the temperature of these would rise rapidly causing to overheat the occupied space, necessitate venting excess heat to outside to maintain comfort and high temperature fluctuations during daily cycle. Moore (1993) mentions the basic requirements for a direct gain system as a large south facing glazed aperture with a living space directly behind, and solar-exposed thermal mass in the ceiling, floor or walls. Many modern buildings have large south-facing windows, but it is often lack of appropriate thermal storage or conversily, commercial buildings with large areas of glazing can suffer from excessive solar gain due to inadequate shading devices, and require additional cooling mechanisms.

To make these systems more efficient, double glazing can be used. However, this is different from double glazed insulating glass. Having two surfaces of glass, solar apetures becomes a kind of heat wall. Atagündüz (1989) explains the principles of this system that it has higher temperature in between than inner and outer temperature during the day. In literature, the systems that prevent heat flow from one space to the other due to higher temperature of all are called a kind of insulation system (heat barrier). Figure 3.6 and 3.7 show the differances between two glazing systems.

To add to the efficiency and the usefulness of direct gain design and other passive systems, several conditions should be considered (The European Passive Solar Handbook, 1992). The shading devices should be used to prevent excessive solar gain in summer. Addition to this, in direct gain systems, heat loss from the large glazing area is high, and if it is not appreciated, heat loss occurs from aperture appreciably. It is important to conserve energy as much as possible in a passive solar heated building. Unwanted heat loss at nights in winter can be saved by means of insulation panels behind the glazed surfaces. And also, curtains and shutters are effective in preventing heat loss. Direct gain systems have some advantages: according to Paul (1979), it is the simplest solar heating system and can be easiest to build. The large areas of glazing not only admit solar radiation for heating but also allow high levels of natural daylighting and good visual connections to the outside.

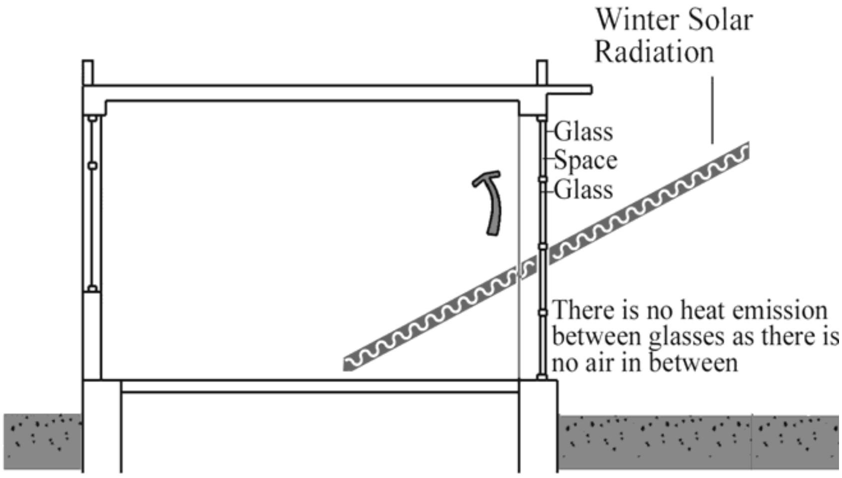


Figure 3.6: In insulating glazing, there is no effective passive gain. Because there is no air and no sufficient distance between glasses. System is more efficient for energy savings.

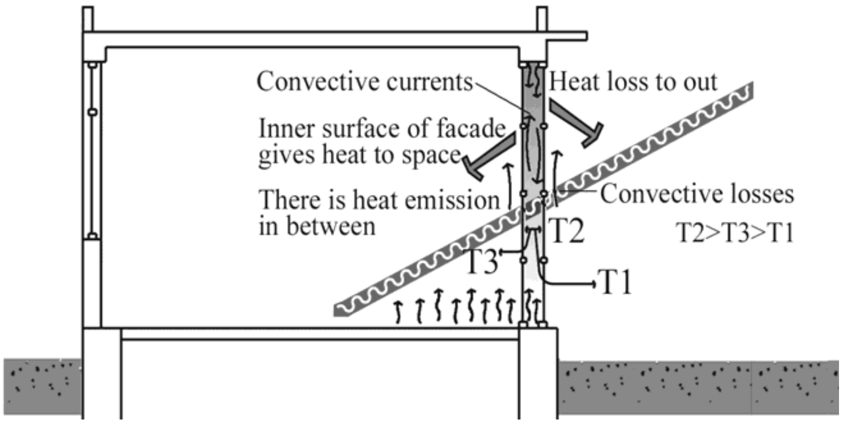


Figure 3.7: Double-glazing has the advantage of air presence between the glasses. While the sun's beams is passing through the glazing, some of them are captured in between and converted to heat, so the air space becomes heat generator. As this space has the highest temperatrature of all, it does not let heat transfer occurs from inside to out. Additionly, it gives heat to inside.

Glazing has been well researched, beside good visual connection to the outside; when properly chosen, sized and placed the windows can contribute to reduce the need for heating and artificial lighting in a building. Therefore, glazing also includes the energy saving features. Hovewer, Doğrusoy (2001) warns that unless the windows for the natural lighting and visual connections between inside and outside are designed in the direction of proper sizing, they can make the cost of heating and cooling higher than the benefits from the artificial lighting. She determines that there are some available advanced technologies in material glass such as reflective, selective, low-e coatings, and more advanced ones with electrochormic, thermochormic and photochormic coatings windows that can remove the dilemma between the natural lighting and excessive heat loss or gain due to the Sun. They can obstruct the unwanted wavelenght from entering into the space while allowing desired ones to penetrate. On the other hand, care should be taken that large glass areas can result in glare by day and loss of privacy at night.

To summarize, direct gain design strategies can be achieved just with true fenestration. The larger the aperture the greater the thermal mass will be needed to moderate temperature fluctuations which can be expensive if only the mass serves this thermal purpose. Conversly, it will be effective in case of contributing to the building's load-bearing structures. Because of this close relation with the fabric and structure of the building; spatial organisation, materials and fenestration are important in conceptual phase of the architectural design for using passive direct gain systems.

Indirect Gain Systems

Indirect gain passive solar design differs from the direct method with one buffer that impedes penetration of solar beams into the occupied space directly. There are some indirect gain system components; Paul (1979) defines them as thermal mass walls, trombe walls, water walls, and sunspaces separated from main space by a thermal wall, roof ponds, and convective air loop systems. These are all indirect gain systems that combine the collection, storage, and distribution of solar heat in the building's envelope, which covers the space to be heated (The European Passive Solar Handbook, 1992). In this system, solar beams are collected first, then absorbed by a thermal mass, and then some of the collected energy is released to warm the space by natural convection, the others are conducted through the thermal mass to heat the space by radiation at non- solar time. Integration of these systems within the building is related with resistance to the natural flow of heat.

Some of the system used are placed in the occupied space, rest of them are placed remote provided that convection occurs naturally. Following is brief explanations of the components to be used in indirect gain Passive Solar Design:

Thermal Mass Wall: In the thermal mass wall system, the thermal storage mass for the building is a south-facing wall of masonry or concrete construction with the external surface glazed to increase solar gain and reduce heat losses to the outside (The European Passive Solar Handbook, 1992). They have usually dark color on the glazing side to absorb solar radiation effectively. Figure 3.8 and 3.9 show a thermal mass wall and living space organisation with seasonal operation of it.

Solar radiation falls on the mass wall first then absorbed causing the surface of the wall to warm up, then transferred to the inner surface by conduction, this transfer requires time lag depending on the material's properties and distributed to the space behind it by radiation and convection. The time lag for arriving of heat at the space in this transfer depends on the type and thickness of the storage material. Thickness of the wall here is important in terms of time delay in conducting the heat through the wall. According to Moore (1993), it is possible to optimize the thickness of the wall so that the maximum heating effect is delayed to an evening time when the greatest heating is needed. For instance, a 12-inch-thick masonry wall delays the maximum midday solar heat until just before bedtime. The only requirements for the thermal mass wall systems are a large south-facing glazed collector area, with the thermal storage capacity of a mass wall directly behind the glazing.

In thermal mass wall systems, as there are no vents for air circulation on the wall, the maintenance and operation of the system are very easy. The only requirement is shading devices or openable glazing for summer shading. However, they are poor and vulnerable to cool air, they can loss heat easily as there is no insulation on the wall because of the system requirement. Special care should be taken against this problem, movable insulation panels out of glazing or insulating curtains between glazing and the wall are effective solutions.

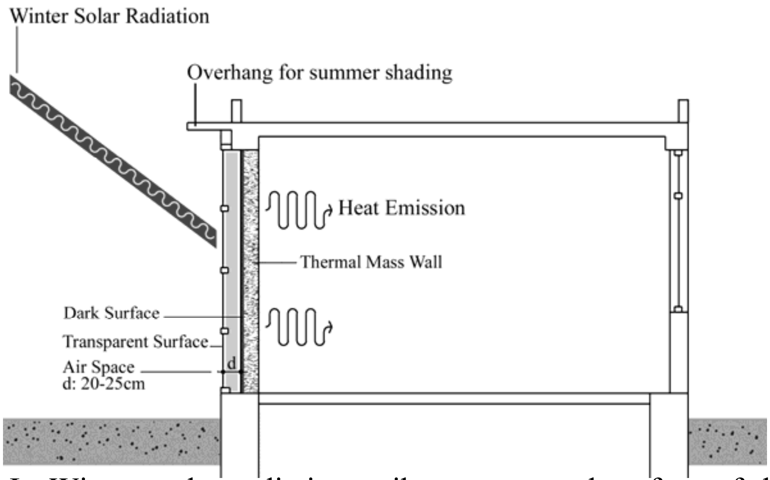


Figure 3.8: In Winter, solar radiation strikes to external surface of thermal mass wall due to low sun altitude, and heats up the mass during the day. At nights, stored heat is emitted to occupied space by radiation.

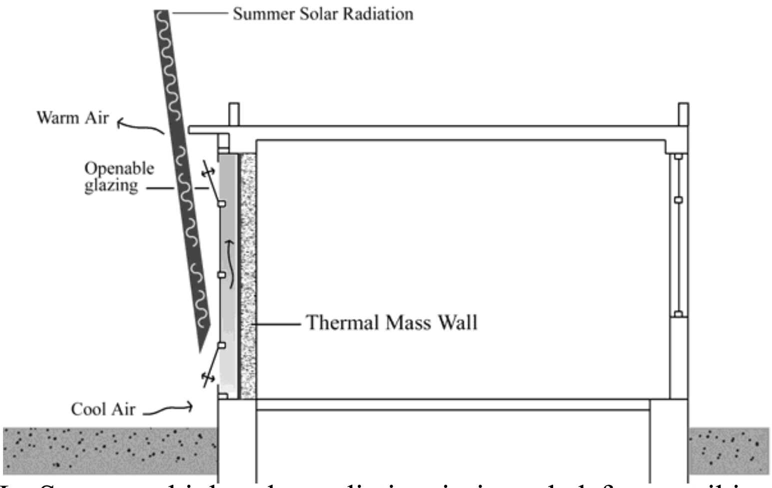


Figure 3.9: In Summer, high solar radiation is impeded from striking to external surface of thermal mass wall by shading devices or vegetation. So, the sun doesn't heat the mass wall, and mass of the wall is cooled by convection opening the vents top and bottom of the glazing.

Trombe Wall: The difference between a Thermal mass and Trombe wall is that the latter has vents top and bottom to allow air to circulate through the occupied space rapidly. Felix Trombe and Jacques Michael at Odeillo in France named the trombe wall system after the pioneering work of Professor Morse. He first proposed it in 1881 (Paul, 1979). Tromb wall allows the distribution of the collected heat by natural convection circulating the solar heated air through the vents top and bottom of the wall. Moore (1993) defines that if one of the advantages of thermal mass wall is its thermal stability, one of the related disadvantages is that they are sluggish requiring a long time to warm up in the morning after a night without sunlight. So, trombe wall system has the advantage of warming up the space in early mornings due to vents.

Operation schedule of a trombe wall is very important in terms of seasonal usage. In trombe wall system, if the vents are left open at cool nights; the reverse circulation effect happens causing loss of inner warm air. To prevent this effect, vents that are at the top should be closed at nighttime in heating season. In summer operation, all vents should be kept closed to prevent convection mean, and a shading device is required so that the solar beam cannot strike the storage mass, preventing heat gain by conduction. Addition to this, openings on the glazing surface should be also kept open in summers to make intervening air circulate to the outside cooling the outer surface of thermal mass wall by convection.

Moore (1993) agrees with The European Passive Solar Handbook (1992) that this system has some architectural advantages and disadvantages and he states them: glare of sunshine and privacy are not a problem as the storage wall blocks the solar beams and direct visuality between inside and outside. Because the control of solar gain is maximum, degradation of fabrics of inner furnitures by harmful solar beams is conserved. Temperature swings are lower than direct gain system and it is not necessary to use mass effective material in occupied space as solar beams cannot penetrate inner surfaces. However, the system impedes the visual relation between outside and inside strictly. To moderate this, they can be designed as partly opened. Figure 3.10 and figure 3.11 show working principle of Trombe walls. They can have maintenance problem, as the intervening space is quite narrow (20-25 cm). To avoid this circumstance, the glazing can be produced collapsible partly. This also effects the system in terms of its cost.

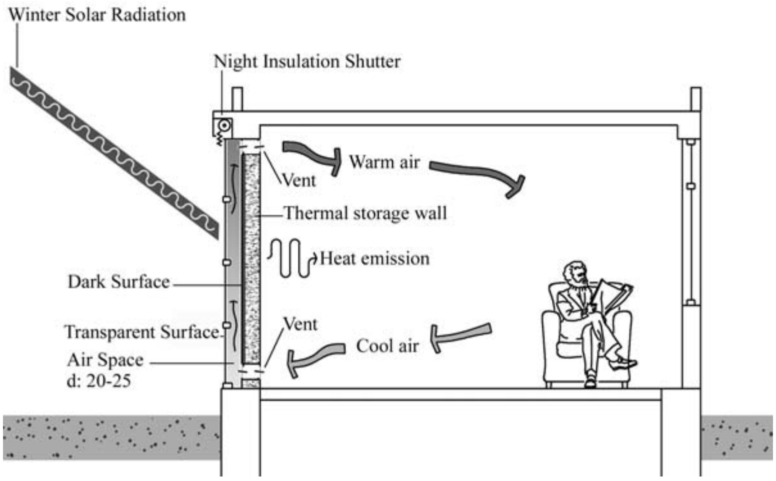


Figure 3.10: Low winter solar radiation strikes to Trombe Wall and heats the air. Heated air becomes buoyant then starts to rise up making circulation between space air and trombe wall air via vents during the day.
At winter nights, vents and glazing insulation ought to be closed to prevent the air from reverse circulation that will otherwise cause to lost of heat to cool night sky.

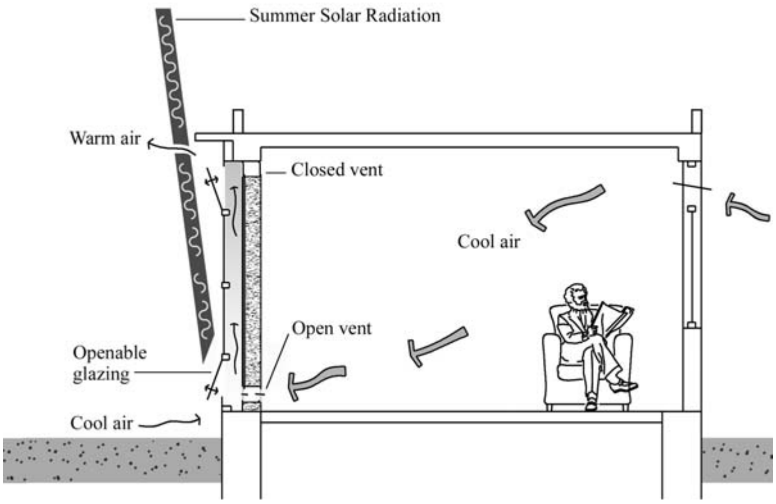


Figure 3.11: High summer solar radiation doesn't strike to Trombe Wall due to shading devices. The air in between gets warmer because of ambient reflecting radiation then starts to rise up making circulation between trombe wall air and outer cool air via open glazing vents during the day. Space ventilation can be achieved opening the upper glazing vent and bottom Trombe Wall vent so that space air can be sucked by stack effect.

Water Wall: The water wall is similar to the thermal mass and trombe wall systems except that contained water replaces the solid wall. Water walls may be an attractive system where low-mass construction is required. Moore (1993) defines the working principle of the system as water walls transfer heat through the walls as a result of convective circulation of the water while Trombe walls do this by conduction. Because water has a greater capacity to store heat per unit volume than brick or concrete and because convection currents within the water cause heat to transfer in water by conduction and convection increasing the efficiency of the system, thermal performance of a space can be achieved at highest levels with this material. But they cannot contribute load bearing structure of the building causing extra cost. This is the most important obstruction of the system to use. As a result of convective circulation within the container, the water is constantly being mixed and the temperature is virtually the same from one side of the wall to the other. This also causes the effect of heat absorbed on the solar side of the container to be felt immediately on the room side of the container, namely there is no time lag in transferring process as do Trombe walls.

The water wall system must also have a large south-facing glazed area on the outside of the contained water storage. The water may be contained by various methods affecting the heat storage capacity and the speed of distribution of the stored heat. Containers made of metal or glass in the form of tubes, bins or drums have all been used. However the water wall systems must have special construction in use of other systems such as Transwall and Phase Change Material (PCM) (The European Passive Solar Handbook, 1992). And these systems may not be economic as well as the others. Additionally water wall systems have no constructional contribution to the building structure. So this is the most important disadvantage of the system.

Sunspace, Greenhouse or Conservatory: All these names have almost the same meaning, the attached sunspaces, greenhouses or conservatories consist of a glazed enclosure on the sun facing sides of the building. Cofaigh et ell. (1996) explain that use of sunspaces in architecture appears under different names: winter garden, conservatory, orangery, summer room and glazed balcony. It is a very popular direct and indirect gain strategy for heating of the buildings. If there is a common wall, having thermal storage capacity, obstructing visual link between sunspace and main space, the system is called as indirect one if not as direct one. Henceforth, the system will be called as sunspace.

This space has some architectural aspects with its large glazed and extended area to the outside or its specious outdoor feeling. Depending on the climate and the way in which the sunspace is used, there may be different design strategies that are important to consider. In the indirect gain systems, it is used with a common wall, as the concept of indirect system is to preserve occupied space from direct solar beams. If a building is planed to include a sunspace in its design, designer should first decide on the primary function of this space. The design considerations for a food-growing sunspace, a living space and a supplementary solar heater are very different, and although it is possible to build a sunspace that will serve all three functions, compromises will be necessary. To consider the architectural design of this system, the architect should get in touch with the users of such a building that will have sunspace in its plan. So it is necessary to mention the possible aims to use this space in a building. Usage alternatives of sunspaces include the followings:

► For instance, a sunspace can be a comfortable and healthy home for plants. In this case, plants will need fresh air, water, lots of light, and protection from extreme temperatures. And to stay healthy and free of insects and disease, plants need adequate ventilation, even in winter. Sunspaces will consume considerable amounts of energy through evapotranspiration and the evaporation of water in such a use. So, although it gets solar gain, it will be an energy consumer for the suitable levels for plants. Additionaly, the system may be an expensive one as the function of the space is to provide adequate light for plants beside the energy gain for the building. This will call for overhead glazing, which complicates construction and maintenance, and glazed end walls, which are net heat losers. The bottom line in terms of energy efficiency, however, is that a sunspace designed as an ideal horticultural environment is unlikely to have any energy left for supplementary space heating. Figure 3.12 and 3.13 show the working principle of the sunspaces.

► If the purpose of the sunspace is to collect solar heat and distribute it effectively to the space, designer is faced with a different set of design criteria. The primary purpose of the sunspace as a solar heating system is to deliver heat to the adjoining rooms; this may be by conduction through a masonry common wall or by natural convection via openings (doors, windows, or special vents) on it.

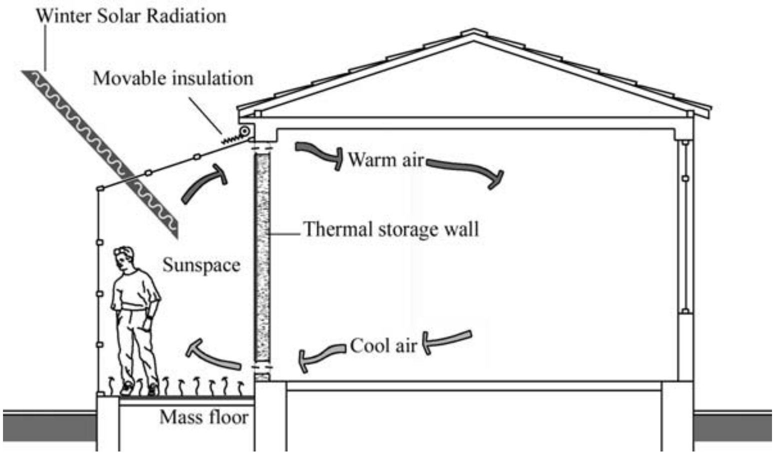


Figure 3.12: Thermal storage materials in the sunspace collect heat during the day, and collected heat is distributed to occupied space by vents and openings on the common wall.
At winter nights, all vents and openings ought to be closed to prevent heat losses through the glazing of sunspace.

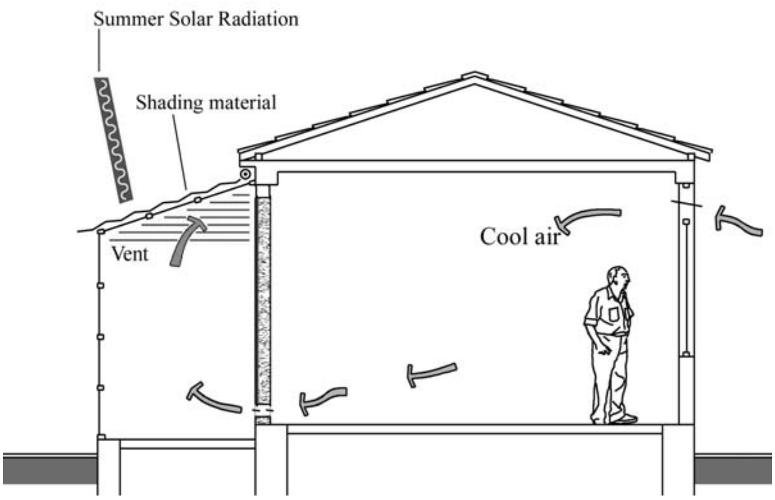


Figure 3.13: In summers, sunspace ought to be impeded from direct solar beams by using shading devices and ventilated by opening some part of the glazing of sunspace as far as possible.

In this case, the sunspace resembles a trombe wall system (Moore, 1993). Maximum gain is achieved with sloped glazing, few plants, and insulated, unglazed end walls. The system will get more usable heat into the living space if there aren't plants and lots of mass soaking it up in the sunspace. Sun-warmed air can be moved into the house through doors or operable windows in the common wall, as well as blown through ductwork to more remote areas.

► If the sunspace will be an additional living space, designer will need to consider comfort, convenience, and space furniture in addition to energy efficiency. A room planed to live in must stay warm in the winter, cool in the summer, have minimum glare levels, and moderate humidity for achievement of environmental control. This space can be a sitting space, dining space, or a space for lesiure time activities according to the weather and the inclination of the users. Vertical glazing is the choice of increasing numbers of designers for a variety of reasons. First of all, although sloped glazing collects more heat in the winter, it also loses significantly more heat at night, which offsets the daytime gains. Sloped glazing can also overheat in warmer weather, usually the spring and fall, when the solar access is not wanted. The performance of a vertical glazed south wall more closely follows the demands of heating degree days, heating effectively in winter when the angle of the sun is low and allowing less solar gain as the sun rises towards its summer zenith.

A sunspace designed for living requires carefully sized thermal mass, if the masonry floor and wall mass are the only thermal storage materials in the space generally, three square feet of masonry surface per square foot of south glazing is the recommended ratio. If water in containers is the only heat storage medium used, the recommended ratio is three gallons per square foot of glazing, and, as mentioned earlier, special care must be taken to assure that the sun can get to the mass. According to Roaf et al. (2001), sunspaces can exceed the the performance of any other passive solar heating systems having the same area of sun-facing wall. They can serve multiple functions working in many different ways. On sunny winter days, sunspaces collect solar energy for space heating and they act as a buffer space at nights and during non-solar days reducing the heat losses. However, to minimize nighttime losses and maximize comfort level movable glazing insulation should be used.

Isolated Gain Systems

In isolated gain systems, collection and storage of the solar energy is thermally isolated from the occupied space. In other words, occupants cannot experience the process of solar heating. There is no radiation from the inner side of the collection wall to the space whereas it is possible the storage wall to radiate heat into the occupied space.

The most common of these processes for transferring energy from the collector is the particular form of natural convection known as thermosiphonic loop. Air is heated in the collector first, becomes buoyant and rises drawing in cooler air from below. The warmer air transfers its energy to remote storage or to the room. These systems may be appropriate in retrofit projects because of its additional feature (The European Passive Solar Handbook, 1992). However, it may not be seen easy to apply this system in existing buildings, it requires some components unlike direct or indirect ones in terms of storage. Generally, the storage is rock and it is placed under the space or behind the collector directly.

This system is freer of architectural integration whereas direct or indirect ones include architectural elements more strictly. In isolated systems, only the storage unit needs to be integrated close to the spaces in terms of heat flow requirements of passive solar design. This means, it should achieve all the processes by natural means without any mechanical systems. Figure 3.14 and 3.15 shows different alternatives of combination of collection and storage units.

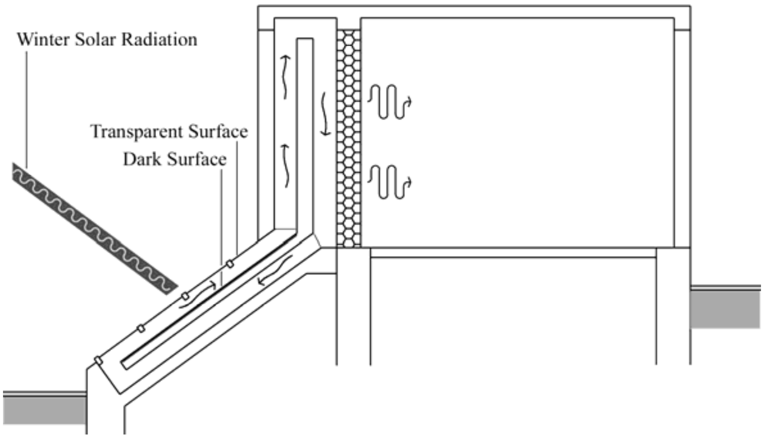


Figure 3.14: The collection unit may not be the structural element of the building. However, the storage and distribution system are integrated within the building, as in this figure, storage wall is also building's element.

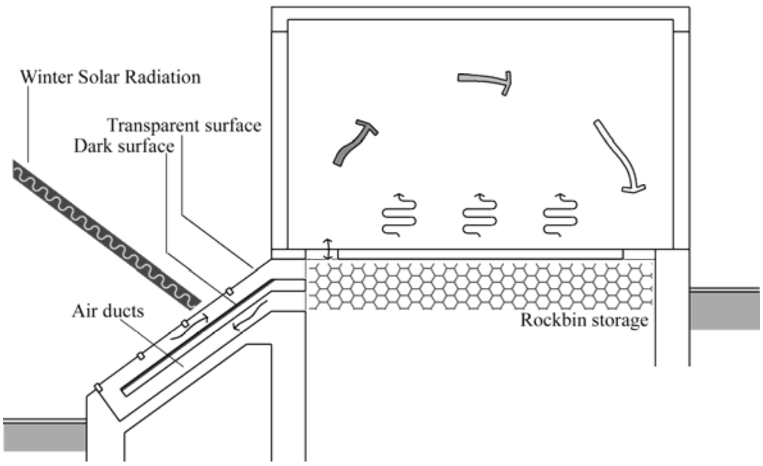


Figure 3.15: The air heated in the collection unit circulates by means of thermosiphoning effect warming the rockbin storage that is commonly used in passive solar houses. Then stored heat turns to the occupied space at night.

3.4.2. Passive Cooling Systems

Normally, buildings are conditioned to supply a comfortable environment for the occupants. This process involves heating, cooling, humidifying, dehumidifying or ventilation. Cooling is an important element from the point of energy economy in developed countries, with air conditioning causing peaks in electricity use on summer days. If passive cooling and passive solar technologies can be utilized to cool the buildings, it will decrease the demand of electricity use for the cooling of buildings. Beyond this, with a combination of solar heating and passive cooling will be in most places more economical than heating or cooling alone and will be celebration of logic and beauty in terms of architectural design (Swartman, 1979). There are four types of passive cooling for the buildings: Ventilative, Radiative, Evaporative, and Mass effective cooling methods.

Passive cooling techniques can be used to reduce, and in some cases eliminate, mechanical air conditioning requirements in areas where cooling is a dominant problem. According to the European Passive Solar Handbook (1992), there are many options available to the designer for cooling domestic and non-domestic buildings which can help to avoid the use of mechanical air conditioning while achieving comparable comfort levels with much lower energy use and consequent savings in atmospheric pollution. Useful design strategies for the overheating season are to first control the amount of heat from solar radiation and preventing heated ambient air reaching the building, then to minimize the effects of unwanted solar heat within the building skin (The European Passive Solar Handbook, 1992). There are three major sources of unwanted summer heat: direct solar impacts on a building through windows and skylights, heat transfer and infiltration of exterior high temperatures through the materials and elements of the structure, and the internal heat produced by appliances, equipment, and inhabitants.

Of the three, the first is potentially the greatest problem, but it is usually the easiest to control. In a passively cooled building, this problem is overcome by using sun control devices. The European Passive Solar Handbook (1992) states that typically, shading devices are used in two directions: horizontal or vertical. Fixed shading devices are most commonly used on the external facades where they can prevent direct radiation from reaching glazing or other openings. If placed internally, heat will build up between the shading system and the glazing thus reducing the efficiency of the system by nearly 30%. Following, as an essential theme, heat gain control is going to be expanded then passive-cooling strategies will be expanded in more detail.

Heat Gain Control: Many of the principles and techniques of passive solar heating are adaptable to passive cooling. Insulation and weather-stripping that prevent heat loss in winters will also retard heat gain during summer. Movable insulating shutters for winter nighttime saving of heat gained can also be used to reduce summertime daytime heat gains. Firstly, heat gain control should be considered in passive cooling intended buildings.

Inside the building, thermal mass such as masonry, concrete or brick walls and floors act as "heat sponges", absorbing heat and slowing internal temperature rise on hot days, and can be cooled down by nighttime ventilation and using mechanical cooling during off-peak cost hours (nighttime). Suitably placed near a window, skylight, or vent, the same thermal mass can be exposed to cool night air to release the heat absorbed from the space earlier in the day. And earth integrated buildings, embedded into the ground, benefit from the lower difference between interior and exterior surface temperature. Mitigation of undesirable summer direct sun and thermal impacts is achieved through use of vegetation for instance: deciduous trees which interrupt the summer sun's direct path, and ground covers which prevent ground reflection as well as keep the earth's surface cooler thereby preventing re-radiation.

Glazing should be minimized on the roof and the east and west walls where summer sunlight is most intense. The summer sun is much higher in the sky and has a negative impact on skylights and roof windows and lead to enormous solar heat gains. They should not be used in hot climates unless they are insulated and/or shaded. A horizontal overhang or an awning above a south window is an inexpensive and effective solution. Another good strategy is to use of deciduous trees that shade the south face and roof during the summer. All these shading methods work equally well with Trombe walls, water walls, greenhouses, and other south-wall passive solar gain strategies.

Mitigation of heat gain for the roof and the east and west walls requires a different approach. Since the sun is low in the horizon during sunrise and sunset, horizontal overhangs are not effective for solar mitigation and vertical shading is in order.

Vegetation is perhaps the most effective way of keeping the intense morning and afternoon sun off the east and west walls and windows, but care must be taken to avoid blockage of nighttime summer breezes that can be part of the diurnal cooling strategy. If vegetation is impractical, a combination of tinted or reflecting glass and exterior shades or shade screens that roll down over east and west windows can be effective strategies. Additionally, light-colored paints and materials on the roof and the walls are effective in reflecting away most of the sunlight in hot climates.

Ventilative Cooling:

The main concept of ventilative cooling is to carry heat away from the building and human body by using air. Air movement may be induced either by natural forces or mechanical power. But in passive systems, the considerations of thermal comfort should be integrated into the building's fabric and its architectural design without relying on any mechanical devices. The European Passive Solar Handbook (1992) points out that natural ventilation can produce a significant cooling effect, depending on the configuration of the building on the site and the surrounding spaces and according to it, the layout of internal spaces in plan and section according to function is important for air movement and the potential for cross ventialtion. The distribution of openings on the building facade (fenestration) is a key issue for efficient natural ventilation. Air flow patterns are the result of differances in the pressure distribution around and within the building. Ventilating a building provides air exchange between the inside and outside, this overall ventilative replacement of warmer inside air with cooler outside air is the source of building cooling.

