PASSIVE SOLAR SUBDIVISION DESIGN

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A GUIDEBOOK FOR: BUILDERS
SITE PLANNERS
DEVELOPERS

CENTRAL NAUGATUCK VALLEY
REGIONAL PLANNING AGENCY
20 EAST MAIN STREET
WATERBURY, CONNECTICUT 06702
SEPTEMBER 1982

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September 1982

TITLE: Passive Solar Subdivision Design: A Guidebook for Builders, Site Planners and Developers

AUTHOR: CENTRAL NAUGATUCK VALLEY REGIONAL PLANNING AGENCY

SUBJECT: An evaluation of site planning, landscaping and subdivision design techniques for siting and orienting passive solar energy systems and protecting solar access.

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ABSTRACT: This Guidebook presents state of the art techniques for builders and developers concerned with protecting solar access and properly siting solar-energy systems. The Guidebook was prepared to implement Connecticut's mandatory 1981 State Legislation concerning passive-solar-subdivision design. It includes a detailed description of passive solar design tools, such as street and lot layout, building orientation, siting of vegetation, designing with slopes, and legal and landscaping techniques for protecting solar access. The report includes 35 illustrations and legal and technical data useful for developing solar easements and evaluating solar-access issues within the Connecticut latitudes.

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The preparation of this report was principally the responsibility of Charles Vidich, Principal Planner.

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Introduction

With recent increases in the price of fossil based fuels many builders have taken a greater interest in energy conservation and the use of solar energy in building and site design. While energy conservation and solar energy were important elements of the building practices of our forefathers, these concepts lost much of their relevance during the first part of this century as fossil fuels offered apparently limitless supplies of cheap energy. The age of apparently unlimited oil resources is clearly coming to an end. With the increasing cost of fossil based fuels, architects, builders and site planners are now finding that building design and site planning practices offer cost effective means of reducing energy costs for residential developments as well as increasing the opportunities for the use of solar energy for space heating, space cooling and domestic hot water.

This guidebook is intended to provide builders and site planners with a basic introduction to site planning techniques which maximize heat gain and minimize heat loss in the heating season and minimize heat gain and provide for natural ventilation during the cooling season. The natural and man made landscape can have a dramatic impact upon the long term opportunities for using renewable energy resources and conserving energy resources. Simply stated, topography, vegetation and the microclimate of a site can influence (1) solar radiation levels, (2) solar access, (3) prevailing wind patterns and (4) ambient air temperatures.

Altering the microclimate of a site through passive solar energy techniques can help reduce year round energy costs for future residents of a development. Moreover, the utilization of certain passive solar site design techniques can also protect expensive investments made in solar energy systems. It is important to understand that solar access protection is as much a part of a solar energy system as a fuel nozzle is a part of a fuel oil burner.

However, despite the significance of protecting solar access for solar energy systems, many contractors and builders have failed to understand or apply solar access principles properly. For example, a recent inspection of 153 solar domestic hot water systems installed in Connecticut found that 27% of the units either had serious shading problems or were likely to face serious shading problems in the very near future. Errors of this kind and magnitude will continue to have an adverse impact upon the growth of solar technologies and concepts until such time as builders and contractors properly understand solar access principles and the techniques for siting solar energy systems. Solar access protection must be achieved through site planning, subdivision design and private agreements as there is no right to light law in the United States. Courts have historically rejected a right to light doctrine as being inappropriate in a developing nation where vertical development has been the order of the day. Largely because of the courts rejection of the right to light doctrine Connecticut builders and developers must take the lead role in protecting solar access in new residential developments.

Another reason for protecting solar access is to ensure that future solar homes are eligible for property tax exemptions under the provisions of Public Act 80-406. This Act enables local governments to exempt passive solar energy systems from property taxation. The Connecticut Office of Policy and Management had stipulated that a passive solar home is only eligible for property tax exemption on those portions of the home that are used for the collection, storage and distribution of solar energy. Moreover, a passive solar home will not be considered eligible for a property tax exemption if the solar energy collector is shaded for greater than 25% of the time between the hours of 9 a.m. and 3 p.m. on December 21st. Careless errors in siting or in the level of solar access available to the solar energy system may result in costly increases in the property tax burden of the future homeowner - not to mention the adverse affect on the efficiency of the solar collector itself.

However, the most important reason for considering solar access issues in the development of land comes as a result of Public Act 81-334, An Act Concerning Passive Solar Design for Subdivisions. This Public Act mandates all planning commissions to require any person submitting a plan for a subdivision after October 1, 1981 to demonstrate to the commission that he has considered in developing the plan, using passive solar energy techniques which would not significantly increase the cost of housing to the buyer, after tax credits, subsidies and exemptions. Public Act 81-334 also specifies what passive solar energy techniques shall be addressed by a developer.

The Public Act States:

> Passive solar energy techniques mean site design techniques which maximize solar heat gain, minimize heat loss and provide thermal storage within a building during the heating season and minimize heat gain and provide natural ventilation during the cooling season. The site design techniques shall include but not be limited to: (1) house orientation, (2) street and lot layout, (3) vegetation, (4) natural and manmade topographical features, and (5) protection of solar access within the development.

Solar access and energy conservation considerations in site design are now a matter of state and local policy. While there will undoubtedly be a variety of regulatory approaches adopted by the State's 169 municipalities, this guidebook provides some basic solar access and energy conservation principles which should assist developers and builders in meeting the intent of the recent state legislation.

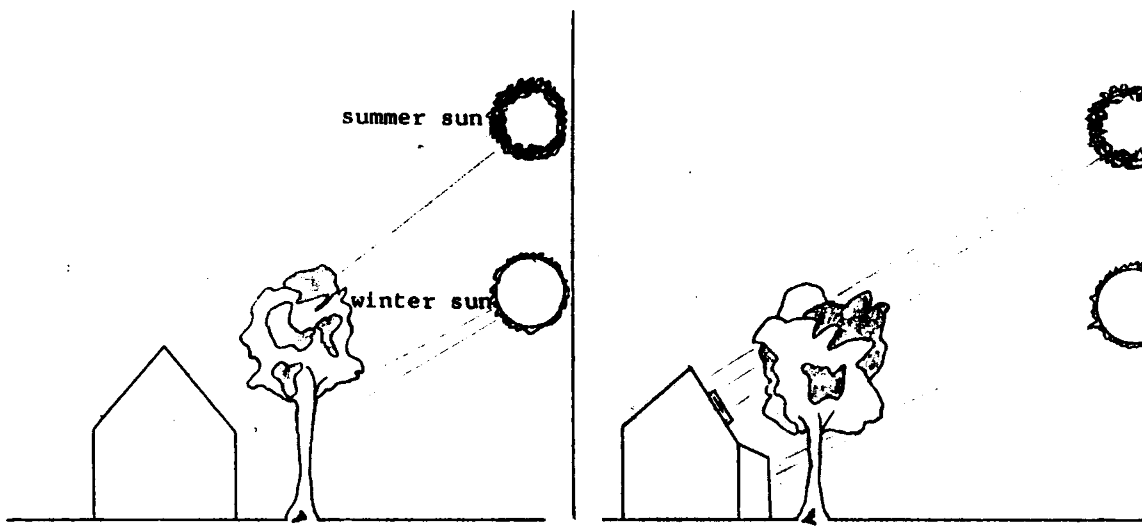
This report addresses the following topics: (1) Site Planning for Solar Access Protection, (2) Techniques for Siting Solar Energy Systems, (3) Techniques for Protecting Solar Access and (4) Site Planning for Energy Conservation.

1. Site Planning for Solar Access Protection

Types of Solar Energy Systems

Before determining the type of solar access protection that will be needed it is first necessary to determine the types of solar energy systems that will be installed within a development. Solar energy systems used exclusively for space heating require access to sunlight during the winter months but do not require direct access to sunlight during the summer months. The selective use of solar energy for space heating is generally accomplished by the use of roof overhangs which block out the high summer sun and admit the low winter sun. However, it may also be possible to use deciduous trees to shade the south wall of the house. In contrast, solar energy systems used for heating domestic hot water must have year round access to sunlight in order to function properly. As can be seen in Figure 1 it would not be appropriate to plant deciduous trees on the south side of a building when the rooftop solar collector panels are being used for domestic hot water purposes.

Figure 1



passive solar home

Excessive solar heat gain blocked by deciduous trees.

solar domestic hot water system

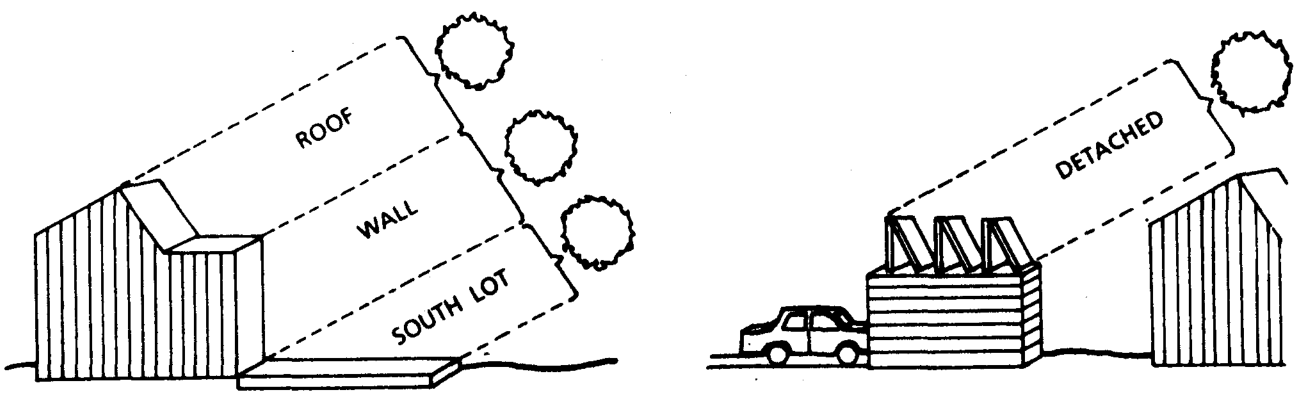
Solar access blocked by deciduous trees.

Levels of Solar Access Protection

The type of solar energy system and its intended purpose has a direct relationship to the level of solar access protection required. Solar energy systems used for hot water heating generally require rooftop solar acess protection. In contrast solar energy systems used for space heating are often incorporated into the south wall of the dwelling unit requiring a greater level of solar access protection. In some cases, solar energy systems for space heating or domestic hot water may be installed in the south yard either because of improper building orientation, rooftop solar access problems or aesthetic considerations. As can be seen from Figure 2, it is much more difficult to protect solar access to a south yard and comparatively easy to provide protection to a rooftop. Developments in which solar energy systems are incorporated into the structure at the initial design of the building should be able to easily achieve rooftop or south wall solar access as long as the building is properly oriented to the south.

