Chapter 20
Guidelines for Sizing Shading Devices for Typical Residential Houses in Muscat, Oman

Alya Al-Hashim, Nader Chalfoun and Colby Moeller

Abstract Energy consumption of Oman's building sector is around 55 % of country's total energy demand and it has increased by 59 % from 2005 to 2010. Although Oman's Carbon Dioxide emissions are the lowest amongst the Middle East countries, it has witnessed a growth rate of 10 % from 2005 to 2010, which is considered the highest in the region. Since the country has not yet adopted nor developed any green building guidelines and lacks an energy performance benchmark, improving energy performance in Oman's housing stock is very challenging. This paper has three main objectives. The first is to establish guideline for sizing shading devices for different window orientations in Muscat, Oman. The second is to give a set of recommendations for designing the shading devices in order to make them culturally suitable, so they can be accepted and adopted by the community. Finally, the research studies the impact of the shading device application on energy consumption of the house using eQUEST. An energy reduction of around 10 % was achieved without drastically increasing cost of construction while also taking into consideration society's requirement for privacy and its concern to visually maintain its cultural identity.

Keywords Energy conservation · Residential buildings · Shading device

20.1 Introduction

Oman, especially the Muscat region—currently is developing at an astounding rate and transforming itself into a progressive developed area, Modern buildings are increasing on a daily basis and are rapidly replacing the traditional buildings.

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However, the modern buildings have failed to cope with the external thermal conditions to provide comfortable climate inside the building without relying on mechanical systems. This is largely due to the fact that traditional buildings were built with thermal mass and less window area than in modern buildings with extensive use of unshaded glazing [1].

As the development continues in Oman, demand of energy is also increasing. As per Oman energy report of 2011, the energy consumption has increased by 14 %, whereas energy production increased by only 1 % [2]. The country has started experiencing severe power cuts, reflecting the difficulties faced in bringing sufficient electricity production capacity to the grid. The residential sector is the single largest consumer category with consumption taking more than half of the total system energy, most of which is used for cooling. Energy demands of the residential sector have witnessed a rapid increase of 59 % since 2005 as compared to other sectors [3].

Energy conservation in Oman is urgently needed, as almost half of the produced energy is wasted needlessly to cool poorly designed buildings. As Oman's energy resources are in fact limited, it becomes apparent that if the problem is not addressed now, the next generation will have a bigger problem to deal with and solving it might be beyond their capabilities.

Many researches have analyzed Oman's potential for adopting renewable energy techniques, but there have been very few studies concerning demand-side management and energy conservation. Although renewable energy technologies are promising, many are not yet cost effective on the large scale. Reducing energy demand, in many cases, is less expensive than producing clean energy with cutting-edge generation technology.

There is a large opportunity for reducing energy demand in the building sector by promoting more energy efficient building design. Since most buildings have long life-times, in many cases 40 years or more, design choices whether energy efficient or inefficient, will be adding to the environmental impact for a long time [4].

One of the most, if not the most important passive cooling strategy is shading, which is a simple method of blocking the sun before it can get into the building. Application of this method in Oman will be studied in this paper.

20.2 Methodology

This paper has three main objectives. The first is to establish guideline for sizing shading devices for different window orientations in Muscat, Oman. The second is to give a set of recommendations for designing the shading devices in order to make them culturally acceptable. Finally, the paper will study the impact of the shading device application on energy consumption of the house.

20.2.1 Impact of Climate on Energy Consumption in Muscat, Oman

Muscat is located at the Tropic of Cancer in the Coastal region of Oman, and is highly influenced by its proximity to the sea. Since the climate of Muscat is hot-humid, solar radiation absorbed by roof, walls and windows is a primary source of built up heat in buildings. Shading helps in minimizing solar radiation, which effectively cools the building. Shading reduces the peak-cooling load in buildings, thus helps in reducing the required air-conditioning size [5].

Solar radiation received by exterior building surfaces depends on the surface orientation, time of day and day of the year. In Fig. 20.1 solar radiation throughout the day is shown for summer day (21 June) and winter day (21 Dec). The position of the sun in the sky is described by the altitude and azimuth angle. Both angles vary throughout the day and year. The altitude angle is measured from the horizon to the position of the sun in the sky. The azimuth angle described the direction of the sun in relation to the cardinal directions. Typically North is 0°, East is 90°, South is 180° and West is 270°. Alternate methods of angle definition exist depending on application. It is noticed that solar radiation received by roof, East and West facades is relatively highest, as a result of high solar angle, which reaches at azimuth angle of 89.8° at noon and high altitude of the sun in the early morning and late afternoon. Whereas in winter roof and South façade receive most of the solar radiation, because of the low azimuth angle of the sun at noon, around 43°.