Understanding Airflow and Ventilation Strategies: Air moves between different pressures and spaces, in order to provide enough ventilation to clear and cool the exhaust air, it is necessary to understand some basic principles of airflow around the objects. The more proper the openings ordered the greater air flow occurs in the spaces. In passive ventilative cooling, inlets' and outlets' position in the spaces are important to provide adequate air flow. The European Passive Solar Handbook (1992) showed in the following figures how air flow moves in and around the spaces in terms of placing of openings on the facades.

► If the wind is parallel to the openings, no significant movement occurs within the occupied space. When inlets and outlets are aligned with the wind, the air flow is short circulated (Figure 3.16). If the wind is oblique to the openings, the air flow circulates in the entire building (Figure 3.17). When the direction of wind is paralel to the openings, there is almost no airflow through the openings (Figure 3.18).

► The vertical position of inlets is important in maxsimizing the airflow through the lower, occupied portion of the room. The high inlets is the best for cooling, and outlet location has little effect on air flow in the space (Figure 3.19). High inlets and outlets do not generate a strong air velocity in the occupied zone and are thus less suitable for occupant cooling (Figure 3.20). Openings at body height generally offer good cross ventilation (Figure 3.21). When the building is too deep to offer cross ventilation, roof openings may be used to encourage airflow (Figure 3.22).

► Cross ventilation can be further enhanced by placing two outlets on the building's sidewalls. Doing this, it is assured to create different air pressure regions far each other for ventilative flow of air (Figure 3.23, 3.24, 3.25, 3.26).

► If the room has apertures on adjacent walls, wingwalls can considerably enhance cross- ventilation constituting high differences between pressure regions. On the other hand, wingwalls modify the initial flow within the space. Cross ventilation is often optimal if a room has three openings on different facades. Unfortunately, this configuration is rare as most rooms have only one external wall. In that case of two windows being placed on the same façade, ventilation can be improved placing them as far apart as possible and using wing wall between them to increase pressure difference (Figure 3.27, 3.28, 3.29, 3.30).

Both the design of the building itself and its surrounding spaces can have a major impact on the effectiveness of natural cooling (The European Passive Solar Handbook, 1992). Apart from openings, some application can be integrated into the building design for ventilative cooling such as wind towers, solar chimney that have been used in ancient civilazitions. They are effective to cross ventilation of the building and should be considered as the main source of airflow.

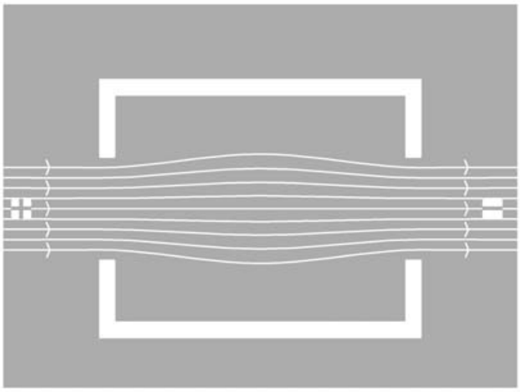


Figure 3.16: When inlets and outlets are aligned with the wind, the air flow is short circulated.

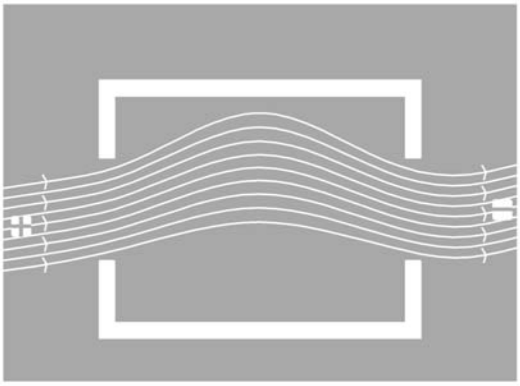


Figure 3.17: If the wind is oblique to the openings, the airflow circulates in the entire building.

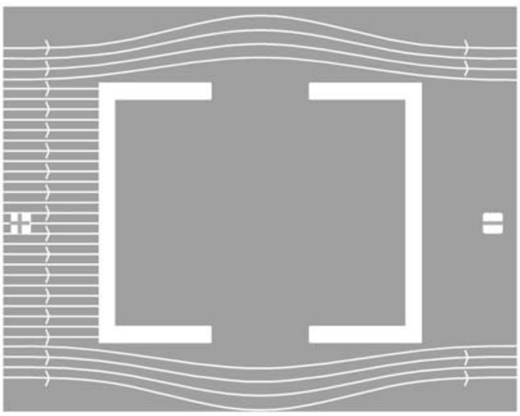


Figure 3.18: When the direction of wind is paralel to the openings, there is almost no airflow through the openings.

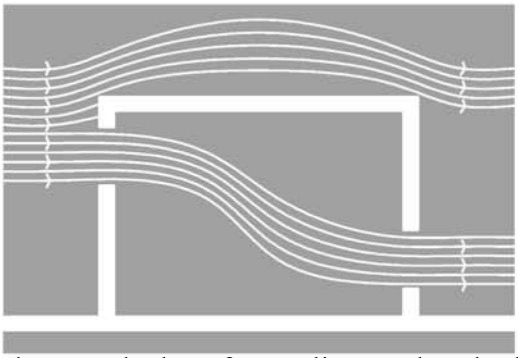


Figure 3.19: The high inlets are the best for cooling, and outlet location has little effect on airflow in the space.

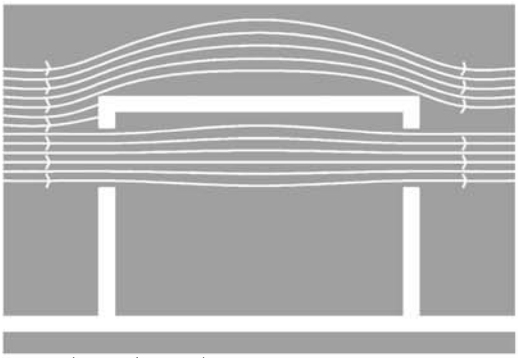


Figure 3.20: High inlets and outlets do not generate a strong air velocity in the occupied zone and are thus less suitable for occupant cooling.

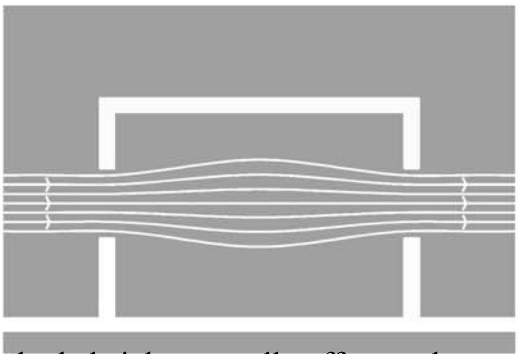


Figure 3.21: Openings at body height generally offer good cross ventilation.

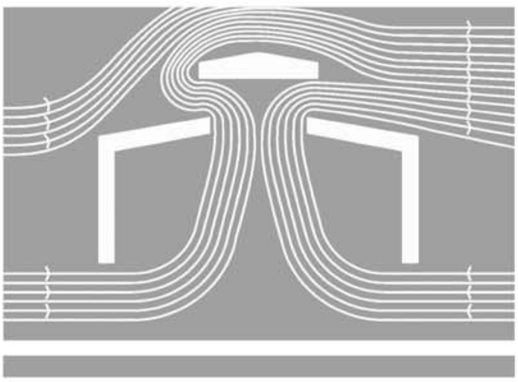


Figure 3.22: When the building is too deep to offer cross ventilation, roof openings may be used to encourage airflow.

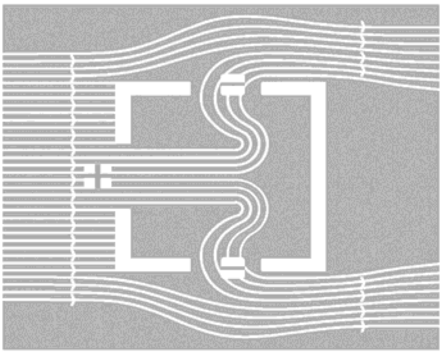


Figure 3.23: Cross ventilation can be further enhanced by placing two outlets on the building's sidewalls.

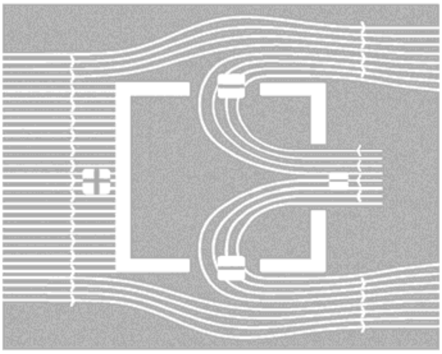


Figure 3.24: Placing outlets on building's sidewalls, it is assured to create different air pressure regions far each other for ventilative flow.

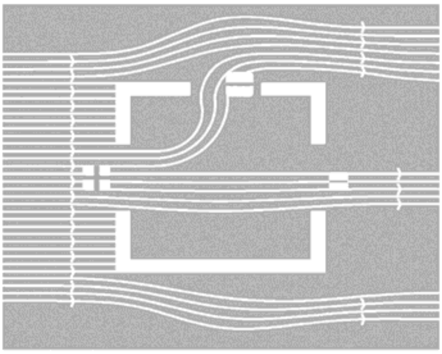


Figure 3.25: Long circulation of air flow can be provided by opening the side walls.

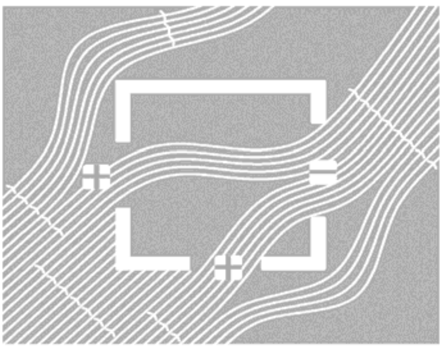


Figure 3.26: Achievement of cross ventilation is cricual for sufficient air flow, so place of openings has determinant effect on this kind of cooling.

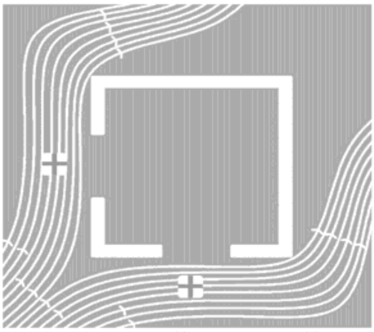


Figure 3.27: If the room has apertures on adjacent walls, wingwalls can be used for cross- ventilation.

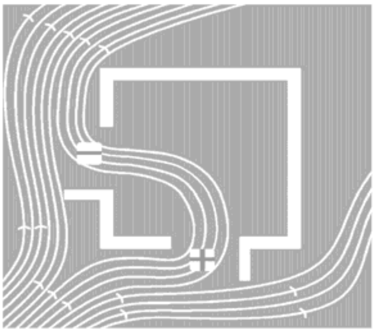


Figure 3.28: Placing wingwalls on adjacent walls can considerably enhance cross-ventilation.

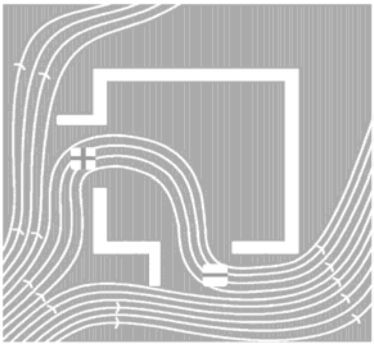


Figure 3.29: Wingwalls constitutes high differences between pressure regions.

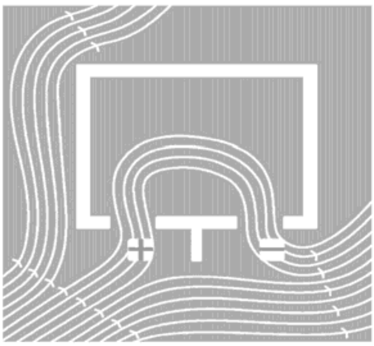


Figure 3.30: In case of two windows being placed on the same wall, ventilation can be improved placing them as far apart as possible and using wing wall between them to increase pressure difference.

Wind Towers: Wind Towers or 'Baud-Geers' or 'Malkaf' are mass structures such as masonry or concrete that are used to provide ventilative cooling in a space catching the prevailing or any wind. Wind Towers draw upon the force of the wind to generate air movement within the building. The wind-scoop inlets of the tower, oriented toward the windward side capture the wind and drive the air down the chimney. The openings on top of the tower may be directed in all or only predominant wind directions. It is important to know wind towers are for summer use only, if not left out of work exactly in winter days, they can considerably increase the infiltration heat losses (Swartman, 1979).

► When there is no wind at night, the wind tower acts as a chimney. The tower walls that have been heated during the day transfer heat to the cool night ambient air.

► When there is a wind during the night, the air circulation is in the opposite direction that described. And the walls of tower are cooled by cooler outside air.

► When there is no wind during the day, the tower operates as the reverse of a chminey. The hot outside air is cooled by the walls of tower that have been cooled at the previous night and pulled down to the passages.

► While there is a wind in day time, the air circulation and rate of cooling are increased, and this cool air can reach far distances. Figure 3.31 shows operation of a wind tower in summer, air flow during the day (1) air flow during the night without wind (2).

There are lots of wind tower designs that can be used in passive systems and they can be easily varied in terms of their heights, openings, and cross-sections for the airflow passages. Figure 3.32, 3.33 and 3.34 show different wint towers from traditional buildings. Figure 3.35 and 3.36 show schematic airflow diagram of wind towers.

Solar Chimney: Solar chimneys use the sun to warm up the internal surface of the chimney. This is a passive cooling strategy to increase stack effect ventilation. If the night-time temperature remains above the interior operative temperature then night-time ventilation is undesirable. This system can be used for encouragement of airflow in buildings. Figure 3.37 shows working principle of a solar chimney.

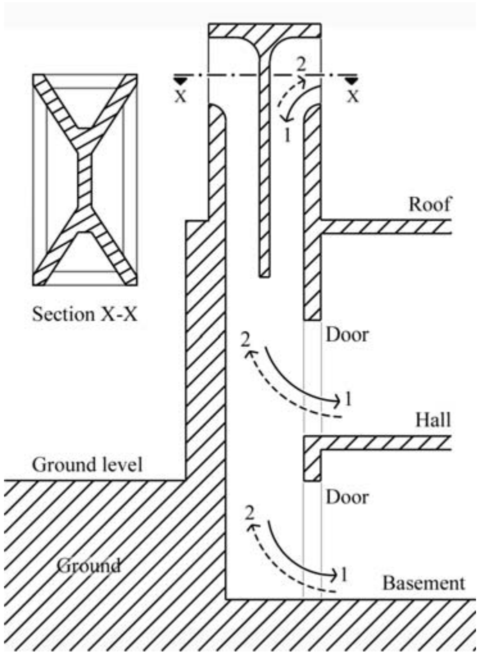


Figure 3.31: Operation of a wind tower in summer. Air flow during the day (1) Air flow during the night without wind (2) (Adapted from Sayigh, 1979).

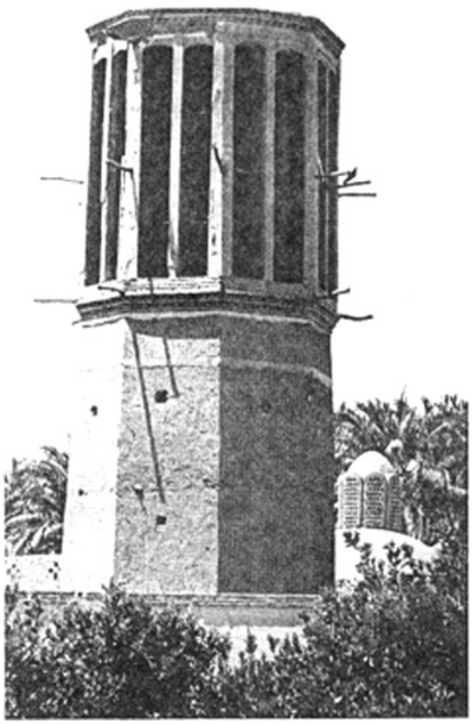


Figure 3.32: The wind tower of a house in Bam. This tower is connected to the basement by a 50m-long underground masonry duct (Sayigh, 1979).

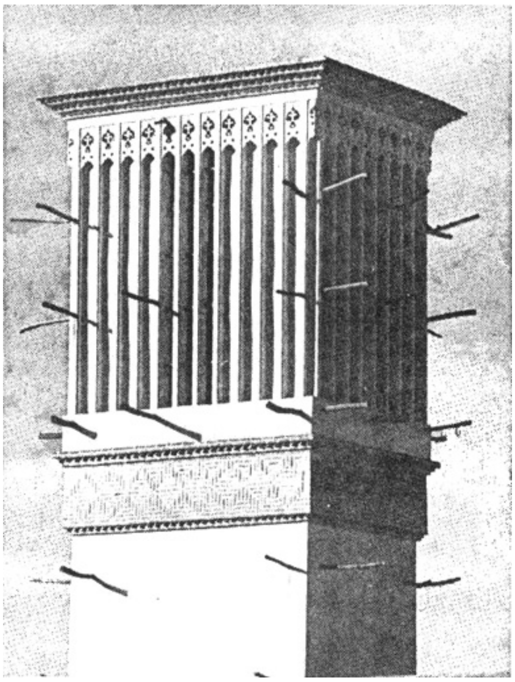


Figure 3.33: The wind tower of a residence in Yazd. The openings have a height of 3m and the tower is about 13m tall (Sayigh, 1979).

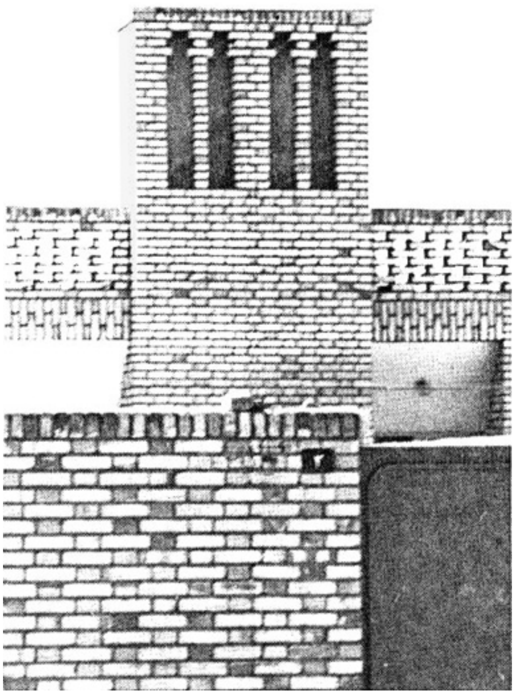


Figure 3.34: The wind tower of a new house in Yazd. The openings have a height of 1.25m and the tower is about 5.5m above the ground (Sayigh, 1979).

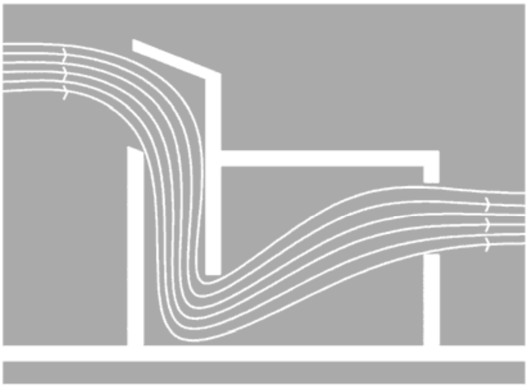


Figure 3.35: Schematic diagram of wind towers. Opening of the tower is facing wind direction.

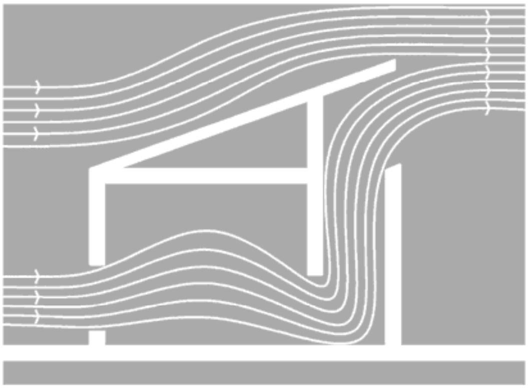


Figure 3.36: This configuration of wind towers also works for cross-ventilation.

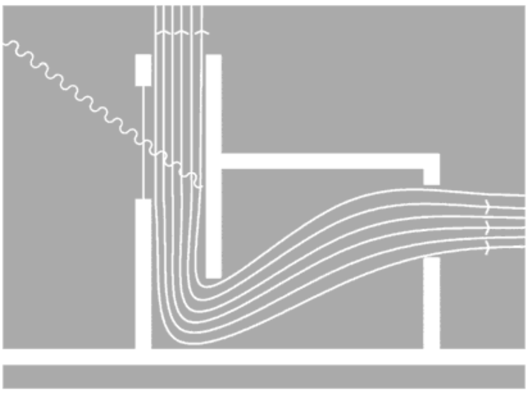


Figure 3.37: When there is no wind, stack-effect ventilation associated with wind towers can be created by using solar chimneys.

Radiative Cooling:

Radiative cooling is the transfer of heat from a warmer surface to a cooler surrounding surface. Any object emits energy by electromagnetic radiation. If two elements at different temperatures are facing one another, a net radiant heat loss from the hotter element will occur. And if the coldest element is kept at a fixed temperature, the other element will cool down to reach equilibrium with the colder element. This physical principle forms the basis of radiative cooling (The European Passive Solar Handbook, 1992).

Radiative Ice-Ponds: Radiative cooling was used to produce ice in hot-arid regions of ancient Iran, Energy storage from one season to another is an important feature in passive systems. This was provided by the production of ice during winter nights and its storage in deep underground pits for summer use. Shallow rectangular ponds were created. An adobe wall was built on the southside of pond, high enough to shade the entire pond during the ice-making season. On cloudless winter nights, the ponds were filled with water. The radiative cooling to clear night sky was sufficient to freeze the ice several inches in thickness. Then the ice was stored in covered and insulated pits for storage untill the summer. However, this use was cut because of health reasons. Figure 3.38 and 3.39 show working principle of radiative cooling process of an ice-maker. Swartman (1979) attracts attention on modern architects and engineers should acquire a knowledge of passive systems that is related with the climate, the consciousness of past from the point of energetic use in architectural environment makes the designer capable to provide today's convenience using relatively small amount of external energy for thermal performances and productions.

Courtyards: Enclosed patios and courtyards benefit from radiative cooling. The roof can be designed to enhance the courtyard cooling cycle. If the roof surrounding the courtyard is sloped toward the courtyard, as the roof cools by radiation at night, the layer of air above the roof is also cooled and drains into the courtyard displacing the warmer air. Therefore, this design strategy has had the priority in architectural style in hot regions. Markus, and Morris (1980) sample the most effective examples of these type of design approach in middle eastern, courtyard town house as found in most of the urban areas, typically in Baghdad, in central Anatolia, North Africa and most sites of Mesopotamia.

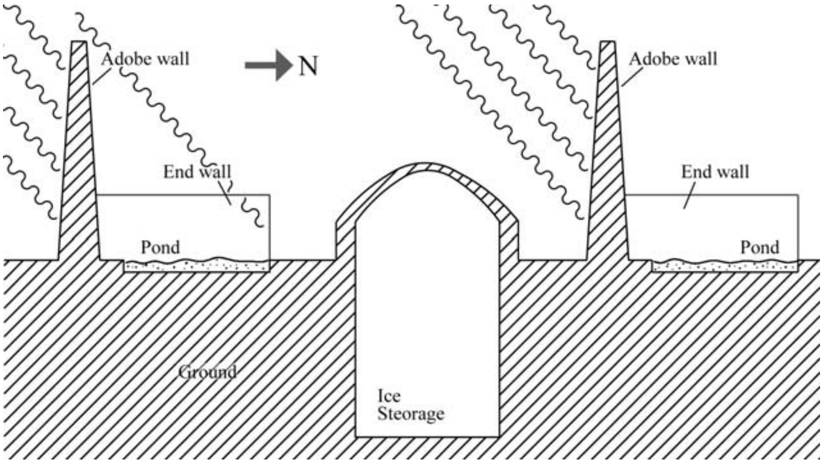


Figure 3.38: Working principle of an ice maker. They have been used for creating ice for summer use. In this system, water is cooled by cool winter air during season, as soon as some ice were created they have been stored in earth-burried pits (Adapted from Sayigh, 1979).

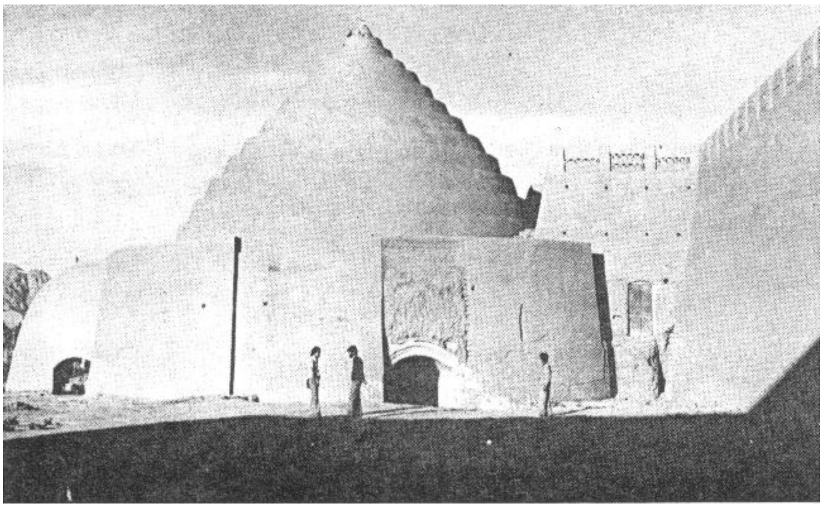


Figure 3.39: The storage pit and shading walls of a natural ice-maker in Kerman (Sayigh, 1979).

Evaporative Cooling:

Evaporation occurs whenever the vapour pressure of water is higher than the partial pressure of the water vapour in the adjacent atmosphere. The phase change of water from liquid to vapour is accompanied by the release of a large quantity of sensible heat from the air that lowers the dry bulb temperature of the air while moustire content of the air is increased (The European Passive Solar Handbook, 1992). The efficiency of the evaporative cooling process depends on the temperatures of the air and water, the vapour content of the air and the rate of airflow past the water surface.

Direct Evaporation: The system that the moustire content of the cooled air is increased causing augmentation of relative humidity in the atmosphere. Direct evaporation system occurs when dry air is blown over a wetted surface. Many examples of this system exist in vernacular architecture. Their main disadvantage is in the increased moustire content in the ventilation air supplied to the indoor spaces.

Wind Towers have been also used in energy storage systems. The people living in hot-arid regions have used deep earth's good insulation feature, for instance, they have stored water in cisterns 10-20 m deep for summer use. The cisterns were filled during the cold winter nights, and to keep this water cold a natural cooling system was provided by wind towers. The following figure 3.40 and 3.41 show the working principle of a wind towered cistern in Yazd, it is about 12m deep with six wind towers about 12m high.

Indirect Evaporation: Indirect evaporative systems avoid the problems associated with increased humidity levels. In this system, the evaporatively cooled air is seperated from the conditioned room air allowing reducing the dry-bulb temperature without adding humidity to the room air. Exterior building wall and roof surfaces heated by radiation or convection may be cooled by spraying them with water. As the water evaporates it cools the surface. It is sufficient to keep the surfaces moist.

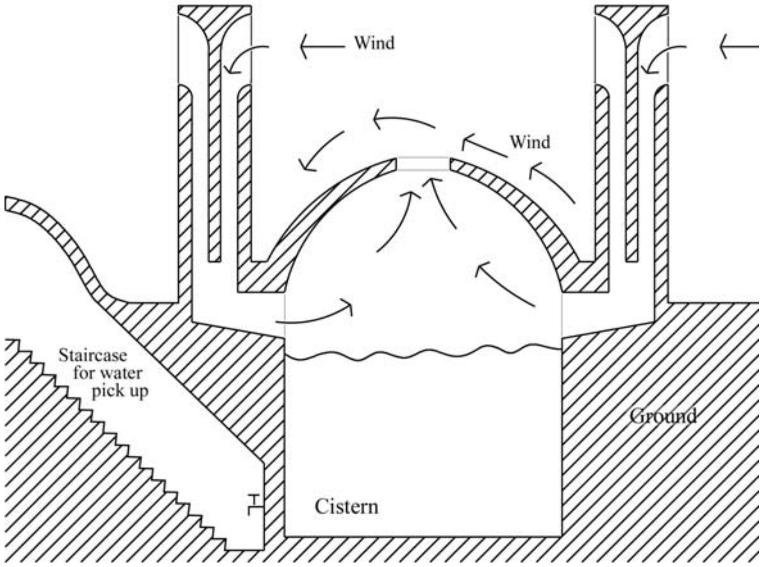


Figure 3.40: Working principle of a wind towered cistern. They have been used for cooling of water and spaces. In this system, dry air is saturated with water particles by air velocity (Adapted from Sayigh, 1979).

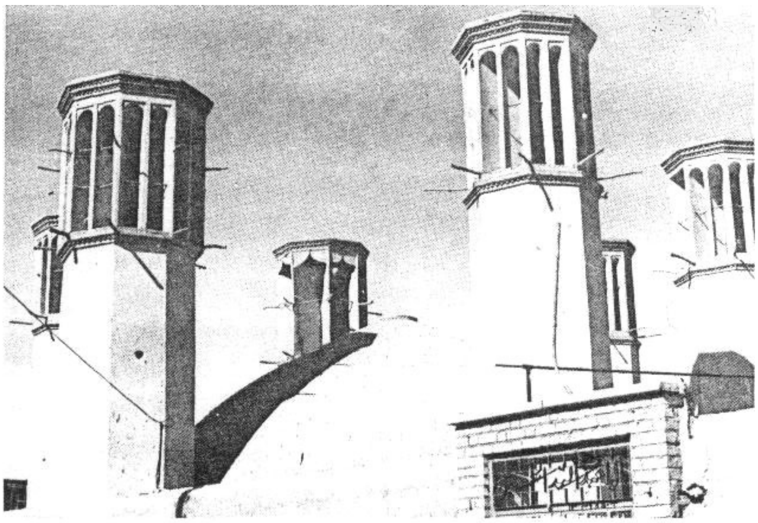


Figure 3.41: A six-wind-towered cistern in Yazd, it is about 12m deep with six wind towers about 12m high (Sayigh, 1979).

Mass Effective Cooling:

Mass effective cooling is to utilize high insulation properties of the earth in which the stable thermal conditions exist. Labs (1989) stated that the current interest in using the ground as a component of a building's conditioning system goes to ancient settlements. He points out that ancient societies could design their architectural environment by using the effect of earth in providing thermal comfort and defense.

Göksu (1992) samples the climate-responsive architectural environment from Türkiye, he attracts attention that there are many examples of underground cities found in Anatolia. In hot and cold climates, the underground cities that have been constructed in the different aim, were used in conditioning the buildings. 'Lithospheric living areas', 'geotecture', and 'terraspace' exemplfy such efforts (Labs, 1989). It can be said that, the underground cities are the urban pattern which can be the best climate-balanced design approach whereas they were constructed for Christian to use with the aim of protecting the most themselves in Göreme. According to Labs (1989), 'Earth-sheltered', 'earth-integrated', 'earth-contact', 'earth-covered', and 'terratecture' are descriptive and indicate the purpose of the buildings abutting the earth.

Earth Contact: The rate of winter heat loss to the soil is much less than it is to the air as the ground is naturally warmer than the winter air. As a rule-of-thumb, the temperature in the earth about 12ft deep is stable at a temperature of 15 degrees. The earth is an infinite heat sink virtually. The magnitude of its heat storage capacity makes it possible to use it for seasonal storage purposes. At depths below 20 ft, the soil temperature is virtually stable and equal to the average annual surface temperature (which is typically two or three degrees warmer than the average annual air temperature, as a result of insolation namely incident solar radiation and the higher temperature of the deep core of the earth). In addition there is a time lag that induces with depth (the annual peak soil temperature at a depth of 12 ft typically occurs about three months after that of the surface).

The thermal characteristics of soils vary with the soil type. Generally, earth is an effective insulation material that has the potential of stabilizing the temperature fluctuations. There are some strategies for earth contact with the building for passive cooling of the spaces: direct contact and indirect contact. These are the strategies used mostly in mass effective cooling.

Direct Contact: Earth sheltering is used as a strategy to protect the building both from cold winter winds and temperatures or hot summer ambient air. In cases of completely undergroud construction, the increased thermal mass of soil provides nearly constant annual temperatures resulting in seasonal storage.

Some of the advantages of earth-sheltered construction are reduced cooling and heating loads, the possibility of using the area of earth-sheltered part of a building for planting, in case of earth-covered roof. Addition to this, as the earth has the high level of insulation grade, the heat loss is minimum due to the roof and it responses to the acoustical problems. The disadvantages of earth-installed building are induced waterproofing cost and condensation problem. Condensation is a problem in cool, humid regions. It damages the interior finish surfaces such as paint, plaster, wallpaper and carpet. This problem can be overcome with the use of the waterproofing membrane which limits the moisture release to the interior wall surface only.