Figure 2

Figure 16. Levels of Solar Access

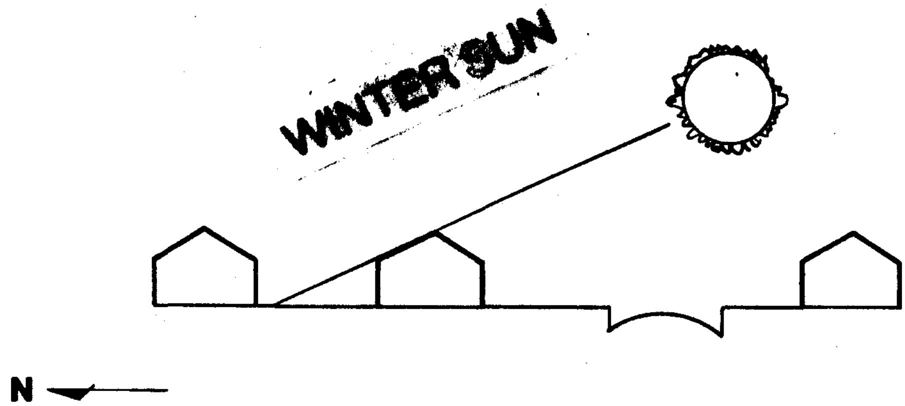


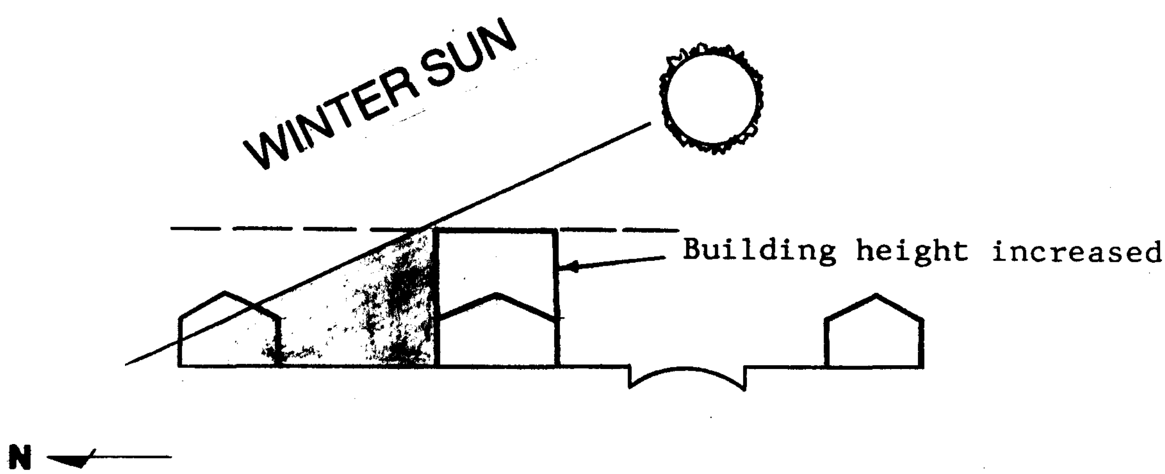
A choice in the level of solar access protection desired for a development may affect the density of development or the overall design of the tract. Offering south wall solar access will clearly require adequate setbacks between buildings whereas rooftop solar access will probably impose few setback restrictions but may impose some restrictions on the maximum height of buildings to the south (see Figure 3).

Legal Barriers to Solar Access

A third factor to be considered when evaluating solar access objectives for a development are potential barriers to solar access permitted by the zoning regulations of the town. A dwelling unit may have adequate solar access as planned and built but later be threatened with a possible loss of sunlight because the zoning regulations allow neighbors to the south to build taller buildings which could obstruct access to sunlight for the house to the north (see Figure 4).

Figure 3



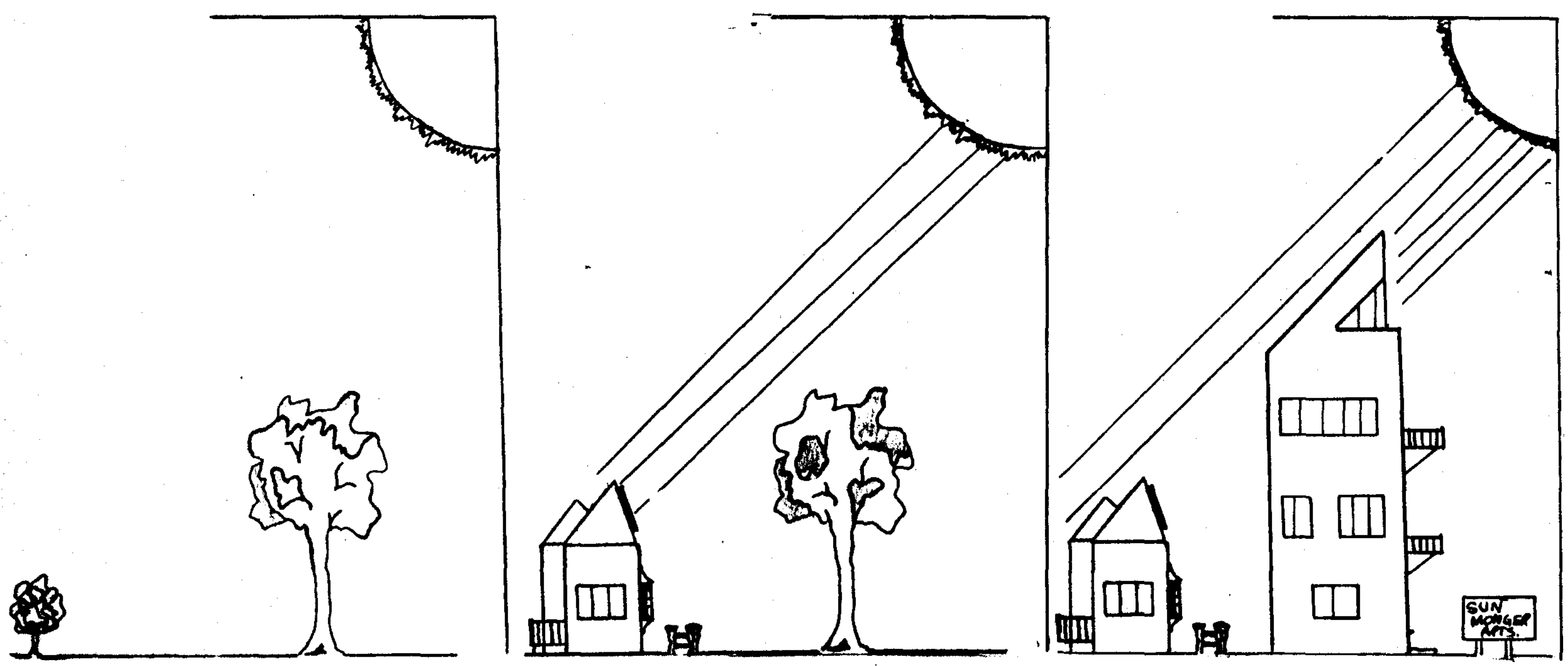


It is important to determine the possible future shading problems that could emerge under the worst case conditions allowed by zoning regulations so that houses are oriented and sited to avoid these problems at the outset (Figure 5). Moreover, where solar access problems associated with permissive zoning can not be eliminated it is important to know the magnitude of the problem and provide alternative methods of protection wherever possible. Solar easements, deed restrictions and restrictive covenants all offer potential tools for privately controlling long term access to sunlight.

Figure 5

Solar access before apartment construction.

Solar access after apartment construction.



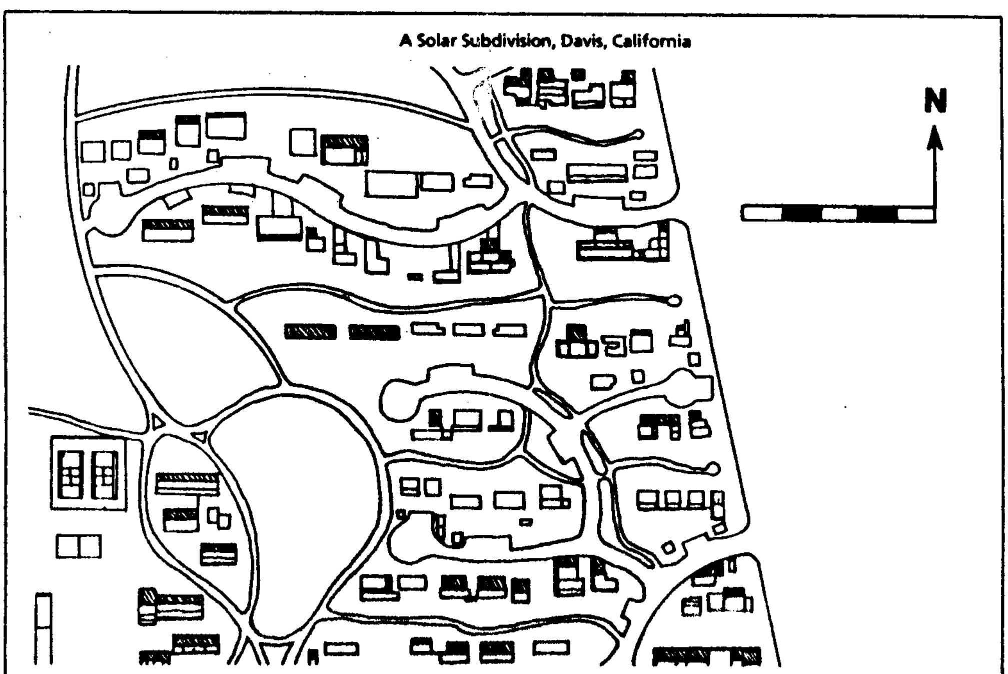
2. Techniques for Siting Solar Energy Systems

The level of solar energy available to a solar energy system can be influenced by the design of the subdivision and the site plan for the tract. In particular when the subdivision is designed special attention should be given to meeting the intent of Public Act 81-334 which stipulates that five (5) site design techniques shall be included within the array of techniques used by developers for maximizing heat gain, minizing heat loss and providing thermal storage within a building during the heating season and minimizing heat gain and providing for natural ventilation during the cooling season. The five site design techniques specified by Public Act 81-334 are: (1) house orientation, (2) street and lot layout, (3) vegetation, (4) natural and manmade topographical features and (5) the protection of solar access within the development. In addition, recent experience with the design of several conventional and solar subdivisions in Connecticut has revealed that other factors such as the location of septic system leaching fields, sewer and water line easements and the density of development influence the level of solar access available within the development. Each of these factors is discussed in the following section.

Street Layout

One of the essential prerequisites for the effective use of solar energy systems is a southerly orientation. If a building is not oriented with its longest axis facing south it may not be feasible to make use of the south wall or the roof of the building to collect solar energy for space heating or domestic hot water. Significantly, building orientation often depends upon street and lot line layout especially in higher density developments where the street layout strongly influences the ultimate location and orientation of the building. Traditionally, street systems are designed to tie into the existing street network while at the same time harmonizing with the topography of the land and avoiding construction upon wetlands and other unbuildable soils. In a solar subdivision, these basic planning considerations still remain, but one additional item must be kept in mind. The layout of the proposed street system must facilitate the subdivision of lots and the placement of houses which will have adequate access to the sun. (See Figure 6).

Figure 6



Streets which are constructed along an east-west axis should have little trouble in accomodating passive solar dwelling units. On an east-west street, the longest axis of the dwelling unit is easily placed parallel to the street thereby ensuring a conventional appearance to the overall design of the neighborhood while at the same time providing for the optimum orientation of dwelling units to the south.

Solar subdivisions may also be possible on north-south streets if (1) development is at relatively low densities or (2) development is proposed on south facing slopes. Under both of these circumstances, solar access protection can be achieved by limiting the installation of solar energy systems to rooftop locations.

Lot Layout

In those cases where roads can not be properly oriented along an east-west axis and a north-south street pattern is inappropriate, it may be possible to achieve a southerly orientation for future buildings by delineating side lot lines parallel to true south. This technique provides future homeowners with a greater degree of control over vegetation and objects directly to the south of the house thereby offering greater solar access protection. (See Figures 7 and 8). The delineation of side lot lines parallel true south can be an effective means of improving the orientation of future buildings in higher density developments where house orientation is most strongly influenced by the layout of the side lot line. In contrast, in low density developments it may not be necessary to alter the side lot lines since lot sizes of one acre or more generally offer sufficient space to site a building to the south regardless of the layout of the lot.

