Improvement of Thermal Comfort in Residential Buildings by Passive Solar Strategies Using Direct Gain Techniques

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Submitted to the
Institute of Graduate Studies and Research
in Partial Fulfillment Requirements of the Degree in

Master of Science
in
Architecture

Eastern Mediterranean University
September 2013
Gazimağusa, North Cyprus

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ABSTRACT

Sustainable environment and energy issues have been increasingly in demand in worldwide architecture over recent years. This subject has provoked the architects and developers to deal with renewable energy more and more. Sun as source of energy is clean, endless, as well as human is very familiar with it as daylight. In this regard, passive solar energy as a kind of solar energy can be used for buildings to take advantage of solar power. Moreover, progresses in passive solar technologies accelerate improvement of the building energy quality. To deal with ecological issues such a problem interconnection is required between human and its environment.

Housing not only is a place to meet the fundamental demands for shelter, but it also meets other demands related to provide sustainable life. Energy performance of residential buildings according to climatic changes may influence on the building and its environment. A building can be developed by taking advantages of environmental control or might be harmed by it.

Apart from all, technology developments in energy usage especially solar use; whether directly or indirectly, provide a ground to harness solar radiations in an easier and more applicable way. In one side, in the case of North Cyprus, considerable potential is seen in solar use and the relevant strategies. On the other side, trend of reducing the dependency trigger a great attention to exploit energy from sun like using solar collectors in North Cyprus as the most outstanding ones.

Passive solar energy exploited different sections of buildings through architectural design such as incorporating windows to invite solar light and heat or thermal mass as natural cooling and heating system. This study makes effort to demonstrate scarcities and defects of passive solar elements by surveying on a series of buildings along with discovering their potential areas on Salamis Road, Gazimağusa (Famagusta), North Cyprus. Ultimately, this study will clarify how energy consumption decreases by taking advantages of passive solar strategies result in thermal comfort and more efficient residential buildings as a main objective.

Keywords: Renewable energy, Energy consumption, Energy efficiency, Passive solar design**,** Thermal comfort

ÖZ

Son yıllarda, sürdürülebilir çevre ve enerji konuları, dünya çapında mimaride önemli bir konu haline gelmiştir. Bu konu, mimarların ve planlamacıların yenilenebilir enerji ile daha fazla ilgilenmelerine neden olmuştur. Bir kaynak olarak güneş, temiz, sınırsız ve gün ışığı nedeniyle insanların yakından tanıdığı bir kaynaktır. Bu bağlamda, bir tür güneş enerjisi olarak pasif güneş enerjisi, güneş enerjisinden yararlanmak amacıyla binalarda kullanılabilmektedir. Buna ek olarak, pasif güneş enerjisi teknolojilerindeki gelişmeler, binalardaki enerji kalitesindeki gelişimlerin hız kazanmasına da neden olmuştur. Ekolojik sorunlarla baş edebilmek için insan ve çevresi arasında bir arabağlantı kurulması gerekmektedir.

Konutlandırma barınacak bir yer ihtiyacını karşılamakla birlikte, sürdürülebilir bir yaşam için gereken diğer gereklilikleri de karşılamaktadır. Konut yapılarının enerji performansları, iklim değişikliklerine bağlı olarak bina ve binanın çevresini etkilemektedir. Binalar çevresel kontrolün ele alınmasıyla gelişim gösterebilir veya zarar görebilirler.

Bunlara ek olarak, başta güneş enerjisi olmak üzere, enerji kullanımı ile ilgili olan teknoloji gelişmeleri, güneş ışınımı için daha kolay ve uygulanabilir bir temel oluşturmaktadır. Bir açıdan, Kuzey Kıbrıs'ta güneş enerjisi kullanımı ve ilgili stratejiler konusunda, önemli bir potansiyel görülmektedir. Başka bir açıdan ise, bağımlılığı azaltma eğilimi, güneş kolektörü kullanımı başta olmak üzere Kuzey Kıbrıs'ta güneş enerjisinden yararlanmayı tetiklemektedir.

Mimari tasarım sayesinde, pencere dahil edilmesiyle ışık ve ısının içeriye girebilmesi veya doğal ısıtma-soğutma sistemi olarak termal kütlenin kullanılması, pasif güneş enerjisinden konutun farklı bölgelerinde yararlanılabildiğini göstermektedir. Bu çalışmanın amacı, Kuzey Kıbrıs'ın Gazimağusa şehrinde bulunan Salamis Yolu'ndaki binalarla anket yaparak pasif güneş enerjisi elementlerinin yetersizliklerini ve kusurlarını belirleyebilmektir. Son olarak, bu çalışma, pasif güneş enerji stratejilerinin doğru kullanılmasıyla enerji tüketiminin ne derece azaldığını ve bunun bir sonucu olarak ısıl komforun ve konut yapılarında daha elverişli koşulların sağlandığını gösterecektir.

Anahtar Sözcükler: Yenilenebilir enerji, enerji verimliliği, pasif güneş enerjisi tasarımı, ısıl komfor

ACKNOWLEDGEMENTS

Firstly, I would like to express gratefulness to my family for persuading me about higher educations and continuous support over my life. Besides, I also gratefully thank Prof. Masoud Mansouri who develop my interested in architecture and I had the great deal of fondest memories in my undergraduate educational periods with him.

In addition, I really appreciate Prof. Mesut B.Ozdeniz who is full-scale expert in environmental control issues for his useful suggestion and I was helped by him during interview. I also want to appreciate Assist.Prof.Dr. Harun Sevinç who opened the gates of solar energy to me for checking the manuscripts patiently, and for guiding me during all recent months.

I wish to thank Assoc. Prof. Dr. Yonca Hurol and Inst. Nicholas Wilkinson who taught me how to write an article during related course. I cannot forget the role Assoc. Prof. Dr. Mukkades Fasli for clarifying me the identity of architecture. Finally, I wish to appreciate the all the academic staff of Faculty of architecture at Eastern Mediterranean University for supporting me during my master education.

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INTRODUCTION

1.1 Research Introduction

Solar energy is vital to support life on earth in order to many variant factors. It is with regret seen that there are limited source of fossil fuels over the world and human use them in a very fast rate. Conversely, utilizing natural and renewable sources like sun has numerous benefits such as preventing global warming as most famous one. It proves an efficient way to respect environment as well. Indeed, preventative precautions should be applied to abandon fossil fuels that are non-renewable energy sources as a deleterious item about built environment and climatic changes (because of producing Carbon dioxide-CO_2).

From an ecological architecture viewpoint, building design should be tended to environmentally friendly. To be more specific, building design should guarantee that constructions and actions today would conserve future opportunities. It might be feasible by enhancing solar energy strategies and energy efficiency.

If we could not create a lasting change for our useless lifestyle and trend of diminishing energy consumption, the only possible way is to rely on sustainability for the future. Therefore, utilizing solar architecture will become a necessity. Currently, with progress of science and technology in the architectural world, it is beyond a simple new style in buildings. Its principles can be a basis of all buildings.

Technical and functional requirements of solar architecture combine with aesthetically satisfying concept presents an acceptable standard of building design in favor of present and future society. (Schittich, 2011, p.11)

In fact, Sustainability is a philosophy of design, a way for providing healthy living conditions and it contains all sciences and principals such as economic, social, culture, environmental and ecological approach. Renewable energy can be classified based on renewable energy sources such as wind, solar, bioenergy, geothermal hydro and hydrogen. Some are new in the world and have been used just in developed countries. Some have been used for a long time such as solar and wind. Solar energy is one of the world's fastest growing renewable energy sources and can be harnessed through different strategies. The simplest one in the case of residential buildings is solar radiations used through openings.

In this respect, as an important issue for designing sustainable, potential, availability and possibility of usage should be considered in order to organize energy plan for a location. To achieve desirable feedback, responsive passive energy design should be a main and basic sustainable development. On the other hand, energy management strikes a balance between logical energy demand and suitable energy supply. Furthermore, the process requires energy conservation, energy awareness and energy efficiency.

1.1.1 Energy Conservation

Energy conservation cannot be obtained only through building's operation; it includes urban planning consideration, energy of employed materials and materials, recyclability of buildings components and production techniques. As a sustainable strategy, timber are preferable to use in buildings compared to materials which only be produced by consuming energy generated from large amount of fossil fuels. (Schittich, 2011, p. 9)

1.1.2 Energy Efficiency

Energy efficiency for buildings means to reduce amount of energy needed to provide human comfort by using elements such as insulation and air-tight systems. To intend energy efficient factors it is crucial to control input energy by regulatory systems and/ or by passive technologies.

Previously, it needs so complicated equipment and depends on energy supply and regular functioning; however, today which is passive technology requires more interaction and knowledge by the users, and it therefore deals with human and environment factors, though it is simpler and more reliable technically. (Rosenlund, 2000, p. 4)

1.1.3 Low Energy Buildings

Nowadays, one of the admirable architects' efforts is to design and build residential building with the highest level of comfort index whereas they have minimum energy requirement for cooling, heating, lighting and etc. This effort and consideration along with maximum use of free energy, controlled fresh air by ventilation systems and suitable thermal insulation for minimizing heat loss lead them to achieve a low energy house design. Low energy buildings have a better energy performance than a building with standard and primary features. They also have been known as passive houses or eco-buildings.

To have a deep look, all the above items especially having maximum usage of free energy would be feasible through skillful design. A relevant example in this vein is maximum solar energy by maximum absorption and optimum energy transformation with solar panels as active solar approach.

1.1.4 Comparison of Different Kinds of Buildings in Terms of Energy

Generally, a low energy building consumes 50% of energy than a normal building. Based on the Ministry of Environment guidelines, calculated heat losses in planning of a low-energy building should be maximum 60% of the heat losses in a building with normal regulation. Thus, by designing a building on this principle, total energy consumption can be reduced up to half. Nevertheless, a passive solar building according to common definition does not require cooling and heating energy and energy consumptions in passive houses are less than low energy buildings.

It is possible also to create building with zero energy consumption as a Zero energy building produces at least the same amount of renewable energies than the consumed non-renewable energies in building. In addition, those buildings that produce more energy than they consume called plus energy buildings. (URL 10, 2011)

An energy efficient building requires minimum requirements of building regulations and it is economically rewarding. It needs 3-4% additional initial cost compared to the normal buildings; however, living and maintenance cost are less than normal buildings. For instance, insulating a building result in using less heating and cooling energy to maintain and acquire thermal comfort and good air quality of indoor spaces. Reducing energy use certainly reduces energy costs and may cause to a financial saving in favor of consumers.

1.1.5 Energy Transformation

Thus, a major consideration in this respect is energy transformation. It is necessary that one form of energy change to another one to energy in positive time period and with at least energy wasting (in the optimum way). Solar energy, which is free, clean and renewable energy as a source, would be transformed to electric and thermal energy as a produced energy, for cooling or heating demands according to seasonal periods and dwellers' metabolism requirements.

Similarly, controlled solar radiation by architects and through designing process conducts day lighting in a building. In another similar passive way, light transmission would be occurred in order by using appropriate material for a place. Then, it would prove fruitful to using renewable energy increasingly in contemporary society because future life guarantee by human's hands.

1.2 Why a Thesis about Passive Energy?

Although solar energy is considered to be a very environmentally friendly, free and endless source of energy, whose usage does not lead to the risk of global warming, there are still certain problems encountered as a result of lack of passive solar measures used in residential buildings.

There are various motivations to improve passive solar technologies and emphasis on sustainable buildings. Reducing of energy use causes to reduction of energy costs in favor of consumers and also decreases world's energy requirements and emissions of greenhouse gases in favor of livable environment.

The energy consumption is a significant issue in the third world countries. Nowadays, emerging countries are by far more dependent on fossil fuels such as gas, coal and oil than emergent countries. Regarding fossil fuels, it is hardly to be transferred and distributed throughout islands, remote and rural areas; it is not affordable in general. Consequently, producing renewable energy can be the best alternative in this respect.

In the case of North Cyprus (TRNC), the precautions for solar energy as active use is insufficient for buildings and it seems that it is not responsive alone. Meanwhile, as solar precautions in buildings, only solar panels exist for hot water supply in the majority of cases, there are no preparations for meeting other demands in the field of renewable energy use. The power cost is relatively high, because the amount of energy used for appliances and lights are large. Thus, passive solar energy precautions could facilitate living circumstances in this region as ecological solutions.

Passive solar energy strategies can create comfortable thermal space for humans, based on heat index and serve as energy saver for buildings. In Cyprus, because of climate conditions and lack of solar knowledge during the construction period, most of the residential buildings are not able to refuse solar energy in summer and distribute it as form of heat in winter efficiently; meantime, construction of buildings regardless of passive solar energy elements such as appropriate shading devices windows, thermal insulation, natural ventilation strategies and thermal mass is considered as a big problem. To sum up, following statements have been emerged for the case study problems:

(1) For buildings that are not adopted to climatic conditions, the amount of energy to run the cooling and heating systems are excessively high, and it will have a negative effect on environment.

(2) Deleterious environmental impacts caused by fossil fuel usage in the city such as oil and gas.

(3) Residential buildings are designed regardless of solar energy gain and renewable energy consumption. Hence, they have problem in distributing and refusing solar energy according seasonal climatic changes and it certainly will have a negative effect on human comfort.

1.3 Research Objective

Generally, this research seeks to unravel and tackle the various problems associated the lack of passive solar technologies and/ or improper usage of energy in buildings.

Furthermore, this study aims to analyze residential building energy performance focused on passive solar use; the analysis highlights fundamental passive solar measures and solutions for residential buildings. Meanwhile, it is crucial not only to assess the efficiency of certain components of the residential buildings, but also the efficiency of the cooling and heating systems. Thus, the objectives are to:

(1) Determine in which strategies thermal comfort can be improved by using passive solar energy as sustainable strategy.

(2) Define a standardized methodology for passive energy use towards to optimize building performance

(3) Evaluate the auxiliary energy source for heating and cooling spaces in a whole system (building)

(4) Analyze quality of energy efficiency in terms of seasonal performance

(5) Determine energy sources for heating, cooling, lighting and ventilation demands in terms of the best energy conservation efficiency

(6) Raise public awareness about solar building design, by considering passive measures.

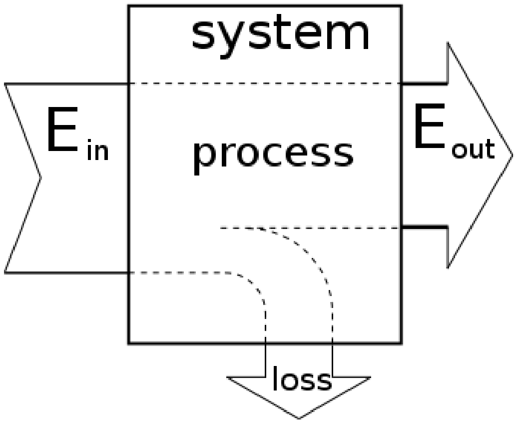


Figure 1.1: Energy Conservation in Building Envelop Diagram (Illustration drawn by author)

To sum up, main goal is to create optimum comfort in residential buildings, both in summer and winter, with as little energy consumption as possible with regard to environmental passive factors, via the use of solar energy as a natural source.

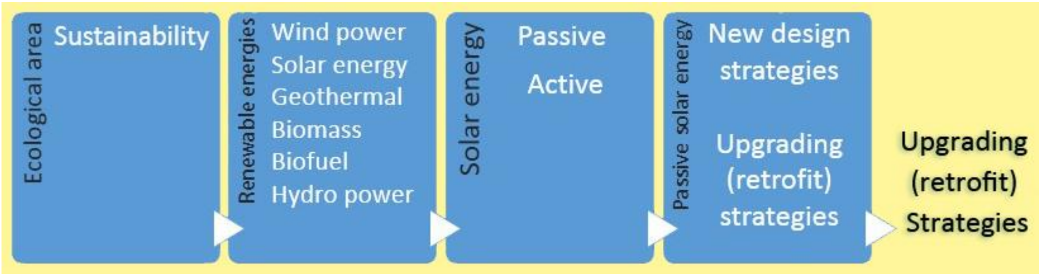


Figure 1.2: Research Process (Illustration drawn by author)

1.4 Gazimağusa Famagusta Town in Northern Cyprus

Cyprus situated at 35° N latitude of the equator and 34° E longitude is the 3_{rd} largest island in the Mediterranean Sea after Sardinia and Sicily. Furthermore, it has 65 km distance with Turkey, 750km from Greece, 350 km from Egypt, and 95 from Syria. Geographically, there are two main mountains known as Besparmark and Trodos, which are situated on the northern part and in the middle part of the island respectively. Nevertheless, city of Gazimağusa (Famagusta) is a coastal town at the eastern part of Cyprus with 7m elevation above sea level. (Ozay, 2005)

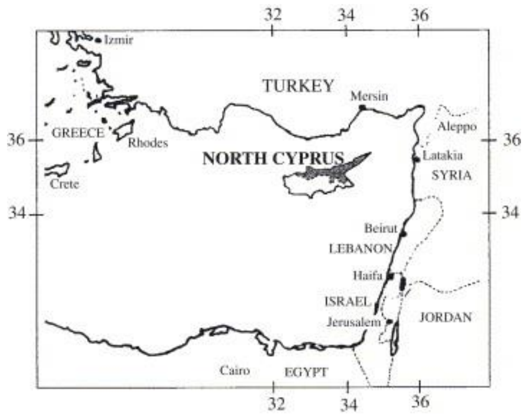


Figure 1.3: Map of Cyprus (Illustration taken from Ozay (2005))

Gazimağusa (Famagusta) is one of the fast growing cities recognized as an upturn in favor of North Cyprus development with a historic core and a harbor. Actually, with the advent of University (EMU) at 1979 trend of city development have been increased, so that it has been one of the migration destination especially for students. Gazimağusa (Famagusta) is full of great medieval architecture examples. Besides, according to 2006 census, the population of city is 42,526 (URL1, used on 08.04.2013).

Figure 1.4: Location of Gazimağusa (Famagusta) in North Cyprus (Edited by author. Illustration taken from URL: http://en.wikipedia.org/wiki/File:Cyprus_location_map.svg)

1.4.1 Cyprus Solar Energy

5kWh/m2 solar radiation and the average of 9 hours sunny period (range from 5.5 to 12.5 hours daily) offer almost high potential in solar energy use for buildings (Soteris, 2003). Apart from that, July and August as hottest months reach a peak showing highest average temperature of 36 C° and 8.1 kWh/m2 radiations; by the way of contrast, coldest periods occurs for December and January accounted for radiation of approximately 2.3kWh/m2. In other words, according to Atalar's thesis of 2001 (a 4-year period research) Gazimağusa (Famagusta) town represents the most desirable solar rays and radiations among other cities in North Cyprus such as Ercan and Guzelyurt. Gazimağusa (Famagusta) receives more than 3.84 kWh/m2 solar energy and just in January and December (less than 5% of all occasion) the radiations represent just below 1.92kWh/m2.

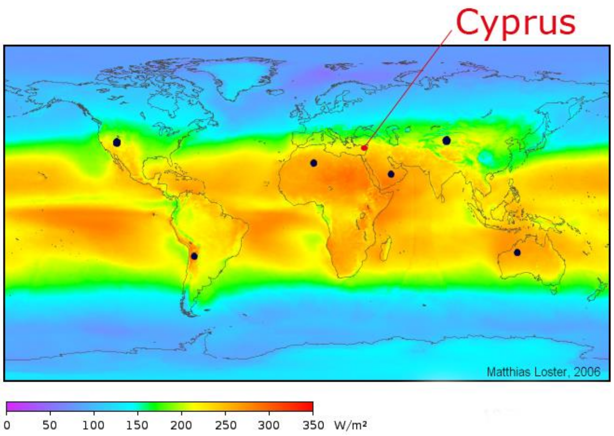


Figure 1.5: Cyprus Situation Based on Solar Land Use (Edited by author. Illustration taken from URL: http://en.wikipedia.org/wiki/File:Solar_land_area.png)

Figure 1.6: Average Monthly Hours of Sunshine over the Year in Gazimağusa (Famagusta) (Illustration taken from URL: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2013))

The figure 1.6 shows the average insolation land area and solar areas shown with black dots could supply more than world's total primary energy requirements. The different shades of colors show the average local solar irradiance taken with weather satellites. It appears that Cyprus can be taken into account as one of proven solar lands with great potential.