Indirect Contact: In this concept, a fluid is cooled through an underground tunnel, duct or pipe. The fluid that is cooled in the earth deep enough in turn cools the structure. The circulation pattern can be open-loop or closed-loop. In the first, the air to be cooled is evacuated from the outside and then drawn into the building. In the second, the air is circulated between building and underground. A historic example of an open-loop indirect contact system is the villa Aeolia, built in 1550 which was cooled by air drawn through large underground caverns which had been excavated previously in the process of digging out slabs of marble as far back as the empire of Augustus (27B.C.-14A.D.).

Chapter 4

CASES OF ENERGY-CONSCIOUS BUILDING DESIGN WITH SOFTWARE-SIMULATED RESULTS OF ENERGY CONSUMPTION

4.1. Summary

In this chapter, it is aimed to expand upon in what ways energy consumption of a building is estimated and how an architect can have information about whole thermal behaviour of a building in a year.

In a building design, an architect is responsible for providing comfort conditions and besides determining these provisions regarding visual, auditory, and aesthetic qualities, he or she should take part in designating the thermal behaviour and energy consumption of a building as well. To inform the readers about this issue, some cases with energy-efficient features are selected from the literature. These studies are based on thermal performance analysis by the help of some softwares that are capable of calculating the energy need of a building by taking energy-efficient strategies and active-passive solar components into account. The purpose of this chapter is to show the architects the ways of guidance his or her design to be a low-energy building using a thermal analysis software. Hence, the cases which were analysed for a whole year thermaly by using such softwares were chosen. These samples include existing ones with passive solar components, energy-consciously designed, or unbuilt ones and all the cases do not exceed two or three stories with relatively small sizes. The examples that have become subject in the articles are: a- Energy Conscious Dwelling Design for Ankara, b- Analysis of the Thermal Performance of Antalya Saklıkent National Observatory Guesthouse, c- Computer Aided Energy-Conscious Design.

In the following section, first of all, the cases are going to be summerized with energy-efficient features and the thermal performance results will be compared, then a conclusion on all of the features of the buildings with thermal similarities, differences, and deficiencies will be made with a discussion. As the last of this chapter, example buildings in which passive and hybrid solar technologies are used will be given from all over the world.

4.2. Cases of Software-Simulated Studies

A. Energy Conscious Dwelling Design for Ankara: In this study, it is aimed to emphasize the role of the use of passive tools and design considerations on energy efficiency in low-energy architecture, and to demonstrate how an energy conscious design is achieved with simple active and passive components integrated with the architectural design. To do this study, and investigate the possibilities of energy gains from renewable sources, two buildings were designed with the same quantities in storey, size, and with the same form with only some differences of energy efficient design considerations and applications. Then an energy analysis software 'SUNCODE-PC' which is well known as computer based thermal performance software was used to show the differences in energy use of the two buildings.

In the designing stage, the research team firstly designed the energy conscious building with the minimum requirements of thermal insulation regulations of Turkey. Then they designed a neighbour building with the same properties but with one orientation difference of the main facade facing the main road at North providing the minimum requirements of thermal insulation regulations that were being used before the revision of Turkish Standards for Thermal Insulation (TS825). Figure 4.1 shows the drawings of plans, sections, and views of the buildings. In the analysis, heating, cooling, and total energy requirements of the conventionally designed building were calculated. Then the energy amount saved by the active and passive solar components was compared with the conventionally designed dwelling's energy use accounting each low-energy design features step by step.

All the energy efficient features are explained briefly so that contribution of each components to energy saving would be more understandable. The criteria of energy efficient design are taken in the context of form and site layout, plan organization, building materials, and additional features of energy consciousness.

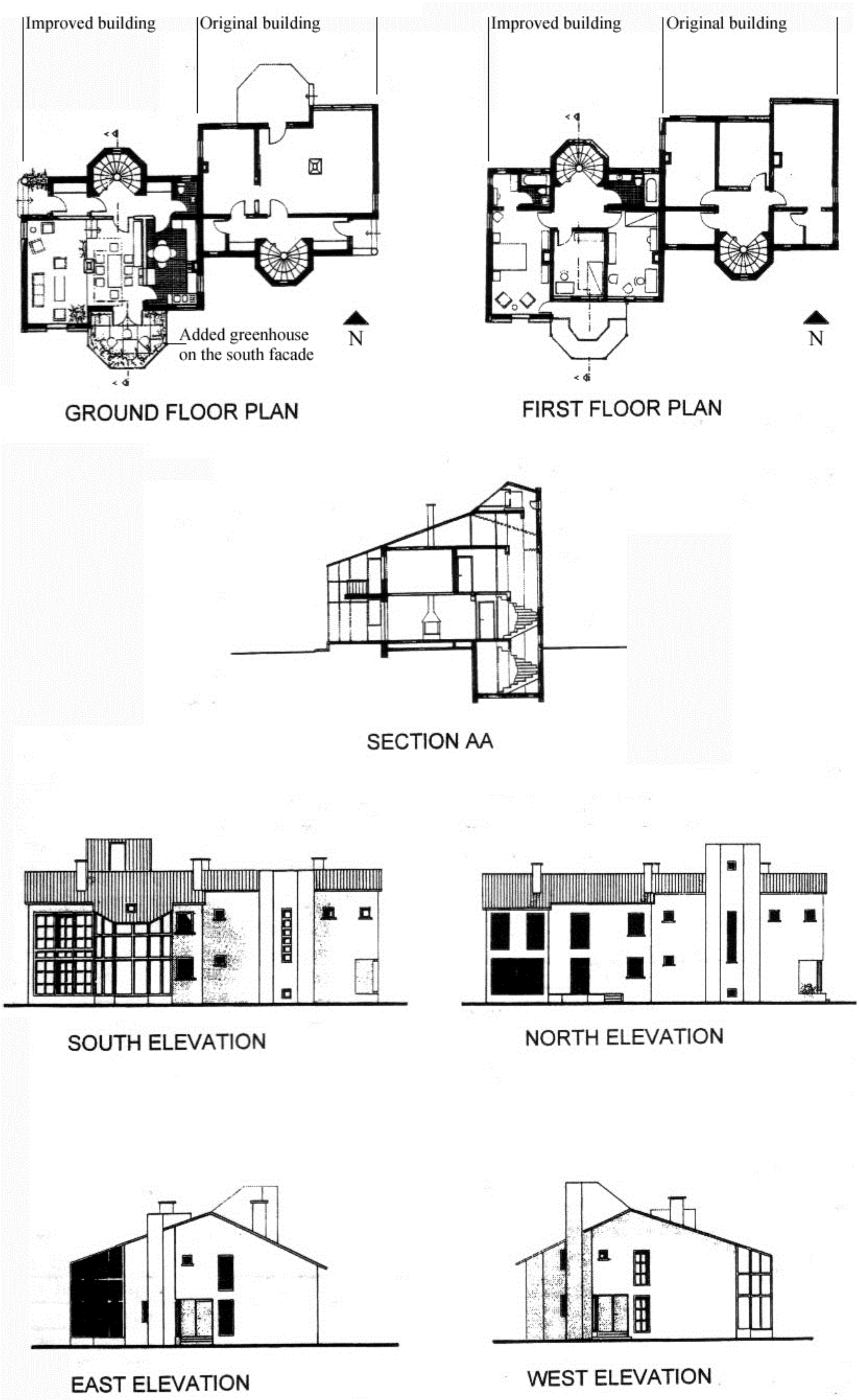


Figure 4.1: Plans, section, and elevations of the conventionally designed (CDD) and energy-consciously designed (ECD) dwellings (Demirbilek et al., 2000).

To expand energy efficient design criteria:

► With the criterion of form and site layout, Demirbilek et al. (2000) intended to plan these two buildings as twin houses each having a floor area of 152 m2. In order to be passively conditioned, the main facade of energy conscious dwelling was faced south whereas conventionally designed one's was facing north with the result of clients' commercial approach which aimed to link the main facade to the passing road visually.

► With the criterion of plan organization, distribution of spaces on floors was considered in order to take their effects on thermal performance of the dwelling into account. In both designs, living room, kitchen and dining room were located on the ground floor. In energy-conscious design, all the servicing areas were placed at north side of the building for contributing to thermal performance. Apertures (openings) were held minimum in north maximum in south to benefit from solar gains and use of daylight. And a greenhouse was added to two floors to create a buffer zone between inner and outdoor conditions.

► With the criterion of building materials, the requirements for fulfilling of thermal regulations of Turkey were done exactly in both conventional and energy conscious design. In analysis, insulation material's thicknesses of energy-efficient building were increased for the improvement of comfort conditions.

► With additional features, other energy saving and passive solar strategies were used in energy conscious design. To explain them briefly, use of night insulation and improvement of shading coefficient of glazing for excessive heat losses in winter nights and for excessive solar gains in summer days. Trombe walls for contributing to heat loads of the building, they were added to south facades. Greenhouse located south on two floors creating a buffer zone and livable additional living space for the occupants in different times of the year.

Analysis included evaluating the thermal performance of each building determining the benefits from passive solar components by the aid of SUNCODE-PC. With this study, advantages and contributions of energy-conscious features on conventionaly-designed building in terms of orientation, insulation material thickness, trombe walls, greenhouses, and rockbin storages have been revealed. In analysing process, first of all, the savings and gainings that were caused by only true orientation were calculated and showed as heating and cooling loads of the building, then the process was conducted by taking each features into account. In results, both of the buildings needed total energy demand of 90,7 GJ at the begining whereas energy-conscious one needed total energy demand of 35 GJ after some improvements through several runs. The ratio of total energy saving is about 62%.

B- Computer Aided Energy-Conscious Design: In this study, the advantages of low-energy design strategies in a building were aimed to be showed via a thermal analysis work of a building. Considering that the aim in an energy-conscious building design is to minimize the amount of external energy needed for heating, cooling, and lighting, the criterion of low-energy design that would provide energy savings and gainings were applied to a building. Calculating the amount of total energy saving was done with the help of the software "ENERGY" which is an hourly dynamic simulation program.

In order to complete the study, Weizmann Institute's Environmental Science and Energy Research Department building that was situated in the hot-humid climate of Rehovot in Israel was selected. Shaviv (1998) states that the suggestion to make the building energy-efficient one came after schematic design was over. So, at the begining, the geometry of the building, its location, and orientation had already been determined not to be changed. The alternatives were applied to the building only at detailed design stage. Besides this most important constraint, there were other environmental obstructions such as trees that block the winter solar beams from reaching the building's south facade. Therefore, solar energy was obtained most via collectors which would be situated on the roof.

The parameters that remained free of changing for improving the thermal performance are thickness of insulation materials, color of the walls and roofs, the design of the window shading systems, the artificial illumination control units, and a sunspace on the upper floor to obtain passive solar energy. In this study, besides the thermal improvements, the most attention paid to the level of daylight strategies that would take great part in improving of energy use of a building. To reach the desired level of the daylight use, window systems have considered in terms of shading devices and night insulation states. The factors that effected the decision of the optimal glazing-shading system were the cooling load in summer, the heating load in winter, and the illumination load during a year.

According to the results of the analysis: double clear glass with external blinds and clerestory, adding a sunspace to the upper floor for solar gain, and otomatic control of the artificial illumination system making the system on or off depending on the sufficient or insufficient level of daylight were found as the best solutions for achieving of low-energy use of the building. With the alternatives that included improving the building's insulation, cooling the thermal mass by night ventilation, adding ceiling vents for better ventilation, adding a sunspace on the roof, and careful design of the window's glazing shading system, it became possible to reduce the need for electricity consumption for heating, cooling, and lighting by 60%. It can be observed that with some architectural characteristics, it is possible to turn additional strategies for energy efficiency into cost-efective benefits for long term.

C- Analysis of the Thermal Performance of Antalya Saklıkent National Observatory Guesthouse: In this study conducted by Prof. Nur Demirbilek and her research team, it is aimed to show the positive effects of passive solar applications on thermal performance of a building in a very harsh climate. This project differs in terms of having architectural requirements and owing such a high altitude with severe climatic conditions in winters. So, this study was also aimed to fill the gaps for the analysis of thermal performance of special-purpose buildings under harsh climates and with the functional restrictions. Antalya Saklıkent National Observatory building having all mentioned climatic and functional resctrictions was selected to accomplish the study. In analysis, the software "SUNCODE-PC" was used to determine the thermal performance of different modes of application.

First of all, it is essential to explain the building's properties: The building was completed in 1997 and is in use since that time. Figure 4.2 shows general view of the building and figure 4.3 shows inner and outer temperatures of original design under worst conditions. The building has some restrictions because of characteristics of astronomical observation. Demirbilek et al. (2000) state that these restrictions have determined functional solutions, material choices, and also perhaps the mostly thermal behaviour of the building. The astronomical observations require clear, stable and clean environment.

Figure 4.2: General view of TÜBİTAK National observatory. Greenhouses and trombe walls are seen on the south side of the rooms (Demirbilek et al., 2003).

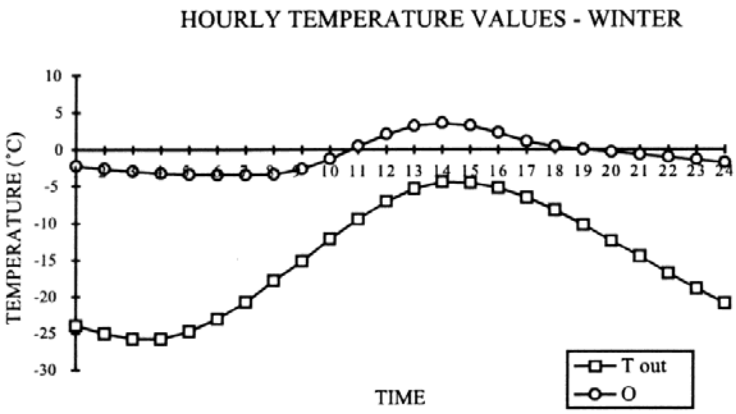


Figure 4.3: Hourly values of outside temperatures (Tout) and inside temperatures of original design (O) (Demirbilek et al., 2003).

So, the building should not be smoke, electromagnetic wave, and light-producer. During the observation period heat radiation at night time would be the most important problem for telescopes and must be avoided strictly at nights. This restriction also determined the choice of passive solar systems and materials dramatically. When the building is not in use, mechanical and electrical devices may be affected due to harsh indoor conditions so, the most important purpose of this study was maintaining the internal conditions at reasonable levels so that equipments are not affected from sudden fluctiations. Another important restriction was the occasional usage of the building, this tends to make the building self-sufficient in terms of providing reasonable conditions for equipments and occupants. The building is highly insulated and earth-bermed from the north facade. Sloped south facade is designed to accomodate the passive solar gain components such as trombe walls, sunspaces, and direct gain apertures.

South facade has an isolated trombe wall permiting only convective heat transfer to the interior spaces, this kind of trombe wall wall system was used because of the fact that the building should not reradiate any heat back to the sky, and this system does not produce radiation. In this study, other restriction is lack of climatic data necessary for thermal analysis. Outdoor climatic data consist of hourly values of outdoor air temperature, outdoor dew point temperature, wind velocity, direct normal radiation, and horizontal total radiation as necessary values. The site has climatic datas for four months and had to be generated for remaining part of year in order to make the computation and analysis. To complete missing climatic data, six meteorological stations with altitudes varying from 1725 to 2400 m and latitudes between 37,57 degrees north and 40,30 degrees north in which climatic data measured for more than six years have been analysed. It was found that the most important geographical characteristics of Saklıkent are its altitude and its proximity to the Mediterranean Sea. With this characteristics, it was found similiar to geographical and climatic properties of the town Van Başkale that is close to lake Van with an altitude of 2400m and latitude of 38,47 degrees north among other locations. Because of this close properties, Van Başkale station was selected for use in the remaining period for the site of the building. The direct normal and total radiation on a horizontal surface were calculated for Saklıkent that is at 36,85 degrees north and 2500m high, then the results were compared with the values of Van Başkale, and it was found that they were similiar to meteorological station's of Van Başkale.

The building is designed to be conditioned passively and has some energy-efficient design criterion in conjunction with form, site layout, plan organization, building materials, and passive solar components. Figure 4.4 shows plan drawings of the building, figures 4.5 and 4.6 show sections and south facade detail of the building accordingly. To accomplish the study, some modifications have applied to original design to see the different results between modes of varying applications and to decide the most suitable one for such a special-purpose building. Original design has been analysed using the software SUNCODE-PC. The auxiliary heating load (Qaux), solar heating fraction (SHF) for heating season and the hourly indoor temperatures were computed. And the daily Qaux of the building was found for 2,34 GJ. Then the alternative applications tested for improving the thermal conditions of the building, changing the material of trombe wall, increasing of thickness of insulation materials, changing the number of glazing of trombe wall and green houses, using different ratios of direct gain windows instead of trombe wall and green houses, applying night insulation in winter time, applying shading and ventilation in summer and adding curtains to the direct gain windows of bedrooms for day-time sleeping.

The original design does not fulfill the thermal reguations of Turkey with its single glazing and insufficient floor insulation. Therefore, all alternatives have been modified to have double glazing for vertical windows, 5 cm extruded polystyrene, and 4 cm concrete layer between parquet and aerated concrete blocks as the floor material. After more than 100 runs, three alternative modifications have been developed. Due to the reasons of preventing outgoing radiation from the building, making the passive systems self-control as far as possible and easing the construction works as the site has difficulty of transportation, it was concluded that the alternative which added double glazing to the sloped glazing of greenhouses and trombe walls and 5 cm insulation with 4 cm concrete to the floors were found as the most appropriate combination for this specific building.

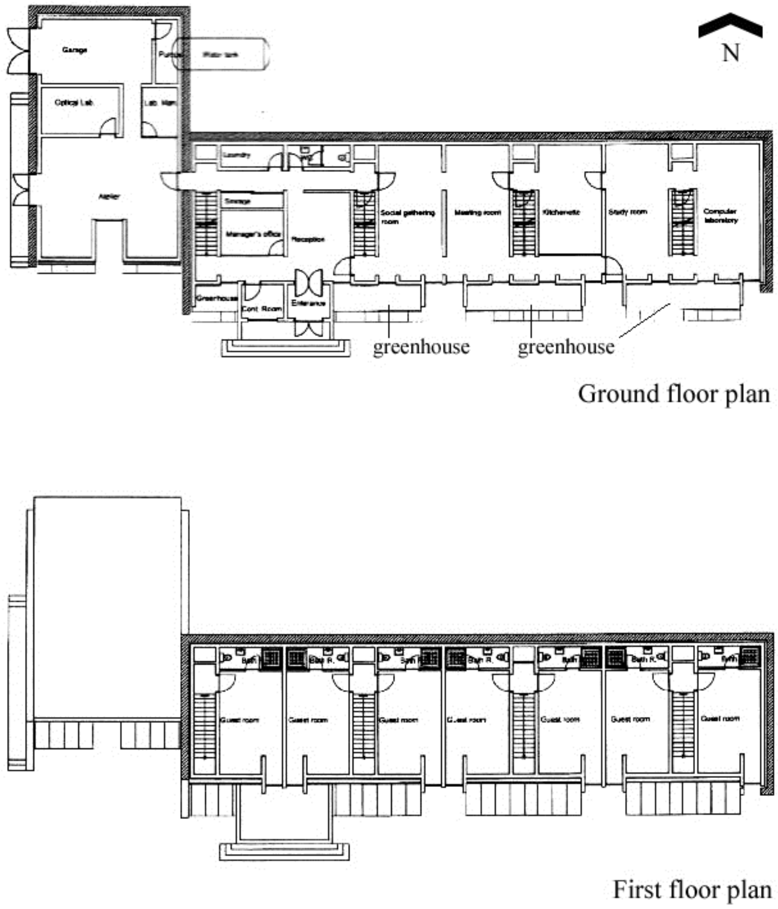


Figure 4.4: Plans of ground floor and first floor of the building. On the south side of the building, greenhouses can be seen on ground floor and trombe walls can be seen on the first floor (Demirbilek et al., 2003).

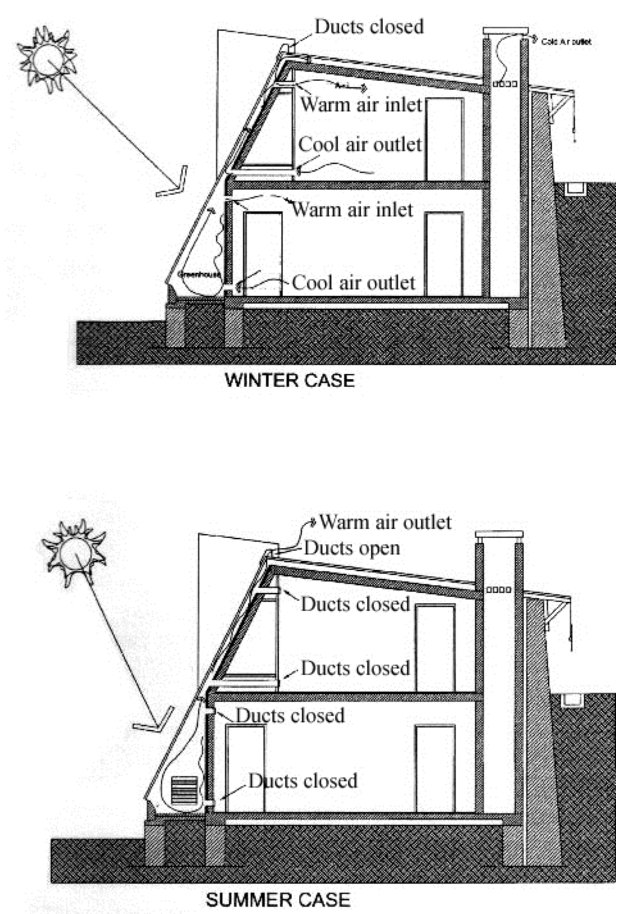


Figure 4.5: Sections of the building. On the south side of the building, greenhouses and trombe walls can be seen. Vents' schedules are showed for seasonal use of Passive System Components (Demirbilek et al., 2003).

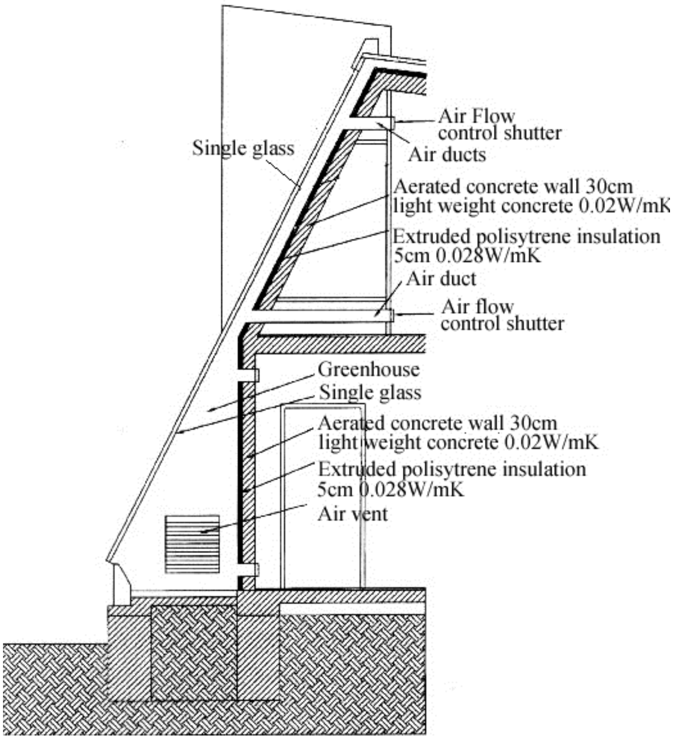


Figure 4.6: Section detail of the building. Original building has single glass on the south facade, this has been improved to double glazing in the study (Demirbilek et al., 2003).

4.3. Discussion

These studies have been conducted in the contex of low-energy design applications in architecture. And they all proved that with energy eficient design criteria it is possible to create low-energy buildings without thermal disturbance of occupants.

Generally, it is emhasized that almost half of the total energy consumption are accounted by the building industry, and architecture is responsible for environmental deteriorations in terms of use of fossil fuels in the long term period of the buildings. This circumstance necessitate designers to consider also how the building will operate without paving the way for exhausting of natural sources and environmental pollution. Effective attentions have not been paid to solar design because of some restrictions in Turkey although active, passive and hybrid solar gain strategies are being considerably used in architecture in foreign contries especially in European contries with less solar exposure than Turkey has in a year. Reasons for this irrelevance will be discussed in conclusion part.

In this chapter, according to the studies conducted by the aid of thermal analysis softwares, it is possible to have an idea about thermal and whole energy performance of a building that thermal behaviours of the buildings can be predicted and foreseen before their construction and operation period. It appears that designers need some tools for estimating thermal performance of a building to make good decisions about energy efficiency in early phases of design process. These softwares mentioned above can handle daylighting, passive solar heating, cooling and active solar components in terms of energy-conscious building design.

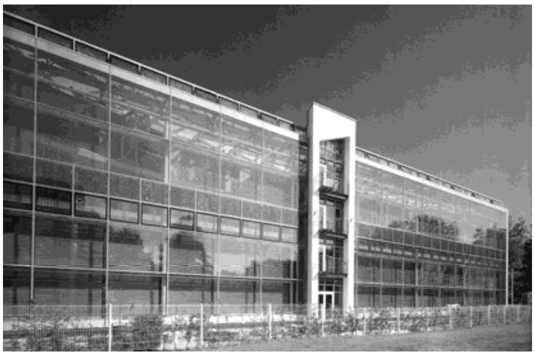
The major barrier to low-energy building design is having difficulty in estimating the thermal performance of a building for a designer, and such an obstruction leads the architects to disregard energy efficiency strategies. However, such buildings should be considered for long term of life cycle analysis.

4.4. Examples in which Passive Solar Design Strategies are used

In this section, some of applicated low-energy, passively designed solar buildings are going to be introduced. Building's thermal and energy-efficiency features will be summarized briefly. To limit the examples, residential, small office and low-rise buildings were chosen. As it was mentioned before, effectiveness of the Passive Solar Design strategies is strictly related with the size of the buildings. When the size and scale of a building exceed the requirements of Passive Solar Design components in terms of natural flow of conditioned air, some mechanical assistance are needed to distribute the collected solar heat to the whole building. This situation can lead to active systems wholly or can weaken the integration of Passive Solar Design and building design. So, to show the influences of these strategies on building design as the main aim of this study, relatively small and low-rise buildings have been chosen.

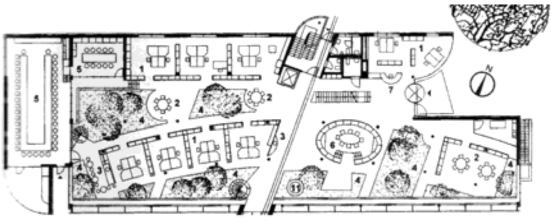
Project 1: OFFICE BUILDING in Dresden, Germany
Architectural design: LOG ID

Low-Energy Features: The great glazed South facing wall receives solar heat during the heating season. It drives climate control in most conditions of outer climate.

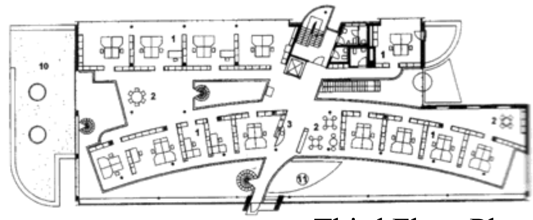


Northern facade is more heavier and opaque against north winds. It lets little energy loss.

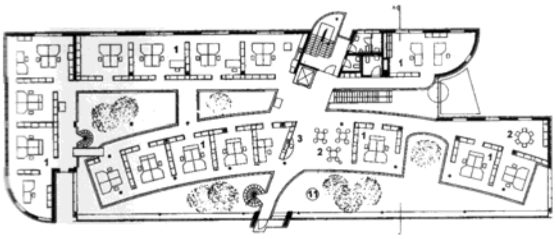
Greened roof terrace for high insulation value of earth.



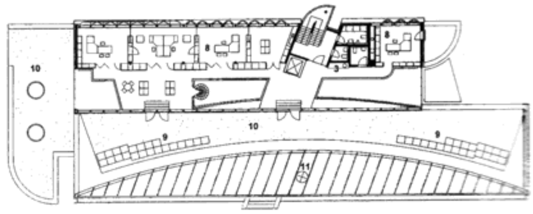
Ground Floor Plan



Third Floor Plan

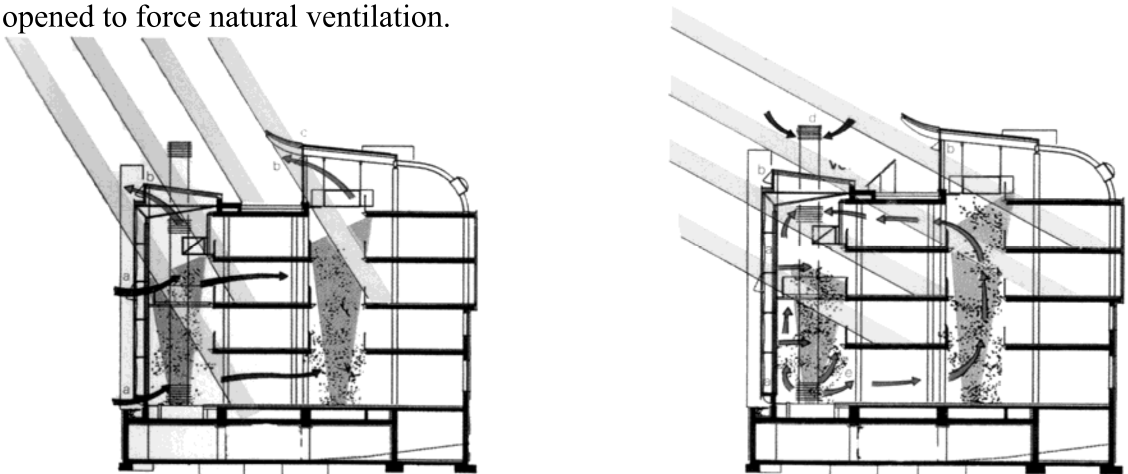


First Floor Plan



Top Floor Plan

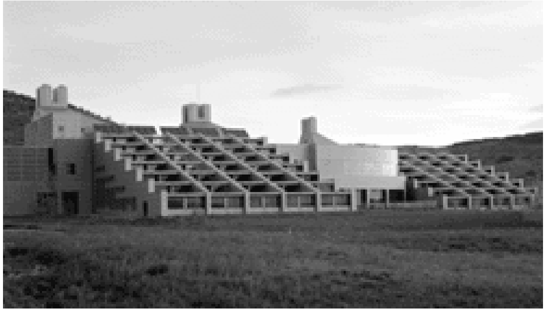
Plan organisation of the building is designed to facilitate the natural heat flow by the thermal chimney effect. This plan lets the sun's beam penetrate deep into the building spaces. Holes on slabs also lets the trees grow for full height of the building enhancing the quality of air. In summer, vents at the bottom and the middle of the glass wall are opened to force natural ventilation.



Sections show the climate control strategies of the building. Passive Solar Heating and Natural ventilation are dominant characteristics of this low-energy building.

(Figures are quoted from Architectural Review, July 1997)

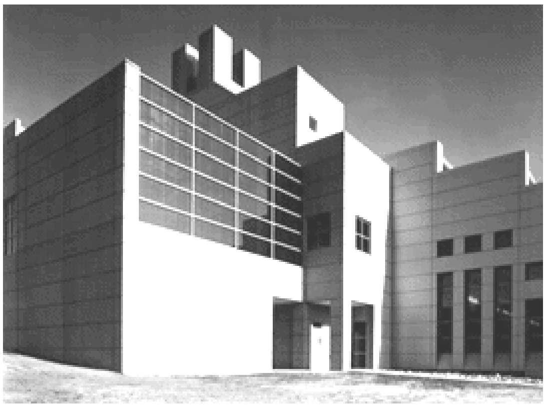
Project 2: NATIONAL RENEWABLE ENERGY LABORATORY BUILDING in Washington



Low-Energy Features: Situated on a rural area the NREL building has Passive Solar strategies to decrease building's energy use without disturbing the occupants. It uses all the opportunities for Passive Solar Design (orientation, natural lighting, direct gain, indirect gain by Trombe wall, and natural ventilation).

The south side of the building has tilted facade and it accomodate solar apertures to provide daylighting and direct solar gain to offices for passive heating.
Photovoltaics on the roof provide building's artificial lighting energy need.

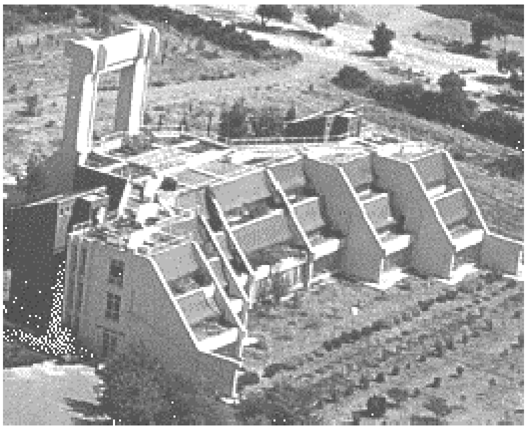
The natural light are efficient for offices. The form of the roof is the result of the Passive Solar Design considerations.
The office area has ventilation strategy, ventilation towers (innovative air trees) are seen under the tilted and partly glazed roof. The evaporatively cooled air forced by mechanical chillers is blown from the towers.