Figure 7

Poor Orientation on Intercardinal Streets

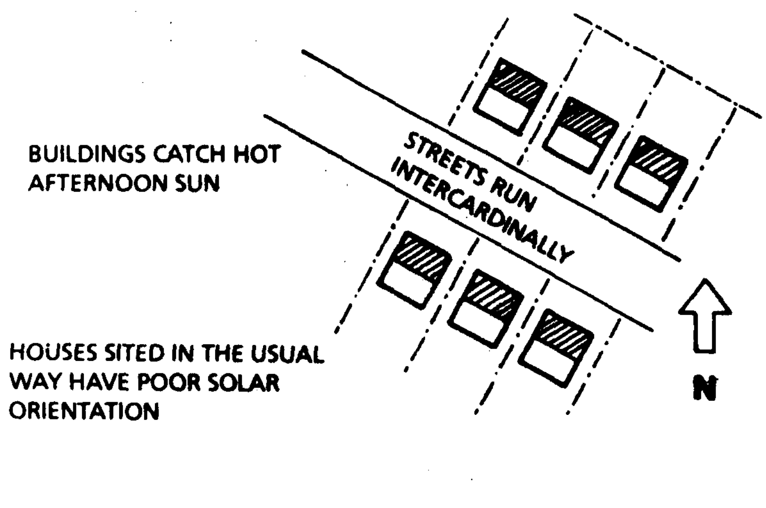
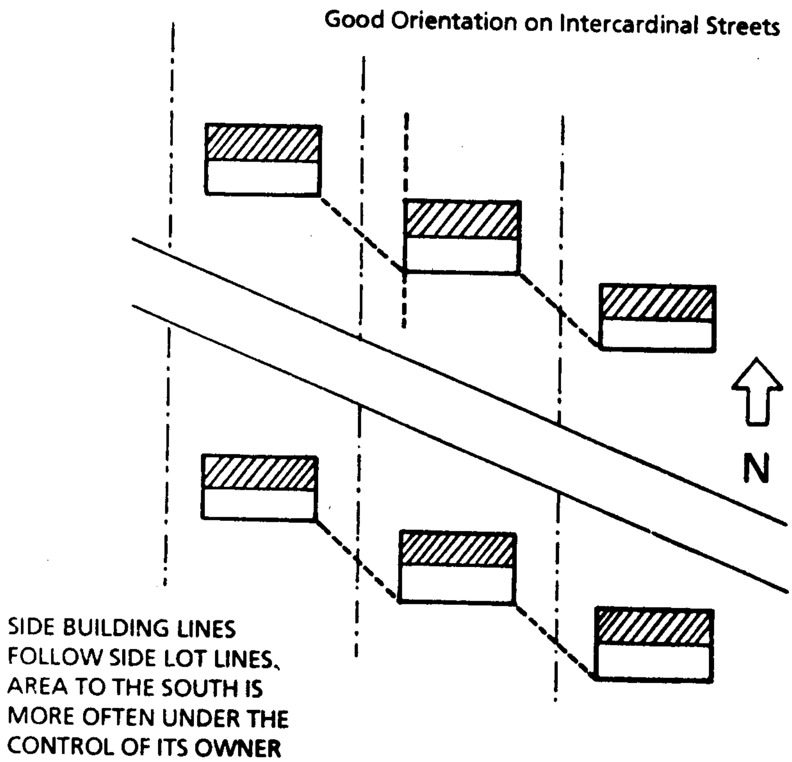


Figure 8



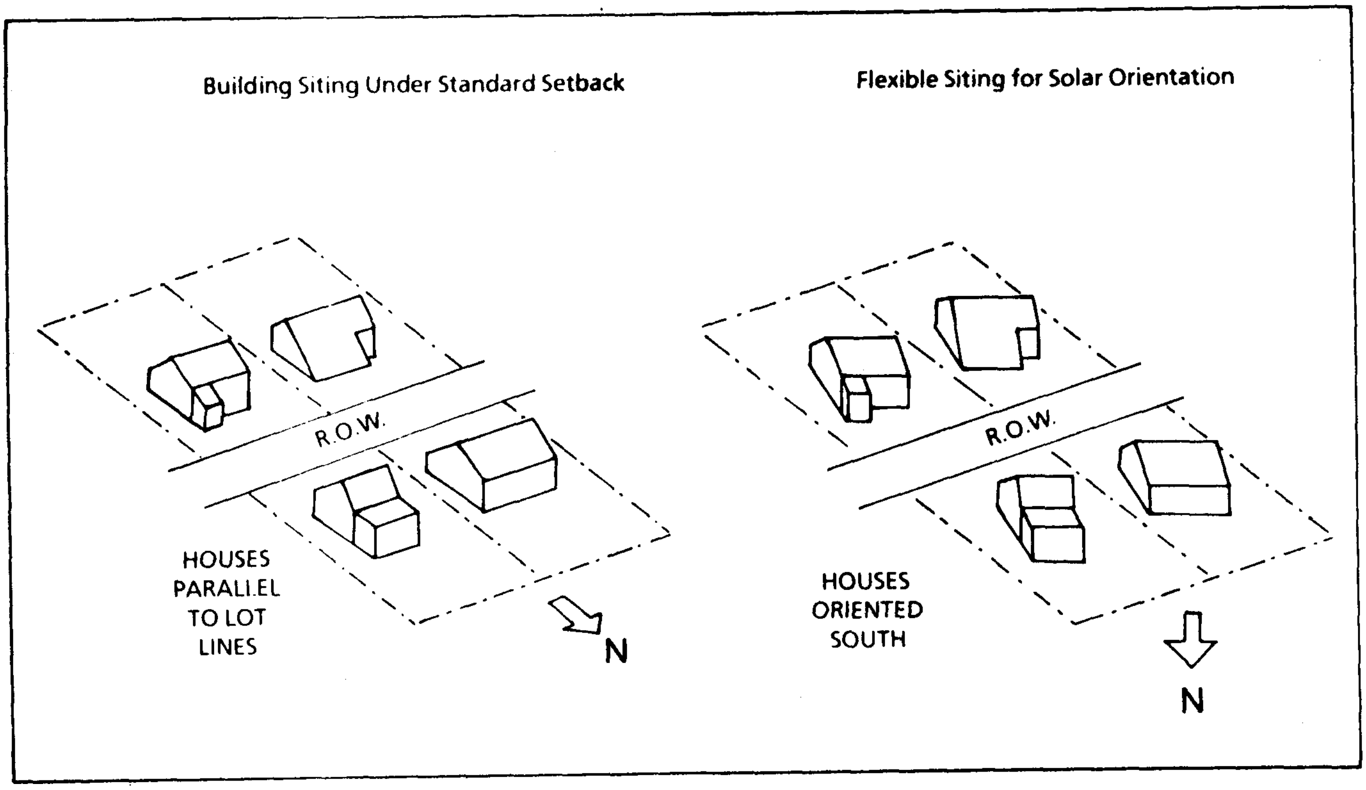
Building Orientation

While the layout of the street and lot offer important tools for creating solar subdivisions, it is generally the location and orientation of the house which is the most significant factor. This is particularly true when development is planned at relatively low densities of one or two acres per dwelling unit. Under these conditions, there is generally sufficient space within the buildable area of the lot to orient the house in any direction without infringing upon the rear, side or front yard setback zones. (See Figure 8-1).

For example, a 1980 survey of the last eight subdivisions approved by the Southbury Connecticut Planning Commission revealed that in all but one case, proper orientation to the south could have been accomplished by the developer if he had simply reoriented the houses to the south.

From the standpoint of encouraging the greastest use of solar energy all dwelling units should be oriented so that their longest axis faces directly to true south. This orientation standard ensures the greatest availability of solar energy for space heating and domestic hot water purposes. However, in practice it may not be possible to achieve this ideal orientation for all dwelling units due to limitations imposed by the existing street network, the grade and orientation of slopes, the vegetative characteristics of the site and the overall design objectives for the development. When assessing the extent to which "solar conscious" subdivision design can be incorporated into the proposed development it is important to consider a number of factors which influence the feasibility of utilizing solar energy systems. The principal factors which should be considered when planning the design and orientation of proposed buildings are (1) the percentage of solar radiation available at any given orientation off of true south, (2) the orientation standards stipulated by Connecticut's solar property tax exemption laws, (3) the proposed use of the solar collector whether it be for space heating, domestic hot water or electrical generation and (4) the outdoor temperature.

Figure 8-1

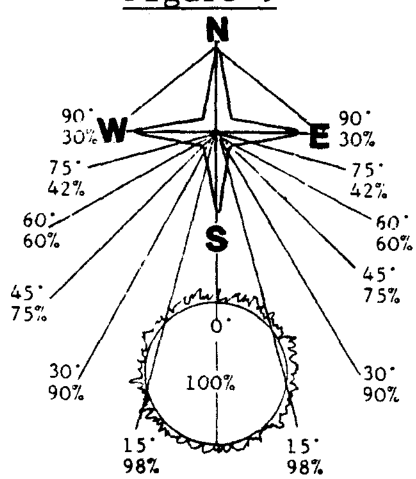


Orientation for Property Tax Exemptions

From a marketing standpoint one of the most significant factors a developer should consider is Connecticut's definition of a solar energy system eligible for property tax exemptions. The State of Connecticut provides property tax exemptions for passive and active solar energy systems under Public Act 80-406 and Public Act 76-409 respectively. In order to be eligible for property tax exemptions, an active solar collector panel should be oriented within 20 degrees of true south and a passive solar collector (eg. a south wall of a building) must be oriented within 30 degrees of true south. The greater flexibility provided for passive solar energy systems largely reflects the fact that building orientations may not be as flexible as individual solar collector panels. Moreover, flexibility has been provided for the orientation of passive solar collectors in order to encourage builders, developers and homeowners to retrofit passive solar design considerations into the existing housing stock.

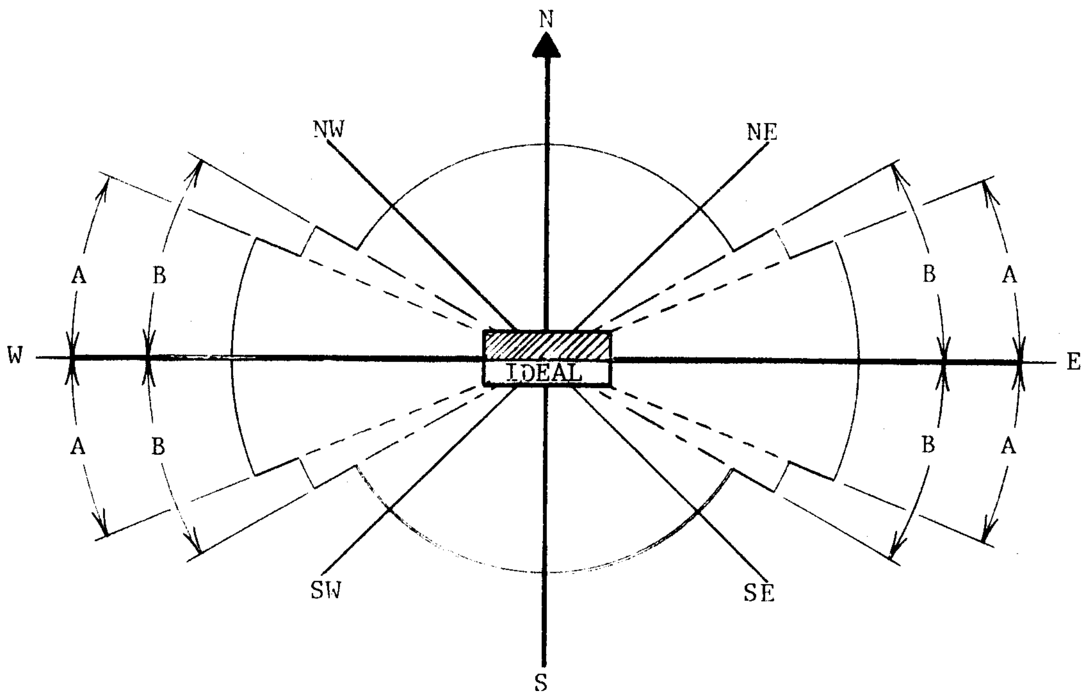
Significantly, at the winter solstice a building which has its longest axis facing within 30 degrees of true south actually receives 90 percent of the solar radiation received by the same building facing exactly true south (see Figure 9). Clearly, Connecticut's property tax exemption requirements for building orientation offer considerable flexibility in the siting of houses without any serious adverse impact upon the level of solar radiation available to power passive solar collectors.

