Chapter 28
The Proper Utilization of Passive Solar Energy in Residential Buildings, Northern Cyprus

Seyedeh Ayeh Mirrezaei, Harun Sevinç, and Ahadollah Azami

Abstract In the past, humans have always tried to have a relationship with the environment in order to create comfortable conditions for their lives. Over time, different cultures of the world created the architectural styles and techniques to adapt to climatic conditions. Unfortunately, building adaptation to the climate was gradually ignored with the arrival of the industrial revolution. Followed by high-energy consumption, environmental pollution and an energy crisis emerged. Thus there has been a revised consideration by architects motivated toward climatic design which is an effective approach to reduce the energy consumption in buildings. Undoubtedly, one of the important issues in compatible design with climate in mind is the proper utilization of solar energy. In this context, attention to the form and orientation of the building can significantly reduce energy loss especially in countries that enjoy solar energy such as Cyprus. This chapter focuses on the evaluation of appropriate orientation and form of dwellings regarding energy efficiency in Northern Cyprus based on a problem-solving method. The main purpose of this work is reducing building heat in summer and gaining heat in winter in order to achieve a favorable residential space. Ignoring climatic design can lead to harmful effects on human comfort.

Keywords Solar energy • Form • Orientation • Energy efficiency • Climatic design

28.1 Introduction

Today, building adaptation to climate has unique significance due to high-energy consumption, shortage of fossil fuels, environmental pollution, and human comfort. Climatic design is an effective way to achieve comfortable conditions and energy efficiency in buildings. Different characteristics of each climatic region have a great influence in shaping architecture. In this context, solar architecture plays a

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particular role in building design. The combination of architecture and solar energy can create convenient space for our living as well as being cost effective and affordable, therefore optimum utilization of solar energy is one of the effective factors for providing indoor comfort in residential buildings. In order to achieve this goal it is necessary to focus and apply the form and orientation of dwellings integrated with solar architecture in regard to energy efficiency. In this research, there is an attempt to present solutions for the problem of high-energy consumption of residential buildings and settlements in Northern Cyprus that have been evaluated in the terms of form and orientation. Mesan Apartment was selected as a case study in the city of Famagusta. Cyprus, due to geographical location and climate, can achieve energy savings by taking advantage of natural energy such as solar. However, current construction could not properly find ways to use this energy which is accessible and renewable, so the question comes to mind of why the ideal orientations and forms in contemporary dwellings are neglected regarding the appropriate utilization of solar energy and how we can achieve energy efficiency. The first step in solar design is based on analyzing the location and climate of Cyprus then compliance of the building with the climate. In the following, form and function of space should be evaluated in architectural design.

The methodology of this chapter is applied through problem solving and followed for the aim of this research via observation, questionnaires, and interviews. The case study research is a type of qualitative and quantitative research. Observation has been done to show the relationship between the building and sun and apperceive the best form and orientation for the building. The questionnaires designed for the people account for different ages and genders living in Mesan Apartment. The content of questions was based on location, orientation, shape, and plan of apartment relationship to the sun, cost of energy, use of passive solar system, and the tendency of energy efficiency measurements for the house. The outcomes revealed a significant dissatisfaction of spatial performance in two dimensions toward enjoying the sun. Also energy consumption accelerated enormously especially in winter and summer which led to an increase in energy prices. At the end, interviews with professional people have been done in order to deduce the best solution to the problem. The purpose of this chapter is based on heating the interior space in winter and cooling it in summer by attention to passive solar energy. As a result, disregarding building compatibility with the climate can have the greatest negative impact on the trend of energy use. Thus by proper form design, dwelling, and orientation in a proportionate and reasonable manner we may take advantage of the free resource of solar energy in our lives.

28.2 Literature Review

For energy efficiency one of the important characters in efficient building design is understanding the regional climate. Thus, compatible design with nature is one approach to providing comfortable conditions for the inhabitants. In this context,

consideration of solar radiation has a significant impact on the process of suitable design of buildings. In order to create pleasant spaces for our habitat, it is necessary to pay attention to the relationship between the sun and architectural features of the building so we can take advantage of passive solar energy. In this regard, orientation, shape, and space performance of a building are the main architectural features in order to capture or lose solar energy during the different seasons [1].

