Author: Andrew Duncan B.Eng(Hons) M.Eng MIPENZ CPEng IntPE

Tel:06 3708175

e-mail: entwood@xtra.co.nz

Solar design tools for sustainable land development

Keywords

Solar access, sustainable development, solar resource

Abstract

As New Zealand's natural gas reserves decline and electricity demand growth exceeds the building of new generation plants, greater focus needs to be applied to energy efficient design in domestic buildings and land developments. As society evolves, so too should our understanding of what helps form safe, healthy communities: this should be reflected in the way we design the places that we live in.

A case study of residential land development was analysed in terms of its potential for energy efficiency gains and optimisation of solar resources. A design tool was developed to assess the solar energy loss of a specific building site due to existing land features. 'Solar obstruction contours' were produced that define the maximum permissible height of obstructions before solar shading occurs. These contours were produced based on a minimum percentage solar energy capture.

Thermal energy demand for the development case study was calculated by specification of a Building Performance Index (BPI) relative to floor area. The demand was then balanced against on-site thermal energy production from biomass to give a percentage thermal energy self sufficiency.

The tools developed can be used to optimise the design of a residential land development resulting in an increase in renewable energy use above that of standard residential developments. The study concluded that incorporation of the tools as standard practice by municipalities is viable, and if implemented would increase the energy efficiency and renewable energy use of the New Zealand housing stock.

Contents

Introduction

When land is developed for residential purposes in New Zealand and elsewhere, in general little consideration is given towards planning for solar energy benefits. Passive solar building design, building orientation, solar water heating and photovoltaic electricity generation are at present rarely considered to any extent by developers, designers or builders. Whilst there has been a resurgence of passive solar design in the last few years, there is still a gap between general understanding of solar access, and standard design practices.

The predictability of the solar path across the sky has enabled solar planning to exist, to some extent, for thousands of years. Solar access planning for communities has been carried out since Ancient Greek times when the city of Olynthus was reportedly designed with this in mind in 500B.C. (Chiras, 2000). The arrival of cheap fossil fuel energy sources, and latterly technological advances in space heating and cooling led to a decline in the importance of solar access planning. Now, as fossil fuel use declines, solar access planning is once again becoming recognised as an important design tool.

The design stage of the land development process is the stage at which the greatest effect on energy efficiency and sustainability can be applied to land use, yet it often fails to do so. Access to the solar energy resource sets the upper limit of dwelling energy efficiency on a site: simply put, with no access to the sun there can be no harvesting of solar energy. Maximizing solar access is therefore an energy efficiency goal, as is a more detailed knowledge of when solar energy is desired, and when it is not.

Methods

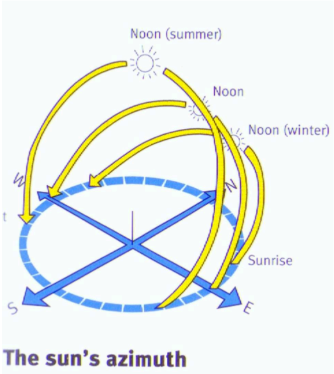

Figure 1 Sun path/azimuth

An understanding of the geometries of the sun's path across the sky allows the beneficial incorporation of this information in land development planning. Maximising the use of solar energy can affect boundary shapes, house lot location, planting restrictions, and acceptable building height. Such differentiations can have great effect on the available solar resource at a proposed dwelling location.

The economic viability of active collection of solar energy via photovoltaic or solar water systems is linked to the net available energy at the site. This in turn is governed by the theoretical solar resource at that location, and the individual site characteristics. At a fixed time of day the solar position varies throughout the year both in altitude angle[1] and azimuth[2] (Fig. 1), and hence the effective shadow caused by buildings, trees, or other obstructions in the vicinity is dependent on the time of day, day of the year, latitude, and longitude.

The concept of a "solar access butterfly" is sometimes used (EECA, 2002), where shadow lengths for known solar obstructions are plotted for varying times of a specific day (normally the winter solstice). There are however limitations with this method in terms of energy capture.

Two additional tools are presented: a modified solar resource diagram, and solar access contour diagram. Solar resource diagrams depict the solar path for a given location for different times of the year (fig 2). Here the apparent horizon may be added to visualise when the site will be shaded by land or obstacles (the hatched area represents the apparent skyline in this example).

---

[1] Altitude angle is described as the angle between the horizontal and the line to the sun. It is the complement of the zenith angle.