Figure 9



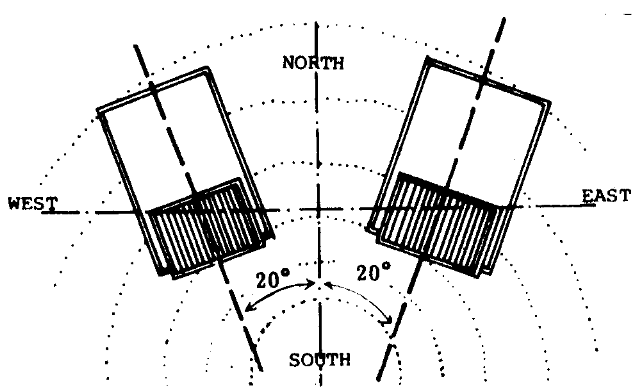
While Connecticut's property tax exemption standards for passive solar homes offer flexibility in building orientations, several national studies suggest that buildings should be oriented closer to true south. In particular, the U.S. Department of Housing and Urban Development (HUD) suggests that active solar collectors used for space heating or hot water should not deviate more than 20 degrees off of true south. (See Figure 11). Similarly, the American Planning Association suggests that passive solar houses should have their longest axis facing within 22.5 degrees of true south in order to have good exposure to the sun. (See Figure 10).

Figure 21: Building Orientation Standards



A - 22.5° American Planning Association suggested orientation
B - 30° Mandatory Orientation for Property Tax Exemption

Figure 11

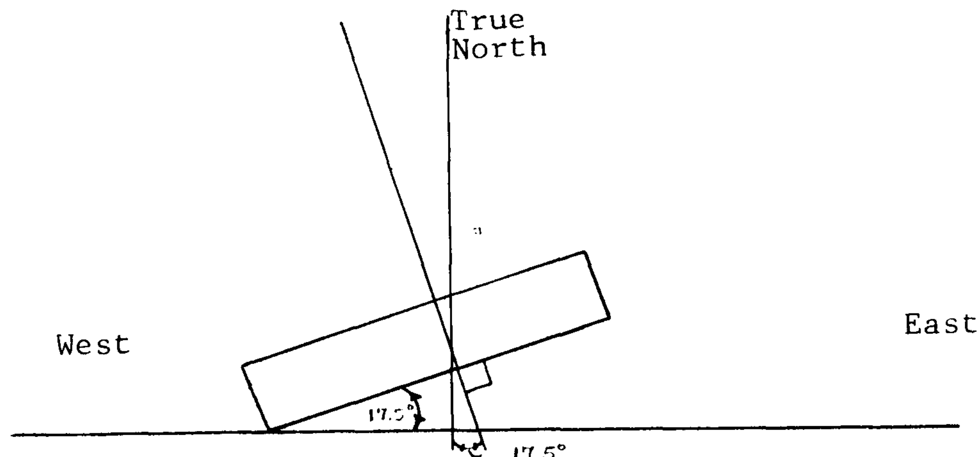


COLLECTOR ORIENTATION A collector orientation of 20 degrees to either side of true South is acceptable. However, local climate and collector type may influence the choice between East or West deviations.

Sol-Air Orientations

While deviations on either side of true south are equivalent in value from the standpoint of collecting solar energy they are not equal in terms of ambient air temperatures. Early morning temperatures are generally lower than those experienced in the afternoon. Higher afternoon temperatures, when combined with solar radiation, tend to create greater space cooling demands for houses oriented to the west of true south. In contrast, houses oriented to the east of true south avoid the hot afternoon summer sun and receive slightly more early morning winter sun when space heating needs are greatest (see Figure 12). This approach is particularly valuable where summer space cooling and winter space heating requirements are both significant. In certain instances the sol-air orientation principle must be modified in order to take into consideration local climatic factors such as early morning fog or local solar access constraints such as evergreen trees to the south of the proposed dwelling unit. An assessment of these site specific limitations to the sol-air orientation principle may require adjustment in building orientations toward the southwest.

Figure 12



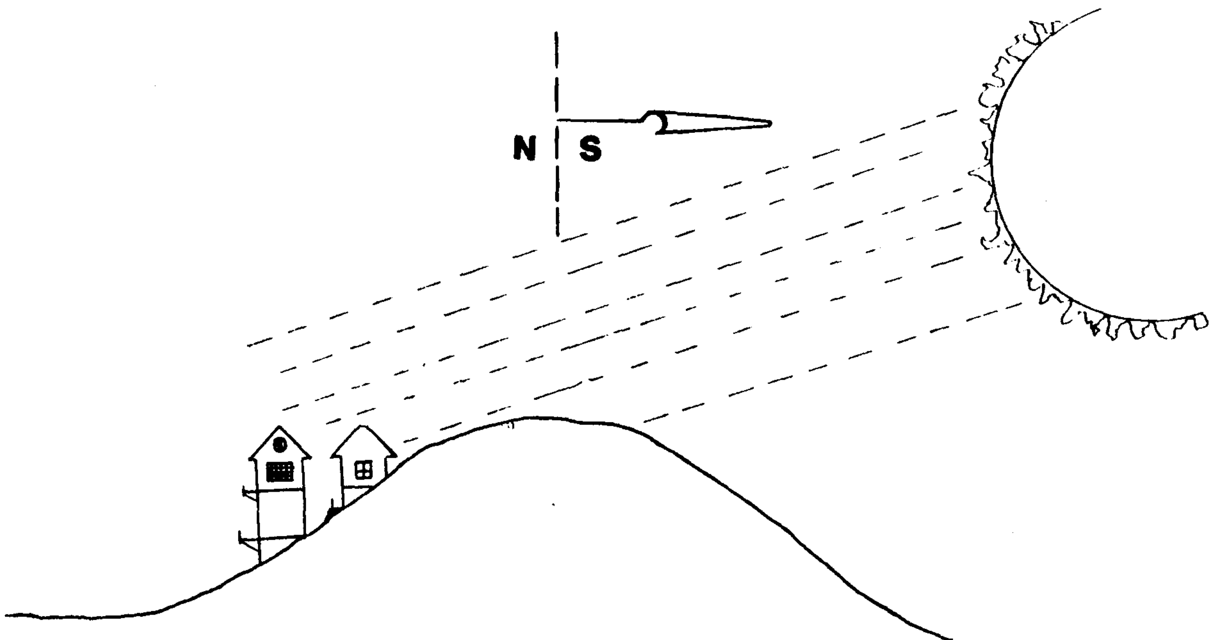
Ideal Solair Orientation for Connecticut

Natural and Manmade Topographic Features

Varied topographic conditions on a tract of land can be both an asset as well as a liability for those interested in solar energy applications. Steeper south facing slopes offer (1) greater levels of solar radiation per square foot than flat land, (2) valuable windbreads to northerly winter winds and (3) increased levels of solar access protection. The combination of these three factors clearly indicates that south facing slopes are the equivalent of energy resource zones that can be "mined" if proper environmental precautions are taken. In contrast, steep north facing slopes serve little value for those interested in developing solar homes or solar subdivisions.

Because of the limited energy value of north facing slopes and the fragile character of these sensitive lands, it is best not to develop these tracts of land or where they are part of a development to dedicate these land areas as open space areas. In those cases where some level of development is planned for a north facing slope it is advisable to reduce the density of development to levels consistent with the long term protection of solar access. In some cases, it may not be financially attractive to reduce the development potential of the tract since the benefits derived from a solar development on a north facing slope might not outweigh the reduced density of development. Under the circumstances solar access protection should not automatically be ruled out. Even under the worst grades on north facing slopes it may still be possible to provide rooftop solar access in a selected number of dwelling units. (See Figure 13).

Figure 13



Rooftop solar access may be possible for selected dwelling units on steep north facing slopes.

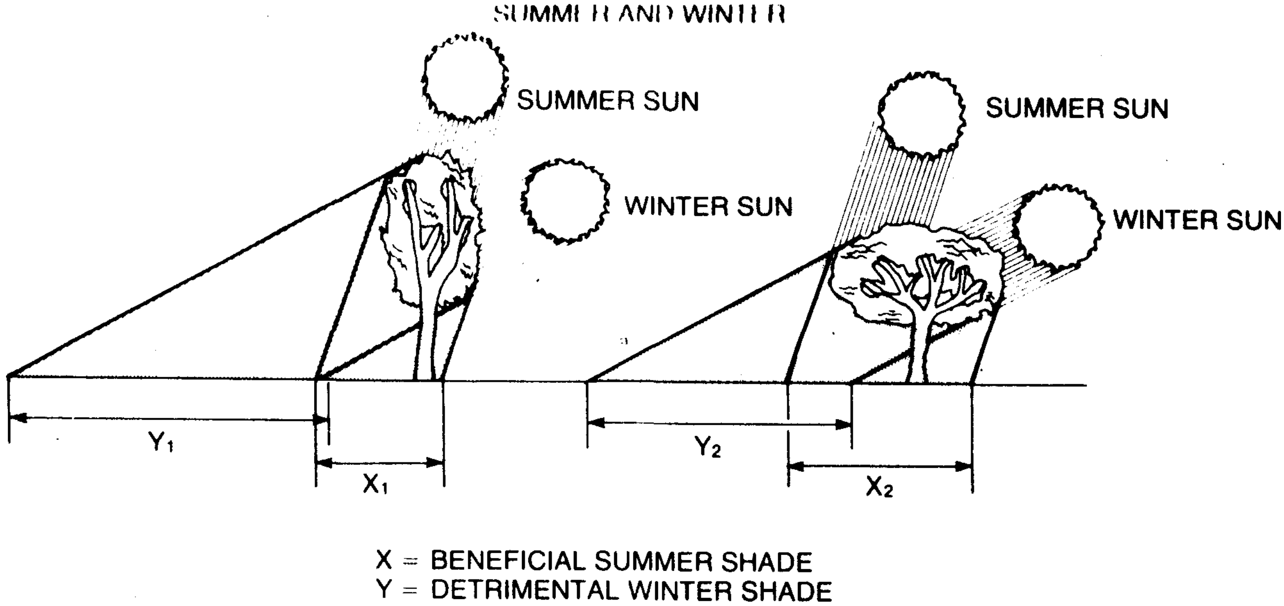
Vegetation

Vegetation can hinder as well as enhance the application of solar energy for space heating and domestic hot water. The important point to remember is that the solar energy system must receive unobtructed solar access during its normal operating cycle. For a passive solar home, the normal operating cycle is from September to March whereas for a solar domestic hot water system the normal operating cycle is year round. Because of the differences in operating cycles these two types of solar energy systems require different levels of protection from shadows. A passive solar house may benefit by the placement of decidous trees in front of the south side of the building as long as the species chosen drops its leaves relatively early in the fall and does not send out new buds until relatively late in the spring. In contrast, deciduous trees planted on the south side of a house utilizing rooftop solar collectors for hot water heating may run into serious problems if the tree species chosen grows too tall thereby blocking out rooftop solar access during the summer months. For this reason, the American Planning Association recommends the use of short trees with wide crowns as the most effective means of balancing the need for solar access protection with the need for summer shading of the south wall of the house. (See Figure 14).

