4.0 Reducing Energy Demand – Layout and Building Design

4.1 Introduction

4.1.1 An effective way of harnessing the renewable energy resource of the sun is through the application of passive solar design principles to new developments. It is based on the concept of minimising the energy needs of a building by making the best use of solar gain. This reduces the need for energy to heat and light buildings, which in turn minimises CO_2 emissions and energy bills for future residents. It is, however, also important to avoid excessive solar gain during the summer which can cause overheating and increase the energy demand for cooling.

4.1.2 Passive solar gain works by allowing solar radiation to enter a building through its glazing providing natural light and thermal energy which can be absorbed into the floor and walls. The thermal energy absorbed during the day is re-radiated at night into the living space, reducing diurnal fluctuations in temperature. To facilitate this process a number of complementary passive solar gain features need to be incorporated into the design of both the site layout and individual buildings.

4.1.3 The following sections consider the role of site layout and building design in delivering successful passive solar design. Ways of responding to the existing local microclimate in order to create a comfortable urban environment is also considered as well as the complementary role of landscaping.

4.2 The Role of Site Layout

4.2.1 The site layout needs to be based on an analysis of the site's natural features and its microclimate. Important microclimate considerations include: the position of the sun throughout the year; seasonal characteristics, including temperature ranges; and the direction of the prevailing wind. The site's natural features which contribute to naturally sunny or sheltered locations should be taken advantage of in the design of the site layout. Such features include slopes, tree belts and the shape and orientation of the site.

Orientation

4.2.2 Buildings need to be orientated within 30° of south to gain the full benefit of passive solar energy. Buildings orientated within 30° to the east will benefit from the morning sun while buildings orientated within 30° to the west will receive the late afternoon sun (see Figure 4.1). Rectangular shaped blocks with a west-east emphasis will facilitate optimal south-facing front or rear building layouts.

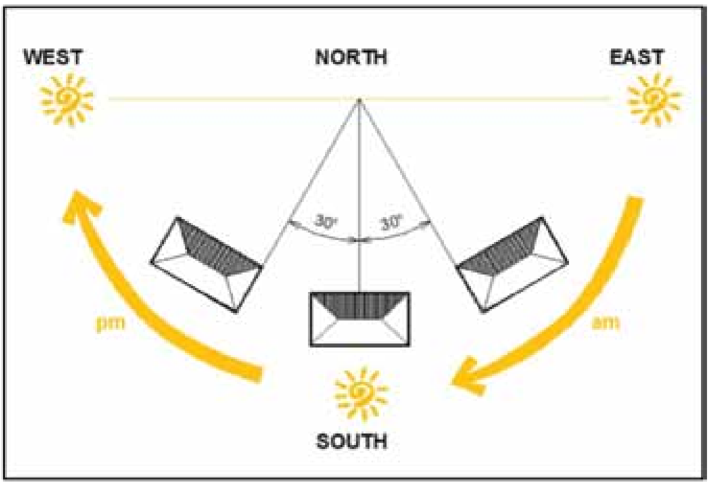

Figure 4.1

4.2.3 There may be instances where a west-east alignment is not favoured because of site shape or topography, or other urban design considerations, such as the need to respond to the street patterns of adjacent areas. In such circumstances opportunities will still exist to take advantage of solar gain. On north-south roads, detached buildings offer greater flexibility for maximising solar gain. On diagonal roads (e.g. northwest-southeast), buildings need to be positioned at an angle to the road to optimise passive solar gain (see Figure 4.2). These approaches would need to be balanced against the need to create a common building line which provides continuity of frontage and provides definition and enclosure to the public realm.