In addition, the trace of political issues can be seen in the usage of wide-spread solar hot water collectors to emphasize high potential of the solar energy in North Cyprus particularly in Gazimağusa (Famagusta). When Cyprus was divided into two parts after 20th of July 1974, refugees as one-third of the population settled in temporary homes; hence, the beginning of an important evolution in construction started. Consequently, a sudden upsurge of energy supply and demand imposed an emergency reaction for politician, which happened mostly as to solar hot water collectors. In the most part, banks were obliged to provide loans and facilities for developers, clients and land owners in order to accelerate trend of construction (Korniotis, G. 1999). Thus, the great potential of solar energy use along with political matters flourished widespread usage of solar collectors.

1.4.2 Climatic data at a glance

Initially, Cyprus does not have a definite climate. Furthermore, Cyprus climate in terms of architectural approaches can be described as both hot-humid climate and composite. Moreover, Gazimağusa (Famagusta) city possesses hot-dry summers along with rainy winters in general. Apart from that, the prevailing wind belongs to west direction and there are very high relative humidity levels during the nights and early in the day (Ozay, 2005). (Figures 1.7, 1.8, 1.9 and 1.10) (URL2, used on 23.03.2013)

Figure 1.7: Average Minimum and Maximum Temperature over the Year in Gazimağusa (Famagusta) (Illustration taken from URL: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2013))

Figure 1.8: Average Humidity over the Year in Famagusta (Illustration taken from URL: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2013))

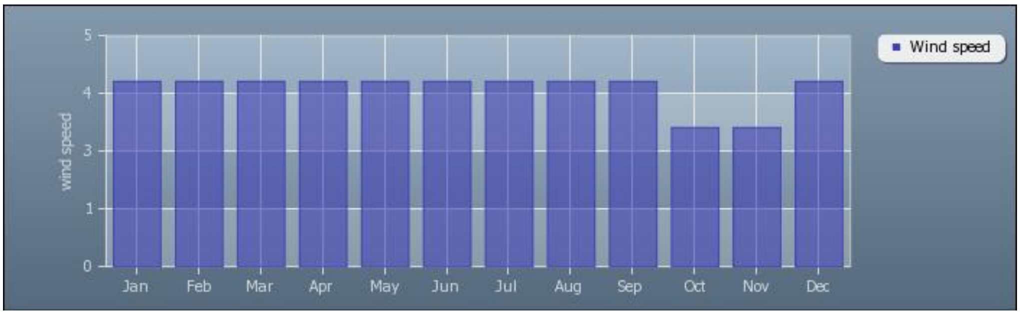


Figure 1.9: Average Wind Speed over the Year (m/s) (Illustration taken from URL: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2013))

Figure 1.10: Average Monthly Precipitation Including: Rain, Snow, Hail and etc. (Illustration taken from URL: http://www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Famagusta,Cyprus, (2013))

1.4.3 Situation of Salamis's Road as Field Study

The research investigates quality of the passive solar energy use in residential buildings at northern part of Salamis Road, Gazimağusa (Famagusta), North Cyprus. Indeed, it stretches from Eastern Mediterranean University to Gulseren junction for limitation of field study. Moreover, the street can be considered as a connection between EMU University and main nodes of the city. The Salamis road is arguably the most famous street and one of the most expensive strips of real estate in Gazimağusa (Famagusta). The street runs for 1.3 km and 12 meters wide (according to Google map scale).

Figure 1.11: Field Study which is Restricted between Eastern Mediterranean University and Gulseren Junction (Illustration taken from Oktay, Jalalaldini (2011))

It accommodates diverse uses and functions along this street such as commercial, recreational and service functions, so that variety of activities such as cafes, clothing stores, supermarkets, pharmacies, electronic stores and betting clubs are located at the ground floor of mixed-used buildings (Oktay, 2011, p. 668).

The street has been developed over 15 years. It was previously outside the city to link Gazimağusa (Famagusta) to Karpaz region. The street has not been designed and planned as public spaces and it does not follow any distinguished master plan as well. (Oktay, 2011, p. 669)

The problems	Level of the problem	Percentage of people suffering from this problem
Inefficient sidewalks	High	96.6
Lack of bicycle path	High	72.4
Lack of public transportation facilities	Medium-high	62.1
Poor quality of architecture and lack of magnet building	Medium	51.7
Lack of street lighting	Medium	51.7
High speed traffic	Medium	48.3
Pollution and dirt	Medium	41.4
Lack of spaces for gathering outdoors	Medium	41.4

Figure 1.12: Existing Problems of Salamis Road as Field Study (Illustration taken from Oktay (2011))

To be more specific, field study is located in low-density part of city developed with improper land use. It is with regret seen that buildings have been designed on street layout with lack of sustainable urban growth management. Problems appear in mixed used strategies instead of developing public spaces and building's compactness. Anyway, aforementioned district can be recognized as new suburban development area or major sprawling developments which mostly have been developed to accommodate students, their recreational requirements and to justify the role of the university and city growth (Oktay, 2007).

Figure 1.13: Left: Residential Buildings Close to University and Vividness of Street / Right: Street View Close to Gulseren Junction and Vividness of Street (Photos taken by author)

Figure 1.14: Salamis Street Has Mixed-used Functions and It Is the Center of Recreational Area in the City (Photo taken by author)

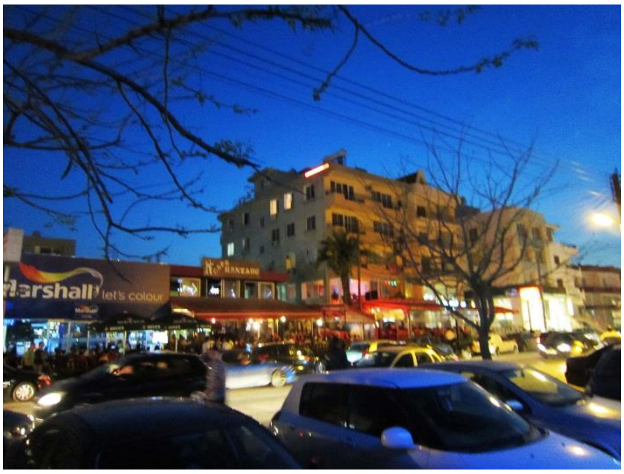


Figure 1.15: Vibrant life in nighttime, Salamis Street (Photo taken by author)

Chapter 2

DEFINITIONS AND BASIC PRINCIPLES

2.1 A Growing Demand for Energy

Population and economics increase result in boosting energy demand. From 1971 to 2004, energy consumption in world increased to 87%. It would appear that the annual average growth rate of the total energy consumption was 1.9%. About 43% of this growth allocated to third world countries with 4.1% annual average growth rates nearly more than twice global growth. Explosion of energy consumption leads third world countries toward environmental sustainability (Hong, 2007, pp.8-9).

The indiscriminate growth of buildings in global scale leaves significant outcomes for global energy use. Heating and cooling the buildings today account for high amount of energy consumption. Creating standard living spaces is the second contributor for the increase of energy demand (Rosenlund, 2000, p.4).

Energy consumption has become an urgent issue around the world, that countries can no longer neglect. It would prove irreparable consequences regarding environmental damage and contamination. To tackle such a problem, a global movement should be taken to substitute fossil fuel and turn to sustainable growth (Hong, 2007, pp.5-6).

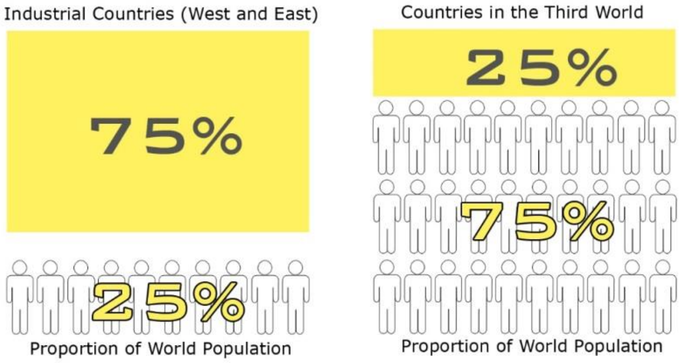


Figure 2.1: Unequal Consumption of World Energy (Illustration taken from Behling (1996))

Renewable energies gradually have become popular among all human generations. Obviously, Figure 2.2 has been provided on the proportion of energy consumption via different energy sources over 2010 in the world. 16.7% of total energy consumption belongs to renewable energy. Accordingly, it can substitute for fossil fuels in future years. Meanwhile, solar energy represented around 0.9%. Surprisingly, a dramatic rise occurred when it comes to solar sources reaching 74% and 37% annual growth rates as pioneered renewable energy compared to the other energy sources at 2011 (Figure 2.3) (Sawin, 2012, pp.21-22).

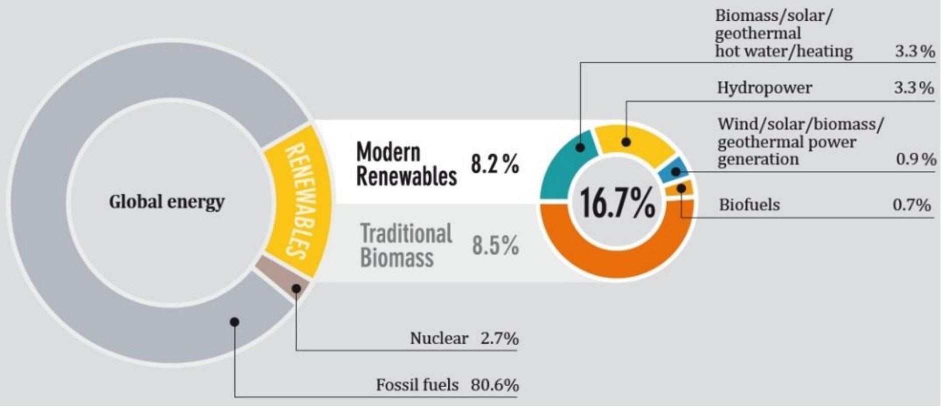


Figure 2.2: Renewable Energy Share from World's Energy Consumption (Illustration taken from Sawin (2012) p.21)

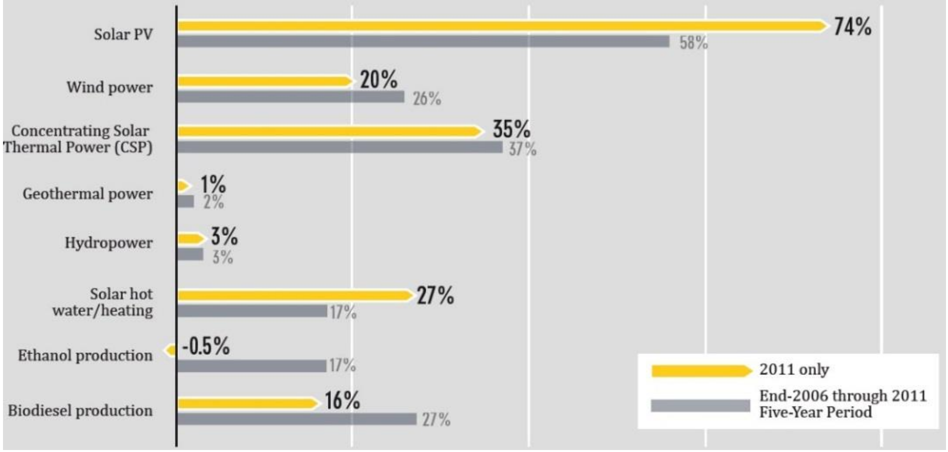


Figure 2.3: Average Annual Growth Rates of Different Renewable Energy Capacity and Biofuels Productions (Illustration taken from Sawin (2012) p.22)

2.2 Importance of Residential Buildings Related to Energy Efficiency

Admittedly, one of the largest energy consumers in the world are buildings, accounted for approximately 30% of all energy use. In addition, it is seen with regret that they emit greenhouse gas with similar amount. Certainly, residential buildings are the main contributor for climate changes and they will impress energy consumption patterns and climatic issues for many upcoming years.

Upgrading buildings and improvements are undoubtedly the most cost-effectiveness way to diminish amount of energy usage and greenhouse gas emissions. When The

McKinsey Global Institute, the center of energy efficiency studies, investigates energy efficiency issues based on a worldwide survey, they estimate four of the five ecological items to reduce greenhouse gas emissions are related to buildings energy efficiency (The measures such as building's lighting system, insulation, air conditioning, water heating). The only non-building item is improved efficiency for commercial vehicles (Hong, 2007, pp. 2-5).

On the other hand, nearly all of diverse effect of buildings can be avoided by sustainable design and accordingly passive solar design would prove effective for this approach. Often, in buildings, dealing with renewable energies, productivity has increased, health has improved and human comfort has obtained.

People spend most of daily life in their residential buildings. So well designed and renewable energy-generated building is important in order to respect to human life. If a power cut happens; residents will encounter real dangers in hot summer or in cold winter times. Apart from that, they may also suffer by poor air quality. The reason is that they are rarely perfect in installation and maintenance.

People can improve the quality of life via considering well-designed and well-constructed buildings in which mechanical cooling and heating, artificial lighting and ventilation systems requirements are minimized. In some cases, even a properly-orientated building contributes to large amount of energy with no financial cost because it allows natural ventilation and lighting to benefit the buildings. (Bainbridge, 2011, pp. v-viii)

2.2.1 Sustainable Development of the Existing Buildings in Comparison to New Design

It is by far more cost-effective to consider energy efficiency parameters over design process in comparison to retrofit and change an existing building, because new buildings are more flexible in all their construction stages. To achieve the success, the most of developers who place emphasis on energy performance of new buildings seriously are integrating passive solar energy technologies to approach thermal comfort and to improve energy efficiency (Richarz, 2007, p.10).

Regarding both new and existing building, it would definitely work to consider building's components and systems. To have a deeper look, it hugely influences on enhancing or degrading energy efficiency. A major component in determining building's energy use is the building envelope. It includes parts of a building in separating of indoor and outdoor spaces such as doors, walls, thermal insulations, roofs and windows.

For instance, the penetration of solar radiation as daylight for the spaces without glare and heat might be achieved by integration of window strategies and design approaches in the building envelope (Hong, 2007, pp. 33-37).

Energy management is a main factor of energy efficiency for existing buildings. In the case of designing new buildings, clients via human-educating systems can be convinced about advantages of energy efficient building for a long term and also developers can be aware of energy saving fruitful outcomes; yet, energy consumption of existing building stocks in comparison to new buildings are roughly high (Hong, 2007, pp. 47-48).

Passive solar strategies would prove helpful to upgrade buildings that have been ignored living standard requirements and sustainable aims. For the old buildings the heating requirement is almost 200 KWh/m^{2}a, for the sake of poorly insulated envelop surfaces, that results in high transmission of heat losses; however, new buildings in accordance with energy conservation utilizing standard installations and thermal insulation can bring down the heating requirement to 80 KWh/m^{2}a. Finally, the minimum energy requirements (15 KWh/m^{2}a) occurred for passive-energy buildings considering passive technologies such as ventilation and heat recovery systems (Clemens, 2007, pp. 10-18).

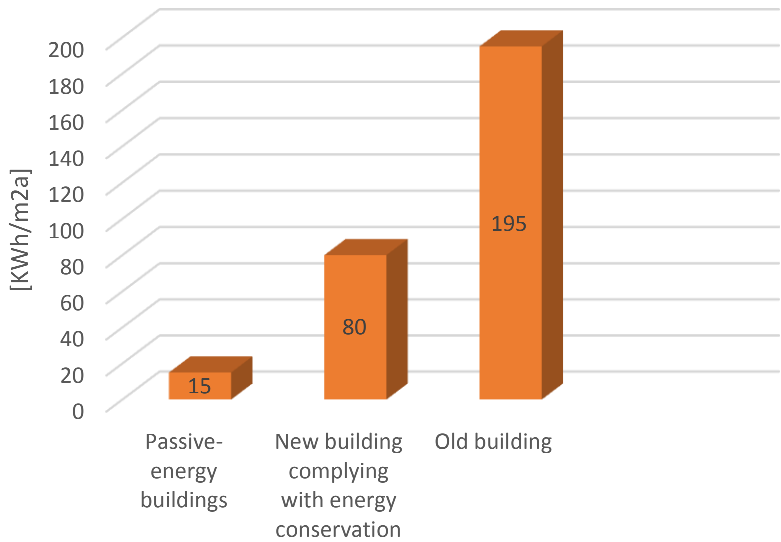


Figure 2.4: Importance of Passive Energy Developments for Heating Requirements (Illustration taken from Clemens (2007))

2.2.2 Refurbishment and Upgrading of Buildings

Generally, building's refurbishment comprises repair, maintenance and restoration a major part of construction activity. On the one hand, building's owner and developers attempted to release the potential of old and obsolete buildings in recent years. On the other hand, there is a growing attitude of conservation advantages and recycling of resources. Hence, a sustainable way of existing building has been developed to reduce fossil fuels demand and carbon dioxide emission (Gorse, 2009, p. 1).

One of the greatest challenge encountering designers is survey on the actual situation of buildings. Because, it will harvest basis knowledge about buildings for architects. Besides, sustainable refurbishment and living standard should be improved in buildings so that guarantee the healthy living space and other demands and of current and future inhabitants.

Renewal of installation and the applying renewable energy can make a great reduction in energy consumption (up to 95%) in an energy efficiency system of upgrading building. For example, by changing glass of old windows with improved or coated glass, it may result in thermal comfort passively (Richarz, 2007, p.21).

If the sustainability continues to gain its importance, it is to be expected that financial benefits and healthy environment will be obtained via upgrading building in the future. Meantime, the majority of deleterious effect on environment comes out of existing usual buildings and has become the increasing global concern. In this regard, defects and harmful parts of buildings substitute components of much more efficient. A helpful way to improve existing building absolutely is the application of passive solar elements, because these installations of buildings can take advantages of renewable energies like solar energy (Gorse, 2009, pp. 3-4).

2.3 Solar Energy as a Matter of Sustainable Energy

Sustainability has become a dominant issue in the debate on buildings and architecture in recent years. Undoubtedly, main characteristic of sustainable architecture is the consideration of solar radiation and the passive solar use in buildings. On other words, it is the correct treatment of environment and responsibility of buildings for a long lifespan (Schittich, 2011, p. 13).

Based on United Nation's Conference in 1994 on climatic issues, sustainability is defined as “ability to meet the needs of present without compromising the needs of future generations” (Bainbridge, 2011, p. 1). Thus, human activities should be interconnected environment to approach sustainable living space. Indeed, detailed analyzing of site opportunities, orientation and microclimate prove the basic steps to design solar buildings in a sustainable way.

Since the sun overshadow all aspects of the climate, it proves logical to build and develop solar buildings for humans. Meantime, it is clear that energy conservation and the intelligent usage of solar radiation can play a constructive role in sustainable building. People are also familiar with solar energy as a matter of light and energy (Schittich, 2011, p. 13).