28.2.1 Orientation

Proper building orientation is one of the most important features in architecture in order to reflect natural light and bring solar rays and fresh air to indoor spaces. Thus design seeks to improve user well-being and quality of spaces by considering the relationship between the path of the sun and the building [2]. As seen in Fig. 28.1, the best orientation of the building toward the sun is the southern side because of the sun's position toward the building. To utilize solar radiation in the building, it is necessary to situate it on the ground using the largest amount of solar radiation. Therefore the site should be identified and determined in order to find the proper location having a vast view to the southern side. Thus, the important factor about the building location is the low angle of solar radiation and latitude of the site (Fig. 28.1).

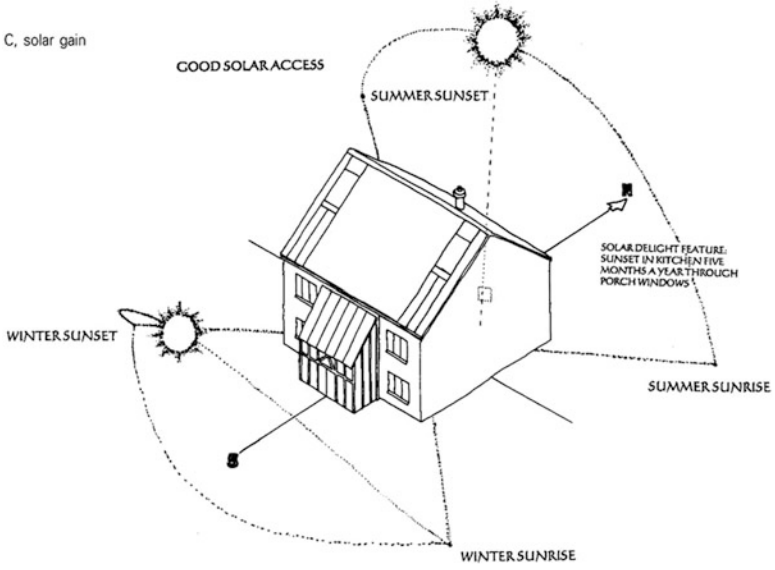


Fig. 28.1 Sun direction in summer and winter (Roaf [4])

28.2.2 Form

Consideration of climate, environment, and time (day, night, and seasons) is a particular part of designing the appropriate form in order to discover the amount of heating and cooling for creating comfortable spaces [3]. In this context, the southern facade, roof, and the number of windows should be considered in the building form. In the process of designing the plan these items should be considered:

- East–west elongation of the plan, in order to utilize maximum solar radiation.
- Allocation of main spaces on the south side and nonsignificant spaces on the west and east sides.
- Placement of spaces: for example, the kitchen which produces heat is better situated in the center of the plan in order to avoid heat loss.
- Arrangement of the plan due to penetration of solar radiation in interior spaces.
- Design of solar greenhouse on the southern side and near the main spaces.
- Attention paid to the path of the sun in indoor spaces [4].

Thus, efficient performance of spaces arises from an appropriate form of plan. The form of building plays an important role in the preservation of energy. The best building form should provide more absorption of energy and minimum heat loss in winter and maximal sorption in summer. Shaping the form is based on the demands of our shelters.

28.2.3 Passive Solar Design in Buildings

Passive solar design consists of direct and indirect gain systems. In the direct type, the roof, walls, and floor are integrated parts of the building for adsorbing the sun during the day and then transferring it to internal spaces at night. In this issue, windows play an important role in order to bring solar radiation directly into interior spaces. In an indirect gain system, solar radiation penetrates into interior spaces through intermediaries. A solar greenhouse (sunspace), the Trombe wall, atrium, the water wall, Thermo-syphon, and roof ponds are the main components of an indirect gain system. The performance of these elements causes the interior spaces to be heated in winter and cooled in summer. For instance, solar greenhouses capture solar energy on sunny days and then by natural convection come into indoor spaces in winter. By opening the windows of a sunspace, natural ventilation happens during the summer for cooling the spaces. In addition, it creates a pleasant space for users. As a result, designing the proper form in dwellings can allow us to bring passive solar energy into our shelters [5].