The south facing Trombe wall uses the Sun provide Passive Solar heat for shipping and receiving area during the cold months.
This indirect gain strategy is effective for Low-energy buildings. They provide heat immediately after the sun rise as the system use the termosiphoning effect.
With these low-energy design strategies, the building is **40% energy-efficient** when compared with its conventional one having the same dimensional and functional values.

(Figures are quoted from the web site: www.nrel.gov)

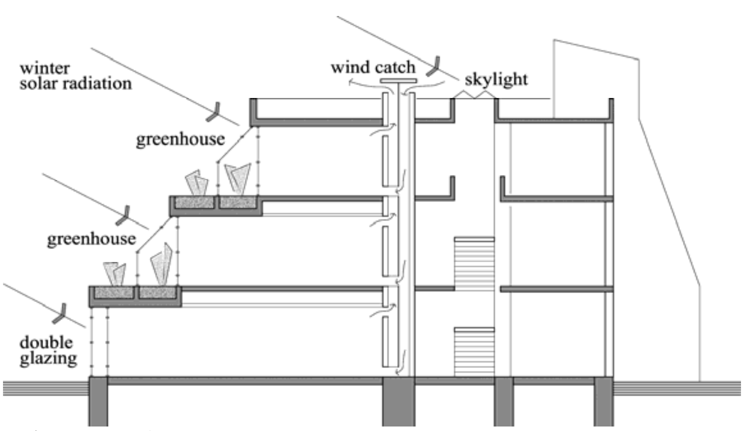
Project 3: EGE UNIVERSITY SOLAR ENERGY INSTITUTE BUILDING in İzmir, Türkiye



Low-Energy Features: Having the area of 3000 m2 the building is the biggest one that is heated passively in Türkiye. The building's architectural design has passive solar design considerations. Geometry, orientation, sun spaces, ventilation chimneys, insulation are the characteristics of this passively designed building. The building has double glazing and and sunspaces as direct gain method for space heating, ventilation chimneys and north vents for passive cooling.

In o peration, the building has the negative impact of not having shading devices for summer use, so it is refurbished to improve the glazings thermal characterictics. On the core facade of the 'V' shaped building, reflective glazing has been applied to solve overheating problem. The building in its original state has same sunspaces on all floors.

As it is seen in the figure, the Sunspaces as heat generator also accomodate vegetation as well. They improve the Spatial quality beside thermal one. Natural lighting is also other important strategy for the building, on the staircase the skylights are situated for improving the visual quality.

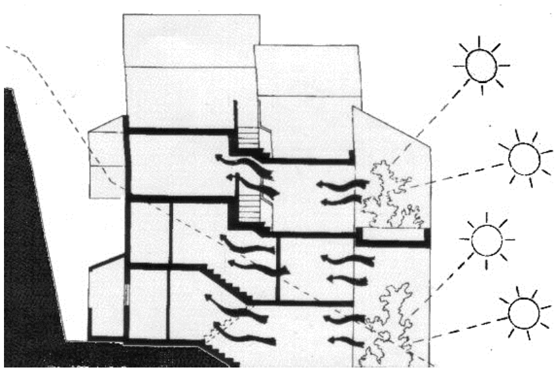


(Figure is adapted from Atagündüz, 1989)

Project 4: APARTMENT HOUSE in Biel, Switzerland
Architectural design: LOG ID

Low-Energy Features: This building is designed according to greenhouse principles. The greenhouses are designed as two-storey high for the plants' growth. The facede that accomodates the greenhouses is faced to south to gain heat from the Sun effectively. The greenhouses provide considerable heat energy to the houses as they collect solar heat passively. The system is named as direct one as either inner or outer side of the greenhouses have glazed walls.
These Passive Solar Design components provide about **30%** of the building's heating energy demand.

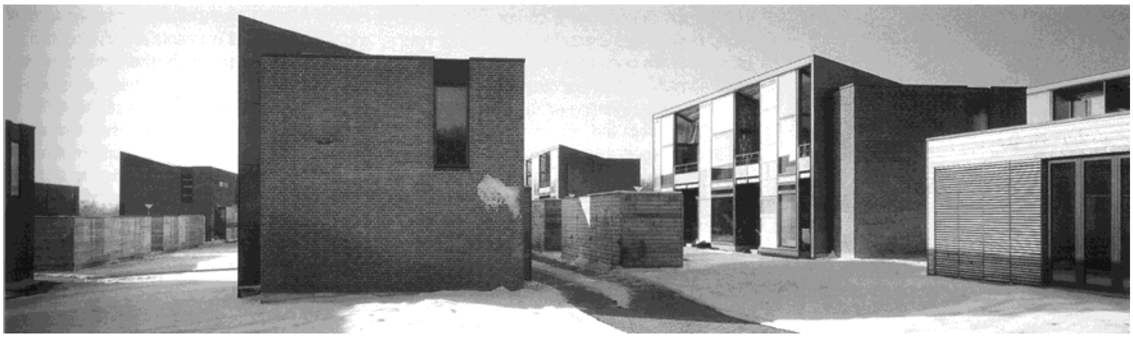
With these features of the system, the greenhouses can be used as a living space in the sunny winter days. In the non-solar day, the glazed wall between the greenhouse and the spaces is closed and traditional systems are used for heating of the houses. In the winter months, the ventilation occurs by means of greenhouses, and this also reduces the heat loss.



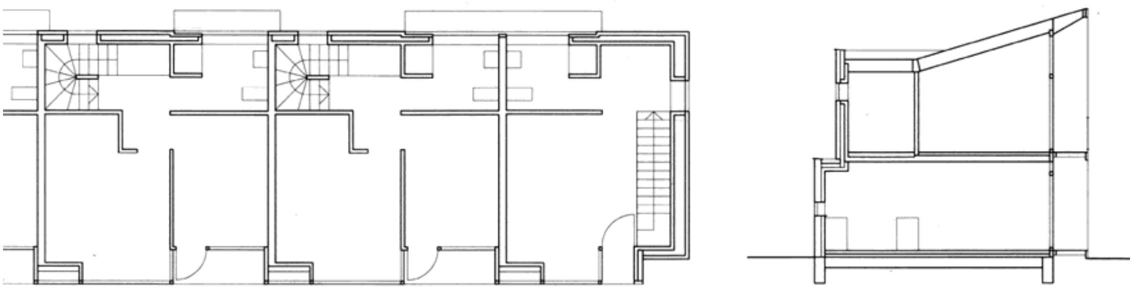
(Figures are quoted from Tasarım, June 1998)

Project 5: HOUSING ESTATE in Kolding, Denmark
Architects: Lars Frank Nielsen, Kim Herforth Nielsen

Low-Energy Features: This housing settlement is planned to comprise 59 terraced houses in the context of a competition for environmentally friendly buildings. In the planing phase, the buildings were turned at an angle of 15 degrees from the true south to provide a maximum use of solar energy, this deviation of angle is the most optimum one for the conditions of Denmark. As a passive solar strategy in urban design, the buildings are arranged in order not to impede solar radiation reach each building. Other strategy is to make buildings low-rise for again this purpose.



The south facades of the buildings are almost fuly glazed and accomodate Passive Solar design components and strategies. Direct gain and Trombe walls between 6 and 8.5 m2 in area are used in the context of passive energy utilization. As it is observed in the section, south facades of the buildings is constructed high than the north facades to increase solar gain.



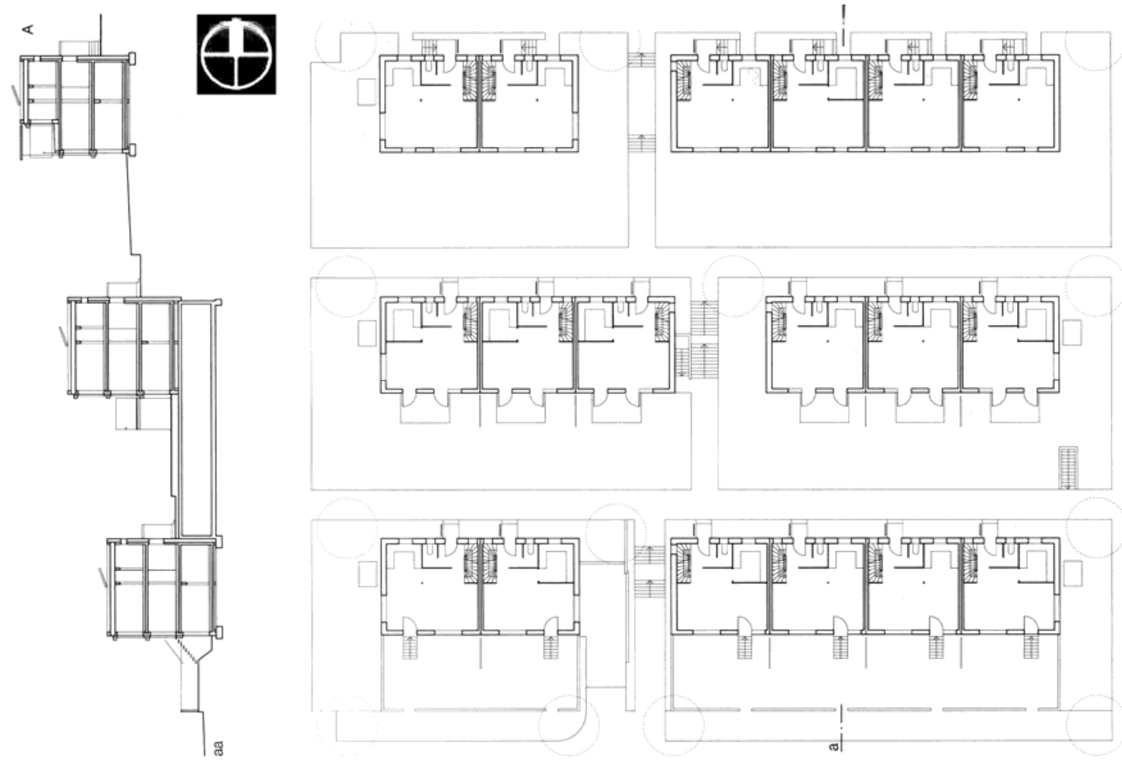
Plan and section drawings of a unit of housing

These Passive Solar Design strategies ensure an additional thermal energy to the central heating system of the community building. According to measurements, the annual energy gains from the solar elements are around 120 kWh/m2. In the drawings, it is seen that the north and end facades of the buildings are high-insulated having cavity walls, this level of insulation makes such buildings effective in running of Passive Solar Design strategies.

(Figures are quoted from Detail, 6, 2002)

Project 6: PASSIVE ENEGY TERRACED HOUSING in Ulm
Architect: Johannes Brucker

Low-Energy Features: This housing has 18 houses laid out in three rows stepped up the Site. As Passive Solar strategies, the buildings are ordered and oriented to optimize the use of solar energy.
The south facades of the buildings have large-scale prefabricated timber elements.

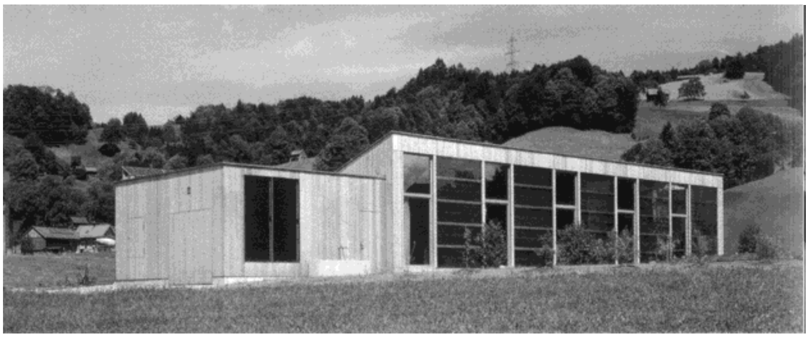


Section and plan drawings of a unit of housing

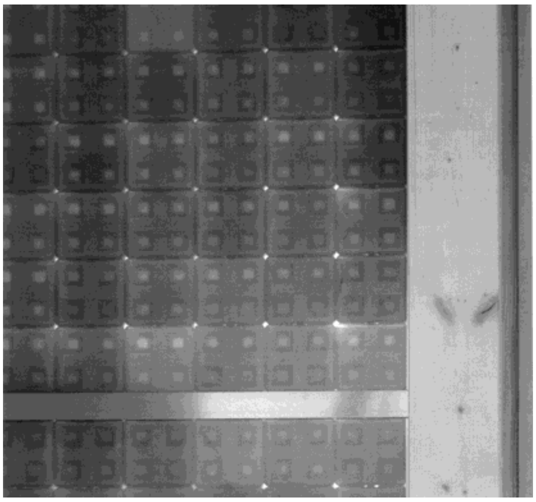
The entire development is planned to be heated by Passive Solar components and strategies.
In this frame, the dwellings are Planned to have high standard thermal insulation level.
By means of these features, the buildings are intended not to have their individual heating systems. The envelopes of the buildings are tightly sealed with joints, and the windows are executed with triple, low-e glazing.
Besides these strategies, hot water is provided by solar collectors mounted on the greened roofs of the houses.
In this project, the infiltration level of the buildings is kept at minimum as an energy-saving strategy. The most important low-energy concept in this settlement is Direct gain method.

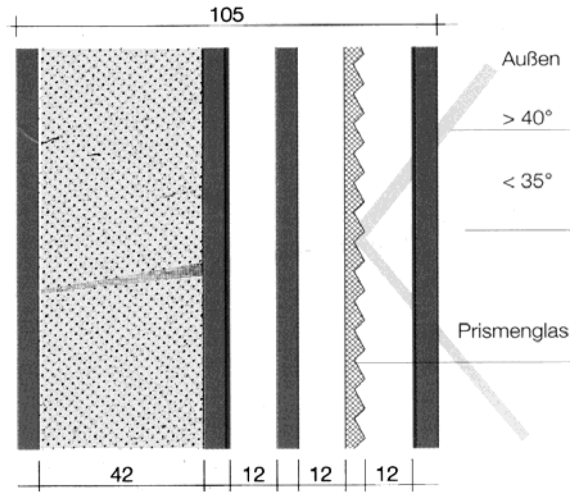
(Figures are quoted from Detail, 6, 2002)

Project 7: SOLAR HOUSE in Ebnat-Kappel, Switzerland
Architects: Dietrich Schwarz, Domat/Ems (CH)

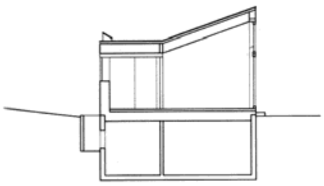


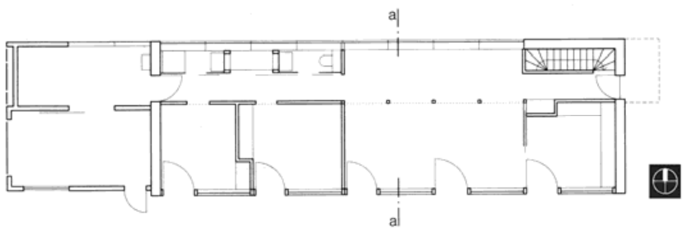
Low-Energy Features: In this passively designed house, a new facade element was developed. The wall element consists of paraffin-filled plastic containers between panes of glass. The most important feature of this material is its high thermal capacity. The system has thermal storage capacity ten times as great as that of concrete. The thermal storage wall (indirect gain system) is used almost two thirds of the south facade Removing the necessity for thermal storage elsewhere in the building.





The building has south-oriented plan, and south facade is kept higher than others to catch more solar beams. The prismatic surface of the second layer (seen in detail) of triple glazing reflects high-angle solar beams, this feature of the system provides protection from summer sun. This passive solar component also provide natural light when the paraffin melts at the end of the day by means of being lighter and more permeable to light. In summer, the material paraffin does not melt as it is protected from summer solar beams and facade remains dark. As a necessary feature of low-energy design, building's insulation value is kept maximum complying with Passive Solar Design strategies.



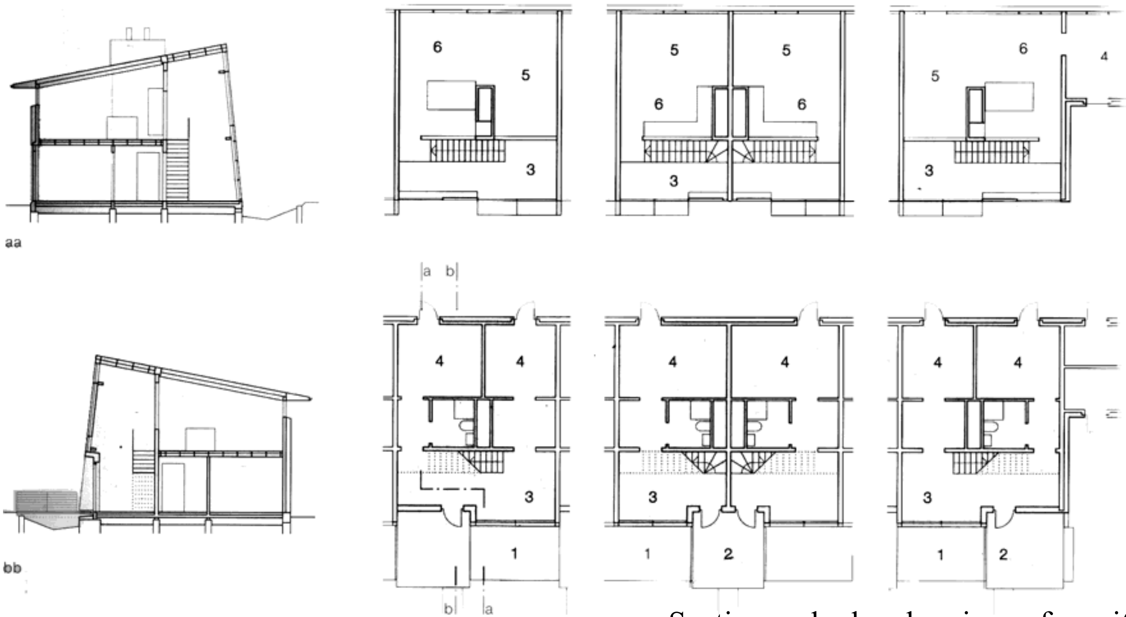


Section and plan drawings of a unit

(Figures are quoted from Detail, 6, 2002)

Project 8: TERRACED HOUSES in Ikast, Switzerland
Architect: Tegnestuen Vandkunsten

Low-Energy Features: This housing includes six rows of two-storey terraced houses. This development is designed in collaboration with the Danish Ministry for building with the aim of having low-energy concept. The glazed south facades of the buildings have thermal collectors and direct gain sunspaces. The collectors serve as hot water supply for domestic use and supplementary for space heating system

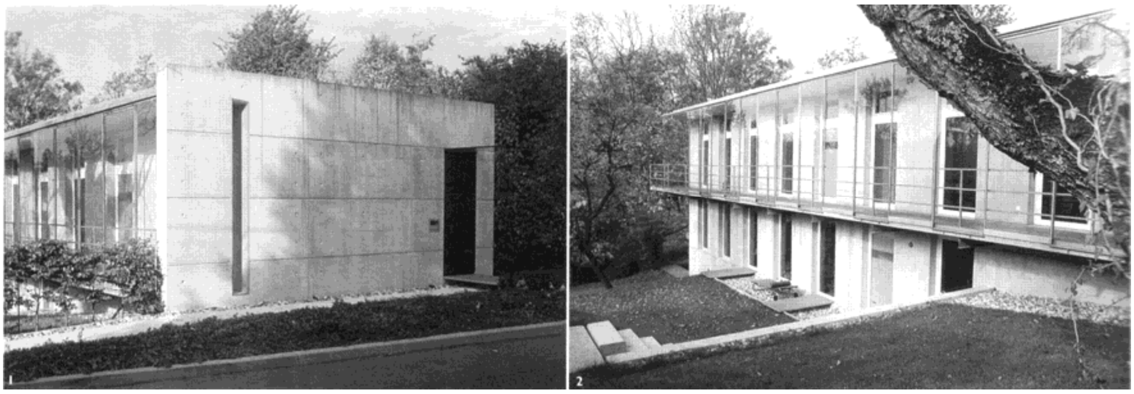


Section and plan drawings of a unit

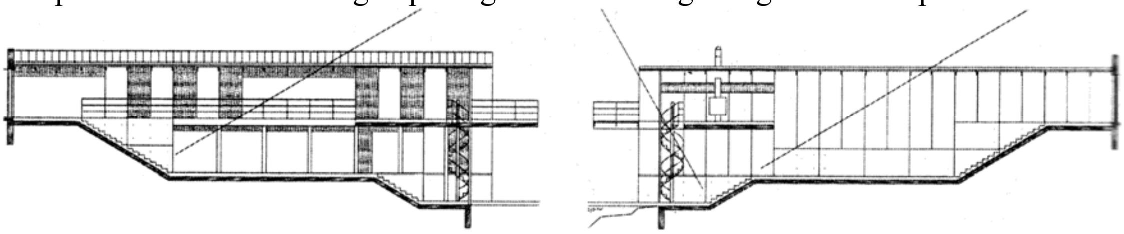
The conservatory space situated behind the glazed wall forms a buffer zone between internal spaces and the outer space. The wall between the conservatory and spaces has glazed sliding panels, the living spaces opening the sliding elements can benefit from solar heat gained by the sunspace. During the heating period when the sun is deficient for passive solar heating the panels are closed then the sunspaces act as an additional insulation layer, so minimizing the heat losses from the spaces they are multifunctional components of Passive Solar Design concept.

(Figures are quoted from Detail, 6, 2002)

Project 9: SOLAR COLLECTOR



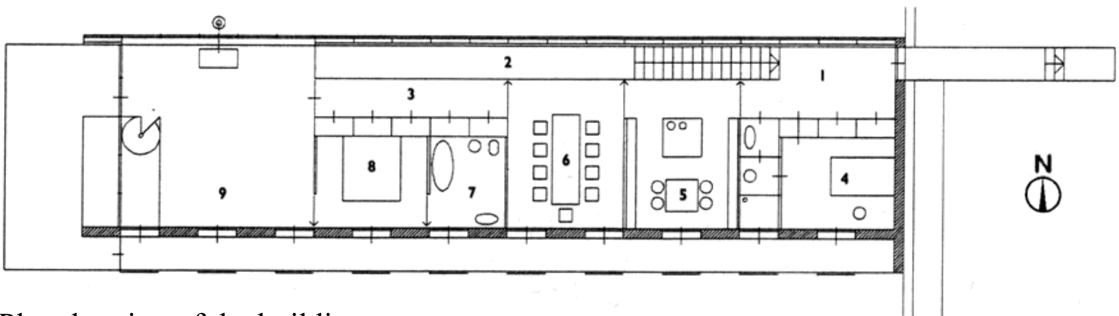
This building is designed with the principles of Passive Solar Design. The main features of its architectural and low-energy concept are orientation, south glazed area as sunspace, direct gain apertures and thermal mass. The building's main facade is oriented towards south to maximize the solar gain in winter days. The heat gained in sunspace is circulated through openings on the inner glazing of the sunspace.



Section drawings of the building.

As space organisation strategy, all the spaces are designed to face south being adjacent to common sunspace. This basic consideration provides all the spaces to gain from solar radiation directly. The sunspace is situated only on the top floor, so its lower surface faces to the outdoor. This forms insulation problem.

The building has a cooling strategy, on the floor of the sunspace there is a thick carpet. This carpet closes the grid spaces preventing the air to circulate from out to inside in winters. In summers it is taken out allowing the air to circulate throug the grid spaces on the floor of the sunspace.



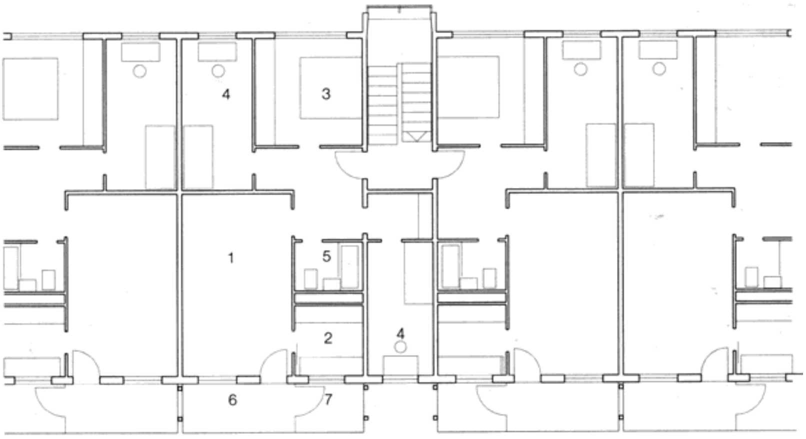
Plan drawing of the building.

(Figures are quoted from Architectural Review, 8, 2002)

Project 10: REFURBISHMENT OF AN APARTMENT in Dresden
Architects: Knerer&Lang

Low-Energy Features: For the rehabilitation of this apartment building, sunspaces are added to the solar side of the building. The old facade is replaced with the new loggias of prefabricated steel structure like a system of shelves over it. Entire load--bearing balcony units with a depth of 30 cm were installed.

The conservatories or sunspaces are enclosed by large glass louvres fixed between the vertical structure of the new loggias. They are intended to become a new outdoor sitting areas -extended living areas- for sunny winter days. In the sunny winter days, they perform as Passive Solar heat gainer for thermal conditioning of the houses; in the cold, overcast, non-solar winter days, they decrease the heat losses from the houses as additional insulation buffer zones. The louvres provide good ventilation when they are opened, they also act as shading devices for summer use obviating the need for external shading elements. Having Passive Solar strategies thermal performance of this building is enhanced. This system -glazed balconies- is used as a very effective way of increasing the energy performance of the buildings in their renovations.



Typical floor plan drawing of the apartment building

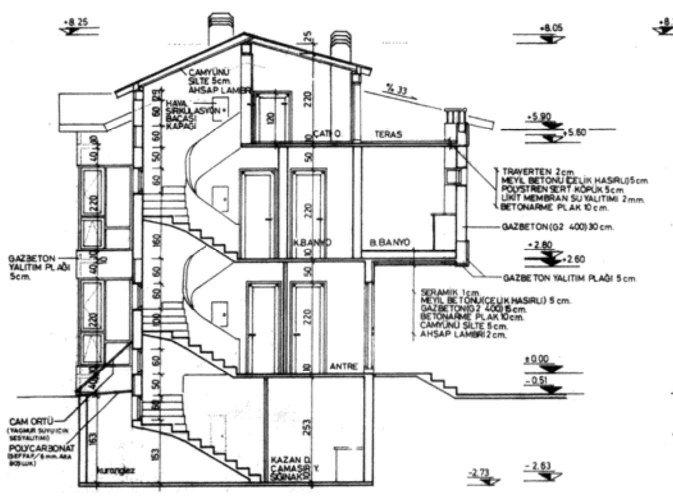
(Figures are quoted from Detail, 4, 1998)

Project 11: GÜZELBAHÇE SOLAR HOUSE in İzmir, Türkiye
Architect: Fikret Okutucu

This house has the floor area of 246m^2, and it was designed as a low-energy building. It accomadates some passive solar desing components and strategies. Trombe walls on south facade, sunspaces on west facade and buffer zones on east facade are the additional parts which implement either building construction or passive solar gain purposes. The building with its components and materials is highly insulated providing good energy saving. To impede heat flows via structural elements, gas concrete insulation panels are applied as heat insulation.

Okutucu (2002) in his study states that changing ability of the houses according to climate and season is very important passive solar design strategy. Passive heating components that are designed on south and southern combination of the building and heat buffers designed on north and northern combination of the building are spaces that hold heat-flow constant when the outdoor climate is not at comfort level. And they provide opportunity for the occupants to extend out in springs and falls.

Besides the heating strategies, passive cooling has also been considered. A ventilation chimney adjoining the staircase is constructed to facilitate cross-ventilation in the building. With these features, the building has very good thermal performance. According to Okutucu's measures, the building pays its investment cost of additional passive solar strategies within five heating seasons.

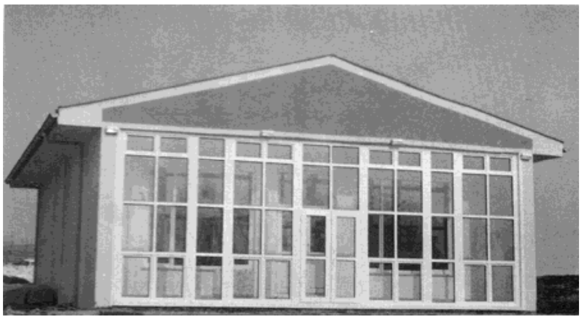


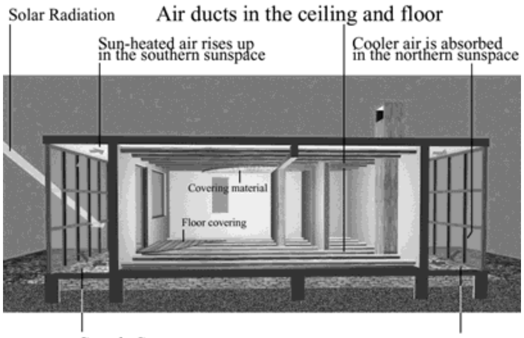
(Figures are quoted from Okutucu, 2002)

Project 12: MURAT REİS CULTURAL CENTRE in İzmir, Türkiye
Architect: Fikret Okutucu

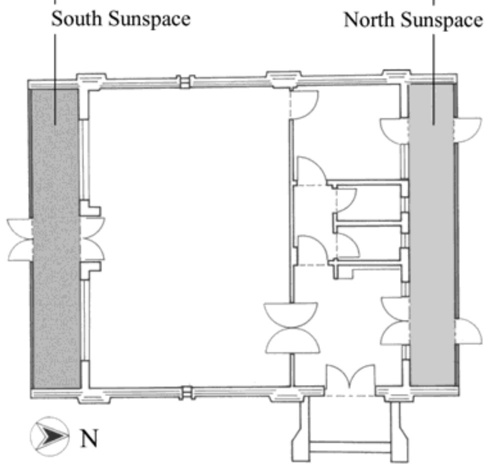
The building's site has slope looking to the west, so the site has good exposure to summer winds called 'imbat' localy and solar radiation for winter use. The building has a meeting hall on the ground floor, a library on the first floor. Passive Solar Design strategies are used to condition the building's spaces. The components used are sunspace facing south and west direction, and trombe walls looking the same directions, and wind captures at the eaves' level. The cares regarding the urban fabric energy-efficiency and protection of ecological balances have constituted the main design decisions.
As other Passive Design strategy, the building has buffer zones on north and east sides on the first floor providing heat and sound insulation. With this strategy, meeting hall and library have been core spaces which is an important criterion for passive buildings.
As summer strategy, ivy landing is placed on the south facade to overshadow the Trombe walls in the summer.
In the interviews with the occupants of the building, they said that they did not experience good performance of Passive Solar strategies. This might be because of lack of good care of the components and detail failures.

Project 13: ENERGY SAVING INFIRMATION HOUSE in Ankara, Türkiye
Project: Melih Tan





Low-Energy Features: This building was designed as energy saving information office. The aim of the project is to show the energy saving precautions, to explain the applications regarding these precautions.
The building has the area of 100 m^2 with one storey. This building was designed as a dissertation study by Dr. Melih Tan in 1993. After the setting of the project, it was taken by Belko c ompany of greater Ankara municipality. Though the building has only direct gain, space conditions were observed at comfort level in terms of thermal performance.



In the building, natural airflow is provided by greenhouses that are attached to north and south sides of the building. The aim of two greenhouses at different directions is to create heat barrier around the building and make the heat losses minimum. As it is observed in the figures, the inner glazing of the south greenhouse has more apertures than north's, this is for heat losses. The south greenhouse is a heat generator and north one is not, it is a buffer zone.

Solar energy is collected by south greenhouse that is covered by 30m2 vertical double glazing. Heated air rises up and flows through the air ducts placed in the ceiling and reaches to the northern greenhouse. Displaced air is replaced with cooler air in the north greenhouse. The building's surrounding is protected from outer harsh conditions by means of this system. The requirement for natural air flow is to have a distance of 10 m between the ends of the flow ducts. The solar house constructed as energy saving information office is compared to an apartment house. According to Tan's measures (1993), when the external temperature is –12C, in the south greenhouse, heat rises up to 35C and it constitutes a thermocirculation effect. Theoretical studies show that with these strategies, it is possible to save energy used by **75%**.

(Photos are quoted from introduction book published by Belko, 1993)

Chapter 5

CASE STUDY

5.1. Summary

In this chapter, there is an analytical sample about energy consciousness and thermal improvements in existing low-rise residential buildings associated with passive solar design tools. Within the objective of this study, this chapter aims to investigate the ways of foreseeing the whole thermal performance of buildings in their lifetime so deciding the optimal solutions providing sound energy-efficient designs for the best performance in terms of thermal performances of the buildings. In this frame, thermal improvement of a unit of dormitories in İzmir Institute of Technologies' Campus will be realized and analysed by using a software called 'Energy-10' which is an award winning tool capable of making designers to desing for energy-efficiency.

5.2. Improvement of an Existing Residential Building's Thermal Performance by using Passive Design Tools

In buildings, the term 'passive' has importance related with the implications of mechanical provision, associated with the problems of complexity, cost, servicing, and dependency on technology rather than independence from it. The goal of energy efficient building design is to decrease energy consumption of buildings for heating, cooling, and lighting that account considerable consumption as mentioned before. So while providing comfort to occupants, residential buildings do not need so complicated conditioning systems or need them with smaller sizes, and less problem in terms of mechanical provision in buildings with energy conscious design strategies.