Energy consumption in residential units in Oman is mostly climate-driven, cooling being the major energy consumer almost year round. Annual energy consumption of one of the houses is shown in Fig. 20.2, where it can be seen that January is the month with lowest energy consumption and August with highest consumption level. The annual demand reflects the climate in Oman and is highly seasonal. The average summer demand is more than double of the average winter demand, owing to the increase in cooling demand during the hot weather in summer [6].

20.2.2 Typology of Omani Houses

Building form in Oman may differ from one another, but the functional distribution is generally the same. Most of the single family houses have two floors, where the ground floor usually consists of semi-public (Majlis, Dinning) and semi-private spaces (Kitchen, Living). Semi-public spaces are where guests are welcomed, while semi-private areas are where family members and female guests are allowed to enter. The second floor consists of semi-private (Family Living) and private spaces (Bedrooms), where only family members are allowed (Fig. 20.3).

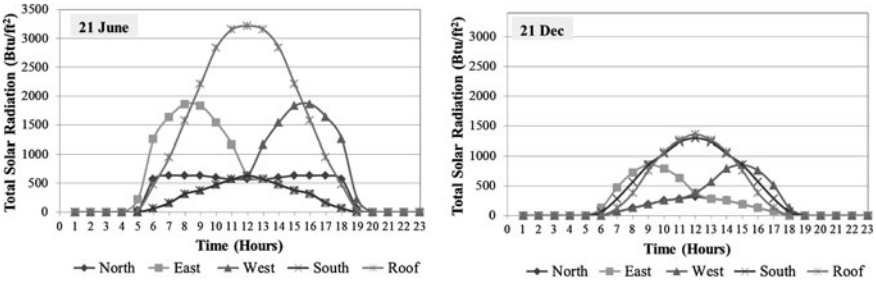


Fig. 20.1 Solar radiation on exterior surfaces in Sohar-Oman (Latitude 24.28) on 21 June and 21 Dec

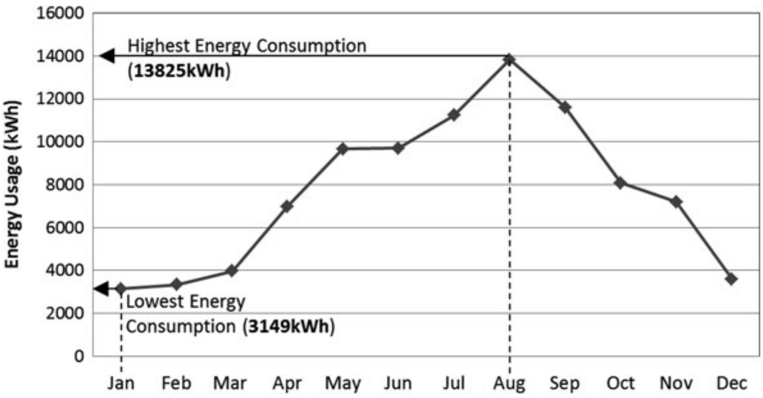


Fig. 20.2 Annual energy consumption of one of the residential units in Oman

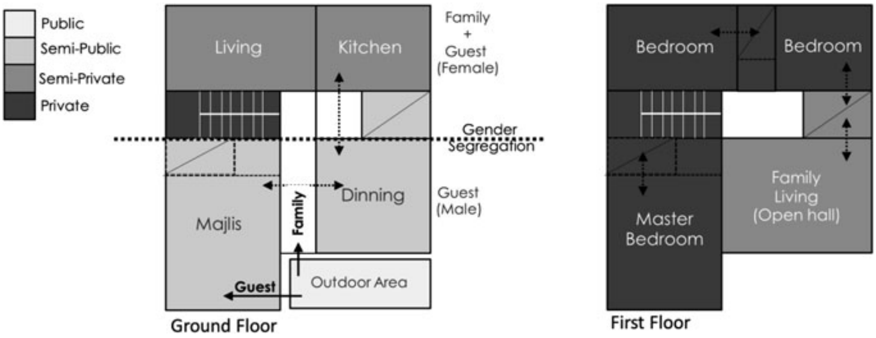


Fig. 20.3 Functional distribution in a typical Omani house

20.2.3 EUI Benchmarking and Interpretation

One of the techniques of benchmarking building energy performance is the use of established Energy Use Index EUI based on existing building energy codes Analysis of form, spatial distribution construction material and occupant behavior of an average Omani house, a base-case was prepared and tested using the RES-check and e-QUEST software, both developed by U.S. Department of Energy (Table 20.1).

