IIIEE Theses 2008:22

Energy efficient buildings in warm climates of the Middle East:

Experience in Iran and Israel

Soheila Bahrami

Supervisors

Lena Neij

Bernadett Kiss

Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, October 2008

Published in 2008 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

This work would not have been possible without the support of my supervisors, Lena Neij and Bernadett Kiss who taught me and helped me with their sound advice and inspirational ideas. I am deeply grateful to the other IIIEE family members who provided me with their knowledge and efforts during the last two years, with special thanks to Fredrik Eriksson, our helpful librarian.

I wish to thank my interviewees for imparting the required information for this thesis especially, Issac A. Meir, Mohammad H. Ayatollahi, Yair Etzion, Dori Hershgal, Riyad Dwere and Mehdi N. Bahadori. I also wish to thank Abolfazl Rastgar who carried out an exact on-site inspection in one of the buildings under my study and supported me with useful information and photographs.

I owe my sincere gratitude to my spouse, Amir and our son, Arya for providing me with a favorable environment at home, where I wrote this paper.

Abstract

Fast development of energy efficient buildings is necessary to deal with growing and high levels of energy consumption and related environmental impacts in the Middle East countries including Iran and Israel. Design for climates such as hot arid and Mediterranean climates entails facing challenges regarding both heating and cooling energy demands in buildings. Since the late 70s, research has been conducted in both countries focusing on environmental impacts of the buildings and above all, energy consumption. Relevant policies, regulations and standards have been launched in both countries. A number of building projects are implemented by using general passive design strategies, traditional architecture elements and innovative techniques. Nonetheless, several barriers including limited know-how, lack of effective leadership and market related obstacles are hindering the development process of applying energy efficient technical solutions in buildings. Educational programs and communications, improved regulations and standards and financial incentives are suggested to overcome the existing barriers.

Executive Summary

Climate change due to increasing temperatures is a significant environmental concern throughout the world. Over the last 50 years, frost and cold days and nights have become less frequent while hot days and nights, and heat waves have become more frequent. In addition, precipitation has decreased in some parts of the world such as Mediterranean and southern Asia. Wind patterns have also changed and the areas affected by drought have been globally expanded since the 1970s (IPCC, 2007b). To deal with these issues it is essential to know about the reasons for this dramatic change.

Human activities have contributed to striking raises of greenhouse gases (GHGs) emissions (IPCC, 2007a). Change in atmospheric concentration of GHGs is one of the factors in altering the energy balance of the climate system. Further warming and changes in global climate would be caused by continuous global GHG emissions at or above present rates (IPCC, 2007a). Energy consumption in various sectors is the main source of the most important GHG, carbon dioxide (CO_2) emissions.

Improvement of energy efficiency in buildings is a sustainable way to reduce energy consumption and related environmental impacts. Throughout the last decades, several concepts and approaches have emerged concerning energy efficiency in buildings including: passive house, green building and bioclimatic design. The latter approach is focused on climate types. Climate refers to the average weather experienced over a long period including temperature, wind and rainfall patterns (UK Department for environment, 2008). There are different climates in the world, which means different levels of cooling and heating energy demands in buildings. Adopting energy efficient design strategies are relatively complicated in climates with hot summers and cool winters as energy is required for both cooling and heating demand in the buildings. This is a significant challenge particularly in developing regions such as the Middle East.

The Middle East & energy in buildings: cases of Iran and Israel

A high level of energy consumption and subsequent environmental problems is more severe in some developing regions such as the Middle East. The Middle East had the second largest energy intensity level in the world in 2006 (World Energy Council, 2008). Most of the energy consumed in the region is produced by fossil fuels causing considerable amounts of GHG emissions. Buildings account for almost 40% of final energy consumption and related GHG emissions in most countries. During the period of 1971-2004, the second largest regional increase in CO_2 emissions from residential buildings was from the Middle East and North Africa (IPCC, 2007a).

This study is focused on energy efficient solutions for buildings in warm climates of two Middle East countries: Iran and Israel, since adequate data about other countries was not available. An initial literature review revealed that both countries have high levels of energy consumption and related emissions particularly in residential and commercial sectors. Iran is one of the largest countries in the region with a population of about 70,000,000. Iranian residential and commercial sectors account for about 40% of total final energy consumption in the country (Iran Ministry of Energy, 2006). This sector has also the largest contribution in CO_2 emissions. Israel has a population of nearly 7 million with a fast growing level of energy consumption. Israeli residential and commercial sectors consume almost 55% of total generated electricity in the country and account for about 30% of total CO_2 emissions (Mor & Seroussi, 2007).

Research objectives

The main objective of this research is to contribute to the understanding of pragmatic sustainable solutions to develop energy efficient buildings in warm climates of the two Middle East countries, Iran and Israel. This goal can be achieved through (1) investigating the experience of using various relevant technical solutions comprising both innovative and traditional design elements in Iran and Israel, and (2) identifying the drivers and barriers to develop the applied solutions.

Methodological approach

Several literatures including books, articles, master theses and doctoral dissertations on the subjects of various types of energy efficient and sustainable buildings, proposed and implemented technical solutions as well as traditional architecture elements used in the region were reviewed. Moreover, related websites as well as governmental and organizational reports and statistics were explored in order to acquire information about the current situation in the geographical boundary of the research regarding the energy efficiency in buildings. Six energy efficient building design or construction cases were selected to review as case studies. The published information about chosen cases was collected via the internet while specific unpublished information was obtained through semi structured and qualitative interviews by email contacts and phone calls. Finally, the collected data were analyzed and the following conclusions were drawn as the results of this research.

Main findings and conclusions

Fast development of energy efficient buildings (EEBs) is necessary to deal with growing and high levels of energy consumption and related environmental impacts in the Middle East. Restricted experience and inadequate available information about EEBs in the region limited the geographical boundary of this research to Iran and Israel. Design for climates such as hot arid and Mediterranean climates entails facing challenges regarding both heating and cooling energy demands in buildings. Since the late 70s, research has been conducted in both countries focusing on the subject of bioclimatic designs to address environmental impacts of the buildings and above all, energy consumption. Israeli professionals are amongst pioneers in bioclimatic design in new buildings. Iranian architects focus on traditional architecture elements in their climatic designs.

Design and construction projects with the aim of improving energy efficiency in buildings bloomed in early 90s at Ben Gurion University of Negev, Israel. Afterwards, prototype and demonstration projects have been implemented in other regions in the country. Meanwhile, several regulation and standards addressing this issue have been launched and come into force. EEBs are growing in Israel in light of an Israeli green building voluntary standard while the pace is rather slow due to some barriers hindering the improvement process.

Design and construction of EEBs have been implemented very slowly in Iran during the last decade. A few projects were stopped after the design stage while others were constructed neglecting proposed energy efficient technical solutions. Relevant standards and regulations have been launched during recent years, most importantly the energy chapter of national building code. This code is believed to reduce energy consumption in buildings by 30%. However, to implement the code successfully, several barriers should be overcome.

Different international concepts have been developed to support sustainable and energy efficient buildings throughout the world. The Green building concept and the Leadership in

Energy and Environmental Design (LEED) certification program introduced by the United States Green Building Council (USGBC) is growing in the Middle East countries including Israel while there is no case of such green buildings in Iran. Intel green building, one of the examples reviewed in this study, is the first building aimed at being certified by the LEED in Israel. The LEED certification program has a well-established structure to reduce environmental impacts of the buildings and to improve occupants' health and comfort conditions. However, when it comes to energy efficiency, it needs supplementary regulations and guidelines to be used as a tool for developing EEBs in countries such as Iran and Israel. The Israeli green building standard that has a structure similar to the LEED program was enhanced by approving an additional energy-rating standard for residential buildings as a prerequisite for Israeli national green building standard. Bioclimatic design has been used by many researchers and designers in both countries. Climatic design is the main approach adopted by Iranian designers to improve energy efficiency in buildings.

Although general passive strategies are used as the main strategies in various building design projects, European passive house concept has been used in neither Iran nor Israel. Moreover, exact information on European passive house concept for warm climates is required to examine this concept as an option for developing EEBs in both countries.

In general, several energy efficient design strategies and technical solutions have been applied in both countries while various factors are influencing the effectiveness of using these solutions to improve energy efficiency of buildings. General passive design strategies used in European warm climate passive houses and other approaches in the northern hemisphere warm climates such as orientation, shading, insulation, air tightness, thermal mass, natural ventilation and day lighting are applicable in both countries taking into consideration the local climatic condition and urban structure. Exact regional and local climatic conditions information such as air temperature, humidity, solar radiation power and direction, and wind power and direction are vital to adopt proper strategies during the design stage. However, to what extent they are used and what levels of energy efficiency can be attained by means of such solutions is highly dependant on diverse factors such as urban structure, technical know-how, accessible technologies, associated costs, and people awareness and acceptance.

Traditional architecture elements are integrated in new buildings with the aim of improving energy efficiency. However, local climatic conditions, new urban structures and resulted microclimates in urban areas should be considered as crucial affecting factors in design process. For instance, integrating evaporative cooling and natural ventilation is a useful method to provide cooling energy demand in buildings in hot arid climates. Wind-catcher is a case in point; two examples of integrating this ancient cooling system into new buildings in Yazd, Iran and Sakhmin, Israel showed satisfactory results while another case study revealed an inappropriate design neglecting real conditions such as effects of adjacent buildings and polluted ambient air of Tehran on the performance of wind-catchers.

One of the significant factors in using traditional as well as innovative passive elements in buildings is people attitude. People attitude to some elements like wind-catchers and solar heating systems is more important than associated costs. The level of energy efficiency is difficult to be compared in the two countries as no uniform measuring system is applied. Whereas, the Sakhnin green building, an educational center building in Israel, revealed that considerable levels in energy saving are achievable by the use of existing expertise and technology in Israel. Moreover, two private houses showed the opportunity of improving energy efficiency and saving energy by means of relevant technical solutions, which are feasible in any building in hot arid climates of both countries.

Results of Sakhnin project showed that additional costs of using traditional architecture energy efficient elements is rather low in comparison with other elements such as PVs and wind turbines considering their contributions to energy savings. A five-year pay back period for the investment on integrating energy efficient solutions into Intel green building is worth being considered by other companies planned to build new offices. Because of inadequate data on costs of applied energy efficient solutions in other cases, no conclusion concerning this question can be drawn by the results of this study.

The Israeli green building standard and the **energy chapter of Iranian building code** were identified as potential drivers to improve energy efficiency of buildings in the countries. **Enhancement of indoor environment quality** in EEBs can be considered as another driver to increase the demand for such buildings while neglecting the inhabitant's comfort for the sake of saving energy is a risky measure especially in demonstration projects.

The main barriers hindering the development of EEBs in the countries under this study were identified as the following:

- *low energy prices;*
- *lack of leadership;*
- *inappropriate urban planning and design;*
- *lack of some energy efficient building components on the local markets;*
- *limited know-how among design and construction sectors;*
- *limited construction skills;*
- *inadequate on-site construction inspections;*
- *people awareness and acceptance; and*
- *lack of repair and maintenance services for energy efficient systems.*

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Climate change

Climate change due to increasing temperature is an important environmental concern throughout the world. Rising sea level has a consistent trend with global warming by contribution from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. In both Hemispheres, overall mountain glaciers and snow cover have shrunk. In addition, precipitation has decreased in some parts of the world such as Mediterranean and southern Asia. Over the last 50 years, frost and cold days and nights have become less frequent while hot days and nights, and heat waves have become more frequent. Wind patterns have also changed and the areas affected by drought have been globally expanded since the 1970s (IPCC, 2007b). To deal with these issues it is essential to know about the reasons for this dramatic change.

Human activities have contributed to striking raises of greenhouse gases (GHGs) emissions (IPCC, 2007 b). The energy balance of the climate system has been altered by changes in atmospheric concentration of GHGs and aerosols, solar radiation and land cover. Global GHG emissions rose by 70% from 1970 to 2004; during the same period, the annual emissions of the most significant GHG, carbon dioxide (CO_2), increased by roughly 80% (IPCC, 2007 b). Moreover, IPCC Special Report on Emissions Scenarios (SRES) predicted a rise of 25% to 90% (CO_2-eq) in global GHG emissions from 2000 to 2030. Further warming and changes in global climate would be caused by continuous global GHG emissions at or above present rates (IPCC, 2007a).

Energy consumption in various sectors is the main source of CO_2 emissions. Buildings account for approximately 40% of final energy consumption (World Business Council for Sustainable Development (WBCSD), 2007) and related CO_2 emissions in most countries. In 2004, an approximately 10.6Gt GHG emission was from building sector (IPCC, 2007a). Figure 1-1 shows the estimated CO_2 emissions caused by energy use in buildings.

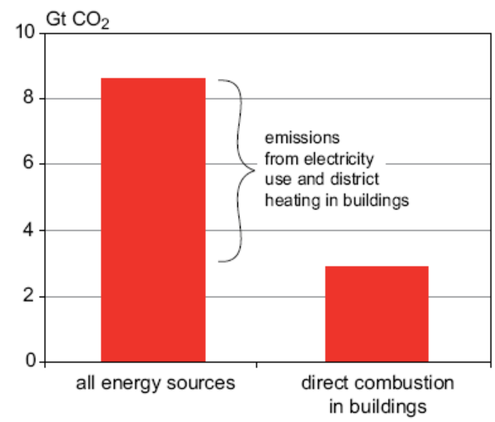


Figure 1-1 Carbon dioxide emissions from energy use in buildings, 2004

Source: IPCC, 2007

1.2 Energy efficient building: an effective remedy

Improvement of energy efficiency in buildings is a sustainable way to reduce energy consumption and consequent environmental impacts. Efficiency involves reduced energy consumption for acceptable levels of comfort, air quality and other occupancy requirements, including the energy used in manufacturing building materials and in construction (WBCSD, 2007).

Throughout the last decades, several concepts and approaches have been emerged concerning energy efficiency in buildings such as passive house, green building and bioclimatic design. One of the main focus areas of the latter approach is climate types. Climate refers to the average weather experienced over a long period including temperature, wind and rainfall patterns (UK Department for environment, 2008). There are different climates in the world, which means different levels of cooling and heating energy demands in buildings. Adopting energy efficient design strategies are relatively complicated in climates with hot summers and cool winters as energy is required for both cooling and heating demands in buildings. This is a significant challenge especially in developing regions such as the Middle East.

1.3 Energy demand in buildings in the Middle East

The Middle East is one of the developing regions with high levels of energy consumption and GHG emissions. As shown in Figure1-2, the Middle East had the second largest primary energy intensity[1] level in the world in 2006, stemming from low energy efficiency, energy intensive industries or low energy prices (World Energy Council, 2008).

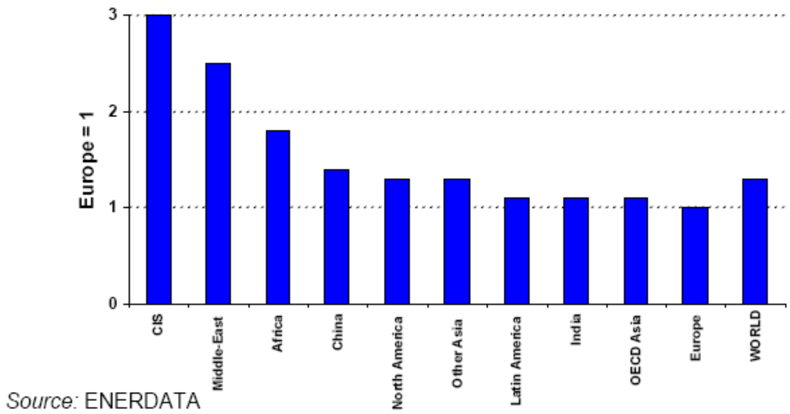


Figure 1-2 Primary energy intensity by world region (2006)

Source: WEC, 2008

Most of the energy consumed in the region is produced by fossil fuels causing considerable amounts of GHG emissions. As can be seen in Figure 1-3, the Middle East is amongst the regions, which had per capita CO_2 emissions higher than the average level of the world in 2006. During the period of 1971-2004, the second largest regional increase in CO_2 emissions from residential buildings was from the Middle East and North Africa (IPCC, 2007a).

The Middle East has a precious history of intellectual architecture concerning environmental, social and economic aspects of buildings. However, many of the valuable architectural elements have been neglected in new building designs as a result of modernization happened during recent decades. Changes in economic and social conditions in the region together with

[1] A general indication of energy efficiency performance is given by the primary energy intensity, which measures how much energy is required by each country or region to generate one unit of GDP (World Energy Council, 2008).

GDP is the monetary value of all the goods and services produced by an economy over a specified period (Law, 2006) population growth have contributed to dramatic increase in energy consumption and related environmental problems.

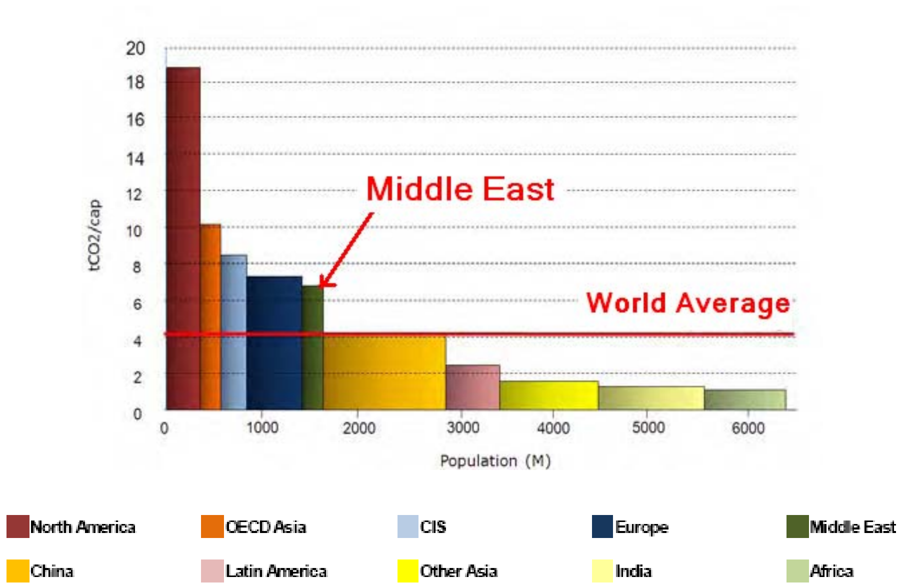


Figure 1-3 World CO2 emissions per capita

Source: WEC, 2008 (Modified)

To come across the way that energy efficient buildings can be developed in the region it is necessary to reveal the feasible strategies and technical solutions regarding local conditions and potentials. Therefore, a clear view of current local conditions and the existing experience is required to assess the applied solutions. Despite several energy efficient building projects pointed out by media in the region, adequate information about such projects is not available. For instance, during initial literature review of this research, limited information about green building projects in Bahrain, Kuwait, Qatar and United Arab Emirates were found on the internet while no adequate information was available. In addition, no respond to requests for more information or interviews were received from these countries. Studies such as this thesis are needed to overcome the information barrier to develop energy efficient buildings in the region.

This study is focused on the experience of energy efficient buildings in warm climates of two Middle East countries: Iran and Israel, attributable to available data. Initial literature review revealed that both countries have high levels of energy consumption and related emissions particularly in residential and commercial sectors. Iran is one of the largest countries in the region with a population of about 70,000,000. The Iranian residential and commercial sector accounts for about 40% of total final energy consumption in the country. Among all energy consumer sectors, the largest portion of CO_2 emissions was from this sector in the same year (Iran Ministry of Energy, 2006). Israel has a population of nearly 7 million with a fast growing level of energy consumption. Israeli residential and commercial sectors consume almost 55% of total electricity generated in the country and account for about 30% of total CO_2 emissions (Mor & Seroussi, 2007). The selected cases of this study are located in hot arid and Mediterranean climatic zones with the common feature of energy demands for both cooling and heating, which requires complex solutions to deal with energy consumption in buildings.

1.4 Objectives and adopted methodological approach

The overall objective of this research is to contribute to the understanding of pragmatic sustainable solutions to develop energy efficient buildings in warm climates of the two Middle East countries, Iran and Israel. This goal can be achieved through (1) investigating the experience of using various relevant technical solutions comprising both innovative and traditional design elements in Iran and Israel, and (2) identifying the drivers and barriers to develop the applied solutions. These aims will be achieved by means of answering the following **research questions**:

What is the experience of energy efficient buildings in warm climates of the Middle East with the focus on Iran and Israel?

How can design strategies and techniques be applied to improve energy efficiency of buildings in warm climates of Iran and Israel?

How are the energy efficient buildings designed and built in warm climates of Iran and Israel considering traditional architecture elements and innovative techniques?

How much energy efficiency is achievable in a building by the applied technical solutions and how much is the potential extra cost?

What are the main drivers and barriers to integrate energy efficient design strategies and technical solutions into buildings in warm climates of Iran and Israel?

1.4.1 Methodology

To answer the aforementioned research questions and achieve study objectives the following approach and methods was taken.

1.4.1.1 Literature review

As the first step, several literatures including books, articles, master theses and doctoral dissertations on the subject of various types of energy efficient and sustainable buildings as well as proposed and implemented technical solutions were reviewed to gain an understanding about energy efficient building concepts and characteristics. Secondly, different approaches adopted to enhance energy efficiency in buildings specifically with consideration to their relevance to warm climate were studied (e.g. passive house in Europe and green building in the United States). To find energy efficient techniques derived from classical and traditional architecture, the most relevant elements of that type of architecture were studied in the next stage. The main strategy was focusing on the common elements in the Middle East traditional architecture to investigate applicable solutions to improve energy efficiency in buildings concerning climatic and cultural features of the region. Moreover, related websites as well as governmental and organizational reports and statistics were explored in order to acquire information about the current situation in the geographical boundary of the research regarding the energy efficiency in buildings. Indeed, the latter was conducted after initial personal communications that determined the geographical boundary of the research.

1.4.1.2 Initial personal communications and interviews

The first stage of data collection was face-to-face interviews with the supervisors and a researcher at the Institute who is experienced on the subject of energy efficiency in buildings as well as searching on related websites to find relevant contact persons and addresses. During the next stage, the research area was communicated with contact persons involving the building industry and energy efficiency in buildings in several Middle East countries with warm climates. These communications included emails and phone calls. The geographical boundaries of research were determined according to the responses from interested individuals and organizations. Subsequently, qualitative and semi structured interviews were conducted via phone calls and email contacts to observe the current situation of the selected countries regarding energy issues in building sector and the trends of energy efficient buildings. The interviewees were chosen from different involved actors such as researchers, architects, constructors, authorities and users. The interviews questions were formulated according to interviewee's experience on the subject and role in the area of topic. The outcomes of the latter stage were employed to get an overall perspective of the energy efficient buildings situation in both countries and to find examples of buildings design or construction projects which of some selected as case studies.

Studying a number of buildings design and construction projects was adopted as a useful method to gain a deep understanding of applied technical solutions with the aim of improving energy efficiency. Therefore, six energy efficient building design or construction cases were selected to review. The published information about chosen cases was collected via the internet while detailed unpublished information was obtained through semi structured and qualitative interviews by email contacts and phone calls. The most relevant actors in each project were selected as Interviewees. The interview questions were formulated based on the case features and the role of interviewee in the project. The questions were created in a manner that gave the respondents sufficient flexibility in answering. In each case, the aim was to seek out the drivers to integrate energy efficiency concept into the buildings, the achieved level of energy efficiency, applied energy efficient technical solutions, additional costs for implementing those solutions, and barriers to develop the technical solutions. Examples of general interviews questions are mentioned in Appendix 2.

1.4.1.3 Analysis of collected data

At the first stage, the boundary for data analysis was limited to technical aspects of applied energy efficient solutions. Data on utilized solutions in each case were scrutinized to understand why and how they are used. At the next stage, a wider boundary for data analysis was used to assess the energy efficient building as a system comprising the use of energy efficient technical solutions as a main process. Therefore, each technical solution was reviewed in all relevant cases as a sub-process. At this phase, it was necessary to assess some inputs to these sub-processes such as policies and related regulations, energy efficient products and know-how. Besides, the relevant costs and energy saving were reviewed as the outputs of the whole process. This generalization of specific data led to the drawing of the main conclusions from this study.

1.5 Scope and limitations of the research

The scope of this study is limited to the experience of energy efficient buildings in warm climates of Iran and Israel with the focus on the applied technical solutions. There are several aspects associated with building life cycles; however, the only aspect addressed by this research is the energy consumption and ways to lower the negative impacts of this aspect by means of improving energy efficiency in buildings. The geographical boundaries of this research are limited to Iran and Israel. As mentioned before, the aim of this study is to explore the experiences of energy efficient buildings in the Middle East, whereas the limited available data restricted the geographical boundary to Iran and Israel. Iran was selected to use the author's experience of 34 years living in Iranian buildings and acquire required information through straightforward communications by use of the author's first language. Israel was selected as the other geographical area of this research due to responses received from individuals and organizations interested on the topic of this research; no response was received from the other countries. Four buildings under this study are located in hot-arid areas of both countries while two of Israeli buildings are situated in Mediterranean climate. This means that all six buildings need energy for both cooling and heating purposes.

During this research, the focus is on the applied technical solutions with the aim of energy efficiency improvement in buildings. Moreover, other related factors such as policies, actors and technologies will be discussed as the feasibility of technical solutions is directly affected by those aspects. Lack of some fundamental data about energy consumption and costs in the buildings under this study was a constraint. The other limitation factor was the duration of the research between May 16, 2008 and September 12, 2008, which made it difficult to study more countries in the region.

1.6 Reader's guide

Chapter2 summarizes general passive design strategies for improving energy efficiency in buildings: the *Passive house* concept as the main approach adopted in European countries to develop energy efficient buildings; and the *Green building* program initiated in North America and bio-climatic design as another common approach. *Chapter3* is a brief review of some traditional architecture elements used in the region that can be used as climatic design solutions to enhance energy efficiency in new buildings. *Chapter4* includes the results of studying six buildings designed or constructed at the aim of improving energy efficiency. The collected information on energy performance, applied technical solutions and related costs has been described in this chapter. In *Chapter5,* the main features of applied technical solutions, their advantages and disadvantages are discussed. This chapter also contains findings and conclusions including main drivers and barriers to apply mentioned technical solutions.

2 Common approaches to improve energy efficiency in buildings

Several approaches are adopted in many countries worldwide to deal with the environmental impacts and energy consumption of buildings. This chapter is a review of the basic principles and some experiences of energy efficient buildings that could be applicable in the other parts of the Middle East taking into account the local socio-economic and environmental conditions. In the first part of this chapter, some general design strategies aimed at reducing energy demand and especially cooling energy demands of buildings will be explained. Subsequently, the main features of the European passive house, one of the most dominant types of energy efficient buildings in Europe, and examples of developing this concept in warm climates of Europe will be described. Afterward, the major characteristics of green buildings, one of the prevailing kinds of sustainable buildings in the world, will be mentioned. The last part is a brief review of bioclimatic design, globally adopted by several designers to consider environmental aspects and dwellers' thermal comfort in the context of climate.