Despite the many advantages of solar energy use, aforementioned system like other useful systems has its disadvantages. In summary, following items are some of the most important disadvantages of solar energy use:

High initial cost: Applying solar elements result in reducing power costs. Reduction of power cost will compensates for the building's owner financially over the years; however, the primary cost of equipment and upgrading might be high in some cases.

Location: Location can limit or enhance a solar system. Thanks to dependence of solar systems on daylight, it is mandatory to consider the best location orientated to take advantage of solar gain.

Practical consideration: supportive requirements and spaces to accommodate solar systems are one of the major disadvantages for building owners and technicians (URL5, 2013).

Solar energy can be used and offered in two different ways (accurate definitions of different kinds of solar use and have explained in upcoming titles):

- Passive solar energy
- Active solar energy

2.3.1 Passive Solar Energy Strategies

Passive use of solar energy was the only available source prior to beginning of the fossil fuels age. Buildings had been designed to take advantages of solar gain entirely without any intermediate contributor. To maintain building's thermal comfort, passive solar strategies have been adopted into building taking advantage of natural energy flows. These strategies attempt to trap and store solar energy as a form of heat in winter, and exclude sun and increase cool air movement in summer (Smith, 2001, Chapter 4, p. 45).

Figure 2.5 illustrates possible reductions in temperature fluctuations achieving with optimum use of passive solar opportunities. For instance, if buildings are well situated according to the orientation and climate conditions; further improvements in thermal comfort derived from the best usage of passive strategies (Hancock, 1999, p. 6).

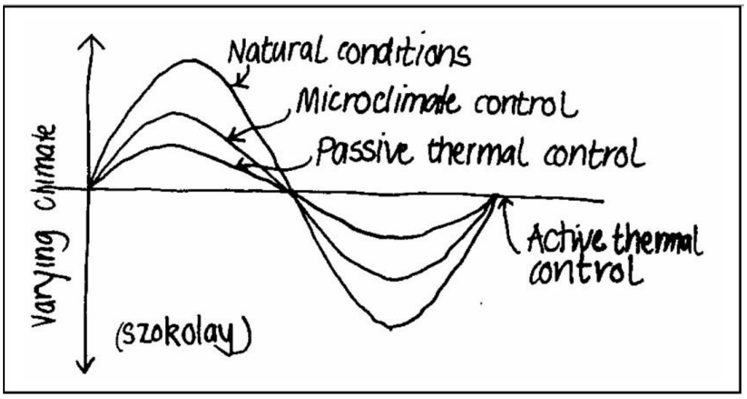


Figure 2.5: Diagram of Passive Strategies and the Relationship with Climatic Conditions of Location (Illustration taken from Szokolay (1980), Environmental Science Handbook for Architects and Builders)

The passive solar energy through cost-efficiency tries to make a building sustainable. In this circuit and approach, energy from sun is collected, stored and distributed for the entire building without interposition of technical systems. In fact, the building itself takes advantage of solar direct use by considerations including geometry, placement, buildings elements and components. This is the simplest and the most effective form of solar architecture, in which building's components work such a solar system (Schittich, 2011, pp. 13-14).

Generally the concept and principles of passive solar use in the case of residential buildings can be summarized under following items:

- Minimization of the surfaces in order to prevent undesired transmission heat loss as low as possible (A/V-ratio).
- Orientation of warm rooms and spaces to the south side and cool ones to the north side (Solar Zoning).
- Utilization of heat storage (thermal mass) in order to compensate the indoor temperatures.

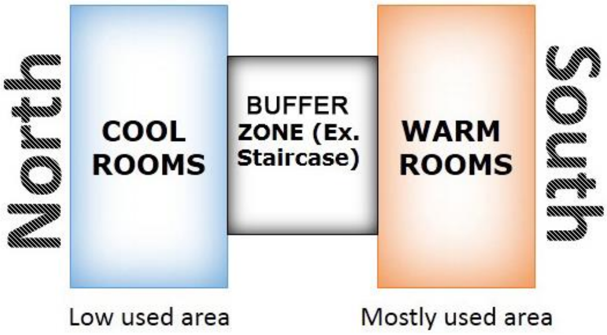


Figure 2.6: Zoning (Division of Warm and Cool Area in Terms of Sun Orientation) Is a Beneficial Way of Solar Energy Gain (Illustration drawn by author)

- Protection against high solar altitude in summer by using of selective shading devices.

Passive solar energy strategies can be classified in three vast categories in terms of design techniques. In this study, author's focus is more on direct gain in which solar radiation penetrates directly into the building's indoor spaces.

Passive solar heating techniques generally fall into one of three categories: direct gain, indirect gain, and isolated gain. Direct gain is solar radiation that directly penetrates, and is stored in, the living space. Indirect gain technology collects, stores, and distributes solar radiation using some thermal storage material (e.g., Trombé wall). Conduction, radiation, or convection then transfers the energy indoors. Isolated gain systems (e.g., sunspace) collect solar radiation in an area that can be selectively closed off or opened to the rest of the house. Hence, in direct gain, architects try to incorporate glazing on the sun-facing surface (Smith, 2001, Chapter 4, p. 46-47):

- Direct gain
- Indirect gain
- Attached sunspace or conservatory (isolated gain)

A complete passive solar design encompasses five steps. These steps are related to direct gain and each of them has different performances. Nevertheless, all the items must work together to achieve a successful passive solar building. These five steps are listed below in terms of priority:

1. <u>Aperture (collector):</u> It is about using of large glass areas as collector of solar energy and it should not be shaded via other buildings during sunny times.
2. <u>Absorber:</u> In which wall, floor, or any other dark surfaces can be used as absorber. Sunlight hits the absorber in which energy is absorbed as heat.
3. <u>Thermal mass:</u> Materials that store heat from sunshine can be presumed as thermal mass. An absorber is an exposed surface; however, materials as thermal mass are located below or behind the surfaces.
4. <u>Distribution:</u> It is a main method which delivers solar energy from storage points to all indoor spaces.
5. <u>Control:</u> Every successful system should be controlled carefully. In this regard, an overhang for aperture area can act as controller for optimum solar gain as well as operable vents, damper or low emissivity blinds allowing or restricting heat flow (Torcellini, 2011, pp. 2-3).

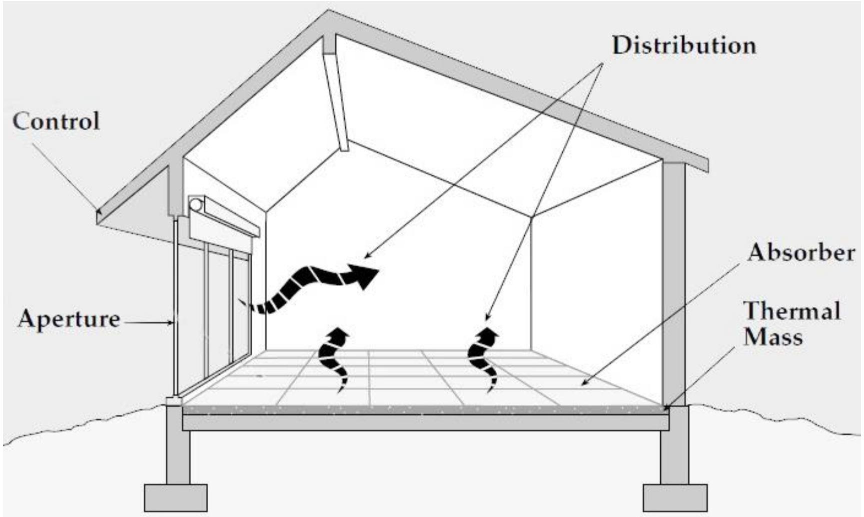


Figure 2.7: Five Elements in an Entire Passive Solar System (Illustration taken from Torrcellini (2011))

There are some techniques and elements related to passive solar design facilitating investigation and discussion of building's performance. In this study, following main elements have been discussed in the framework of passive solar architecture for the sake of analyzing case study (these elements have selected in terms of investigating existing buildings and direct gain systems):

- Site location
- Area to volume ratio
- Openings (windows)
- Shading devices
- Thermal insulation
- Thermal mass

2.3.1.1 Site Location

To understand how to design a building in a specific site location, it is necessary to realize where sun's position accurately. Clearly, the earth is motionless as well as the sun as source of renewable energy is continuously in orbital movement around the earth. As figure 2.8 shows the sun's position in northern hemisphere is shown (+) and conversely in southern hemisphere is shown (-), on the 20th day of each month. The highest sun's angle occurred in three months over the summer for northern hemisphere, then by passing quickly via autumn it moves towards winter, where it reaches the lowest sun's angle about other three months.

Thereby, a very significant factor for consideration of solar energy in planning and designing of building, is realizing of accurate sun's angle and position. In fact, this factor is very important to locate buildings, arrangements of interior rooms, windows, shading devices as well as greenery (Mazria, 1979, p. 267).

20th of	Degrees
JAN	-20
FEB	-11
MAR	0
APR	11
MAY	20
JUN	23
JUL	21
AUG	13
SEP	1
OCT	-10
NOV	-20
DEC	-23

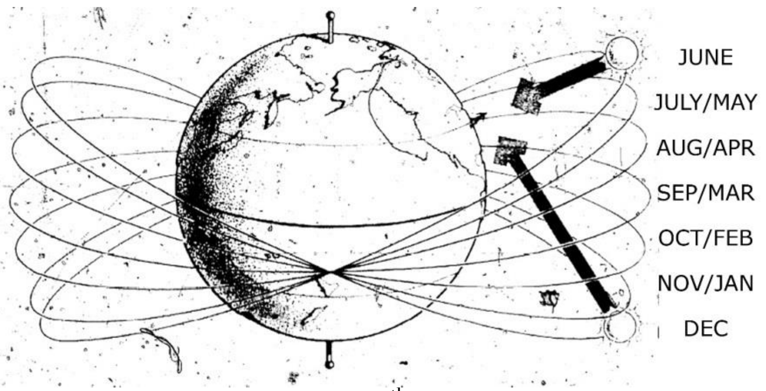


Figure 2.8: The Sun's Position Appearing on the 20th Day of Each Month (Illustration taken from Mazria (1979))

To achieve optimum solar design, site opportunities and climate conditions should be evaluated precisely. The energy derived from the sun falling onto the earth's surface during finite period of time is called "insolation". Based on figure 2.9, the inverse relationship between insolation and heating requirement oblige architects to consider seasonal energy storage. Excess heat can be stored in summer to provide heating in winter as an efficient alternative.

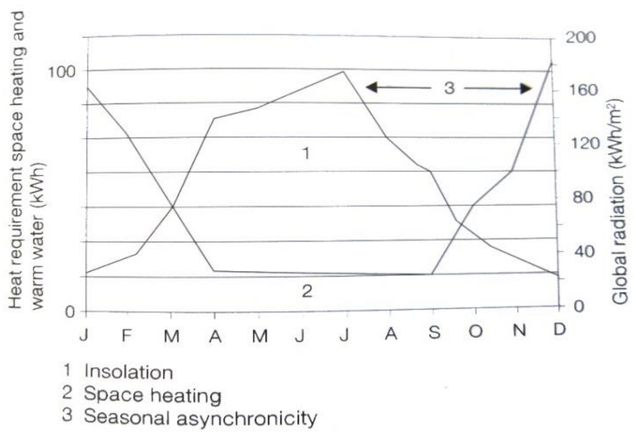


Figure 2.9: The Inverse Relationship between Insolation and Heating Requirement at the Same Time (Illustration taken from Schittich (2011), P. 43)

Firstly, the research on the site location is inextricably connected on insolation along with local microclimate, such as reverse wind flows, morning or night fog. As an example, it is necessary to mention that in the recent months of winter, night fog sometimes happens for Gazimağusa (Famagusta), North Cyprus. Besides, building's orientation is one of the passive solar strategies based upon solar heat gain which can be considered in the residential building site analysis. Other physical passive elements in design encompass roof slope, appropriate overhang providing shading, south-faced openings (Galloway, 2004, chapter 2, pp. 15-17).

To have deeper look, the most important strategies are related to potential of given site based upon natural sources such as wind, geothermal heat and solar energy along with climatic conditions that should be harnessed for distinguished buildings and then reflected in design process especially building form, volume and layout. Indeed, these strategies specify the impact of site situation on designing and applying building elements related to passive use. Generally, the building and construction development patterns are in a mutual connection with the appendix items:

- Climatic conditions of location

- The exposure rate of all surfaces related to building design especially open surfaces.

- Conditions of existing site surrounding such as geometry, volume and distance of neighbor buildings.

- The potential of given site to use the solar energy as strategies and possibilities for thermal storage.

- Human and environmental interactions during solar design.

- Situation of existing site according to architectural heritage of the location. (Herzog, 1996, p. 3**)**

2.3.1.2 Area to Volume Ratio (Compactness)

Designing building surfaces (envelope) as effective wind protection and insulation as well as optimum utilization of solar radiation and natural light are almost non-economic and elaborate. Indeed, ecological design and economy are closely linked together. One helpful and effective value in designing optimized building form is the so-called A/V-ratio. Sign (A) determines the area of the building envelope (heat-radiating surfaces) and (V) is the building's volume; thus, a low A/V-ratio in needed to save costs and energy (Smeds, 2006, p. 274).

Since a sphere with possessing the best A/V-ratio cannot be used as building form due to planning problems, the half sphere has become an ideal shape for building from. Human beings in cold regions prefer to design igloo in order to have optimum A/V-ratio as well (Figure 2.10).

Figure 2.10: An Igloo Has a Suitable A/V-Ratio (Illustration taken from URL: http://www.montserratvolcano.org/merapi%202.htm)

Consequently, geometry of buildings should not be ignored by architects in all design phases. To clarify A/V-ratio in majority of existing cases, when building volume increases in compact forms, accordingly, transmission of heat loss decreases because of the diminished surface area. Therefore, compact and large forms are preferable in comparison to small and free-standing buildings, because they have less A/V-ratio (Schittich, 2011, pp. 17-18).

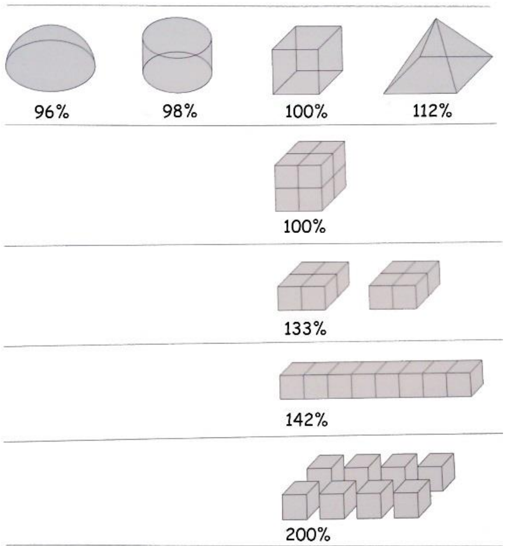


Figure 2.11: Area to Volume Ratio in Terms of Different Shapes and Forms (Illustration taken from Schittich (2011))

2.3.1.3 Window Options for Passive Solar Energy Gain

The openings of buildings offer both opportunities (benefits) and at the same time, risks for passive solar design. The reason is that the openings considerably can be as an energy supplier for a building. Conversely, they can be as a main source of overheating or heat loss causing to diminish the human comfort levels (Schittich, 2011, p. 20).

Windows play a significant role not only in transmission of sunlight, but also solar heating via building envelope and indoor air movements. Nowadays, manufacturers have produced improved windows in order to convenience of users and optimum energy performance. Mainly, the window specification and performance determine through its U-values and SHGS.

- U-value: Thermal transmittance is determined by U-value. Therefore, smaller U-value demonstrates higher level of insulation performance. One of the main goals of appropriate windows is to reduce heat transmission between indoor and outdoor of building envelope. The U-value amount less than 4 $W/m^2/^oC$ is proved as an energy efficiency standard.

- SHGC: Solar heat gain coefficient (SHGC) is a value of glass's transmittance. SHGC is a decimal number and less than one. For example a number of 0 .70 determines 70% of solar radiant have passed from windows and 30% of them have rejected. Hence, a passive solar building requires windows with high value of SHGC. SHGC is also known as g-value and shows the total solar energy transmittance. Therefore east and west façade should incorporate windows with low SHGC (less than 0.40), whereas south-facing windows need high value of SHGC along with shading devices to offer optimum solar gain.

- Low-e coating windows: The letter "E" is abbreviation of emissivity. It is a determinant of high performance and thermally insulated windows .This kind of window is considered to use for cold climates, because it reflects the heat into the indoor spaces. In fact, at least a pane has coated with a thin silver material to increase the reflectance (Wilson, 2004, pp. 1-8).

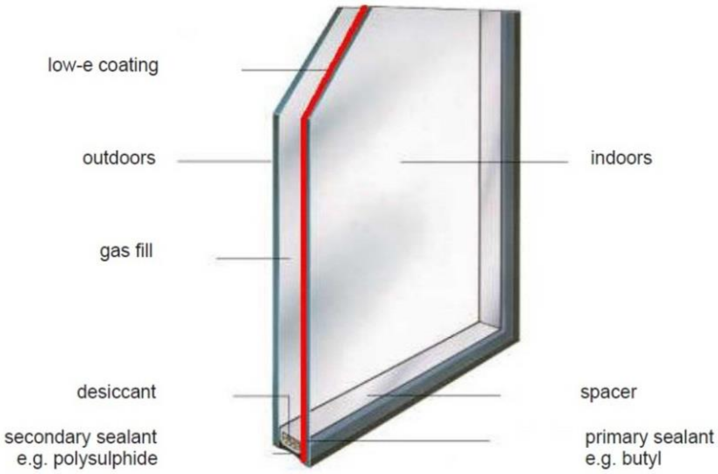


Figure 2.12: The Simple Example of Low-e Windows (Low-e Coating Is on Outer Surface of Indoor Pane) (Illustration taken from Wilson (2004))

To sum up, it is a complicated process because a window with low U-value rejects most of solar radiations (low SHGC). It would difficult to buy a window with high SHGC and low U-value. To deal with such a problem, it is recommended that designers pay due attention to climate condition. For example, in a hot-dominated climate, SHGC is less important than U-value.

To ensure sufficient daylight of indoor spaces, the room depths should be maximum 2.5 times window height. Hence, vertical windows are preferable for deeper rooms in buildings. As energy efficient approach, maximum percentage of using window openings in total surfaces of a building is 45%, when standard windows are applied (Schittich, 2011, p. 20).

Glazing Choice

There are three kinds of window in terms of number of panes (single, double and triple glazing). In double and triple types, trapped air or special gas between layers (panes) acts as thermal insulation. Normally, as much as the number of panes increases, the U-value decreases. For example, a double glazing window has the better performance in insulating spaces than single glazing windows.

Quality of solar gain varies with number of glazing layers. A fine example in this relevant in that triple-glazed windows having normal glass reduce solar gain up to 20 percent in comparison to single-glazed windows with the same proportion of glazing area. Similarly, double-glazed units decrease solar gain by 10% (Figure 2.13) (Robertson, 2009, pp. 9-11).

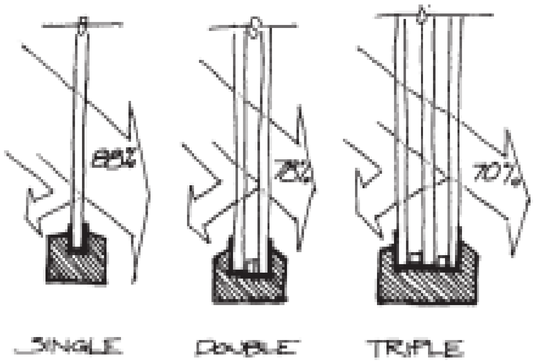


Figure 2.13: Rate of Solar Gain Shown in Different Kinds of Windows (Illustration drawn by author)

The most solar energy into a building is transferred via clear glasses. Glass with special, coating, insulating and tinted glass would diminish solar gains up to nearly one third. For example, a double-glazing window (low-e coating on one surface's pane) might transfer up to 20% less solar energy in the form of heat to the interior spaces, contrasted to a standard double-glazed window with the same glazing area (Figure 2.14) (Robertson, 2009, pp. 9-11).