When tested on RES-check, to determine whether new residential projects or additions to existing structures meet the requirements of the Model Energy Code (MEC) or the International Energy Conservation Code (IECC), it was found that the building did not comply with the code and failed by 83.8 %.

After that an energy model of the same house was generated using eQUEST and it was found that the Energy Use intensity, which is defined as energy use per square foot per year was around 140 kBtu/ft^2. Allowed Energy Use Intensity for detached single family house in a hot humid climate according to ASHRAE is 40 kBtu/ft^2, indicating that the Omani household consumes 100 kBtu/ft^2 more (see Fig. 20.4). Although climate in Oman forces people to intensively use air-conditioning system, but subsidies have also played a large part in producing a culture used to energy waste [7]. Oman's domestic energy consumption is supplied by natural gas 67 % and oil 33 % [8], and the energy prices are relatively low, around 3.9 cent/kWh because of the support provided by the government of Oman [9]. As a point of reference electrical rates in Tucson, AZ in the United States are around 11 cent/kWh.

In order to reduce the energy consumption in the residential sector of Oman, it is very necessary to introduce passive energy efficient strategies during design stage to reduce the energy demand of the building. However, these strategies will not be accepted by the community unless they aesthetically maintain cultural identity, do not compromise privacy of the inhabitants and do not increase construction cost.

As mentioned earlier, shading is perhaps the most important passive cooling strategy, so integrating this strategy with requirements of the community will help in making it an acceptable design option.

20.2.4 Defining Shading Mask and Projection Factor [10]

Theoretical framework for sizing shading devices has been provided by Olgyay [11]. In this paper the method of appropriately sizing shading devices for different orientation for Muscat, Oman is divided into two steps: shading period selection and form finding.

In order to reduce solar gain and eliminate glare, windows should be shaded most of the daytime in Muscat. However trying to accomplish this can result in horizontal

Table 20.1 Description of parameters used for energy model

Category		Value used			
		Construction	Finish Color	+	Insulation
Construction	Roof	8in Concrete	Light (abs = 0.4)		2in polystyrene
	Wall	8in CMU	Light (abs = 0.4)		No insulation
	Glass	Single Clr/Tint			
	Floor	Ceramic/Stone	8in Concrete		Earth contact
HVAC		Split system + Single zone (system per floor)			
Operating Schedule		Weekdays: 7am–2 pm			
		Weekends: Open 24 h			
Temperature set-point		Occupied:	Unoccupied:		
		Cool: 22 °C	Cool: 25 °C		
		Heat: 20 °C	Heat: 20 °C		

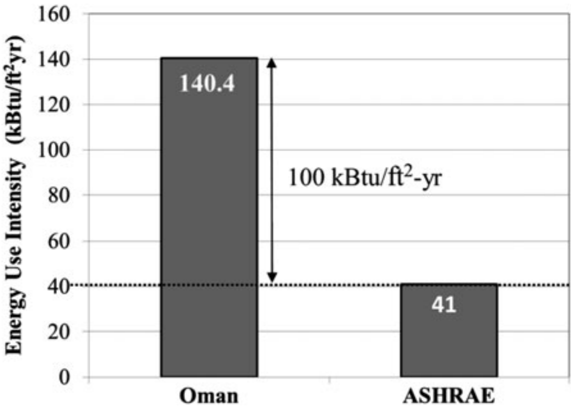


Fig. 20.4 Energy use intensity of an Omani house compared to ASHRAE standard

overhang and vertical fin design which would be impractical, particularly for the east and west orientations during early morning and late afternoon.

The overhang and fin designs recommended in this section have been developed to balance cultural identity with practical application. Solar gain is not significant during late December and early January (see Fig. 20.1) because daytime outdoor temperature is lower compared to the rest of the year; the average in December and January is around 23 °C, whereas in June it can reach up to 40 °C (Fig. 20.5).

An in-depth analysis was conducted for windows in different orientations and recommendations for overhang and fin sizes for Muscat, Oman were concluded (Fig. 20.6).

To make the table comprehensible by designers, data in Table 20.2 were converted into a graph that shows the overhang and fin factors (Fig. 20.7).