28.3 Field Study

Famagusta is a small coastal city, located in Northern Cyprus with a Mediterranean temperature. The north latitude of Famagusta is 35.13° and the east longitude is 33.95°. The height difference from sea level is 1 m. The population of the city is about 42,500 [5]. The maximum temperature of Cyprus reaches 41 °C in the summer and then in winter reaches 5 °C. Therefore, Cyprus has hot summers and cold winters [5] (Fig. 28.2).

The city of Famagusta was selected because it is in the best position to use solar energy. This city has an international university with many students, necessitating more residential buildings for their students. Therefore much new construction was built. Unfortunately, climatic design was ignored in these buildings. Disregarding this factor led to the emergence of the essential problem of high-energy consumption. Because of Cyprus' climate, paying attention to solar energy is an effective answer in this realm.

28.3.1 Data Collection and Methodology

The methodology of this chapter is based on problem solving along with both qualitative and quantitative analyzing. Data gathering was executed through the use

Fig. 28.2 Famagusta, Cyprus (18 Dec 2013. [7])

of observation, interviews, and questionnaires. The quantitative analysis of residential buildings was applied in order to improve the dwellings for their users. In this context, different questions were drawn in various fields such as satisfaction of daylight and sunlight, sources of energy for cooling or heating, arrangement of space performance, importance of windows, and also general questions about the financial investment for using solar energy. The qualitative analysis was conducted via observation and interview. During the observation, pictures for the case study were taken at different times of the morning, noon, and afternoon. Thus, the movement of the sun toward this building was evaluated. In order to comprehend how people provided comfortable conditions in their interior spaces and could reduce energy consumption by using passive solar energy in the future, the interview was done with regard to proficiency.

28.3.2 Interview with Local People

The questionnaires were conducted with the residents in theMesan Apartment in order to analyze the form and plan of the building regarding the sun. Over 45 users participated in this research. In the pie chart shown in Fig. 28.3 a large majority of inhabitants [87.7 %] complained about daylight. They have to use electricity for lighting their rooms. Only a few were happy: they liked dark spaces and avoided incandescents in their spaces during the day (Fig. 28.3).

The pie chart in Fig. 28.4 shows that 89 % of residents were disappointed in the amount of sunlight in heating their spaces during cold days, and only a handful of them [11 %] were satisfied. They explained that they weren't at home during the day so the sunlight was never important for them.

The chart in Fig. 28.5 expresses the various types of sources for domestic heating and cooling. As seen, electricity was allocated the highest level in both cooling and heating, whereas solar energy was in the lowest position.

Figure 28.6 indicates the space performance arrangement in the plan of Mesan Apartment. According to this chart, the majority of user dissatisfaction was about

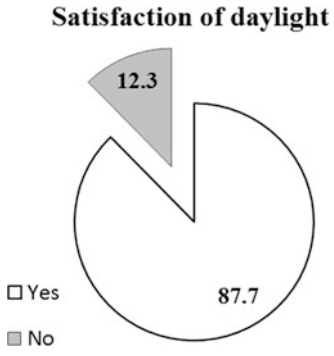


Fig. 28.3 Satisfaction of daylight (drawn by author)

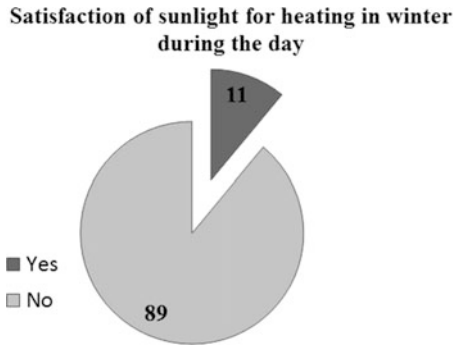


Fig. 28.4 Satisfaction of sunlight for heating in winter (drawn by author)