[2] The angle between the meridian and the sun on a horizontal plane

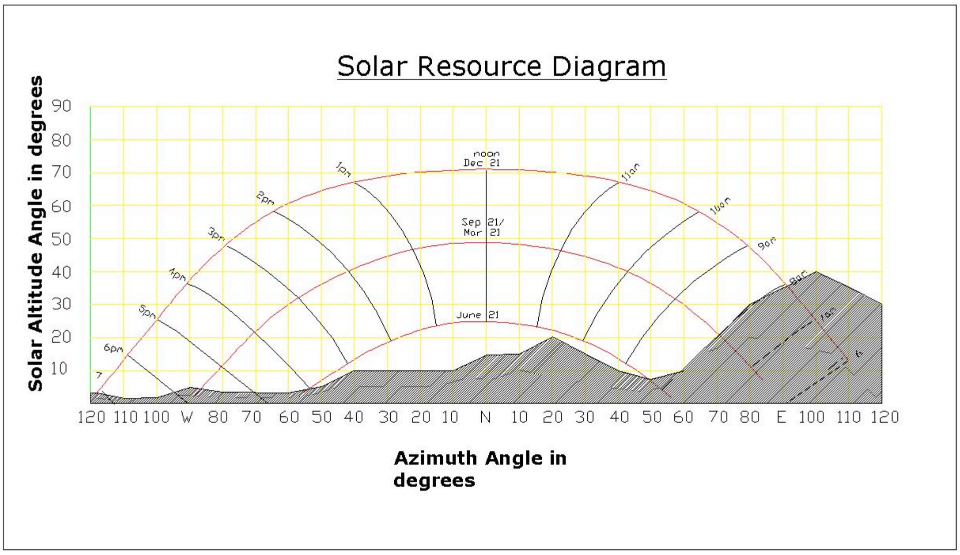

Fig 2 Solar resource diagram

A relatively simple addition to this diagram may be carried out by calculating the average energy distribution through the day per hour for the site in question. By superimposing this distribution, the energy loss from shading then becomes apparent.

This allows for quick comparison of alternative prospective building sites.

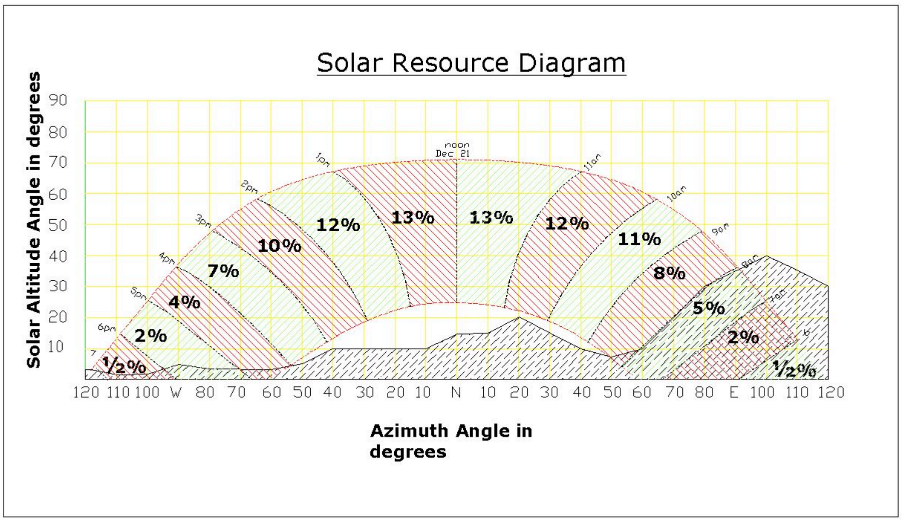

Fig 3 modified solar resource diagram for Taratahi solar data, Masterton

Solar obstruction contours.

For a given location a specified range of sunshine hours may be used to define the percentage of the total solar energy available for capture. Thus in figure 3 above, the two hours spanning over noon represent 26% of the total daily solar energy and so on. Conversely if a percentage energy capture is required, the required daily solar access timespan can be deduced (fig 4).