Passive solar design strategies can provide a profound seasonal reduction in energy use in buildings for heating, cooling, and lighting with satisfying thermal conditions. In order to prove this hypothesis, a residential building from İzmir Institute of Technologie's Campus (i.e., dormitories) was selected for development. This study is based on thermal performance analysis of an existing residential building and improving its thermal comfort conditions by using renewable and environmental energy resources available at neighbourhood via passive design instruments, thus enriching the building's energy wise expressiveness while providing comfort with low-energy use. In this study, it is aimed to demonstrate how energy consumption of the existing buildings would change with passive solar components to be added to them in their renovations. To achieve this study, firstly, the building's thermal insulation properties will be examined as the insulation in an energy efficient building is so vital, and improved in size and material if it does not meet the necessary conditions of thermal insulation standards of Türkiye. Then improvements for the purpose will be applied through different sets of application of:

- ► Building Insulation,
- ► Winter night insulation,
- ► Type of glazings,
- ► Trombe walls,
- ► Sunspaces,
- ► Thermall storage systems,
- ► Solar chimneys,
- ► Wind capturing towers,
- ► Shading devices for summer overheating.

The aim of an energy conscious building design is to minimize the polluting fossil energy needs for thermal and visual (regarding daylighting) comforts as far as possible. The components of energy conscious design that will give the feature of energy efficiency to the building are explained in detail in chapter 3. Some of the components will match structures of the building for improving the thermal comfort and energy use. It means, according to existing function, shape, materials and location of the building, the solar instruments will need to be evaluated for appropriate choices. For instance, it may not need to use wind towers due to sufficient vind velocity at site or it will strongly require thermal mass to keep solar heat for a longer time because of night-time use of the building. Then seasonal gains from applied components will be calculated by using the data that are going to be taken into consideration individually. It is possible to achieve whole study manually but it takes long term and would be awkward for architects to accomplish design process involving the energy-efficient strategies for estimating the performance results.

Technical information about Energy-10:

To implement the study, Energy-10 software is used. Energy-10 is a software tool created for thermal, daylight and life cycle cost analysis of buildings having the area of 10000 ft^2 and under. It works in three general ways:

I. Starting from the beginning of a design. The most effective way of using the software as there is no or little parameter and decision about project, all morphological and energy efficiency strategies can be analysed step by step observing their results from the early beginning.

II. Using 'Energy-10' to evaluate a building that is already well into design. It means: after some design decisions are made it can be used for guiding to probable material and dimensional features in a design process.

III. Using 'Energy-10' to evaluate an existing building in terms of energy use. The software can be used for analysing of existing buildings. This phase is the least efficient one as almost all building parameters determined. But in this way, it can help designers evaluate their retrofit projects in designing of modifications in terms of thermal performance and energy use.

Energy-10 software always forms two cases, one for reference or original, other for improved building. Designers can apply form and materials they want and edit them fitting eachother by means of this feature of the software. First of all, a reference case that is intended to be conventional design is created automatically as bldg1 during the *AutoBuild* process. This building is based on inputs that the designer define in a rectangular shoebox model derived from the aspect ratio defined by the designer. Many features such as wall height, window-to-wall ratio, occupancy schedules, insulation levels, window types and etc. are determined by algorithms in Energy-10 according to building-use category. In case of original defaults would not meet code in the area, users can modify the defaults to be more suitable. After *AutoBuild* is complete, designers can modify all the inputs as they wish including geometrical parameters, dimensions, size of components, materials' thermophysical properties, aperture patterns and schedules of user and HVAC systems. At this point, users may want to modify bldg1 description to meet characteristics of a more realistic reference building than the shoebox produced by Energy-10. Or it is possible to describe another actual building already designed and constructed.

A second building is created automatically as bldg2 during the *AutoBuild* process. This building is formed in accordance with the energy efficiency strategies defined by the user as default. This building is aimed to be low-energy one with the same rectangular shoebox geometry except that several energy-efficiency features of designers' choosing are applied. This dialog box includes all strategies from daylighting, glazing, shading, insulation, air leakage control, thermal mass, solar absorption as passive solar design strategies and energy-efficient lights, high efficiency HVAC and duct leakage as active strategies. Users can select among them as they wish and modify their properties to characterize their solutions. The purpose of two buildings is to make an early estimate of how a typical or conventional building will perform and the low energy one having potentials for energy savings will perform in terms of thermal conditions. At this point, users may think that the initial two buildings are far from the case and there is need to guide the analysis process according to case. As in this study, there is an existing building to be analysed and improved. So after the *AutoBuild,* the building will need to be modified to become realistic reflecting the true situation. Then all the features of bldg1 will be copied to bldg2 using the tools for this on the toolbar.

This study does not include any new approach in terms of design guidelines for passively conditioned buildings as the issue is not a new one. It produce a new point to existing buildings in the context of energy efficiency. The method includes:

► The collection of climatic and environmetal data, assesment of them for thermal analysis and choosing a building of dormitories with site analysis.

► The assessment of the building in the context of relationships between physical properties and solar components.

► The evaluation of thermal conditions and energy use features of the building.

► Improvement of the existing building's thermal conditions by adding some passive solar components and analysing the added strategies by the help of Energy-10 software.

The Collection of Climatic and Environmetal Data, Assessment of Them for Thermal Analysis and Choosing a Building of Dormitories With Site Analysis:

In this part, geographical position and regional solar and wind effects will be investigated then their values are going to be showed in figures. For further radiation and shading works, the solar geometry of the site and the angular values of the sun will be calculated by using a software on the internet site of 'Sun Position' (www.susdesign.com/sunposition).

Depending on the occupation season it will be suitable to orientate the buildings to south as they will be occupied in heating season most (i. e., fall, winter, spring). In site plan, there are buildings with different orientations regardless of energy efficient design considerations. In operation phase, many of the buildings are going to have lack of true solar exposure for heat gain strategies. It can be said that the buildings facing to the south are going to have the most solar heat gain. Therefore, a building with true solar orientation and the least shadow effect due to other buildings, trees, hills, etc. will be chosen as case study. Figure 5.1 and 5.2 show sun's position of site having the latitude of 38,46 degrees (i. e., İzmir) for winter and summer. By the help of these critical angles, it can be observed which building will obstruct the other most. Figure 5.3 and 5.4 show shading patterns of the buildings for these critical angles of the sun at the site in winter and summer. After the building site has been analysed, meteorological data of the site was formed by using 'WeatherMaker' which runs under Energy-10.

For the choice of the building, the only ones which have best solar orientation are taken into consideration for a suitable choice, in this regard, the buildings that have this position are numbered as 1, 2, 3, ... As it is observed from the figures 5.3 and 5.4, the building numbered as 7 has the minimum impact from its surrounding in terms of having accsess to the sun at the critical angles. So the building numbered as 7 is chosen for refurbishment project.

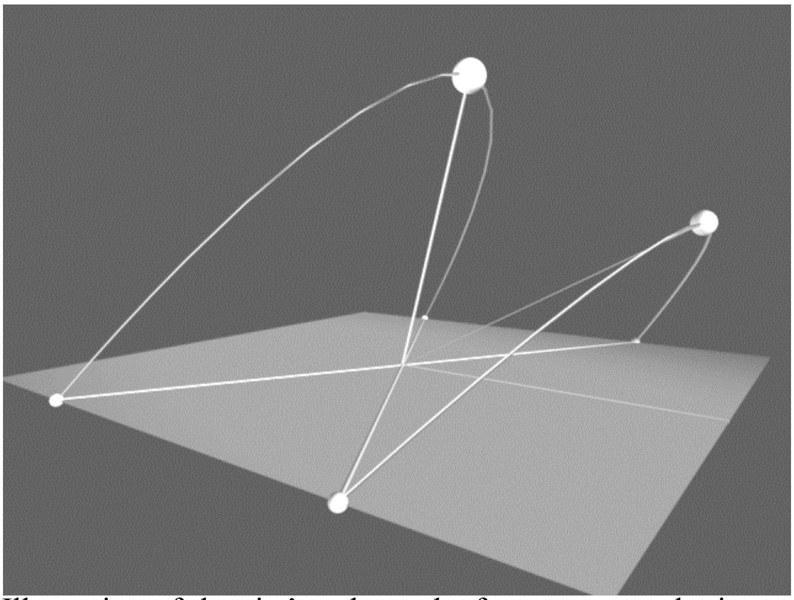


Figure 5.1: Illustration of the site's solar paths for summer and winter seasons. In summer, sun tracks a higher orbit than it does in winter.

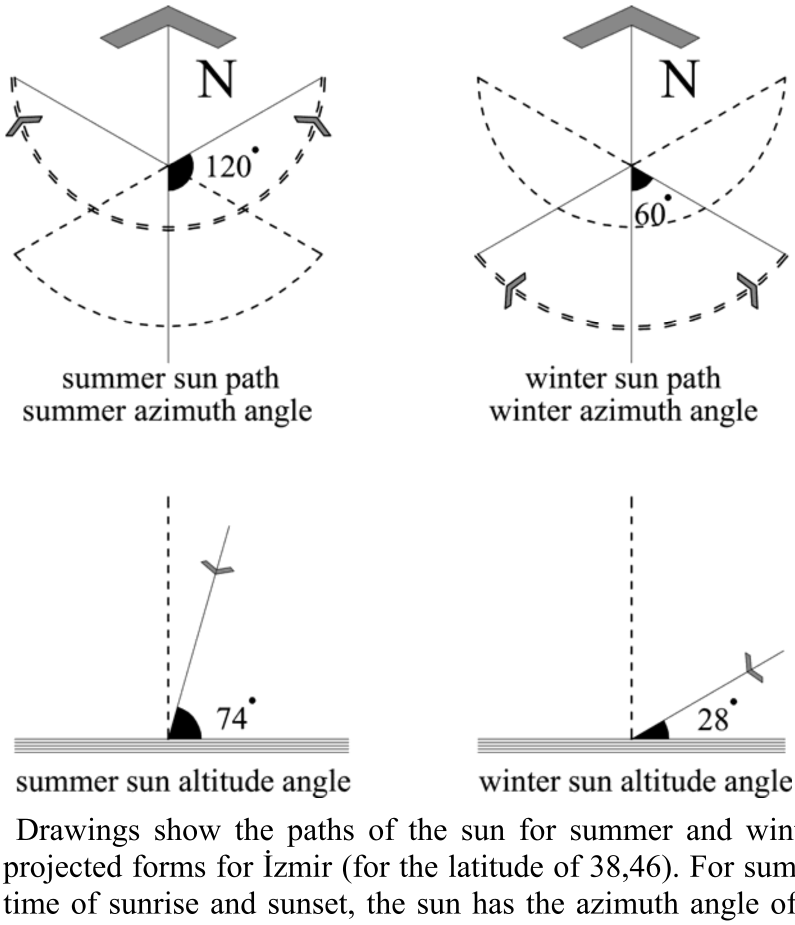


Figure 5.2: Drawings show the paths of the sun for summer and winter in their projected forms for İzmir (for the latitude of 38,46). For summer, in the time of sunrise and sunset, the sun has the azimuth angle of about 120 degrees, and it has altitude angle of 74 degrees in section. For winter, in the time of sunrise and sunset, the sun has the azimuth angle of 60 degress, and it has altitude angle of 28 degrees in section. These are the critical angles to be considered in a building design in terms of thermal condition.

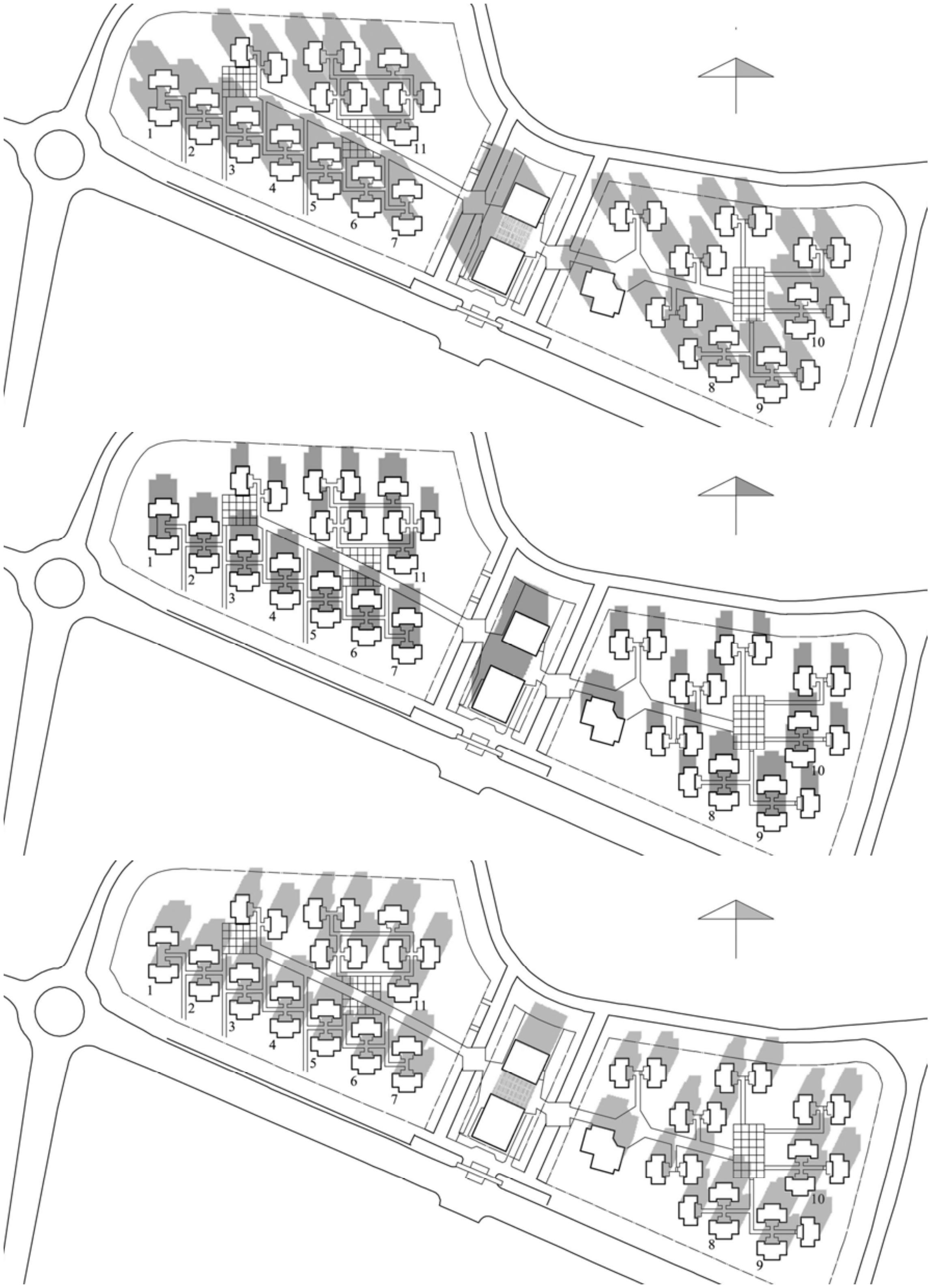


Figure 5.3: Shading ptterns of the site for critical solar angles for winter. The top figure illustrates the shading pattern of the buildings for two hour before solar-noon. The middle figure illustrates the shading pattern of the buildings for the time of solar-noon. The bottom figure illustrates the shading pattern of the buildings for the time of two hour after solar-noon.

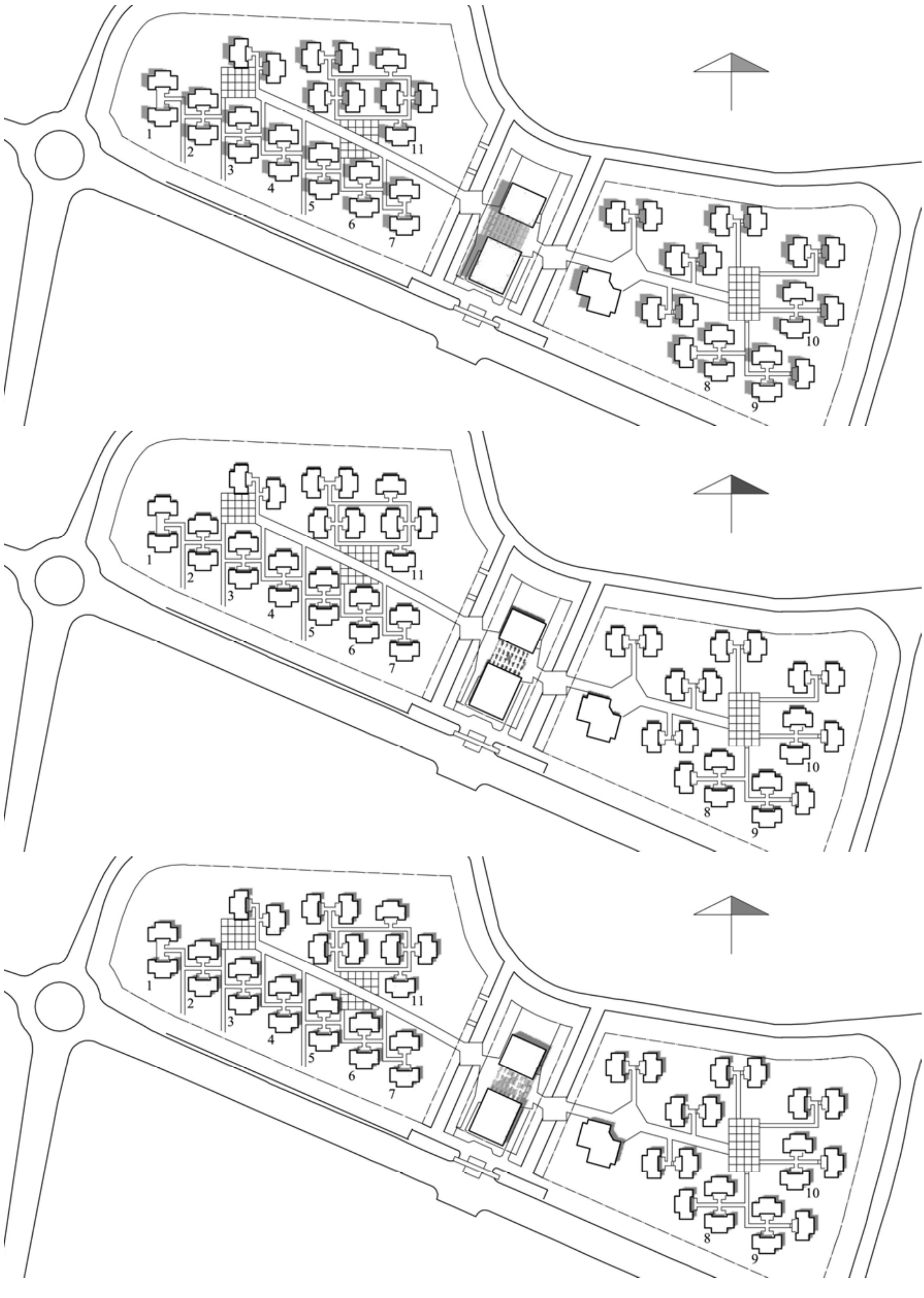


Figure 5.4: Shading ptterns of the site for critical solar angles for summer. The top figure illustrates the shading pattern of the buildings for two hour before solar-noon. The middle figure illustrates the shading pattern of the buildings for the time of solar-noon. The bottom figure illustrates the shading pattern of the buildings for the time of two hour after solar-noon.

The Assesment of Chosen Building's Physical Properties:

This part will include examination of the building's ratio of openings to wall area insulation level in terms of infiltration and shading paterns of the building for summer conditions when solar exposure is high.

The chosen building in its original state has some disadvantages in terms of thermal and visual comforts. Figures 5.5, 5.6, 5.7, and 5.8 show the drawings of the original building. Firstly, though it has solar orientation it has no sufficient apertures for direct gain which will be an important part of the Passive Solar Heating strategies in cold seasons. The glazing to wall ratio of the original building is 6%. Glazing to floor area ratio is 6,12%. Generally, 12 to 15% of glazing to floor area ratio is said as suitable level for Passive Conditions of the buildings in temperate climates.

This deficiency of apertures causes insufficient daylight as well. Daylight factor of a building is another important one for low-energy characteristics of the buildings in terms of visual comfort and electricity use for illumination. However, this glazing to wall ration can be an important energy-saving strategy that is also cruical for Passive Solar Design of the buildings. This dilemma can be overcome by taking some precautions. Keeping the insulation level of these apertures high in terms of heat transfer by having low conductivity coefficients for glazings and reducing the infiltration level will help impeding mentioned contradiction. This might also be achieved by creating buffer zones as sunspaces. One of the most important suggestion is to enhance glazing to wall ratio for use of solar energy for passive heating and natural lighting.

The most important weakness of the original building that needs to be considered is its north vulnerable entrances to the accomodation units. Opening of the doors of the units to the out directly will cause substantial heat losses by means of convection transfer. Besides, there will need for shelter to protect the occupants from outer physical conditions such as rain, intense solar radiation, harsh winds, and etc. This deficiency overshadows the building's insulation standard and need to be considered. In this direction, a closed common hall will be designed for thermal and functional purposes.

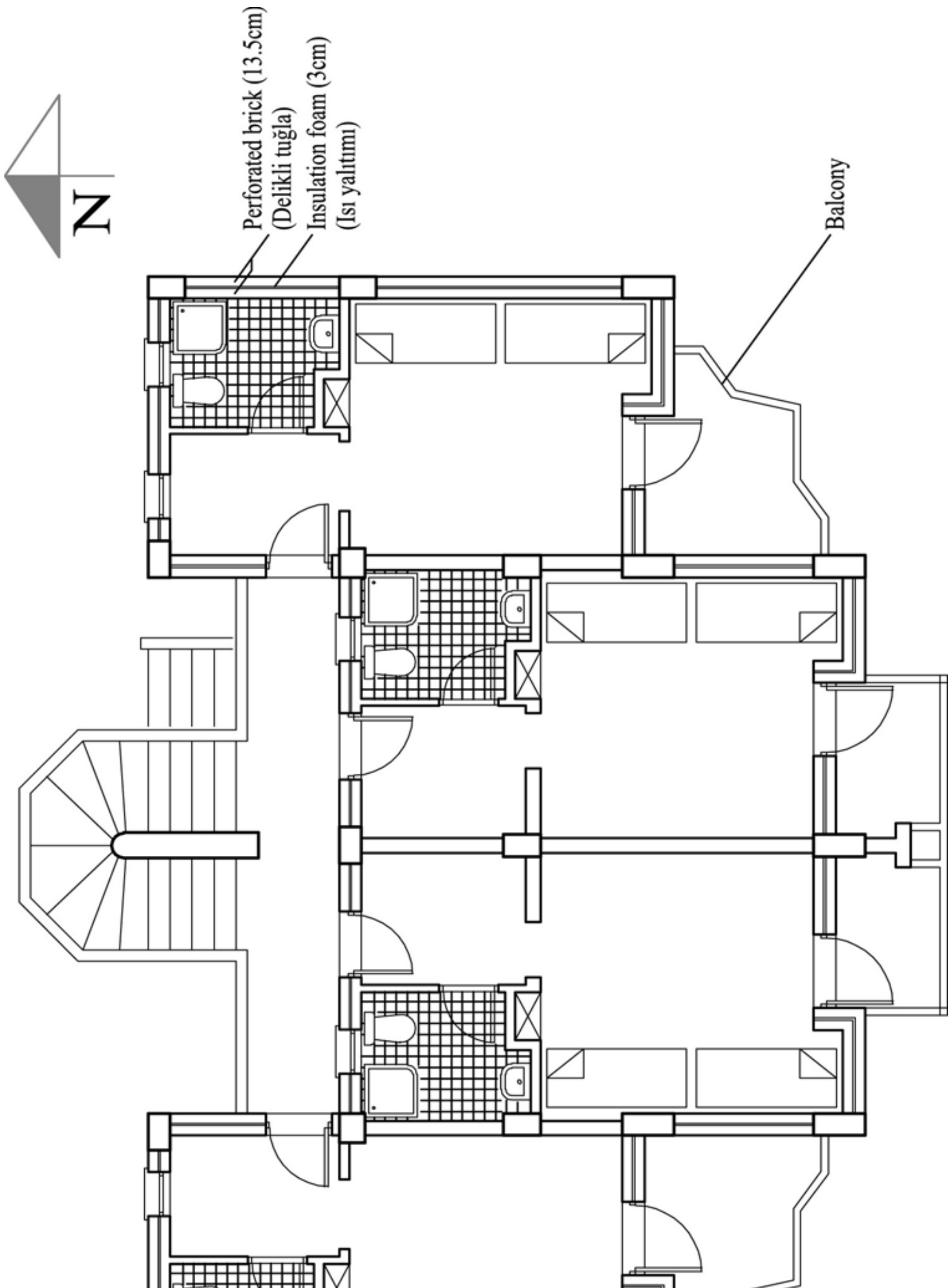


Figure 5.5: The typical plan of the original building.

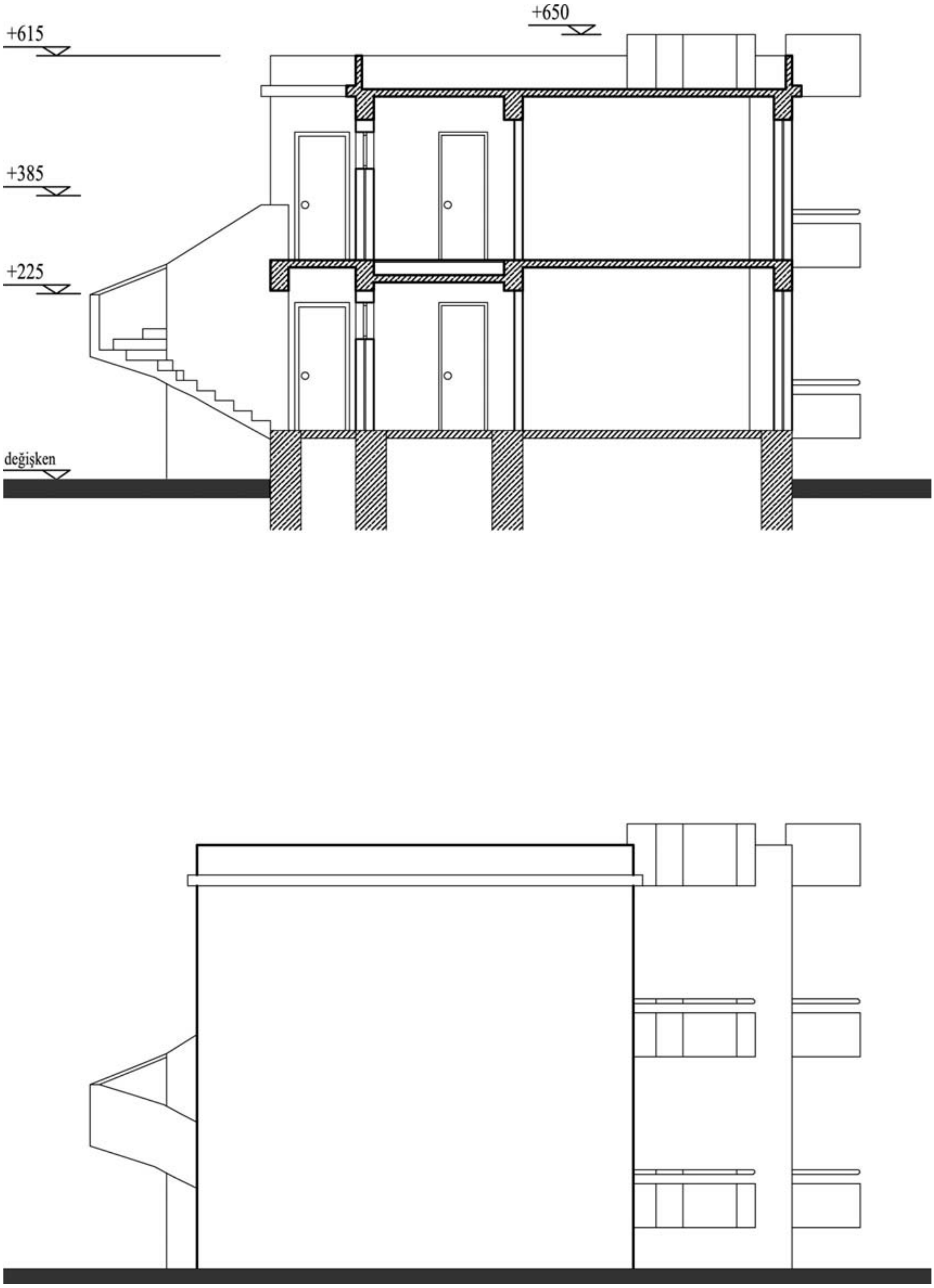


Figure 5.6: The section and west elevation of the original building.

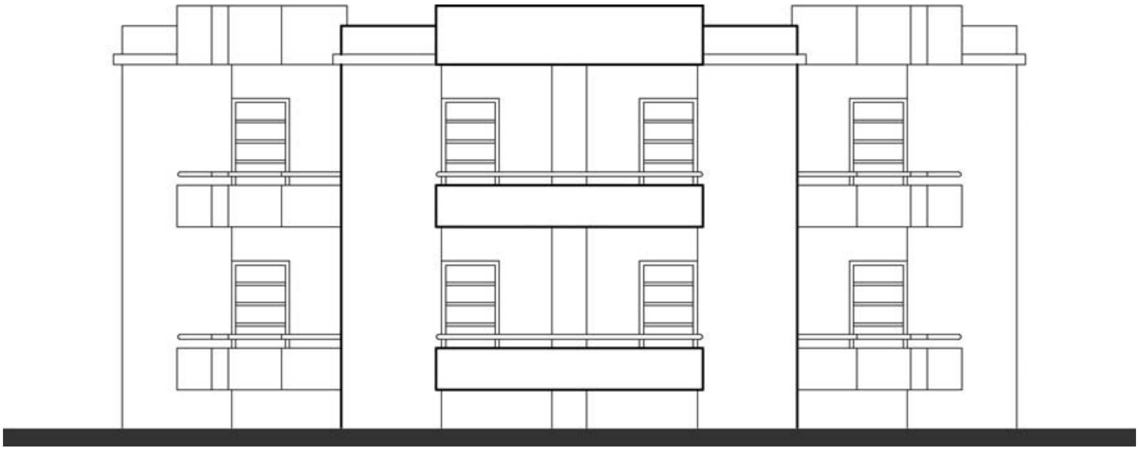


Figure 5.7: The south elevation of the original building.

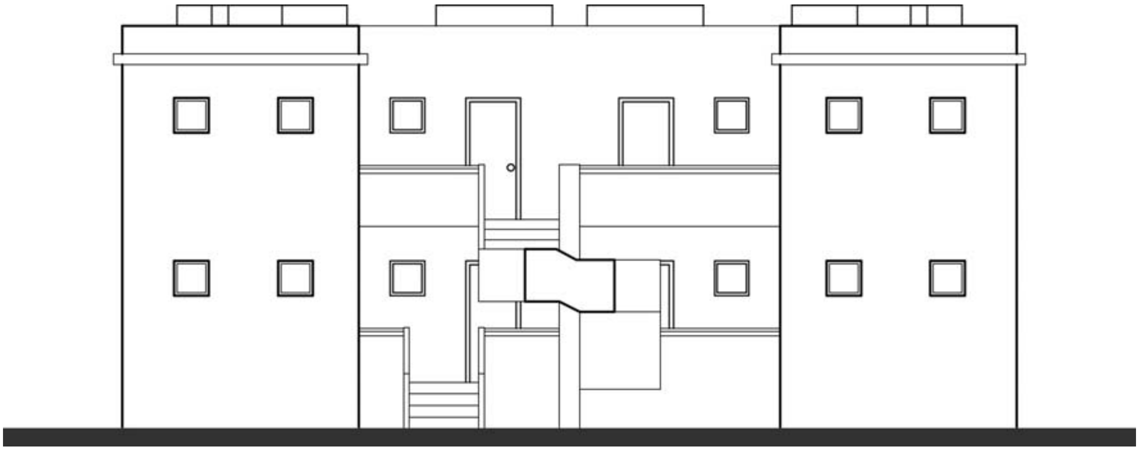


Figure 5.8: The north elevation of the original building.

The Evaluation of Thermal Conditions of The Existing Building:

This part includes examination of thermal insulation properties of the existing building. For the analysis of thermal insulation of the original building, a software was used to ease and shorten the calculation process. For the analysis of thermal insulation level of the existing building, the software "TS825vb1" (heat insulation calculation tool) is obteined from 'ODE' a company of insulation materials for heating, water, sound and fire. For this, the building's dimensions obtained as surface area that loss heat, reinforced concrete exposing to the outside, window and door sizes and materials. According to results of the analysis via TS825vb1, the building does not meet the requirements of building insulation standards of Turkey with its original state. Table 5.1 shows the heat conductivity of the materials as building's components and table 5.2 shows the energy losses and gains of the building by the results of the software TS825vb1. As it is seen original insulation level is not sufficient, the most important reason for this is non-insulated skeleton system causing great loss of heat. As it is mentioned in the text, the insulation is crucial for passive buildings and an accurate insulation provide energy efficiency on a large scale. To show the role of insulation, a second calculation has been done applicating insulation material to the skeleton. Table 5.3 shows that great amount of energy is saved with this additional insulation.