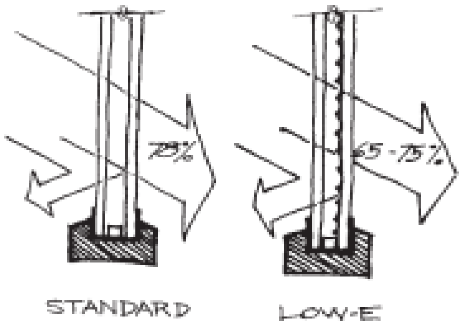


Figure 2.14: Reducing Solar Heat Transmittance by Coating in Double Glazing
(Illustration drawn by author)

Double Glazing Windows: Many advances have acquired for window technology in recent years and the glazing itself can harness the inside and outside flows of energy effectively. Based upon energy efficient approaches, double glazing window are one of the helpful components in saving building's energy and decreasing total energy consumption.

Besides, noise pollution are the another subject of environmental concern and problem, particularly in urban textures. A fine example in this vein is that the noise of 80 decibels produced by the outside traffic during a continuous period of time can make stress definitely. To combat it such a problem, glasses have been improved in window industries to diminish unwanted acoustical levels (URL 3, 2012).

Double glazing allows penetrating sunlight in winter and excludes solar heat gain in summer. Meanwhile, summer shadings are required for unprotected double glazing. They also can be used in large glazing area, skylights, roof glazing, and where energy cost is high.

There are enormous advantages for double glazing use which help to enhance human comfort levels in residential buildings; these advantages are listed below in general for double glazing windows:

- Diminishing amount of heat loss.
- Decreasing costs as a long-term viewpoint.
- To respect the environment and turn it to healthier and more friendly way.
- Preventing the amount of unwanted noise
- Existing little discrepancy between the temperature of innermost pane and room (Balcomb, 1992, p. 219).

FRAME MATERIAL	U VALUE OF GLAZING TYPE (W/m²/°C		
	SINGLE GLAZING	DOUBLE GLAZING	DOUBLE AND LOW E-COATING
PVC/timber	4.5	3.0	2.4
Aluminium	5.5	4.0	3.3
Aluminium–with thermal break	4.6	3.1	2.5

Figure 2.15: U-value of Different Glazing and Frame Types (Illustration taken from Robertson (2009))

2.3.1.4 Daylight and Shading Devices

The best way to control the amount of daylight can be obtained by appropriate shading devices use. In fact, there are many reasons to harness daylight by shading devices. For instance, in warm climates, high cooling energy consumption might be taken place because of the excess solar heat gain. Conversely, in cool climates, solar radiations penetrate and heat indoor space through opening directly and in a positive way. Little cast of doubt is there shading devices can control daytime overheating and provide ventilation in a solar-designed building. Hence, shading devices have gained their importance in an entire passive solar system (Kreith, 1982, p. 27).

To design operable shading devices, position of sun in the sky should be evaluated during different seasons. The different ways of harnessing solar energy by shading element are listed below:

- Various shading device's classification in terms of orientation such as horizontal, vertical or egg-crate shading devices.
- Green areas and landscape such as trees.
- Exterior elements of buildings such as overhang, awnings, louvers and fixed shading devices.
- Indoor devices of glare control such as venetian blinds.
- Textured surfaces on the building's facades.
- Different kinds of automatic and movable shading systems to accelerate trend of approaching to energy efficiency (URL 3, 2012).

Effective shading systems have fruitful outcomes. Some of their indications deriving from controlling daylight are listed below:

- Prevent overheating in indoor spaces.
- Adopted to different climates.
- Reduce energy consumption for cooling and heating.
- Providing glare-free environment.
- Help to control the ventilation of indoor spaces (Schittich, 2011, p. 62).

Different kind of shading devices according to orientation

To ensure maximum benefit from solar energy, shading devices should be provided on south-facing facades as a result of high solar altitude to facilitate light deflection and prevent direct sunlight in summer. Conversely, sunlight can readily enter through south-facing windows because of low angle of sun in winter time (Figure 2.18) (Schittich, 2011, p. 62).

Shadings devices are significantly necessary to be designed on east and west building's façade due to low solar altitude and strong solar radiation. Indeed, it is difficult to understand shading mask or light deflection in this condition. Hence, possible solution is that common horizontal shading devices replace with vertical elements for better reflection of shallow angles. In addition, horizontal shading devices would prove advantageous for south-facing façade. Accordingly, egg-crate shading devices (both horizontal and vertical shading elements) serve both west-facing and south- facing façade. Therefore, orientation is a dominant factor to determine and select kinds of shading devices (Rungta, 2011, pp. 26-30).

Shading devices may have same shadow mask but vary in ventilation system. As figure 2.16 shows, the all horizontal shading devices create the same shadow mask during a whole day; nevertheless, they offer various qualities of ventilation (ventilation of overheated air under the shading devices) and solar gain in terms of the colors and materials (Rungta, 2011, pp. 29-30).

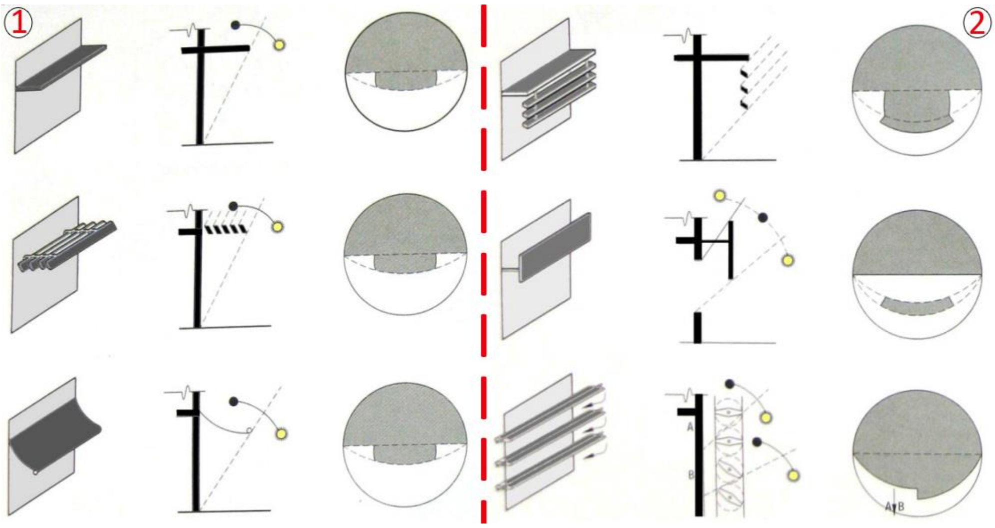


Figure 2.16: Examples of Horizontal Shading Design and Shadow Masks (Illustration taken from Rungta (2011), P. 29)

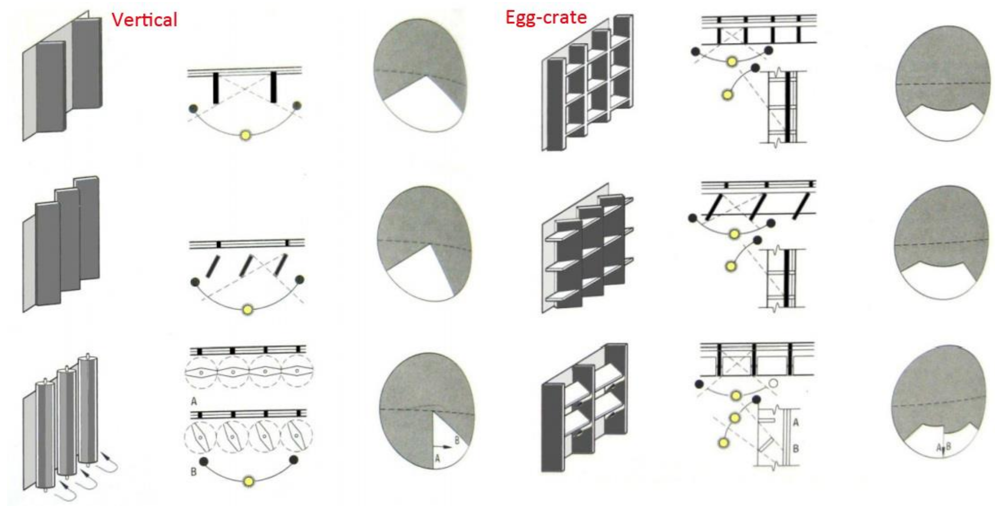


Figure 2.17: Examples of Vertical and Egg-crate Shading Devices Together with Shadow Mask (Illustration taken from Rungta (2011), P. 29)

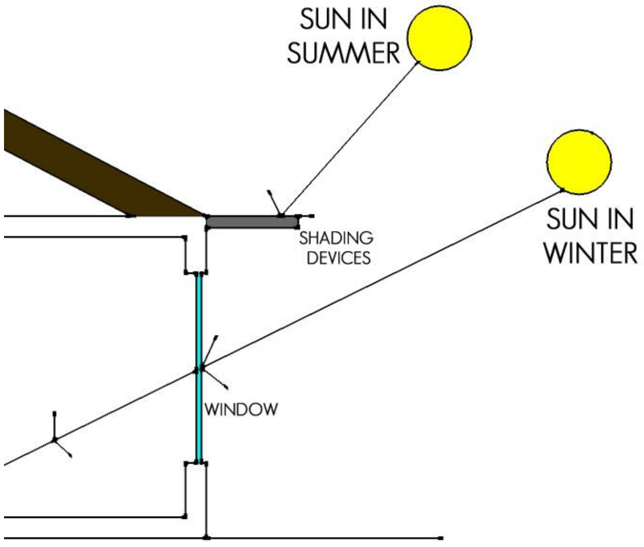


Figure 2.18: Overhang of a Building or Simple Shading Devices (Illustartion drawn by author)

External Factors in Building Shading

External solar energy absorbs by building envelope and then heats up the surfaces transmitting solar energy as form of heat in interior spaces. To control solar gain, external building surfaces should take into account, because they might be shade by vegetation or proximity (neighbor buildings). Apart from that, insulation and the color of finishes also influence on amount of solar energy gain (Baker, 2000, p. 31).

Vegetation (trees and shrubs) can provide both the summer shade and the winter solar gain. Trees on the south or south west side serve as obstacles for solar radiation and cool the building in summer time. Over winter time, sunlight through without leaf trees can reach inside to heat the indoor spaces (Kamal, 2011, p. 22).

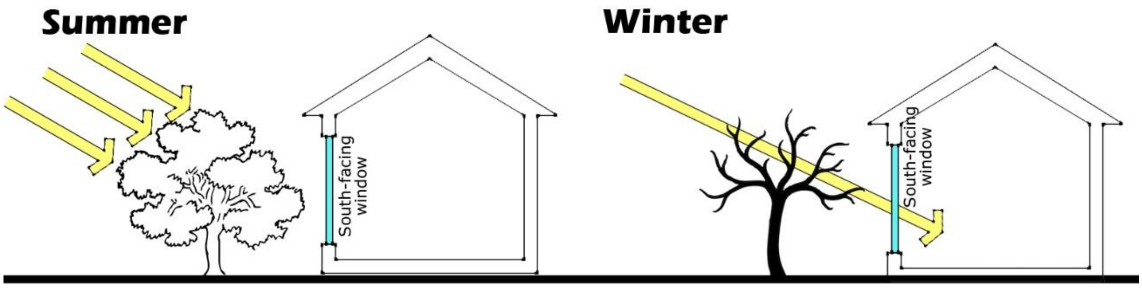


Figure 2.19: Making Effective Seasonal Shading on South Façade by Deciduous Tree (Illustration drawn by author)

Generally, natural shadings like deciduous trees can make some protection in summer. Meanwhile, the combination of deciduous foliage with horizontal shading devices is the most effective way to control solar penetration in summer months. Apart from that, an effective parameter in shadow design is to extend shading devices beyond window edges to increase the shadow and to protect the window from penetration of solar radiation in summer (Figure 2.20) (Hislop, 2013, p. 9).

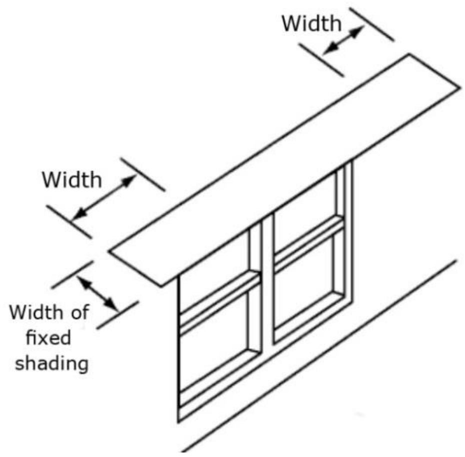


Figure 2.20: Width of Horizontal Shading Devices (Extend Past the Edges of the Window for at Least the Same Distance as Its Depth) (Illustration taken from Hislop (2013))

2.3.1.5 Thermal Insulation

Insulation is specified as combination of materials or a material, which impede the flow of heat. The materials can be adjusted as different shapes, sizes or surfaces. A distinct sort of finishes is to protect the insulation from environmental damage and to enhance appearance.

Mechanical insulations in buildings such as houses, hospitals, schools, shopping centers and hotels, are installed to upgrade the energy use of the buildings' heating and cooling systems, indoor hot and cold water supply, and refrigerated systems including housings and ducts (Smith, 2003, pp. 129-131).

Insulation's Function:

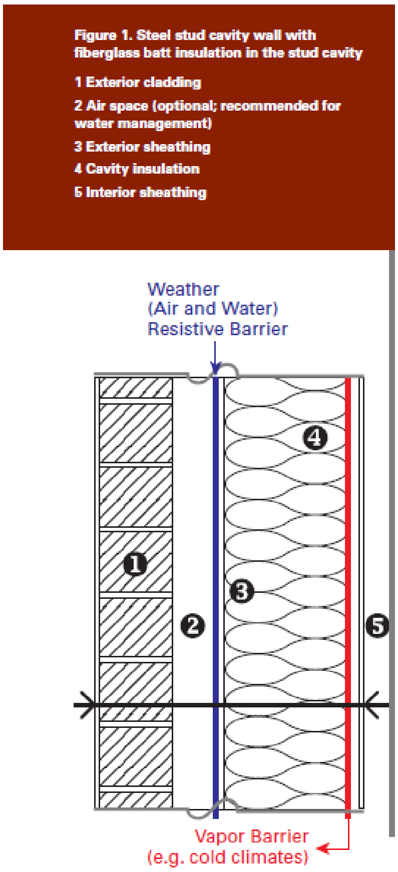
Admittedly, insulations are used to fulfill one or more of the following functions:

- Heat gain to access energy conservation or diminish heat loss.
- Protect through the reduction of greenhouse effects such as NO_x, CO2.
- Control surface temperature for personnel and equipment conservation.
- Control commercial and industrial processes temperature.
- Decrease or intercept condensation on surfaces.
- Increase operating efficiency of heating/ventilation/cooling, steam, process, plumbing and power systems.
- Decrease or intercept damage to material from corrosive, atmospheres or disposal to fire.
- Decrease mechanical systems noise.

The Area for Insulation Use

- Saving energy
- Process Control
- Personnel protection
- Fire protection
- Diminish unwanted acoustic pollutions
- Reducing greenhouse effect (Khandelwal, 2013, pp. 1-10)

In the case of wall construction, the thermal insulation could be located within the stud cavity (Figure 2.21) or outside the cavity (Figure 2.22). The exterior insulation is also generally used with back-up walls of masonry.



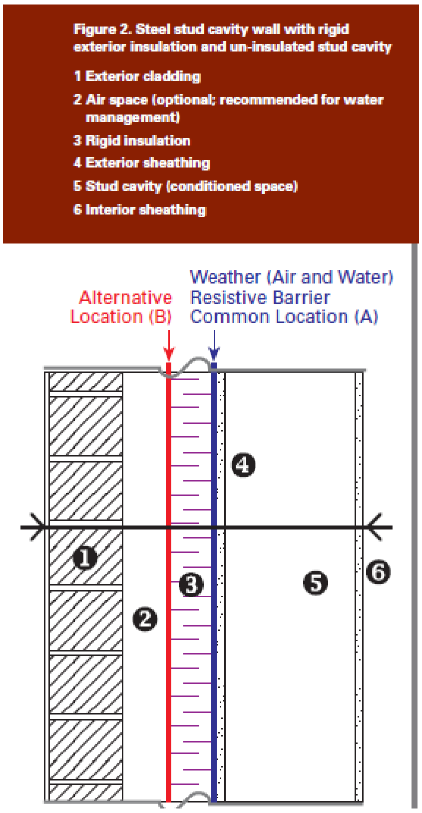


Figure 2.21 and 2.22: Interior Thermal Insulation on the Left Side and Cavity on the Right Side (Illustrations taken from Building Science bulletin, DuPont Tyvek (2006))

2.3.1.6 Thermal Mass

Thermal mass is an essential item in the success of most passive solar heating and cooling strategies. Generally, it offers optimization of the efficiency of buildings that have relied basically on mechanical cooling and heating systems. Meantime, thermal mass is a term that used to specify material potential and ability in buildings to store and distribute heat acquired by solar energy. In fact, the indispensable characteristic of materials as thermal mass is the ability of heat absorption, reservation and distribution at later. Thermal mass incorporated within the insulated building envelope control the fluctuations of inside temperature and make the indoor spaces more comfortable to live in (Clemens, 2007).

Thermal Control

The daily changes in temperature and hours of sunshine lead architects to use thermal comfort for user comfort in buildings. Indeed, passive use of the solar energy in buildings is in the pursuit of thermal energy to fill dips and pull down peaks in order to promote human comfort conditions. Thus, thermal mass is one of the effective tools that designers can consider in buildings to control the indoor temperature (Scott, 1978).

Ideal thermal mass

Impressive and effective thermal mass typically have a high thermal capacity, an intermediate density, an intermediate conductivity and a high emissivity. Besides, material (thermal mass) can serves as a decorative function or structural function in the building.

Timber and some masonry products are appropriate materials for thermal mass, because of possessing a high capacity for heat storage, moderate conductance that allows heat to be transferred in depth of the material for the maximum possible storage, high emissivity to permit heat absorption more than heat reflection. In this regard, timber is efficient in order to control energy flows daily, when it is in appropriate shape and size. Since, structural thermal mass and timber as a material for thermal mass can share common size and proportions; hence, there is little wasted mass (Clemens, 2007).

Similarly, water is efficient as a thermal mass in which high capacity for heat storage is existed and proven. Architects and engineers claim that water also can be efficient in designing a daily thermal management. Nevertheless, water usage is more problematic than concrete as it has difficulty in construction (structural design). Apart from that, translucency of water provides light and views by the thermal mass as an advantage (Anderson, 1990).

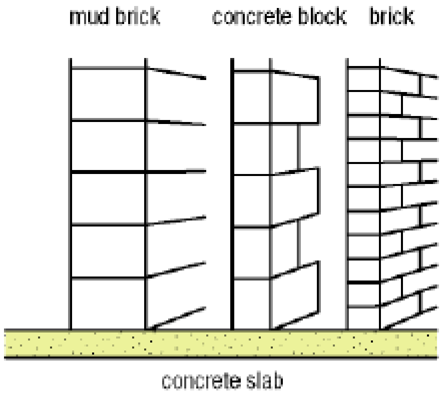


Figure 2.23: Different Materials Used as Thermal Mass (Illustration drawn by author)

Seasonal Effects of Thermal Mass

In summer: Thermal mass would be heated by solar radiations entering the building. As a matter of fact, thermal mass serves as a heat sink in hot weather because it has a lower primary temperature than the environment. Absorbing heat from the air surrounding would cause to lower indoor air temperature in daytime and accordingly without supplementary cooling requirement, comfort index is improved.