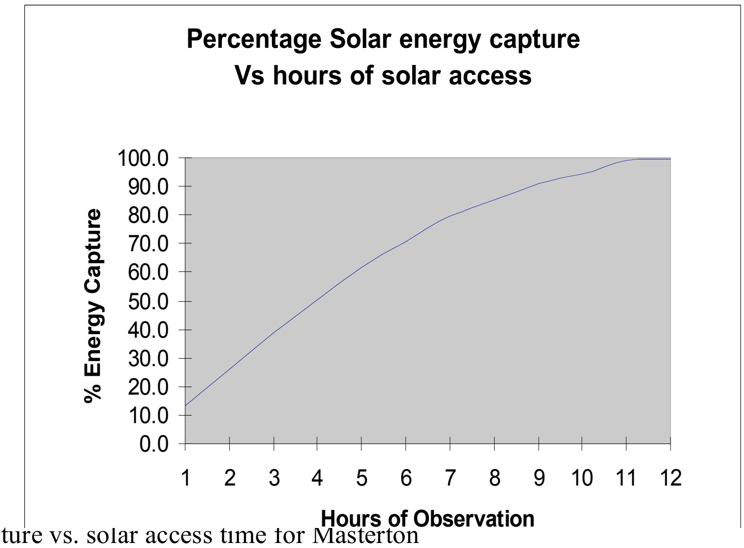

Fig 4 energy capture vs. solar access time for Masterton

Solar geometry may be used to calculate the sun's altitude and azimuth angle at any time of any day of the year (Duffie and Beckmann, 1991). Using the required percentage energy capture, and thus solar access timespan it is then possible to calculate the minimum solar altitude angles (at given azimuth) throughout the year based on this timespan (for the case study example 8:30am to 4:30pm clock time, which equates to around 85% of the total daily solar energy available).

Now the degree of solar shading from an object is related to the object's height, its distance from the observation point, and the altitude angle (fig 5). Assuming an arbitrary distance from the observation point then allows simple trigonometrical calculation of the maximum height that an obstacle in that location can reach before casting shade on the observation point. This gives a three dimensional point in space relative to the observation point. This process is repeated for each of the hourly minimum solar altitude angles for a number of different radii and azimuth from the observation point, giving a series of three dimensional points.

Having calculated the three dimensional points it is then possible to construct solar obstruction contours - lines connecting points of equal height defining the boundary between obstruction heights that will cause shading, and those that will not (fig 6).