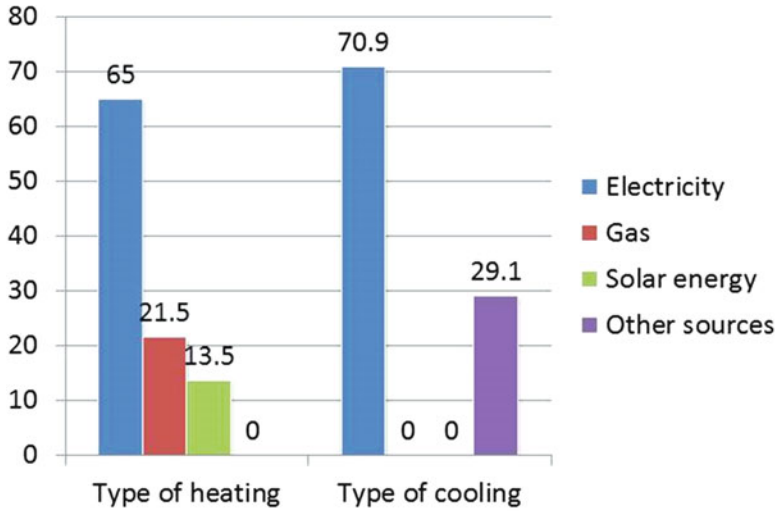


Fig. 28.5 Prototypes of cooling and heating

the situation of the living room, master bedroom, and other bedrooms. They explained that they could not benefit from solar radiation especially in winter for heating and lighting their rooms. The interior spaces were very cold and also gloomy, so they had to use electricity or gas for heating and lighting. On the other side, the position of the kitchen was the best one. They pointed out that this part was the heated section of the building in winter because it enjoyed the sun. They believed that these spaces should be shifted. The other three graphs reflect the importance of windows from various aspects (size, numbers, and orientation) in order to absorb the sunlight. As expected, the majority of occupants were dissatisfied with the number and size of windows because the apartment had small-sized insufficient windows on the southern side. Almost all of them showed their agreement that the windows should be located on the southern side in order to provide

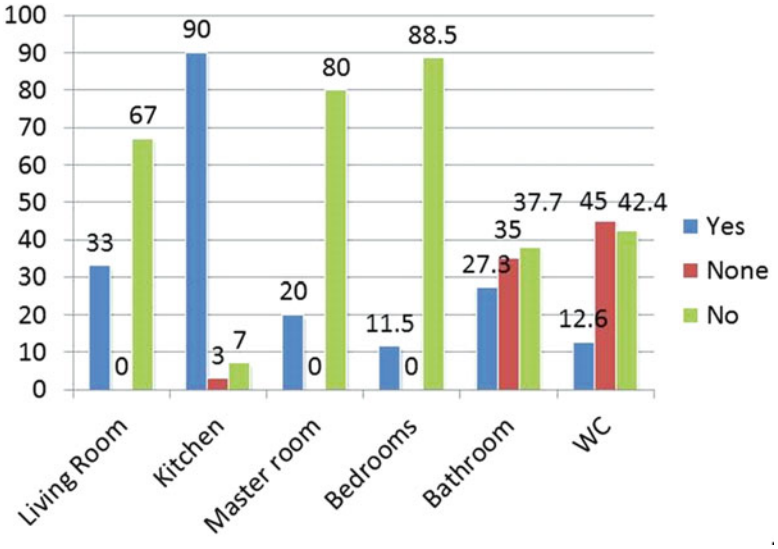
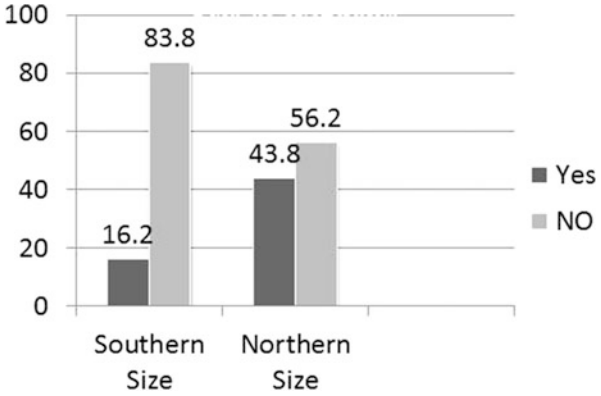


Fig. 28.6 Space performance arrangement satisfactory (drawn by author)

Fig. 28.7 Size of windows



sufficient sunlight. Due to the cold wind in winter, people were dissatisfied with the large number of with huge-size northern windows (Figs. 28.7, 28.8, and 28.9).