In the night time, the heat is slowly distributed to be passed by cool breezes, or is ventilated into the room itself, or extracted by fans (or other ventilations systems existing in a building unit). Indoor temperatures at night time are slightly higher than if there is low thermal mass; nevertheless, temperatures are still remain in the comfort zone by the help of cooling night breezes.

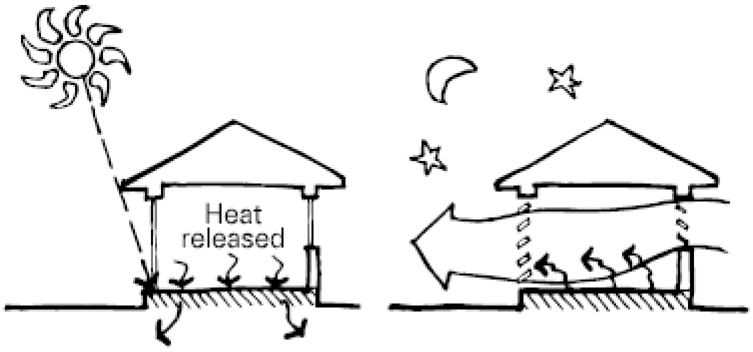


Figure 2.24: Thermal Mass Strategies for Daytime and Night Time Usage in Summer (Illustration sketched by author)

In winter: Thermal mass - incorporated in the floor or walls - absorbs solar energy in the form of heat through west, east and south-facing openings. Heat is gradually released back into the room during the night then the room temperature drops to provide comfort for inhabitants (Scott, 1978).

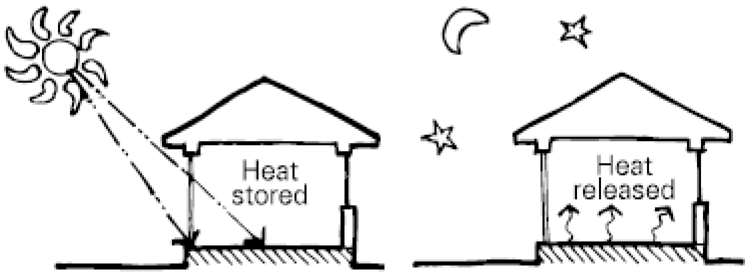


Figure 2.25: Thermal Mass Strategies for Daytime and Nighttime Usage in Winter (Illustration sketched by author)

Heating Strategies with Passive Use of Solar Energy

Direct gain: This strategy is considerably depends on solar radiation entering the space over the hot seasons; the thermal mass absorbs excessive heat from solar energy gains.

High-mass cooling: High-mass passive cooling systems utilize mass as indoor heat storage which is produced each night by using fans or natural ventilation.

Courtyard cooling: One of the incredible effects of thermal mass in courtyards is the use of mass in exterior floor or wall as a passive cooling strategy in hot and dry climates. As an example, a massive floor's courtyard surrounded by rooms of a building with a shaded area provided by arcade increasingly help to cool spaces. The colder air is circulated throughout the building and it will replace warmer air. During the day time, the arcade provides shading and conserves the building from direct solar radiations, apart from that, cold mass absorbs an enormous amount of solar heat in the courtyard's floor (Anderson, 1990).

2.3.2 Active Solar Energy Use and Relationship with Passive Solar Energy Use

Active solar strategies like other renewable sources reduce energy requirements derived from fossil fuels for buildings. They also collect, store and distribute solar energy like passive use but in a different way. In general, energy from active use of solar energy offers two applications for users in residential buildings. One is related to heat supply (heating space or hot water) and other one is generation of electricity.

To summarize, collectors (usually on the roof) absorb solar energy and transform it to heat and then reach it to the point of usage. Solar heating systems considerably supply 50% to 75% of domestic hot water use (in the most of the climate zones) (Reyes, 2007, p. 1).

The main difference in procedure of active solar energy use in comparison to passive solar use is the existing of intermediate operation (mechanical system) such as collectors, solar cells, fan and etc. Typically, passive solar energy use relies on south-facing façade to harness solar energy. Apart from that, the simplest way of using solar energy in passive use is convection; however, active solar energy technologies convert solar energy by particular equipment (URL4, 2013).

2.4 Passive Solar Design According to Various Climates

Natural conditions can provide satisfactory living space for dwellers; however, they should be changed by building elements to resist against severe wind, rain, sun rays, storm and different climate conditions. In fact, Passive elements' features have a large influence on cooling and heating requirements. Meantime, to achieve thermal comfort and favorable temperature for human, passive behavior of buildings elements should be investigated in different climate conditions.

Each passive solar element can have a distinct reaction in different climates. For example, a useful and energy efficient window in cold climates might waste energy in hot climates. Thus, different specification, materials and orientation of passive solar elements is needed in different climates. Consequently, following subtitles unfolds role and effect of passive solar elements in various conditions of climates.

2.4.1 Passive Solar Elements in Cold Climates

Normally, there are four zones for building space that each of them requires different thermal comfort level. These zones can be classified as living space, sleeping space, service zone and circulation zone. In this regard, with changing sun position over the course of day, characteristics of indoor spaces and zones considerably changes. In the morning, sunlight heat and brighten zones on the eastern side by passing south side moving towards western side in the late afternoon. Then, living spaces in this climate conditions are suggested to be on the southern side of buildings, to take advantage of solar radiation and reducing heating requirements.

In cold climates, wind protection is nearly as useful as building orientation. Because, severe wind loads by increasing transfer rates have a negative effect on heat loss and air leakage. Preventative measures should be taken by windbreakers, hedges, trees, screens to combat against strong winds. Meantime, well-designed shading devices sometimes can offer both solar radiation controller and wind breakers.

Besides, the new cold air should be heated or harnessed before penetrating indoor spaces to keep the indoor comfort level. Materials with high level of heat capacity and proper thickness are needed in cold climates, since they can gradually release solar energy in the form of heat back to indoor spaces over the nighttime. High heat capacity materials can be applied and installed as building components as well as passive elements used in buildings such as shading devices and thermal mass. Hence, these materials can markedly influence the performance and efficiency of passive solar elements (McGregor, 2012).

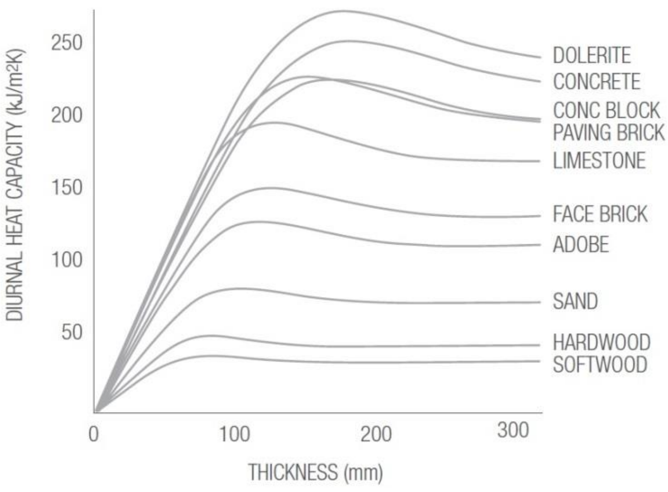


Figure 2.26: Heat Storage Effectiveness of Various Materials. Illustration taken from Mazria, Baker, Wessling Sunworld Vol 2. No. 2 1978

Well-designed passive solar buildings have 80% of all windows facing solar façade (south facade for countries located on north hemisphere). Frames also can be effective in window systems. Wood and plastic frames improve insulation systems; however, metal frames act as heat sink.

What is more, different kinds and position of insulation exist to apply for roofs (ceiling), walls, floors, drafts and windows; nevertheless, all may not be responsive for cold climates. In general, to reduce conduction heat loss, radiation heat and convection heat loss, bulk insulation, reflective insulation and drafts seals are respectively recommended. The amount of R-value is important to know insulation resistance to the heat flow. Higher R-value means higher resistance and it is needed especially for those who live in cold climates (URL7, 2012).

Generally, light weight and transparent building envelope in cold climates cause to take maximum advantages from solar radiation and accordingly it decrease heating demands for interior spaces. Larger and plenty of glazing area on the south-facing façade dramatically improve thermal comfort level for the dwellers.

2.4.2 Passive Solar Elements in Hot Climates

Definitely, Passive solar elements for heating, cooling, delighting should be incorporated to buildings for all climate conditions. In hot climates, the primary requirement is to find out a solution to enter adequate daylight through indirectly while building is shaded from undesirable direct sunlight. In this respect, the situation of passive elements with regard to surrounding geography would be designed.

According to the building orientation and direction of exposure, openings and overhangs can be incorporated to buildings. North-facing façade is a place for large windows and shallow overhangs in hot climates in north hemisphere; because, it provides natural and glare-free light without direct solar heat gain. On east facing façade to take advantage of view large window with deep overhang can be appropriate. Sometimes it is recommended to allow early morning sun entering indoor spaces particularly in kitchen or breakfast area. East and west facing facades should have deep shading devices to control sunlight radiating façade. Deciduous trees are also fruitful in order to provide shading in summer and to allow sunshine to enter in winter (Hasse, 2009).

Creating appropriate depth of overhang to provide shading in hot climate is one of the most important factors to build a passive building. The depth should be designed according to sun angles of extreme summer and winter for latitude of a specific region. Overhang have used commonly as roof eaves or canopies in buildings. For example a wooden trellis over the window can be a good alternative to shade openings. Besides, they should be made of material with ability of blocking the sun and the heat. Thus, canvas cannot be a proper option for overhangs in hot climates because it does not have thermal mass.

Light shelf is a solid canopy that locates at two-thirds of window height. It shades the glazing part existing below the shelf while at the same time reflects up light to the ceiling (indoor spaces) through a transom window located above shelf. Nevertheless, direct solar radiations bring much heat gain than reflected solar radiations.

Less transparency in needed to improve passive behavior of buildings in hot climates, because it helps to protect building envelope from overheating during sunny hours. Besides, each opening especially on the east, west and south direction should have appropriate shading devices to control sunlight. Thus, it is recommended to face living spaces where users spent most of their time toward north direction to use natural light without heat and to decrease mechanical cooling requirements.

Figure 2.27: Example of Light Shelf Overhang. Illustration taken from blog.buildllc.com

There are numerous other factors for passive design in hot climates. In the case of walls, well-insulated and with adequate thermal mass is suggested to prevent heat penetration. Roofs also should be in lighter color, well-insulated and equipped with appropriate ventilation to send out exhausted air and heat. In this climate condition, natural ventilation can be achieved by locating large windows on opposite walls (URL 8, 2008).

Useful recommendations for **Hot and arid** Climates: As an additional passive strategy in hot-arid climates, wind catchers are one of the best options to provide natural ventilation and reduce indoor space temperatures in the midday. Meantime, building orientation should be according to the prevailing wind.

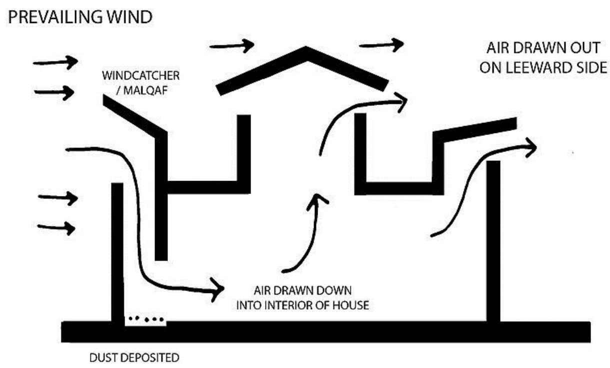


Figure 2.28: Wind catchers in detail as passive cooling strategy for buildings. Illustration taken from URL 9.

If the walls aren't shaded, smaller windows on the east and west should be placed. Windows mostly have to be located on the leeward side instead of wind to let the hot air escape. As a matter of landscape design, with attention to the prevailing wind on the site location, keeping vegetation moist helps to bring cool breezes. Applying reflective roof insulation to reduce radiation heat is the best passive way to avoid heat loss. Sky lights should be avoided in this climate unless it is tinted or equipped with operable openings (URL 9, 2012).

Depended on the time of day, there is always shaded area in courtyards. According to different courtyard geometry, it at least shades two of the courtyard wall surfaces and part of courtyard floor by itself. Thus, one of the best options to reduce cooling requirements in this climate conditions can be acquired by courtyards.

The main advantage of courtyard is the relative isolation from outside environment. In addition, there is thermal advantages for buildings with courtyard because it reduces the effect of solar radiation, although solar radiation it is not completely eliminated. Providing shading and increasing humidity by trees and pools (landscape design) in courtyard also is usual in hot and dry climates.

2.4.3 Passive Solar Elements in Temperate Climates

In temperate climates, where there is seasonal variation between under heating and overheating, building envelope should strike a balance between opaque and transparent building envelope to control the solar energy radiating building's skin.

Meantime, natural ventilation should be designed in buildings for hot seasons of temperate climates that it is temporary and it can be controlled by building habitants over the day. For example, designing operative openings in ground floor and toppest floor provide natural air circulation vertically for the corridors, staircases as well as waiting areas.

Regarding passive solar energy strategies, building and window orientation play a key role. For instance, in temperate climates, where there is constantly winter heating demand and it generates a considerable energy requirement, the exposure of living room spaces to the midday solar radiations decreases mechanical heating demand. When these spaces with their window locate east or west, the advantage is also decreased. Therefore, there are two ways to ensure optimal orientation (Morrissey, 2011).

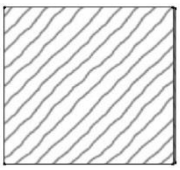
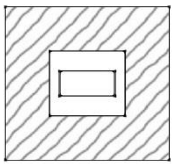
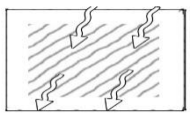
Passive solar principles according to the different climate conditions	**Cold**	**Hot**		**Temperate**
		Dry	**Humid**	
Building orientation	South	North	North	South with passive measures to exclude summer sun/ Look for a suitable area of glass on north facing walls with access to winter sun.
Building envelope	Lightweight and transparent /resistant and radiation thermal insulation	With less transparency compared to cold climates/ resistant and capacity thermal insulation	With less transparency compared to cold climates/ resistant and capacity thermal insulation/ using materials to prevent condensation	Balance between opaque and transparent level of building envelope to control building performance optimally
Solar Zoning / layout	The most used spaces to south/ compact building form 	The most used spaces to north/ courtyard as well as trees and water elements(Ex. Dry air breeze can be gain humidity by passing over pool and become as cool breeze) 	The most used spaces to north /building orientation according to the prevailing wind to provide ventilation 	Openings should be primarily orientated southwards, consider the use of conservatories and buffer spaces. Kitchens are better facing east, living rooms to the south and west. Bedrooms are often better to the north to avoid light disturbance.

Figure 2.29: Passive Solar Design with Respect to Different Climate Conditions. Illustration drawn by author

2.5 Thermal Comfort

Admittedly, human body is like a complicated system with specific body requirements. As a matter of fact, body temperature should be kept at the right temperature in various climates. Although it seems to be a challenge for the body metabolism in medical sciences; however, human skin performance is limited to challenge with body temperature. In this regard, clothing and building are two dominant factors for compensating deficiencies (Behling, 1996, p. 37).

Most of the discomfort cases are related to imbalance of losses and metabolic gains or long-term encountering one of environmental parameters with extreme value. To compensate both cases, many technologies as well as passive solar energy use can be applied in order to keep the temperature as stable as possible in different climates and time of day.

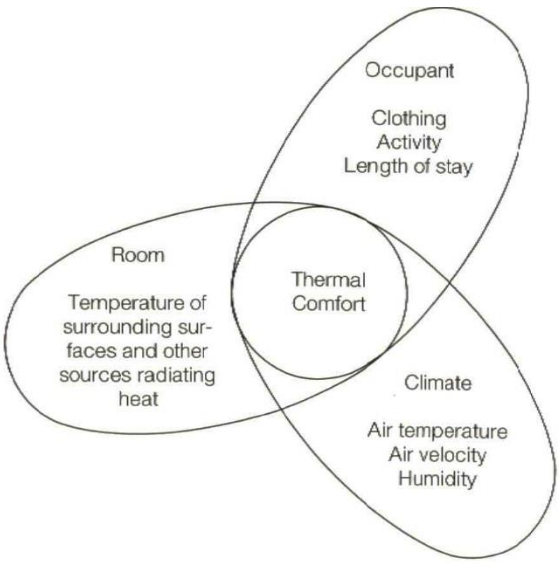


Figure 2.30: The Thermal Comfort Mainly Depends on Three Main Factors: Room, Occupant and Climate (Illustration taken from Schittich (2011) p. 47)

The comfort range is hugely depended on the type of activities, clothing and body type, health rate and dweller experience. The harnessing radiant temperature from the furniture, interior surfaces, thermal mass and windows as indoor building components are determinant to guarantee the comfort space in different climate conditions. For instance, younger and healthier people feel more comfortable than older ones in the same circumstances (Bainbridge, 2011, p. 28).

Figure 2.27 illustrates average temperature of enclosing surfaces is 19.5-23.0 ^{o}C that specify comfort zone. In addition, the relative humidity over 75% is uncomfortably moist and less 35% creates uncomfortably dry place and then it is likely annoying enclosed area (relative humidity between 35%and 75% is by far the best living condition) (Schittich, 2011, pp. 14-15).

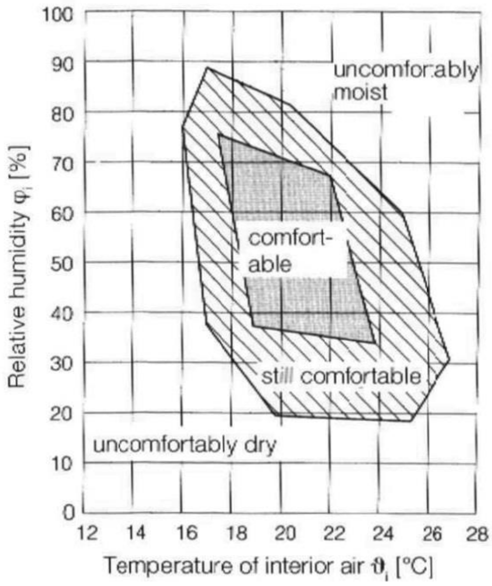


Figure 2.31: Determining Thermal Comfort in Terms of Interior Temperature and Relative Humidity in Enclosed Room (Illustration taken from Richarz (2007) p. 14)

A number of technical design strategies are listed below in order to avoid conflicts between thermal comfort and passive measures:

- Prevent overheating the space by means of occupant's activity level and clothing.
- Do not allow space to be overheated from solar heat gains by ventilating, providing shaded area and environmental control.
- Do not underestimate heat loads during hot seasons by well-designed façade.
- Consideration of passive solar energy strategies such as appropriate window design and appropriate shading devices (Baker, 2000, p. 10).