It is clear from Fig. 20.8 that East and West orientations require large fins and overhangs and can be very difficult to shade with architectural strategies alone.

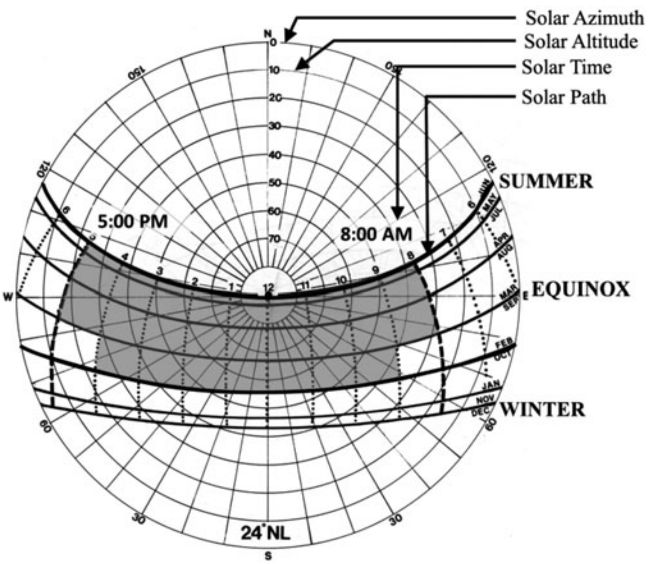


Fig. 20.5 Shading mask for 24-degree north latitude

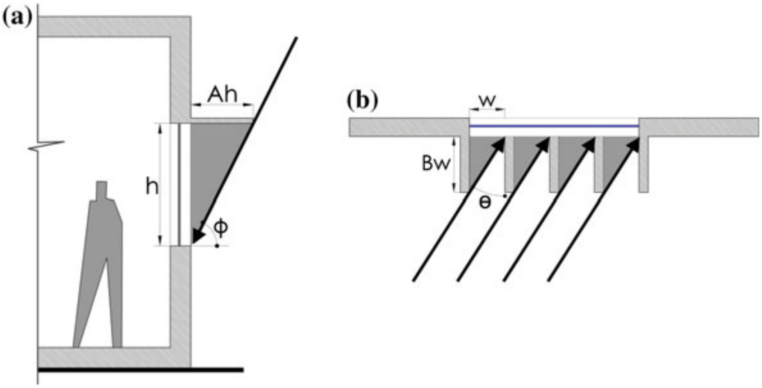
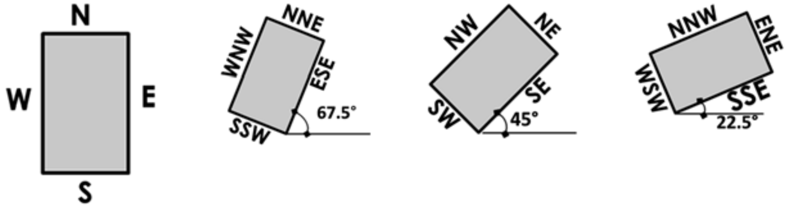


Fig. 20.6 **a** Section through overhang with Φ-degree cut off angle, **b** Plan view showing vertical fin with ⊖-degree cut off angle

20.2.5 Design Recommendations

Shading devices can be designed in many ways as long as the relationship between the window height and the depth of the shading device (the cut-off angle) does not change. In Fig. 20.8 examples of multiple shading design options are presented for overhang and fin sizes that are feasible to build (Figs. 20.9 and 20.10).

Table 20.2 Recommendation for overhang and fin sizes for Muscat, Oman



Orientation	Overhang		Fin	
	A	ϕ (°)	B	⊖ (°)
North	0.1	85	0.3	73
East	0.5	63	2.6	21
West	1.7	30	2.2	24
South	0.7	56	0.15	67
North East	0.8	50	1.4	55
North West	1	45	0.8	51
South East	1.6	32	1.6	32
South West	1.1	42	1.4	55
North North East	0.8	52	0.7	54
North North West	0.8	52	0.5	62
South South East	1.7	30	–	–
South South West	0.8	50	1	44
East North East	1	45	1.4	35
East South East	0.8	50	1.4	36
West North West	1.5	34	1.9	28
West South West	1.7	30	3	19