What will be mentioned in the following as passive design strategies, are common energy efficient solutions amongst all sustainable or climatic designs of buildings around the world.

2.1 General passive design strategies

There are various solutions to provide cooling and heating demands in buildings without utilizing conventional energy supplies such as fossil fuels. Most of these solutions are derived from traditional architecture elements applied for centuries around the world. However, some of the traditional solutions are not feasible any more regarding changes happened to urban patterns and lifestyles and thus should be improved by innovative solutions. The following passive design strategies are generally used as the ways to improve energy efficiency in buildings.

2.1.1 Typology/ Shape

Energy demand in a building is highly affected by the shape and typology of the building. In fact, building typology and shape is a significant component in absorption, storage and release the heat during day and night, and thus is a key factor for heating and cooling demands in the building. Buildings can be categorized as detached houses without any party walls, semi-detached houses with one party wall and terraced houses, which are joined in a row with two or more party walls for each house. Moreover, buildings typologies can be ranked by a parameter called "compactness" which is defined as the ratio of the building volume to its exterior wall area. The higher compactness contributes to lower heating and cooling energy demand and consequently the higher energy efficiency (Ourghi, Al-Anzi & Krarti, 2007; Passive-On, 2007).

2.1.2 Orientation

The amount of solar radiation received by a building depends on its orientation. For all typologies in northern hemisphere, a plan orientation towards south with maximum glazing area on the south façade increases solar radiation gains and consequently reduces required energy for heating in winter. The glazed areas can be equipped with proper shading devices in order to block solar gains and consequent overheating during summer. East and west oriented buildings are not able to gain adequate solar radiation in winter.

2.1.3 Shading

It is possible to reduce cooling energy demand in building by using proper shading in summer. Solar shading devices such as overhangs, awnings and blinds should be designed in an effective way in order to allow solar radiation to reach the building in winter and block it in summer. A variety of movable and permanent shadings can be utilized. As shown in Figure 2-1, the different solar radiation angles during summer and winter is a critical factor in designing permanent solar devices such as overhangs. This leads to energy saving by reducing cooling demand in summer as well as heating demand in winter.

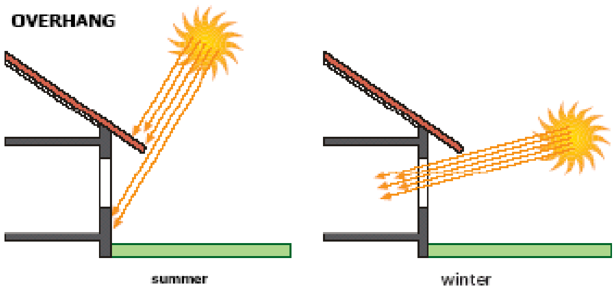


Figure 2-1 Overhangs function in summer and winter

Source: PEP, 2006

2.1.4 Thermal Mass

Thermal mass is a term to explain a material with high thermal capacitance, which absorbs and stores thermal energy. Masonry walls and concrete blocks are examples of thermal mass in buildings. Indeed, thermal mass acts as a thermal battery; in winter, it stores the heat absorbed from the sun or heaters in daytime and releases it during night. During summer, thermal mass can be cooled through nighttime ventilation and used for lowering cooling demand in the following day. The cooling effect of thermal mass in combination with night ventilation is appropriate for climates with considerable fluctuations in ambient temperatures during day and night.

2.1.5 Natural ventilation

The main function of the ventilation system is to provide exceptional indoor air quality. During summer, a ventilation system can be used as a part of cooling system by venting the indoor warm air to the outside. Natural and mechanical ventilation are two methods to supply fresh air into a building and removing foul air. A mixed mode is also achievable by the combination of these two types of ventilation. Natural ventilation is achieved by naturally created pressure differences stemmed from temperature difference, wind, or both. Natural ventilation is performed by airflow into and out of the building through the openings such as windows and doors or by means of specific ventilation components like chimneys. The effectiveness of this type of ventilation depends on temperature difference, wind speed, size, location and form of the openings (Santamouris & Farrou, 2007).

Natural ventilation is a passive ventilation method without any required energy. The main disadvantage of this method is its reliance on weather conditions while this drawback can be overcome by using mechanical ventilation, which includes fans to draft and exhaust the air. Utilizing the mixed method enables the inhabitants to benefit from the advantages of both mentioned methods i.e. energy saving and independency of weather conditions. The selection between different types of ventilation systems depends on the climate, building air tightness, the value of heat recovery and inhabitants preferences. The most common methods are:

- **Single sided ventilation:** As shown in figure 2-2 outdoor air enters the building through openings on a wall and leave out through the same opening or another opening on the same wall. This way is inexpensive and suitable for moderate climates and small internal spaces. A method to enhance the efficiency of this type of ventilation is the use of double opening (See Figure 2-3).

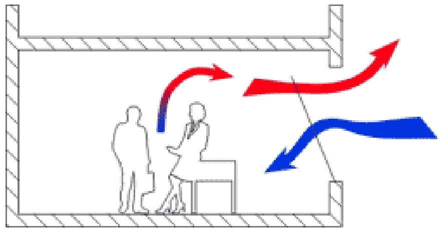


Figure 2-2 Single sided ventilation (One opening)
Source: Dyer Environmental Controls, 2008

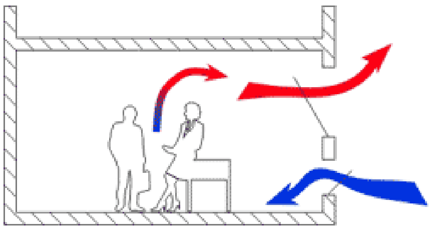


Figure 2-3 Single sided ventilation (Double opening)
Source: Dyer Environmental Controls, 2008

- **Cross flow ventilation:** As shown in Figure 2-4, In this kind of ventilation, cool fresh air (blue arrow) enters into the building from openings on a wall while warm and foul air moves out of the building from openings on the opposite walls (red arrow). Using this method can provide more airflow rates and thus is effective in larger internal spaces.

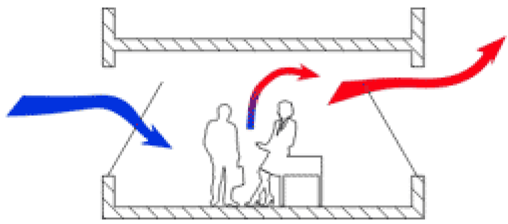


Figure 2-4 Cross flow ventilation
Source: Dyer Environmental Controls, 2008

- **Stack ventilation:** In this method, hot air, naturally flows upward, is vented through high-level openings and replaced by fresh air entering from lower openings. Figure 2-5 shows an advancement of this method, which includes the integration of both stack and cross ventilation using a double façade.

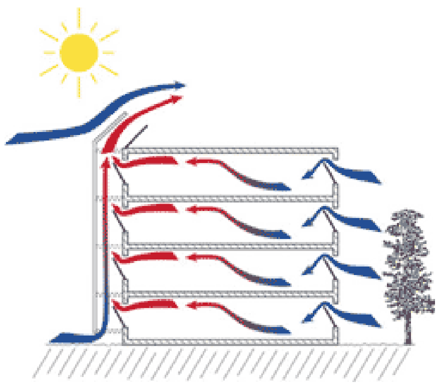


Figure 2-5 Combination of cross and stack ventilation
Source: Dyer Environmental Controls, 2008

Double façade operates as a chimney to enhance the efficiency of the ventilation system. It also acts as an acoustic insulation to block the noise in buildings situated in noisy urban areas.

It is worth bearing in mind that natural ventilation is not usually, sufficient to achieve a satisfactory level of indoor air quality and thermal comfort in energy efficient buildings. As a result, even in passive house, electrical energy is used to provide proper ventilation.

2.1.6 Night ventilation

In summer, when night time temperatures drop, cool air can be used to pre-cool the internal fabric of the house for the following day (See Figure 2-6). The airflow paths together with appropriate thermal mass provide adequate cooling. Automatic vent openings can also be applied to regulate both the airflow rate and the temperature inside the building.

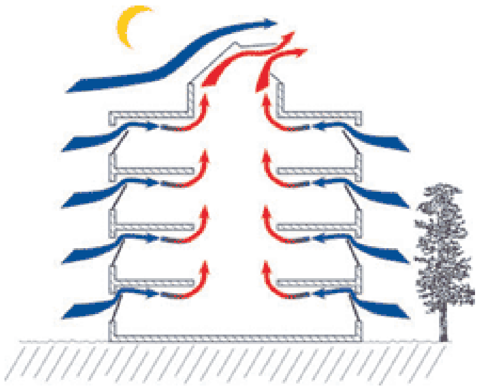


Figure 2-6 Passive cooling by night ventilation
Source: Dyer Environmental Controls, 2008

2.1.7 Evaporative cooling

The cooling capacity of evaporating water has been utilized to cool hot air in southern Europe, northern India and the Middle East for centuries. Indeed, hot air is cooled by flowing in contact with water and transferring its heat to water, which makes the water to be evaporated. The reduction in temperature is depended on humidity of the supply air. This differs from a few degrees when the air is relatively humid to around 12°C, when the air is relatively dry; therefore, the evaporative coolers are more effective in low humidity. The rate of evaporation and the airflow through ventilation openings should be controlled to avoid over-humidification and achieve a desirable performance (Passive-On, 2007).

2.1.8 Wall Insulation

The average heat flow through the wall construction can be reduced by wall insulation, which consequently reduces both heating and cooling energy demands in buildings. This effect is described by U-value which implies the heat flow through one square meter of wall area at a constant temperature difference of 1 K (= 1 °C) (Passive-On, 2007). Proper insulation of walls decreases heat losses in winter and contributes to energy saving and thermal comfort. During summer, thermal insulation reduces the heat transfer from the outside to the inside and thus decreases the cooling demand in the building.

2.1.9 Roof Insulation

During summer, roofs are generally more exposed to solar radiation than walls due to different angles of solar beams in winter and summer (See Figure 2-7). Inadequate roof insulation, results in heat transfer from the roof into the building and consequently undesirable hot indoor air during summer. In inclined roofs, insulation can be applied between roof rafters or on top of the rafters below the tiles (See figure 2-8). For concrete roofs, a functional way is to use outer insulation over the concrete (Passive-On, 2007).

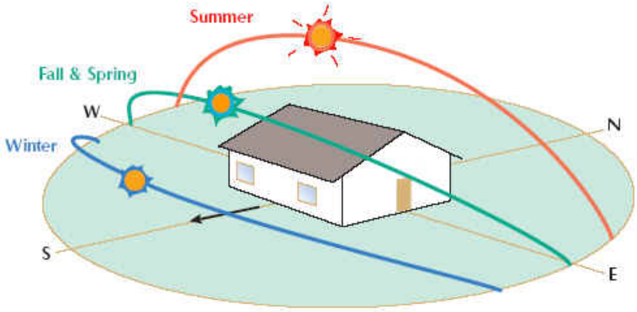


Figure 2-7 The arc of sun radiation in different seasons in northern latitudes
Source: www.tommorrowshomes.net

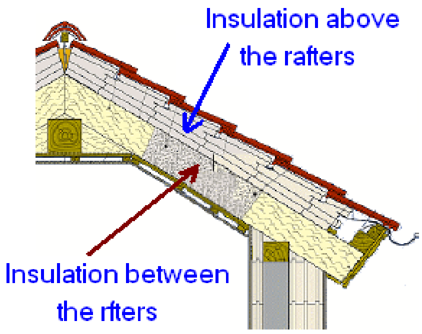


Figure 2-8 Inclined roof with insulations
Source: Passive-On, 2007 (Modified)

2.2 European Passive House & Passive-On project

A passive house concept is the predominant approach to enhance energy efficiency in European houses. In 1990, the first European passive house was built in Darmstadt, Germany showed a reduction of 90% in space heating demand compared to a standard building of the time (Elswijk & Kaan, 2008). Afterwards the passive house concept has been widely accepted as the main solution to improve energy efficiency in European buildings. Until 2007, more than 8,000 passive houses had been constructed in Europe (Passive-On, 2007) most existing in Austria, Germany, northern France, Sweden and Switzerland. The following definition has been offered by German Passive House Institute.

A Passive House is a building, for which thermal comfort (ISO 7730) can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to fulfill sufficient indoor air quality conditions (DIN 1946) - without a need for re-circulated air (Feist, 2006 b).

The basic features of current German passive house standard for central European countries are (Feist, Schnieders, Dorer& Hass, 2005; Passive-On, 2007):

- The annual useful energy demand for space heating does not exceed 15 kWh/m².
- The house has an appropriate compactness and all components of the exterior shell of the house are sufficiently insulated to achieve a U-factor that does not exceed 0.15 W/ m²K (0.026 Btu/h/ft²/°F).

- Passive use of solar energy is an important factor in passive house design, which is achieved by southern orientation and proper shading.
- Windows glazing and frames, combined should have U-factors not greater than 0.80 W/ (m^2K) (0.14 Btu/h/ft^2/°F), with solar heat-gain coefficients around 50%.
- Air leakage from unsealed joints should be less than 0.6 times the house volume per hour at a pressure test of 50 Pa.
- Energy for hot water is supplied by solar collectors or heat pumps.
- Using energy-saving household appliances such as Low energy refrigerators, stoves, freezers, lamps, washers, dryers, etc. are obligatory in a passive house.
- The operative room temperatures can be kept above 20 °C in winter, using the abovementioned amount of energy in order to meet thermal comfort requirement.

The *Passivhaus* standard was initially developed for cold climates of northern and central Europe. Therefore, new design guidelines were needed to develop the passive house concept in warmer climates of Europe.

Passive-On was one of the projects supported by Intelligent Energy-Europe program of the European Community on energy efficiency in buildings. The partners to the project were private and public research institutes from France, Germany, Italy, Portugal, Spain and UK. The project aimed to offer guidelines, which indicate how to use passive house design solutions for the buildings in warmer areas in the southern Europe. The 'Passive-on' project consortium has formulated a proposal for the Passive house standard in Warm European Climates adding the bellow criteria to German Passive house requirements.

- Cooling criterion: The useful, annual energy demand for space cooling of net habitable floor area does not exceed 15 kWh /m^2.

- Air tightness: If good indoor air quality and high thermal comfort are achieved by means of a mechanical ventilation system, air leakage from unsealed joints should be less than 0.6 times the house volume per hour at a pressure test of 50 Pa. For locations with winter ambient temperatures above 0 °C, this limitation can be increased to 1.0, which means the air leakage can be equals to the house volume per hour.

- Thermal comfort criterion in summer: operative room temperatures remain within the comfort range defined in EN 15251. Furthermore, the operative room temperature can be kept below 26 °C if an active cooling system is the major cooling device (Passive-On, 2007).

During Passive-On project, a few passive house prototypes were designed and constructed in warm climates of Europe. The following are two examples of prototypes were designed for Seville in Spain and Lisbon in Portugal.

2.2.1 Spanish passive house

The Spanish passive house prototype is a typical semidetached or terraced Spanish house, which has a total floor area of 100 m^2 situated in Seville. Seville is located at 37˚24´ North latitude with Mediterranean climate and warm summers. The house fulfils the current Spanish regulations called “Building Technical Code” came in to force from 2007 and particularly the energy demand limits.

Seville has more than 11 hours of daily sunshine during summer; average ambient air temperature is about 28°C with the mean maxima above 36°C in July and August (Erell, Yannas & Molina, 2006). Total energy demand in the Seville house is 24.5kWh/m^2, which includes a heating demand of 2.8kWh/m^2 and a cooling demand of 21.7kWh/m^2. Although these values show very good levels in the national energy labeling system (A in heating - B in cooling), the house does not achieve the cooling demand requirements of a passive house (Passive-On, 2007). As it can be calculated from figure 2-9, the house shows a total energy saving of 57.2% in comparison to a new standard Spanish house (For each house the left column shows the heating demand and while the right one shows the cooling demand).

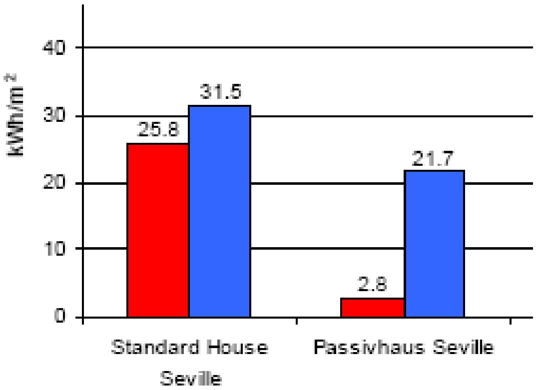


Figure 2-9 Predicted annual heating and cooling demands
Source: Passive-On, 2007

The additional cost of Spanish passive house is around 25€/m² which shows an increase of 5% compared to standard building construction costs in Spain. The average discounted payback is approximately 5 years (Passive-On, 2007). The following passive design strategies were adopted in the Spanish Passive house.

2.2.1.1 Thermal mass and inertia

The proposed solutions include conventional low inertia with a 6cm thick layer of brick to indoor space, and a new of high inertia with a low density-ceramic block. The latter should be used with proper ventilation in order to facilitate heat exchange between indoor air and high thermal mass internal walls (Passive-On, 2007).

2.2.1.2 Orientation, glazing and shading

The house is oriented to the south with a glazing area of about 50% of southern facade while approximately 10% of northern façade is glazed (Passive-On, 2007). The high levels of glazing to the South create efficient use of solar heat gains in winter. The other benefit of south orientation, in preference to the East and West, is the possibility of controlling the solar gains in summer. In other words, solar radiation control is simply achieved by means of movable shadings on south facing openings whereas it is complicated on eastern and western facades. It was recommended to use the minimum glazing on the North side surface to minimize heat loss during winter but fulfill day lighting requirements.

2.2.2 Lighting and night ventilation

The large south oriented glazing area provides natural lighting for the building. Furthermore, as mentioned previously, a portion of required lighting is provided by glazing area placed on the northern façade. In addition, a long window oriented to the south has been designed on the top of the stairs in order to natural lighting of the northern zone. During summer, the space above the stairs operates similar to a chimney, which facilitates movement of indoor warm air to the outside. Indeed, it provides the building with stack ventilation (See Figure 2-10).

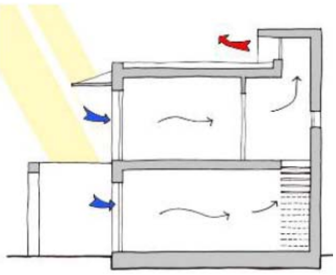


Figure 2-10 Natural ventilation

Source: Passive-On, 2007

2.2.3 Portuguese passive house

The Portuguese Passive house proposal was a single story house with two bedrooms and total floor area of 110m² located in Lisbon and fulfilling the national Building Regulation 2006 (RCCTE, DL 80/2006) requirements. The climatic condition of Lisbon is illustrated by its ambient temperatures and relative humidity in Figure 2-11.

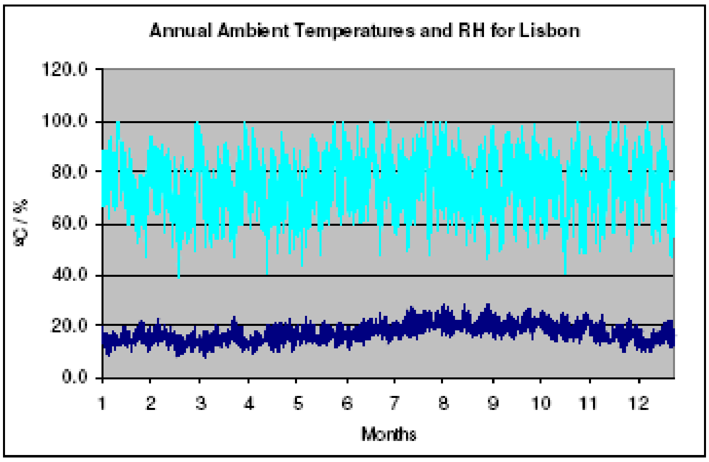


Figure 2-11 Annual ambient temperatures and Relative humidity for Lisbon
Source: Passive-On, 2007

The total annual heating and cooling energy demand in this proposed house is 9.6kWh/m² of which 5.9kWh/m² is for heating and 3.7kWh/m² is for cooling. As shown in figure 2-12 the heating (left column for each house) and cooling (right column for each house) demands of the house according to Portuguese building standard are respectively 73.5 and 32.0 kWh/m² (Passive-On, 2007).

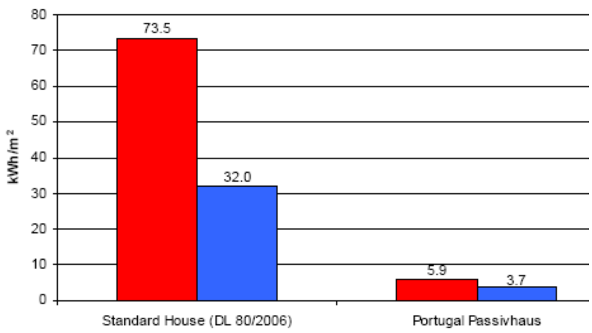


Figure 2-12 Predicted annual heating and cooling demands
Source: Passive-On, 2007

This means that the proposed passive house shows a reduction of about 91% in heating and cooling energy demand compared to a standard house. The additional costs of the proposed Passive house for Portugal is 57 €/m² with a payback period of 12 years (Passive-On, 2007). The following strategies have been adopted for the Portuguese passive house.

2.2.3.1 Thermal mass and inertia

A high thermal mass was proposed to control temperature fluctuations. The design combines the ability to absorb solar heat through large south oriented windows and the ability to regulate inside temperature by its thermal mass. The offered strategy to achieve a high thermal inertia was utilizing heavy concrete slabs, brick internal partitions and external insulation of the walls and roof. The combination of thermal mass and an effective strategy for ventilation provide the building with natural cooling during summer. The proposed cross ventilation strategy will be described later in section 2.2.3.5.

2.2.3.2 Walls and roof insulations

The proposed insulation for the roof is 150mm with a U-value (the rate of heat transfer per unit of area) of 0.23 W/m^2K. An insulation layer of 100mm with a U-value of 0.32 W/m^2K is proposed for the exterior walls. In addition, 80 mm Insulation for the floor slab is beneficial in colder climates. Nevertheless, where cooling is more significant than heating, a maximum 1m stripe of the perimeter below the floor slab should be insulated to facilitate heat transfer from the house to the soil in summertime (Passive-On, 2007).

2.2.3.3 Glazing and shading

South oriented large windows increase the useful solar gains during winter. East and west oriented glazing areas are smaller and north-facing windows are the minimum. All windows are equipped with exterior Venetian blinds and overhangs (See figure 2-13) are utilized for further Shading to the south oriented windows. In colder climates of Portugal, Low-emission double glazing with U-values of 2.9 W/m^2K can be effective but standard double glazing with U-values of 1.9 W/m^2K is more cost-effective in most locations (Passive-On, 2007).

2.2.3.4 Thermal solar system

The main feature of the Portuguese Passive house proposal is using a thermal solar system (See figure 2-13). This system provides hot water as well as most of the heating demand in the house. The thermal solar panels are installed facing south and angled 50º from horizontal surface, to enhance the efficiency of the system during winter (Passive-On, 2007).

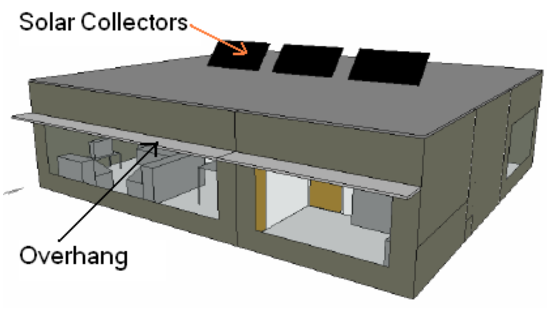


Figure 2-13 Proposed passive house for Portugal
Source: Passive-On, 2007(Modified)

2.2.3.5 Ventilation

During summer, using an effective cross ventilation strategy makes the core of the building release its stored heat and become cool for the next day (See Figure 2-14). Blue (vertical) arrows show the flow of night cool air into the building through southern façade and orange (horizontal) arrows show warm indoor air leaving the house from bedroom windows on east and west facades. To avoid draft during sleeping period, ventilation can be carried out in the evening. This strategy together with an effective control of solar radiations by shading devices can considerably reduce the cooling energy demand in the building. This natural ventilation is proposed to perform in the evening in order to avoid undesirable flow of air during sleeping time.

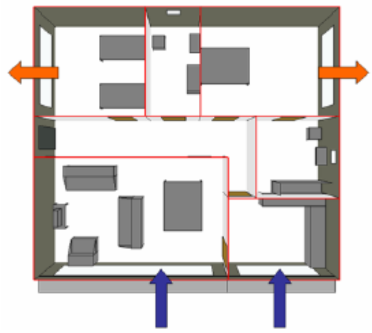


Figure 2-14 Summer ventilation strategy
Source: Passive-On, 2007

The two mentioned prototype projects are examples of the attempts to develop passive house concept in Europe and extend it to warm climates. Although passive house concept is growing in Europe, there are barriers hindering a fast growth of this concept. Most frequently, barriers are limited know-how, insufficient construction skills and inadequate acceptance in the market (PEP, 2006). Despite the availability of passive house components on the Western Europe market, lack of such components on the other countries can be considered as a potential barrier as well. Stringent regulations on energy efficiency performance can be used as a driver to promote the concept.

In the following, one of the other approaches to deal with environmental impacts and above all, energy consumption in buildings will be described.

2.3 Green buildings

Green building is an approach to deal with energy, water and materials consumption and to reduce related impacts on the environment and human health. This concept is promoted by the World Green Building Council (World GBC) worldwide. In recent years, Green buildings have shown a rapid growth in the United States and are increasing in other countries such as Australia.

In general, the green building concept is not only based on energy efficiency but it also comprises several environmental aspects such as water conservation, waste management, transport, etc.; nevertheless, the most weight is normally allocated to the energy criterion. Energy aspect of green buildings is addressed by the U.S. Environmental Protection Agency (U.S. EPA) and the U.S. Department of Energy (U.S. DOE) by ENERGY STAR labeling program. There is no green building certification program by EPA and DOE while a variety of private and non- profit green buildings programs are on the U.S. market including Leadership in Energy and Environmental Design (LEED) and Green Globes (U.S.EPA, 2008a).