Improvement of The Existing Building's Thermal Performances by Adding Some Passive and Active Solar Components:

For the improvement in thermal performance and energy use, some passive and active solar components and strategies will be applied to the original building then, the added strategies will be analysed by the help of Energy-10 software. These components:

- ► Insulated Trombe walls with one-way lids.
- ► Advanced glazed balconies (sunspaces).
- ► Some additonal windows for natural light and solar apertures for direct gain.
- ► North buffer zone.
- ► Shading devices to prevent the building from overheating in summer.
- ► Thermal solar collectors for domestic water heating and
- ► Photovoltaic panels for the building's electricity use.

Figures 5.9, 5.10, 5.11, 5.12, 5.13, 5.14, and 5.15 show the improved building.

Binanın Özgül Isı Kaybı Hesabı

BİNADAKİ YAPI ELEMANLARI			Yapı elemanının kalınlığı d (m)	Isıl iletkenlik hesap değeri λ_H (W/mK)	d/λ, 1/α (m^2K/W)	Isı iletkenlik katsayısı U (W/m^2K)	Isı kaybedilen yüzey A m^2	Isı kaybı A x U (W/K)
DUVAR (dış havaya açık)	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,13			
DUVAR 1	4.2	Çimento harcı	0,030	1,400	0,021			
	7.1.6	Yatay delikli tuğlalarla duvarlar (TS 4563)	0,135	0,450	0,300			
	10.2.1.1	Polistiren - partiküler köpük (TS 7316)	0,030	0,040	0,750			
			0,135	0,450	0,300			
	4.2	Çimento harcı	0,020	1,400	0,014			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,04			
TOPLAM					**1,56**	**0,642**	**229,60**	**147,40**
DUVAR (dış havaya açık)	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,13			
DUVAR 2	4.2	Çimento harcı	0,030	1,400	0,021			
	5.1.1	Normal beton, (TS 500'e uygun), doğal agrega veya mıcır kullanılarak yapılmış betonlar (Donatılı)	0,300	2,100	0,143			
			0,020	1,400	0,014			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,04			
TOPLAM					**0,35**	**2,868**	**78,00**	**223,70**
TAVAN (üzeri açık)	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,13			
TAVAN 1	3.1	Kum, çakıl, kırma taş (mıcır)	0,050	0,700	0,071			
	9.2.2.6	Polimer bitümlü su yalıtım örtüleri	0,003	0,190	0,016			
	4.6	Çimento harçlı şap	0,050	0,040	1,250			
	4.6	Çimento harçlı şap	0,040	1,400	0,029			
	5.1.1	Normal beton, (TS 500'e uygun), doğal agrega veya mıcır kullanılarak yapılmış betonlar (Donatılı)	0,120	2,100	0,057			
	4.2	Çimento harcı	0,020	1,400	0,014			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)			0,04			
TOPLAM					**1,61**	**0,622**	**110,00**	**68,42**
TABAN (toprağa oturan/iç ortam)	$1/\alpha_i$	Yüzeysel ısıl iletim katsayısı (iç)			0,17			
TABAN 1	9.1.4	Halı vb. kaplamalar	0,010	0,070	0,143			
	8.1.1	İğne yapraklı ağaçlardan elde edilmiş olanlar	0,020	0,130	0,154			
	4.6	Çimento harçlı şap	0,040	1,400	0,029			
	5.1.2	Normal beton, (TS 500'e uygun), doğal agrega veya mıcır kullanılarak yapılmış betonlar (Donatısız)	0,100	1,740	0,057			
	9.2.2.6	Polimer bitümlü su yalıtım örtüleri	0,002	0,190	0,011			
	5.1.2	Normal beton, (TS 500'e uygun), doğal agrega veya mıcır kullanılarak yapılmış betonlar (Donatısız)	0,050	1,740	0,029			
TABAN 1	3.1	Kum, çakıl, kırma taş (mıcır)	0,150	0,700	0,214			
	$1/\alpha_d$	Yüzeysel ısıl iletim katsayısı dış)						
TOPLAM					**0,77**	0,5 x**1,240**	**110,00**	**68,20**
PENCERE						**2,800**	**4,32**	**12,10**
KAPI						**4,000**	**16,00**	**64,00**
Yapı elemanlarından iletim yoluyla gerçekleşen ısı kaybı toplamı :							**583,82**	**W/K**

H = Hi + Hh

Hi = 583,82 W/K

Hh = 162,6 W/K

H = 746,44 W/K

Table 5.1: Building's components and their thermophysical properties.

YILLIK ISITMA ENERJİSİ İHTİYACI

Aylar	Isı kaybı			Isı kazançları			KKO	Kazanç kullanım faktörü	Isıtma enerjisi ihtiyacı
	Özgül ısı kaybı	Sıcaklık farkı	Isı kayıpları	İç ısı kazancı	Güneş enerjisi kazancı	Toplam			
	H = Hi + Hh (W/K)	Ti-Td (K,C)	H(Ti-Td) (W)	ϕ_i (W)	ϕ_g (W)	$\phi_T = \phi_i + \phi_g$ (W)	γ (-)	η_{ay} (-)	Q_{ay} (kJ)
OCAK	721,62	10,0	7.216	986	40	1.026	0,14	1,00	16.044.480
ŞUBAT		8,7	6.278		58	1.044	0,17	1,00	13.566.528
MART		6,5	4.690		81	1.067	0,23	0,99	9.418.472
NİSAN		2,3	1.659		103	1.089	0,66	0,78	2.098.431
MAYIS		0,0	0		123	1.109	0,00	0,00	0
HAZİRAN		0,0	0		129	1.115	0,00	0,00	0
TEMMUZ		0,0	0		126	1.112	0,00	0,00	0
AĞUSTOS		0,0	0		114	1.100	0,00	0,00	0
EYLÜL		0,0	0		89	1.075	0,00	0,00	0
EKİM		0,0	0		62	1.048	0,00	0,00	0
KASIM		4,7	3.391		42	1.028	0,30	0,96	6.231.479
ARALIK		8,6	6.205		34	1.020	0,16	1,00	13.439.520
							$Q_{yıl} = \Sigma Q_{ay}$ =		60.798.910

Qyıl = 0,278 x 1/1000 x 60.798.910 = 16.902 kWh

Bu bina için sınırlandırılan enerji ihtiyacı Q' = 18,82 kWh/m3

Bu bina için hesaplanmış olan ısı ihtiyacı Q = 27,44 kWh/m3

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

Table 5.2: Building's energy losses and gains with the case of uninsulated skeleton system.

YILLIK ISITMA ENERJİSİ İHTİYACI

Aylar	Isı kaybı			Isı kazançları			KKO	Kazanç kullanım faktörü	Isıtma enerjisi ihtiyacı
	Özgül ısı kaybı	Sıcaklık farkı	Isı kayıpları	İç ısı kazancı	Güneş enerjisi kazancı	Toplam			
	H = Hi + Hh (W/K)	Ti-Td (K,C)	H(Ti-Td) (W)	ϕi (W)	ϕg (W)	$\phi_T = \phi i + \phi g$ (W)	γ (-)	η_{ay} (-)	Q_{ay} (kJ)
OCAK	571,05	10,0	5.710	986	40	1.026	0,18	1,00	12.140.928
ŞUBAT		8,7	4.968		58	1.044	0,21	0,99	10.198.068
MART		6,5	3.711		81	1.067	0,29	0,97	6.936.217
NİSAN		2,3	1.313		103	1.089	0,83	0,70	1.427.414
MAYIS		0,0	0		123	1.109	0,00	0,00	0
HAZİRAN		0,0	0		129	1.115	0,00	0,00	0
TEMMUZ		0,0	0		126	1.112	0,00	0,00	0
AĞUSTOS		0,0	0		114	1.100	0,00	0,00	0
EYLÜL		0,0	0		89	1.075	0,00	0,00	0
EKİM		0,0	0		62	1.048	0,00	0,00	0
KASIM		4,7	2.683		42	1.028	0,38	0,93	4.476.280
ARALIK		8,6	4.911		34	1.020	0,21	0,99	10.111.910
							$Q_{yıl} = \Sigma Q_{ay} =$		45.290.817

Qyıl = 0,278 x 1/1000 x 45.290.817 = 12.590 kWh

Bu bina için sınırlandırılan enerji ihtiyacı Q' = 18,82 kWh/m3

Bu bina için hesaplanmış olan ısı ihtiyacı Q = 20,44 kWh/m3

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

Table 5.3: Energy losses and gains with the case of insulated skeletonsystem.

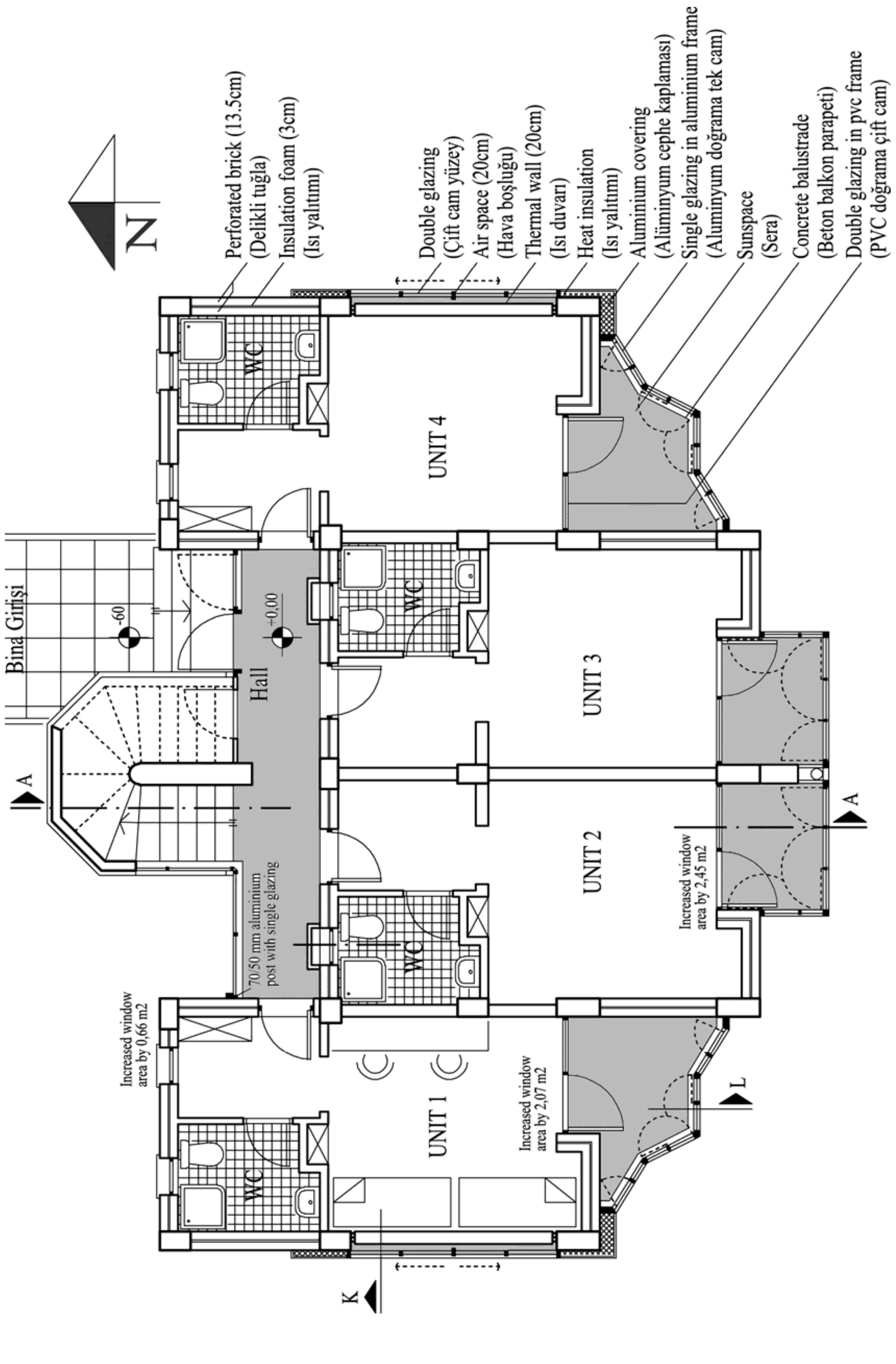


Figure 5.9: Ground floor plan of the improved building (scale: 1/100).

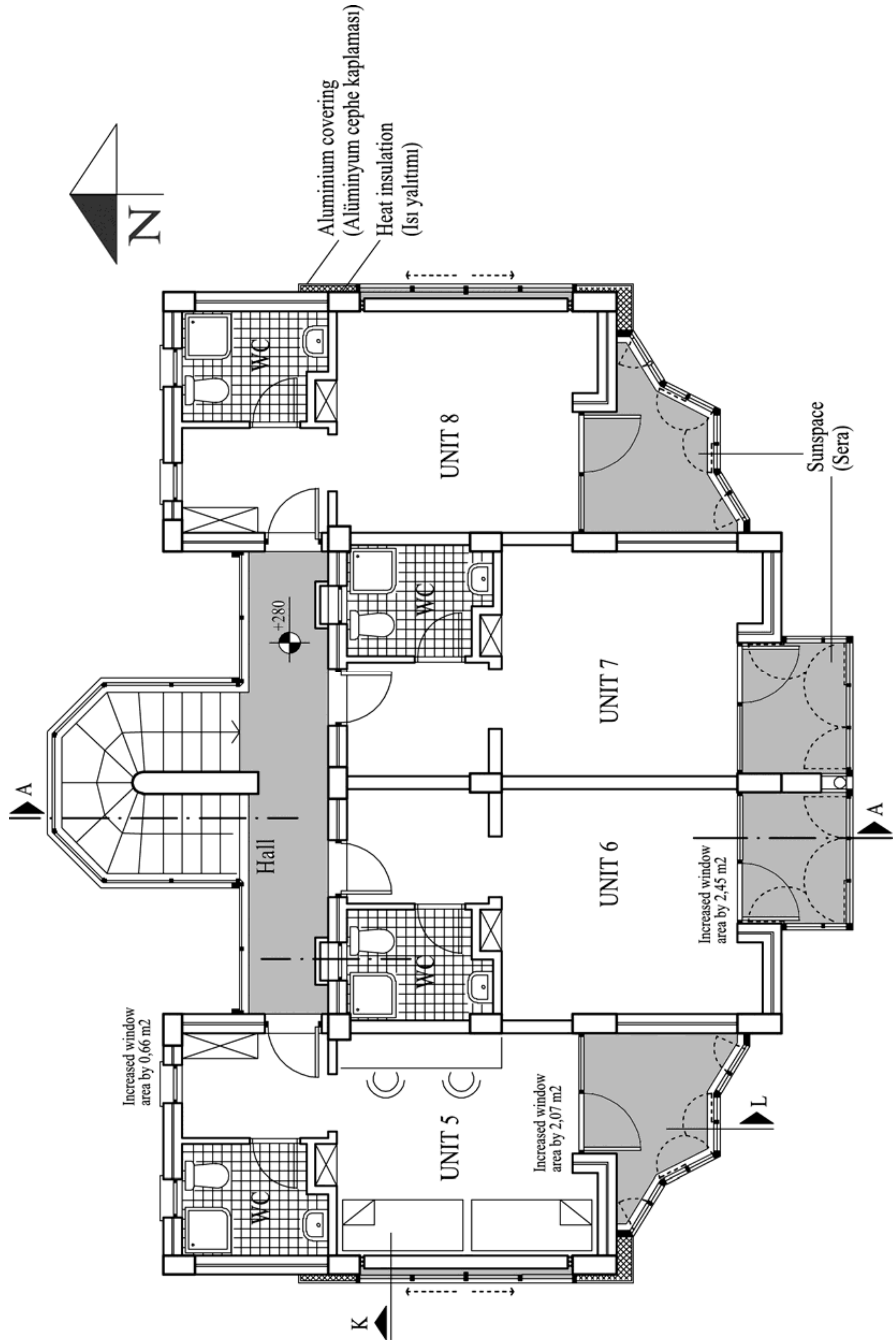


Figure 5.10: First floor plan of the improved building (scale: 1/100).

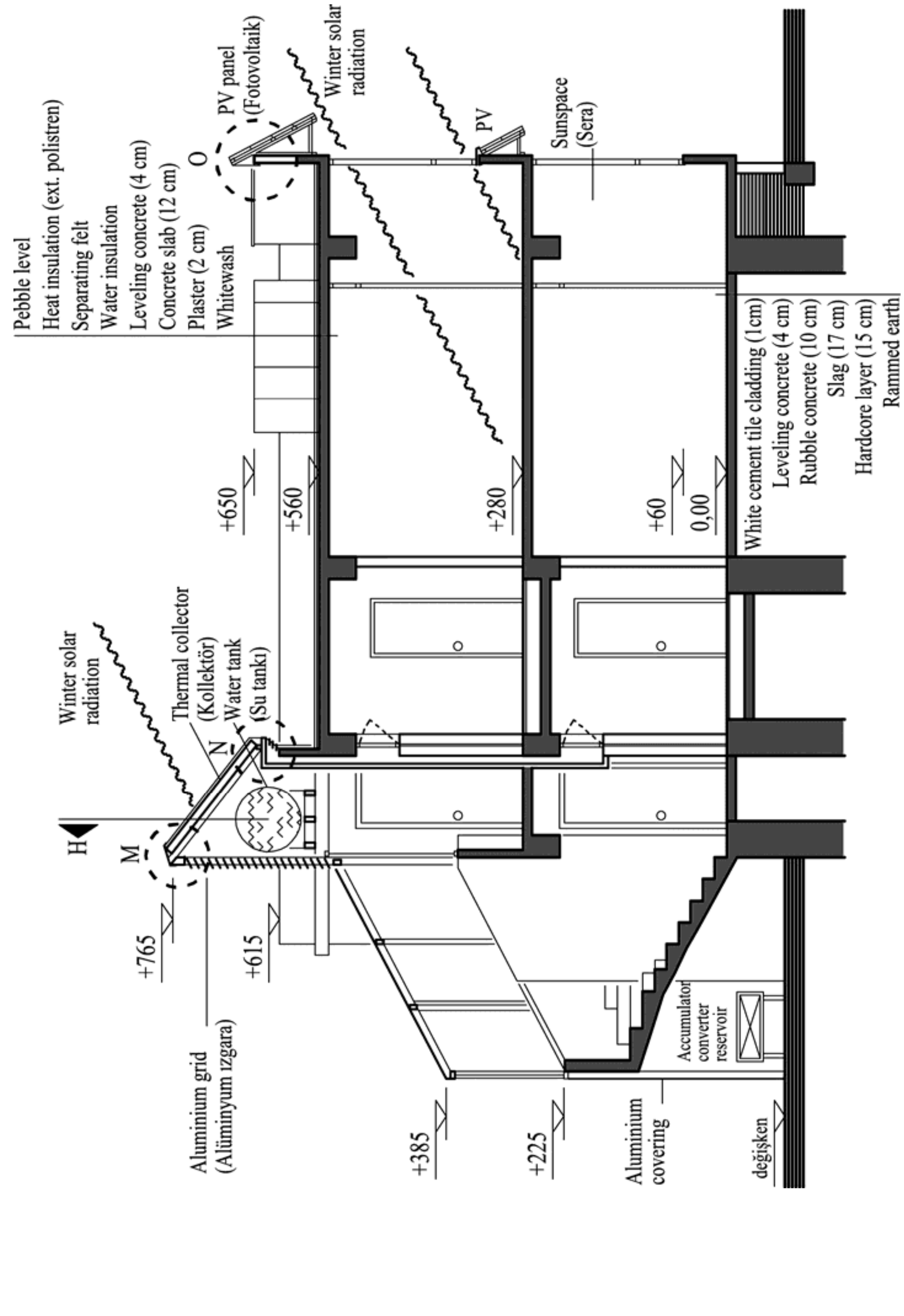


Figure 5.11: A-A section of the improved building (scale: 1/100).

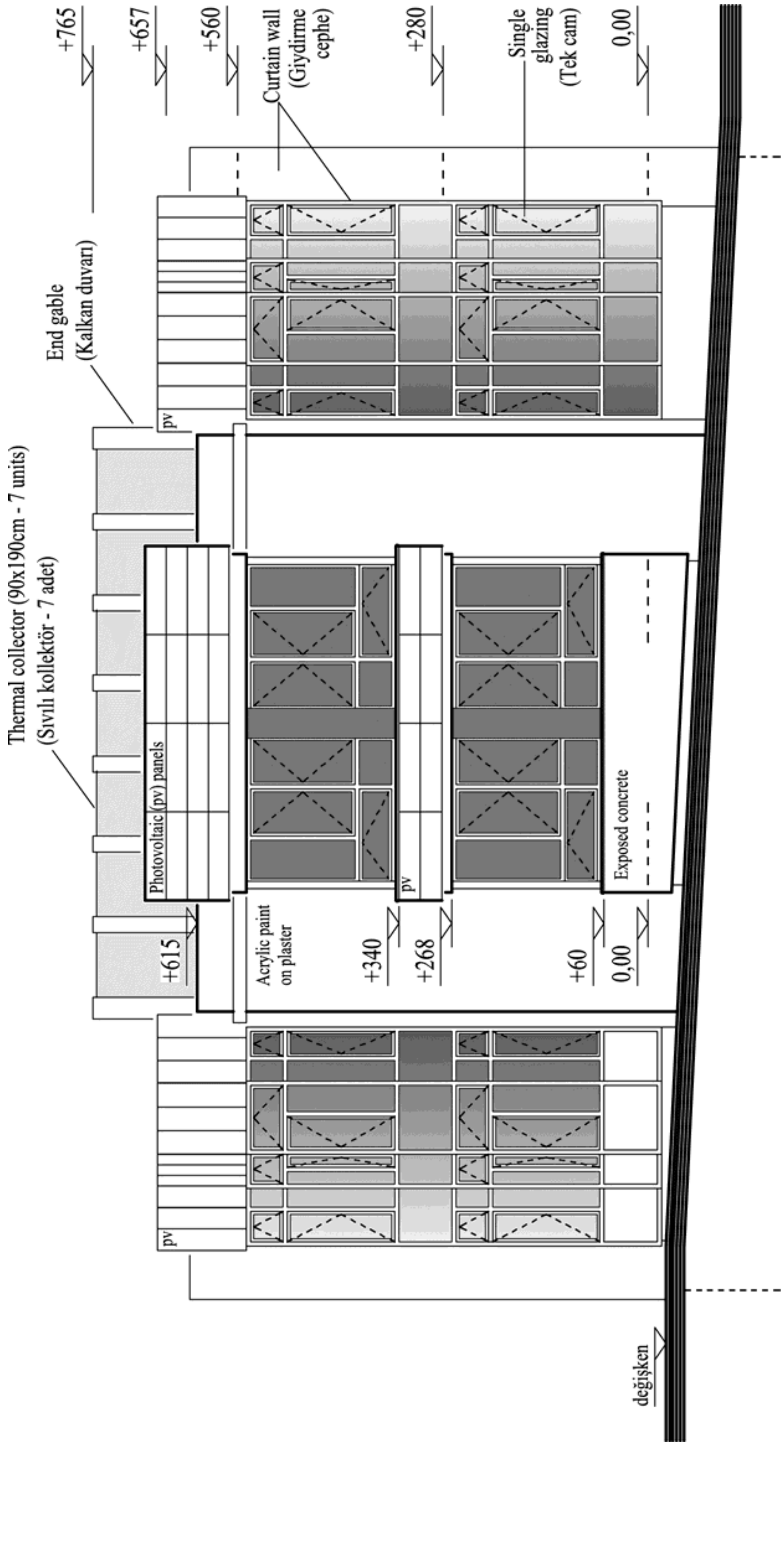


Figure 5.12: The south elevation of the improved building (scale: 1/100).

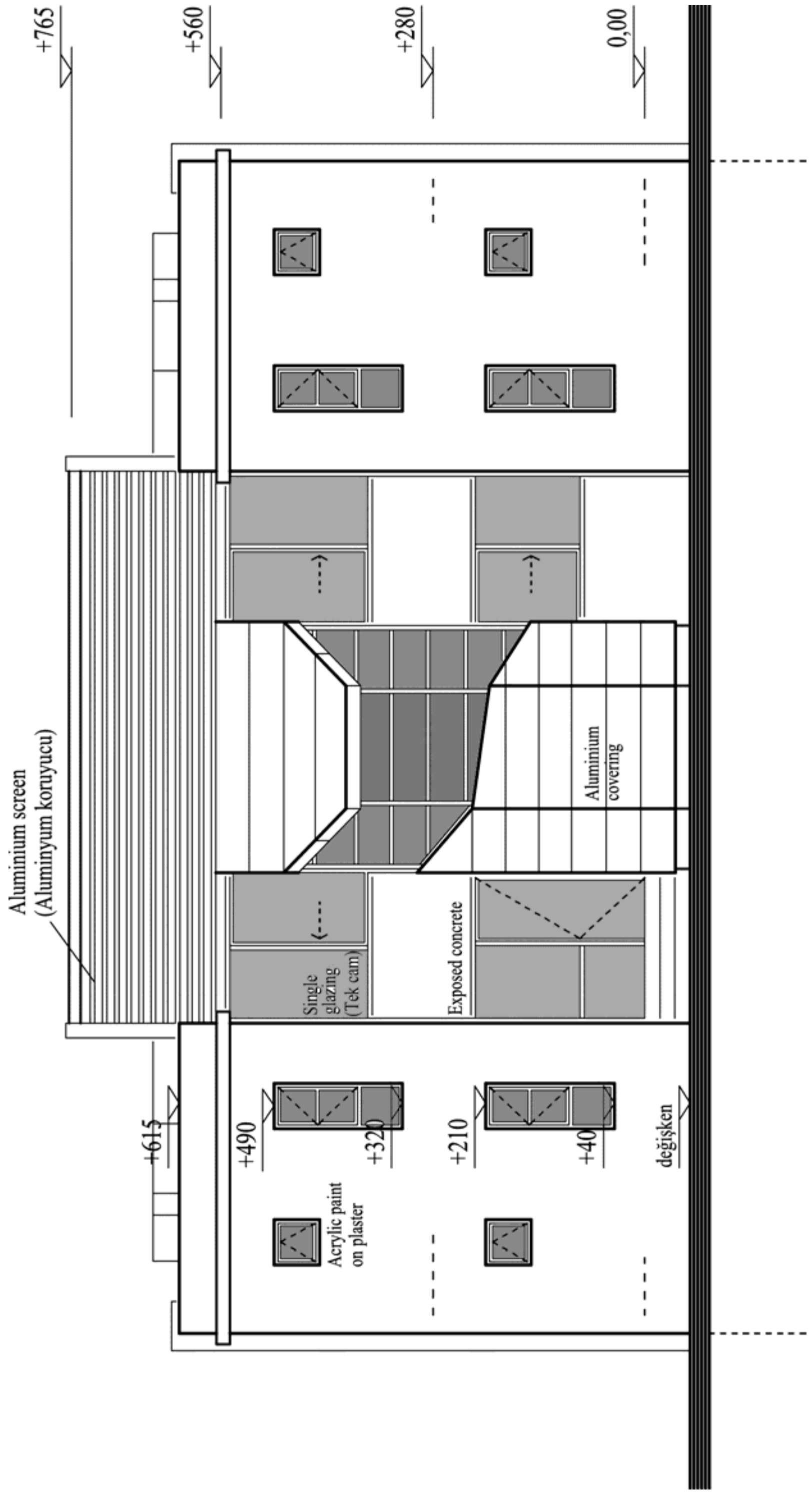


Figure 5.13: The north elevation of the improved building (scale: 1/100).

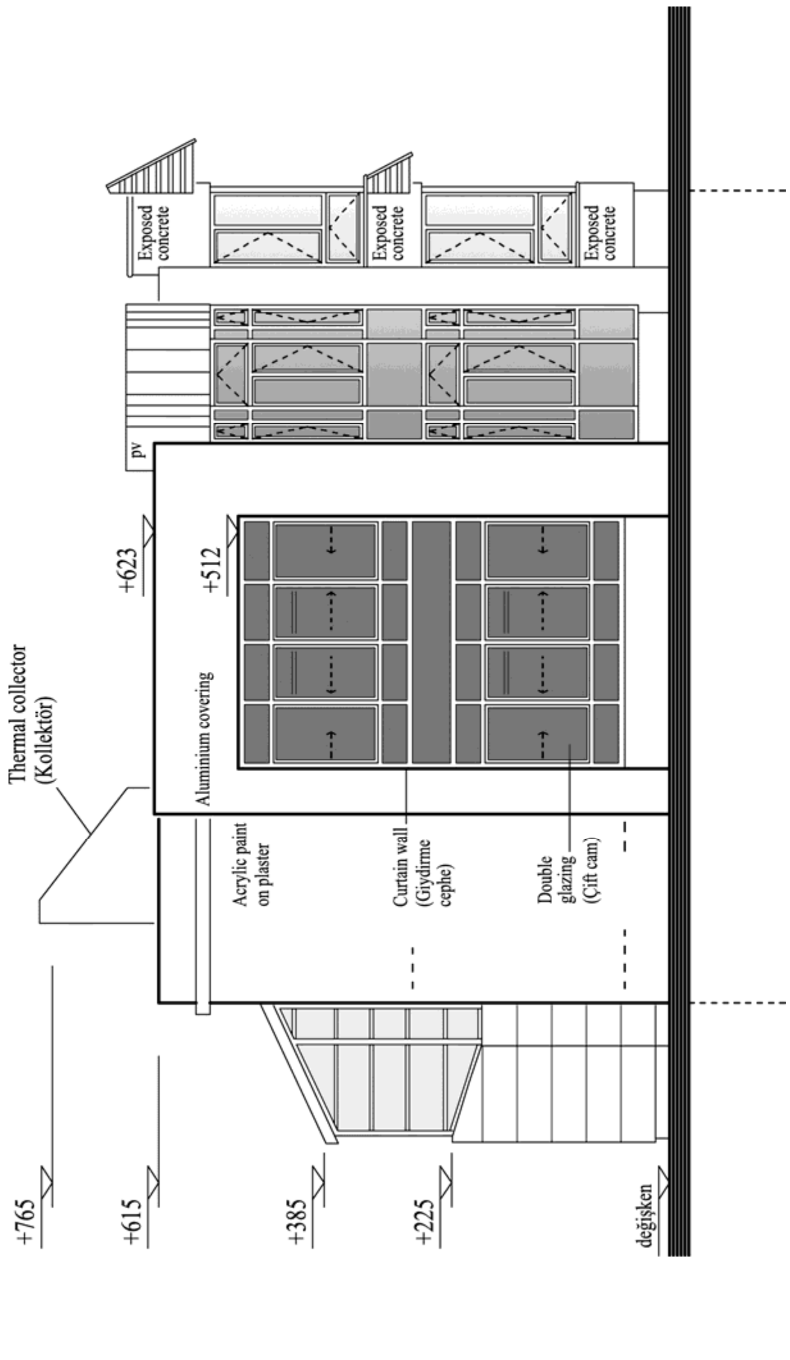


Figure 5.14: The west elevation of the improved building (scale:1/100).

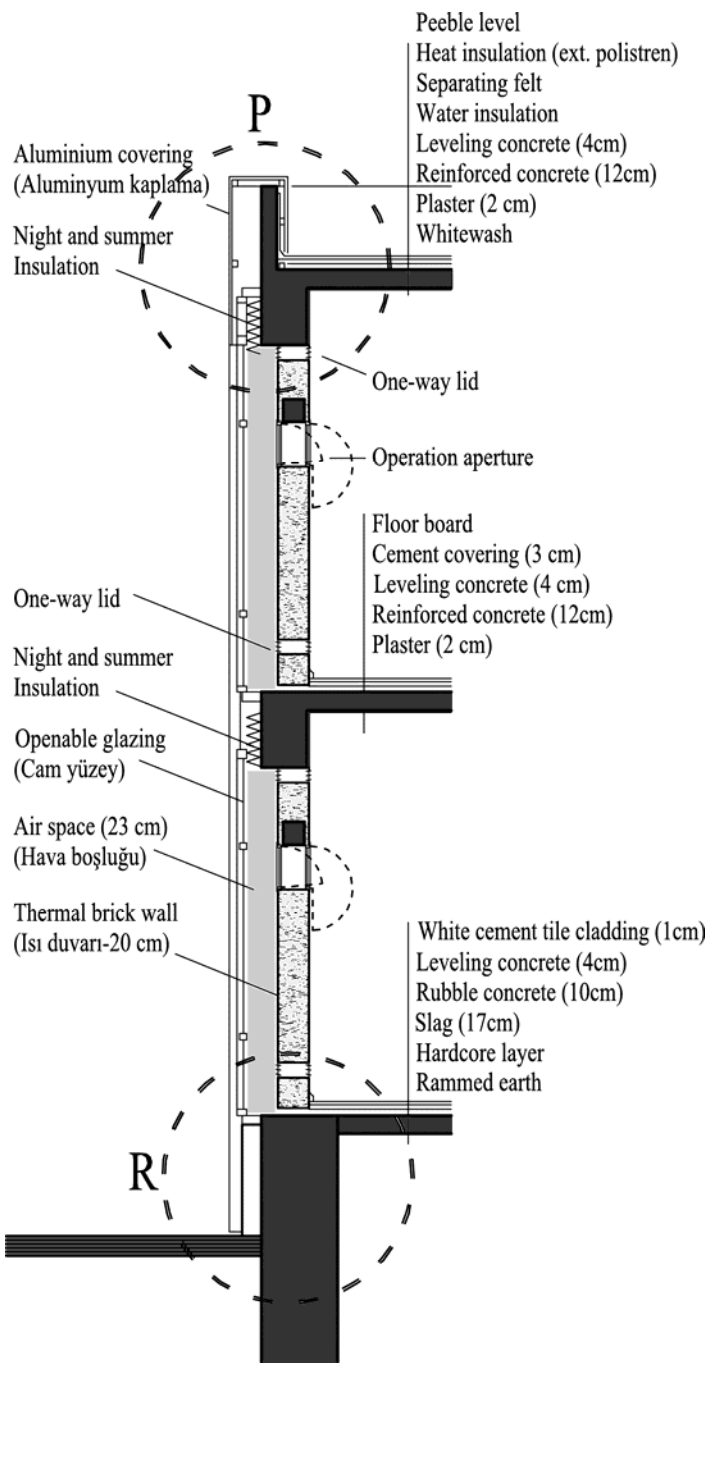


Figure 5.15: K point detail of the improved building (scale: 1/50).