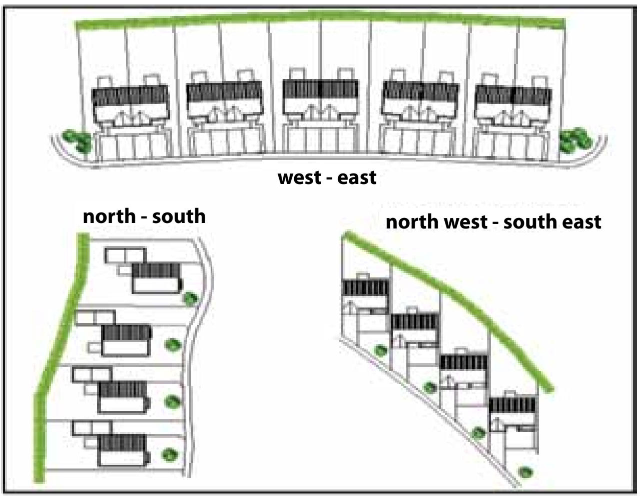

Figure 4.2

Overshadowing

4.2.4 The overshadowing of new buildings by neighbouring buildings, trees and other site obstructions can undermine solar gain. It is therefore important to ensure that trees and tall garden walls or fences do not unduly overshadow facades, and that adequate space is provided between buildings. Detailed information on how to calculate building spacing distances can be found in the Energy Savings Trust's guidance entitled "Sustainable Site Layout: An introduction to creating a sustainable housing development"[3].

4.2.5 Tall buildings have the potential to cause excessive overshadowing and need to be positioned carefully if this is to be avoided. It is recommended that tall buildings be located to the north of the site, or to the south of road junctions or car parks (see Figure 4.3).

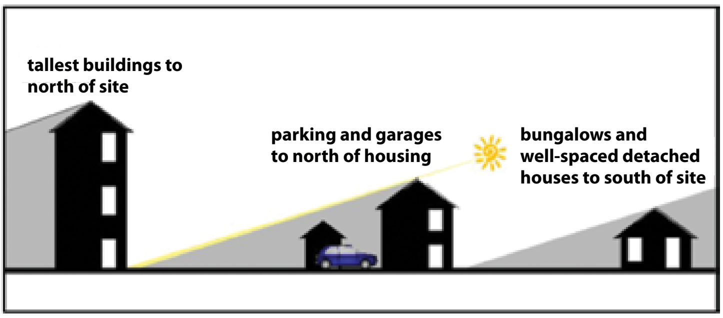

Figure 4.3

4.2.6 The slope of a site will have a considerable effect on the extent of overshadowing. South facing slopes are particularly advantageous as they can maintain suitable levels of solar access with less spacing between buildings. Consequently, this provides opportunities to achieve passive solar gain while building at higher densities. In contrast, north facing slopes can increase the amount of overshadowing making them less favourable for passive solar designs (see Figure 4.4).

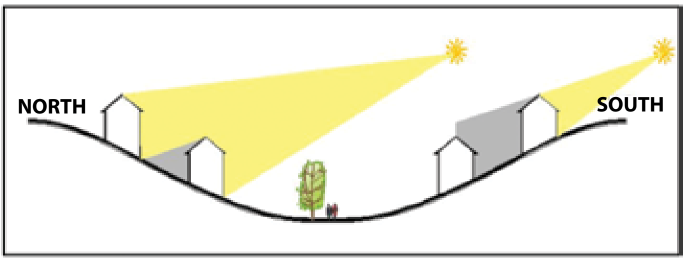

Figure 4.4

[3] *Energy Saving Trust. 2010. Site Layout: An introduction to creating a sustainable housing development (London, EST).*

4.2.7 There can be tension between achieving higher levels of density and maximising opportunities for passive solar gain. In certain situations it may be more appropriate to offset lower solar gains by incorporating more energy efficient built forms, such as terraced houses and low rise blocks of flats. These built forms have smaller external surface areas exposed to the elements which reduces the amount of heat escaping from the building and limits the infiltration of cold air into the building from the wind.

Wind Sheltering

4.2.8 The site layout should use landform and landscape features to shelter from cold winds which would otherwise result in heat losses in the winter. A shelterbelt of hedges and trees can be used to provide protection from the prevailing south westerly wind, and less frequent, but particularly chilling, north easterly winds (see Figure 4.5). In both instances, the shelter belt needs to be orientated along a northwest-southeast axis and sited a distance of 3-4 times their mature height from the facing elevation of a building. The length of the shelterbelt should be at least ten times its height, and approximately 15m longer than the area to be protected to prevent the buildings being affected by circular movements of air (known as wind eddies). Any trees that grow above the shadow line should be deciduous to allow low angle winter sunlight to pass through. Low level planting should also be used around tree trunks to avoid the channelling of wind at ground level (see Figure 4.6).