The LEED Rating System is a third-party certification program for design, construction and operation of green buildings by the U.S. green building council (USGBC). This program has been developed for Homes rating system (USGBC, 2008) in addition to other types of buildings to promote sustainable design, construction and operation practices in the US houses. However, as mentioned before, green building concept is generally used for office buildings worldwide. New commercial and institutional buildings can be evaluated by the LEED rating system for New Construction. The LEED rating system for new constructions evaluates the overall performance of a building by the following criteria (USGBC, 2007a & b):

- **Innovation and design process (5 points):** Special design methods, exceptional regional credits, measures not presently dealt with in rating system, and excellent performance levels
- **Sustainable sites (14 points):** Minimization of the negative impacts of the project on the site
- **Water efficiency (5 points):** Measures to enhance efficient usage of water
- **Energy and atmosphere (17 points):** Energy efficient design of the building envelope, heating and cooling systems
- **Materials and resources (13 points):** Selection of environmentally friendly materials, efficient use of materials, minimization of construction waste
- **Indoor environmental quality (15 points):** Reduction of exposure to pollutants in order to improve indoor air quality

The rating system is implemented by requiring prerequisites and satisfying improved performance in each of the above-mentioned categories. Prerequisites required for energy and atmosphere category include fundamental commissioning of the building energy systems, minimum energy performance and fundamental refrigerant management.

A total of 17 points in the Energy & Atmosphere category can be obtained by six credits: (1) optimize energy performance (energy-cost savings), (2) On-site renewable energy, (3) enhanced commissioning[2], (5) measurement & verification and (6) green power. All LEED for new construction projects registered after June 26, 2007 are required to achieve at least two out of ten points from credit 1. This represents at least 14% optimization in energy performance of a new building compared to the reference building (USGBC, 2007b).The level of performance is determined by four performance ranks including: Certified, Silver, Gold and Platinum based on the earned scores (See table 2-1).

[2] Building commissioning is a quality control process that begins with the early stages of design (IPCC, 2007)

Table 2-1 LEED for new construction Certification Levels

LEED for new construction certification levels	Required points
Certified	**26-32**
Silver	**33-38**
Gold	**39-51**
Platinum	**52-69**
Total available points	**69**

Source: USGBC, 2007 (Modified)

Results of a study carried out in the US (Kats, 2003) revealed that average energy use of green buildings is by 30% less than conventional standard buildings in California. The average reported cost premium (additional cost compared to a conventional building) for 33 green buildings with different rating levels and certifications is 1.84% (See table 2-2). The average energy consumption of Gold-Platinum green buildings studied recently in the US (Turner & Frankel, 2008) was 51 kBtu/sf (160.8 kWh/m^2) while the best practices achieved the energy consumption level of less than 20 kBtu/sf (63 kWh/m^2).

Table 2-2 Level of green standard and average green cost premium

Level of Green Standard	Average Green Cost Premium
Level 1 – Certified	**0.66%**
Level 2 – Silver	**2.11%**
Level 3 – Gold	**1.82%**
Level 4 - Platinum	**6.50%**
Average of 33 Buildings	**1.84%**

Source: G. Kats, 2003 (Modified)

Several regulations and standards approved in the U.S. function as drivers for growing the green building concept in the country. "The Energy Independence and Security Act of 2007", which includes requirements for high performance green federal buildings is an example of such drivers (U.S.EPA, 2008b). Financial drivers such as grants, tax credits, loans etc. are available at the national, state and local levels for residential, commercial and public green buildings (U.S. EPA, 2008C). Many energy efficient products are available on the market and users are supplied by sufficient information by ENERGY STAR website to be able to select proper components for their buildings. This can also be a driver to promote all types of energy efficient buildings and amongst them, green buildings.

Moreover, federal and state agencies, industry-academic partnerships and non-governmental organizations fund green building research. "Energy and Atmosphere" has been the best-funded topic among green building LEED categories. Nonetheless, the total amount constituted only 0.2% of all federally funded research during the period of 2003-2005. Approximately 45% of research on energy and atmosphere is dedicated to energy efficiency while 54% is related to renewable energy technologies and 1% on other atmospheric issues (Baum, 2007). Intel's green building in Israel is an example of LEED green building projects, which will be discussed in chapter 4.

As bioclimatic design is a common approach amongst many architects throughout the world, its main principles will be briefly mentioned in the last part of this chapter.

2.4 Bioclimatic design

Bioclimatic aspects in building were addressed by Olgyay during the 1950s and developed as a process of design during the 1960s. The design process integrates principles of human physiology, climatology and building physics by considering design components such as:

- climate types and requirements;
- adaptive thermal comfort;
- vernacular and contextual solutions;
- microclimate: sun path, wind and rain; and
- working with the elements, such as passive and active systems, and development of a responsive form.

In addition, the following principles have been proposed to redefine the previous ones:

- creating user health and well-being;
- using passive systems;
- restoring ecological value;
- utilizing renewable energy;
- utilizing sustainable materials; and
- applying life-cycle thinking, assessment and costing.

Bioclimatic design has been addressed by the building design professions in terms of regionalism in architecture and, during recent years, has been considered as a basis to develop more sustainable buildings. Research interested in bioclimatic issues has taken the form of passive low energy architecture research worldwide with a well-developed field, as is evidenced in the passive and low energy architecture (PLEA) conference. PLEA is committed to the development, documentation and diffusion of the principles of bioclimatic design and the application of natural and innovative techniques for heating, cooling and lighting. This research has led to the development of bioclimatic design principles, which are used by design professionals as a starting point for designing with climate in mind. Considerable amounts of energy saving can be achieved in bioclimatic buildings by the use of building's microclimate, form and fabric, instead of efficient equipment (Hyde, 2008).

Bioclimatic design has been paid attention by many architects in the Middle East countries including Iran and Israel. Indeed, Israeli architects are pioneers in using this concept to design energy efficient and thermally comfortable buildings. Since Iran is a country with diverse climatic zones, the main approach adopted by the researchers and architects to address energy consumption in buildings is climatic architecture. The examples will be described in chapter 4 as case studies.

3 The Middle East traditional architecture: artistic climatic design

Many architectural elements and even innovative technical solutions applied in new buildings aimed at reducing energy consumption are based on traditional architecture principles. This chapter is a review of the Middle East traditional architecture elements relevant to energy efficiency and sustainability concepts. The aim of this review is to put in more understanding about the applied technical solutions by ancient architects that can be used to deal with energy consumption in new buildings.

Iran is the land of several ancient civilizations during the history of the Middle East. The ancient Persian (Iranian) culture was based on respecting four elements of nature: water, soil, wind (air) and fire (light). This belief affected the traditional Persian architecture through effective use of the four mentioned elements in buildings in order to meet human needs. Utilizing water ponds in courtyards and wind catchers to provide natural ventilation and cooling are examples of such efforts. There are principles in traditional Persian architecture applied to fulfill quality and performance needs regarding environmental impacts of the building. For instance, *Mardomvary*, (considering inhabitants satisfaction and comfort), *Khod-Basandegy* (efficient use of local and available materials and techniques for construction), *Parhiz Az Bihoudegy* (eliminating unnecessary parts of the building during design stage in order to avoid additional costs, construction loads and waste) (Vakili-Ardebili, & Boussabaine, 2006). In the following, some elements with their potential effects in energy consumption in buildings will be explained.

3.1 Courtyards

Courtyards have been one of the main elements of the residential buildings in the Middle East for centuries. Courtyards together with water pools in the middle and green plants around them have been significant parts of the passive cooling systems of the buildings in the region. They provide privacy and security for the dwellers and maximize the possibility of using natural lighting where privacy is an important factor for occupants. Water pools provide evaporative cooling for the buildings described in previous chapter (Section 2.1.7). Figure 3-1 shows a courtyard with water pool in a traditional house in hot arid climate of Iran.

Figure 3-1 The Boroujerdis ' house, Kashan, Iran
Source: www.Flickr.com, 2008

Courtyards can also be used by inhabitants as suitable places to relax or spend their leisure time during summer evenings and eating their breakfast in the summer mornings. In addition, courtyards protect the internal spaces of the buildings located in hot arid areas from hot and dusty winds.

Indeed, courtyard is a microclimate with an air temperature of a few degrees lower than the external environment. The relative humidity inside the courtyard is slightly higher than that the outside environment. It should be noted that the size of the courtyard is essential to achieve an optimum level of both cooling and heating efficiency, which is important in hot arid climates with hot summers and cold winters. Courtyard should be narrow enough to provide shading in summer and wide enough to receive adequate solar radiation during winter. There are some examples of using this traditional element in order to improve thermal comfort and energy efficiency in new buildings that will be discussed in the next chapter.

3.2 Domed and vaulted roofs

Domes and vaults have been widely used to cover buildings roofs in the Middle East. They have been proved as useful elements in natural ventilation and passive cooling. Vault is an elongated arc covering a space and dome is a type of vault constructed on a circular, elliptical, or polygonal plan (Curl, 2006); (See Figure 3-2).

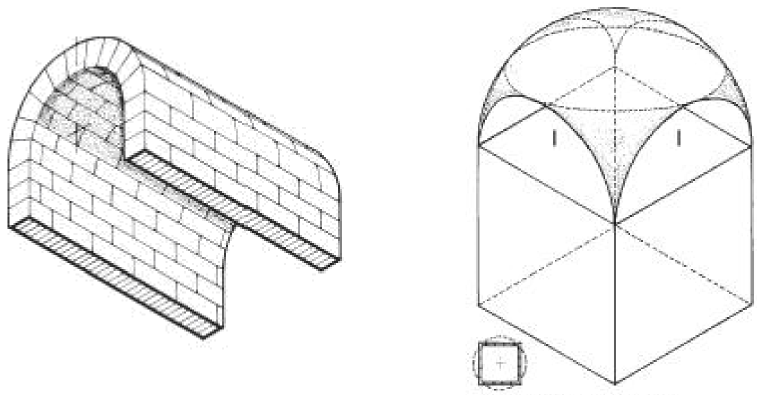


Figure 3-2 Vault (left) and Dome (right)
Source: J.S. Curl, 2006

In fact, a vaulted or domed roof has a larger surface area in comparison with a flat roof covering the same area. A study carried out by Iranian researchers (Bahadori & Haghighat, 1986) showed that wind speed around a domed roof is higher than that on a flat roof. As a result, the amount of the heat loss by convection is higher than that of a flat roof. On the other hand, the heat gain from solar radiation is almost the same for a flat roof and a domed roof.

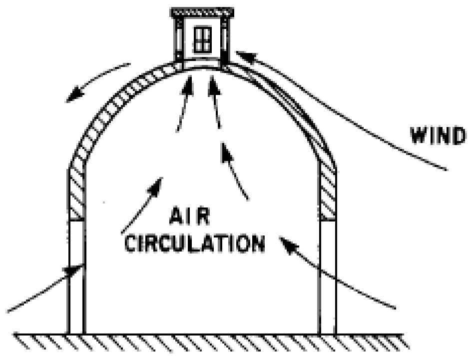


Figure 3-3 Air flow pattern in a building with domed roof and wind catcher

Source: Bahadori & Haghighat, 1986

To sum up, the heat gained by both type of roofs are the same while the heat loss by domed roof is higher than the flat one, which makes the dome an appropriate choice for hot areas. Whereas, this would be a limitation for domed roof concerning heating demands during winter.

Locating openings in proper positions in vaulted roofs creates an effective ventilation system. For instance, warm indoor air accumulated under a dome can be vented through an opening at the dome apex. As shown in Figure 3-3, Fresh air enters the room from openings (e.g. doors and windows) at the lower level and forces the indoor warm and foul air vent outside through the dome opening. In windy weather, the airflow on the dome generates suction in the opening and forces the indoor foul and warm air to leave the interior. This opening can also be used to natural lighting of the internal space. Another method to provide natural daylight for spaces under domes in the region was to make several small holes on the roof and cover them by bulbous glass (See Figure 3-4).

Figure 3-4 Domes on the roof of Hamam, Hama, Syria

Source: www.Flickr.com, 2008

3.3 Mashrabiah

Shading is a necessary strategy to avoid heat in the building during summer. Various shading devices have been used in the region for centuries. For instance, Mashrabiah is a wooden screen for covering the window has been used to provide shading and privacy for buildings (Sharag-Eldin, 1998). This device provides occupants with shading at the same time as natural lighting, ventilation, access to outside view and privacy. In other words, dwellers can see the outside while the interior is not visible from the outside. In Figure 3-5, a Mashrabiah can be seen through another one.

Figure 3-5 Mashrabiah

Source: www.Flickr.com, 2008

3.4 Wind catchers

Wind catchers or wind towers have been used to provide natural ventilation and passive cooling in the Middle East buildings for centuries. In general, a wind catcher is a tower that operates as a ventilation and cooling device by catching the air at its highest elevation and transferring it into the internal spaces of the building. Wind catchers vary in shape and number of openings depending on the climate of their location. In areas with one predominant wind direction, the tower head has only one opening facing that direction while wherever the wind blows in various directions, the towers are equipped with openings in other directions as well. Wind catchers have different shapes including square, rectangular and octagonal cross sections (Bahadori, 1978; Mazidi, Dehghani, Aghanajafi, 2007), (See Figure 3-6).

Figure 3-6 Wind-catchers, Kashan, Iran

Source: www.Flickr.com, 2008

Wind catchers can operate as a part of evaporative cooling systems in combination with a water pool located in the courtyard. In some cases such as Dowlat Abad garden in Yazd, Iran, a small water pool located inside the building in the space under the tower is used to provide evaporative cooling for the building (See Figures 3-7 & 3-8).

Moreover, when no wind blows or the wind speed is lower than certain amounts, wind catcher operates as a chimney to provide stack ventilation as well as evaporative cooling in along with water pool. This function depends on various factors such as the type, height and size of the wind catcher, wind speed, number of rooms and windows in the connected building.

Figure 3-7 Dowlat Abad garden wind catcher

Source: www.Flickr.com, 2008

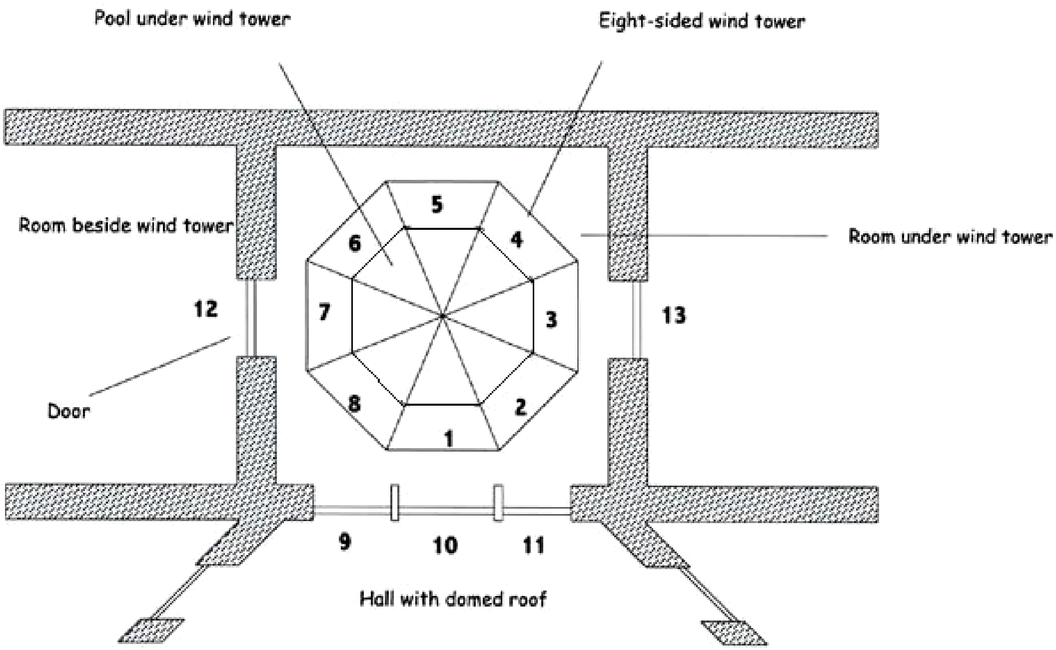


Figure 3-8 Plan of Dowlat Abad garden wind catcher

Source: Mazidi et al., 2007

3.4.1 A new design of wind catcher

As mentioned before, in hot climates of Iran and neighboring countries, wind catchers have been used as natural ventilation and passive cooling systems in buildings. However, the conventional wind catchers have some disadvantages that could be summarized as follows (Bahadori, 1985):

- Dust and insects can enter the building with inlet air
- In the wind catchers with more than one opening, a portion of entered air from the opening facing the wind is lost through other openings
- In general, the amount of stored coolness in the tower mass is limited due to small mass and low specific heat of the energy-storing material which can hinder fulfilling cooling needs during hot summer days
- The evaporative cooling potential of the air is not used efficiently
- They are not applicable in areas where wind speeds are very low

In order to eliminate the above-mentioned disadvantages, two new designs of wind-catchers were constructed and tested at Yazd University campus in the city of Yazd, Iran. These new designs were: 1) the wind-catcher with wetted column or wetted curtains and 2) the wind-catcher with wetted surfaces. In both designs, the tower head was equipped with screens and plastic curtains behind them at all openings in order to filter the entering air and prevent the air lost from the openings.

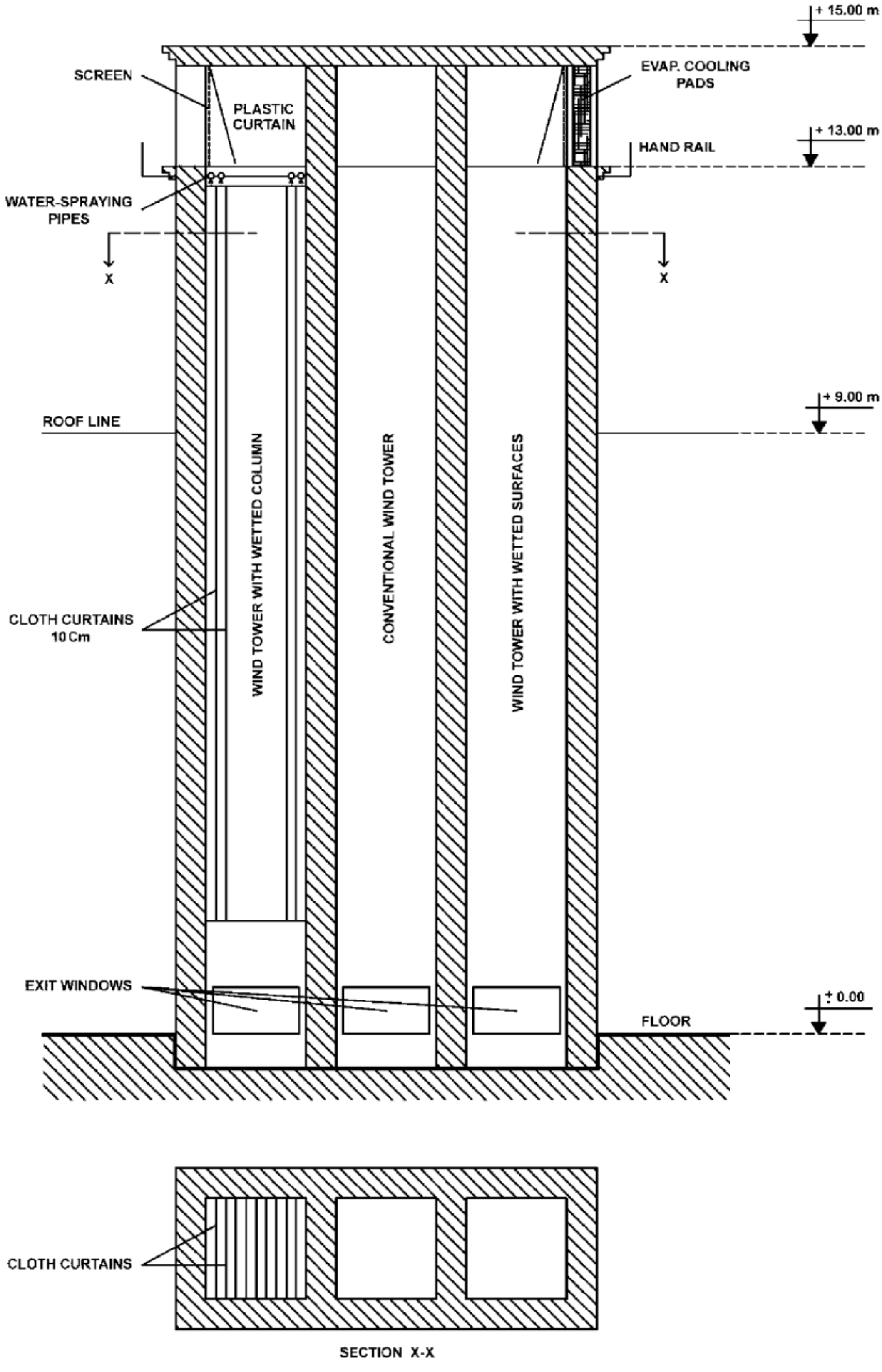


Figure 3-9 New design of wind-Catcher

Source: Bahadori, et al., 2008

The wind-catcher with wetted column was equipped with fabric curtains as wide as the internal width of the tower. The curtains were installed vertically in distances of 10 cm from each other and fixed firmly at the bottom side to prevent them from fluttering. The curtains were wetted by water spray on the top (See Figure 3-9).

The wind catcher with wetted surfaces was also equipped with evaporative wetted pads as they are utilized in typical evaporative coolers. The pads were installed at the openings on the top of the wind catcher and wetted by spraying water on top of them (See Figure 3-9). Figure 3-10 shows the temperatures of the outgoing air from two different types of new wind catchers (Bahadori, Mazidi, Dehghani, 2008). As can be seen, the cooling effects of new designed wind catchers are more than that of the conventional ones while the wind catcher with wetted column has the best performance.

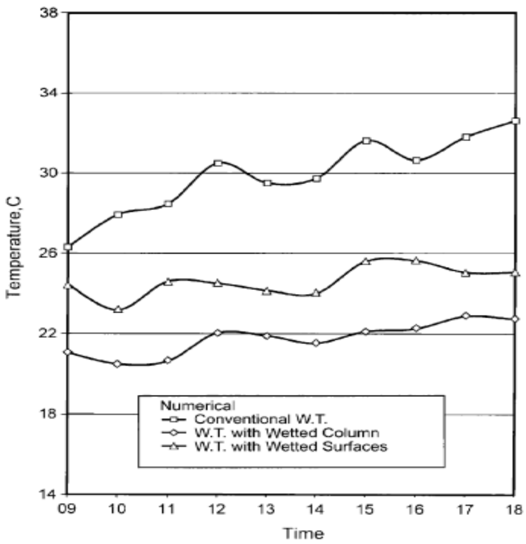


Figure 3-10 Temperature of the outgoing air from tested wind-catchers[3]

Source: Bahadori, et al., 2008

[3] W.T. stands for Wind Tower (Wind-catcher)

4 Energy efficient buildings in the Middle East: examples of Iran and Israel

This chapter is a review of what is happening with regard to energy efficiency in buildings in Iran and Israel as two examples of the Middle East countries. Valuable experience of intellectual architecture exists in the Middle East that can be used to design and construct new energy efficient buildings. A growing number of energy efficient buildings are expected, taking into account the implemented and running projects in the region. For instance, energy efficiency in construction sector in the Mediterranean (MED-ENEC) is a project running in ten Middle East countries located in Mediterranean region including Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Palestine, Syria, Tunisia and Turkey. The project, cooperation between the European Union and the mentioned countries, aimed at promoting energy efficiency measures and using solar energy in building sector by demonstration projects and capacity building (MED-ENEC, 2008). In addition, rising number of applications for LEED certification in countries such as Bahrain, Israel, Kuwait, Qatar and United Arab Emirates shows a growth in green building concept in these countries. However, statistical data on energy efficient buildings and data on characteristics of such buildings in the region are not available. Therefore, finding some examples and reviewing them as case studies was adopted as an appropriate way to attain detailed information.

There are several articles on the topics of energy efficiency in buildings written by researchers in the Middle East countries including Iran and Israel. In both countries, bioclimatic architecture and reducing energy consumption in buildings have been addressed by academia since 70s. Furthermore, several policies with different approaches have been made by both countries with the aim of improving energy efficiency in the buildings. A very few number of buildings constructed aimed at improving energy efficiency were found in Iran during this study. An emergent number of energy efficient building projects are running in Israel despite barriers are hindering the sufficient pace of developing such buildings. The first part of this chapter gives a perspective of the current situation in Iran with reference to energy efficiency in buildings. The characteristics of energy efficient buildings in Iran will be later reviewed through three examples in the country. The same order will be followed in the next two parts of this chapter regarding Israel.

4.1 Iran, building sector and energy at a glance

4.1.1 Geography and climate of Iran

Iran with an area of approximately 1,648,000 square kilometers is located in the Middle East bordered by Armenia, Azerbaijan, Turkmenistan, Afghanistan, Pakistan, Iraq, Turkey, the Caspian Sea, the Persian Gulf and the Oman Sea (See Figure 4-1). According to national census of population and housing, Iran population was 70,495,782 in 2006 (Statistical Center of Iran, 2008).

Iran can be divided into four main climatic regions (Ghobadian, Taghi & Ghodsi, 2008):

- Temperate climate in northern shores
- Cold climate in mountain and high plateau region
- Hot and dry climate in central plateau
- Hot and humid climate in southern shores

Figure 4-1 Map of Iran
Source: http://www.cse.msu.edu/~borzoo/non-acd/iran.htm, 2008(Modified)

As shown in Figure 4-1 most parts of the country is covered by hot and dry climate which need both heating and cooling energy supplies for buildings due to relatively cold winters and hot summers.

4.1.2 Energy use in Iranian residential and commercial sectors

Iranian residential and commercial sectors used 40.5% of total final energy in the country in 2006 (Iran Ministry of Energy, 2006). The main energy carriers used to supply this energy demand are natural gas, petroleum products and electricity (See Figure 4-2) (Iran Fuel Conservation Organization, 2008).

Electricity is the main energy carrier used for cooling purposes in addition to lighting in Iranian buildings. Approximately 91% of the electricity is generated from fossil fuels while the rest comes from hydropower generation.

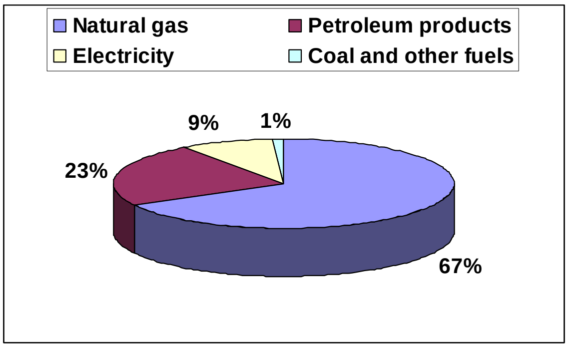


Figure 4-2 Energy carriers used by residential and commercial sectors (According to IFCO Statistics, 2008)

In 2006, Iranian residential sector accounted for 33.2% electricity consumption, which was the largest portion amongst all sectors. Per capita consumption of electricity was reported 2690 kWh showing a 2.4% increase compared to 2005 (Tavanir, 2008). Undoubtedly, air quality has been influenced by this huge amount of fossil fuel consumption due to related pollutant emissions.