	Parameters influencing comfort	Season	Limit values		U-Value [W/m²K]
1	Temperature of interior air	Winter Summer	20 to 22 ≤ 26	°C °C	
2	Average temperature of enclosing surfaces	Winter Summer	≥ 17 ≤ 25	°C °C	≤ 1.25
3	Temperature difference between interior air and component surface	Winter	≤ 3	K	≤ 0.75
4	Temperature difference between opposite vertical components	Winter	≤ 5	K	≤ 1.25 (wall) ≤ 1.40 (window)
5	Temperature difference between floor and ceiling	Winter	≤ 3	K	≤ 0.75
6	Temperature of floor surface	Winter Summer	17 to 26 ≤ 26	°C °C	≤ 1.25
7	Temperature of ceiling surface	Winter Summer	17 to 34 ≤ 34	°C °C	≤ 1.25
8	Heat flux density	Winter	≤ 40	W/m²	≤ 1.25
9	Relative humidity of interior air	Winter Summer	40 to 60 40 to 60	% %	
10	Relative humidity of interior air	Winter Summer	≤ 0.15 ≤ 0.30	m/s m/s	

Figure 2.32: Limit Values for Human Comfort in Habitable Rooms and Ensuring Requirements for External Components (Illustration taken from Richarz (2007) p. 14)

2.5.1 Thermal comfort Standard (ISO 7730)

Although thermal comfort is a state of mind, there are equation to calculate heat and mass transfer and energy balance. Hence, the thermal comfort level is expected to be impressed by variables dealing with mass and heat transfer and energy balance. ISO (international organization for standardization) has written standards related to the thermal comfort on the international level.

Generally, ISO 7730 is a standard and analytical determination and interpretation of thermal comfort evaluating PMV and PPD indices and local comfort conditions. This standard defines PMV (predicted mean vote) and PPD (predicted percentage dissatisfied) indices and determines desirable conditions for thermal comfort. The PMV shows the mean value of the votes related to a group of people according to the ISO thermal sensation scale and PPD predicts Percentage related to a group of people that likely feel "too warm" or "too cool" (Parsons, 2012).

Value	Sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

Figure 2.33: ISO 7730 Thermal Sensation Scale. Illustration taken from Parsons, 2012

It is applicable that indoor spaces provide for human a whole-body thermal sensation close to the neutral. Apart from that, a draft rating index for equation related to air temperature and velocity and turbulence intensity.

To calculate PMV data on climate, metabolic rate and cloth insulation are necessary. Data on the cloth (I_{cl}-value) and metabolic heat production rate comes from ISO 9920 and ISO 8996 respectively. These are two fundamental factors to understand PMV; however, regarding dynamic and practical contexts it is more difficult to calculate and some corrections may influence amount of PMV (PMC_{corr}) such as walking speed, relative wind speed and skin wetness.

The significance of metabolic rate estimating can be showed in an example of the PMV calculation for conditions: air temperature (*ta*) = mean radiant temperature (*tr*) = 24 °C; partial vapor pressure (*Pa*) = 1000 *Pa*; air velocity (*v*) = 0.15 *ms*-1; clothing insulation 1.0 Clo; and metabolic rate estimate of 100 *Wm*-2 provides a PMV = 0.9. However with a 15% accuracy adjustment, a metabolic rate value of 85 *Wm*-2 provides PMV = 0.7 and 115 *Wm*-2, PMV = 1.1.

$t_a = t_r = 24$ °C; $Pa = 1000$ Pa; $v = 0.15$ ms^{-1}			
M Wm^{-2}	Clo m^2 °C W^{-1}	PMV	PPD %
50	0.130	-1.0	27.7
58	0.155	0.0	5.0
66	0.180	0.4	8.8
85	0.130	0.5	10.5
100	0.155	0.9	22.6
115	0.180	1.2	36.4

Figure 2.34: Importance of Accuracy of Metabolic Rate and Clothing Insulation on the PMC and PPD Values. Illustration taken from Parsons, 2012, p.25

Chapter 3

INVESTIGATION OF DIFFERENT PASSIVE SOLAR STRATEGIES

3.1 Data Collection Methods

This study is a problem solving research with the focus on residential buildings as case study situated on northern part of Salamis street from the EMU University and the Gulseren junction. Data collection method is exploited both qualitative and quantitative category of research. Comparative analysis about data derived from qualitative and quantitative research category has accomplished to achieve outcomes and facilitate precise discussion regarding the existing buildings.

To collect data, the qualitative part of research personal mostly has been achieved by personal observations. Then, interview and literature survey acquired qualitative data. To discuss and evaluate data, combination of both qualitative and quantitative outcomes was indispensable to be done.

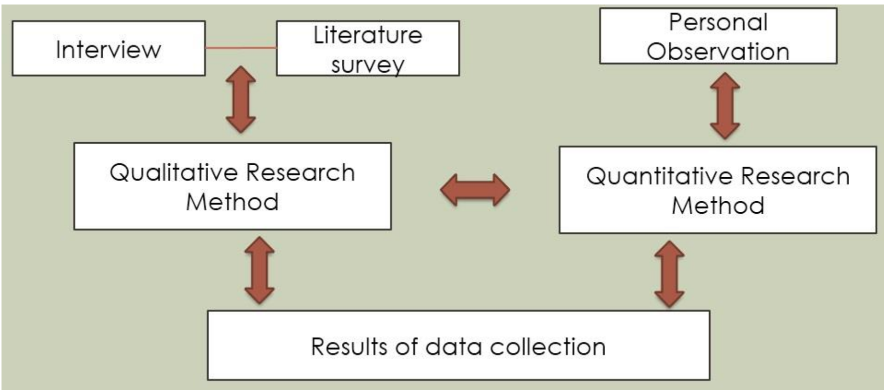


Figure 3.1: Data Collection Methods (Illustration drawn by author)

3.2 Observation

Personal observation is essential element of all qualitative research. Basically, the main advantages of observation are validity and flexibility of data. Accurate personal observation has become main focus of the data collection method in this research. In addition, surveys of the existing situation of buildings helps to acquire knowledge regarding human and physical environment interactions on Salamis street, Gazimağusa (Famagusta), North Cyprus. Occasionally, it helps to find the problem existing in building's envelope. For example, building's surfaces has counted one by one to achieve needed statistic in the entire series of buildings.

The data, derived from observation, have categorized in order to facilitate trend of evaluating. Clarify and evaluate facade characteristics were by far the main target of observation part because it was visible and tangible sector of buildings for researcher during observation. Despite, the all visible components have been processed by observation, data of invisible and unclear components have achieved by interviewers.

Photography was by far the most important sector of observation in this research so that all the building's skin and their necessary specifications have recorded. It also considerably helped to evaluate impact of the sun and its shadows on the buildings whether single or series.

After determining the building's orientation and sun's situation, building's surfaces have proven as secondary contributor to be investigated of the passive solar strategies particularly in their façade's design.

3.3 Identity of the Case Study

After all, the case study comprises 48 multi-storey building stock laid out in a row (one strip) in one of the most important places in local scale and destination of many people in day and night. 33 out of 48 buildings devoted the ground floors to the mix-used activities (mostly commercial use) (Figure.3.2). Six buildings had been utilized just for residential functions among the forty-eight buildings (Figure.3.3). Other buildings have been ignored, because this study aimed to provide thermal comfort for human who spent hours in residential buildings.

They were constructed in different periods mostly after 1974 as new development area attached to the Salamis Street (located on the street). In addition, this street is one of the recreational places over day and night (Figure 3.4).

Figure 3.2: Examples of Multi-Storey Residential Buildings without or Together with Commercial Use at Their Ground Floor (Photos taken by author)

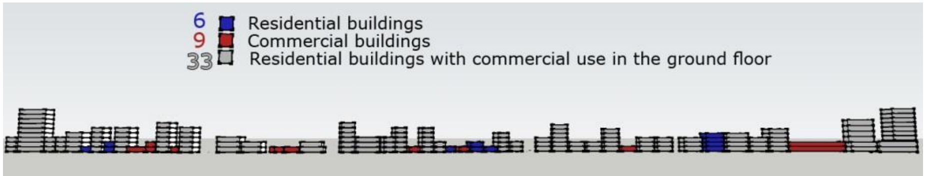


Figure 3.3: Three categories of Buildings Have Spread in the Salamis Street Encompassing: Residential Buildings, Commercial Buildings and Residential Buildings Together with Commercial Use at the Ground Floor (Illustration drawn by author)

Figure 3.4: Buildings Attached to the Street in the Case Study (Photos taken by author)

Main construction material and structural system in this regard is concrete which is suitable for solar gain and to absorb the solar rays. Common finishing materials are plaster coated with the painting and thirty-six out of thirty-nine of them were colored with bright shades to avoid overheating the building envelopes (Figure 3.5).

Figure 3.5: Facade Examples with Bright Colors (Photos taken by author)

Multi-storey buildings arranged with wide range of floors from 1 to 9 floors disorderly result in deep fluctuation as roof line property (Figure.3.6). Generally, the buildings stretched from northwest to southeast as dominant direction; however, a number of buildings laid out closer to east-west direction due to a curved movement in the middle of street. In this study, the figure 3.7 shows buildings have categorized into three partial research groups based on their orientations to facilitate analysis and evaluation. First building group are stretched from EMU University until beginning of street curve; second building group are in the middle of street and third building group are laid out from ending point of street curve until the Gulseren junction.

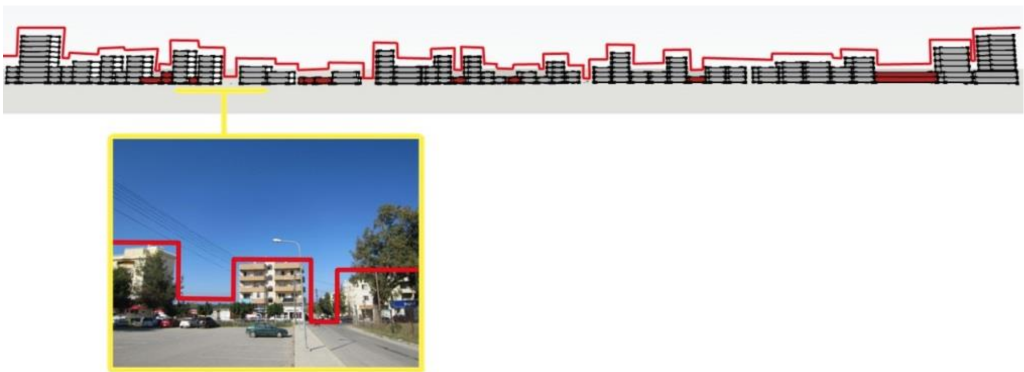


Figure 3.6: Roof Line Property Is Shown with Red Line on the Top of All Buildings (Red Buildings Have Just Commercial Usage) (Illustration drawn by author)

Figure 3.7: Three Categories According to the Orientation (Google map. Illustration edited by author)

3.4 Analysis of the Stereographic Sun Chart Diagrams

The main aim of the sun charts is evaluation of solar access. Stereographic sun chart diagram is one of the most useful diagrams to evaluate the buildings based on sun path in specific time precisely. It is also one of the most often used diagrams for solar architects due to design and develop effective solar buildings. The diagrams may vary upon the latitude angle of a place. Based on the literature survey the latitude of Gazimağusa (Famagusta) town, North Cyprus is 35^{o} N. apart from that, every place on the Latitude 35^{o} N can be taken into account for specifying their solar situation in following application (Figure 3.8).

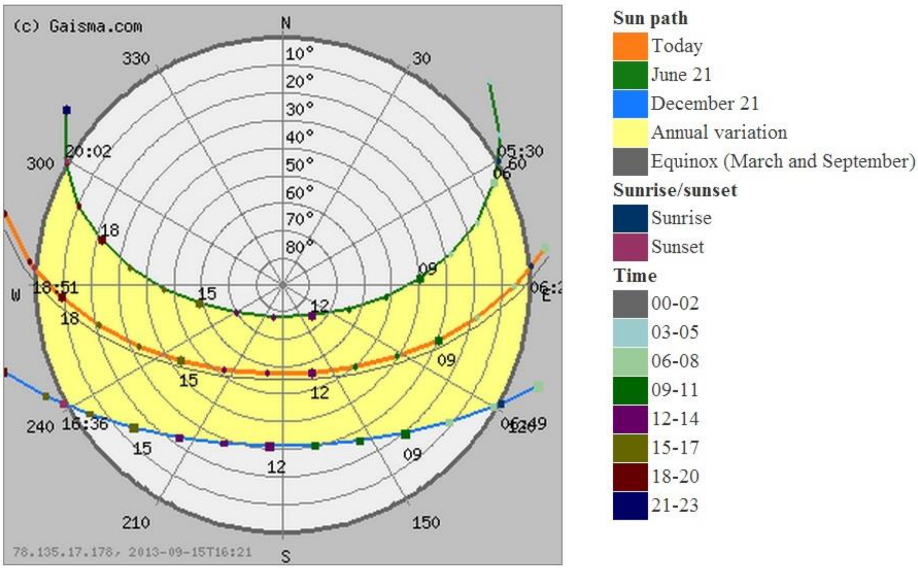


Figure 3.8: Stereographic Sun Path Diagram for 35^{o}N Latitude (Illustration taken from URL: http://www.gaisma.com/en/location/gazimagusa.html)

Figure 3.9 demonstrates overheated area in the Gazimağusa (Famagusta), North Cyprus. Darker hatch pattern area is determinant of overheated period in the winter and summer. The chart enables to specify accurate cooling and heating periods. Accordingly, architects can readily decide about set passive elements to achieve optimum solar design. For instance, based on the diagram if there is high altitude in a particular month and specific time in summer, it might be protected by selective shading elements.

The picture below is taken from www.sunearthtools.com that shows the sun path as well. It is obvious that buildings at northeast and northwest take less solar energy compared to the southwest and southeast directions. Nevertheless, in part 2 of the case study (see former topic), southwest surfaces are more exposed to sun in comparison to southwest surfaces in part 1 and 3. Because, the buildings in part 2 have rotated counterclockwise with closer angle to horizontal line (Figure 3.9).

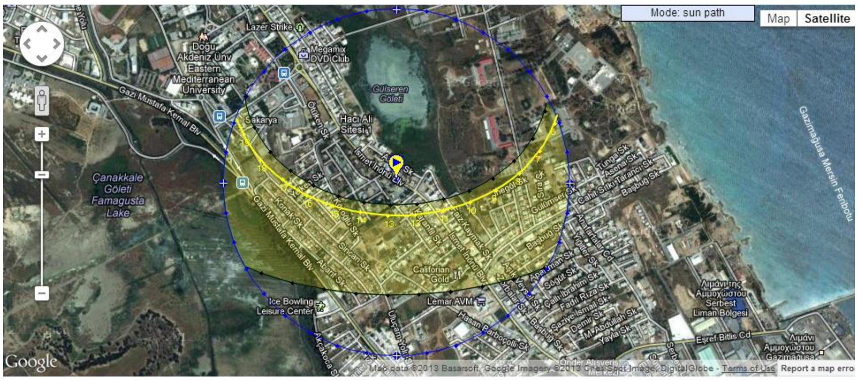


Figure 3.9: Sun Path Diagram for the Case Study Shown by Yellow Color (Illustration taken from URL: www.sunearthtools.com/dp/tools/pos_sun/php)

3.5 Impact of Buildings' Shadow on the Each Other

Although shading devices have been applied to provide shading of openings and desirable areas, buildings also can shadow each other by themselves. To know how a building can shadow others, four basic factors should be inextricably taken into account: spacing between buildings, slope (topography), height of buildings and sun path (based on Azimuth and Altitude).

In winter, when the significance of solar heat gain reaches its peak, overshadowing of buildings should be avoided. Accordingly, spacing between the buildings increasingly gain importance. For instance, if overshadowing should be avoided in design process on latitude of 50^{o} N, rows of buildings on north facing slope 10^{o} should have as twice distance as rows of buildings on south facing slope with the same degree (Figure 3.10).

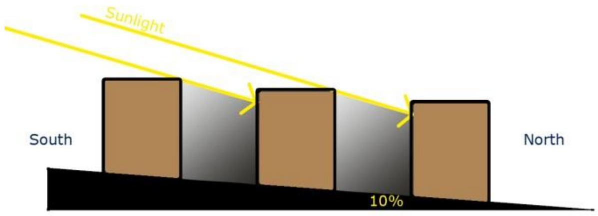


Figure 3.10: Investigation of Building Shading on the 10% North Facing Slope (Illustration drawn by author)

In north slopes as much as spacing between buildings increase in order to permit penetration of solar radiation for each building block, the proportion of detached buildings increase and gradually buildings forms escape from compactness. Consequently, height and spacing can play a constructive role in the overshadowing of surrounding buildings (Figure 3.11).

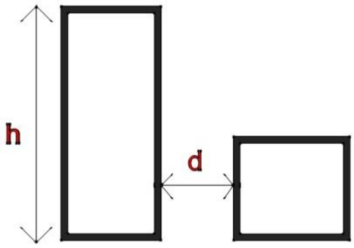


Figure 3.11: Height and Spacing between Buildings (Illustration drawn by author)

In the case of intended buildings on Salamis Street, when the sun radiate from south does not effectively overshadow other buildings in the identical category, because the buildings are stretched from northwest to southeast direction. In addition, the majority of cases, there is alley behind the selected buildings so that shadow falls and influences just on the alley. Nevertheless, when the sun is in southeast direction with low angle, buildings overshadow each other especially in part 1 and 3 between 11 to 13 o'clock.

Figure 3.12 shows the buildings overshadow by neighbor buildings. Totally sixteen building shaded from east facades when the sun radiation penetrates from southeast direction. In Part 2 overshadowing is less tangible than part 1 and 3.

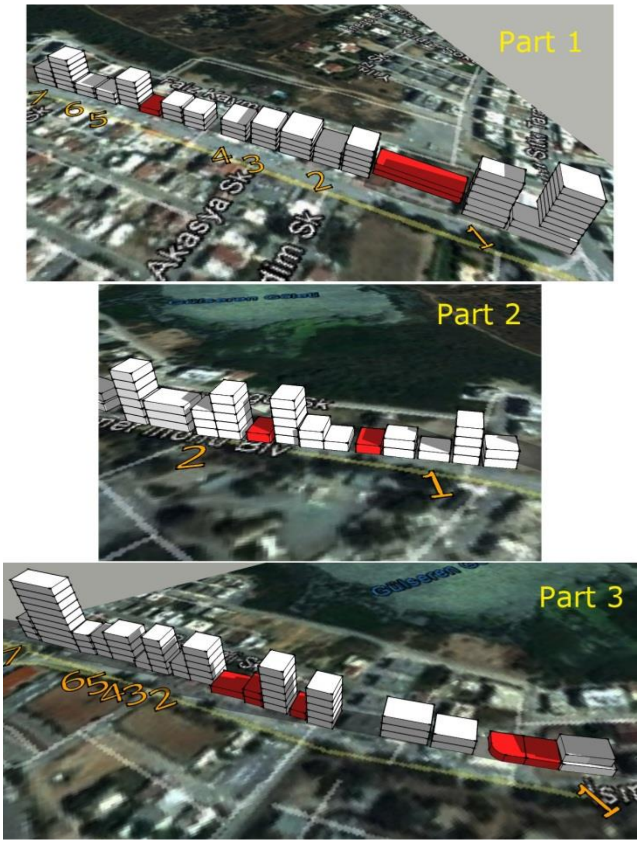


Figure 3.12: Overshadowing by Neighboring Buildings (Simulated by author in Sketch up software (October at 11:00 o'clock))

3.6 Investigation of the Buildings' Surfaces and Forms

Building's envelope constantly is presumed as a connection between interior and exterior spaces in a building by architects. It is also a major contributor of heat transmittance through the walls, windows and other components. Thus, less surfaces means less heat loss. It is with regret seen that a great deal number of buildings have more than two surfaces (separated buildings); whereas, they could be attached at two sides to maintain the compactness.