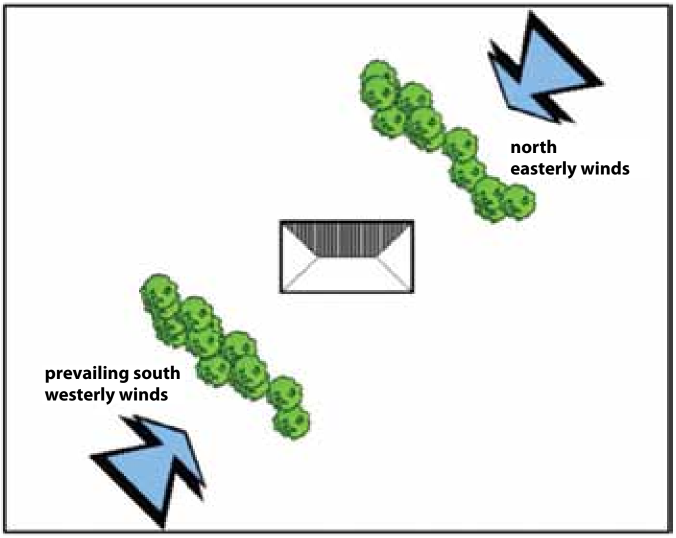

Figure 4.5

4.2.9 Wind patterns at street level can be influenced by site layout. Buildings arranged in an irregular pattern minimise the funnelling of the wind, while long uninterrupted rows of buildings can channel the wind along streets. Passive solar design layouts tend to reflect the latter as buildings need to have the same orientation in order to maximise solar gain. This problem can however be overcome by placing another building or landscape feature at right angles on the windward side of the row of buildings. The chilling effect of the wind on individual buildings can also be minimised by presenting the narrow frontage in the direction of the prevailing wind.

4.2.10 Tall freestanding buildings, such as blocks of offices or flats, can create wind eddies which channel the wind to ground level. Where such buildings are proposed, consideration needs to be given to the environmental performance of nearby buildings and implications for adjacent open spaces. Buildings of uniform height, set within highly integrated street patterns, are preferable as they encourage high levels of air movement.

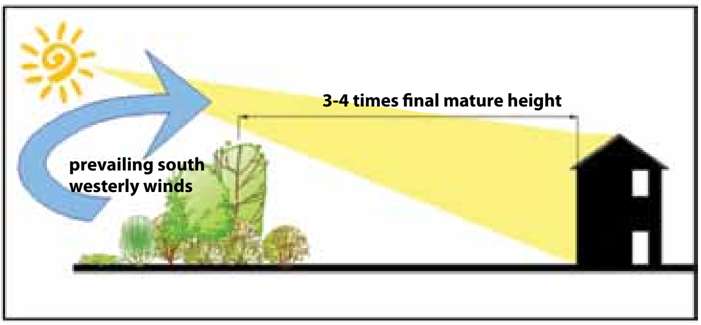

Figure 4.6

4.3 The Role of Building Design

4.3.1 There are a number of complimentary design features which need to be incorporated into new buildings in order to optimise passive solar gain. Some features facilitate the capture, storage and redistribution of the sun's energy, while others enable shading and cooling during the warmer summer months.

Internal Layout

4.3.2 The internal layout should ensure that the main living spaces (living room and office/study) are located on the south side and rooms which are less frequently used (bathroom and utility) are located on the north side. Kitchens should also be located on the northern side to avoid excessive heat gain. Bedrooms, which are unoccupied for the majority of the day, should face east in order to benefit from the morning sun. Conversely, they should avoid a westerly aspect as the late afternoon and evening sun can potentially warm the bedroom to temperatures which remain uncomfortable at night.

4.3.3 Building depth will affect the extent to which internal spaces can benefit from natural ventilation and lighting. The optimum building depth for naturally lit and well ventilated spaces is between 9-13 metres[4]. Buildings of greater depth will require some artificial ventilation and lighting, and consideration should be given to the use of double-aspect cellular building forms with the insertion of an atrium/light well for particularly large buildings, such as offices (see Urban Design Compendium for further information).