4.1.3 Environment and emissions

In 2004, Iran's per capita carbon dioxide emission was 6.4 metric tonnes (World Bank, 2008). In 2006, total CO_2 emission caused by energy consumption was 381,938,000 tons which of 29% was emitted from residential and commercial sectors (Iran Ministry of Energy, 2006); (See Figure 4-3)

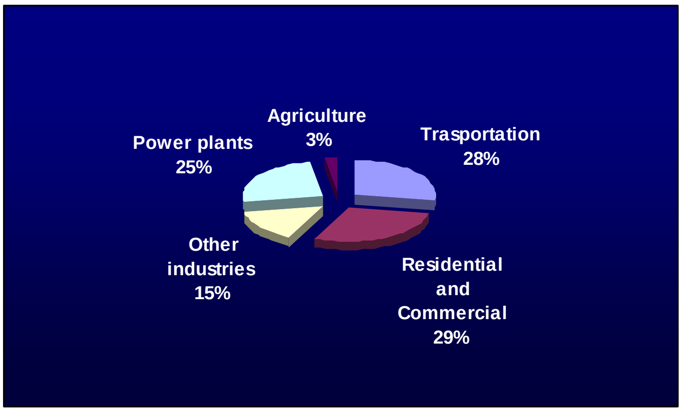


Figure 4-3 CO_2 emissions from different Iranian sectors (2006)
Source: Iran Ministry of Energy, 2006 (Modified)

Air pollution is a major environmental impact of energy consumption and related emissions in the country, particularly in the capital city of Tehran. Figure 4-4 illustrates the quality of air in Tehran during 2006; only for nearly 36 days the air was clean which according to Iran Department of Environment (Iran DOE), is the satisfactory level for air quality implying low levels of pollution. As shown in Figure 4-4, for about 244 days the air quality had been reported as healthy which is an acceptable level although it can be harmful for people who are sick or sensitive to air pollution[4].

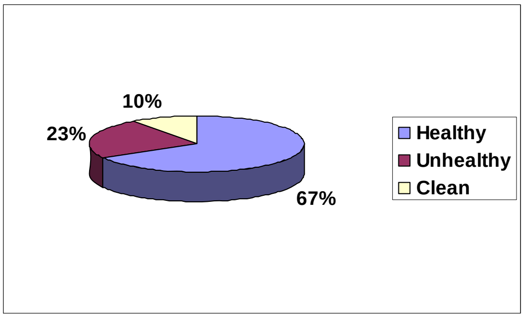


Figure 4-4 Tehran's air quality in 2006
Source: Iran DOE, 2008

In 84 days or 23% of year time, people were exposed to unhealthy air, which is harmful for everybody (Iran DOE, 2008). Taking into consideration the buildings contribution to energy consumption and related emissions, urgent actions are needed to reduce the associated impacts. Policy tools such as building codes and standards play a critical part in improving energy efficiency in buildings.

4.1.4 Policies to promote energy efficiency in buildings

Building energy codes are regarded as significant drivers to improve energy efficiency in new buildings. They can be categorized as: 1) overall performance-based codes that oblige achievement of an annual energy consumption level or energy cost budget in accordance with a standard method. This type of code offers flexibility while well-trained professionals are

[4] Considering the mentioned characteristics, 'healthy' might not be an appropriate title for this range of air quality.

required to implement the code; 2) Prescriptive codes that set specified performance levels for building envelop and components (e.g. minimum thermal resistance of walls and minimum boiler efficiency); and 3) A combination of an overall performance requirement and some component performance requirements (IPCC, 2007).

In 1992, a building code was approved by the Iranian Council of Ministers on energy conservation in buildings. The main criterion was the level of energy conservation in the building while climatic parameters were not taken into account. Buildings were categorized in four groups regarding energy conservation levels. The building code was a combination of prescriptive and performance methods (Kari & Fayaz, 2006).

In 1995, a new approach was initiated by Building and Housing Research Center (BHRC), which led to adoption of what is called chapter 19 of national building code. This code came into force in 2000 with different deadlines determined for various provinces based on their climates and floor areas of the buildings. There are two methods introduced in this code: The first one is a prescriptive method for small apartments as well as detached single houses with medium and low level of energy saving expectance. The second method is based on the performance of the envelope by introducing the heat loss coefficient of the whole building. The results of a research carried out by BHRC demonstrated that an energy saving of 30% is achievable by chapter 19 of Iranian national building code (Kari & Fayaz, 2006).

In addition, since 2003, several standards with the aim of improving energy efficiency in buildings have been approved by Iranian Standards and Industrial Research Institute. These standards are for: doors, panel walls and windows, double or multiple pane glazing, thermal insulation products, lightweight concrete, construction systems and materials- determination of thermal resistance and heat transfer coefficient, labeling for appliances based on European model.

Supporting producers of energy efficient building components by giving subsidies is another policy adopted by Iranian government. The energy efficient products received governmental subsidies include energy efficient windows and doors, double glazing systems, natural gas fired chillers, concrete blocks, polystyrene panels and insulation materials. Solar water heaters are also produced in Iran while the use of them is limited.

4.1.5 Building materials and equipment on the Iran market

A variety of standard construction materials is produced in Iran; however, using non-standard materials due to their low prices is a major problem in Iranian construction industry. Moreover, the quality and energy performance of products is an aspect that needs to be assessed. For instance, 10 of 124 models of produced evaporative air coolers ranked F[5] as the most energy efficient ones in 2004 (Iran Energy Efficiency Organization, 2004). According to Iranian labeling standard, the electrical evaporative coolers that have energy efficiencies in the range of 33%-39% are fallen in class F (Iran Ministry of Energy, 2008).

Considerable amounts of subsidies allocated to different energy carriers including electricity, natural gas and petroleum products result in low levels of energy prices. In fact, inexpensive

[5] The rating system includes seven levels distinguished by the letters of the alphabet from A (most efficient) to G (less efficient)

energy prices hinder the use of relatively expensive energy efficient products by constructors who want to reduce the building costs.

Interaction of the mentioned and the other affecting factors create the current situation for energy efficiency in buildings in the country, which will be pointed out in the following.

4.2 Energy efficiency in Iranian buildings

In Iran, the main method adopted to improve energy efficiency in buildings is to implement the previously described chapter 19 of national building code (Section 4.1.1). The adopted approach is to develop climatic design and construction. Indeed, there is no building in Iran built in accordance with specific energy efficient building concepts such as green buildings, passive houses, zero energy buildings, etc. Several projects have been carried out aimed at improving energy efficiency of existing buildings; whereas sufficient efforts has not been expended to build new energy efficient buildings. During this research, after exact review of available information resources such as interrelated authorities' websites and reports, proceedings of relevant conferences and interviews with associated academics and research centers, 18 building design projects with the aim of improving energy efficiency were identified in Iran. Unfortunately, nine projects were stopped after design stage, have not been developed yet. Most of the constructed projects have not been implemented according to proposed designs. Three of the mentioned projects will be discussed as case studies in following parts of this paper. The three examples are located in Tehran and Yazd in hot arid climate zone of Iran. These two cities illustrated by circles on the map of Iran in Figure 4-1.

4.2.1 Case study 1: Tehran Climate House

In 2002, Tehran climate house demonstration project was commissioned by the Iranian Fuel conservation Company (IFCO) and designed by NG Architects in association with Pierre d'Avoine Architects. The location was in an urban site in northern part of Tehran (Saberi, Saneei, & Lankarani, 2006). The city covers an area of approximately 2000 km^2 and has a population of about 12 million (Tehran municipality, 2008) located at 35˚41' North latitude and 51˚19'East longitude, 1191m above sea level in the hot arid region of Iran. The heating period is from the middle of November to early March while the cooling period is from early June to mid August. Temperature fluctuations between day and night are quite high due to dry conditions (Ghobadian et al., 2008).

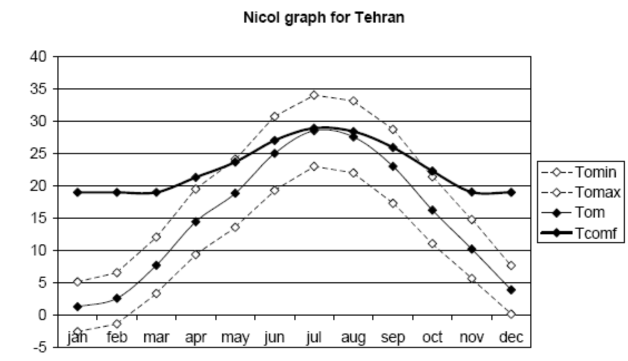


Figure 4-5 Thermal comfort curves for Tehran[6]

Source: Saberi et al., 2006

[6] Tomin: Minimum outside temperature (˚C)

Tomax: Maximum outside temperature

Tom: Mean outside temperature

Tcom: Comfort temperature

The project was aimed to raise people awareness about the efficient use of energy resources in the country by an effective integration between culture and technology. To phase out the use of fossil fuels as energy carrier for the building was a major target of the design. The house was planned in a larger site for an exhibition and conference center. However, the project stopped due to land ownership and other problems, has not been implemented so far. The design was based on the study of local climatic and comfort conditions such as solar radiation as well as wind speeds and directions. As a result, thermal comfort diagram for Tehran was prepared (See Figure 4-5).

The estimated cost for building was almost twice as much as a conventional building (O. Saberi, personal communication, August5, 2008). According to one of the designers, this high estimated stemmed from their design strategy based on exploitation of the most energy efficient technologies regardless of their availability in the local market. Indeed, the designers aimed to demonstrate the best innovative technologies for energy efficiency improvement in the houses (N. Golzari, Personal communication, June26, 2008). The house was estimated to achieve an energy saving of 70% in comparison with similar conventional buildings in Tehran (Saberi et al., 2006) by means of the following elements and strategies.

4.2.1.1 Orientation and external environment

House plan orientation is directed towards the south in order to maximize solar gains in winter and to minimize heating demand in the building (See Figure 4-6). Courtyard described in chapter3 (Section 3.1) was integrated into the house design as one of the traditional architecture elements. A north cold courtyard with water pool and a south warm courtyard were designed in order to provide thermal comfort in the house by means of evaporative cooling and cross ventilation. The cold courtyard considered to be shaded in most of the daytime creating natural cooling by the flow of cool air from the courtyard into the building during summer.

A high wall along west side of the site would hinder noise from the street and solar radiation in warm seasons (See Figures 4-6). This wall was the exterior wall of an office building, a part of the exhibition and conference center. The office-building roof was planned to partly plant as a green roof (pergola) in order to provide the occupants with its cooling effects during summer.

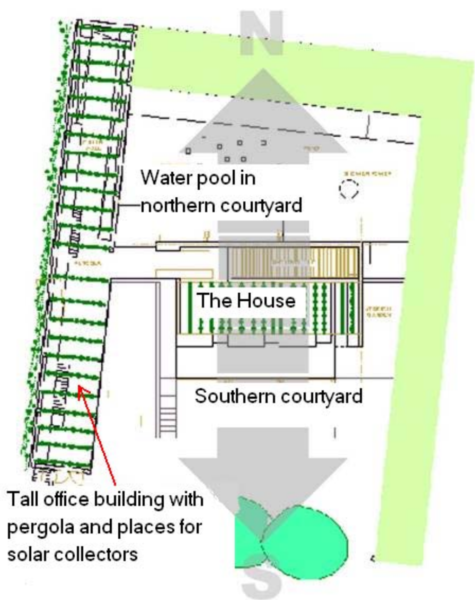


Figure 4-6 Tehran climate house plan
Source: IFCO, 2008 (Modified)

This roof was also considered as the place for installing solar collectors in order to supply solar energy. In addition, shading effects of various parts of the building on each other was considered as an effective solution to minimize cooling energy demand.

4.2.1.2 Thermal mass and insulation

The proposed material for walls was cellular concrete blocks; thus, in winter, heat gained from daily solar radiation would be stored in this high thermal mass and transferred to the internal space of the building during night. Thermal insulation of the walls, roof and floors were considered to minimize required energy for heating and cooling in the house. In order to effective use of thermal mass, the insulation layer would be applied in the external layer of the building envelop.

4.2.1.3 Passive cooling and natural ventilation system

A combination of passive cooling and natural ventilation system was designed to provide thermal comfort passively and thus reduced energy consumption in the building. The system includes a wide water pool equipped with fountains designed for northern courtyard to provide the house with the passive evaporative cooling system during summer (See Figure 4-6). As shown in figure 4-7, the air will be cooled flowing over the water pool and fountains by evaporation of water. This cool air enters the house through the openings facing the courtyard. The indoor warm air will be replaced by the entered cool air and leave the rooms through the openings located on the opposite walls and moves out of the building via a chimney designed as a part of this combination of passive evaporative cooling and natural cross ventilation system. The upper part of the chimney will be heated by solar radiation to create an effective suction due to temperature difference.

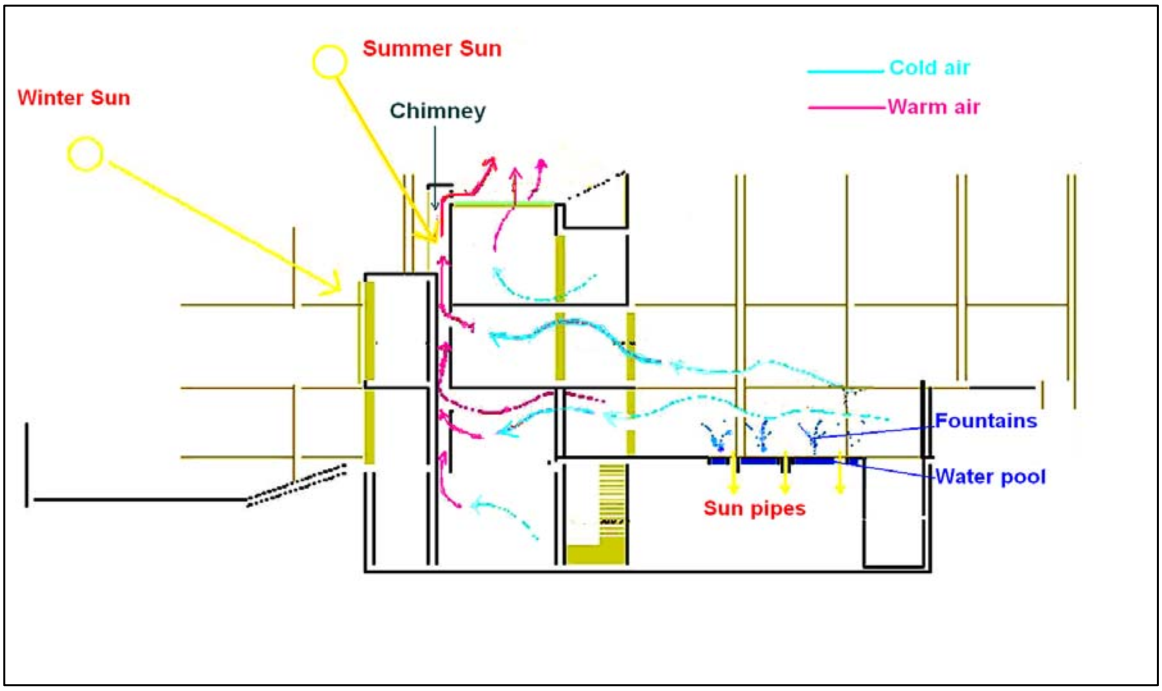


Figure 4-7 Cross section of Tehran climate house: passive cooling and natural ventilation system

Source: IFCO, 2008 (Modified)

In addition, wind catchers were proposed as an innovative technology based on traditional architecture to supply the cooling demand in the basement (See Figure 4-8). In this system: (1) the warm ambient air enters the wind catcher from its upper opening. (2) The entered air is cooled and draught down by spraying water from a shower installed in the upper part of the wind catcher. (3) Cool air enters the basement makes the warm and foul indoor air move upward. (4) Subsequently, the warm air leaves the basement through the openings located on its roof. The other advantage of water spray is absorption of dust by water, providing a clean air to the indoor space. The water after pouring into a container blow the wind catcher will be filtered and reused in the shower.

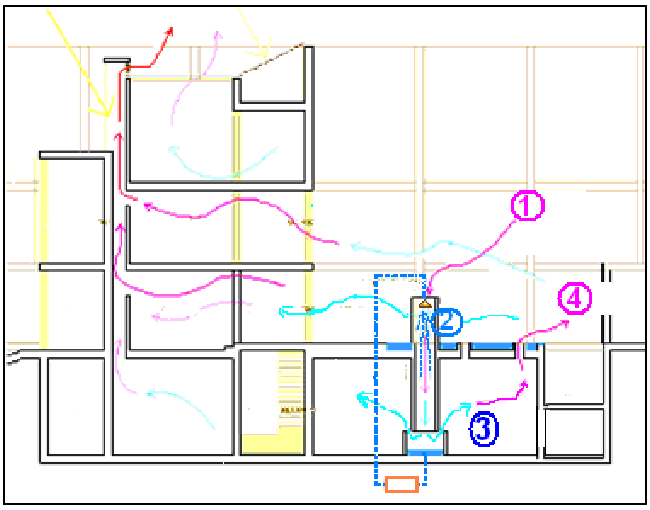


Figure 4-8 Wind-catchers for cooling the basement
Source: IFCO, 2008 (Modified)

4.2.1.4 Passive heating

As mentioned before, orientation design of the building allows solar radiation gains directly through large south facing openings and thus supplies a portion of heating demand in the building (See Figure 4-7, Winter Sun). The main designed space heating system included an under floor piping, which will provide the interior by heat released from warm water flowing in the pipes. Warm water will be heated by energy supply from solar collectors located on the roof of tall building. A natural gas fired heating system was designed as a back up to provide the energy required for heating water.

4.2.1.5 Lighting

Natural lighting would be provided by sunlight through South oriented openings. Sun pipes were recommended to supply natural lighting for the basement that has no access to daylight. They were decided to install on the water pool floor. As shown in Figure4-9, the main components of Sunpipe are a glass dome to maximize the received light, a pipe with reflective internal layer to intensify and transmit the light into the building and a domed diffuser at ceiling level to diffuse the sunlight in the internal spaces. This element was proposed to import since it was not on the market at the time. The electricity required for night lighting in the house would be supplied by Photovoltaics (PVs) as well as electricity grid.

Figure 4-9 Sunpipe for natural lighting
Source: www.sunpipe.com, 2008

4.2.2 Case study 2: Tehran green office

The project was implemented through collaboration between IFCO and Tehran municipality district 10, one of the 22 urban districts of Tehran. The geographic and climatic condition of Tehran was described in the former case study. The building designed by the same designers of Tehran climate house (discussed in section 4.2.1), is a 3-story office building with a floor area of 550 m². A reduction of 40% in the energy demand in the building compared to existing buildings was predicted (Saberi, Saneei & Kenari, 2006). In contrary to the former case, this building was constructed; however, the main elements designed to lower energy demand in the building have not been exploited that will be more discussed in the following parts and the next chapter.

Figure 4-10 Tehran Green Office simulation image
Source: APRS, 2008

4.2.2.1 Building form and components

The overall typology of the building is based on using traditional architecture elements although the building has a contemporary form (See Figure 4-10). The ground floor includes a central courtyard, a small water pool and a green roof designed to be planted in order to provide shading and to operate as a part of passive cooling system. However, at present, the green roof is covered by a dried grass (see Figure 4-11) and thus the building is not shaded by any plants during summer. It should be noted that ceiling of the rooms under this roof has been harmed by water leakage due to irrigation on the roof.

Figure 4-11 Green roof in Tehran green office
Source: A. Rastgar, 2008

Figure4-12 shows the water pool used as a spare space; capped fountains are shown by circles around them. Two glazed surfaces shown by arrows were installed to provide natural day light for the basement.

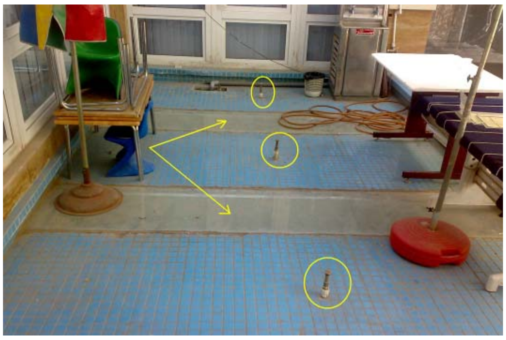


Figure 4-12 Water pool in Tehran green office

Source: A. Rastgar, 2008

4.2.2.2 Building envelop and insulation

A 10 cm thick layer of polystyrene insulation was applied for all walls, which was twice as much as requirement of national building code. The U-value proposed by the building code was 0.7 W/m²K while the achieved U-value by using doubled thickness of insulation was 0.3 W/m²K. This led to an additional cost of 20% compared to the proposed thickness by national building code since the main portion of insulation cost is installation cost (O. Saberi, Personal communication, August5, 2008). All external windows and doors are equipped with thermal break Aluminum profiles and double pane glazing. An overall reduction of 75% in heat loss from the building envelop in comparison with a conventional building was predicted (Saberi et al., 2006).

4.2.2.3 Passive cooling and ventilation

The proposed strategy to provide the building with passive cooling and ventilation included two passive evaporative systems: 1) passive downdraught evaporative cooling tower (PDEC) for the first and second floors of the northern part of the building, and 2) a wall integrated porous ceramic evaporative cooling system for the ground floor offices in the northern and southern parts of the building (Ford & Schiano-phan, 2004), (See Figure 4-13). The basic principles of evaporative cooling and natural ventilation methods were explained in chapter 2 (Section 2.1.5 through 2.1.7).The main concept of this cooling system is based on wind catcher's functioning principles described in chapter 3 (Section3.4). The mechanism of designed PDEC system is as follows.

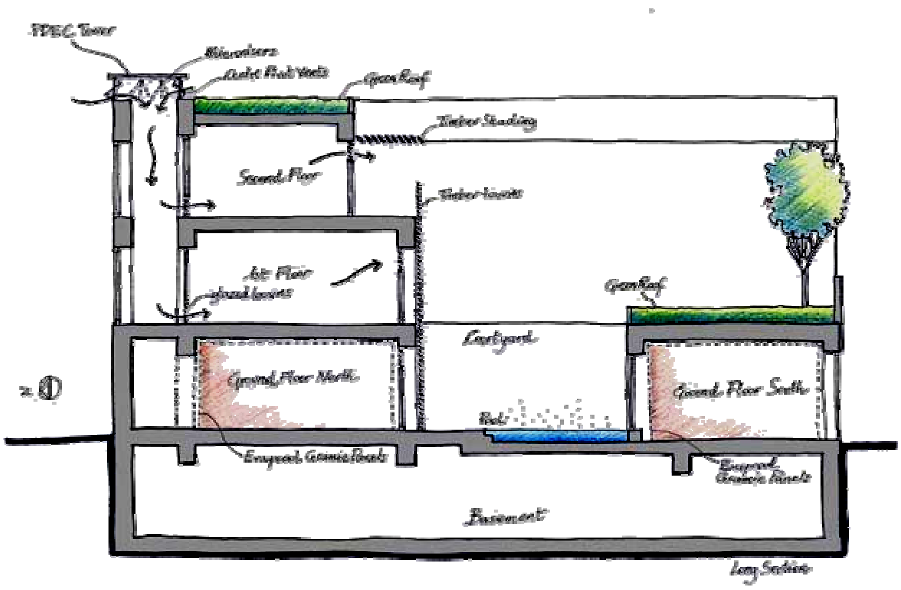


Figure 4-13 Summer mode of wind catcher designed for Tehran Green Office

Source: Ford& Schiano-phan, 2004

During summer, the ambient air entered the wind catcher from the upper part of the tower is cooled by spraying water. This cool air is delivered into the rooms through the openings located near the ground level. The warm and foul indoor air is vented through openings located at the high level on the south facing walls. In winter, the wind catcher functions as a chimney to provide ventilation (See Figure 4-14). According to the design, fresh air enters the building through south facing openings and indoor unclean air will be vented by the stack ventilation through the tower operating as a chimney. The amount of fresh air entering the rooms will be minimized by adjusting the perimeter louvers in order to reduce the heat loss. As mentioned before, this building was not constructed according to design. Elimination of PDEC system was one of the main deviations from designed cooling strategy during construction stage. Tower has been blocked at its upper level and on the second floor. The two blocked surfaces are shown in Figure 4-14 by red strips.

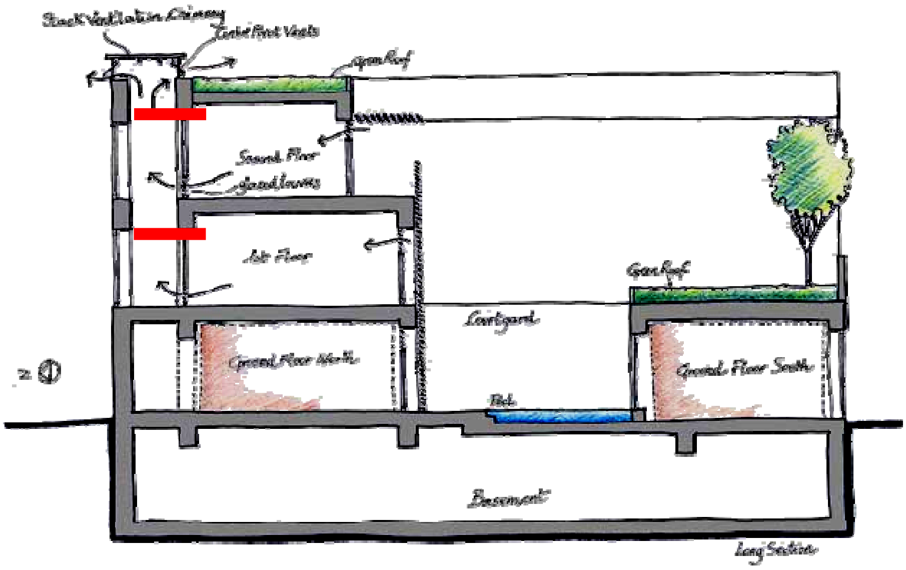


Figure 4-14 Winter mode of wind catcher designed for Tehran Green Office

Source: Saberi et al., 2006(Modified)

The passive cooling system designed to cool ground floors in both north and south offices was a new direct evaporative cooling system based on porous ceramic evaporators. This cooling system was the subject of a research project funded by the European Commission under the title of EVAPCOOL[7]. According to primary assessments results, the proposed EVAPCOOL system would meet 85% of the cooling load of the building. This means for 15% of the time, the threshold temperature of 26˚C would be exceeded. The annual saving in cooling energy demand was predicted at 32-42 kWh/m2 while the estimated water consumption of the system was nearly 12.3m^3/year i.e. 5 liters per person per day (EVAPCOOL, 2003).