Figure 14

Crown Height and Breadth for Solar Access

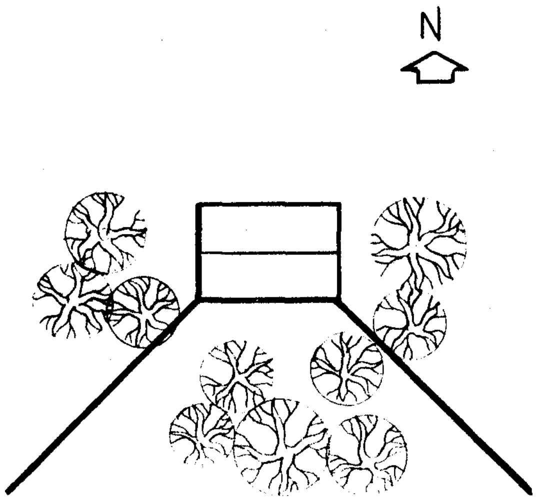
COMPARISON OF TREE FORMS:
$Y_2 < Y_1$ AND $X_2 > X_1$. SO, WIDE, SHORT TREES GIVE BETTER SHADE PATTERNS BOTH SUMMER AND WINTER



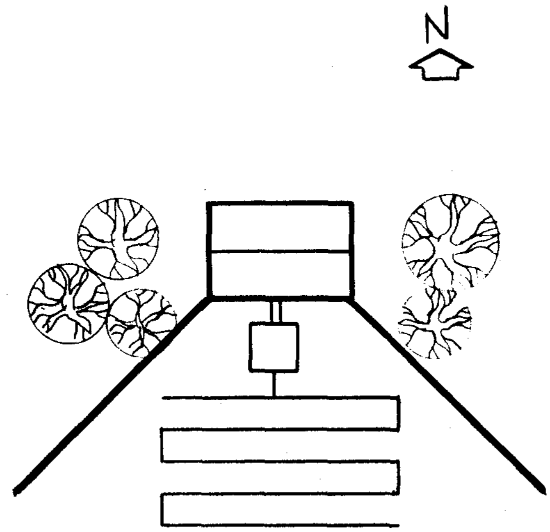
Tree species that should be avoided on the south side of a house include all evergreen as well as oak trees. Evergreen trees pose a year round threat to solar access while oak trees may threaten solar access during the late fall and early spring periods due to its late leaf drop characteristics. Other deciduous tree species may also interfere with solar access during the winter months but by and large such interference is limited to the density of the bare branch profile of the tree rather than to the presence of late dropping leaves. Selective pruning of deciduous trees located to the south of a proposed passive solar home can help improve solar access in the winter without adversely affecting the beneficial summer shade cast upon the home.

Septic System Leaching Field Location

Surprising as it may seem, the location of the future septic system leaching field in developments not served by public sewers can be a significant factor in protecting future access to sunlight. In heavily vegetated areas septic system leaching fields require the cutting of tree cover in order to dig the trenches for the leaching fields. The placement of the leaching fields on the south side of the house ensures that significant shadow casting vegetation is removed in the early stages of the development (see Figure 15). In some circumstances, the south side of the house may not be the best location for the placement of the septic system leaching field.



Solar Access Prior To
Installation of Leaching Field



Solar Access After
Installation of Leaching Field

The slope of the land, soil conditions and location of the water well can influence the proper placement of the septic system. However, whenever possible the septic system should be constructed on the south side of the proposed dwelling unit location as long as an engineered septic system is not required.

On large lots, several test pits should be tried in locations which would be suitable for septic system leaching fields as well as the enhancement of solar access to the proposed dwelling unit. Assuming all of the test pits are equivalent in terms of the installation cost of a septic system, the preferred test pit should be the one offering the greatest opportunity for increased south wall solar access to the proposed dwelling unit.

Sewer and Water Easements

Where sewer and water facilities are available, it may occassionally be possible to increase solar access by the careful siting of homes to take advantage of cleared swaths created by water or sewer line easements. Sewer and water lines generally are installed along street lines in order to efficiently serve houses on both sides of the street. From the standpoint of protecting solar access, sewer and water easements should be sited on the north side of east-west streets to facilitate the removal of potential shadow casting vegetation. On north-south streets, easements for water and sewer lines may have less value as a tool for increasing solar access. However, in isolated instances a sewer or water line easement on a north-south street can be an effective means of removing certain tree stands which might block early morning or late afternoon sunlight to solar collectors.

It should also be kept in mind that sewer and water line easements may, in certain instances, cross rear property lines in order to connect into the existing sewer and water system. In these cases, the choice of alignment for the easement combined with the siting of houses can offer another possible mechanism for tree removal which is not likely to be opposed by local sewer authorities nor the local planning board.

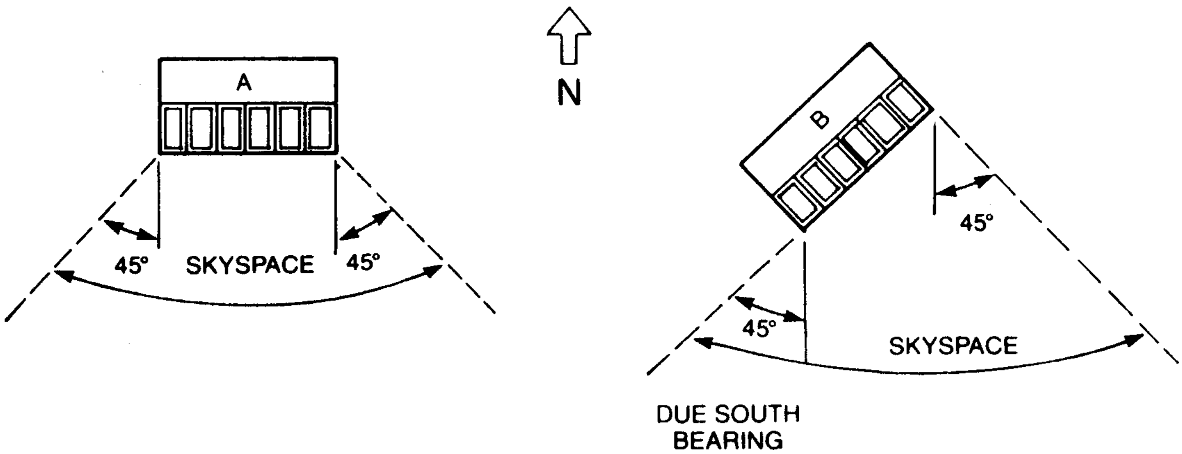
3. Techniques for Protecting Solar Access

Solar access protection begins with a delineation of the solar skyspace of the solar energy system. The solar skyspace is that area of the sky which must remain unobstructed for a solar collector to operate efficiently (see Figure 16). The solar skyspace for most solar energy systems is determined by the sun's position at the winter solstice when the solar altitude and solar azimuth are smallest and shadows are the largest. Generally, if solar access can be protected on December 21st. it can be protected throughout the remainder of the year (see Figure 16).

The solar skyspace may be conveniently defined by the angle of the early morning and late afternoon sun on December 21st. and by the altitude of the sun on December 21st. and June 21st. These four points essentially outline the eastern and western boundaries of the solar skyspace and its lower and upper reaches for the entire year. Of course as mentioned earlier, the exact nature of the solar skyspace will depend upon the type of solar energy system being considered: solar domestic hot water systems will require the largest "window" to the sun whereas passive solar energy systems for space heating will only require access to the sun between the months of September to March. Figure 17 indicates the difference in the shape of the solar skyspace for a solar domestic hot water system and the solar skyspace for a passive solar energy system for space heating only.

Figure 16

Solar Skyspace (Plan View)



Solar Skyspace (Plan and Isometric Views)

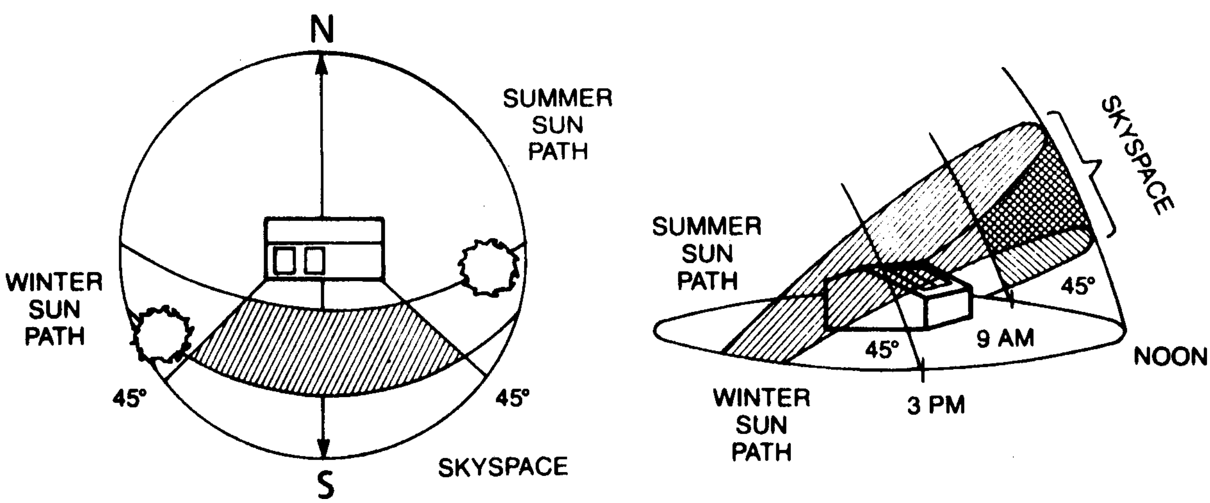
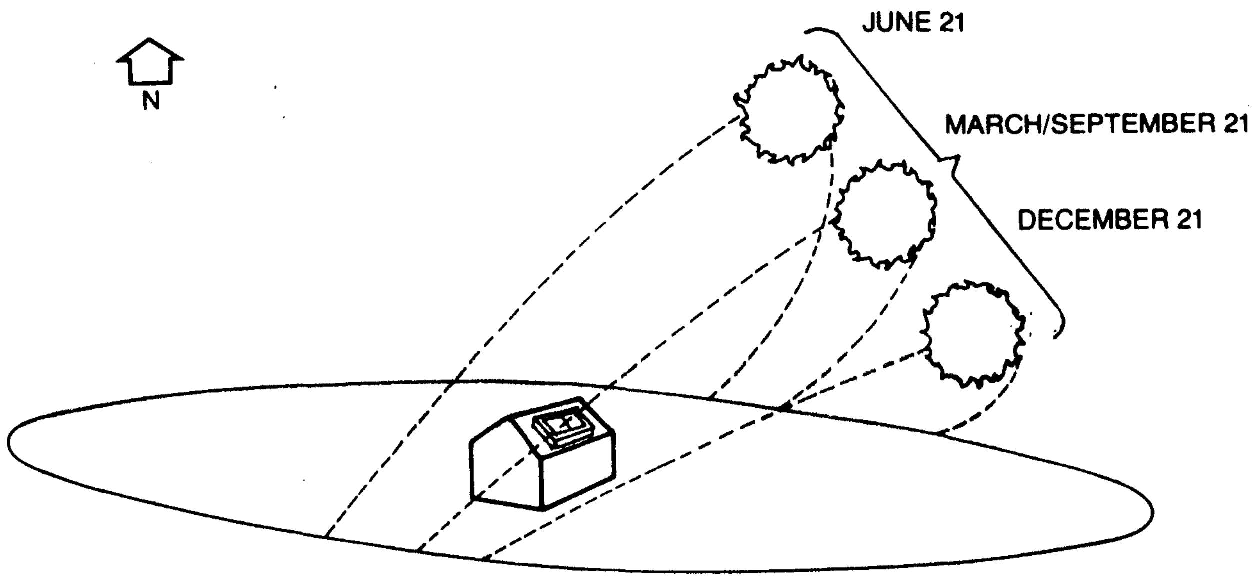
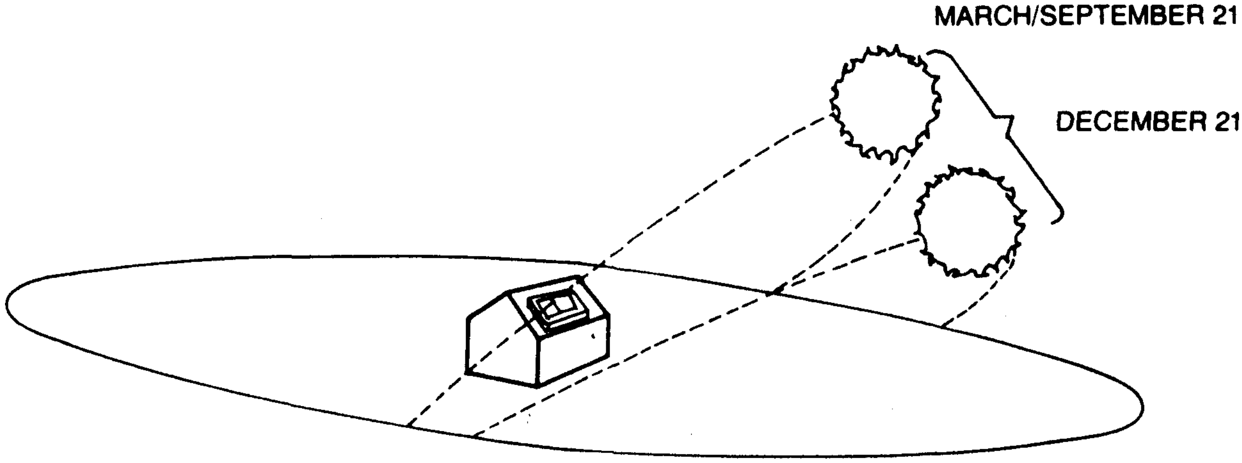