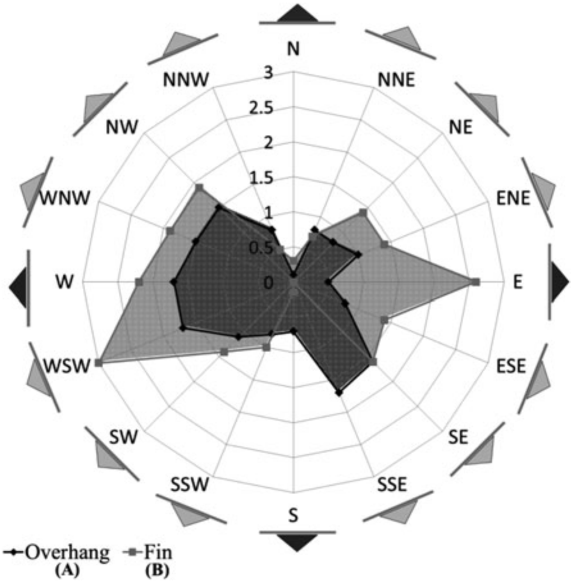


Fig. 20.7 Overhang and fin sizing factors (proposed by author)

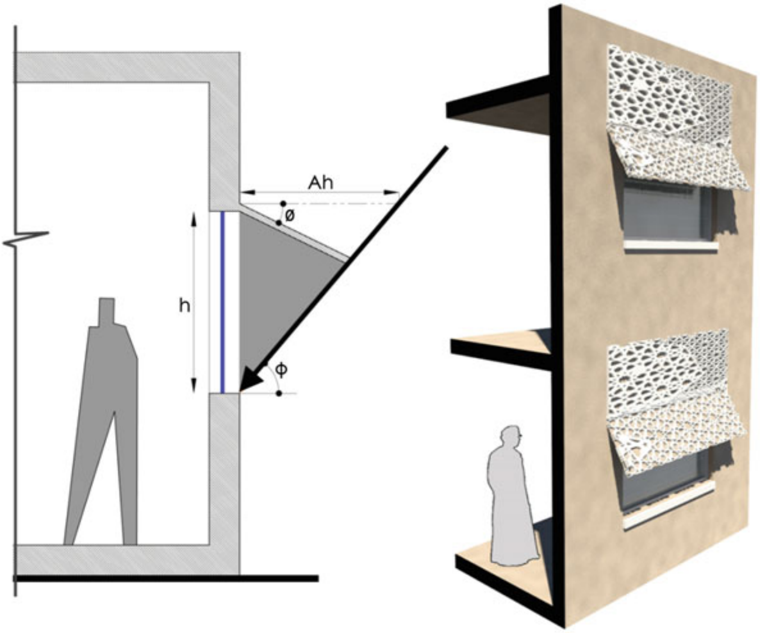


Fig. 20.8 Section and proposed design for inclined overhang

20.3 Analysis and Results

In order to test the impact of given recommendation for shading device size on energy consumption of a house, two existing houses were chosen from Muscat, Oman and their energy models were built using e-QUEST. One house had Energy Use Intensity of 189.6 kBtu/ft^2, higher than the average (140 kBtu/ft^2), and the other house had Energy Use Intensity of 104.2 kBtu/sq-ft, lower than the average.

The energy models of the houses were validated by comparing the results with actual energy bills of the houses, where it was found that the difference was less than 5 %. This shows that the results obtained from the energy model are correct and can be trusted.

The houses were then analyzed in order to choose appropriate shading dimension as per the given recommendation. Both houses had the same orientation, entrance façade facing West-North-West, which had the highest requirement for fin and overhang sizes compared to the other orientation of the building, so balconies were used for both houses to shade the façade and create aesthetically pleasing features at the entrance.

In case of the house with low Energy Use Intensity, the rest of the facades were shaded with a detached glass reinforced concrete (GRC) wall, which had inclined