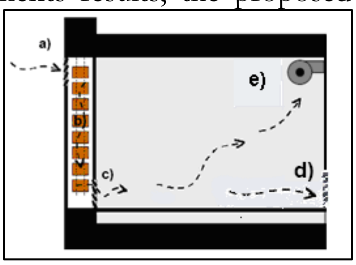


Figure 4-15 EVAPCOOL system
Source: Ford& Schiano-phan, 2004 (Modified)

---

[7] FP5 Programme Acronym: *EESD* Project Reference: ENK6-CT-2000-00346

The system integrates thin porous ceramic evaporators into the building envelop by means of a perimeter cavity wall. For the ground floor of the north office, the design strategy included ceramic panels with thicknesses of 35mm installed in rows adjacent to a 450-500mm thick structural concrete column in the west exterior wall. As shown in Figure 4-15 the ambient air enters the cavity wall through an opening at high level on the exterior wall (a). This air is cooled by flowing through the wetted ceramic evaporators causing an increase in its density and consequently a downward flow (b); afterwards it enters the internal spaces through dampers located near to the ground level (c). The warm indoor air will leave the room via an opening located on the opposite wall near the floor level (d). During hot days in summer, thermal comfort can be achieved by means of small electric fans installed near to the roof level on the opposite wall to create a forced flow of indoor air to the outside(e).

During winter, the water on ceramic panels would be drained with the purpose of using the wall as a chimney to vent out the foul indoor air. The inlet and outlet air openings would be adjusted to minimize the flow of fresh air into the room and the unclean air out of the room in order to reduce the related heat loss. Similar strategies for cooling in summer and ventilation in winter were considered in the south office with the exception of the air suction opening that was designed on the inward side of the green roof to benefit from the fresh air from planted area on the roof (See Figure 4-16)

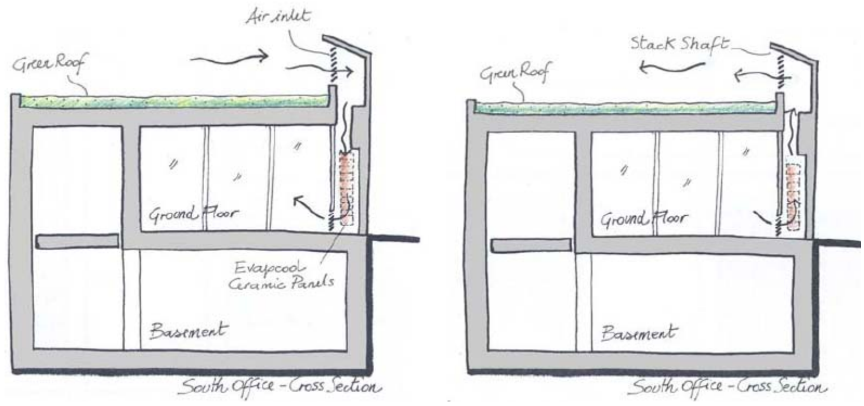


Figure 4-16 Summer cooling (right) and winter ventilation (left) system for Tehran Green Office

Source: Ford& Schiano-phan, 2004

However, in construction stage, Cavity walls were built by bricks with places for installation of ceramic pots. Water supply system for wetting the walls was also made and the walls were equipped with glass doors to facilitate maintenance operations. The pots were decided to be full of water and thus function as a part of evaporative cooling system. As shown in Figure 4-17, there is no pot installed on the wall (labeled by number 2).

Figure 4-17 Current cooling system in Tehran green office
Source: A. Rastgar, 2008

The passive cooling system is replaced by split air conditioners (labeled by number 1), which use grid electricity. Openings installed to deliver cool air from wetted wall into the room are labeled by number 3 in Figure 4-17.

4.2.2.4 Heating

Heating energy demand in this building is partially supplied by solar radiation gained from south facing glazed areas. The main designed heating system included solar collectors combined with under floor heating system. Heating demand in the internal spaces is supplied by warm water flowing in under floor piping system. Solar collectors were designed to supply energy required to heat water flowing in the pipes. A supplementary natural gas fired boiler was designed to provide warm water during cold winter days. However, as shown in figure4-18 solar collectors have not been installed and thus all the energy required for heating is supplied by natural gas.

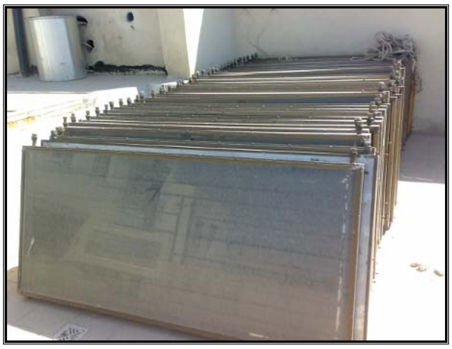


Figure 4-18 Unused solar collectors on the roof
Source: A. Rastgar, 2008

The two described cases were examples of governmental projects on energy efficient buildings. The next case is the illustration of individual attempts to improve energy efficiency in residential building by available and affordable techniques.

4.2.3 Case study 3: Ayatollahi house

The building was designed by Professor Ayatollahi as his private house and was constructed in Yazd, Iran (Ayatollahi, 2008). This house was constructed in 2000 in accordance with the energy efficient design strategies and elements that will be discussed subsequently (See Figure 4-19).

Figure 4-19 South-East view of Ayatollahi house
Source: Ayatollahi, 2008

The city, famous for its traditional wind catchers, is located in the hot arid climatic zone in the central plateau of Iran (See Figure 4-1) at 31˚54'North latitude, 1237.2m above sea level. In 2008, a minimum air temperature of -4.7˚C was reported in January while a maximum air temperature of 40.7˚C was reported in July (Yazd Meteorological Organization, 2008). This wide range of annual temperature requires accurate design of efficient heating and cooling systems considering thermal comfort in buildings. The main design target was to integrate traditional climatic design concepts into a new building and to decline heating and cooling energy demands. According to the designer, any energy audit or exact performance evaluation has not been conducted yet. Nonetheless, In comparison to a conventional house, reductions of 44% in heating demand, 48% in cooling demand and 20% in water consumption were calculated by conducting a survey on similar conventional houses in neighboring area in the city (Ayatollahi, 2008). The following elements and strategies have been used to improve energy efficiency at the same time as thermal comfort in the house.

4.2.3.1 Building form

Living room, sitting room, kitchen, and facilities covering an overall floor area of 138m² are located on the first floor of the house. The house also includes a courtyard with an area of 150m² and a 50m² area backyard (See Figure 4-20). Three bedrooms and two terraces positioned on the second floor have an area of 112m². The basement, which has an area of 50m² includes a multipurpose room and a storeroom (Ayatollahi, 2008). The open internal spaces enhance cooling, heating and ventilation efficiencies due to adequate heat transfer and air circulation (See Figure 4-21).

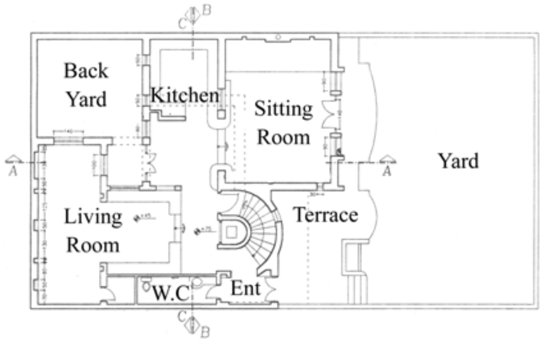


Figure 4-20 First floor plan
Source: Ayatollahi, 2008

Figure 4-21 North view of the interior
Source: Ayatollahi, 2008

4.2.3.2 Trombe wall

In general, a Trombe wall is a south facing concrete, brick or masonry wall covered by a glazed surface while a few inches gap is between the wall and the glass. As shown in Figure 4-22, the wall absorbs the heat from solar radiation through glazed surface. The stored heat will be slowly transferred into the internal spaces of the building some hours later (Gan, 2008; Comfortable Low Energy Architecture, 2008).

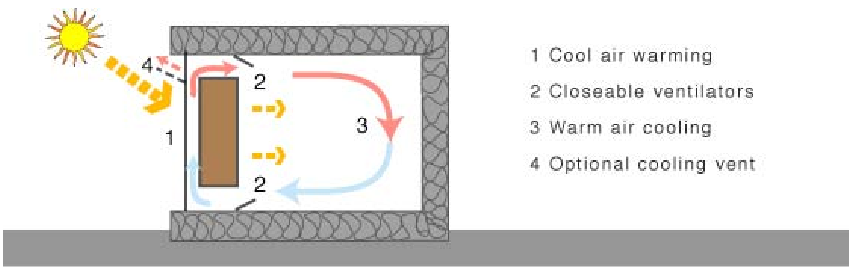


Figure 4-22 passive solar heating by a typical Trombe wall
Source: www.greenspec.co.uk, 2008

Ayatollahi house is oriented towards Southeast direction due to urban planning limitation. Two Trombe walls with a total glazed area of 10m² provide the passive solar heating (See Figure 4-23). The walls are coated by steel sheets painted by black color with a thickness of approximately 2mm as a heat absorption layer to improve heat transfer to the Trombe walls. Each wall has two openings, the lower one is located near the floor and the higher one is located near the roof. There is a 15cm gap between the coated walls and glazed surfaces; the glazed surfaces are equipped with openings at their highest levels.

Figure 4-23 South-East façade of Ayatollahi house
Source: Ayatollahi, 2008 (Modified)

In winter, the two openings on each wall are opened while the opening on each glazed surface is closed. The portion of indoor air with lower temperature and higher density, placed near the floor level, leaves the room from the lower opening on the Trombe wall and enters the space between the wall and the glass. The temperature of this air will increase by the heat of solar radiation on the glazed surface. The air flows up due to higher temperature and lower density and then enters the room through the upper opening on the Trombe wall. During summer, the lower openings on the Trombe walls are closed while the upper ones together with the openings on the glazed surfaces are opened and used for ventilation purpose. (S.M.H. Ayatollahi, Personal communication, June 17, 2008). The openings of one Trombe wall are shown by arrows in Figure 4-24.

Figure 4-24 Openings and shading in sitting room
Source: Ayatollahi, 2008 (Modified)

4.2.3.3 Heating

An additional South-West facing glazed area of 20m² together with previously described Trombe walls provide the building with passive heating. However, due to higher amount of heating energy demand in the building, a gas heater in the basement, a fireplace and a gas heater on the first floor were installed to supply required heat during winter. Nevertheless, only one of the heaters is used most of the wintertime. A vertical duct equipped with two fans, one at the basement level and the other one on the second floor transfers the heat generated in the basement into the bedrooms on the second floor. Fireplace chimney has a double wall structure to recover heat from flue gas and provide the interior space with warm air trough two openings shown in Figure 4-24 by circles. The house showed 44% reduction in heating demand compared to conventional buildings (Ayatollahi, 2008).

4.2.3.4 Natural ventilation and evaporative passive cooling system

A $50m^2$ backyard with high walls was designed to minimize heat gain from the external environment and to play a part in natural ventilation and passive cooling during summer. Natural ventilation provided by opening north and south facing windows during summer evenings and nights. The cool air movement through thermal mass of the building causes the stored heat move out of the walls and consequently a decrease in cooling demand for the next day (Ayatollahi, 2008).

Figure 4-25 Water pool for evaporative cooling
Source: Ayatollahi, 2008

Evaporative cooling system includes a small water pool located at the basement level in the backyard (See Figure 4-25). In addition, the system includes a canal and a fan connected to a vertical duct to create forced flow of cooled air into the first and second floor spaces (See Figure4-26). As previously mentioned, this duct is used to heat generated by the gas heater in the basement to upper floors during winter. It should be noted that the passive cooling system is not sufficient to provide thermal comfort for the dwellers hence two electrical evaporative coolers running with grid electricity have been installed.

Figure 4-26 Canal and fan for cool air flow
Source: Ayatollahi, 2008

4.2.3.5 Shading

Windows are equipped with shadings from both inside and outside while the inhabitants properly benefit from daylight penetrating the internal spaces through the openings located near the roof level (See Figure 4-24). These openings are also the main elements of the passive cooling and natural ventilation system. As shown in Figure 4-25, water pool was exposed to solar radiation during some hours per day that made the owner to undertake more shading solutions. As a result, vine trees have been planted in the backyard to make a pergola, which provides adequate shading during summer.

4.2.3.6 Water heater

For the period of last March to early October, required hot water is supplied by a simple black water tank placed in a double glazed box (See Figure 4-27). Therefore, the gas fired water heater installed in the house is not used during summer that eliminates a potential source of heat from inside space and consequently reduces the cooling energy demand in the building. During rest of the year, this tank is used to preheat the input water into the gas fired water heater in order to reduce natural gas consumption in the building.

Figure 4-27 Black water tank in a double pane glass box
Source: Ayatollahi, 2008

In a nutshell, the main approach adopted by Iranian architects is climatic design while a variety of passive design strategies, traditional architecture elements and innovative energy efficient components have been used in the mentioned projects. South directed orientation, shading, insulation, thermal mass, evaporative passive cooling, Trombe walls, solar heating systems and natural lighting were the main proposed and or used means to enhance energy efficiency in explained examples. These examples will be further discussed in chapter 5; the next parts of this chapter are an introduction of energy efficiency in Israeli buildings and description of three case studies from Israel.

4.3 Israel and energy efficiency in buildings

4.3.1 Geography and climate of Israel

Israel, located in the Middle East, has a total area of 22,145 km² and a population about 7.1 million. The country is bordered by Lebanon, Syria, Jordan, Egypt and the Mediterranean Sea (See Figure 4-28). Israel can be divided into four main climatic regions:

- Hot, humid summers and mild, wet winters on the coastal plain
- Dry, warm summers and moderately cold winters, with rain and occasional light snow, in the hill regions
- Hot, dry summers and pleasant winters in the Jordan Valley
- Semi-arid conditions, with warm to hot days and cool nights, in the south (Israel Ministry of Foreign Affairs, 2008)

Figure 4-28 Map of Israel

Source: www.theodora.com, 2008

4.3.2 Energy consumption in Israel and its building sector

Israel energy supply is based on imported fuels; with a total final energy consumption of 13.2 million tons of oil equivalents (Mtoe) in 2005 and a predicted rise to 48 Mtoe in 2025. This showed a growth of 44% compared to 1991(See Figure 4-29). This is a considerable escalation in comparison with an only 15% increase in the average per capita energy consumption in the EU at the same period. (Mor & Seroussi, 2007).

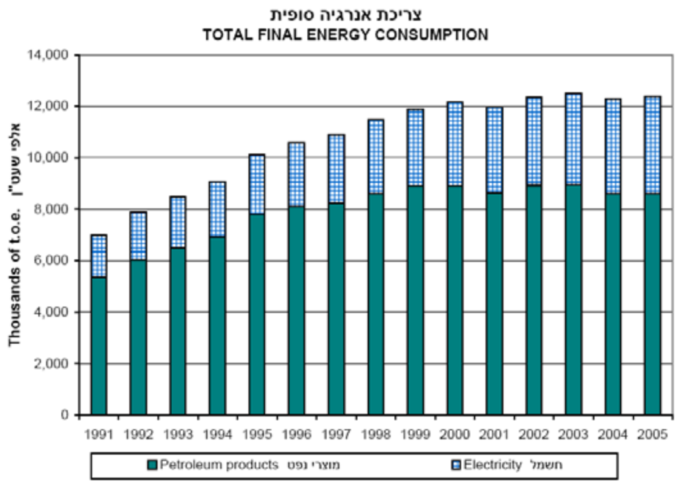


Figure 4-29 Israel final energy consumption 1991-2005

Source: Israel Central Bureau of Statistics, 2008

The household sector accounts for 30% of final energy consumption in Israel. In 2004, the electricity consumption in building sector was 13,795 GWh, which represented a growth of 4.45% compared to 2003 (Vaturi & Hirsch, 2006). In 2004, the average price of electricity for household sector was reported at 0.077 €/ kWh while it was 0.071 €/ kWh for trade and services sector (Vaturi, 2006).

4.3.3 Environment and emission

The energy demand in Israel is supplied mainly by oil (60.9%) and coal (36.2%) while with recently significant offshore natural gas discovery, it is predicted that natural gas will supply 25% of the country's energy demand by 2025 (Vaturi, 2006). Israeli residential and commercial sectors consume almost 55% of total generated electricity and account for about 30% of total Co_2 emissions (Mor & Seroussi, 2007).

4.3.4 Adopted policies to improve energy efficiency in buildings

Several regulations and standards regarding energy conservation in buildings have been set such as energy efficiency of air conditioners and refrigerators, and thermal insulation standard. In 1980, a regulation published on mandatory use of solar water heaters in every new residential building with less then 27m height. This regulation was a key factor in growing the installed solar collectors to an annual capacity of 280 MW. Afterwards, two standards on solar collectors and solar storage tanks were published by the Standard Institution of Israel (SII). Selling and using the solar collectors and storage tanks without SII standard mark is forbidden in Israel (Vaturi, 2006).

The Israel's green building standard 5281 was approved as a voluntary standard in 2005. The standard includes five parts (Nelin, 2007): energy, land, water and waste water, other environmental subjects and general assessment with a maximum score allocated to each one while some points are determined as threshold conditions that represent the minimum requirements of each chapter. New or renovated residential and office buildings can be labeled as "green building" by achieving a total score of 55-75 points. An overall score of more than 75 points leads to certification as an "outstanding green building"

The energy chapter has 29 points which of 14 are the threshold condition. This chapter covers the most points and thus has the most weight amongst all chapters. Thermal comfort is the key factor in this chapter, which should be determined for each specific site, season as well as inhabitants' age, gender and activities. The buildings that provide the required level of thermal comfort without energy consumption from external sources can achieve full accreditation whereas buildings consuming external energy supplies would be assessed on orientation, insulation, natural light and passive techniques, for cooling, heating and ventilation.

In addition, for the period of preparing the energy chapter concerning the significance of energy issue in the general framework of green building, it was decided to prepare a standard on the energy rating of residential buildings. As a result, the Israel Standard 5282 was approved by the Standards Institution of Israel in 2005. To comply with the energy chapter of standard 5281, it is necessary to accomplish some of the requirements of Standard 5282, particularly regarding insulation and windows (Israel Ministry of Environmental Protection, 2008).

4.3.5 Energy efficient products for Israeli buildings

There are several products used in energy efficient buildings produced in Israel, including efficient air conditioning and ventilation systems, solar water heating systems, efficient lighting systems, insulation materials and double glazing, shading devices, skylight systems, computers, refrigerators and building energy management systems(BEMS). Moreover, photovoltaic and related systems as well as several kinds of the above-mentioned products are imported from Europe, US, South America, China and Taiwan (Vaturi & Hirsch, 2006).

Although, advanced technologies are available in Israel's market, utilizing of them by local construction sector is very limited. Some of these new technologies are exported to Europe and North America. As it is mentioned previously, the new green building standard is voluntary and the regulations and standards regarding energy efficiency in buildings are limited. Furthermore, building owners are generally unaware about these products and constructors do not use them due to their additional costs (Vaturi & Hirsch, 2006). An Israeli innovative technology for producing energy efficient windows is explained in the following and illustrated in Figure 4-30.

4.3.5.1 A novel ventilated reversible glazing system

The main function of glazed windows are to allow sunlight enter the building and provide a view to outside. A considerable proportion of heating demand can be provided by sunlight radiation through properly designed windows. However, uncontrolled solar radiation through glazed openings may cause thermal discomfort, visual discomfort due to glare and deterioration of furnishings such as fading of fabrics and degradation of plastics (Etzion & Erell, 2000). A novel glazing system was designed at Ben-Gurion University of Negev, Israel in order to overcome the mentioned drawbacks. The new glazing system include a reversible frame holding two glazing components: an absorptive glazing with a low shading coefficient to provide solar control and a clear or transparent glazing to provide weatherproof seal (See Figure 4-30). The two glazing components and the ventilated channel between them can rotate through 180˚ to change from summer mode to winter mode and vice versa.

The system's thermal and aerodynamic behavior in different glazing types and geometries and environmental conditions was modeled through cooperation between Universities and research centers from Israel, Sweden, Spain, Portugal and Germany during SOLVENT project since 2000 to 2002 funded by European commission. The tested prototype showed a thermal conductivity (U-value) of 1.1 W/m^2K in both winter and summer modes. The solar transmittance (g) of the prototype was 0.68 while rotating the window to the summer mode decreased that amount to 0.36 (Erell, et al., 2004).

A recent study showed a reduction of 27% in primary energy use for heating, cooling and lighting by this window compared to a double clear glazing window and 8% compared to a double glazed solar control window (Leal & Maldonado, 2008). This window has been produced and put on the market by an Israeli producer company (Alubin located in Kiryat Bialik, Israel) since April 2008 (Y. Etzion, Personal communication, July1, 2008). The company has named the window as "Seasons window" and is seeking for the demand for it (M. Segal, Personal communication, July4 & 21, 2008).

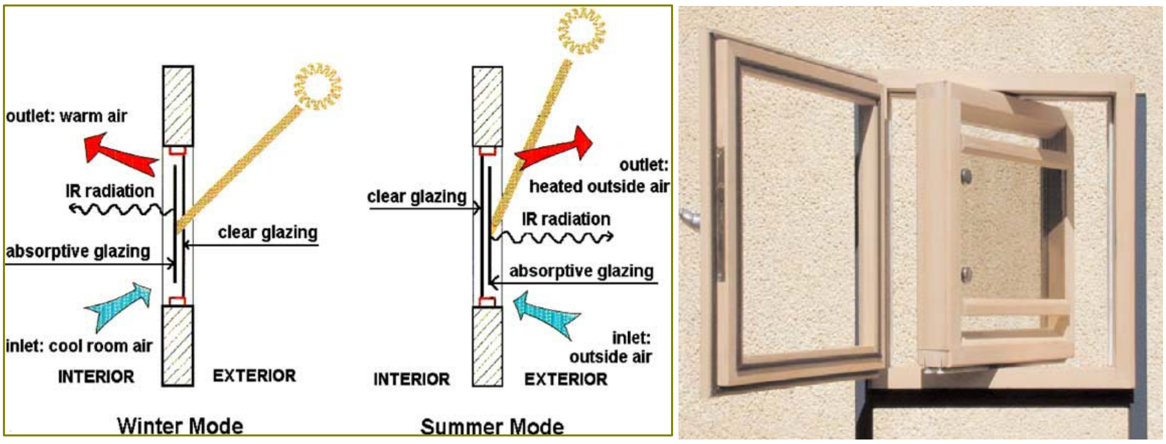


Figure 4-30 Seasons window and solar radiation and air ventilation patterns through it
Source: Etzion & Erell, 2000

4.4 Energy efficient buildings in Israel

Until now, several demonstration projects with different approaches such as bioclimatic design and green buildings have been implemented in the country (Vaturi, 2006) for instance:

- The Blaustein International Cenetr for Desrt Studies
- The Neve-Zin desert solar neighborhood (79 lots)
- The Adobe desert house
- The Zuckerman Community Center at Sede-Boqer Campus
- The Netivot Kindergarten
- The Sammar public library
- The Sakhnin Research and Education Center
- The new Yitzak Rabin building at the Technion Univrsity

On the other hand, a few projects were stopped in design stage. The Yaffo experimental building is a case in point. The project, which was a joint venture between the Ministry of National Infrastructure and the Ministry of Construction and Housing, was designed by the architects in Blaustein Institute for Desert Research at Ben-Gurion University of the Negev. The project was discontinued at the stage of detailed design that might be due to deviation of design from what developers accept as the standard type of building. This experience was a reason to adopt a different design strategy in Ramot residential neighborhood project in northeast of Be'er Sheva, Israel. The project involves nearly 840 housing unit located in the neighborhood consist of approximately 17,000 housing units. In this project, designers' effort was focused on designing building prototypes that would be accepted by developers while contain solar and wind access as much as possible. The project is in final design stage called "Master plan for implementation" by the Israeli Ministry of Construction and Housing (I.A. Meir, Personall communication, July3, 2008). During this research, three implemented energy efficient building projects was reviewed as the case studies from Israel, which will be described subsequently.

4.4.1 Case study 4: Meir house, a bioclimatic desert house

The Meir house was built during 1992-1994 in the Neve-Zin neighbourhood of the Sede-Boqer Campus of Ben Gurion University of Negev, the first bioclimatic/solar neighborhood in Israel (Meir, 1998). This neighborhood including 79 lots was designed in the mid-1980s by Desert Architecture and Urban Planning Unit (DAUP) for the Ministry of Housing (Vainer & Meir, 2005). The Meir house was designed by Professor Issac Meir as his private house. The main design strategy was to adapt the building with local climatic condition to provide thermal comfort for inhabitants while lowering the environmental impacts of the building. Therefore, local climate information was a key element in design process.

4.4.1.1 The climate of Negev

Sede-Boqer campus is at 30.8˚ north latitude and situated 500m above sea level. The average annual precipitation is 80mm. The climate of the region is hot and dry; at the time of designing the project, the region had an average maximum temperature of 32˚C, average temperature of 24˚C and an ambient relative humidity of 20%-40% during summer days. However, relative humidity on occasion was 90% during night when the ambient temperature dropped sharply. Maximum solar radiation was 7.7kWh/m^{2}day on a horizontal surface during June and July. Winter had a mean temperature of 10˚C and an average minimum daily temperature of 3˚C in January. During winter nights, the temperature was occasionally bellowing 0˚C. Maximum solar radiation on a horizontal surface was 3.3kWh/m^{2}day and about 4.6kWh/m^{2}day on a south-facing vertical surface (Etzion, 1994). Winds speeds were 30 km/h in summer and 40km/h in winter. During night hours and in the early morning wind direction was between north- east and southeast while in the rest of the day wind blew in north and north-west directions (Meir, 1998).

The region has experienced a climate change as shorter and colder winters, higher temperature and higher relative humidity in summer (I.A. Meir, Personal communication, June30, 2008). The last reported climate information from Sede-Boqer meteorological station represents a lowest minimum air temperature of -3.6˚C in January (with recent minima reaching -5C over four consecutive nights in January 2008), while a highest maximum air temperature of about 40˚C was reported in May, June, July, August and September. Minimum Mean relative humidity at 12 GMT was 28% in May and maximum mean relative humidity at 6 GMT was 77% during January. Annual mean rainfall was 99.2 mm (Israel Meteorological Service (IMS), 2007). This means some changes are required in new designs, which will be pointed out in the next sections. The following design elements and technical solutions were utilized with regard to local climatic condition at the time.

4.4.1.2 Building Characteristics

The building is a single-family detached house extended along east-west axes and directed towards south orientation (See Figure 4-31). The ground floor includes four bedrooms, kitchen, living and dining spaces, facilities and storage with an overall area of approximately 150m². A 37m² library and study space is built on an internal balcony over the living room. Living room is situated between children's rooms and facilities at the eastern end of the building and master bedroom, bath and closet, kitchen and dining room in the western end.