In the case of three surfaces, one blocked side constantly located in either southeast or northwest directions and two other open sides conversely located in southwest and northeast directions. Based on the accomplished survey, nine buildings have three open surfaces and the rest thirty buildings have open surfaces of four sides. Meanwhile, five out of nine buildings have open surfaces in southeast direction. It eminently followed closely by four buildings having open surfaces on their northwest directions.

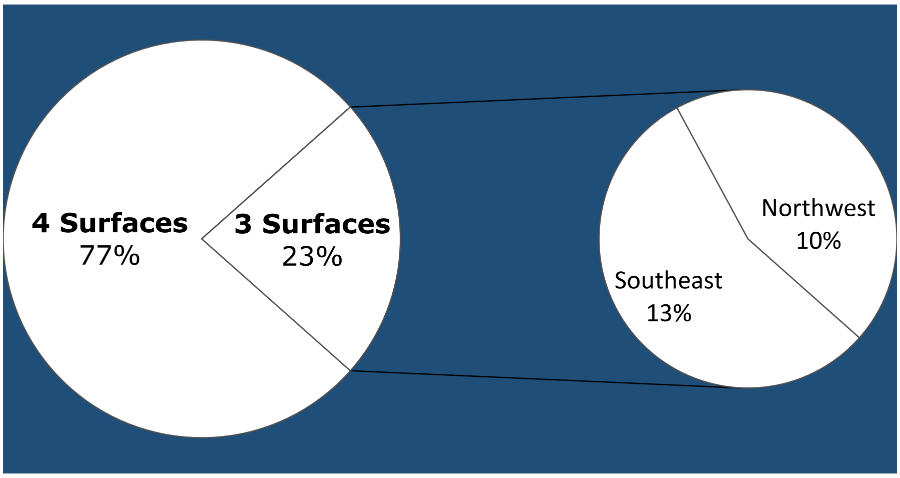


Figure 3.13: The Number of Building Surfaces on Salamis Street (Chart made by author)

Three main destructive factors have been detected in this case study. These factors actually make a distance among the most of the building blocks which result in increasing of open surfaces to three or four (the roof surfaces always are open in this case study unless it be overshadowed by neighbor buildings) (Figure 3.14, 3.15, 3.16).

1. Peripheral streets

2. Parking entrance

3. Building entrance

Figure 3.14: Example of Peripheral Streets (Photo taken by author)

Figure 3.15: Example of Parking Entrance (Photo taken by author)

Figure 3.16: Examples of Building Entrance (Photos taken by author)

On the one hand, peripheral streets are inevitable existing contributor of spacing between building stocks in the street so that they are defined as public space. On the other hand, a great deal of buildings prefers to hide the entrance from street. It may occur because of commercial activities at the ground floor. Meanwhile, some of them incorporate both entrance of building and shop in the same street-facing facade.

In some cases, these factors are only destructive contributors individually; nevertheless, sometimes two or three factors have combined together result in distance between two buildings. For example, a gap between residential buildings is occurred with both entrance of a building and parking entrance (Figure 3.17).

Figure 3.17: Example of Combination of Building Entrance and Parking Entrance Contribute to the Increase of Surfaces More Than Two (Photo taken by author)

It would appear that both building entrance and parking entrance are pioneered compared to others accounted for twelve buildings. In the case of "building entrance & parking entrance" and "peripheral streets & building entrance" just the gap was observed, five and six buildings respectively. The proportions of "peripheral streets" and" building entrance & parking entrance & peripheral streets" hit just one with a sharp contrast in the case study (Figure 3.18).

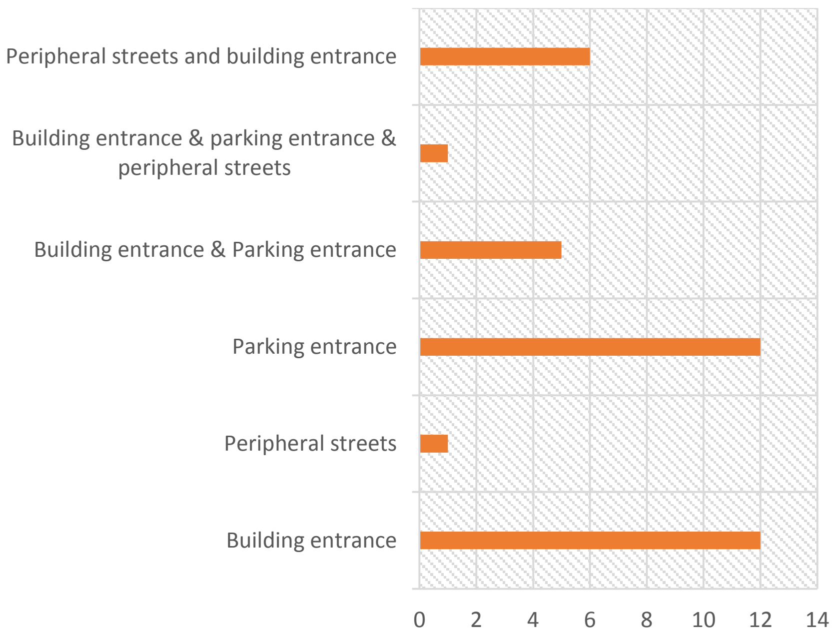


Figure 3.18: Factors of Making Distance and Increasing of Building Surfaces (Chart made by author)

3.7 Investigation of Windows

Window as opening type is the most significant element in the building's envelope. As well as it certainly plays a key role in determining human comfort in interior spaces. It is the main façade's component to harness natural light inside the buildings. As a matter of fact, it dramatically helps to maintain indoor spaces in right and stable temperature as much as it causes heat loss and energy waste.

Various window types offer different functions. The triple glazing window has the most capacity to combat heat transmittance with no marked shift as for U-value and acoustic insulation of double glazing in despite of its high price. By the way of contrast, a sharp contrast is seen as to the single glazing windows in U-value rates compared to other types.

In fact, the advantageous in both summer and winter, is the insulation, because it keeps the heat out for cooling demands and keeps heat for heating demands. As a result, double glazing windows are preferred to be in use in this case study.

Due to the better perceiving of the quality of the existing windows regarding the case study, an analysis about window types has been accomplished. Based on the census, the proportion of using double glazing windows in buildings represented twenty-eight; it came for a two and half-fold compared to proportion of using single glazing windows in eleven buildings (Figure 3.19).

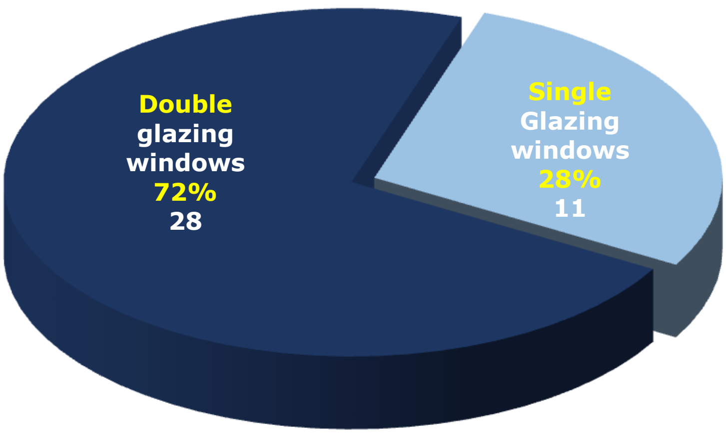


Figure 3.19: Proportion of Buildings with Single Glazing and Double Glazing Types of Windows (Chart made by author)

3.8 Investigation of the Shading Devices

In passive solar strategies, applied shading devices in proper position based on orientation as well as sun path are highly recommended to take maximum benefit of solar energy gain. Proper shaded openings provide natural light without glare and ventilation by harnessing solar radiations. Accordingly, it raises inhabitant's thermal comfort in both summer and winter.

For the most part, buildings have constructed with little attention to the function and significance of shading devices for residential buildings in the case study. Each residential block can be assumed like rectangle building form with holes in building envelope (openings) and without sun protections (shading devices). For example, majority of the multi-storey buildings have more than twenty windows in all surface areas without applying any shading devices.

According to the orientation in this case study, egg-crate shading devices are the most effective and operable ones because buildings are exposed to both south and west directions. Furthermore, it proves beneficial when prevents entering solar radiation from both west and south directions via windows in high angle of summer sun. Conversely, buildings can be heated by solar energy penetrating directly through the windows and indirectly through thermal mass in winter. Horizontal shading devices can be ranked as second choice of shading device types in this case study as well.

In this case study, only fixed shading devices have integrated on facades. Each kinds of shading devices work with specific systems like fixed and automatic models. They can be appeared when it is needed and can be hided when heat is needed for heating demands. It is requisite for each building to be adapted with fixed shading devices in suitable orientation; and the performance may rise by operation of using automatic one.

In this respect, the shading devices in order to different situation of windows according to building's orientation have analyzed in two stages. One is related to southeast- and southwest-oriented facades and the other one is related to northwest and northeast.

Figure 3.20, 3.21, 3.22, 3.23, 3.24 illustrate examples related to variety of shading contributors and elements used in different building facades of the case study. According to the literature survey in former chapter, the egg-crate shape is compulsory for both sides of southeast and south west. Similarly, it is easily understandable that vertical shading devices are the best choice for northeast and northwest based on the orientation diagram in figure 3.25.

Figure 3.20: Examples of Loggias Which Are Shaded Building in Southwest Direction (Photos taken by author)

Figure 3.21: This Building Has No Shading Devices in All Facades (Photos taken by author)

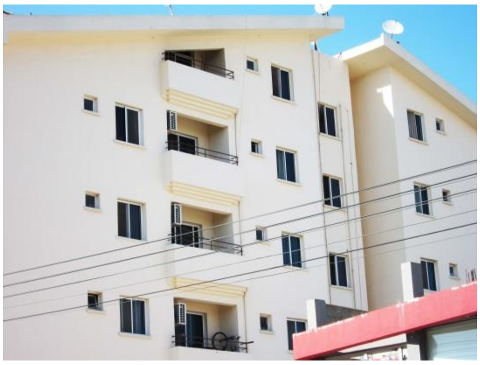


Figure 3.22: Example of Loggias Which Are Shaded Building in Southeast Direction (10% of Openings) (Photo taken by author)

Figure 3.23: Example of Balconies Which Are Shaded Building Horizontally (Photos taken by author)

Figure 3.24: Example of Shading Provided by Trees (Photo taken by author)

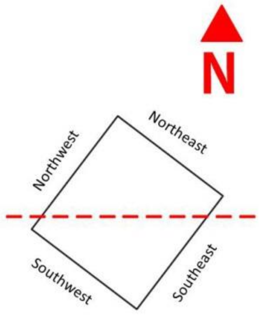


Figure 3.25: Real Orientation of Buildings in the Case Study (Illustration drawn by author)

The figure 3.26 below focuses on the shaded area on buildings located on northwest and northeast direction. In the case of northwest, the proportion of non-shaded windows markedly outnumbered the other categories. The most important shading in this direction took place for shaded areas by balconies (by shading 10% of openings) accounted for just 5 buildings. By the way of contrast, distribution of different shading contributors is conspicuous for the windows in the northeast direction so that the major discrepancy of the proportions are five times and minor one is one time.

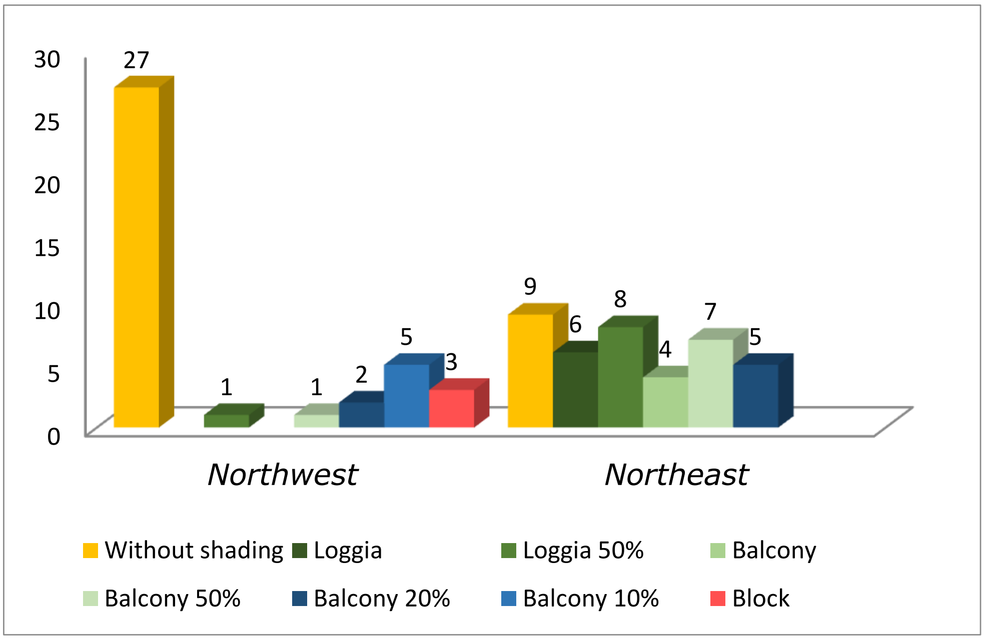


Figure 3.26: Investigation of Shaded Areas in the Northwest and Northeast Building Surfaces (Chart made by author)

Figure 3.27 focuses on the different kind of shading contributors (with their percentages of usage according to existing openings on building surfaces) faced to southwest and south east direction. In southwest direction, shaded areas by balconies came for highest proportion. Besides, loggias with shading 50% of openings came very close to balconies with shading 50% of openings (respectively eight and seven times). Quite surprisingly, a building have provided shading through decidous trees. Souhwest direction in all buildings is not blocked.

Non-shaded windowa stunnigly ranked first in the case of southeast direction. One of the buildings have fully shaded windows with loggias as in the southeast. Apart from that, three building have been blocked on the south east surfaces.

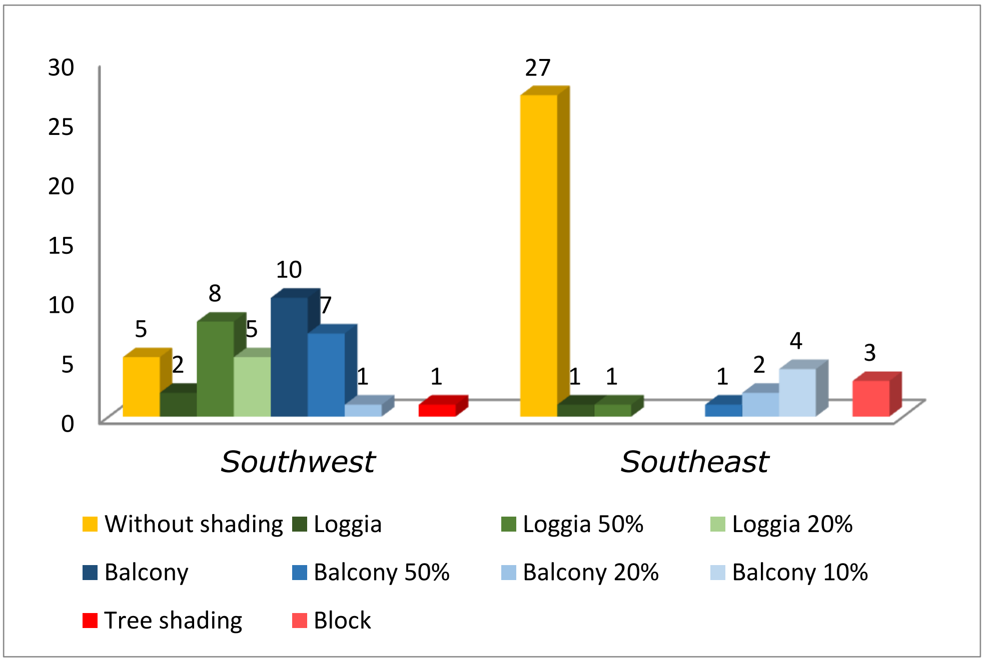


Figure 3.27: Investigation of Shaded Areas on the Southwest and Southeast Building Surfaces (Chart made by author)

3.9 Interviews in Depth

Meanwhile, professional viewpoints have acquired by the interviews with architects and experts in Gazimağusa (Famagusta), North Cyprus. In this respect, fruitful outcomes have extracted same open-ended questionnaire and interviews in depth. Meanwhile, detailed information of buildings, necessary points, and qualitative data in general regarding environmental issues of existing buildings in case study is uncovered. Meantime, inaccessible components of buildings related to passive solar design elements have evaluated by interview outcomes.

Initially, useful information was obtained about climatic conditions and characteristics of Salamis Road buildings. Comfort zone based on ISOPLETH map for Gazimağusa (Famagusta), North Cyprus occupies temperature range between 18°C-22.1°C. Moreover, mechanical cooling and heating systems like air conditioners are essential whenever the temperature reaches beyond 22.1°C which is called overheated period (O.H.P) or below 18°C which is called under heated period (U.H.P). Consequently, passive solar elements would have a constructive role to maintain buildings temperature within the comfort range.

There are various professional viewpoints regarding insulation position in Gazimagusa (Famagusta) buildings. On the one hand, some claim that Climate of Gazimağusa (Famagusta) town is hot-humid in which summer is generally longer than winter. In this circumstance, thermal insulations should be designed inner side of walls to work in effective way. Indeed, external wall will be bombard by sunshine. Thus, thermal insulation material should be located on the internal layer to prevent heat penetration inside the building.

If the thermal insulation was located on the external layer while external wall have radiated by sunshine during the day, the heat penetrates the wall cannot flow outward; thus, inside the building become very hot when the temperature falls over the night.

On the other hand, some hold a different idea. According to the EU Research of Energy Performance on Buildings in Greece, South Cyprus and Turkey, outer side of the exterior walls are suggested for insulation position and similarly, they expected the same insulation position for North Cyprus residential buildings. However, insulation materials and position can be completely different about non-domestic buildings such as theatre and conference hall. Wet rooms in the residential buildings even have insulation at inner side of buildings with different construction details. As a result, Northern Cyprus has no building code in this regard and all expressions are limited as suggestions.

Insulations can be used for walls, roofs and foundations in buildings. Vapor barriers also prevent condensation on the walls. However, in majority of the cases, there are no insulation materials for roofs in Salamis buildings. In the case of using air conditioner in buildings, thermal insulations are needed to control condensation; otherwise, natural ventilation of buildings is required. Another solution to avoid condensation in winter is using double or triple glazing windows. Because, double glazing windows does not allow condensation because inner glass cannot become wet (Ozdeniz, 2012).

3.10 Interview Sample

The questionnaire prepared to overshadow frameworks of this study and to clarify suspended and suspect issues about passive solar energy gain with focusing on climatic data of Gazimağusa (Famagusta). Author took advantages of the useful recommendations and suggestions; thus, applied them in the research particularly to evaluate data collection of the case study.

Focus: Passive solar energy **Area:** Ecological architecture

Field study: Salamis Road

Problem: The buildings cannot distribute heat in winter and reject solar heat in summer

Name: ____________ Field study at university: _____________________

How many years you have been taught relevant courses? _________

1. What is the effect of orientation of these buildings on their thermal comfort? (according to map)

Source: Google map Edited by author

2. What solution do you recommend to improve the existing buildings with current condition by using passive solar energy strategies?
3. How can comfort zone temperature range be achieved in Famagusta's buildings?
4. Which passive solar energy strategies are the most useful to reduce energy cost in North Cyprus?
    - Insulation
    - shading
    - openings
    - thermal mass
    - orientation
    - others

5. What should be the correct position of insulations in terms of climate condition?
6. Which heating and cooling systems should be used in Famagusta houses according to climate condition?