Figure 17

Skyspace Boundaries for Water and Space Heating



WATER HEATING
REQUIRED YEAR-ROUND



SPACE HEATING REQUIRED
FROM SEPTEMBER/MARCH

In practice, the lower boundary of the solar skyspace is the most significant portion of the "window" to be protected since it is the most vulnerable to obstructions from buildings, vegetation and other man made and natural features of the environment. Moreover, the solar skyspace of a south wall solar collector will be more vulnerable to obstructions than a similar skyspace which begins at the eaves of the roof. (See Figure 18). The solar skyspace can be protected to a greater degree by the placement of the solar collectors on the rooftop. This is particularly important to bear in mind in areas of variable slope and topography. The solar skyspace to a solar collector on flat land may be relatively easy to protect but on a north facing slope the lower boundary of the solar skyspace may have litle or no clearance above natural and manmade objects. (See Figure 19).

Figure 18

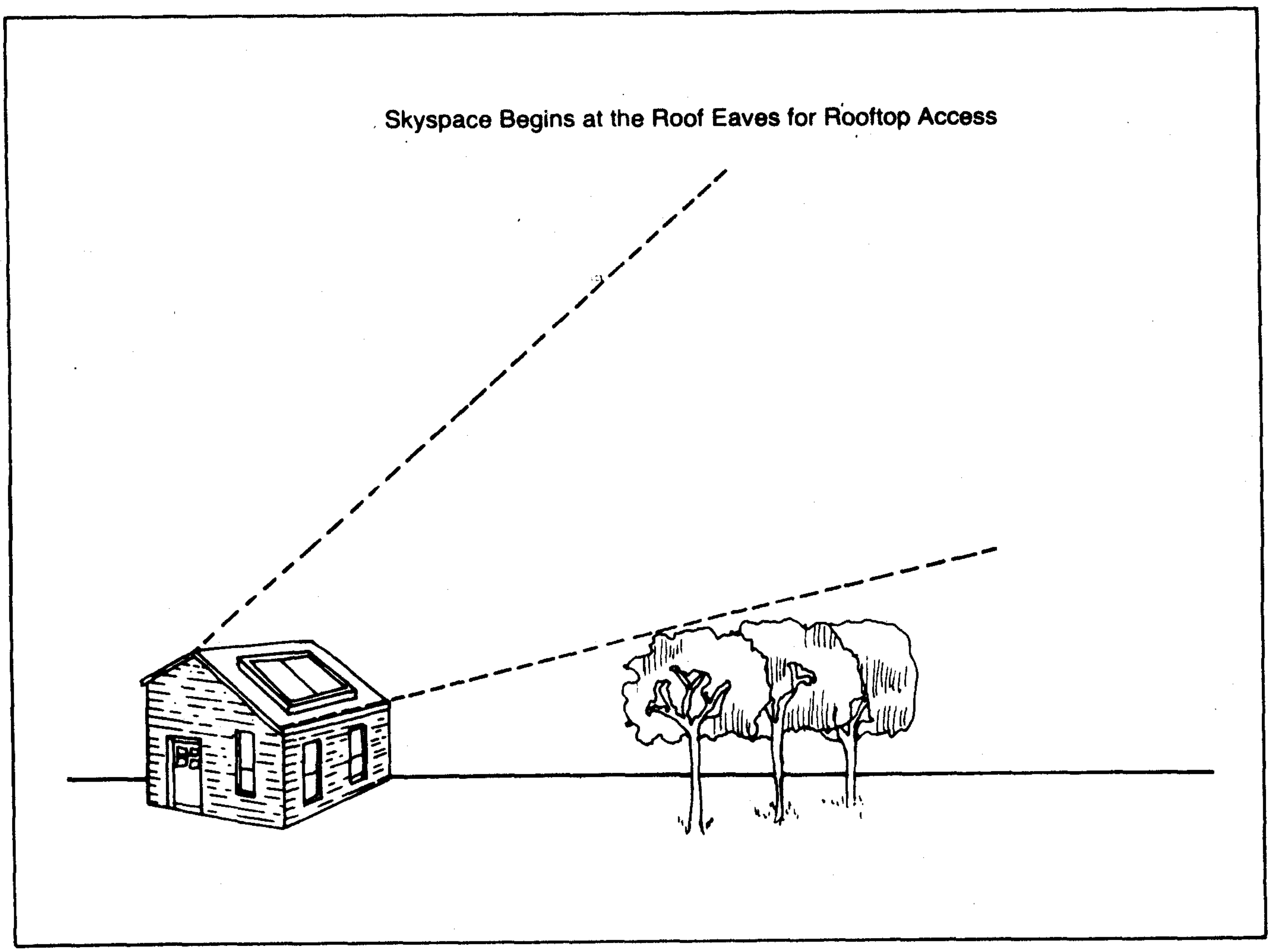
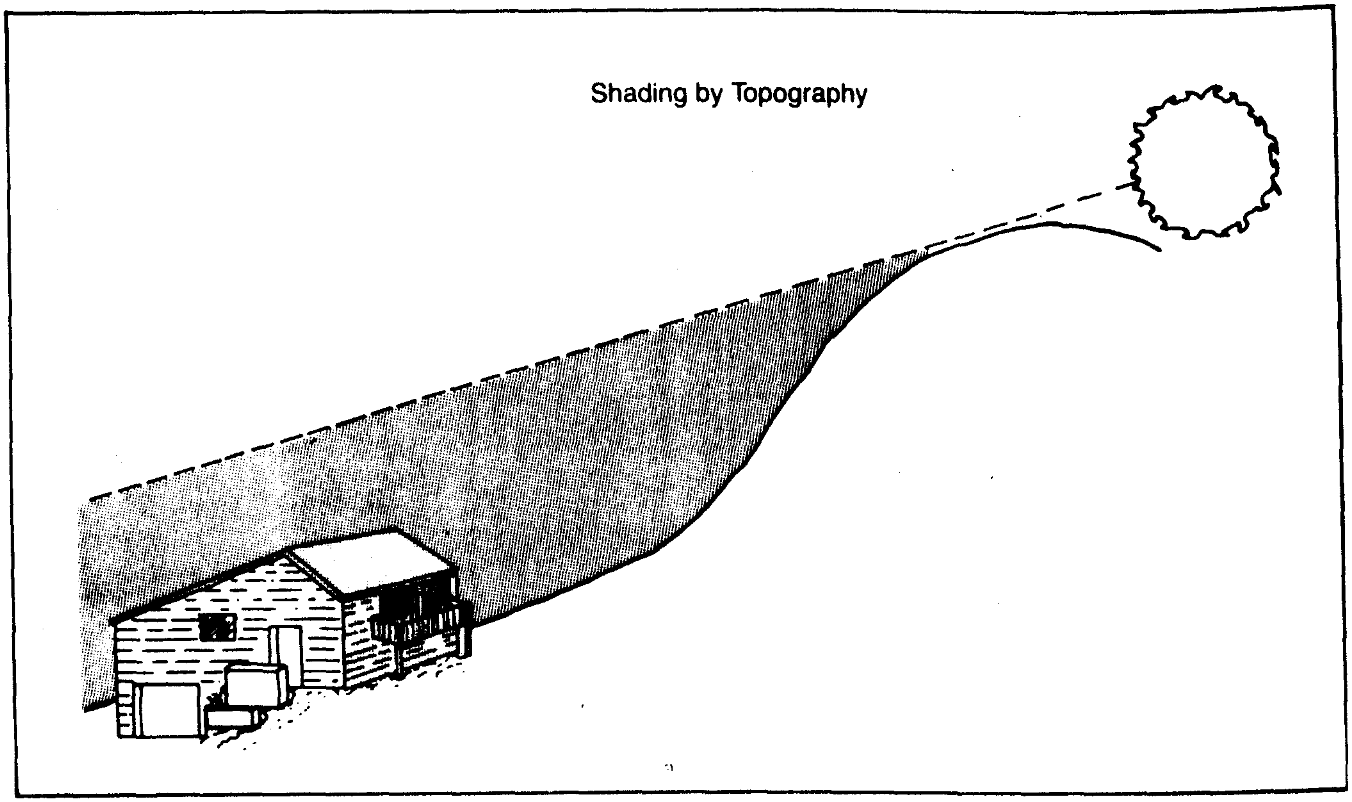


Figure 19



Before any effort is made to protect solar access it is necessary to determine the minimum level of solar radiation necessary to efficiently operate a solar energy system. Perhaps, the most significant guidelines for evaluating solar access are those included in the Connecticut Standards and Specifications for Exemption from Property Tax for Passive and Hybrid Solar Energy Systems. These standards apply to all passive solar energy systems which are eligible for property tax exemption under Public Act 80-416. It is important to recognize that one of the eligibility requirements for exemption from local property taxes is that passive solar energy systems must have:

> "Glazing materials with a U value of .65 or less on a south facing wall, ± 30 degrees of true south, that is at least 75% free of shading between the hours of 9:00 a.m. and 3:00 p.m. on December 21, in fenestrating a building as part of a design for the purpose of direct or indirect solar heat gain."