Figure 4-31 South view of Meir house
Source: I.A. Meir, 1998

Taking into account the climatic conditions such as ambient air temperatures, solar angles and wind directions, it was decided to locate living room and all bedrooms at the southern part while the kitchen, baths and laundry room were considered to act as buffers at the northern part of the plan. In order to achieve appropriate ventilation, all rooms are equipped with windows in two directions. All the spaces were designed as an integrated thermal zone except the 20 m² garage near the west side of the building which acts as a buffer on the western wing (Meir, 1998).

Two south and north verandas, and a southeast oriented balcony were designed. The southern veranda is open to the garden and protected by the building mass on the north side and the garden wall on the west side. This veranda facilitates solar radiation exposure and protects the house from wind during winter. A pergola with movable fabric shadings enhances thermal comfort in summer. The northern veranda is protected by the building mass on its west and east sides; this veranda is partly covered by the second story and thus shaded partly or entirely during summer. The building is protected against hot summer wind by adjacent buildings and vegetation. Southeastern breezes make the southeastern balcony suitable for hot summer nights (Meir, 1998).

4.4.1.3 Thermal mass

To provide thermal comfort and energy efficiency in building it is necessary to utilize a thermal mass in hot arid climate due to wide range of temperature fluctuations during day and night. As a result, the walls were built of 25 cm thick cellular concrete blocks with a specific weight of 650 kg/m³ and 0.2 watt/m˚C conductivity (Meir, 1998). This thermal mass provides thermal comfort regarding wide range of temperature fluctuations in a desert climate and reduces heating and cooling energy demands. According to performance test results, this medium weight material did not significantly decrease the thermal performance of the building. Floors at the ground level were made of reinforced concrete poured over cardboard moulds to prevent mechanical problems resulted from swelling soil and corrosions due to high salinity of the local soil. Roofs were made of cast reinforced concrete and internal partitions were made by hollow concrete blocks. Poured concrete was used to build staircase and structural elements.

4.4.1.4 Insulation

A 5 cm thick insulation layer made of cellular concrete blocks was utilized to insulate the thermal bridges. Roofs were covered by extruded polystyrene, aerated slopes cement and waterproofing insulation layers. The overall insulation value[8] of the roof insulating layers was 2.22m^2°C/Watt. To avoid corrosion caused by high salinity of local soil and mechanical problems stemmed from swelling soils, floors were made suspended by pouring concrete over cardboard moulds (Meir, 1998). This method is common in making floors in desert regions in Iran as well. According to the designer, the thermal mass and insulation should be reassessed due to local climate change.

4.4.1.5 Fenestration

Aluminum frames were utilized because climatic conditions and termites made it impactical to use wooden frames. Double-glazing applied in order to avoid undesirable noise from adjacent high school dormitory. Utilizing metal mesh screens to prevent entering insects into the house was unavoidable. All glazing areas were equipped with internal Venetian blinds and external shutters made by aluminum louvers filled with polyurethane as an efficient thermal and noise insulator (Meir, 1998); (See Figure 4-32).

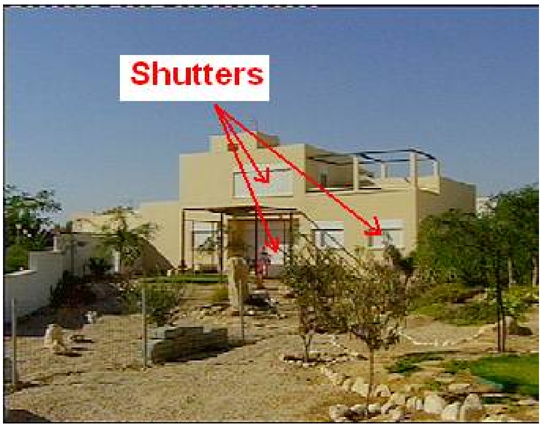


Figure 4-32 External shutters in Meir house
Source: I.A. Meir, 1998 (Modified)

4.4.1.6 Finish materials

Exterior walls were painted by a latex-based paint in order to avoid cracking which is common in cement stucco coating layers in such climates. An ochre color with an estimated absorptivity factor of 0.4 was selected to minimize glare in adjacent spaces and to prevent undesirable change in the appearance of the building due to dust absorption on its external surface. Roof waterproofing layers were selected with a reflective coating and internal walls were whitewashed to enhance light intensity in the house. Light colored terrazzo tiles were applied to pave the balconies while in order to increase heat absorption by floors indoors, these were paved with terra cotta tiles (Meir, 1998).

4.4.1.7 Ventilation

During cool summer nights, cross ventilation is possible through north and south facing windows. Different levels of windows enable tenants to benefit from cross, suction and stack natural ventilation. Mesh screens decrease wind speed by 20-25% and limit ventilation

---

[8] Insulation level is specified by R-Value. R-Value is a measure of insulation's ability to resist heat traveling through it. The higher R-Value means the better thermal performance of the insulation (www.energystar.gov, 2008).

performance whereas they are necessary to prevent insects enter the house. Installing a ceiling fan over the two-story living room enhances the ventilation rate and makes it possible to shut the windows in the afternoon when ambient temperature is higher than desired. Ground floor shutters should be closed during summer nights to protect the inhabitants against snakes, scorpions and other reptiles and mammals and for security reasons; this affects natural night ventilation efficiency (Meir, 1998).

4.4.1.8 Heating

A total south oriented glazing area of 24 m² which constitutes about 30% of the south façade as well as a 8m² east facing windows area are the primary sources for heating purpose. Deeper parts of the building gain solar radiations through high-level located windows. Closing shutters during winter nights decreases heat losses from windows (Meir, 1998).

Figure 4-33 Meir house in winter
Source: I.A. Meir, 1998

For a period of 2-3 years, a collapsible greenhouse was utilized on the roof aiming at increasing the indoor air temperatures in winters. The green house was equipped with a thermostat that turned a fan on when the air temperature in greenhouse rose above 22˚C. The fan blew the warm air into the northern parts of the house, which were not heated by solar gains. Greenhouse air temperature yielded a maximum of approximately 35˚C during sunny winter days. However, was neglected since was a prototype without proper construction and installation in winter and dismantling in summer was inconvenient (I.A. Meir, Personal communication, June30, 2008).

4.4.1.9 Solar water heater

A solar collector with a capacity of 7,000 kcal and a 150 l water tank with electrically backed up heater were installed on the roof of the building. More than 80% of the residential buildings in the country use solar water heaters (Vaturi & Hirsch, 2006). As mentioned before, installation of domestic hot water systems in new residential buildings less than 27m height has been mandatory in Israel since 1980.

4.4.2 Case study 5: Intel Green building

Intel corporation decided to design and construct a new building for its research and development department in Israel at the aim of increasing productivity, reducing energy and maintenance costs of the building and enhancing employees' satisfaction and health by using Green Building concept. The Intel green building located in Haifa, Israel, was designed in comply with LEED certification program described in chapter 2 (Section 2.3). According to Israel meteorological service, the air temperature in Haifa ranges between a minimum of 0.7˚C in January and a maximum of 42˚C reported in April, May and June. The maximum mean relative humidity at 6:00 GMT is 71% in January and the minimum mean relative humidity at 12 GMT is 49% in November. Therefore, energy is required to provide both heating and cooling demands in buildings (IMS, 2007). The building has five underground and six aboveground floors. The objectives of the design process were:

- to consider a location and plan with minimum environmental impacts
- to reduce energy and water consumption
- to utilize environmentally friendly materials in the building
- to follow waste management strategies
- to provide a high quality indoor environment

Figure 4-34 Intel green building simulation image
Source: D. Hershgal, 2008

4.4.2.1 Energy consumption and costs

The total designed annual energy demand in the building was calculated as 7,371,630 kWh (508.9kWh/m^2), which presented a 15.3% reduction referenced to ASHRAE standard 90.1 baseline building[9] (Hershgal, Personal communication, Aug.8, 2008). A reasonable additional cost was required for third-party audits, documentation and communication between the LEED Accredited Professional consultant and design consultants. Certification fee was estimated as $12,500 based on the building size. The premium construction costs were estimated less than $600,000 which most of are due to improvements in energy saving and indoor environment quality (See Figure 4-35). These costs were estimated to save more than $200,000 annually. The estimated return of investment (ROI) related to the operational costs is nearly five years.

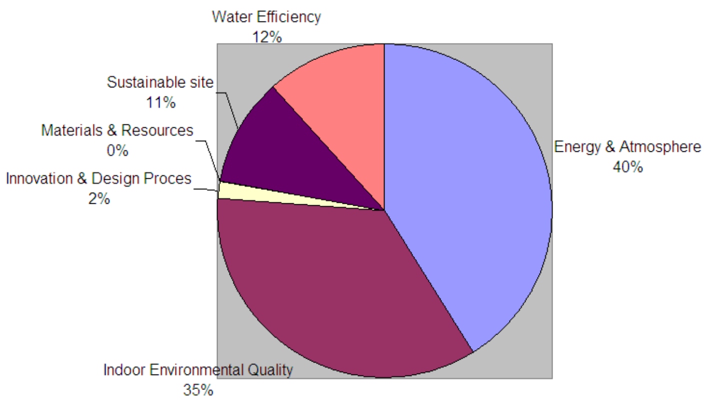
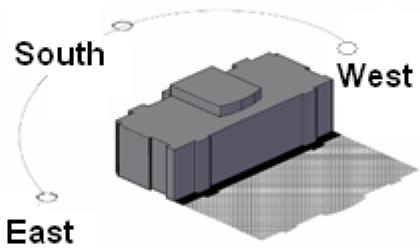


Figure 4-35 Premium cost distribution of the project

Source: Hershgal et al., 2008

4.4.2.2 The building site and orientation

The building site, which used to be a parking lot, is located near a main transportation station with a train station, a city bus station and a central bus station, which facilitates using public transportation by employees. As shown in Figure 4-36, the building is extended along the



---

[9] American Society of Heating, Refrigerating and Air-conditioning Engineers Energy standard for buildings

east-west axis while its orientation is directed towards the south.

Figure 4-36 Intel green building orientation
Source: D. Hershgal, 2008

This orientation strategy reduces the heating energy demand during winter as a result of solar gains. Solar angles are considered during design in order to control solar radiations during winter and summer.

4.4.2.3 Shadings and roof

The building envelop is structured with extended shading plates (See Figure 4-34). This strategy in combination with utilizing insulated cladding and roofing materials with high solar reflective index lead to a considerable reduction in cooling energy demand. In addition, all south, east, west facing openings are equipped with Venetian blinds. A typical wooden Venetian blind is shown in Figure 4-37; Vertical blinds are suitable for East/West facing windows while horizontal blinds are appropriate for North/South facing windows (Occupational Safety & Health Administration, 2003).

Figure 4-37 A typical Venetian blind
Source: www.terrysfabrics.co.uk, 2008

Moreover, the building will be covered by a green roof with low water consuming trees and shrubs (See Figure 4-38). Planting a green roof, using reflecting materials and shades as well as landscaping reduce heat islands[10] in the building surrounding area.

Figure 4-38 Green roof of Intel green building
Source: D. Hershgal, 2008

4.4.2.4 Glazing and natural day lighting

Low emissive double pane glazing filters day light and prevents heat transfer into the open space offices. In addition, internal laminated glass utilized to provide security and to control outside noise. Low-emissive coatings allow radiation to be absorbed but limit the emission of long wave infrared radiation back to the surroundings (Harris & Helwig, 2007). Internal reflective panels are utilized in South, East and West facing facades in order to maximize daylight gains (See Figure 4-39).

[10] The term "heat island" refers to urban air and surface temperatures that are higher than nearby rural areas. Heat islands form as cities replace natural land cover with pavement, buildings, and other infrastructure (U.S.EPA, 2008d)

Figure 4-39 Low emittance double pane glazing and internal reflective shelf
Source: D. Hershgal, 2008

In addition, two symmetric atriums increase daylight penetration into the building through three upper floors (See Figure 4-40). This strategy provides 75% of natural lighting in the building, which equals to 25 foot-candle (Hershgal, 2008). Adequate daylight and appropriate ventilation provide a high quality indoor environment.

Figure 4-40 inside and outside views of atrium in Intel green building
Source: D. Hershgal, 2008

4.4.2.5 Heat recovery

Heat from water- cooled condensers, which is a part of cooling system for equipment in Data Center,[11] is recovered to heat the building and preheat the domestic hot water supply to the kitchen and gym showers. Conventional fuel-powered boiler heating systems are not used in the building.

4.4.2.6 Development of the know-how

During the first year of operation, a measurement and verification plan will be carried out and the learned lessons will be used for other projects. Furthermore, a visitor center has been considered at the lobby of the building to raise the visitors and employees' awareness about sustainable construction and the building's features through interactive presentations.

---

[11] A data center is a place for computer systems and related components, such as telecommunications and storage systems.

4.4.3 Case study 6: Sakhnin green building

The green building project by the Towns Association for Environmental Quality (TAEQ) Agan Beit Natufa in Sakhnin, Israel ranked first amongst 31 projects submitted to Energy Efficiency in the Construction Sector in the Mediterranean (MED-ENEC) competition. The project is funded by the European Union in the framework of the MED-ENEC project. Located at a 100,000 m^2 ecological village in Sakhnin, this two-story building with a total floor area of 2,101m^2 is an education, research and demonstration center for green building technologies. The building with a stone structure and a traditional architecture style includes lecture halls, classrooms, laboratories, offices and public areas. Implementing individual projects on the green concepts of the building is one of the required parts of the curriculum offered by the center. Moreover, about 50,000 people visit the center annually (Israel Ministry of Environmental Protection, 2007).

Sakhnin, located in Galilee in the north of Israel, has a Mediterranean climate with a mean temperature of 26.2˚C during summer and a winter average temperature of 10.9˚C. The solar radiation is 1000-1100 W/m^2 in summer and 500-700 W/m^2 in January, the coldest month in winter. During summer, wind velocity is ranging 2.8-8.3m/sec while typical wind velocity is 7.1 m/sec in winter (R. Dwere, Personal communication, June 25, 2008). Therefore the building requires energy for both heating and cooling purposes. The achieved level of energy efficiency in the building and related costs were as the following.

4.4.3.1 Energy performance

The energy saving target has been achieved by the implementation of three levels of activities: first, several architectural elements such as building envelope, central courtyard, domed and vaulted roofs, shadings, fountain, etc. were used to enhance energy efficiency of the building. An energy saving of 50%-70% compared to conventional buildings was estimated to be achieved by implementing this stage. Secondly, some active renewable energy generating systems including PVs, solar heating system and wind turbine was considered to be utilized in order to minimize the need for grid electricity. PVs and wind turbines lead to an energy saving of about 26% (calculated based on light energy demand for a conventional reference building).

The electricity generated by renewable energy resources and grid electricity proposed as the auxiliary supply system would be consumed as low as possible by utilizing energy saving appliances and control instruments (R. Dwere, Personal communication, June 25, 2008). The energy saving attained by using wind-catchers and mashrabia was about 26% (calculated based on air conditioning energy demand for a conventional reference building). During 18 months monitoring, the building with an annual energy consumption of 68,000 kWh showed an overall energy saving of 72% in comparison with a conventional building. A pilot project with the aim of reducing the annual energy demands to 19,000 kWh is running which means an additional 72% reduction in the energy consumption (Israel Ministry of Environmental Protection, 2007).

4.4.3.2 Costs

Taking in to account the environmental principles concerning energy efficiency and water conservation has lowered the operation cost. Natural local building materials such as local stones, soil, straw and stabilized lime as well as recycled materials was utilized in constructing the building that led to a considerable reduction in construction costs.

Total cost of energy efficient were estimated as 102,505 €, which of approximately 30% was for PVs and wind turbines while less than 14% was for traditional elements (wind-catchers and mashrabia). Wind turbine and PVs have pay back periods of about 21-22 years. A pay back period of nearly 2-5 years is calculated for the additional energy saving appliances and instruments (R. Dwere, Personal communication, June 25, 2008). The applied energy efficient elements will be described in the following sections.

4.4.3.3 Central courtyard

The building incorporates courtyard (See Figure 4-41) as a main element of traditional architecture in the region, which was explained in chapter 3 (Section 3.4). Large central courtyard is a part of passive cooling system during summer. Night cold air from the courtyard enters the rooms through distributed corridors. In the morning, the doors to rooms facing the courtyard will be maintained closed to prevent the cool air from moving to the outside. In the afternoon, opening the doors causes the relatively cool air flow from the rooms to the outside and creating a gentle breeze. The central courtyard was planted in order to utilize shading and natural cooling effects in summer days. During winter the central courtyard will be used as a part of heating system as it will be covered by a polycarbonate cover.

Figure 4-41 Courtyard in Sakhnin green building
Source: MED-ENEC, 2008

4.4.3.4 Wind catchers

As described in chapter 3, wind catchers, called Malkaf in Arabic, have been utilized as a passive cooling system in the region for centuries. The building includes four wind catchers with different heights of 6m, 10m, 12m and 14m (R. Dwere, Personal communication, July29, 2008). Air enters the wind catchers from the upper openings, flows down and cooled by spraying water and subsequently flows into the building passing through the lower openings. (See Figure 4-42).

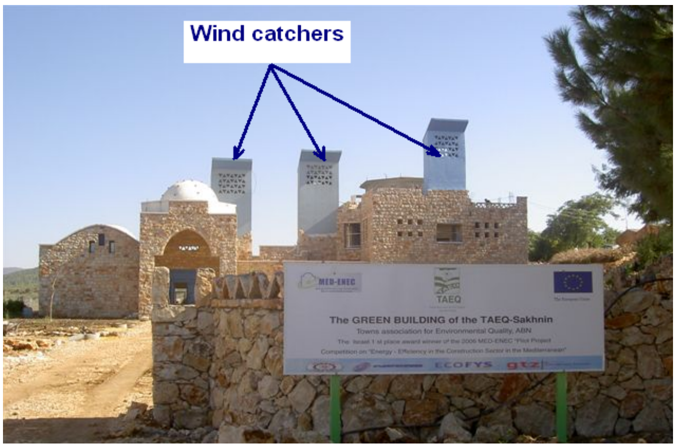


Figure 4-42 Wind-catchers in Sakhnin green building
Source: MED-ENEC, 2008

4.4.3.5 Domes, vaulted roofs and Natural lighting

Domes and vaulted roofs have been used as significant traditional architecture elements in warm climates of the Middle East (See Figure 4-43). The function of these types of roofs and their effect on lowering cooling demand in the buildings was previously described in Chapter

3 (Section 3.2). There are four windows arranged in pairs and facing each other at the base of the dome. Hot air in the building can be naturally suctioned to the bottom of the dome and vented through the windows.

Under the vaulted roof, the warm air flow occurs through the openings positioned on the far sides of the vault (See Figure 4-43). Dominated wind direction during the warm hours of the day is a key factor in designing vaults. In other words, wind blows into the building through the opening facing the wind direction and consequently the internal warm air, which accumulated bellow the roof leaves out from the openings on the opposite side of the vault.

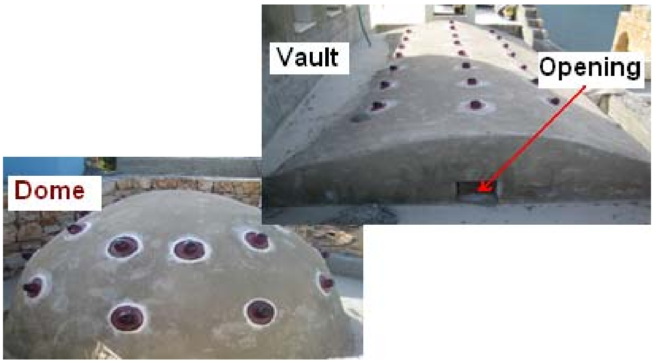


Figure 4-43 Dome and vaulted roof in Sakhnin green building
Source: R. Dwere, 2008 (Modified)

Moreover, natural lighting is supplied by a traditional architecture element described in chapter 3. Natural day light penetrates into the building through special openings positioned on the dome and vaults. The openings are glazed and thus more natural lighting can be provided by these bulbous glazed openings compared to flat glazed surfaces (See Figure 4-44).

Figure 4-44 Natural lighting
Source: R. Dwere, 2008 (Modified)

4.4.3.6 Multiple small Windows

Several small windows were considered instead of a few large ones in order to increase the speed of the moving air and consequently improving the efficiency of the natural cooling (See Figure 4-45). The other advantage of these multiple small windows is creating more shadows and thus reducing the amount of heat gains due to solar radiation during summer (Tarabeah, Dwere & Kimchie, 2005).

Figure 4-45 Small windows in Sakhnin green building
Source: MED-ENEC, 2008

4.4.3.7 Walls and insulation

The exterior walls are typically 60 cm thick including a 15cm thickness external layer made of local stone, a layer of silt and straw with a thickness of 30 cm and a 15 cm thick plastered stone as the internal layer (Tarabeah, Dwere & Kimchie, 2005). These thick walls serve as high heat transfer resistance insulation for the building which reduces the heating and cooling energy demands. Furthermore, they provide shading for windows and thus prevent overheating due to solar radiation during summer. The utilized plaster and concrete are made of local and recycled materials that result in a considerable reduction in construction costs of the building. In order to reduce both cooling and heating energy demands the arcs in central courtyard are glazed with double panes (See Figure 4-46).

Figure 4-46 Arcs with glazed surfaces
Source: www.amheschel.org, 2008

4.4.3.8 Heating

Heating energy demand for the building is supplied by electricity generated by PVs and wind turbines with a backup of grid electricity. Arrows in Figure 4-47 Show the installation of PVs on the (1) South facing wall of the wind catcher, (2) windows shadings and (3) roof. As mentioned before, the central courtyard will act as a part of heating system by means of a polycarbonate cover during the winter. This cover which includes special panels was designed considering the exact angles and direction to the sun in order to provide the courtyard with sufficient day light and solar radiated heat.

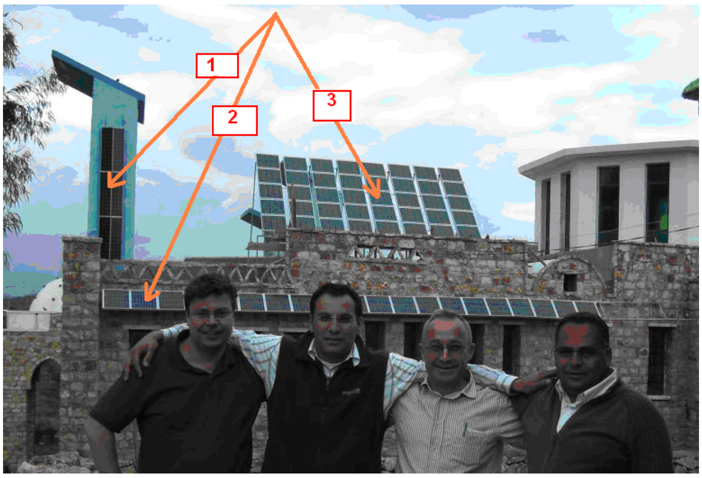


Figure 4-47 PVs installed in Sakhnin green building
Source: R. Dwere, 2008 (Modified)

Moreover, sufficient measures have been adopted to monitor and communicate the achievements of the project. The monitoring process is implemented in the framework of supported project and funded by the grants from Israeli Ministries of Environmental protection and Education as well as Israeli and foreign foundations. Monitoring process involves cooperation between TAEQ and other relevant institutions. The acquired results of monitoring activities is planned to be reported to supporting bodies and disseminated through

TAEQ's website[12]. At present (August, 2008) general information about this project is available on the MED-ENEC website[13].

To sum up, applied technical solutions include general passive design solutions such as orientation, shading, thermal mass and insulation; traditional elements such as wind-catchers and natural lighting elements; new technologies including PVs and wind turbines. Mandatory standard on using solar water heaters has been an effective driver to develop the use of this energy efficient system in Israeli buildings. Sakhnin green building showed the capability of the local construction sector in implementing energy efficient buildings projects. This case also revealed an achievable level of more than 70% saving in energy consumption compared to a conventional building. In addition, this case revealed the low cost of traditional elements such as wind-catchers and their considerable contribution in saving energy in comparison with new technologies. Intel green building is another example of the existing capacity to develop energy efficient buildings in the country. The short pay back period of additional investments on energy efficiency was noticeable in this case.

12 www.taeq.org

13 http://www.med-enec.com/en/pilot_preferred.aspx

5 Concluding discussion and main findings

Statistical data on energy efficient buildings (EEBs) are not available in Iran and Israel. Energy efficiency in buildings has been addressed by Iranian and Israeli academics through their research since the 70s. Design and construction projects with the aim of improving energy efficiency in buildings bloomed in the early 90s at Ben Gurion University of Negev, Israel. Afterwards, prototype and demonstration projects have been implemented in other regions in the country. Design and construction of EEBs have been implemented very slowly in Iran during the last decade. A few projects were stopped after the design stage while the others were constructed neglecting proposed energy efficient technical solutions. In the following, applied passive design strategies, traditional architecture elements, achieved levels of energy efficiency and related costs will be discussed. In addition, main drivers and barriers to use energy efficient technical solutions in buildings will be pointed out and recommendations for improving the status quo will be offered.

5.1 Applied passive design strategies in Iranian and Israeli buildings

Several energy efficient design strategies and technical solutions have been applied in both countries while various factors are influencing the effectiveness of using these solutions to improve energy efficiency in buildings. General passive design strategies used in European warm climate passive houses and other approaches in northern hemisphere warm climates such as orientation, shading, insulation, air tightness, thermal mass, natural ventilation and day lighting are applicable in both countries taking into consideration the local climatic conditions. Exact regional and local climatic conditions information such as air temperature, humidity, solar radiation power and direction, and wind power and direction are vital to adopt proper strategies during design stage.

5.1.1 Building orientation

A common passive design strategy with the aim of energy saving in the buildings in Northern latitudes is designing buildings oriented towards the south and extended along east-west direction in order to benefit from passive heating supplied by solar radiation. The overall area of openings on the south façade should be the largest portion of total glazing area on exterior walls while it should be minimized on the northern facades in order to reduce heating energy demand in the building. Orientation has been considered by architects in all six cases in Iran and Israel although one major possible limitation was proved by Ayatollahi house. The house is oriented toward the southeast direction due to urban planning by the municipality causing a reduction in solar gains during winter and difficulties with control the solar radiations by shading in summer.