Glazing

4.3.4 The main windows should be located on the south elevation of the building (generally 75% of the window area should face within 30° of south). South facing windows should not be too large as heat loss may outweigh solar gain and the occupant's desire for privacy may result in the installation of net curtains or blinds which will restrict the amount of solar radiation entering the building. Windows on the north, east and west elevations should be limited in size and number to levels needed to allow reasonable levels of internal light.

Thermal Mass

4.3.5 Thermal mass is the ability of a material to absorb and store heat energy. Buildings with a high thermal mass take a long time to heat up and a long time to cool down, while buildings with a low thermal mass respond quickly to changes in internal temperatures resulting in greater temperature fluctuations. Generally, heavier construction materials such as concrete, stone and brick, have a higher thermal mass and are best for storing heat. In contrast, lightweight structures such as timber dwellings often have low thermal mass, and as such, tend to be less suited to passive solar design.

4.3.6 Phase change materials (PCM) can be used as an alternative to traditional heavier construction materials. These materials have high thermal properties with the practical advantage of coming as thin boards or sheets, which can be cut to size for ease of installation. PCMs are particularly useful for timber or steel structures and can be tailored to respond to the heating ranges experienced by a given building.

4.3.7 The location of the thermal mass within a building will have a significant effect on its year round effectiveness and performance. The thermal mass should be located internally, on the ground floor of south facing rooms which have good solar access and exposure to cooling summer night breezes. It can also be beneficial to locate thermal mass near to artificial sources of heating or cooling. The thermal mass should be left exposed internally and not covered with thermally insulating materials such as carpets and dry lining.

4.3.8 The use of thermal mass is particularly beneficial in winter as it absorbs heat during the day from direct sunlight and releases it at night, helping the building to stay warm. To be effective, it is vital that the thermal mass is exposed to low angle winter sunlight.

4.3.9 In the summer, the thermal mass will absorb heat to keep the house comfortable during the day. However, there will be unwanted thermal energy released back into the building during the night which could result in thermal discomfort. It is therefore essential that the amount of thermal energy entering the building is reduced during the day by shading out high angle summer sunlight, and effective methods of ventilation are incorporated into the design of the building to

---

4 *Llewelyn Davies Yeang/Homes and Communities Agency. 2000. The Urban Design Compendium (London, English Partnerships and Housing Corporation).*

carry away warm air at night. Further guidance on ventilation and shading is provided below.

Insulation and Ventilation

4.3.10 Insulation prevents heat from flowing into and out of the fabric of the building. High levels of insulation are an essential component of passive solar gain as it enables the re-radiated heat to remain within the building. Floors, walls and roofs should all have good levels of thermal insulation.

4.3.11 Dwellings that optimise solar gain need to incorporate a natural ventilation system within the design of the building so that it is able to regulate unwanted heat gains, particularly during the summer months. If it fails to do so, the thermal discomfort experienced by the occupier could lead to the installation of a mechanical cooling system that will increase energy use and CO2 emissions.

4.3.12 The required ventilation rate can be calculated and a suitable ventilation strategy formulated. Examples of natural ventilation strategies include the use of passive stack ventilation and cross ventilation. Whichever strategy is chosen, it is important to ensure that night time ventilation components, such as louvers or windows, are secure and can be locked in an open position.

Shading

4.3.13 Good passive solar design will need to incorporate solar control. This is particularly important on south and west facing facades where the solar gains coincide with the hottest part of the day. The most effective shading system will allow the building to prevent excessive sun in the summer, gain full sun in the winter and manipulate sun levels at other times.

4.3.14 Solar control devices come in different forms with fixed and adjustable types being commonly used. Fixed devices, such as brise soleil, are positioned horizontally above a window and work by obscuring part of the sky through which the sun passes. These shading devices are particularly effective at regulating solar gain on southern elevations throughout the year and require no user control. High angle summer sun is prevented from entering the building, while low angle winter sun is admitted beneath the device (see Figure 4.7).

Figure 4.7 Brise soleil incorporated into the design of the Woodland Resource Centre, Cyfarthfa Park.