Figure.3.28: Interview Sample (Prepared by author) (Sample made by author)

Chapter 4

DISCUSSION AND CONCLUSION

This chapter concludes the body of research developed over the last year. In author's opinion, the scheduled objectives of the research in the "CHAPTER 1" have been achieved.

4.1 Discussion

To challenge and deal with the data collected throughout the case study of research, discussion in depth accomplished. Meanwhile, some proposals and solutions to combat improve and retrofit the weakness points of buildings have proposed. On the contrary, preventive measures should be taken in order to maintain the positive items existing in the case study. The outcomes of the discussion are listed below item by item:

A/V-ratio. All the buildings possess simple geometric form particularly rectangle with variety of size in area and altitude. A cube as a reference has 100% A/V-ratio. Then, smaller buildings volumes in the case study have less favorable A/V-ratio than larger one. Compactness would be an alternative to minimize the surfaces and increase A/V-ratio for new buildings.

Nevertheless, Salamis Road buildings have weak enclosure by small, free-standing and detached blocks enclosure. There are no outstanding compact forms of building in the case study. To sum up, correct design of surfaces can be used to gain energy and preserve heat.

Undoubtedly, there is little chance to compact existing building forms. Hence, further attention should be toward the improvements of insulation, shading and windows to compensate the lack of compact forms. Tree shading or designing integrated landscape around the buildings would be fruitful to avoid overheated surfaces.

Orientation. Orientation of the buildings is in northwest-southeast direction. In this condition, south façade cannot benefit solar energy as much as a fully south-oriented building. Because, the solar façade which mostly known as south façade is not quite distinguished in order to combination with west and east solar circumstances.

It often refers to use of commercial places at the ground floor. In addition, street orientation is from northeast to southwest. Buildings are attached to the street and have shopping faced to the street. Consequently, buildings are faced to the same orientation like the street. Therefore, the main contributors in this vein are commercial use at the ground floor and street orientation.

In part 2 of case study which street-facing façade is more faced (orientated) to south direction than part 1 and 3, accordingly this facade as solar façade gains more solar energy. Hence, the passive strategies related to south façade should be emphasizing in the part 2 in order to control solar energy for building demands.

Surfaces. Statics reveals that thirty out of thirty-nine buildings have four open surfaces. There are six buildings with fully function of residence and all have been separated by their parking entrance. Others have been a detached building by entrances or peripheral streets. It is with regret seen that spacing between building has caused to detached blocks result in building from all sides can be heated by solar energy in summer and can be impressed by cooling natural flows in winter.

The reason has roots in building design and the municipal maps. Peripheral streets are a matter of public spaces and municipal belonging. In addition, entrances firstly refer to existence of commercials in the street-facing facades and secondly refer to pilot. If the buildings were put up on pilot they had a reasonable combination with their entrances.

Solar Zoning. Solar zoning is an advantageous way of controlling solar energy related to space organization in building planning. To be more exact, the most occupied living rooms are placed on the solar side and less used spaces are located on the other sides (east, west or north). Interior walls in multi-storey buildings with several units in each floor can be organized to adapt with solar zoning rules.

Windows. Although the majority of buildings take advantages of double glazing window; however, 28% of them still utilize normal glazing windows. As matter of upgrading, complete change or improvement should be accomplished for window systems. Meantime, U-value should be 1.0 $W/m^2/^oC$ as a standard factor in thermal transmittance of double glazing windows.

In passive building design, it is necessary to insulate building envelope in order to avoid energy transmittance. Hence, all components and materials should have a favorable rate of insulations. For instance, if a low emissivity and low U-value (high level of insulation) window incorporated on the non-insulation wall, it seems like a building that control solar energy from one side and waste it from other side. Thus, thermal comfort would not be achieved in this condition.

The proportion of all windows in single building is equal whereas larger openings should be located toward south façade to take maximum advantage of solar energy and smaller ones conversely is suitable for east and west facades.

Shading devices. Shading devices mostly applied to southwest and northeast direction compared to two other sides of buildings. The other sides occasionally shaded by neighboring buildings because of their close distance among them. To have a deeper look, southeast and south west direction should have an appropriate protection against all west, east and south solar rays as well. Egg-crate shading devices are recommended to southeast and southwest directions and vertical shading for northeast and northwest.

Unfortunately, none of the buildings have appropriate vertical shading systems on their northwest and northeast directions. Three buildings are fully shaded by loggias, nine buildings are shaded 50% of its openings by loggias and five building are shaded 20% of its openings by loggias in southeast and southwest facades are represented. Generally, different kinds of shading devices as operative elements for indoor thermal comfort and harnessing solar radiation must be integrated on different facades. A design key for integrating shading devices is that shading devices on east and west are deeper than south in order to harness low angle solar rays.

Moreover, a shaded window can have better performance than non-shaded one due to the close relation of these two important passive elements. In fact, windows integrated with shading mechanism maximize penetration of light while minimize heat transfer and glare for users at the same time.

As a part of designing issues, shading elements are mostly undefined in the case of Salamis Road compared to common solar buildings; indeed, horizontal balconies on top of windows or façade fractures are shading producer for buildings' openings. Furthermore, deep eaves or external louvers also prevent overheating the building in summer and external shutters might be used to reduce heat loss at night.

Sun path chart for case study which is located on 35^{o} C latitude is calculated by solar tool 2011 software. This software helps solar architects to decide about solar measures and understand sun position as well. According to sun position, and its azimuth and altitude, shading devices properties can be discussed in Salamis street buildings. Meantime, building orientation is 135^{o}C from northwest to southeast.

In case study acoording to orientation, solar energy radiats building in maximum way when the latitude changes from 65^{o}C to78^{o}C and azimuth changes from 180^{o}C to 240^{o}C in summer season. Thus, shading devices should be designed based on this azimuth and altitude to provide appropriate shading mask for each window in summer time especially on the south façade. For Winter, azimuth changes from 30^{o}C to 40^{o}C in the case of windows facing to the south and it let sunshine enter to the interior spaces. It is obvious that buildings at northeast and northwest take less solar energy compared to the southwest and southeast directions.

Street façade in southwest direction is (between 11:30 and sunset time) exposed to solar radiation both in summer and winter; however, there are differences for sun angle. Shading devices should be designed egg-crate shape for south east and south west; nevertheless, deeper shading devices should be applied for south west because it has more sun exposure with higher altitude than south east. Similarly, deeper vertical shading for northwest can be applied compared to northeast. Meanwhile, some of the buildings have shaded by neighboring building during sunny hours in northwest and south east direction (chapter3, shading building on the each other).

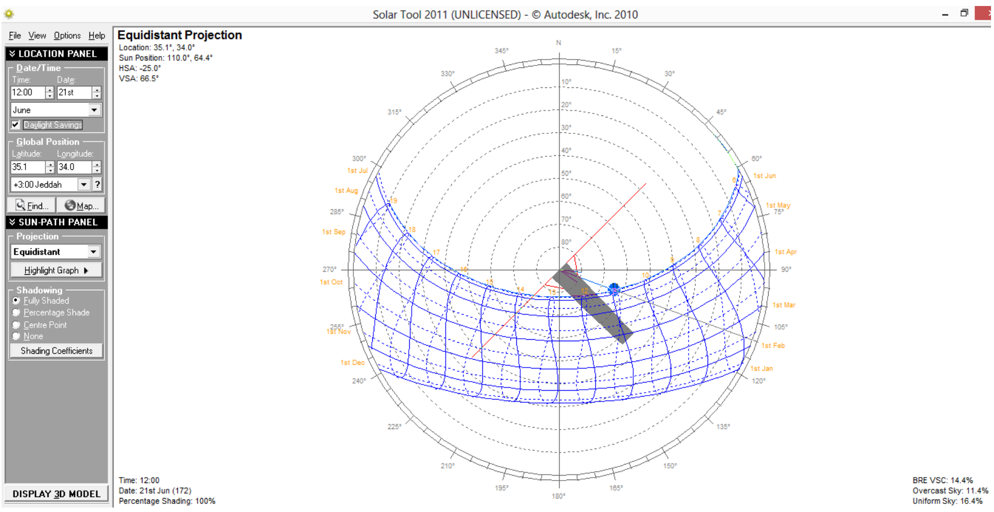
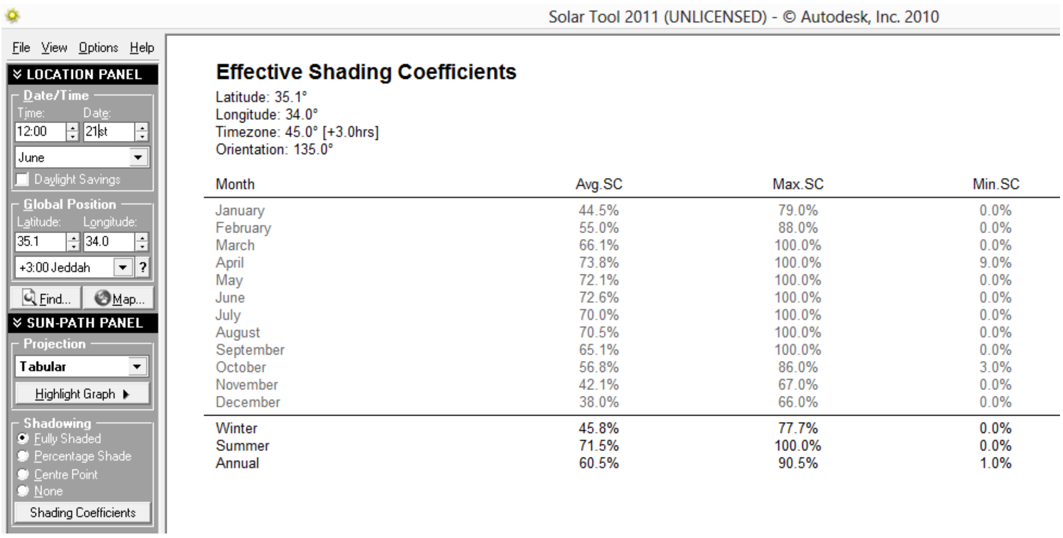


Figure 4.1: Sun Path Diagram for the Case study. It is calculated by author in solar tool 2011

According to the Sun Path Chart of case study, following chart regarding shading coefficient is calculated by solar tools software which shows percenteges of for each months in both hot and cold seasons. Shading coefficient is basically the ratio of solar gain (due to direct sunlight) passing through a glass unit. Obviously, shading coefficient has increased during summer months.



Month	Avg.SC	Max.SC	Min.SC
January	44.5%	79.0%	0.0%
February	55.0%	88.0%	0.0%
March	66.1%	100.0%	0.0%
April	73.8%	100.0%	9.0%
May	72.1%	100.0%	0.0%
June	72.6%	100.0%	0.0%
July	70.0%	100.0%	0.0%
August	70.5%	100.0%	0.0%
September	65.1%	100.0%	0.0%
October	56.8%	86.0%	3.0%
November	42.1%	67.0%	0.0%
December	38.0%	66.0%	0.0%
Winter	45.8%	77.7%	0.0%
Summer	71.5%	100.0%	0.0%
Annual	60.5%	90.5%	1.0%

Figure 4.2: Effective Shading Coefficients. It is calculated by Solar Tools 2011 Software

Thermal mass. Effective thermal mass must be incorporated in all outward surfaces of a room for maximum sorption. In summer, opening the building up at night to ventilate and cool interior thermal masses and closing the buildings up during the daytime to keep the heat out are passive way of diminishing cooling demands. In the winter systems works effectively by inverse precautions.

Direct gain. According to accomplished analysis in former chapter on different direct gain techniques, it demonstrates direct gain strategies are fruitful for the winter time since, solar radiation can act as useful contributor for heating space, however, in the case of summer time it is not fully responsive. In fact, indirect gain and isolated gain also should be incorporated in buildings to take benefit maximum solar energy for summer time. Because, these strategies are related to provide indirect solar gain (via conduction, convection and radiation) for indoor spaces. However research focus in this study is based on direct gain techniques.

Interview. The expressions in the interview shows insulation materials are necessary in wall and roofs. Generally, there is no energy performance regulation in North Cyprus which requires interior or exterior thermal insulation. In addition, vapor barriers should be toward warmer side of any insulation to avoid condensation during high humid and foggy days.

Thermal standard. Although ISO 7730 as a standard for thermal comfort is almost well established, however hardly can say a space satisfies everybody due to individual different sensations. To increase the level of acceptance for thermal comfort of an indoor space, the individual adaptation (individual activity and cloths) and environment control can be so helpful (Olesen, 2013).

PMV changes are parallel with metabolic rate and clothing insulation changes, However, PPD percentage increase with very cold or hot conditions (very high or low cloth and metabolic rate).

Hence, thermal comfort can be improved by upgrading building through passive solar elements, because these elements improve indoor spaces conditions compared to existing conditions and help to maintain indoor temperature in a stable and comfort way. For example, if cloth insulation increases, accordingly PMV increases, PPD show high percentage, dwellers feel warmer and thermal comfort does not achieved.

The maximum benefits and energy saving from insulation is closely linked to insulate all building envelop (window, walls, roofs and etc.). In this condition, thermal comfort can be achieved and cold winter and hot summer air cannot penetrate the interior and living spaces.

Cyprus has a Mediterranean climate and Gazimağusa (Famagusta) climate is mild and moderate which summers are hot and winters are relatively cold. Moreover, summer is a little bit longer than winter. Thus; wind a one of the important passive elements in this city because it offers both negative and positive effect in summer and winter. Thermal comfort range also can be influenced by changes in wind pressure.

In this respect natural ventilation would be provided by applying opposite openings facing prevailing wind in Gazimağusa (south and west); nevertheless, wind breakers also should be incorporated to protect buildings from severe wind loads in winter according to wide range of different wind breakers such as vegetation, different shading devices forms around openings and double skin façade.

The most of opening for the intended buildings in Salamis road according to Gazimağusa climate should be located to the south-facing façade because it invites solar radiation and its heat to the indoor spaces in winter whereas it protects indoor spaces by proper shading devices from direct sunlight.

In buildings with air condition systems, there is condensation risk in summer. Thus, material elections should be carefully accomplished, for instance, the defects related to condensation can be avoided by the use of thermal insulation materials which do not react against water. On the contrary, there is condensation risk for winter.

However, this condensation can be dried as long as the building is ventilating naturally.

The upgrading salamis buildings inextricably are linked to the both climate and existing building potentials for applying new building components (passive elements for retrofit). This potential of upgrading is clearly analyzed and observed in building envelops and facades. Hence, upgrading process should be accomplished with focus on these areas.

There are different window frames in the market, wood frames are environmentally friendly options because the wood is renewable resource, however, they would be expand or contract in the response to temperature changes. Wood is a natural insulator and sound barrier material. Fiber glass frames are a kind of good thermal insulation frames, thus; they can be assumed as energy efficient frames. They will not leak or wrap like wood frames and they will not corrode in the course of time. Vinyl frames are generally a less expensive option. They are energy efficient, excellent insulator and help to cut noise.

In this case study, for those buildings that have single glazing windows, double glazing window systems can be replaced as openings on the facades with low-e coated to the outer surface of inner pane to reflect solar radiation to exterior spaces.

In following figure, there are recommendations and further detail information for intended residential buildings in the case studies started from Eastern Mediterranean University toward Gulseren junctoion at Salamis street. In addition, possible improvements and upgrading in passive solar elements are recommended with regard to climate condition of Famagusta, building and street orientation and site location and existing building envelops.

Picture	Building code	Floors	Open Sides (all have open sides on NE/SW)		Shading Status (neighboring building/shading devices/vegetation)	Windows	Façade Material (Current status: Cement covered with special painting)	Color
	01	3	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun - SE shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	02	9	3	NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	03	3	3	NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Dark
	04	3	3	SE	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	05	4	3	NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	06	1	4	SE/NW	-Egg-crate for SW -Vertical for NE with deep shading devices to prevent low angle sun - SE/NW fully shaded by neighboring buildings	-Low-e coating -U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	07	5	3	NW	-Egg-crate for SW -Vertical for NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	08	2	3	SE	-Egg-crate for SW -Vertical for NE with deep shading devices to prevent low angle sun - SE fully shaded by neighboring buildings	-Low-e coating -U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	09	5	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Larger opening on SW	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	10	6	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	11	5	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m^2/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.masonry, etc.	Dark
	12	3	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with	-Low-e coating -U-Value ≤1.0	Using material with recycle, energy efficient	Bright

					deep shading devices to prevent low angle sun	W/m²/°C	and high thermal insulation ability like timber, bricks, masonry, etc.	
	13	2	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	14	2	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	15	6	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	16	3	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Dark
	17	3	3	NW	-Egg-crate for SW -vertical for NW with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	18	5	3	SE	-Egg-crate for SW/SE -vertical for NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	19	5	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	20	2	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	21	1	3	SE	-Egg-crate for SE -vertical for NE with deep shading devices to prevent low angle sun -SW shaded by deciduous trees	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	22	2	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	23	1	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	24	4	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry,	Dark

							etc.	
	25	2	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	26	3	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	27	6	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	28	2	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	29	2	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	30	5	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	31	3	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	32	3	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	33	3	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Replace window system with Double glazing U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	34	4	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	35	4	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	36	3	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤1.0 W/m²/°C	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright

	37	5	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤ 1.0 $W/m^2/^{\circ}C$	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	38	6	4	SE/NW	-Egg-crate for SW -vertical for NW/NE with deep shading devices to prevent low angle sun -SE fully shaded by neighboring building	-Low-e coating -U-Value ≤ 1.0 $W/m^2/^{\circ}C$	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright
	39	9	4	SE/NW	-Egg-crate for SW/SE -vertical for NW/NE with deep shading devices to prevent low angle sun	-Low-e coating -U-Value ≤ 1.0 $W/m^2/^{\circ}C$	Using material with recycle, energy efficient and high thermal insulation ability like timber, bricks, masonry, etc.	Bright

Figure 4.3: Recommendation for Building Blocks in Detail from EMU to Gulseren Junction. Illustration prepared by author. (N, S, E and W are abbreviations of north, south, east and west directions)

4.2 Conclusion

From author's point of view, a significant step was achieved by analyzing the existing buildings result in raise the public awareness about passive solar strategies. Passive solar design can be a helpful method of retrofit and improvement of human comfort and cooling and heating systems for all the existing buildings at present and in future.

Solar energy in particular passive use is interpretation of existing (local) architecture. Although retrofit existing building with passive solar energy strategies according to local climate hugely optimize energy performance of buildings result in increasing comfort index; however, identity of buildings should not be destroyed or injured during changes, integrations of passive design elements.

It is estimated that intended buildings have great and tremendous potential for applying the passive solar techniques. Based on the study on selected residential buildings, it reveals that there is plenty of attainable area for passive solar use, particularly on the facades. However, considerable limitations have unfolded in some investigations like building's surfaces that can be compensate by other passive solar energy strategies.

The decision about upgrading by applying passive solar systems is also closely linked to lifespan of the existing buildings. It shows potential of a building for adding passive solar elements. Apart from all, upgraded buildings with passive solar strategies have better performance and more lifespan in comparison to selected buildings in current circumstances.

Thermal comfort levels increasingly improved whenever the more passive solar elements participate in the whole solar systems in a residential building. Therefore, with serving a standard passive solar system in buildings, dwellers feel comfort in terms of any conditions either cold weather or hot weather as well as it has financial benefits so that buildings require relatively less cooling or heating systems.

For a long-term sustainable alternative to the residential building's problems facing Gazimağusa (Famagusta), North Cyprus, environment and tradition are not only mutually supportive in building upgrading, however, they are pre-requisite aspects. As an integrated approach, passive solar elements cannot be separated elements that are added after building construction. Passive solar elements should be replaced or integrated to other building components to offer dual functions result in decreasing total energy costs.

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