Approximately 80 percent of all solar radiation received on December 21st. in Connecticut falls between the hours of 9:00 a.m. and 3:00 p.m. local standard time. However, the State's eligibility requirements allow for the possibility of shading to occur 25% of the time during the hours of 9:00 a.m. and 3:00 p.m. on December 21st. In effect, these eligibility requirements permit property tax exemptions to be given on passive solar energy systems which receive as little as 60% of the solar radiation available on December 21st. (ie. 80% times 25% = 60%). While the State's eligibility criteria for solar access must be met in order to obtain tax exemption, the State criteria do not set optimum standards for solar access protection. There are two means of protecting solar access: the minimum approach is to meet the solar access requirements of Public Act 80-406. Using this approach a passive solar home can become eligible for property tax exemptions if solar access is fully protected between the 30 degree solar azimuth positions of the morning and afternoon sun corresponding to 9:56 a.m. and 2:04 p.m. solar time.* If solar access can be fully protected between these periods of the day then a passive solar energy system will receive the minimum of 75% of the solar radiation available between the hours of 9:00 a.m. and 3:00 p.m. local standard time as required by the Standards and Specifications for Exemption. However, the prefered approach is to provide optimum protection of solar access based on 45 degree azimuth positions of the morning and afternoon sun corresponding to 8:43 a.m. and 3:17 p.m. solar time.

From the standpoint of maximizing the efficiency of a passive solar energy system, solar access protection should be available for the longest period of time possible - preferably between 8:43 a.m. and 3:17 p.m. solar time. However, in certain circumstances it may not be feasible or practical to offer this level of solar access protection due to vegetative, topographic or manmade obstructions, steep slopes, or because greater solar access protection might reduce the proposed density of development. On steep north facing slopes, a builder may wish to evaluate solar access using the 9:56 a.m./2:04 p.m. (30 degree azimuth) guidelines rather than the 8:43 a.m./3:17 p.m. (45 degree azimuth) guidelines in order to avoid increasing lot sizes or setbacks to protect solar access. (See the section on Density and Solar Access Protection).

The simplest way of determining the shadow patterns for buildings and vegetation is by using the shadow length tables prepared for various latitudes in Connecticut. In order to use the tables it is necessary to know (1) the orientation of the land, (2) its slope, (3) the height of the shadow casting object and (4) the latitude. Two sets of tables have been developed: (1) the first set of tables provides shadow lengths for one foot poles when the sun is 45 degrees

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*Solar time differs from daylight savings time and local standard time. The difference between Solar Time (ST) and local standard time can be significant particularly when daylight savings time is in effect and when a location is not near the standard time meridian for the eastern seaboard. The formula for determining solar time is as follows: ST = LST + equation of time + 4 minutes x (LST Meridian - Local Longitude) where: LST = Local Standard Time; LST Meridian = 75° for Connecticut; Equation of Time = (See Appendix 2) Local Longitude = (consult U.S. GS map).

east and 45 degrees west of true south (corresponding to 8:43 a.m. solar time and 3:17 p.m. solar time) and for true south (corresponding to 12:00 noon solar time), (2) the second set of tables provides shadow lengths for one foot poles when the sun is 30 degrees east and 30 degrees west of true south (corresponding to 9:56 a.m. solar time and 2:04 p.m. solar time) and for true south (corresponding to 12:00 noon solar time). If the 45 degree azimuth tables are used shadows can be tolerated without affecting eligibility for property tax exemptions. However, if the 30 degree azimuth tables are used the passive solar energy system must be shade free in order to be eligible for property tax exemptions.

The shadow cast by a pole provides the simplest graphic description of a shadow pattern and can be used as a model for constructing shadow projections of more complicated objects. The shadow projection of a tree crown can be approximated by a series of poles of different height. Similarly, the shadow projection of a building can be approximated by a series of poles representing the highest points of the building.

It is not necessary to calculate the shadows cast by all buildings and vegetation within a development. Only those objects standing within the area of concern (ie. 45 degrees either side of true south or 30 degrees either side of true south of the collector depending upon the standard chosen) need to be evaluated. Moreover, it may not be necessary to calculate the shadow cast by an object at every hour of the day during the period chosen for evaluating solar access. The shadow pattern of any object can be approximated based on shadow length data derived from the shadow length tables in Appendix 1. The figure created by plotting the shadows cast by an object at these periods during the day (ie. morning, noon, afternoon) comes reasonably close to the shape of the actual shadow pattern created by the use of hourly shadow length data.

Before calculating the shadow pattern of the object it is necessary to use true north and not magnetic north. For example, in Waterbury, Connecticut true north is at a compass bearing of approximately 13.0° east of magnetic north (see Figure 20). It is also necessary to know how to calculate the slope and orientation of the land. Figure 21 provides a simple method for determining the slope of any parcel of land. In addition, the direction of the slope must be known before determining the length of the shadow cast. When using a topographic site map determine if the numbers on the elevation lines are getting larger or smaller as you measure between Point A and B in Figure 22. If A is larger than B then the land slopes to the south.

<u>Figure 20</u>

Declination of Compass readings from true North in Connecticut

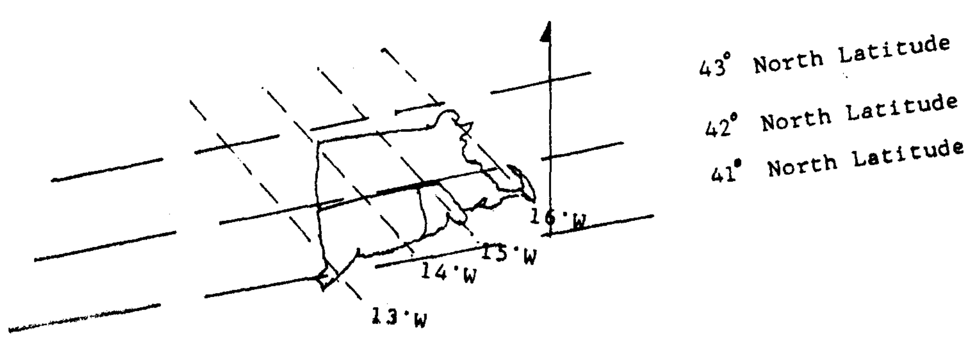


Figure 21

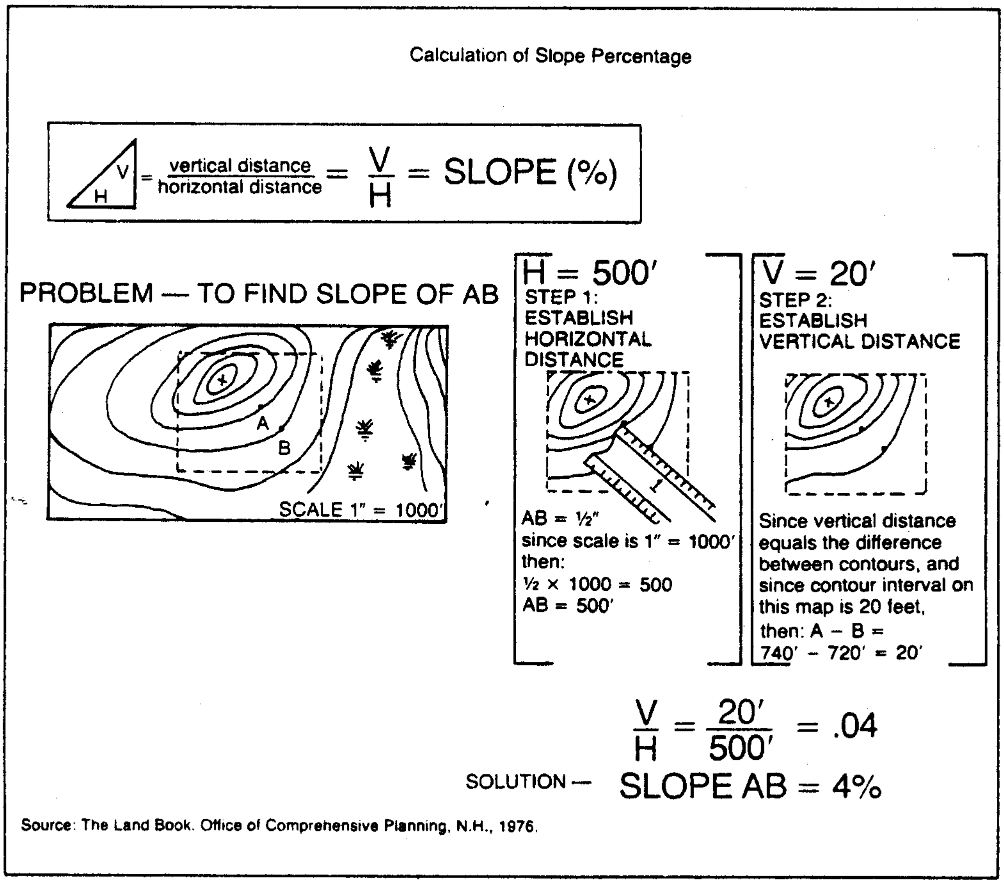
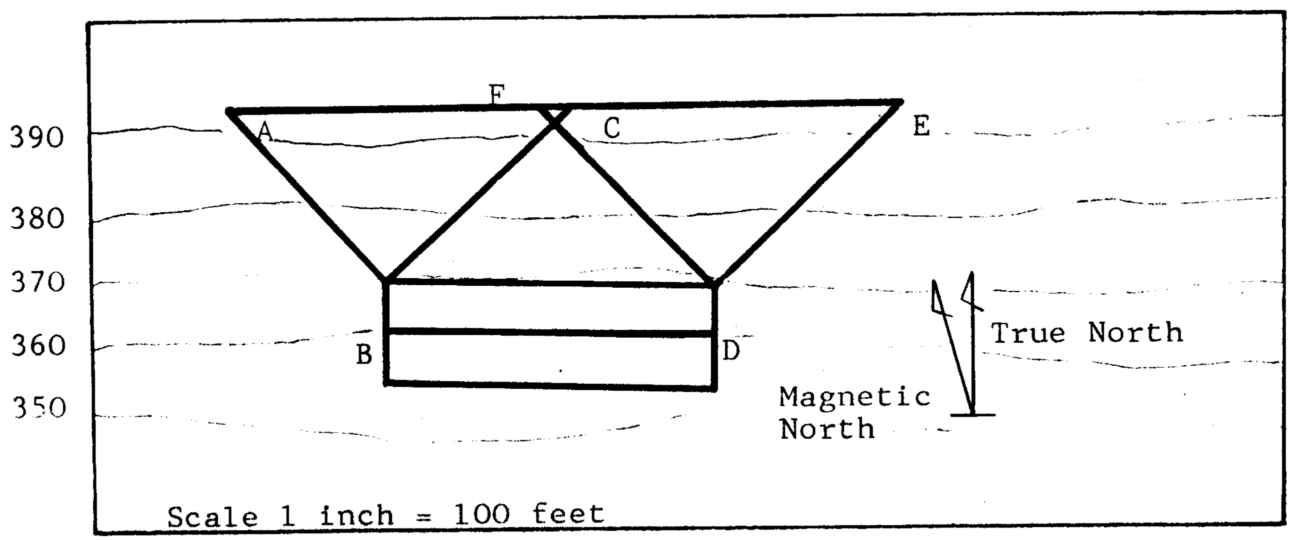


Figure 22



Let's take an example to illustrate the use of the shadow length tables. Calculate the shadow length of a 50 foot pole at 41°30' located on a 15 percent grade sloping to the north in Waterbury, Connecticut. Let's also assume that solar access will be evaluated in the morning and afternoon hours corresponding to 45 degree azimuths from true south.