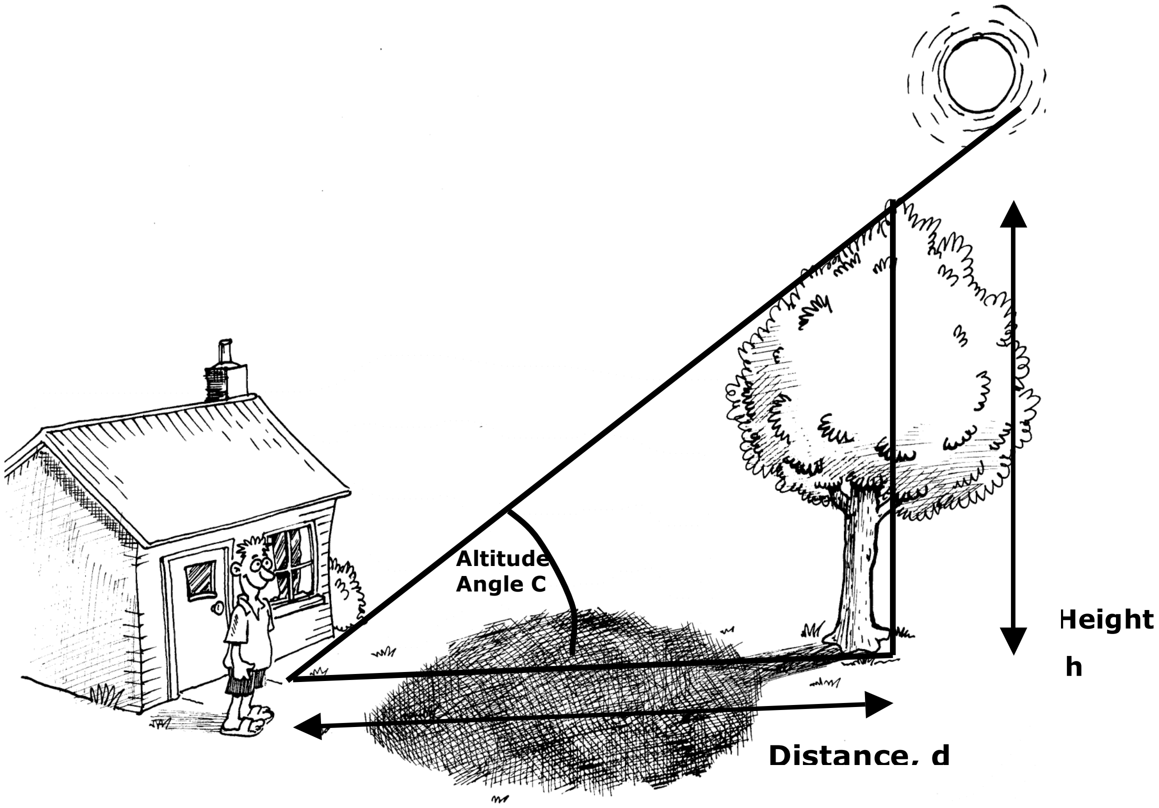

Figure 5 Solar shading geometries showing relationship between solar altitude angle and obstruction height (Reilly & Duncan, 2004)

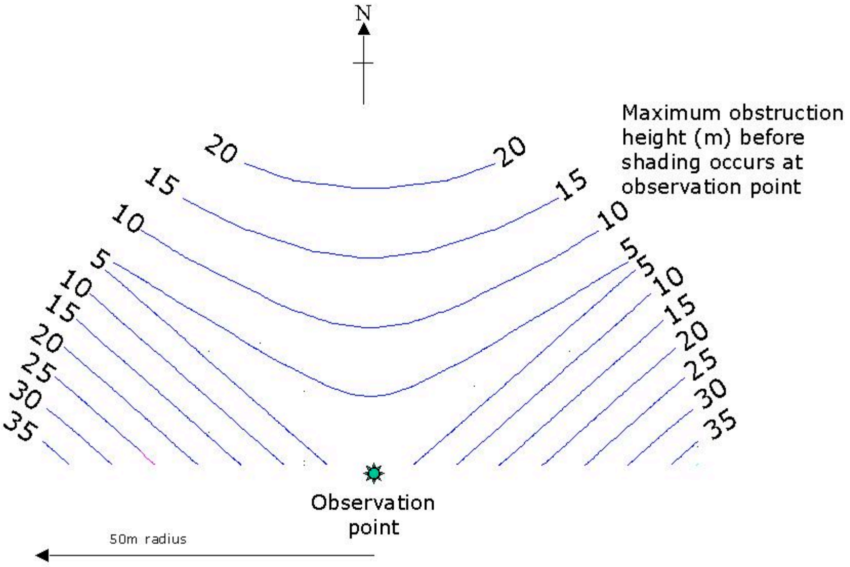

Fig 6 simplified solar obstruction contour diagram for case study site

These contours may now be superimposed onto proposed subdivision plans at the location of each proposed building site. If the contours from each building site are amalgamated, a solar obstruction contour plan for the whole subdivision site may be constructed (fig 7 shows the contour plan for the case study site)

Figure 7 solar obstruction contours for case study site

Conclusion/Discussion

The basic solar resource diagram is a good screening tool for assessing the effect of existing solar obstructions or skyline on potential houses sites. The modified solar access diagram defines the energy implications of this assessment.

For more detailed analysis, solar access contours can be derived: for the case study the solar obstruction contours for an 85% energy yield were established and used to specify legal covenants governing the maximum height of buildings trees etc on the subdivision. Perhaps more importantly the process fosters an awareness of spatial orientation in regard to solar angles, and available solar energy. Using the solar contour overlay allows selection of house sites where optimum access to the solar resource is available, ensuring that the buildings, and occupants, have ongoing access to solar energy.

Bibliography

Bastings, L (1967) Sunshine and shade. Building Research Association of New Zealand. Wellington, New Zealand.

Chiras D. (2000) The Natural House a complete guide to healthy, energy efficient, environmental homes. White river junction, Vermont/ Totnes, England. ISBN 1-890132-57-8

Duffie J and Beckmann W (1991). Solar Engineering of Thermal Processes, second edition. Published J Wiley & Sons inc, USA.
ISBN 0-471-51056-4

EECA (1985) Design for the Sun. Residential design guidelines for New Zealand. Energy Efficiency and Conservation Authority (formerly produced by the Ministry of Energy), Wellington, New Zealand. Reprinted 2002

www.totarabank.com reference information on the case study subdivision