4.3.15 Adjustable shading devices, such as shutters and external blinds, have the advantage of allowing control over the desired level of shading (see Figure 4.8). Such shading devices are particularly suited to east and west elevations where fixed shading devices are ineffective at preventing low angle morning and afternoon sun from entering a building. They are also recommended for south-east and south-west elevations as they receive a combination of high and low angle sun throughout the day.

Figure 4.8 Externally mounted blinds providing solar shading on the Larch House, the Works Site, Ebbw Vale.

4.3.16 Landscape planting can also be used as an effective means of shading. Here it is important to match the vegetation's characteristics (such as foliage density and canopy height) with the shading requirements of the building. A common method is to use deciduous trees to control the amount of sunlight reaching a building at different times of year. In summer, a deciduous tree will shade the building from the sun. In winter, it will allow the sun to pass through and enter the building (see Figure 4.9). Shrubs can also be used for more localised shading of windows.

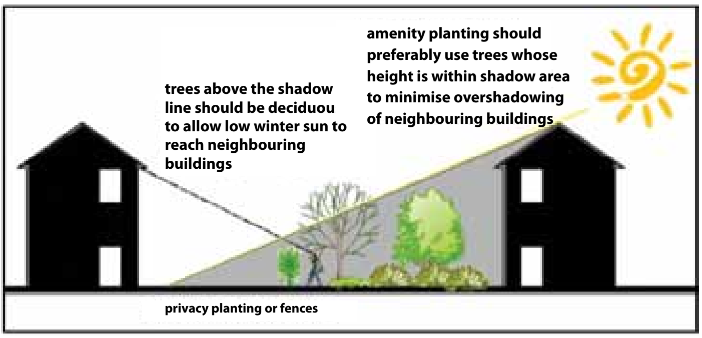

Figure 4.9

4.3.17 Conflict can arise between optimising solar gain and providing adequate levels of privacy for occupiers of buildings. If living spaces are overlooked from public highways occupants may install net curtains or blinds which can reduce solar gain. Appropriate landscape planting, such as hedges, can provide a solution in such circumstances provided they are at a height which affords privacy without overshadowing the building. Where higher hedges are considered necessary, for example where a building fronts on to a busy road, deciduous plants should be used[5].

Sunspaces

4.3.18 A sunspace is a heavily glazed area located outside the main fabric of the building. They can adjoin an external elevation of a building, or be embedded within the main structure. For whichever option is chosen, it is essential that the shared wall and any doors and windows adjoining the sunspace are thermally equivalent to those used for external elevations to prevent uncontrollable heat gains and losses.

4.3.19 Sunspaces function by using passive solar heat gains to warm the air within the glazed area. The warm air is then transferred into the main living space of the building via a natural ventilation system. Warm air flows into the adjoining living spaces through openable vents located in the common wall at the top of the sunspace. Cool air is then returned from the living spaces through lower vents. Mechanical ventilation systems can also be used to extend the reach of the warm air by blowing it via ducting to other areas of the house.

4.3.20 Sunspaces also have a number other beneficial attributes: they act as a thermal buffer by providing an intermediate space between the inside and outside of the building; they shelter the envelope of the building from wind chill and rain; and they provide additional living space when natural conditions make them comfortable for occupation.

4.3.21 South facing sunspaces can be susceptible to overheating in the summer, and as such, it is essential that an appropriate ventilation system is incorporated that allows warm air to be vented out to the external environment when heat gains are not required. Additional shading techniques, such as the use of opaque roofs, louvers and vegetation, should also be considered.

Roof Design

4.3.22 A building's roof design will affect the extent of overshadowing of neighbouring buildings. This in turn influences the required separation distances between buildings to allow solar gain. Generally, high pitched roofs will have a greater shadowing effect than lower pitched roofs. Consideration should therefore be given to configuring buildings to accommodate lower pitched roofs or alternative roof arrangements such as asymmetric, mansard and split-level pitches. Whilst hipped roofs will not reduce the distance of overshadowing, they do have the benefit of reducing the area of overshadowing.

---

5 *It should also be noted that high boundary treatments can reduce the amount of the natural surveillance provided by the occupiers of buildings. As such, consideration should also be given to the need to design out crime. See Section 11.*