5.1.2 Shading

Different shading methods are utilized to enhance energy efficiency by avoiding unwanted heat absorption from south facing openings during summer. The angle of solar radiation is a key factor to select appropriate type, shape and size of shading devices. External shading is a useful method to control solar radiation in desert climates such as Negev in Israel and Yazd in Iran. Using **curtains** made by thick textile such as external shadings in Ayatollahi house could be an inexpensive choice; however, it causes inconvenience due to usual strong winds. **Blind shutters** used in Meir house could be a proper option for windy climates. However, both cases restrict the day light penetration into the buildings. Internal shading can be simply implemented by fabric curtains in houses whereas they also limit penetration of day light into the building. **Venetian blind** used in Intel green building is an example of appropriate shading device to benefit from day lighting at the same time as shading. Several types of shading devices are available on the market in both countries.

Appropriate **vegetation** is another solution to shade areas exposed to unwanted solar radiation. This strategy has been adopted in Meir house by planting trees in the garden and installing a **pergola** with movable fabric shadings. Another example is pergola with vine trees utilized in Ayatollahi house. Moreover, shading can be supplied by some parts of **building structure** or **adjacent buildings**. For instance, the northern verandah in Meir house is covered and shaded by the second floor. Using external shading plates in Intel green building is another example of this strategy.

5.1.3 Thermal mass and insulation

Utilizing massive walls with high thermal capacity is a suitable solution to reduce the energy demand and improve thermal comfort in buildings especially in hot-arid climates due to wide range of temperature fluctuations during days and nights. Concrete and cellular concrete blocks are applicable choices for thermal mass in both countries since they are available on the local markets and have sufficient thermal capacity characteristic. Furthermore, using a polystyrene insulation layer in external surface of the exterior walls is an effective and applicable solution in hot climates of both countries.

Double pane and multiple pane glazing windows are used in both countries. Utilizing reflective panels used in Intel green building is a good solution to control solar radiations in order to achieve energy efficiency objectives. Seasons windows designed and produced in Israel is a superior example of local innovative technologies, which can affect cooling and heating energy demand in buildings in a considerable extent.

5.2 Applied traditional architecture elements and innovative techniques in Iranian and Israeli buildings

Traditional architecture elements are integrated in new buildings with the aim of improving energy efficiency. However, local climatic conditions, new urban structures and resulted microclimates in urban areas should be considered as crucial affecting factors in design process. Obstacles hindering the use of traditional architecture elements in new buildings can be removed by innovative solutions.

5.2.1 Wind-catchers

Wind-catchers, historical architecture elements, were applied successfully in Sakhnin green building and proposed by designers for the Tehran climate house and green office. Furthermore, the result of testing the new design of wind-catcher at Yazd University showed an appropriate level of cooling performance. The efficiency of wind-catchers depend on several factors such as the size of the tower particularly its height. However, in dense urban areas like Tehran where buildings are often surrounded by tall buildings, the effectiveness of wind-catchers as evaporative cooling systems is doubtful. Indeed, the Tehran green office revealed an inappropriate design neglecting real conditions such as effects of adjacent buildings and polluted ambient air of Tehran on the performance of wind-catchers.

All cases included water spray to cool the entering air. This strategy is very suitable for hot arid climates similar to Yazd with low relative humidity and dusty winds. Filtration and recycling water proposed for the Tehran climate house is a proper solution to deal with water consumption of wind-catchers equipped with water spray systems. Nevertheless, water as a considerable portion of consuming water will evaporate during the cooling process and thus this could be a limitation for this system particularly in hot arid areas, which are facing a lack of sufficient resources of water.

The EVAPCOOL system with porous ceramic evaporators is a new technology designed based on wind-catcher performance principles. A similar idea was introduced by an Iranian researcher in 1985 (Bahadori, 1985); however he replaced the ceramics with fabric sheets in his next proposed design due to maintenance problems as well as installation and maintenance costs of ceramic elements (M.N. Bahadori, personal communication, June16, 2008). This limitation together with accessibility of ceramics on the local market has also pointed out by designer of EVAPCOOL. This was a reason for changing the strategy during construction to replace the porous ceramics by a brick structure with ceramic pots.

Despite the vast use of wind-catchers in traditional architecture of Iran, most people are not interested in using this element as a cooling system. By way of illustration, wind-catchers have been built in several private houses and public buildings such as hotels, universities and cultural centers as a symbolic element of traditional architecture while they are not used as cooling systems.

5.2.2 Water pools and fountains

Another traditional architecture element used in Sakhnin green building and proposed for Tehran climate house and green office is water pool equipped with fountains. This element is used as a passive evaporative cooling system. In the Sakhnin building, the water pool is small and the main element is the fountain. In the two Tehran buildings, larger water pools were proposed in order to enhance evaporation by increasing the surface area of heat transfer (the area, which water is exposed to airflow). Wide water pools in traditional courtyards were the main elements of passive cooling systems while they were used in combination with other strategies and elements such as a large central courtyard with several rooms located alongside the four sides of the courtyard and faced toward it. These elements together with adequate shading by vegetation and limited height of surrounding buildings provided desirable thermal comfort for inhabitants by means of sufficient air circulation and cooling.

The Sakhnin green building form is similar to traditional buildings with central courtyard as rooms benefit from cooling effect of fountain. Whereas, the efficiency of small water pool in a small courtyard surrounded by tall buildings and walls such as the one built in Tehran green office is uncertain.

5.2.3 Energy efficient roofs

Green roofs were integrated into the Tehran climate house and green office and Intel green building in Haifa. Green roofs act as an insulating layer to protect the building from solar radiation during summer and thus decrease cooling energy demand in buildings. It can also contribute to filtration of polluted air and reduction of urban heat island effect. Of course, these results are not achieved by what currently exists on the roof of Tehran green office. The green roof concept has not been integrated into Iranian buildings so far and as shown in the previous chapter (Section 4.2.2.1) the Tehran green office demonstration project has failed to introduce and develop this element. In general, people are concerned about inappropriate foundation and water leakage into the building. Water leakage into the Tehran green office ceiling under the green roof shows the risk level of using this element due to typical poor construction operations in the country.

Domes and vaulted roofs are two traditional architecture elements used in the Sakhnin green building in Israel to reduce cooling energy consumption by the enhancement of natural ventilation. They are applicable in one or two story buildings; however, as they are currently used only for roofing Mosques and religious sites, they might not accepted by people to be used in residential buildings in Iran. It should be noted that all Iranian governmental office buildings include mosques for praying at noon and many of them have domes as symbolic elements, which are installed as an excess part on their flat roofs. Therefore, they have no contribution to ventilation and cooling and accordingly energy demand in those buildings.

5.2.4 Courtyards

Courtyards are another traditional architecture element used in the Sakhnin green building, Tehran green office and Ayatollahi house. As mentioned before, the courtyards used in traditional buildings were large with perfect proportions to offer adequate shading in summer and allow sufficient solar radiation gains during winter. They functioned as a microclimate to provide an improved climate inside compared to outside environment. Traditional courtyards were built at the center of the buildings while the rooms were located around the courtyard with the openings towards it. Therefore, all rooms were connected to the courtyard and benefited from its cooling and heating effects. This plan has been used in the Sakhnin green building, an educational center. However, contemporary courtyards in Iran are like what is built in Tehran green office and Ayatollahi house.

Evaluation of energy efficient elements applied in the Tehran green office was not implemented. Whereas, a study conducted at Sharif University in Tehran on a contemporary courtyard with an area of 150m^2 equipped with a water pool (30m^2) and a garden (90m^2) (Safarzadeh & Bahadori, 2005), showed that the effect of the courtyard in reduction of cooling energy demand in the building was rather low (9%). Furthermore, the courtyard had an adverse effect on the heating energy demand in the house (-8.6%) and is an expensive element due to land costs particularly in cities such as Tehran.

5.2.5 Natural lighting

One of the most important technical solutions to reduce energy consumption of buildings is natural lighting by sunlight. This also affects visual comfort and health of occupants. Building **windows** and other **glazed surfaces** are the main means to provide daylight for internal spaces. Indeed, the primary purpose of a window is to provide daylight, and to create a visual contact between inside and outside (Bülow-Hübe, 2001). In addition to windows, other glazed surfaces can be used with the aim of reducing energy consumption for lighting purposes. For instance, small portions of a water pool in the Tehran green office were glazed to supply daylight for the basement.

Two symmetric **atriums** used in the Intel green building in Haifa supply daylight for the building through three upper floors. This idea has been also used in some Iranian tall buildings. In the Sakhnin green building, several holes covered with bulbous glass on the domed roof enhances transmission of daylight to the interior space. By using this method sunlight can be only be transmitted into the space below the roof. This limitation is removed by **sun pipe**, which has long and flexible pipes. A sun pipe was proposed to provide day lighting for the basement in the Tehran climate house; however, they are not available on the local market that should be considered as a major limitation. It should be noted that many apartment buildings in Iran are designed irrespective of sufficient access to daylight. A number of apartments have been built without any access to sunlight or any view to outside. Obviously, the electricity demands in those apartments are considerably high due to necessary artificial lighting during daytime.

Furthermore, day lighting is sometimes restricted by shadings used to provide privacy for the buildings, a significant factor due to cultural features of the region. This is also evidenced by utilizing Mashrabiah on large windows in traditional architecture in the Middle East.

5.2.6 Heating systems

Due to high levels of solar radiation, both countries have the opportunity to benefit from solar energy. The **Trombe wall** built in Ayatollahi house is a good example of applicable passive heating solutions. It is a useful energy efficient technical solution for hot arid climates as it can also be used for natural ventilation and passive cooling during summer. As described in previous chapter, its components and building method is sufficiently simple to be utilized in many buildings.

Israel with 700 m^2/1000 inhabitants is a leading country in per capita installed area of solar collectors (WEC, 2008). Regulation for mandatory installation of **solar water heaters** in buildings has been the main driver in the growing use of this energy efficient device. Utilizaton of solar water heaters are not developed in Iran. As a result, sufficient maintenance services are not offered, which is a hindrance to use them. Solar water heaters installed in the Ayatollahi house is a superior example of using simple and inexpensive passive solutions to reduce energy demand in residential buildings. Indeed, using solar water heaters in Iranian houses not only reduces the required energy for heating water but also lessens the cooling energy demand during summer. In other words, since a solar water heater is located on the roof of the house, a conventional gas fired water heater installed inside the building is not used during summer and thus a heat source will be eliminated from inside the house. Nevertheless, solar water heaters are not accepted as reliable devices to supply required hot water by many people in Iran.

Heat recovery is another solution to reduce heating energy demand in buildings. In the Intel green building, heat recovered from data center equipment cooling system is used to preheat the required warm water in services. In the Ayatollahi house, heat released from fireplace flue gas is recovered for space heating in living room. This experience can be used in other similar buildings in both countries.

5.3 Current concepts and achievable levels of energy efficiency in Iran and Israel

The green building concept and LEED certification program introduced by USGBC has been initiated for office buildings in the Middle East countries including Israel while there is no case of such green buildings in Iran. The LEED certification program has a well-established structure to reduce environmental impacts of the buildings while at the same time, improving occupants' health and comfort. However, when it comes to energy efficiency, it requires supplementary regulations and guidelines to be used as a tool for developing EEBs in countries such as Iran and Israel. This was addressed in Israel by approving an additional energy-rating standard for residential buildings as a prerequisite for the Israeli national green building standard.

The Intel green building in Haifa is the first Israeli office building with the aim of LEED certification. Designed annual energy consumption of the building was 7,371,630 kWh (508.9kWh/m^2). It should be noted that the building is an office building and an energy use of 3,024,800kWh is related to office equipment; as mentioned before, the building contains a data center, which put it amongst energy use intensive buildings. The energy use designed for space cooling was 110.3kWh/m^2, which shows a 28.1% reduction compared to baseline design. Overall designed energy consumption shows a 15.3% reduction compared to baseline building in ASHRAE standard. It is worth bearing in mind that designed energy consumption would be different from actual consumption as showed by a recent study (Turner & Frankel, 2008) that actual energy consumption amounts by several certified buildings are more than design projection. For instance, lab buildings generally use twice the energy as predicted in their designed energy models while the reason is not identified by designers.

The Sakhnin green building accomplished 72% saving in energy consumption compared to a conventional building while an overall saving of 92% is trying to be achieved. It shows the possible level of energy efficiency in public buildings depending on the capacity of construction industry and available technologies in Israel.

A bioclimatic design concept has been used and developed by Israeli researchers and designers since the 70s. Climatic design is the main approach adopted by Iranian designers to improve energy efficiency in buildings. Energy saving targets for the Tehran climate house and the Tehran green office were respectively 70% and 40%; however the possibility of achieving these targets by proposed technical solutions and local construction sector capacity can not be assessed as the former has not been constructed and the latter was not completely built in compliance with energy efficient design strategies. The Meir and Ayatollahi houses were two other examples of climatic design of residential buildings in both countries. Comparable data on cooling and heating energy consumption in these houses are not available. Energy saving in Ayatollahi house, which is measured by conducting a quantitative survey on similar buildings in the same area of the city revealed reductions of 44% and 48% respectively in heating and cooling energy demand in the house compared to similar conventional buildings.

Although general passive strategies are used as the main strategies in various building design projects, no house designed or constructed according to European Passive house was detected in Iran or Israel during this study. As mentioned in chapter 2, total annual heating energy demand for European passive house is 15kWh/m^2 while a total annual cooling demand in 15kWh/m^2 was proposed for warm climates in Europe by Passive-On project. Cooling energy demand for proposed Spanish passive house is 21.7kWh/m^2, which exceeds the proposed amount while the heating energy demand is 2.8kWh/m^2, which is much lower than the requirement level in passive house standard. Heating and cooling energy demands for Portuguese passive house were respectively 5.9kWh/m^2 and 3.7kWh/m^2. These results reveal a need to review the proposed requirements for passive house standard for the European warm climates especially when it comes to developing this concept for other regions. It should be noted that the utilized thermal simulation tool was not the same amongst all group members of Passive-On project. In addition, actual energy consumption amount could be different from designed proposals. Exact information on European passive house concept for warm climates is required to examine this concept as an option for developing EEBs in Iran and Israel.

5.4 Costs of energy efficient buildings in Iran and Israel

The estimated cost for improving energy efficiency in the Intel green building was approximately $240,000, which was 40% of total additional cost for improvement measures in all categories of sustainability. The estimated return of total investment was estimated as 5 years; this is worth considering by organizations in decision making about new construction of office buildings.

Total cost of energy elements in Sakhnin green building were estimated as €102,505, which of approximately 30% was for PVs and wind turbines while less than 14% was for traditional elements (wind-catchers and mashrabiah). PVs and wind turbines lead to an energy saving of about 26% (calculated based on light energy demand for a conventional reference building). The energy saving attained by using wind-catchers and mashrabiah was about 26% (calculated based on air conditioning energy demand for a conventional reference building). These results show the opportunity for utilizing traditional elements in order to achieve considerable levels of energy efficiency in public buildings.

There is no available data on additional costs of integrating energy efficient solutions into the two cases of private houses. The estimated cost for Tehran climate house and Tehran office building were respectively 2 and 1.5 times as mach as a conventional building. The most portions of these costs were due to integrating energy efficient elements into design regardless of their availability on the local market.

Results of the Sakhnin project showed that additional costs of using traditional architecture energy efficient elements is rather low in comparison with other elements such as PVs and wind turbines considering their contributions to energy savings. A five-year pay back period for the investment on integrating energy efficient solutions into the Intel green building is worth being considered by other companies planned to build new offices.

Despite the importance of cost in developing energy efficient buildings, it could be neglected by users due to other factors such as indoor environment quality and inhabitant's comfort. Moreover, the additional costs will be decreased by increased know-how during prototype projects and overcoming some hindrances such as market barriers due to growth in demand for energy efficient solutions and components.

5.5 Main drivers and barriers to apply energy efficient technical solutions in Iranian and Israeli buildings

5.5.1 Policies and building regulations

Building codes are driving forces to develop EEBs if they properly address energy efficient design strategies and technical solutions. However, their effectiveness is affected by several factors. Several regulation and standards addressing this issue have been launched and come into force in Israel. For instance, mandatory use of solar water heaters has been an effective driver to integrate this energy efficient component into Israeli buildings. Moreover, EEBs are growing in the country in light of Israeli green building voluntary standard while the pace is rather slow due to the barriers described in the following sections. As the standard is voluntary, strong incentives are needed to encourage people to use it.

In Iran, relevant standards and regulations have been lunched during recent years, which of most important is energy chapter of national building code. This code is believed to reduce energy consumption in buildings by 30%. However, to implement the code successfully, several barriers should be overcome. For instance, trained professionals are needed for implementing the code, which is a drawback in many regions of the country including warm climates. Fragmentation of authorities is also a significant trouble in implementing Iranian building standards and codes. Furthermore, low energy prices in Iran functions as a main barrier to develop EEBs in this country. In other words, investments on applying energy efficient solutions in buildings have very long pay back periods due to low prices of energy.

5.5.2 Energy efficiency perception and indoor environment quality

Proper use of energy efficient solutions enhances indoor environment quality including indoor air quality as well as thermal and visual comfort in buildings, which is a driver to use EEBs. Indeed, energy efficiency involves reducing energy consumption for acceptable level of indoor environment quality. The occupant's health and comfort has been addressed by European passive house, green building and bioclimatic design concepts. However, for a number of designers, energy efficiency means only saving energy and thus satisfactory level of indoor environment is sacrificed for the target level of energy efficiency. People perception of energy efficient buildings can be adversely affected by such strategies. In other words, utilizing energy efficient passive cooling and heating systems might be avoided due to the poor performance in supplying thermal comfort or insufficient ventilation.

Thermal comfort is a significant factor in designing an energy efficient building. It is defined by British Standard BS EN ISO 7730 as *'that condition of mind which expresses satisfaction with the thermal environment'*. In addition to environmental factors, thermal comfort depends on personal factors including clothing and metabolic heat[14] (Health and Safety Executive (HSE), 2008). Therefore, designing a cooling system based on only climatic data and international standards may not lead to providing thermal comfort in buildings and thus could be a reason for people to avoid using it. For instance, summer thermal comfort level in Iranian office buildings is affected by mandatory special clothing for women. In addition, wearing short-sleeved shirts is prohibited for men in most of the organizations that should be considered at the design stage of cooling systems. Accordingly, determined threshold of 26˚C for indoor air temperature in Tehran green office could not provide an appropriate level of thermal comfort at least for female employees. Most significantly, the indoor air temperature was predicted to exceed the threshold of 26˚C during 15% of work hours that may not be tolerated by occupants. It worth bearing in mind that, in Nicol diagram prepared for Tehran climate house (Section 4 .2.1, Figure4-5), thermal comfort temperature in July was determined at roughly 29˚C, which is higher than that could be accepted as thermal comfort condition.

Appropriate ventilation is vital to achieve energy efficiency objectives. In fact, the performance of energy efficient systems and elements might be disturbed by opening doors or windows to supply fresh air for the interior. In particular, where heating or cooking required energy is generated by fuel combustion in buildings, indoor air will be polluted by emissions from combustion. Most importantly, fresh air is needed to supply adequate Oxygen for combustion process otherwise combustion will not correctly occurred and thus Carbon monoxide, a suffocating gas, will be produced and can kill inhabitants in a few minutes depended on its concentration in the indoor air. The number of people poisoning or dying by Carbon monoxide during winter is considerable in Iran. This is an important issue especially after educational programs by Iran fuel Conservation Company on TV encouraging people to seal all openings and air leakage paths in order to lower the fuel consumption for heating.

[14] Metabolic heat describes the heat that we produce inside our bodies as we carry out physical activity (HSE, 2008).

Public perception of energy efficient technical solutions can be negatively affected by such one-dimensional approaches to decrease energy consumption in buildings.

Visual comfort can be achieved by adopting proper design strategies. Utilizing daylight will influence occupants' health and comfort in addition to electricity consumption in buildings. This can be a good motivator to use energy efficient buildings.

5.5.3 Leadership in demonstration projects

To successfully implement EEB demonstration projects, it is vital to plan, co-ordinate and follow up the projects by effective leadership. Until now, the Tehran green office has failed as an energy efficient demonstration project while it has been successful as a project demonstrating some of the barriers to develop EEBs in Iran. As mentioned before, a passive cooling system has not been completely constructed and solar collectors are left on the roof of the building. Lack of leadership is the major ascertained barrier as there is no integrated management of the whole process of demonstration projects. Several mayors had been appointed during the project. This has radically influenced the progress of the project and implementation of the designed technical solutions.

Lack of an effective leadership has been the main reason for impeding some energy efficient building projects in both countries as they stopped after the design stage due to developers' reluctance to develop the projects. In other words, an effective leadership can provide communications between designers and developers at the early stages of the project to achieve reasonable and acceptable energy efficient design strategies and technical solutions.

5.5.4 Technical, market related and informative factors

Lack of energy efficient products on the market was identified as a barrier to apply energy efficient technical solutions in Iranian buildings. On the other hand, although several products used in energy efficient technical solutions for buildings are available on the local markets in both countries, there are still some limitations to use such components. One of the obstacles is the high cost of some products like double pane windows or additional costs due to using excess amounts of some materials such as wall insulations. By way of illustration, using non-standard construction materials in order to reduce the related cost is a typical problem in Iran. Moreover, in some cases such as PVs and solar collectors, people avoid using such energy efficient systems in buildings since adequate repair and maintenance services are not offered.

Seasons window is an example of existing knowledge and technology capacities in Israel to invent and produce energy efficient products. Moreover, the project revealed the importance of international cooperation in developing energy efficient technologies projects.

One of the major barriers to use energy efficient technical solutions in buildings is imperfect know-how and limited construction skills among construction sector. Water leakage from the green roof into the Tehran green office is a case in point. Most of the construction sector workers and even project managers are not educated in both countries. Furthermore, the author is dubious about the quality and effectiveness of training programs offered by responsible organizations. Inadequate construction site inspection is another barrier to implement energy efficient building projects.

Inappropriate urban design and land planning is another obstacle for the use of some energy efficient solutions in the buildings e.g. orientation and natural ventilation and using some elements such as wind-catchers.

One of the significant factors in using traditional as well as innovative passive elements in buildings is people's attitudes. Attitudes to some elements like wind-catchers and solar heating systems is more important than associated costs. To put it simply, they do not rely on the effectiveness of such systems. For instance, despite their additional costs, wind-catchers and domes are used in Iran for their aesthetic aspects regardless of their ability to supply cooling demand in the building.

The level of energy efficiency is difficult to be compared in the two countries as no uniform measuring system is applied. Whereas, Sakhnin green building project revealed that considerable levels in energy saving are achievable by the use of existing know-how and technology in Israel. Moreover, Meir house and Ayatollahi house cases showed the opportunity of improving energy efficiency and saving energy by means of relevant technical solutions, which are feasible in any building in hot arid climates of both countries.

A key factor in developing energy efficient buildings is the related cost. Although some projects might be stopped due to predicted high additional costs, the ambiguity of real costs is a major obstacle to develop energy efficient buildings. In other words, people presumption of the additional costs for integrating energy efficient technical solutions into the buildings might be much higher than the reality. Moreover, calculations on savings in money related to energy saving and pay back periods are necessary to attract investors to develop energy efficient buildings. As mentioned in previous section, short pay back period of investment on energy efficient solutions in Intel green building and considerable levels of energy efficiency achieved by the use of traditional architecture elements with relatively low costs can be good motivators for the organizations aimed to construct new buildings to benefit from such experience.

5.6 Concluding remarks

Experience of EEBs is limited to demonstration projects in Iran and Israel while the number of such projects is remarkable in Israel although there is no available statistics about EEBs in both countries. Design strategies and techniques such as orientation, shading, thermal mass and insulation, traditional elements (e.g. wind-catchers and natural lighting elements), new technologies including solar PVs and wind turbines are applied in demonstration projects by the existing know-how and capacity in both countries. However, to utilize these solutions in order to improve energy efficiency in buildings it is essential to promote the existing drivers, to create new incentives, and to remove various above-mentioned barriers.

Bioclimatic design, acknowledged in both countries, is an appropriate approach to address energy efficiency in buildings regarding the local climates and microclimatic conditions. As green buildings include a certification program, they can be used to develop EEBs while at the same time raising people awareness about the subject. The passive house concept has a great potential and needs more research to be used in warm climates. Considerable levels of energy efficiency are achievable in both countries by using the mentioned technical solutions. However, the existing knowledge in academics should be transferred into all of the actors involved in the building sector.

Market barriers can be dealt with by improved and effective policies, raising awareness about EEBs, promoting energy efficient production sector and supplying the required energy efficient products by import. The latter is also a proper way of transfer know-how into the construction sectors as many suppliers provide their users with the technical instructions.

5.7 Recommendations

There is always room for change and improvement in various systems facing problems. In the opinion of this author, the following recommendations can be used to overcome the above-mentioned obstructions. Both the Israeli green building standard and the Iranian energy building code have the potential to improve energy efficiency in buildings in combination with sufficient supportive strategies. For instance, negative subsidies can be eliminated to adjust energy prices and subsidies can be dedicated to EEB projects and energy efficient products. Exempting EEBs from some regular taxes is another incentive for using energy efficient solutions.

The energy chapter of the Iranian building code is relatively complicated and needs comprehensive training, which is not feasible in all regions of the country. Simplified versions by dividing different types and categories of buildings and climates could be an effective way to make this code more practicable. Distance training courses about Israeli green building standards and the energy chapter of the Iranian building code on the internet is recommended as many people even in rural areas in Iran have internet access nowadays. The establishment of help desks on the internet to support actors with required information is another recommended option.

To overcome the barriers due to lack of leadership and statistical data, a dedicated authority is suggested to undertake the management of the whole process in EEB demonstration projects as well as monitoring of the related trends in building sectors in each country.

The concept of European passive house for warm climates can be more developed through CDM[15] projects in Iran and Israel and used as an option for developing EEBs in both countries. This can also be an effective way to improve passive technical solutions such as evaporative cooling systems.

To facilitate comparing buildings on their energy efficiency levels, determining a standard building baseline and a uniform unit for measurement of energy efficiency in buildings is recommended. Consequently, comparing energy efficient building on the amount of energy saving with respect to baseline building would be feasible.

A building is a component of and an interaction with an urban area as a larger system. Therefore, using energy efficient design strategies and elements should be considered in urban planning programs and regulations. Integrating the orientation into urban planning process is a case in point.

Actors' involvement in demonstration projects from the early stages of the projects is suggested. Using the existing knowledge in academia and communicating the results of successful energy efficient solutions with involved students, designers, constructors and users is an appropriate manner to develop energy efficient solutions in a reciprocating learning process. Communication strategies in the Sakhnin and Intel green buildings are good examples of such efforts.

[15] The CDM (Clean Development Mechanism) allows emission-reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol (UNFCCC, 2008).

5.8 Further studies

Suggested further research to provide adequate knowledge required for the improvement of energy efficiency of buildings in both countries are:

- Cost-benefit analysis of EEBs in both countries; the results will provide developers and users with a clear view of opportunities and risks to invest on such buildings that is very important in developing phase.