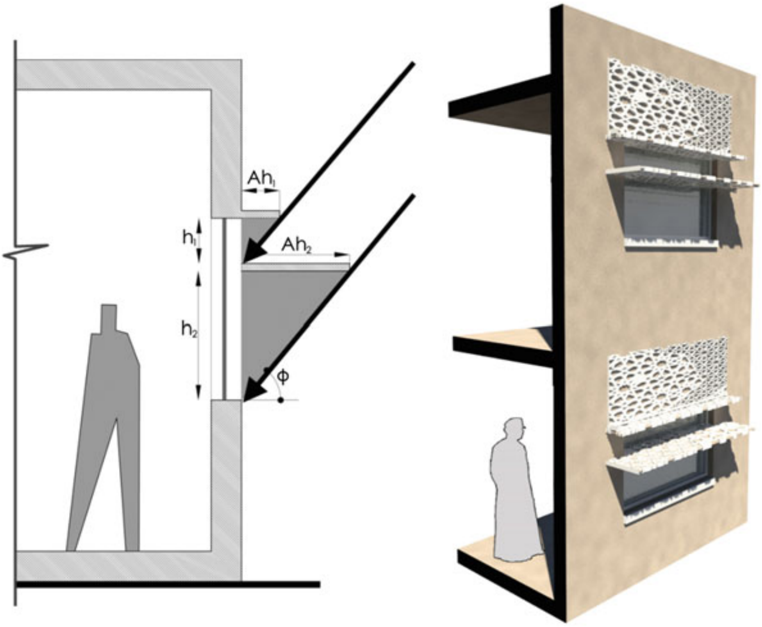


Fig. 20.9 Section and proposed design for light shelf

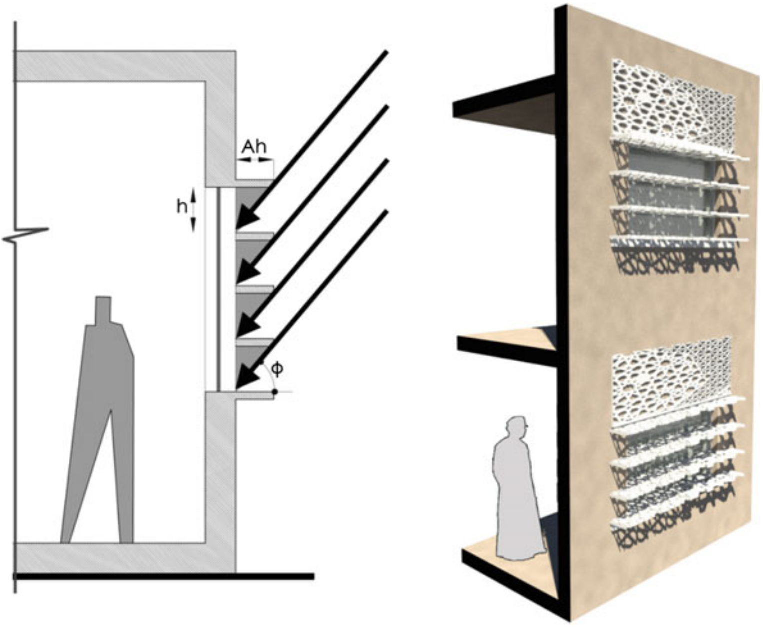


Fig. 20.10 Section and proposed design for multiple overhangs

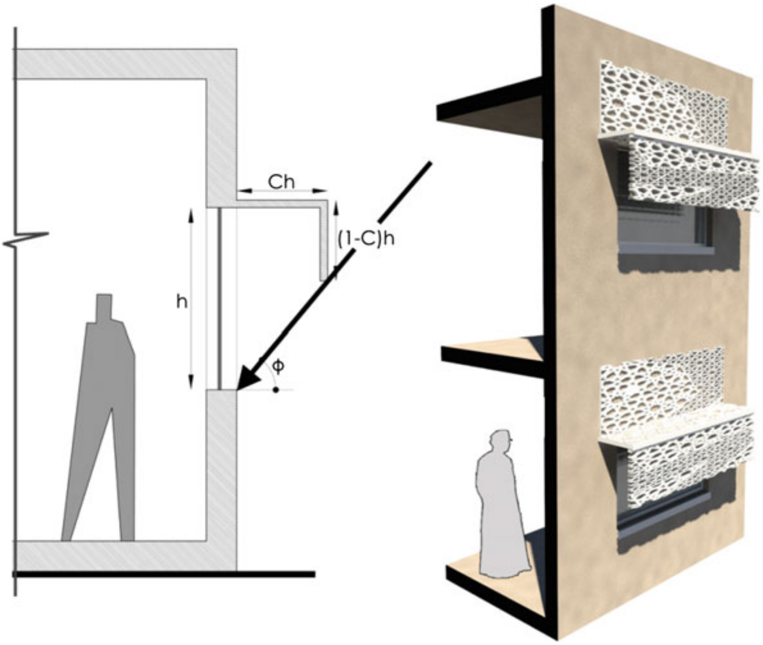


Fig. 20.11 Section and proposed design for light shelf

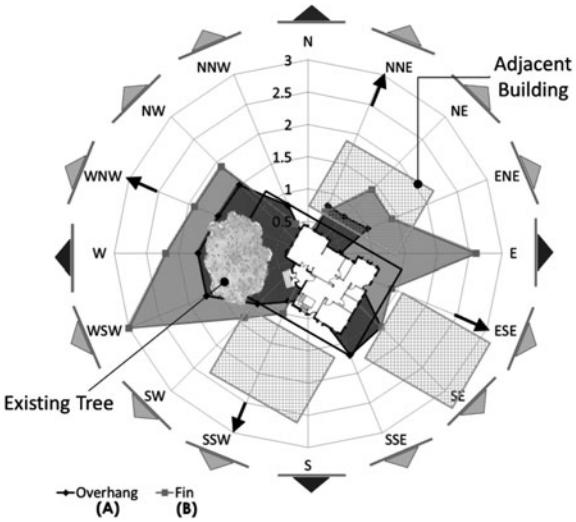


Fig. 20.12 Floor plan of the house with low energy use intensity implemented on shading recommendation diagram

overhang to shade the windows (see Fig. 20.11b). The detached wall helped in shading the wall along with the window and assisted the phenomenon of induced ventilation (Figs. 20.12, 20.13 and 20.14).

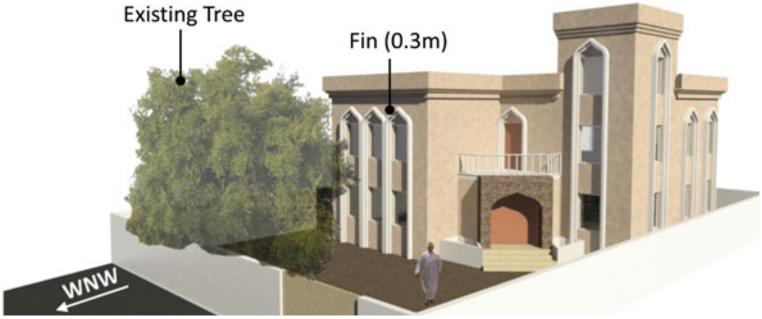


Fig. 20.13 Base case—Low EUI house (21 Oct at 14:00)

Fig. 20.14 Low EUI house after application of recommended shading (21 Oct at 14:00)

Whereas in case of the house with High Energy Use Intensity, parallel strip shading was used with traditional Omani decorations that also helped in aesthetically enhancing the building appearance (Figs. 20.15, 20.16 and 20.17).