This question was drawn from different people in the city, not only those in the mentioned apartment. It was a general question to determine the importance of using solar energy. The pie chart illustrates the tendency of people to make a financial investment in order to benefit from solar energy in their flats. It is apparent from the charts that more than half the people disagreed (64.9 %). Approximately, 21 % of them agreed and a very low percentage (13.5 %) didn't have any idea. The most surprising indicator was that they knew the advantages of using solar energy in

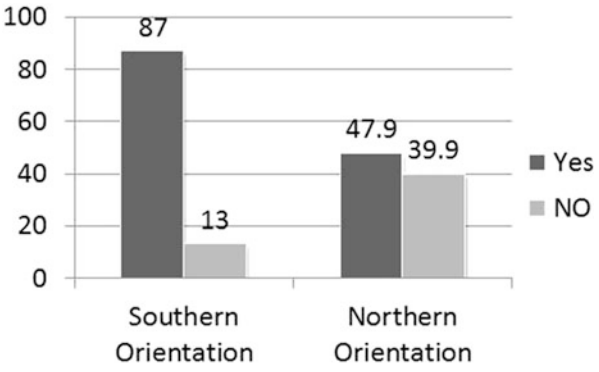


Fig. 28.8 Orientation of windows (drawn by author)

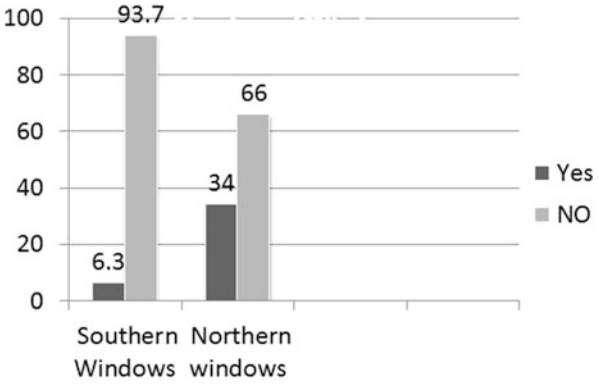


Fig. 28.9 Number of windows

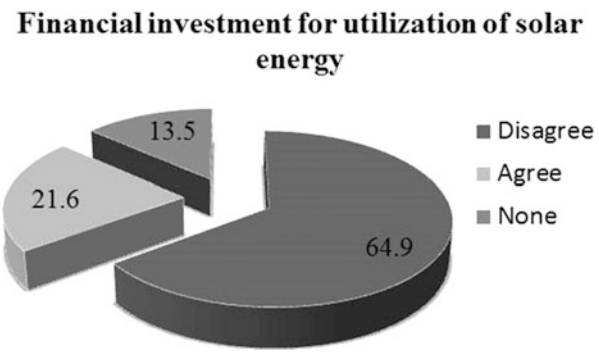


Fig. 28.10 Financial investment for solar energy utilization (drawn by author)

the near future and also about high energy consumption. Despite this fact, they did not show a tendency to invest money for reconstruction of their houses in order to benefit from energy efficiency. They were of the opinion, "Who will give us the money," even those who were financially capable (Fig. 28.10).

28.3.3 Observation

The pictures from Mesan Apartment were taken with the intention of evaluating the relationship between the sun and this building at different times and examining the best form and orientation of the building toward the optimal utilization of solar energy.

- Sunrise will be from the southeast and sunset will be from the southwest at this time of the year. Thus the relationship between the building and position of the sun is very important. According to these pictures, the southern walls receive the largest amount of heat and light from the sun. Therefore openings on the south can make a significant contribution to winter heating. Unfortunately, the southern side of this building has remarkably limited openings for enjoying the sun especially in winter. Moreover, these windows do not have any shading system for sun protection in summer. Instead of a southern wall, the northern walls are arranged with many windows. The height and size of the southern windows are not proportional because solar radiation comes directly to interior spaces and solar glare disturbs human comfort. Southwest walls can enjoy the sun especially in winter but you cannot see the windows in this part of building (Figs. 28.11, 28.12, and 28.13).
- The building form should be designed to have minimal absorption in summer and maximum achievement of solar energy in winter, but we cannot see this feature in this case study.
- A semicircular form of wall is very effective for absorbing the sunlight but in this case, the design is applied only on the balcony of the eastern wall so it is not useful.
- Due to high humidity in the summer, bilateral airflow is particularly important in order to comfort people in interior spaces. However, windows and ventilation are not in appropriate locations for airflow.
- The roof is an effective building component in solar architecture because of design integration. This building has a flat roof that has not been used to utilize solar energy properly.
- On the second floor, the northern side of the envelope incorporates a large balcony that faces the street without any buffer zone. It is not efficient for all of the seasons. People can use it only in summer despite vehicle sound pollution. On other floors there are small narrow balconies on the northern sides that do not have a profitable performance. Other balconies are situated on the eastern side which faces the Mediterranean wind. Thus, they are not beneficial for autumn and winter.
- In general, the planning system was badly designed. The quality of plan performance is very poor in this building. Because the living room and bedroom are located in the north, it is not possible to take advantage of solar radiation. The shortage of daylight causes people to turn on the lights at 4 p.m. In winter, interior spaces of houses are very cold. Only the kitchen and bathrooms are situated on the southern side (Figs. 28.14 and 28.15).