- Assessment the the integration of energy efficient technical solutions into the curriculums at universities; the results will be used to find the knowledge gaps in order to supply adequate knowledge for building sector.

- Effectiveness evaluation of training courses in the construction industry to find the opportunities for the improvement of such programs.

- Feasibility study of developing wind-catchers; as this traditional architecture element has enormous potential to be used and developed as a passive cooling system in warm climates.

- Feasibility study on penetration of energy efficient products such as sunpipes in local markets; the imported products facilitate the use of various energy efficient design strategies and techniques at the same time as transfer the related know-how into the countries.

- Evaluation of EVAPCOOL system in the Tehran green office after installing ceramic pots; this is a good way to assess the proposed change in the system, which can remove the obstacle of lacking porous ceramics and introduce a new technical solution in other buildings.

- Evaluation of indoor environment quality in the Sakhnin and Intel green buildings; this is a proper manner of effectiveness evaluation of the utilized energy efficient design strategies and technical solutions in order to find improvement opportunities.

Bibliography

Al-Temeemi, A.S. (1995). Climatic design techniques for reducing cooling energy consumption in Kuwaiti houses. *Energy and Buildings, 23*, 41-48.

Audenaert, A., De Clyen, S.H. & Vankerckhove, B. (2008). Economic analysis of passive houses and low-energy houses compared with standard houses. *Energy Policy*, *36*, 47-55.

Ayatollahi, S.M.H., (2006, March), Arzyabie karaee khaneye khorshidi dar Yazd ba hdafe sarfe joyee enerjy fe raveshe gheire faal[Efficiency evaluation of a solar house in Yazd with the aim of passive energy saving]. *The forth conference on energy efficiency in building, Tehran, Iran*

Ayatollahi, S.M.H., (2008). The *passive solar of Yazd: Reflections and performance evaluation after 8 years use*. Unpublished article

Badescu, V. & Sicre, B. (2003). Renewable energy for passive house heating II. Model. *Energy and Buildings*, *35*, 1085-1096.

Bahadori, M.N. (1978). Passive cooling systems in Iranian architecture. *Scientific American, 238*(2),144-154

Bahadori, M.N. (1985). An improved design of wind towers for natural ventilation and passive cooling. *Solar Energy, 35*(2), pp 119-129.

Bahadori, M.N. & Haghighat, F. (1986). Thermal performance of adobe structures with domed roofs and moist internal surfaces. *Solar Energy, 36*(4), pp 365-375.

Bahadori, M.N., Mazidi, M. & Dehghani, A.R. (2008). Experimental investigation of new designs of wind towers. *Renewable Energy, 33*, 2273-2281.

Baum, M. (2007). *Green building research funding: an assessment of current activity in the United States*. U.S. Green Building Council. Retrieved on August 27, 2008 from:

http://www.usgbc.org/ShowFile.aspx?DocumentID=2465

Bülow-Hübe, H. (2001). Energy-efficient window systems: Effects on energy use and daylight in buildings. Doctoral dissertation, Lund University, Lund Institute of Technology, Report TABK-01/1022, ISSN 1103-4467

Central Bureau of Statistics, Israel. (2006). Environment data compendium Israel. Jerusalem, Israel, ISBN 965-90423-7-X

Comfortable Low Energy Architecture (CLEAR). 2008. Trombe wall. Retrieved on July 29 from:

http://www.learn.londonmet.ac.uk/packages/clear/thermal/buildings/passive_system/passive_heating/trombe_wall.html

Curl, J.S. (2006). *A dictionary of architecture and landscape architecture*. Oxford University Press 2006. Oxford Reference Online, Retrieved on July20, 2008 from: www.oxfordreference.com.ludwig.lub.lu.se/views/ENTRY.html?subview=Main&entry=t1.e4908

Elswijk, M. & Kaan, H. (2008). *European Embedding of Passive Houses*. Promotion of European Passive Houses (PEP)-Project Report. May 2008. Available online at:

Energy Information Administration. (2007). Country analysis briefs, Iran. Retrieved on May 15, 2008 from:

http://www.eia.doe.gov/cabs/Iran/pdf.pdf

Erell, E., Etzion, Y., Carlstorm, N., Sandberg, M., Molina,J., Maestre, I., Maldonado, E., Leal, V., & Gutschker, O. (2004). "SOLVENT": development of a reversible solar-screen glazing system. *Energy and Buildings, 36*(2004), 467-480

Erell, E., Yannas, S., Molina, J.L. (2006). Roof cooling techniques. *PLEA 2006, the 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland, 6-8 September 2006.*

Etzion, Y. (1994). A bio-climatic approach to desert architecture. The Arid Land Newsletter, 36. Retrieved June 6, 2008 from http://ag.arizona.edu/OALS/ALN/aln36/Etzion.html#value

Etzion, Y. & Erell, E. (2000). Controlling the transmission of radiant energy through windows: a novel ventilated reversible glazing system. *Building and Environment, 35*(2000), 433-444 http://erg.ucd.ie/pep/pdf/European_Embedding_of_Passive_Houses.pdf

EVAPCOOL. (2003). *Passive downdraught cooling systems using porous ceramic evaporators*. Publishable report, Retrieved on July 16, 2008 from:

http://www.phdc.eu/uploads/media/EVAPCOOL_1_Evapcool_Publishable_Final_Report.pdf

Feist, W., Schnieders, J., Dorer, V. & Hass, A. (2005). RE-inventing air heating; Convenient and comfortable within the frame of the Passive House concept. *Energy and Buildings, 37*, 1186-1203.

Feist, W. (2006 a, September). *Definition of passive houses*. Retrieved on July 09, 2008 from:

http://www.passivhaustagung.de/Passive_House_E/passivehouse_definition.html

Feist, W. (2006 b, September). *Factor 10 is a reality*. 15th Anniversary of the Darmstadt- Kranichstein passive house, Retrieved on August 05, 2008 from:

http://www.passivhaustagung.de/Kran/First_Passive_House_Kranichstein_en.html

Ford, B. & Schiano-phan, R. (2004). The application of downdraught evaporative cooling systems in non-domestic buildings. A case study: the green office, Tehran. *IFCO Conference, Tehran, Iran*

Gan, G. (1998). A parametric study of Trombe walls for passive cooling of buildings. *Energy and Building,* 27*,* 37-43

Givoni, B. (2007). Cooled soil as a cooling source for buildings. *Solar Energy, 81*, 316-328.

Ghobadian, V., Taghi, N. & Ghodsi, M.(2008). Tehran: A hot arid climate. In Hyde, R. (Ed), *Bioclimatic Housing: Innovative designs for warm climates* (pp.173-193). UK & USA: Earthscan

Hadavand, M., Yaghoubi, M. & Emdad, H. (2008). Thermal analysis of vaulted roofs. *Energy and Buildings*, 40, 265-275

Harris, D.J. & Helwig, N. (2007). Solar chimney and building ventilation. *Applied energy*, 84, 135-146

Health and Safety Executive (HSE). (2008). Thermal comfort: Workplace temperature and thermal comfort. Retrieved on August 8, 2008 from: http://www.hse.gov.uk/temperature/thermal/explained.htm

Hershgal, D. (2008, June). Intel's first Design and Built Green Building: Management and Implementation. Presentation at *Green Construction Conference, Berlin, Germany*

Hershgal, D., Denner, M., Harush, A. & Bitan, R. (2008). Intel's first Designed and Built Green Building. *Intel Technology Journal, 12*(01), ISSN 1535-864X

Hyde, R. (Ed.) (2008). *Bioclimatic housing: Innovative designs for warm climates*. Earthscan, UK&USA

Intergovernmental Panel on Climate Change (IPCC). (2007a). *Climate change 2007, Mitigation*. Cambridge University Press, USA

Intergovernmental Panel on Climate Change (IPCC). (2007b). *Climate change 2007: Synthesis report, Summary for policymakers*. retrieved on August4, 2008 from: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

Iran Department of the Environment. (2008). *Air pollution measurement stations reports*. Retrieved on June 25, 2008 from: http://www.irandoe.org/doeportal/airp/index.php?pid= 173

Iran Energy Efficiency Organization (IEEO-SABA). (2004). *Rotbeye karaiie masrafe enerjy dar vasayele khanegi* [Energy efficiency rank of housing appliance]. Retrieved on July25, 2008 from:

http://www.saba.org.ir/tmd/tmd10.pdf

Iranian Fuel Conservation Company: IFCO. (2008). News Archieve, *Ejraye mabhase noozdah mogharարate mellie sakhteman*[Enforcement of chapter 19 of national building code]. Retrieved on August25, 2008 from: http://www.ifco.ir/news/mordad87-04.asp

Iran Meteorological Organization. (2006, May). *Climatic statistics report (1952-2005)*, Retrieved June 28, 2008 from: http://www.irimo.ir/english/statistics/synopH/YAZD.txt

Iran Ministry of Energy- Deputy of Electricity and Energy Affairs. (n.d.). *Evaporative air coolers- Method for measuring of energy consumption and energy labeling instructions.* Retrieved on July 25, 2008 from:

http://www.iranenergy.org.ir/statistic%20info/standards/pdf/evaporative%20air%20coolers.pdf

Iran Ministry of Energy. (2006). *Namagarhaye bakhshe energy*[Energy sector Indicators]. Information and Statistics Network. Retrieved on August 5, 2008 from: http://ict.moe.org.ir/_ICT/Documents/masraf.pdf

Israel Central Bureau of Statistics. (2008). *Total final energy consumption*,2005, Retrieved June 20, 2008 from: http://www.cbs.gov.il/www/publications/energy05/pdf/gr6.pdf

Israel Meteorological Service (IMS). (2007). *Climate information*. Retrieved on August08, 2008 from:

http://www.ims.gov.il/IMSEng/CLIMATE

Israel Ministry of Environmental Protection. (2006). Environmental Bulletin, Volume 31/ October 2006. Available from: http://www.sviva.gov.il/Enviroment/Static/Binaries/ModulKvatzim/31_12-13_1.pdf

Israel Ministry of Environmental Protection. (2007). Environmental Bulletin, Volume 32/ May 2007. Available from: http://www.sviva.gov.il/Enviroment/Static/Binaries/ModulKvatzim/32_22-23_1.pdf

Israel Ministry of Environmental Protection. (2008). *Principles of the green building standard*. Retrieved on June 06, 2008 from:

http://www.sviva.gov.il/Enviroment/bin/en.jsp?enPage=e_BlankPage&enDisplay=view&enDispWhat=Object&enDispWho=Articals^l4609&enZone=israel_green

Israel Ministry of Foreign Affairs. (2008)

http://www.mfa.gov.il/MFA/Facts+About+Israel/Land/THE+LAND-+Geography+and+Climate.htm

Janson, Ulla. (2008). *Passive houses in Sweden: Experience from design and construction phase*. Licentiate Thesis, Division of Energy and Building design, Department of Architecture and Built Environment, Lund University, Faculty of Engineering LTH, 2008, Report EBD-T- -08/9

Kari, B. & Fayaz, R. (2006). Evaluation of the Iranian thermal building code. *Asian journal of civil engineering (Building and Housing), 7*(6), 675-684

Kats, G. (2003, October). *The Costs and Financial Benefits of Green Buildings*. California's Sustainable Building Taskforce Report. Retrieved on July 07, 2008 from: http://www.usgbc.org/Docs/News/News477.pdf

Kimmel, T.M., (2000, July) *Weather and climate Koppen climate classification flow chart*. Lecture on Studies in weather and climate on July, 03, 2000. University of Texas at Austin. Retrieved on August24, 2008 from:

http://www.utexas.edu/depts/grg/kimmel/GRG301K/grg301kkoppen.html

Law, J. (Ed.) (2006). *A Dictionary of Business and Management*. Oxford University Press, 2006. Ritrieved on August11, 2008 from:

http://www.oxfordreference.com.ludwig.lub.lu.se/views/ENTRY.html?subview=Main&entry=t18.e2957

Leal, V., Maldonado, E. (2008). The role of the PASLINK test cell in the modeling and integrated simulation of an innovative window. *Building and Environment, 43*(2008),217-227

Mazidi, M., Dehghani, A., Aghanajafi, C. (2007). The study of the airflow in wind towers for the old buildings air conditioning. *The 4th WSEAS International Conference on Fluid Mechanics, Gold Coast, Quinsland, Australia, January 17-19, 2007*

MED-ENEC (Energy efficiency in the construction sector in the Mediterranean): www.med-enec.com

Meir, I. A. (1998). Bioclimatic desert house: A critical review. *Environmentally friendly cities, proceedings of PLEA 98*, Lisbon, Portugal, June 1998, (pp. 245-248). James&James Science Publishers Ltd.

Minke, G. (2006). *Building with earth: Design and technology of a sustainable architecture*. Basel, Birkhauser.

Mor, A. & Seroussi, S. (2007, March). *Mediterranean and national strategies for sustainable development: Energy efficiency and renewable energy*. Israel national study working document. Retrieved on June 10, 2008 from: http://www.planbleu.org/publications/atelier_energie/IL_National_Study_Final.pdf

Mustafa Omer, A. (2008). Renewable building energy systems and passive human comfort solutions. *Renewable and sustainable energy reviews, 12*, 1562-1587.

Nelin, V. (2007). Israeli Standard 5281 – Buildings with Reduced Environmental Impact("Green Buildings")Environmental Technologies: *Alternative Energy and Waste Management International Workshop Rome, January 23rd, 2007*. Available from: http://www.heschel.org.il/fellows/files/Israeli%20Standard%205281.pdf

Occupational Safety & Health Administration (OSHA). (2003). *Computer workstations, workstation environment.* Retrieved on July30, from:

http://osha.gov/SLTC/etools/computerworkstations/wkstation_enviro.html#lighting

Ourghi, R., Al-Anzi, A. & Krarti, M. (2007) A simplified analysis method to predict the impact of shape on annual energy use for office building. *Energy conversion and management*, 48, 300-305

Passive-On Project. (2007, July). *The passivhaus standard in European warm climates: Design guidelines for comfortable low energy homes*. July 2007, Report available online at: http://www.passive-on.org/CD/1.%20Technical%20Guidelines/Part%201/Part%201%20-%20English.pdf

Pearlmutter, D., Rosenfeld, S. (2008). Performance analysis of a simple roof cooling system with irrigated soil and two shading alternatives. *Energy and Buildings,* 40, 855-864.

PEP (Promotion of European Passive houses) project. (2006). *Passive house solutions*. Intelligent Energy Europe program Report EIE/04/030/S07.39990, available online at: http://erg.ucd.ie/pep/pdf/Passive_House_Sol_English.pdf

Saberi, O., Saneei, P. & Hossini, S.M. (2004). *Public participation in energy efficiency culture: An experience and future trends*. The seventh Sharjah urban planning symposium, Sharjah, UAE

Saberi, O., Saneei, P. & Lankarani, M. (2006). *Tarahie sakhtemane behine az lahaze energy tebghe standardhaye jahani* [Designing energy efficient building according to international standards]. Retrieved from: http://www.aprs.ir/article/Lecture%20for%205th%2S0aberi-Saneei-Lankarani.mht

Saberi, O., Saneei, P. & Kenari, A. (2006, April). Tarahi va ejraie sakhtemene khorshidi ba bame sabz dar mantaghe dahe Tehran [Design and construction of solar building with green roof in region 10 of Tehran]. *The fifth conference on energy efficiency in building, April 25-26, 2006, Tehran, Iran*

Safarzadeh, H. & Bahadori, M.N. (2005). Passive cooling effects of courtyards. *Building and Environment*, 40, 89-104

Santamouris, M. & Farrou, I. (2007, November). *Work package 2: Classification of existing building ventilation technologies. Building Advent project report*, Retrieved on July 23, 2008 from:

http://www.buildingadvent.com/WP2_Advent%20D5D6_11_07.pdf

Sharag-Eldin, A. (1998). *Predicting natural ventilation in residential buildings in the context of urban environments*. Doctoral dissertation, Center for Environmental Design Research, University of California, Berkeley

Shaviv, E., Yezioro, A., Capeluto, I. G. (2001). Thermal mass and night ventilation as passive cooling design strategy. *Renewable Energy, 24*, 445-452.

Statistical Center of Iran. (2008a). *A glance at Iran*. Retrieved June,30 2008 from:

http://www.sci.org.ir/portal/faces/public/sci_en/sci_en.Glance

Statistical Center of Iran. (2008b). *Land and climate*. Retrieved August25, 2008 from:

http://www.sci.org.ir/portal/faces/public/sci_en/sci_en.Glance/sci_en.land

Tarabeah, H., Dwere, R. & Kimchie, S. (2005). *Energy saving architectural elements in the design and operation of the green building in the TAEQ-Sakhnin, Israel*. Report submitted to the Israeli Ministry of Environmental Protection.

Tavanir(Iran Power Generation, Transmission & Distribution of electricity management company). (2005).

Statistical publications. Retrieved on June 01, 2008 from:

http://www.tavanir.org.ir/info/stat84/sanatfhtml/s6.htm

Tehran municipality. (2008). *Tehran, Environment and geography*. Retrieved July 09, 2008 from: http://www.tehran.ir/Default.aspx?tabid=12508

Trauthwein, Ch. (Ed.) (2001). *Back to basic: Daylighting*. Retrieved on July31, 2008 from:

http://www.archlighting.com/industry-news.asp?sectionID=0&articleID=452166

Turner, C. & Frankel, M. (2008, March). *Energy performance of LEED for new construction buildings*. Report prepared for U.S Green Building Council

UK Department for environment, food and rural affairs. *Climate change: what is climate change?*. Retrieved on August24, 2008 from:

http://www.defra.gov.uk/environment/climatechange/about/index.htm

United Nation Environmental Programme (UNEP). (2007). *Assessment of policy instrument for reducing greenhouse gas emissions from buildings: Summary and recommendations*, UNEP and CEO, Retrieved on June 17, 2008 from: http://www.unep.org/pdf/policytoolbox.pdf

United Nations Framework Convention on Climate Change (UNFCCC). (2008). *About Clean Development Mechanism (CDM)*. Retrieved on September 8, 2008 from: http://cdm.unfccc.int/about/index.html

U.S.EPA (United States Environmental Protection Agency). (2008a). *Green building: frequent questions*. Retrieved on August 27, 2008 from: http://www.epa.gov/greenbuilding/pubs/faqs.htm#1

U.S.EPA (United States Environmental Protection Agency). (2008b). *Green building: basic information*. Retrieved on August 27, 2008 from: http://www.epa.gov/greenbuilding/pubs/about.htm

U.S.EPA (United States Environmental Protection Agency). (2008c). *Green building: funding opportunities*. Retrieved on August 27, 2008 from: http://www.epa.gov/greenbuilding/tools/funding.htm

U.S.EPA (United States Environmental Protection Agency). (2008d). *Heat island effect: basic information*. Retrieved on August 28, 2008 from: http://www.epa.gov/hiri/about/index.html

USGBC (United States Green Building Council). (2007a). *LEED for new construction reference guide*. Version 2.2, Retrieved on August13, 2008 from: http://www.usgbc.org/ShowFile.aspx?DocumentID=3179

USGBC (United States Green Building Council). (2007b). *LEED for new construction registered project checklist*. Version 2.2, Retrieved on August13, 2008 from:

http://www.usgbc.org/ShowFile.aspx?DocumentID=3998

USGBC (United States Green Building Council). (2008, January). *LEED for homes rating system*. Retrieved on August13, 2008 from:

http://www.usgbc.org/ShowFile.aspx?DocumentID=3638

Vainer, S. & Meir, I.A., (2005, May). Architects, clients and bioclimatic design: a solar neighborhood POE. *Passive and low energy cooling for the built environment (PALENC2005). Santorini, Greece*

Vakili-Ardebili, A. & Boussabaine, A.H. (2006, September), Quality concept in Persian precedent architecture: Alesson in eco-building design. *PLEA 2006, the 23rd conference on Passive and Low Energy Architecture, Geneva, Switzerland*

Vaturi, A. (2006, May). *Baseline Study MED-ENEC-Israel*, MED-ENEC Project Report PN: 55.3054.8-001.00 http://www.med-enec.com//docs/reports/Baseline%20Studies/ISR%20Baseline%20Study.pdf

Vaturi, A., Hirsch, M. (2006, June). *Energy Efficiency in the Construction Sector in the Mediterranean Market Analysis and Capacity Assessment- Israel*. MED-ENEC Project Report PN: 55.3054.8-001.00

http://www.med-enec.com//docs/reports/Market%20Studies/Market%20Study%20and%20Capacity%20Assessment%20-%20Israel.pdf

Von Hardenberg, J.G. (1982). Considerations of houses adapted to local climate – A Case Study of Iranian Houses in Yazd and Isfahan, *Energy and Buildings, 4*, 155-160.

Wall, M. (2006). Energy-efficient terrace houses in Sweden; Simulation and measurements. *Energy and buildings, 38*, 627-643.

World Bank. (2008, April). *2008 World development indicators database*, World Bank, Retrieved on June 20, 2008 from:

http://siteresources.worldbank.org/DATASTATISTICS/Resources/mna_wdi.pdf

World Business Council for Sustainable Development (WBCSD). (2007, October). *Energy efficiency in buildings:buisiness realities and opportunities*, Summary report, ISBN 978-3-940388-12-4

World Energy Council. (2008). *Energy efficiency policies around the world: Review and evaluation*. World Energy Council, London, www.worldenergy.org ISBN: 0 946121 30 3

Yaghoubi, M.A., Sabzevari, A. & Golneshan, A. (1991). Wind Towers: measurement and performance. *Solar Energy, 47* (2), 97-106.

Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BHRC	(Iranian) Building and Housing Research Center
CDM	Clean Development Mechanism
EEB	Energy Efficient Building
EVAPCOOL	A new direct evaporative cooling system
GHG	Greenhouse Gas
GMT	Greenwich Mean Time
HSE	Health and Safety Executive
IFCO	Iranian Fuel Conservation Company
IMS	Israel Meteorological Service
IPCC	Intergovernmental Panel on Climate Change
Iran DOE	Iran Environment Department
LEED	Leadership in Energy and Environmental Design
MED-ENEC	Energy efficiency in the construction sector in Mediterranean project
PDEC	Passive Downdraught Evaporative Cooling tower
PEP	Promotion of European Passive Houses Project
PLEA	Passive and Low Energy Architecture Organization
TAEQ	Towns Association for Environment Quality Organization (Agan Beit Natufa, Israel)
PV	Photovoltaic
U.S. EPA	United States Environmental Protection Agency
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGBC	United States Green Building Council
WEC	World Energy Council

Appendix 1: Interviewees

Person	*Function*	*Organization*	*Date*	*Type*[16]
Avraham Arbib, H.	Director of R&D Department	Ministry of national infrastructure, Israel	July14, 08	E
Ayatollahi, S.M.H.	Architect/ user	Yazd University, Iran	June16,08	P
Ayatollahi, S.M.H.			June17,08	E
Ayatollahi, S.M.H.			Aug.15,08	E
Bahadori, M.N.	Researcher/ Designer of passive cooling system	Sharif University, Iran	June16,08	P
Borhani, B.	User	Kar cultural center, Iran	July15,08	P
Dwere, R.	Architect	TAEQ, Israel	June25,08	E
Dwere, R.			July29,08	E
Emtairah, T.	Researcher	IIIEE, Sweden	May, 2008	F
Etzion, Y.	Architect/User/ Designer of Seasons window	Ben Gurion University, Israel	June17,08	P
Etzion, Y.			June19,08	E
Etzion, Y.			July1,08	E
Erell,E.	Designer of Seasons window	Ben Gurion University, Israel	June24,08	E
Farokhzad, M.	Architect	APRS, Iran	July12,08	E
Ford, B.	Designer of passive cooling systems	Nottingham University, UK	July16,08	E
Ghobadian, V.	Architect	Islamic Azad University,	June7,08	E

16

E: Email

F: Face-to-face

P: Phone call

		Dubai		
Ghobadian, V.			July,11,08	E
Golzari, N.	Architect	NG Architect, UK	June26,08	P
Heidarinejad, M.	Researcher	BHRC, Iran	June17,08	P
Hershgal, D.	Project manager	Intel, Israel	June25,08	E
Hershgal, D.			Aug.12,08	E
Javan, F.	Architect	MandegarAsman Consruction Co., Iran	June5,08	P
Kenari, A			July9,08	E
Kenari, A.	Expert	IFCO, Iran	July8,08	P
Kimchie, S.	Scientific manager	TAEQ, Israel	June13,08	E
Kimchie, S.			June30,08	E
Lankarani, M.	Expert	IFCO, Iran	June17,08	P
Loghmani, A.	Head of public affairs	IFCO, Iran	July1,08	E
Masoudifar	Architect	Amin Co., Iran	June17,08	P
Meir, I.A.	Architect/User	Ben Gurion University, Israel	June30,08	E
Meir, I.A.			July3,08	E
Mirzaei, M.	Expert	IFCO, Iran	June16,08	P
Mirzaei, M.			June17,08	E
Mirzaei, M.			June24,08	E
Olander, Y.	Director	Israel association for green building	Aug.17,08	E
Rahnama	Construction inspector	Construction Engineering Disciplinary Organization, Iran	June16,08	P
Rastgar, A.	Environmental expert	Tehran municipality, Iran	Aug.2,08	
Saberi, O.	Architect	WSP Energy, UK	July29,08	E
Saberi, O.			Aug.20,08	E

Segal, M.	Marketing	Alubin Co., Israel	July4,08	E
Segal, M.			July15,08	E
Schiano-Phan, R.	Designer	Nottingham University, UK	Aug.12,08	E
Tarabeah, H.	Manager	TAEQ, Israel	June12,08	E
Tayebian	Consultant	Mabna Co., Iran	June11,08	P
Tayebian			June23,08	E
Tayebian			June26,08	E
Wenzel, K.	Project manager	MED-ENEC, Tunisia	June5,08	P
Zarei, A.	Designer	EST Co., Iran	June16,08	P
Zarei, A.			June29,08	E
Zolfaghari, A.	Authority	Semnan municipality, Iran	June24,08	P
Zolfaghari, M.	User	Semnan, Iran	June26,08	P

Appendix 2: Examples of interview questions

- How much is the energy consumption per unit area of the most energy efficient residential/ office building prototype built by your institute/Company (Architects)?
- Have you ever designed any specific type of energy efficient buildings such as passive house, green building, etc. (Architects)?
- How did the designers and constructors get the required know-how and experience (Project managers)?
- Have you done any improvements regarding energy efficiency in your house (Architects/ users)?
- What strategies applied in your house do you think are not suitable to be applied today in a new house (Architects/ users)?
- Do you feel your experience and know-how have been properly transferred to the building sector (Architects)?
- What barriers do you think are hindering the development of energy efficient buildings in your country (General)?
- What drivers do you think are pushing the building industry to design and construct energy efficient buildings (General)?
- To what extent the product has been developed and used in the market (Energy efficient products designers and producers)?