Using the given recommendations, shading devices were designed for the two houses. It was found that the energy consumption of both of the houses decreased linearly, it decreased by 10.8 % for the house with high EUI and by 7.3 % for the house with low EUI.

In order to investigate the impact of shading further, sizes overhangs and fins were increased more than the recommendations and it was found that the impact of shading on energy consumption decreased, leading to a diminishing return. This indicates that the recommendations given for sizing the overhang and fin are valid and the impact of any additional shading will not help in decreasing the energy consumption as efficiently (Fig. 20.18).

Fig. 20.15 Floor plan of the house with high energy use intensity implemented on shading recommendation diagram

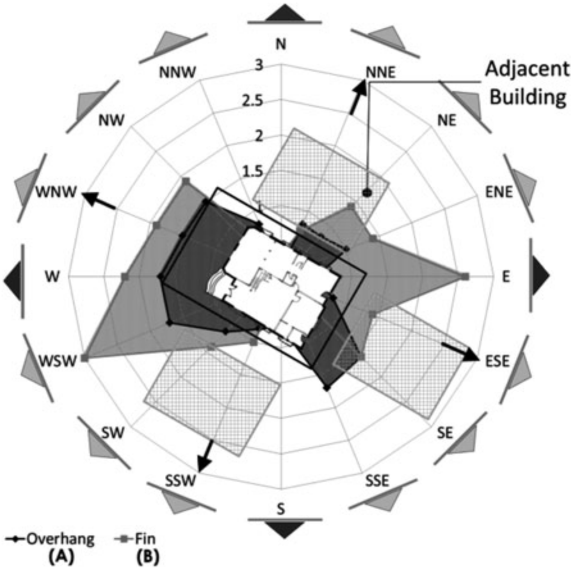


Fig. 20.16 Base Case—High EUI house (21 Oct at 14:00)