Insulated Trombe walls, advanced glazed balconies (sunspaces), additonal windows, north buffer zone and shading devices are called as passive components, and thermal solar collectors and photovoltaics are called as active components. The integration and interaction of these components determine the building's energy-wise characteristic as passive dominant, active dominant or hybrid. For the current case, passive strategies are utilized for thermal and visual improvements dominantly active ones are utilized for domestic water heating and electricity use as supplementary.

Insulated Trombe walls are added to east and west sides of the building to gain passive solar heating. About 31 m^2 trombe wall is applied to four accomodation units of the building, these units will have the opportunity of Passive Solar Gain. However, the core units are not suitable to make modifications on their east and west sides. They have protection by means of the units at left and right of them, so they have buffer zones which will decrease their heat losses. The system has double insulating glazing for providing maximum level of insulation to the component, because before noon and after noon they will only have the solar exposure respectively on being left or right position. During no direct solar radiation, system will need to decrease heat losses. Having double glazing, insulation and one-way lids the system will run effectively.

The original balconies are improved by turning them into sunspaces. For this, they are glazed with single panes of glass, the purpose here is enhancing the solar gain. Single panes of glass reflect sun's beams less than double glazings. As the number of glazing increases, heat gain decreases, so single panes of glass is chosen in aluminium frames without cold bridge. Okutucu (2002) states that single glazings reflect 15% of solar energy and double glazing reflect 25% in vertical surfaces. Because these spaces will be heat generators, it is necessary to consider this physical property of the glass panes. The other important subject here is summer conditions. Beside the solar gains from these spaces, they can cause overheat in summers. To prevent this situation, they need to be made partly openable. For this, 58% of the glazings are made openable for providing enough cross-ventilation and preventing heat generation. This spaces have the advantage of two purposes one for heat generation and insulation zone in winters and other for additional living spaces.

As mentioned before, the original building has lack of natural lighting which is an important strategy for passive solar buildings. To enhance the visual performance and ultimate savings in electricity use, some windows are expanded and some are added on east and west walls. The glazing to wall ratio is enhanced by 200% and reached to 18% from 6%. The windows have double insulating glass with the 'k' coefficient of 1,8 W/m^2K. Natural lighting has positive effects on the occupant's mood. And the strategy causes an increase in occupant's productivity.

The buffer zones are necessary for such climates having cold winters and hot summers. The original building's north facade has direct accesses to the units, and this has the potential of considerable heat losses by convection. Okutucu (2002) takes attention on this subject in his study emphisizing the functional and thermal advantages of such spaces. To improve this deficiency, single glazing in aluminium frame is applied to the north facade of the building. With this application, the building's infiltration level is decreased to a reasonable level and a shelter hall is created for the occupants as well as a desired buffer zone created.

For summer operation, the building's apertures need to be shaded. The original building has shading by means of the balconies. So, it is not necessary to add other shading devices to the south apertures. The balconies when their glazings are open will implement the window shading. For the trombe walls, they have openable glazings which removes the need for shading devices. If the trombe wall has the thermal storage function delaying the heat conduction without insulation, then a shading for summer and extra insulation for winter nights would be necessary for thermal improvement.

Apart from these strategies, some additional energy-efficiency features are designed and added to the building as active strategies for a better energy use. For this, seven thermal solar collectors are designed to be placed on the top of the north buffer zone for domestic water heating of the units and 2640 watt photovoltaic panels are mounted onto the balconies and breast walls for units' lighting electricity need. Figures 5.16, 5.17 5.18 and 5.19 show the buildings' general views comparing with orignal and improved cases.

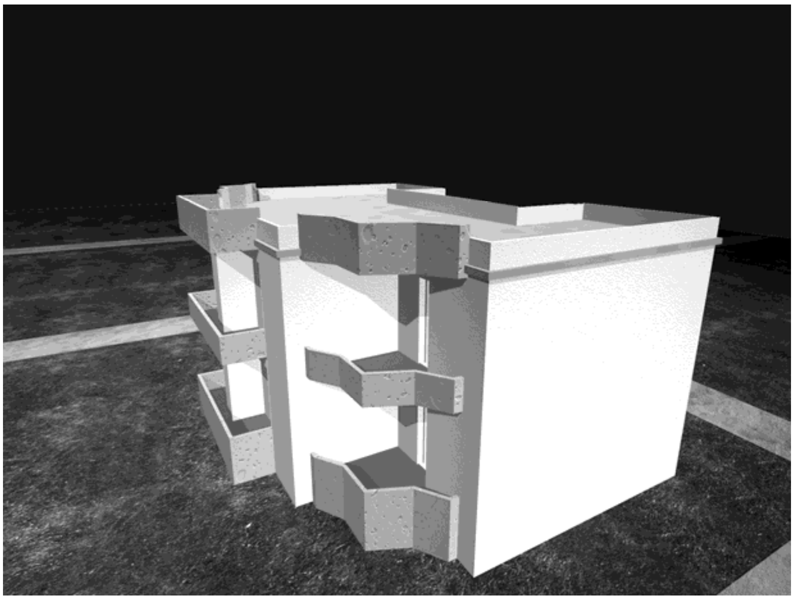


Figure 5.16: The general view of the original building from south-east.

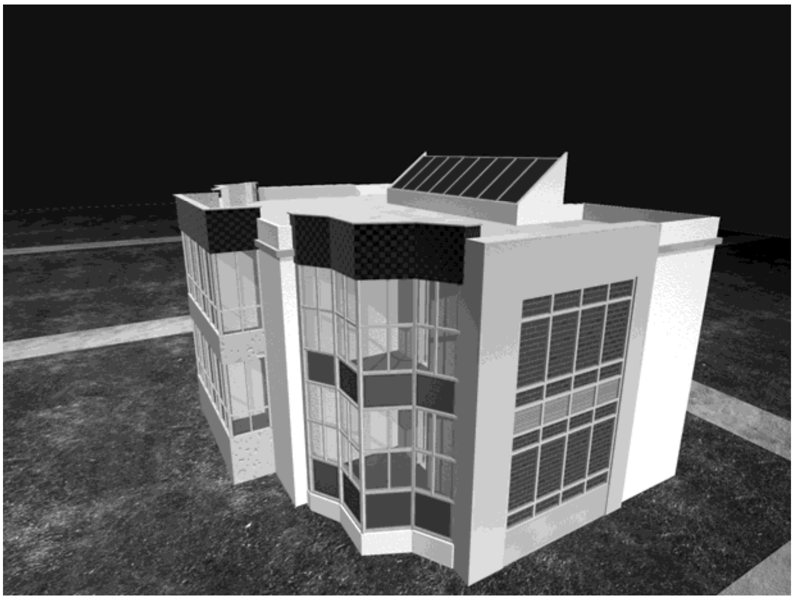


Figure 5.17: The general view of the improved building from south-east.

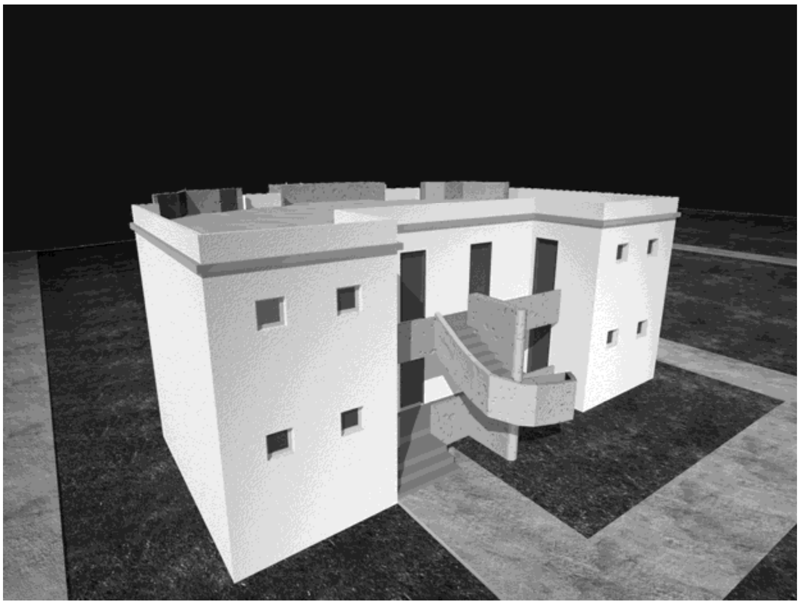


Figure 5.18: The general view of the original building from north.

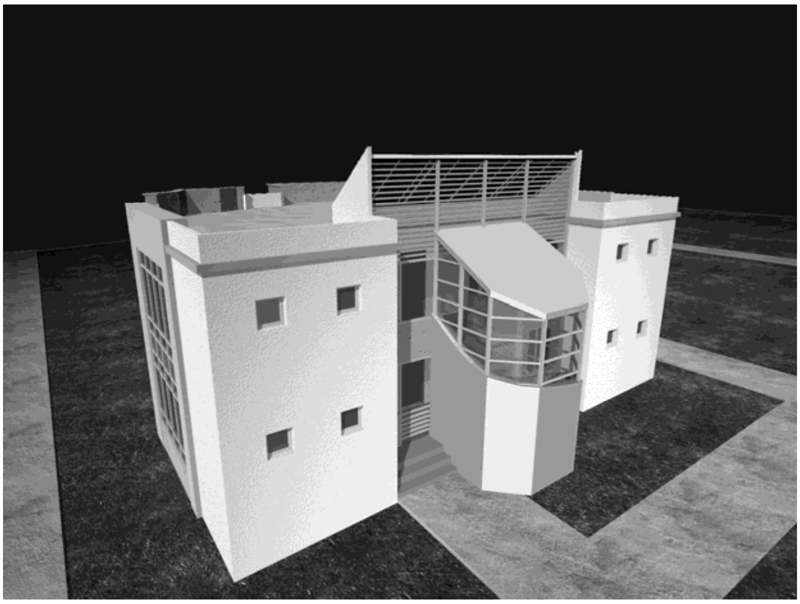


Figure 5.19: The general view of the improved building from north.

5.3. Results and Discussion

From the results of the study, we can observe that improvement of the thermal and visual performances of an existing building is possible by using Passive Solar Design strategies and components properly. In the context of the study, above mentioned improvements have been applied to the building and analysed individually by Energy-10 software. Only the passive strategies have been included in the software-simulation process, thermal collector and photovoltaic calculations have been done separately. The active solar components do not contribute to space heating but decrease the building's domestic water heating and electricity energy needs.

By the application of insulated trombe walls with one-way lids, it is possible to save about **6%** of total energy in annual use. By means of this component, additional thermal storage mass has been added to the structure of the building. Though the original building has the ability to store energy within its existing structure, the thermal mass exposed to direct solar radiation performs better for winter operation as it will need 'time-lag' to conduct stored heat through the material which is an important feature for the case of residential buildings. When we look at the types of energies individually, the application will perform in winter satisfactorly decreasing the need for heating energy by **13%**. The reason for designing trombe walls with insulation in between and one way lids in this application is the positive impacts of such trombe walls on cooling loads of the building. Demirbilek et al. (2000) observe the negligible effects of trombe walls on cooling needs in their study when they are insulated for winter-night and summer-day uses. With this application, as thermal storage of the spaces is increased the cooling needs of the building are affected positively. It provides decreasing of **7%** in cooling energy needs of the building. This application does not affect the other kinds of energies such as electricity for lighting.

The application of glazing to the balconies have enhanced the building's energy performance by about **7%** in annual use additionally. This passive solar component is very effective in operation. The only requirement for seasonal use of it is to make them partly openable for summer use. Okutucu (2002) states that in such temperate climates, it is necessary to make the sunspaces openable at least 50-60% of the total glazing surface area. This feature is not taken as a strategy in analysis by Energy-10 software. As a heat generator, this component has provided **46%** of more energy saving in heating energy use, sunspaces are effective in heating energy needs as they are passive solar heating components but with some modifications they can facilitate the stack ventilation of the building helping cool the building's structure in summer time. It has increased cooling needs of the building by **45%** with its non-operable state. Demirbilek et al. (2000) analyse the effects of sunspaces taking them in different sizes and conclude that effectiveness of sunspaces increases with the augmentation of their size in area. In this case, their contrubitions to conditioning of the building is restricted as there is a constant situation. Besides the thermal considerations, they have functional advantages. For instance: in sunny winter days, they can be additional living space making the occupants have outdoor feeling. And in the cold overcast winter days, they perform as buffer zone providing extra insulation layer to that facade being attached having a thick layer of air, they have high heat flow resistance. This application alone does not affect the other kinds of energies such as electricity for lighting too.

As mentioned before, natural lighting of the building is very important strategy for passively conditioned buildings. It either enhances the occupants' productivity psychologically or building's visual performance by the quality of natural lighting decreasing the need for energy for artificial lighting. In this stage, some apertures are added to the building. The glass area on inner surface of the sunspaces are increased, some windows are added to the north facade of the building and some are added to the trombe walls as operation apertures for the use of natural lighting effectively. With these applications, about **1%** of total energy is saved annualy as additional. However this strategy is contradictory for heating and lighting loads. Excessive use of glazing can cause extreme loss of heat and need for extra precautions on material and system such as triple, insulating glazing or reflective for summer seasons. Because of this dilemma, this strategy ought to be thoroughly considered. The application of some apertures increase the heating loads by **4%**, and it affects the cooling loads of the building by about **1,5%** increase. In return, strategy increased the energy performance of the building decreasing the need for electricity by **40%**. As it is seen in results, this passive strategy is very effective for buildings and the little increments in heating and cooling loads can be neglected by the saving in need for lighting energy and ultimate augmentation in occupant's productivity.

North buffer zone has been very effective in achievement of thermal performance of the building. In terms of annual energy use, this application has improved the energy performance of the building by about **4%**. It has proved its effectiveness by providing energy saving of **26%** in heating energy use decreasing the infiltration coefficient of the building. There are no considerable contributions to cooling and lighting energy needs of the building with this application. It is very effective for heating energy need as a buffer zone. By means of this application, a protective intermediate zone has also been provided for the occupants.

For a better thermal performance of the building, the photovoltaics are taken into analysis as shading devices for summer operation. By means of opening the glazings of the sunspaces, though the balconies have the role of shading devices, additional shading effect is created with the application of photovoltaic panels on balconies and parapets. The annual energy need of the building and natural lighting level are almost constant, the need for heating increases by **6%**, in return thermal performance of the building is improved in terms of cooling needs reducing it by about **5%**, this application balances the thermal performance of the building for seasonal use.

In all charts (figures 5.20-5.39), there is a case with energy-conscious design part named as ‘possible savings’. This shows the savings with the application of all energy-efficiency strategies guided by Energy-10 from the early beginning of the design process. As mentioned before, this can be reached when a new building is designed and using all the energy-efficiency strategies from the early phase of the design process namely preliminary design. It is created by the software automatically for the first time. Then modifications are applied in accordance with the original building design. With all improvements, total saving in annual energy use is about **17%**. This saving value has increased its highest level in heating energy use decreasing the need for heating by **61%** annualy. Other important saving has come in lighting energy use improving the building’s natural lighting use level. This affects the lighting energy use decreasing it by **40%**. In refurbishment of the building, the only disadvantage is the increase in cooling energy need. The applications have induced the cooling energy need by **34%**. But other savings (i. e., heating and lighting) overshadow this negative impact of the improvement.

The software results gained at the end of analysis are questionable. All softwares mentioned in chapter 2 have some imperfections, and these can lead the designers to make wrong judgments on the considerations of energy-efficiency in a building design. At this point, it is important for a designer to know these deficiencies of the software he or she uses. As in this case, the augmentation of the cooling loads significantly can be evaluated as discomfort for summer use of the building. The software's deficiency in analysing of systems (not including openable parts of sunspaces and thermal mass walls as a cooling strategy) has resulted this thermal discomfort. However, the strategies were not taken into cosideration by the software in the analysis process are effective in providing thermal comfort in practice.

The most important imperfections of the software used in this study are not taking into analysis of flued dynamics' patterns of the thermal, trombe walls and sunspaces, and not introducing openable parts of the systems as thermal performance strategy to the software Energy-10. Except for these, the software is a usable tool for the designers to analyse their decisions on thermal behaviours of the buildings in early design process. Such programs have high degree of straightness in terms of thermal performance estimation of the buildings compared to other thermal insulation softwares. In the study, there are different values of energy needs of the building gained from TS825vb1 (heat insulation calculation tool) and Energy-10 (energy efficient design tool). The reason for this is the sensitiveness of the software Energy-10 in calculating all the variables from climatic data to building's physical properties from building usage pattern to heat generating tools inside the spaces and occupation patterns. These detailed inputs taken into analysis by Energy-10 present more correct and reliable results at the end.

Addition to these, building's usage pattern is an important factor in deciding the Passive Solar Strategies as design decisions. For instance: if the building is occupied in only day time, it does not need thermal mass as there is no need for storing the collected heat or in the case of residential buildings there will be need for thermal mass strongly. And climatic data is very important to designing these energy efficiency systems.

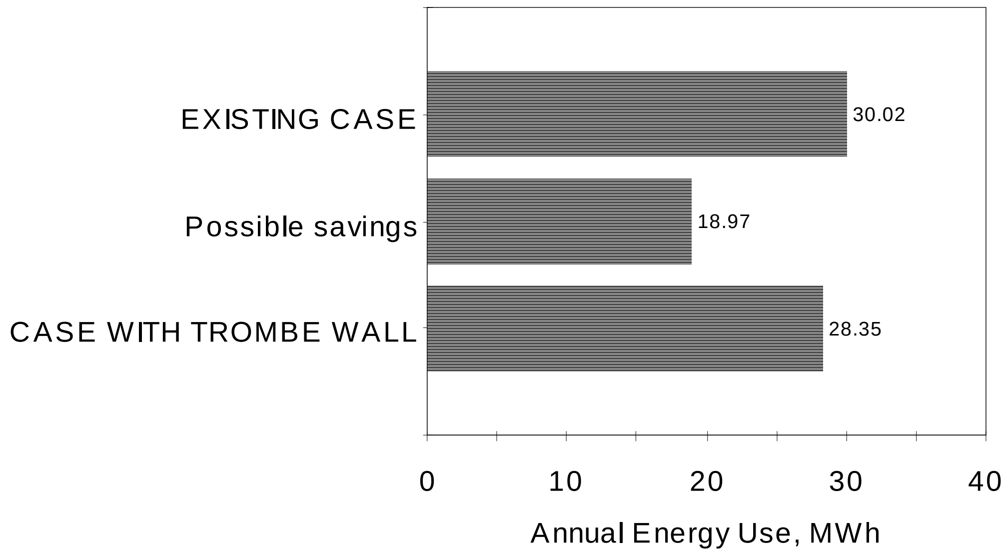


Figure 5.20: When the trombe walls are applied, **6%** of total energy is saved in annual energy use of the building.

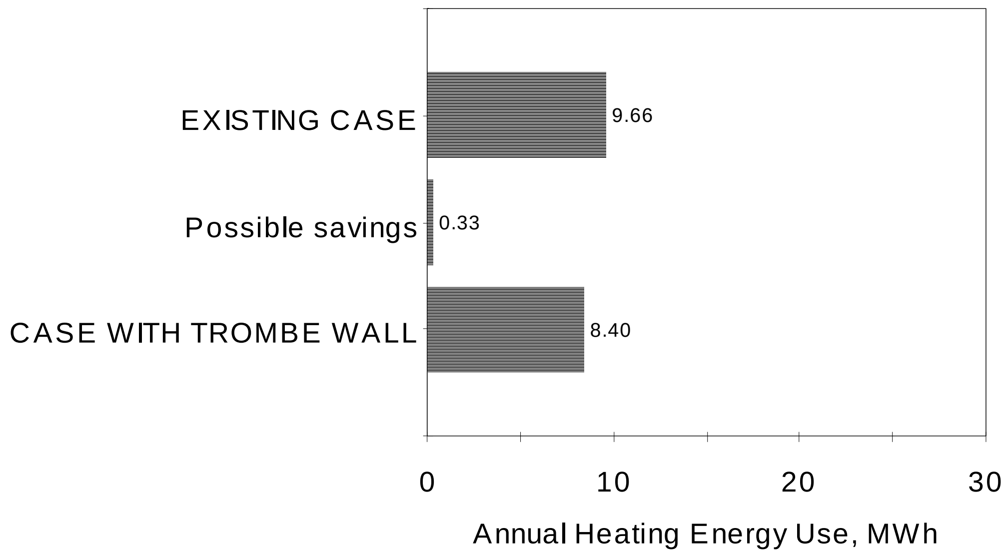


Figure 5.21: Trombe walls have provided **13%** of heating energy need of the building.

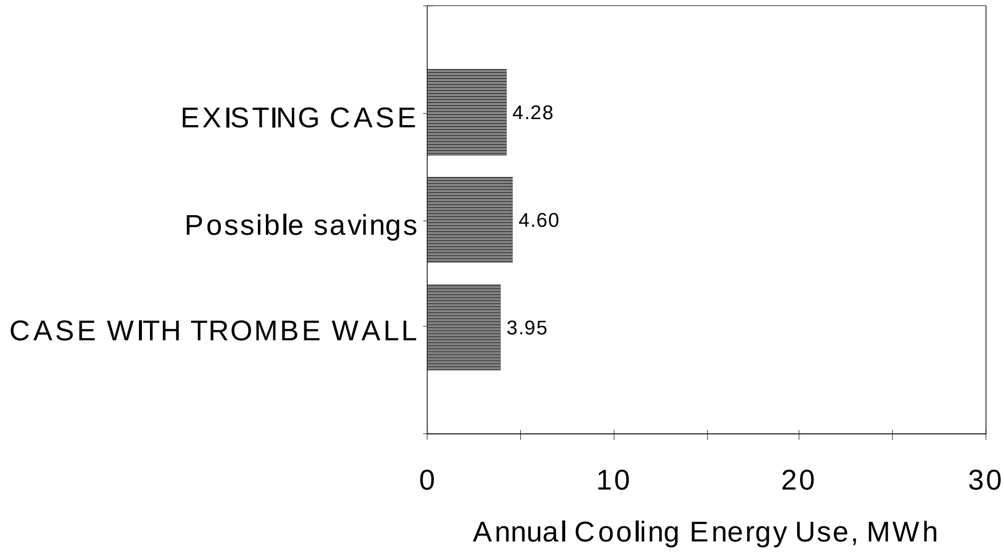


Figure 5.22: Trombe wall application decreases the need for cooling loads by **7%** annually. This positive effect is provided by trhe characteristics of the trombe wall system. If not insulated it would cause augmentation in cooling needs.

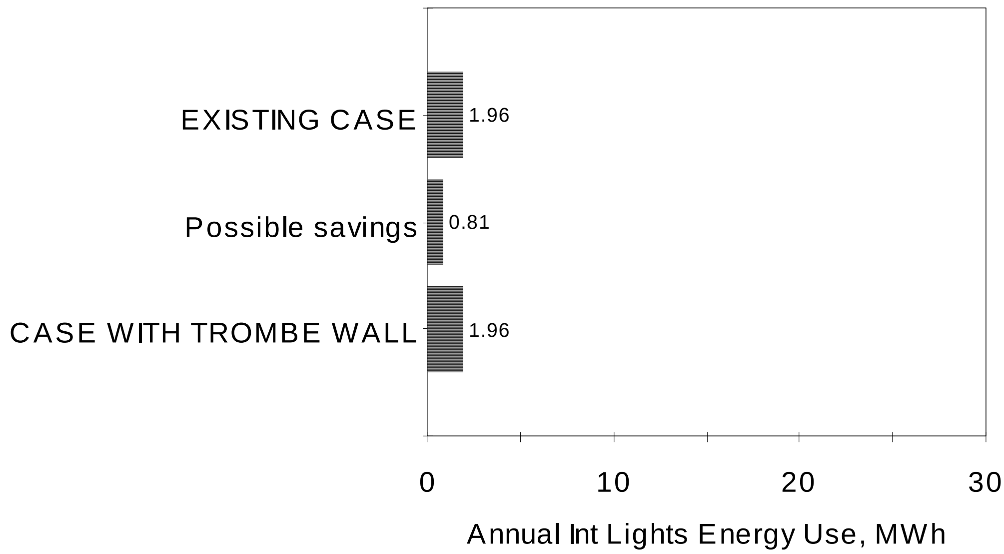


Figure 5.23: Trombe walls have not affect on lighting use of the building in annual use.

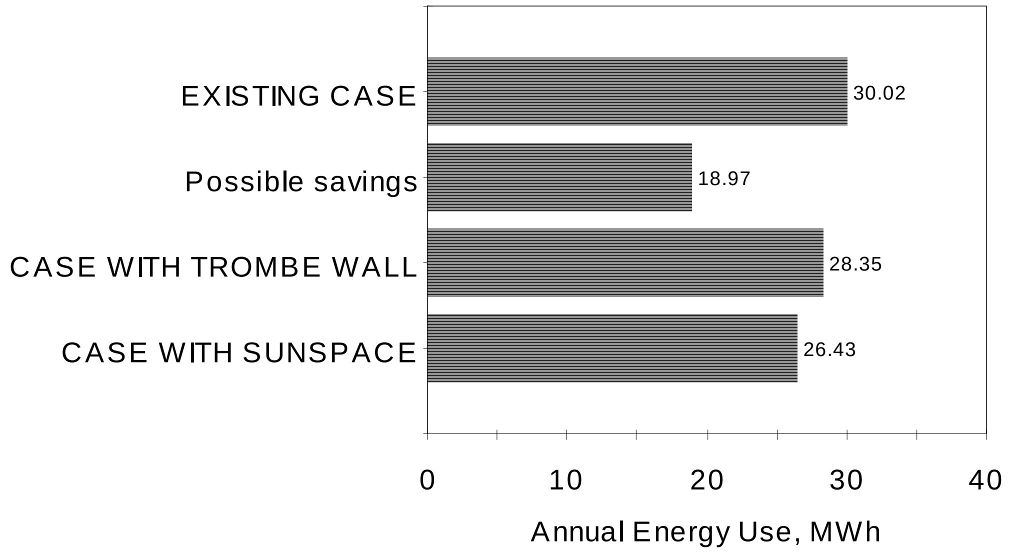


Figure 5.24: When the balconies are glazed turning them into sunspaces, **7%** more energy is saved in annual total energy use of the building.

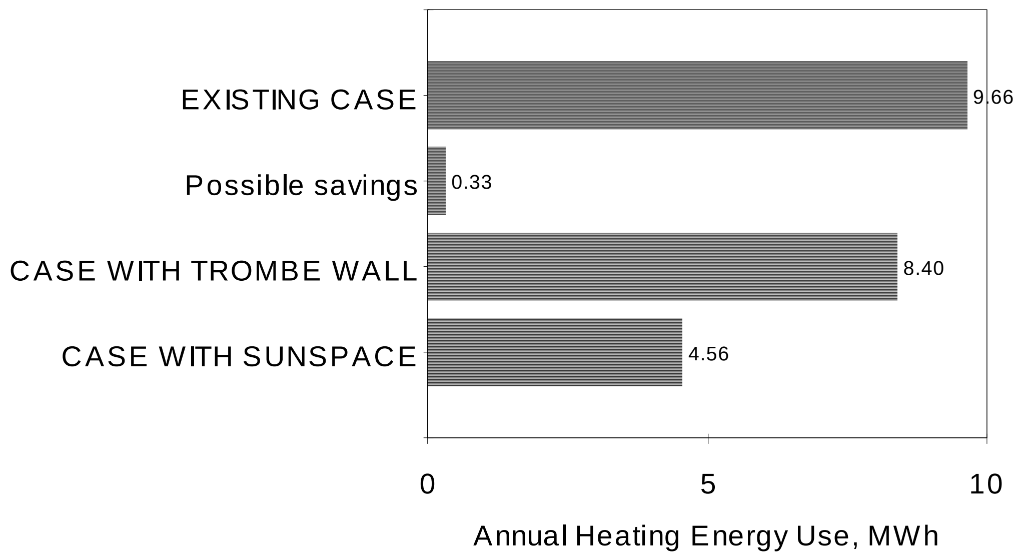


Figure 5.25: Sunspaces have performed well with additional decrease in the need for heating loads by **46%**.

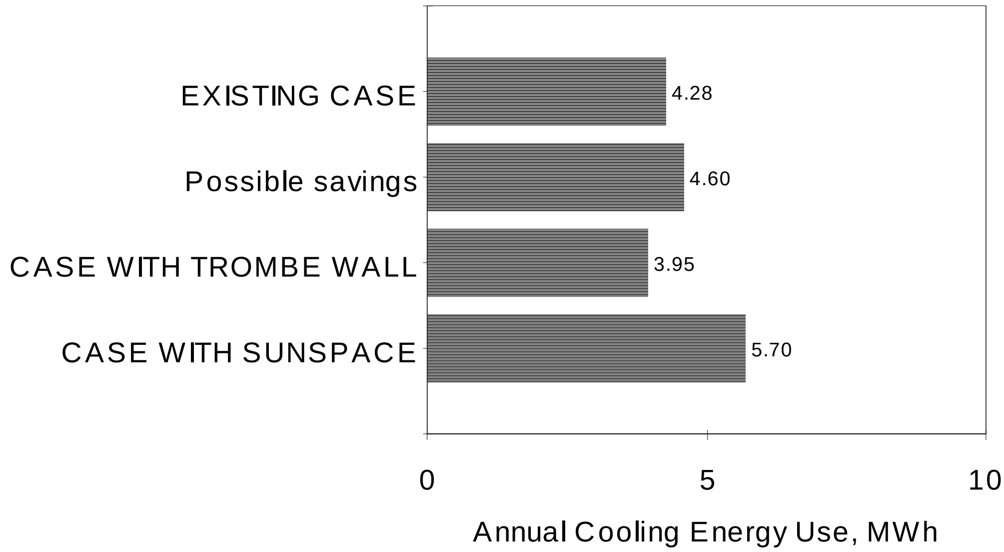


Figure 5.26: The sunspace strategy has negative impact of thermal performance in terms of cooling period. With this application, the cooling needs of the building have increased by **45%**.

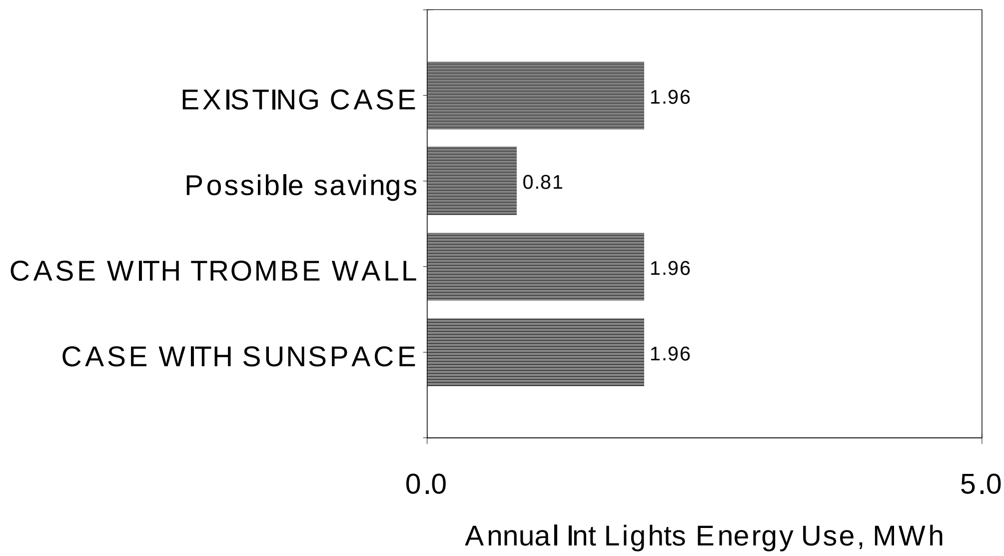


Figure 5.27: Sunspaces have no affect on lighting energy need of the building.