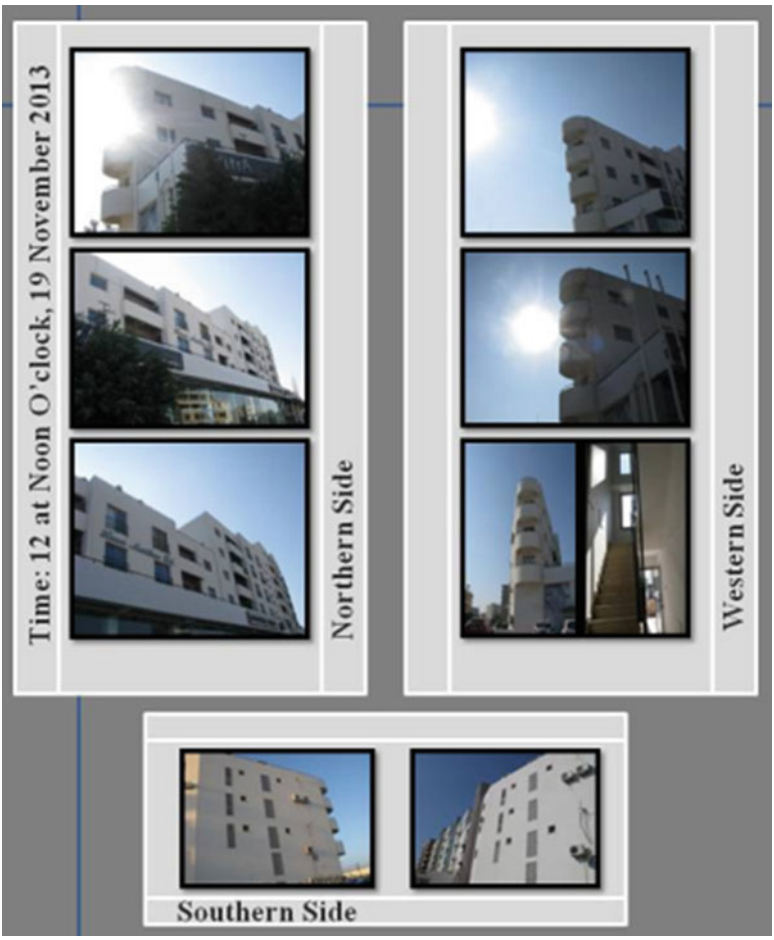


Fig. 28.11 Photos, Mesan Apartment, at 12:00 p.m.

As seen in Fig. 28.16, the southern side does not have efficient windows. Southern windows are very important in order to add their particular contribution for heating internal spaces in winter. Unfortunately, this building cannot enjoy this feature.

28.3.4 Interview

At the end, interviews with professional masters categorized the executable solution for the problem of the case study. Assistant Professor Dr. Harun Sevinç and Ahadollah Azami (solar architects) from the architecture faculty at EMU University

Fig. 28.12 Photos, Mesan Apartment, at 4:00 p.m. (taken by author)

participated in this interview. In this context, attention to the climate of each region during the design stage is an efficient approach to achieving energy efficiency. The position and orientation of the building toward the sun on the site, proper performance spaces in the plan, a suitable form of building, efficient openings, and use of passive and active solar are some factors in solar design. Unfortunately, current construction shows the opposite because architects do not have sufficient knowledge about state organization related to climate effect. It seems that they try to get money rather than quality of their design. As a result, a lack of balance between internal and external temperature, shortage of human comfort in the house, high energy consumption, the energy crisis, and environmental pollution are happening.