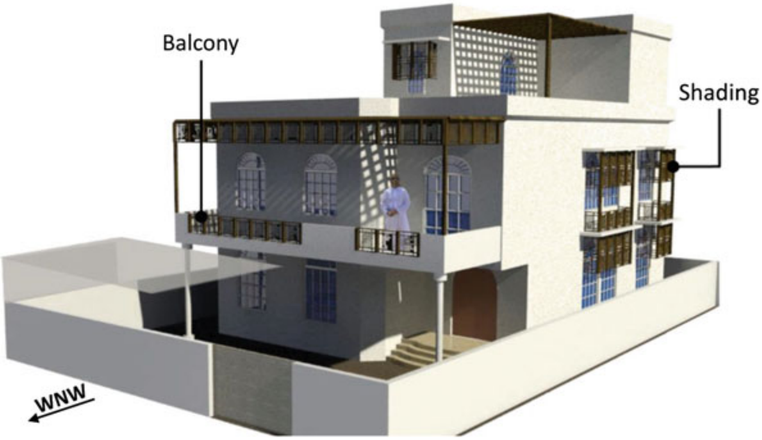


Fig. 20.17 High EUI house after application of recommended shading (21 Oct at 14:00)

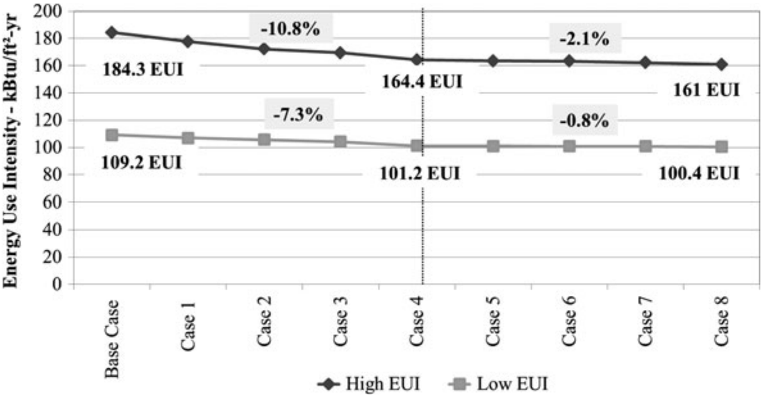


Fig. 20.18 Impact of shading on energy consumption

20.4 Conclusion

Oman has not yet fully adopted nor developed green building guidelines, so it is very necessary to introduce some energy conservation guidelines through sustainable building in the community. Providing designers in Oman with a proposed set of guidelines and recommendations will assist them in making energy efficient decisions during early stages of design, significant amounts of energy can be saved. This will also help reduce building energy consumption without increasing the construction cost. The proposed energy efficient design recommendations are culturally appropriate and can be integrated with the culture of Oman, which would encourage the community to embrace these choices easily.

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References

1. N.H. Abdul Majid, H. Shuichi, N. Takagi, Vernacular wisdom: the basos of formulating compatible living environment in Oman. in *ASIA Pacific International Confrence on Environment-Behaviour Studies.* Giza, Egypt, 2012
2. Statistical year book (2006), Sultanate of Oman: Ministry of National Economy
3. O. Authority for Electricity Regulation (2009), Annual report
4. B.J. Urban, L. Glicksman, The MIT design advisor: a fast, simple tool for energy efficient building design. in *Second National IBPSA-USA Conference,* Cambridge, 2006
5. L.T. Chadwick, *Solar Effects on Building Design* (Building Research Institute, Roorkee, 1962)
6. A. Al-Badi, A. Malik, A. Gastli, Assessment of renewable energy resources potential in Oman and identification barrier to their significant utilization. Renew. Sustain. Energy. Rev. **13**(9), 2734–2739 (2009)
7. H. Al-Hinai, W. Batty, S. Probert, Vernacular architecture of Oman: features that enhance thermal comfort achieved within buildings. Appl. Energy **44**, 233–258 (1993)
8. A. Al-Badi, A. Malik, A. Gastlii, Sustainable energy usage in Oman-opportunities and barriers. Renew. Sustain. Energy. Rev. **15**, 3780–3788 (2011)
9. Mo Economy, *Statistical Yearbook—2010* (Ministry of National Economy, Muscat, 2010)
10. N.C. Chalfoun, V. Cardona, in *Development of Pima County Net-Zero Energy Code; Shading Projection Factors*, Tucson, Arizona, USA, June 2011
11. A. Olgyay, V. Olgyay, *Solar Control and Shading Devices* (Prinston, New Jersey, 1957)