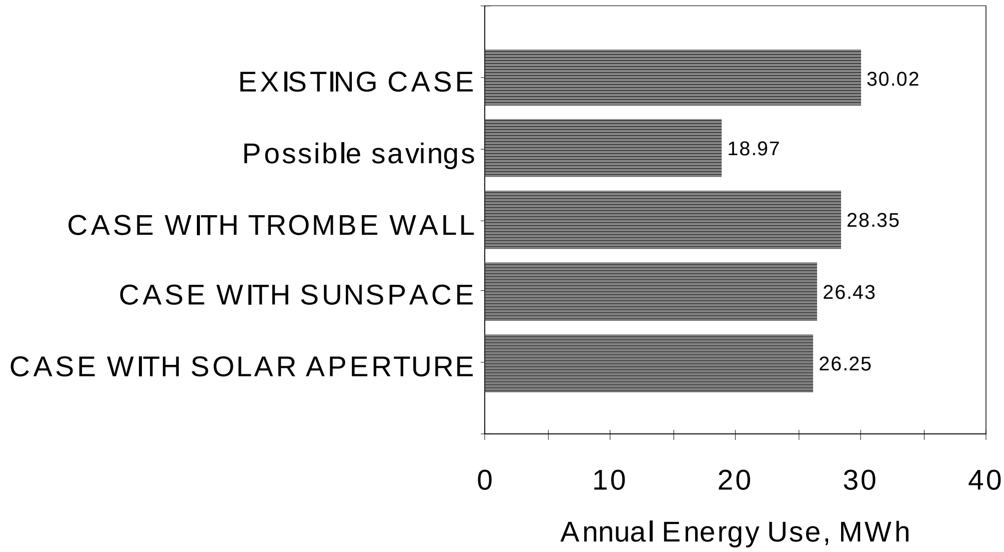


Figure 5.28: When some solar apertures and windows are applied to the building, **1%** of total energy is saved in annual use.

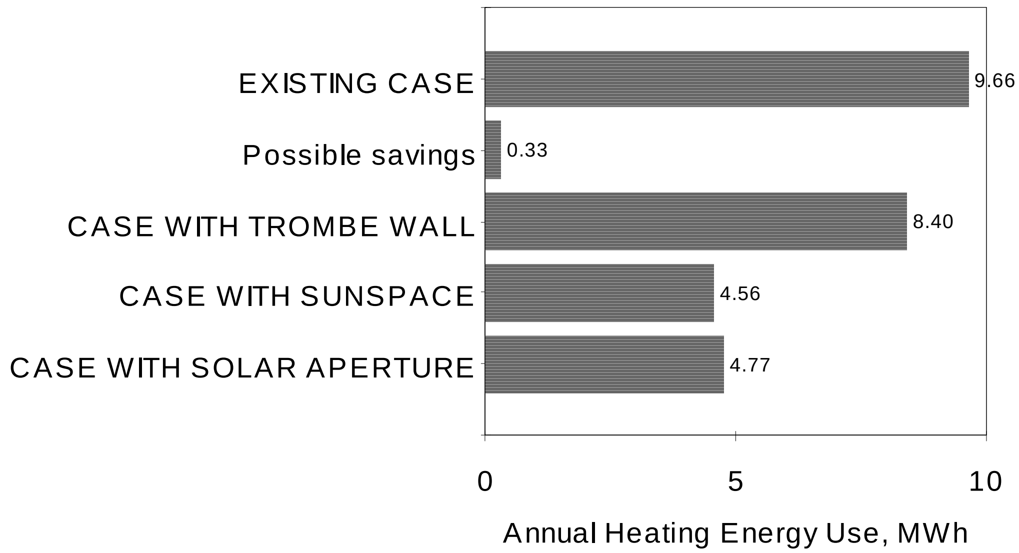


Figure 5.29: Solar apertures increased the heating loads of the building by **4%** as they cause heat loss as mentioned in the text.

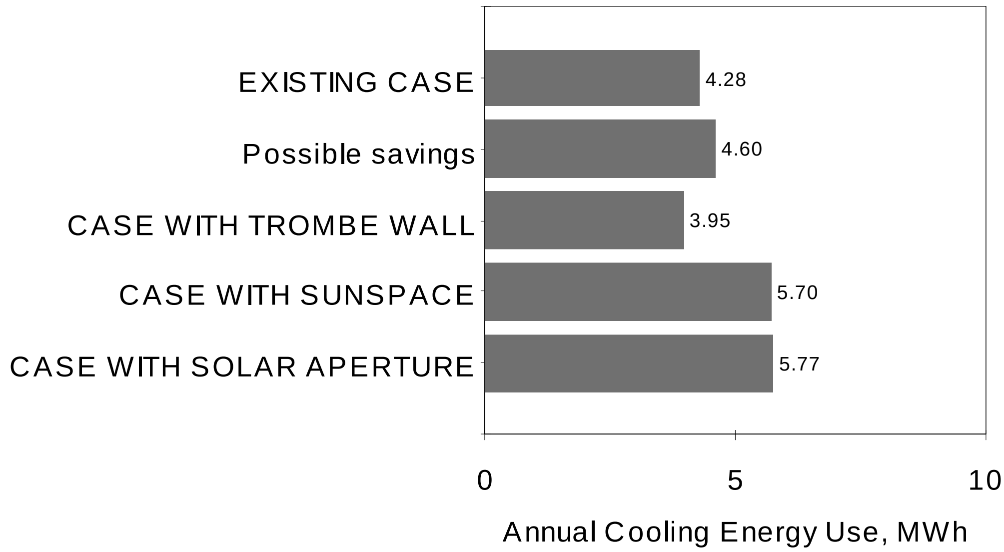


Figure 5.30: Solar apertures have almost no affect on cooling loads of the builiding increasing it by **1,5%** in annual use.

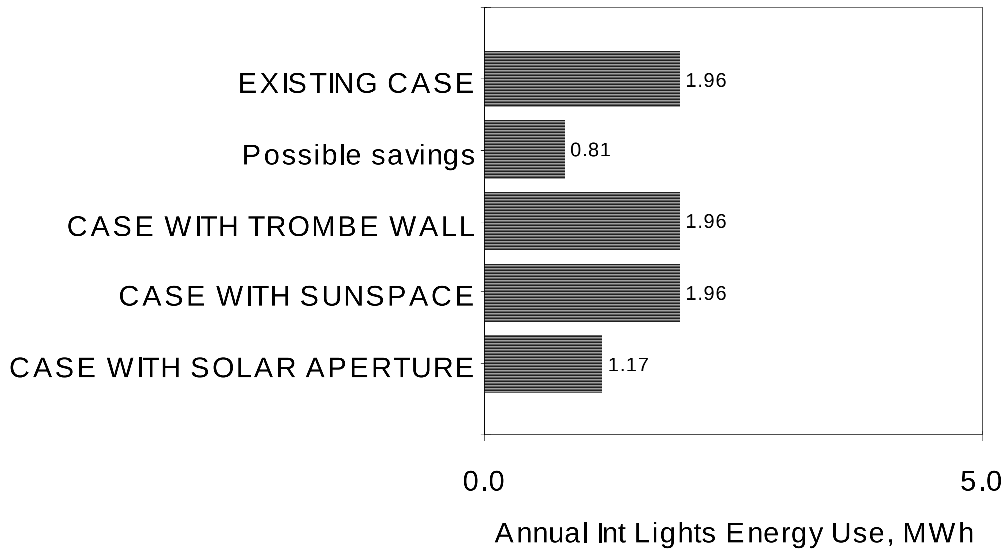


Figure 5.31: The considerable saving is provided by solar apertures decreasing the need for lighting energy need by **40%** and besides the strategy has positive impact on occupant's productivity.

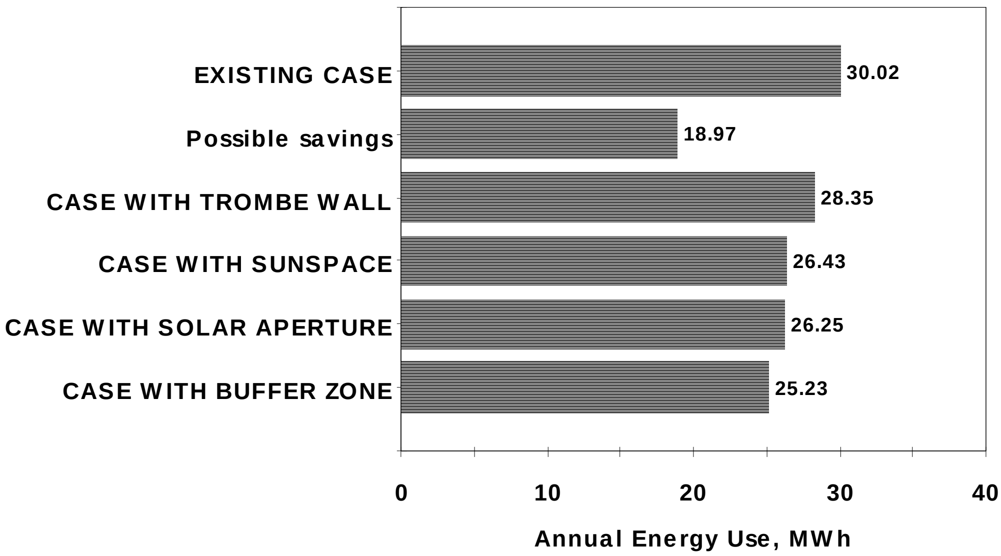


Figure 5.32: North buffer zone application has enhanced the building'thermal performance reducing the need for total energy **4%** annually.

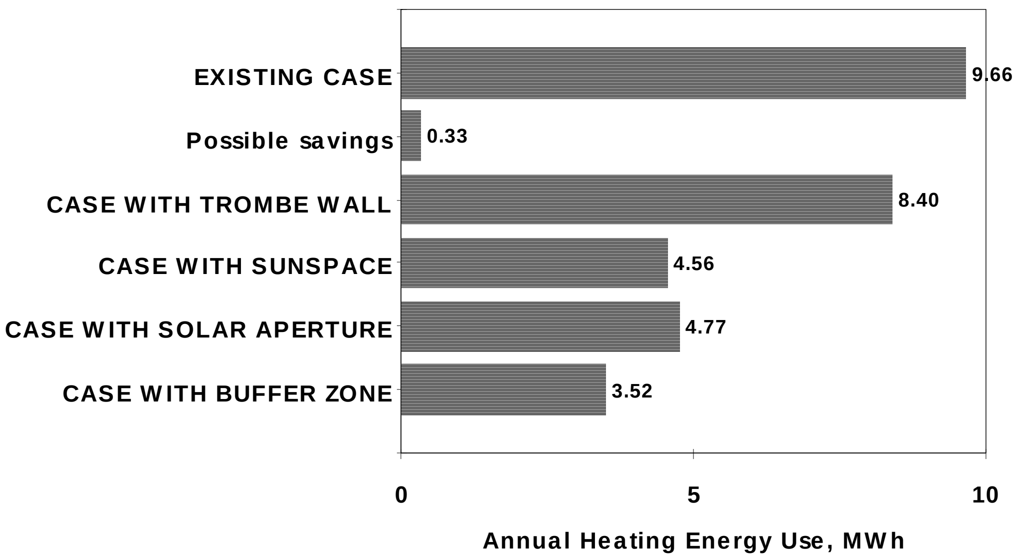


Figure 5.33: North buffer zone performs in heating seasons well decreasing the need for heating loads by **26%**.

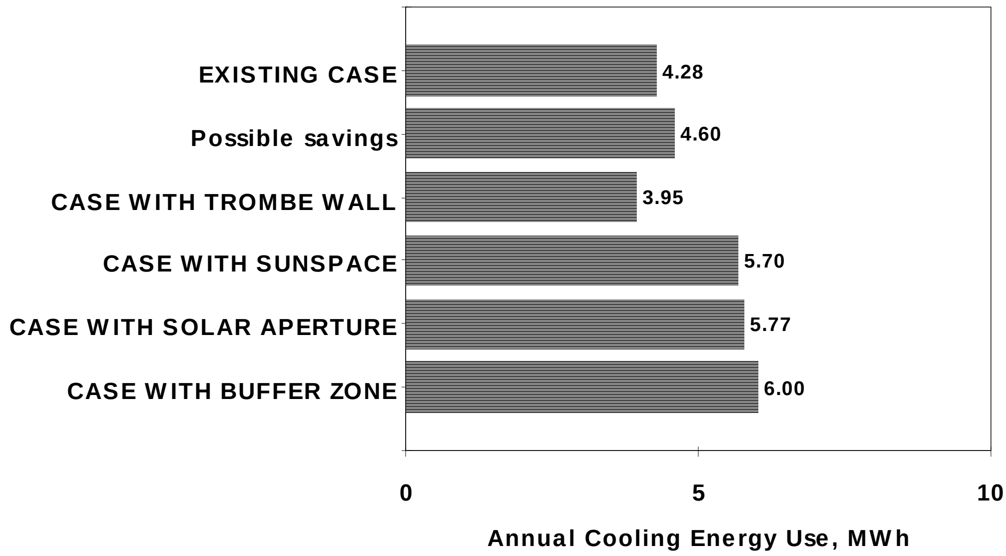


Figure 5.34: The buffer zone application has almost no effect on cooling loads of the building.

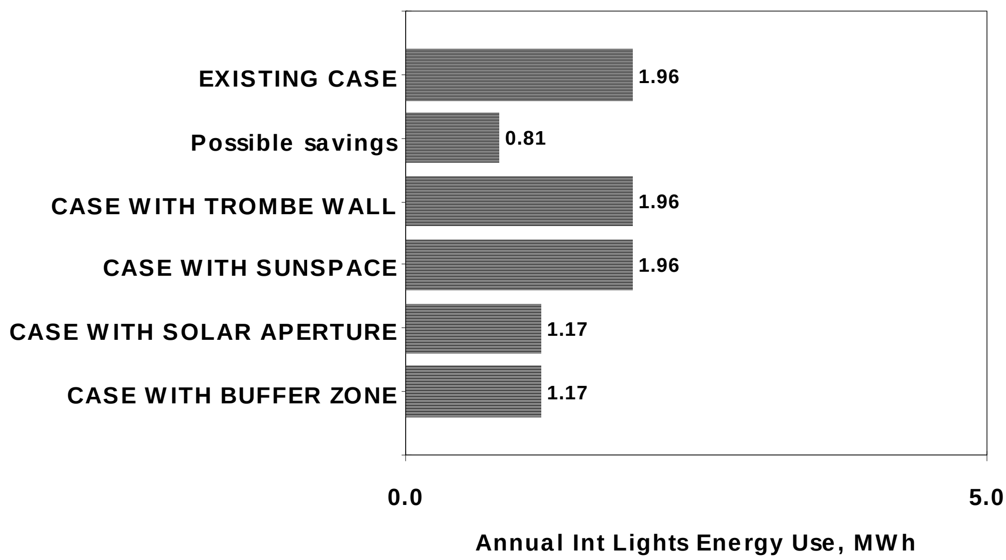


Figure 5.35: North buffer zone has no effect on lighting energy need of the building too.

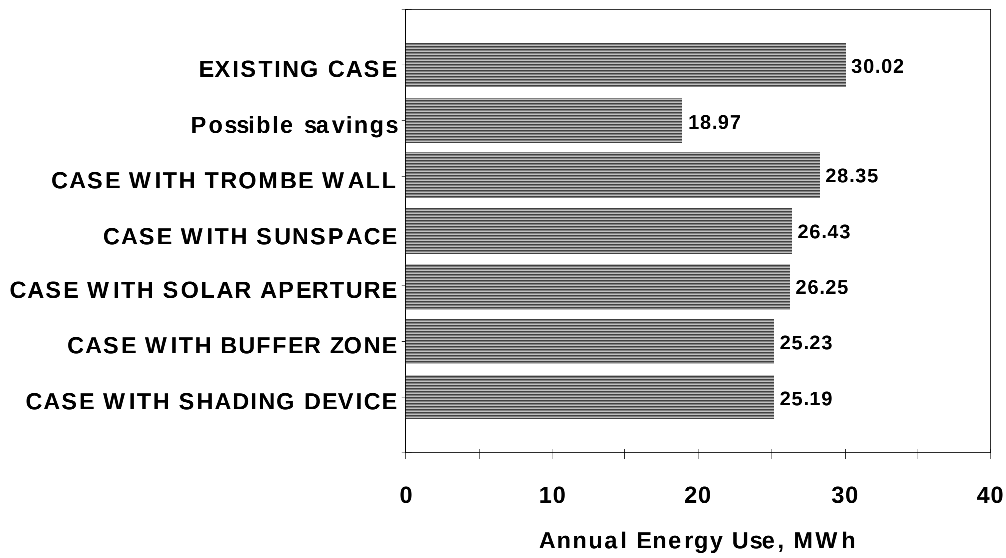


Figure 5.36: As summer precaution, shading devices has performed well increasing the thermal performance of the building annually. It decreases the need for total energy at negligible level. **With the all improvements, total saving in annual energy use is about 18%.**

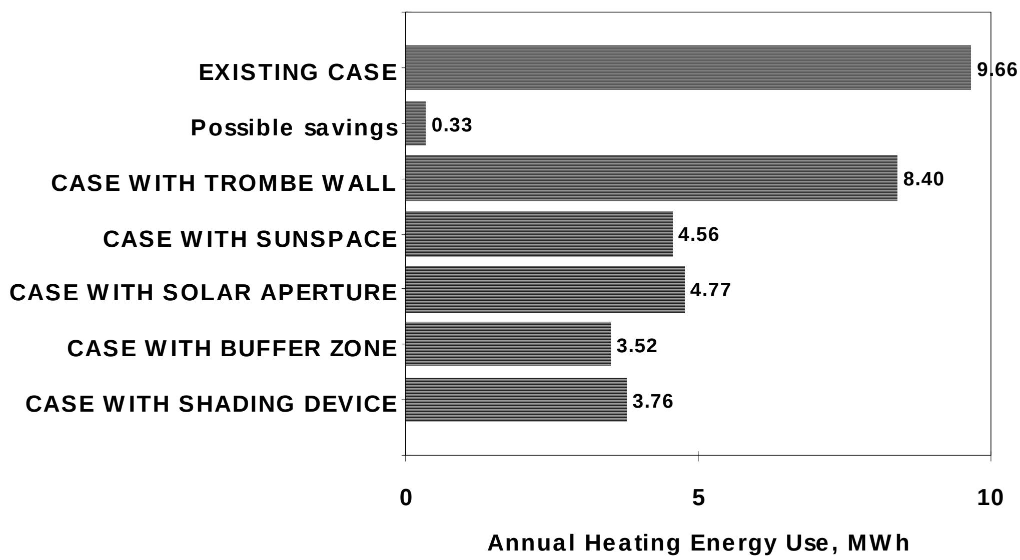


Figure 5.37: But this application increases the need for heating energy by **5%** and decreases the need for cooling energy. **With the all improvements, total saving in annual heating energy use is 61%.**

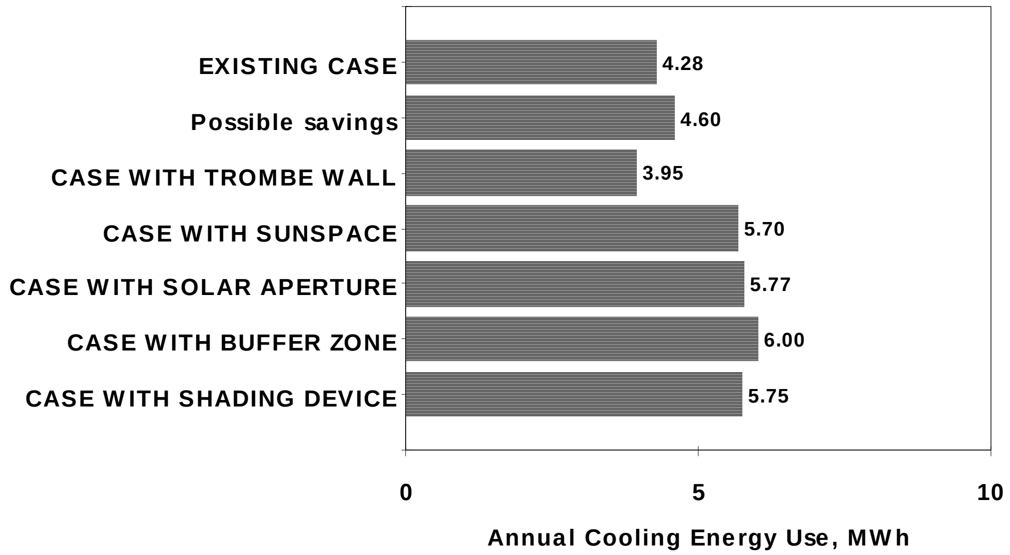


Figure 5.38: Shading devices decrease the need for cooling energy by **6%**. **With the all improvements, total increasing in annual cooling energy use is 34%.**

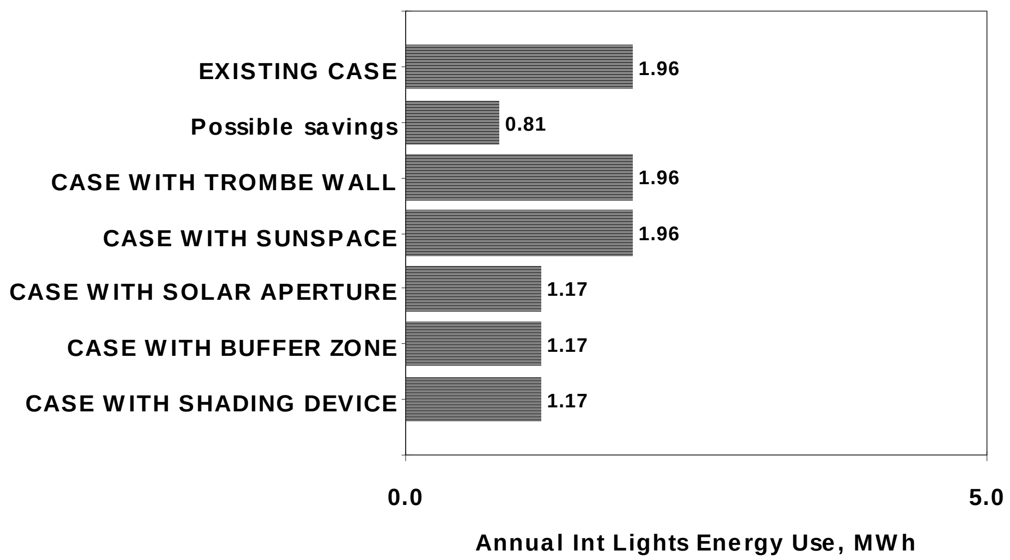


Figure 5.39: Shading devices almost do not have effect on lighting needs. **With the all improvements, total saving in annual lighting energy use is 40%.**

5.4. Cost of the Refurbishment

In this part, the cost of applications and their effectiveness are going to be discussed. As it is mentioned before, the passive solar design of the buildings add just 5 to 15% of the total amount of the building cost according to building's function, site micro climate and general climatic conditions of the region (Holloway, 2002). This state has the average of 10% of the building cost generally. This case study proves this situation by having the cost ratio of about 9 % of the building cost of 38.000$. This value does not include the active solar components (i. e., thermal collectors and photovoltaics). As the study aims to demonstrate the advantages of the passive solar design strategies and their cost effective possibilities, active energy efficiency strategies have not been compared with the building cost.

To calculate the cost of the refurbishment, different cost values have been collected from three different construction firms then their average was calculated as the final cost value. The cost of the passive solar components is affected from the process, namely if one considers these systems in the early beginning of a design process, and utilizes only the passive strategies then the cost of the building arises by negligible level. But this cost increases considerably if energy-efficiency systems are tried to be attached to the building after the design and construction of the building. Integration of these systems to the building in the design stage also enhances the integtration of energy conscious design concepts with architectural design.

Total energy cost of the existing building with its original state is 30,02 x 1000 x 160377 = 5 billions (3570$) approximately for the whole year. With the refurbished case, the demand for energy is decreased by 18% annualy, this causes 1,15 (820$) billions saving in annual energy use for this specific building. With possible savings that were calculated automatically at the beginning of the energy efficient design, this cost value would decrease to 3,1 (2214$) billions saving in total energy use annually. But in this case there is a constant situation with restricted application possibilities. Nevertheless it can be observed that it is possible to save considerable amount of energy without reduction in the comfort conditions of the existing residential buildings. The approximate average costs of the components individually are given below:

Trombe wall glazing: 31,4 m2 (ısıcam 4+9+4) .... 670 $

Trombe wall frame: 2,8 m (without cold bridge) .... 164 $

Trombe wall material: 34 m2 (builder brick) .... 350 $ + 80 $ = 430 $

Trombe wall surrounding: 28 m2 (betopan panel) ....320 $ + 120 $ = 440 $

Corner balcony glazing: 26,62 m2 (single glass) .... 286 $

Corner balcony frame: 4,98 m (normal) .... 230 $

Front balcony glazing: 23,29 m2 (single glass) .... 267 $

Front balcony frame: 1,67 m (normal) .... 90 $

North buffer zone glazing: 11,98 m2 (single glass) .... 142 $

North buffer zone frame: 2,5 m (normal) .... 86 $

Staircase glazing: 2,23 m2 (single glass) .... 28 $

Staircase opaque covering: 18,76 m2 (betopan panel) .... 190 $

Staircase roofing: 10,1 m2 (betopan panel) .... 130 $

(All worker's pays, transportation's and construction materials' costs are included in the cost of the components)

Total cost of the refurbishment is 3200 $

Cost of the building is 38000 $

Chapter 6

CONCLUSION

Passive Solar Design strategies have been discussed and evaluated throughout this thesis in the context of existing residential buildings. To accomplish the above mentioned objective of the study, firstly use of solar energy in buildings for providing thermal comfort is explained historically, then the relationships between Passive Solar Design strategies and buildings are discussed in the contex of climate-responsive design. In this frame, some concepts on relationships between climate and building design are revealed and discussed regarding traditional buildings. Afterward, the modern examples of energy-conscious small office and low-rise residential buildings are given summarizing their low-energy and architectural features. And the thermal improvement of an existing residential building is realized using Energy-10 software which is an energy analysis tool proved its reliability by BESTEST procedure adopted by the U.S. Department of Energy (DOE).

Today, in the context of sustainability of current energy sources and natural environment, buildings are designed to perform with less energy consumption within the 'bioclimatic', 'sustainable', 'environmental', 'eco-tech', and 'ecological' design considerations. As a matter of fact, they all refer to the same thing in terms of energy considerations in building design. With this desire for energy-efficiency, Hausladen and Saldaha (2002) state that buildings imply a new planning discipline called 'energy design'. This approach require interdisciplinary work of architecs, structural engineers, mechanical engineers, and energy specialists from the beginning of the concept phase of a design process.

The main distinction between active and passive strategies explained and discussed in the text is the form of energy collection, storage and distribution processes. This determines the role of the systems in terms of defining them as passive, active or hybrid in a building integrated system. Addition to this differance, passive solar design strategies and components are building-integrated systems in terms of architectural design on the other hand, active strategies are also building-integrated systems in terms of envelope design of the buildings. They are defined as mechanized systems and do not determine the building's spatial organisation, they can effect the orientation of the elements of buildings. For instance: if photovoltaics are going to be mounted on the roof of a building, the roof element will need to have solar exposure well. On the contrary, a building designed conventionally can be converted into an energy station if it has sufficient surface area having enough solar exposure for mounting of thermal collectors and photovoltaic panels. The important consideration here is multifunctionality of these active systems' components to make them building-integrated in terms of architectural design. The elements of active solar design can be replaced with the buildings' elements complementing either the purposes of building construction and energy-efficiency characteristics together.

For the high-rise buildings and dense urban fabrics, new technologies have been developed to lead the buildings to energy-efficient ones with the purpose of enhancing the indoor climate by obviating or decreasing the need for mechanical equipment. For instance: low-E coatings which let short-wave radiation to pass through the apertures and do not let long-wave radiant energy to escape to the ambient, super insulating glasses having layers of glass panes and some low-conductive gasses compared to air between panes are very effective insulating building components; electrochromic, thermochromic, fotochromic glasses which can regulate themselves with changing light, heat and electricity current, and translucent photovoltaic elements which can let daylight to reach the spaces enclosed by them while generating electricity. These technological solutions are inevitable for the use in the context of 'eco-tech' design concept as Hestnes (1999) emhasizes.

These high technologies and strategies in buildings can offer automated control systems which refer to computerized building management systems in intelligent buildings. Computer controlled skin elements of a building can react according to changing environmental physical conditions obviating the need for user participation which is a very important cycle of achievement of thermal performances of the passively designed buildings. On the contrary, 'Eco-tech' concept being an energy-efficiency contract between architecture and environment will benefit from these technological solutions in the building design making the occupants free to control their environments as they wish.

However, in passive solar design, the building is defined as collection, storage and distribution unit itself. Complex techniques and high technologies are not necessary for a lower-energy and more environmentally sensitive building design. It calls way of using energy-efficient planning principles and user awareness in the satisfaction of occupant's thermal and visual comfort. The basic requirement of climatically responsive building here is to design an energy-efficient form of construction. What conditions and considerations do make a building climate-responsive? As every building has to fullfil the environmental control, the design challange of energy problems requires more than traditional climatic design principles in terms of solar design in this new episode of low-energy architecture. With new technologically improved elements, solar architecture will perform another way of climate-responsive design principle than that of traditional buildings have.

Energy generation from environmental renewable sources in buildings is a crucial technical and design challenge of the near future practice of architecture. This new age is called post-fossil architecture which does not entirely rely on just vital energies of the earth. In terms of sustainable architecture, there is a challenge with the large existing building stock that we cannot neglect. The existing housing is an important contributor to the environmental collapse. Refurbishment of the buildings can provide opportunities to turn the energy-unconscious buildings to environmental ones in terms of sustainable renovation of existing buildings. Sustainable renovation can reduce energy demand of the buildings besides preventing the new housing from constructing. Especially in the countries having low-thermal performed stock of existing residential building, the matter has importance to the potential for sustainable building. In the above mentioned development of this study, following conclusions are found to be important:

1- Energy efficient design for existing residential buildings is possible.

2- Sunspaces, Trombe Walls, Thermal Storage Walls and Double-glazed Direct systems as passive solar design components are applicable in refurbishment process of existing residential buildings.

3- Besides, thermal collectors and photovoltaic panels as active solar design components are also applicable for existing buildings as the ingrediant of energy-consciousness of the buildings.

4- Sunspaces are found to be very effective for heating. The Passive Solar Heating from the sunspace is a great contributor of heat. But on the other hand, they can increase the cooling loads of the buildings. To avoid this negative effect, they can be designed to be openable in temperate climates.

5- Thermal storage walls vented as Trombe walls or non-vented as Thermal walls are very effective applications for existing residential buildings.

6- Buffer zones created by non-heated spaces such as halls, stairs, storages and toilets or created by sunspaces are found as great useful and effective applications. They are climate-modifier systems of the building changing physical properties of the buildings' facades and floor area.

7- Daylighting applications are also found very effective provided that enhanced glazings are used for improvement. It has effects on visual comfort besides lighting energy use. The spaces illuminated by day-light induce the productivity and contented feelings of the occupants.

8- User consciousness in terms of energy-efficiency is a key factor for passively-dominated buildings. For instance: user should know that he or she ought to close all vents on a trombe wall at winter nights to prevent reverse circulation. This might be possible to automate the circulation direction of the airflow adding one-way lids but as it is mentioned, the more complex the systems the more vulnerable to defects.

9- Total energy saving of 18% in annual need (i. e., heating, cooling and lighting) can be obtained by employing Passive Solar Design strategies to existing residential buildings.

10- The highest saving of energy is obtained in heating energy by 61%. Other high saving of energy is obtained in lighting energy need by 40%. However the cooling energy is increased by 34%.

11- The cost of the refurbishment accounts about 9% of the total cost of the building.ü

Concluding Remarks and Recomendations for Future Studies:

Throughout this study, the thermal performance of an existing residential building has been analysed and improved. The main aim here has been to investigate the posibilities of thermal improvement of the building in a cost-effective manner. During this study, the most important restriction is to renovate the building in accordance with its original state. So, the components of Passive Solar Design have performed with their restricted limits. In analysis, it has been observed that cooling needs of the building have increased but considering that the building are going to be occupied during most of education term having fall, winter and spring conditions, the summer comfort might be said to be achieved with natural ventilation opportunities.

The applications of such low-energy designs should be realized because the most accurate results of these improvements can be observed in operation of the buildings. And it is emphasized in the literature that one of the key factor to spread out the design considerations for energy-efficiency is to realize such projects to be demonstrated to the public with their energy performances based on low-energy use and high thermal comfort. This subject is not common in Turkey, there have been some reasons for this. The most important ones are low building quality in detail, not introducing of the subject to the designers and public, and not financing the additional cost of the systems by investors. Among them, one may observe, the incorrect detail applications and low building quality as the most important obstacles that are preventing the application of passive solar design strategies in common. Because when the systems are applicated incorrectly, they perform bad and make the users judge the systems negatively. In chapter 4, among the interpreted cases in İzmir, this state has depicted by the occupants of Murat Reis Cultural Center when some of them are interviewed. The building having some wrong detail applications of passive systems is said not to perform well thermaly. So, the true applications are very vital for the favour of the subject.

And as the last statement in the light of these considerations, future researches might include experimental studies with real life measurements, different building types (such as, commercial, high-rise, and etc.), and applications of different strategies and components to the buildings.

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