Fig. 28.13 Photos, Mesan Apartment, at 8:00 a.m. (taken by author)

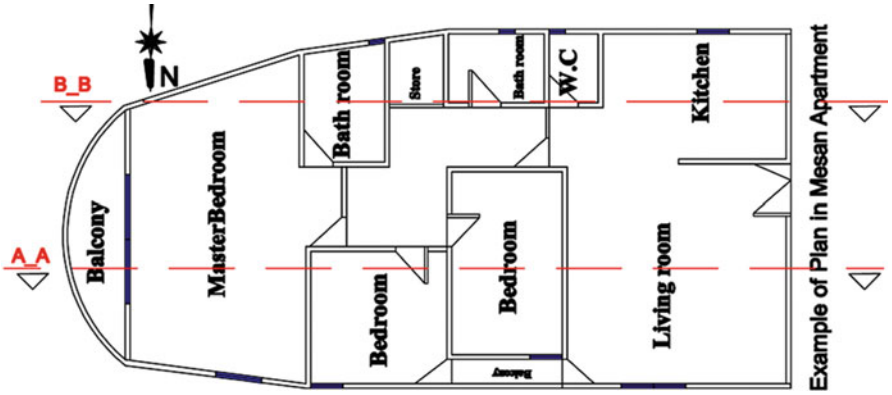


Fig. 28.14 Plan in Mesan Apartment (drawn by author)

Fig. 28.15 Location of case study, Google map (31 Dec 2013. [8])

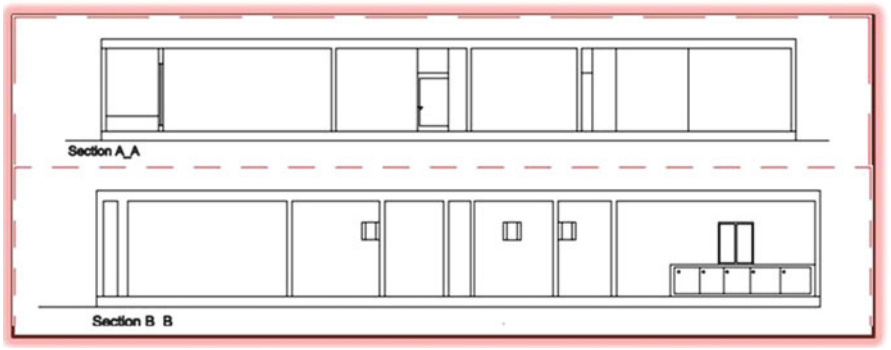


Fig. 28.16 Mesan Apartment section (drawn by author)

28.3.5 Data Evaluation

Throughout the data collection, it was revealed that dissatisfaction of Mesan's residents included the orientation and plan arrangement of their flat, the high cost of energy, high energy consumption, and shortage of solar radiation in internal

spaces. In addition, the most surprising part of the questionnaires implied that people were reluctant to make a financial investment for energy efficiency despite awareness of the advantages of solar energy. During the observation, the relationship between the sun and the building was determined by taking photos at different times. According to the images, inattention to this relationship was proved. This present study has set up an evaluation of the form and orientation of the dwelling regarding energy efficiency and the importance of the relationship between the buildings and the sun. By regarding the outcomes of observations, questionnaires, and interviews, these facts revealed:

- Disregard of coordination of the building with the environment in order to create comfortable conditions for humans in interior spaces.
- Shortage of solar radiation in internal spaces because of inappropriate orientation and form of apartment.
- Inefficient and limited windows in southern walls for enjoying the sun.
- Insufficient daylight in indoor spaces.
- High energy consumption during the cold winter and hot summer.
- Improper arrangement of spaces in the plan of houses.
- Unwillingness of people for reconstruction of their houses in order to use solar energy because of financial issues.
- Architects did not have sufficient knowledge about building compatible with climate in the process of designing both form and plan.

28.3.6 Recommendation

According to the findings mentioned, there are various and effective solutions for improving the quality of residential buildings in order to utilize solar energy, reduce energy consumption, and provide comfortable conditions in interior spaces in different seasons. See Fig. 28.17.

Due to the climate of Cyprus, these solutions were offered:

- Considering the design principles of the building with climate and nature with the goal of reducing energy consumption.
- A possible east–west elongation in the plan.
- Having appropriate width for designing the plan in order to access better airflow and ventilation.
- Main areas requiring more heating should be set in the south side of the plan. It is better to track the sun's movement in designing the plan.
- Designing more windows with appropriate size on the southern side.
- Using a passive solar system such as windows with direct gain and proper sunshade, Trombe wall, roof ponds, and green house.
- Covering the external surface with greenery to modulate temperature and decrease temperature fluctuation.
- Designing a suitable form of building in order to integrate a passive solar system.

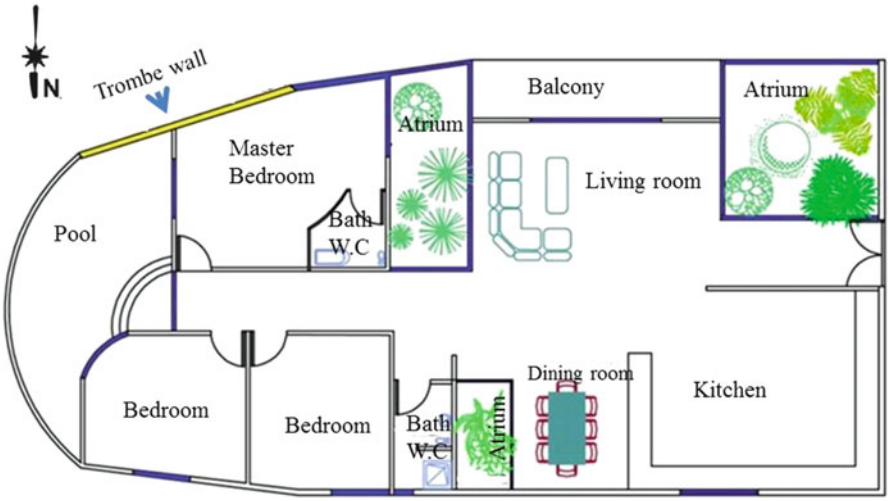


Fig. 28.17 Recommended plan for Mesan Apartment (drawn by author)

- The best range of adsorbing solar radiation is between the 15° West and 30° east toward the south.
- Using efficient shading systems for protection from direct solar radiation (Fig. 28.17).

28.4 Conclusion

Buildings play a key role as climatic modifiers, therefore adaptation of buildings to climate is an effective step for reducing energy consumption. This chapter established that the form and orientation of shelters have a great impact on the reduction of energy consumption and achieve positive results toward the utilization of solar energy. Providing comfortable and pleasant conditions in internal spaces is strongly based on the relationship between the climate and demands of buildings. As a particular prototype, the sun is a significant climate factor and can have both positive and negative effects in a building. By giving consideration to the proper design of form and paying attention to the orientation of the building toward the sun, it is possible to use the eternal energy of the sun. Thus it follows that we will have a decline in energy consumption, environmental pollution, and the energy crisis. Due to the climatic conditions on Cyprus, more utilization of solar energy power and a new approach to solar energy in creating the European Union building in Nicosia for a solar plan or solar energy can be suitable in the near future. In addition, cooling and thermal storage systems are being designed into new and existing buildings during construction. Although some arrangements have been accomplished it is not enough and we need more development. The development of

solar energy usage depends on people's beliefs and cultures in society. As an example, people should be taught and be familiar with the advantages of using solar energy and how to access it. In this trend, government plays an important role in encouraging people toward the optimal utilization of energy. Awareness of people and allocating subsidization can be effective in motivating people to use it.

Cyprus has a high number of sunny days per year and in the case of obtaining an amount of solar energy has suitable conditions, but unfortunately, it does not pay attention to such an immense source of energy. If climatic characteristics of each city are not taken into account we may have big problems such as a negative impact on energy utilization in buildings. Thus, it is better to find new technology designs in order to provide solar energy rather than the consumption of other fuels. Compatible building design can reduce energy dissipation and create a desirable effect on human life. In addition, Cyprus can achieve high independence in the field of importing fuels by the widespread usage of solar energy, thus the government sought to include solar energy in future programs in order to move dramatically into a new era of clean and renewable energy. I hope that this research creates a positive step toward reducing energy consumption and the energy crisis, and motivates architects to revise their designs in order to provide affordable conditions for residents.

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