Step 1: Locate the shadow length value for AM, PM and Noon from the shadow length table for 41°30' for 15 percent grade on a north slope using the tables based on 45 degree azimuths for the AM/PM values.

Step 2: The values given are for a one foot pole so they must be multiplied by the height of the pole, in this case 50 feet.

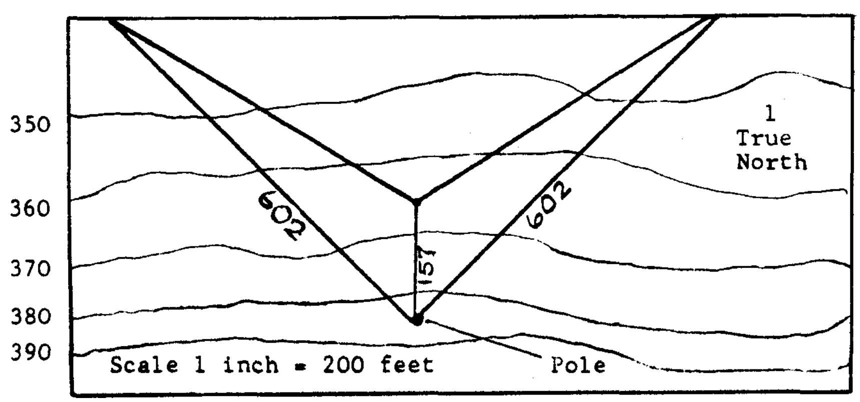
A.M. value x pole height = A.M. shadow length
12.04 x 50 = 602

Noon value x pole height = Noon length
3.15 x 50 = 157.5

P.M. value x pole height = P.M. length
12.04 x 50 = 602

Step 3: Scale the shadow lengths out on paper as viewed from overhead using a protractor to determine the 45°angles on either side of true south constituting the A.M. and P.M. values. Then connect the end points of the shadow lengths. The resulting figure approximates the actual shadow pattern. (see Figure 23).

Figure 23

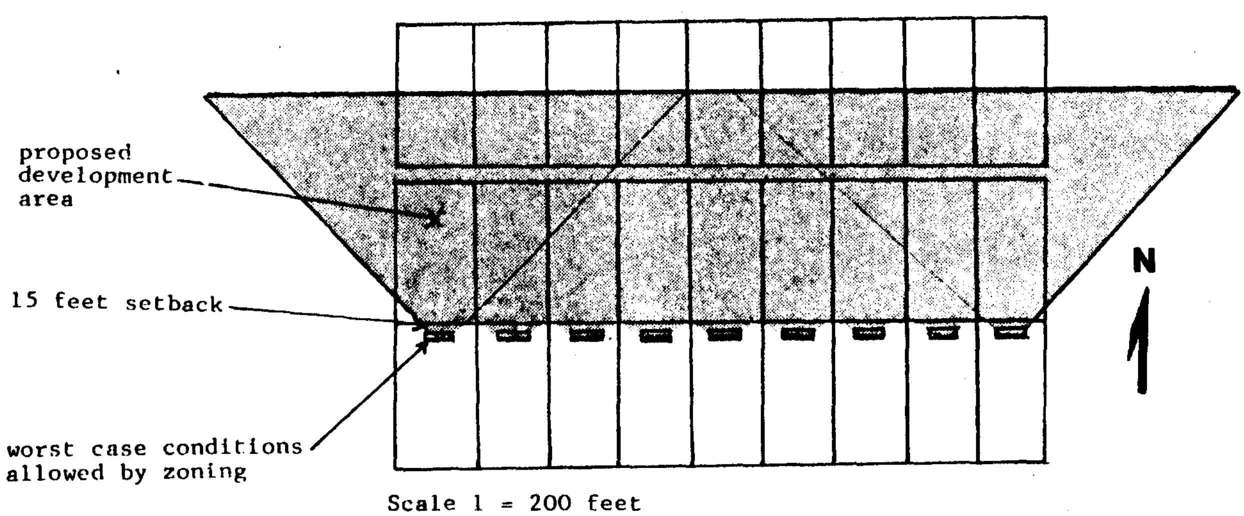


The preceeding technique of calculating shadow patterns allows a developer to determine potential shadow problems without the use of sun angle charts, or angle calculators thereby minimizing the costly field inspection of the site. Once the locations and heights of trees and buildings are plotted on a topographic site plan map, shadow patterns can be evaluated just by referring to the calculation procedure listed above.

For example let's assume that a large single family development is proposed on the lower portion of a north facing slope. The upper portion of the north facing slope (ie. the land to the south) is undeveloped but could be developed at a later point in time. The grade of the slope is 15% and the area is zoned for single family housing with minimum lot sizes of 20,000 square feet per dwelling unit a maximum building height limitation of 40 feet and a minimum setback requirement of 15 feet. Under these conditions, what level of solar access protection is available to proposed passive solar houses within the development?

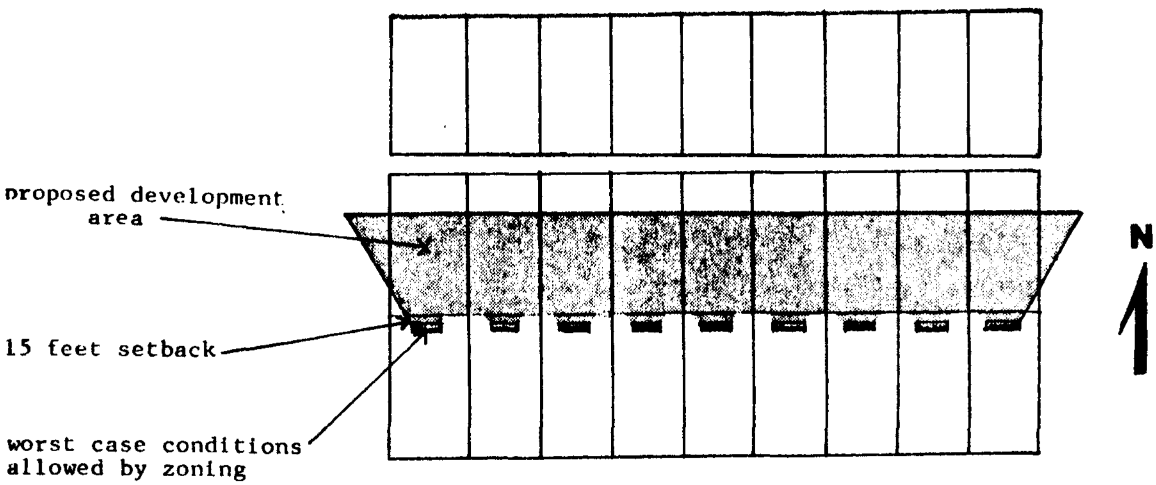
The level of solar access available can be determined by assuming that development to the south will be at the maximum allowed by the zoning regulations. In our example this would mean that buildings to the north will be 40 feet tall and located 15 feet from the south property line of lots within the proposed development (see Figure 24). A delineation of the shadow patterns using a simplified shadow projection procedure (based on the shadow projection of the midpoint of the roof peak of each building) for 45 degree azimuths clearly reveals that future development to the south will shade all lots abutting the development. Indeed, if solar access is to be protected for the 45 degree azimuth positions, it will be necessary to increase lot sizes to 40,000 square feet or greater in order to protect south wall solar access. However, if lower density is not desirable, it is then advisable to select the less restrictive 30 degree azimuth solar access standard. As can be seen in Figure 25 the use of the 30 degree azimuth for evaluating solar access allows development to remain at densities of two dwelling units per acre as long as the dwelling units are located as near as possible to the front setback lines.

Figure 24



Shadow projections from potential development to the south under the worst case conditions allowed by zoning (assumes 45 degree azimuths are used to evaluate solar access).

Figure 25



Scale 1 = 200 feet

Shadow projections from potential development to the south under the worst case conditions allowed by zoning (assumes 30 degree azimuths are used to evaluate solar access).

However, for developers wishing to acquire more sophisticated siting and shading calculation products, there are a large number of companies supplying a variety of products including sun angle charts and instruments for calculating sun angles and sun paths. These products allow for a visual appraisal of solar access based on the sun's path during one or more months of the year. They can be used to identify potential shadow problems that may arise from existing buildings and vegetation but will not identify shadow problems that may arise from proposed developments or vegetation. The best means of calculating solar access problems that may emerge from proposed developments to the south of the collector is by using the shadow calculation procedure mentioned above.

Density and Solar Access Protection

Higher density development need not conflict with solar access objectives when proper attention is paid to the location of proposed buildings. Higher density developments can be easily accomodated by taking advantage of south facing slopes and by laying out street networks along an east-west axis. The protection of solar access is relatively easy in undeveloped areas where off site development poses no solar access barriers to proposed buildings on the tract. However, in areas abutting existing development or where rehabilitation is proposed, a developer must carefully evaluate the existing or potential shadow patterns created by adjoining buildings off the tract and determine the extent to which off site buildings could be increased in height. In downtown areas where no height limitations are placed upon the maximum height of buildings, it may not be advisable to utilize solar energy for higher density housing projects unless some suitable public or private agreements can be reached with adjoining property owners to ensure access to sunlight for the solar energy system. Recent studies of several metropolitan areas in the United States have found that nearly 90 percent of all urban two and three story residential buildings have good rooftop solar access and anywhere between 33% and 72% of all these buildings have good southwall solar access. These studies suggest that solar energy systems may have great potential within the conventional development patterns found throughout urban areas in Connecticut. However, good solar access today, does not imply that solar access will always remain available. Lack of building height limitations in central business districts, the presence of street trees, and planned future development activities to the south of proposed solar energy systems may reduce the certainty of long term solar access. An analysis of local zoning regulations will reveal the maximum building height limitations which will in turn determine the shadow patterns of buildings allowed under the worst case conditions of zoning. This type of analysis can provide an important clue to the future availability of sunlight for proposed solar energy systems.

A simpler method of arriving at the same conclusions shown in Figures 24 and 25 is by using the North Shadow Projection Tables for Connecticut. Table 2 provides north shadow length data that can be used when solar access is being evaluated at the 45 degree azimuth positions. Using this Table we can determine that a 40 foot building on a 15% north facing slope at 41°30' north latitude will have a 340 foot north shadow projection as graphically explained in Figure 26. If lot depth and lot width dimensions are known, it is relatively simple to determine the level of solar access protection available. If the north shadow projection is longer than the lot depth there is clearly no south wall solar access available. In this case, it may be possible to increase lot depth (along the north-south axis) or to adopt the less restrictive solar access standard associated with the 30 degree azimuth positions. Assuming, that density is to be maintained, then it is a simple matter of determining the north shadow projection of a 40 foot building on a 15% north facing slope. At 41°30' north latitude Table 3 indicates that the north shadow projection will be 161 feet which offers some level of solar access protection on a 20,000 square foot lot (100 foot frontage and 200 foot depth).

Table 2: North Shadow Projection Table for 45° Azimuth Ratio of North Projection of Shadow Length to Height of Shadow Casting Object (assumes 45 degree azimuth for AM/PM shadow assessment)

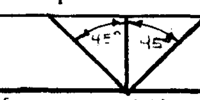
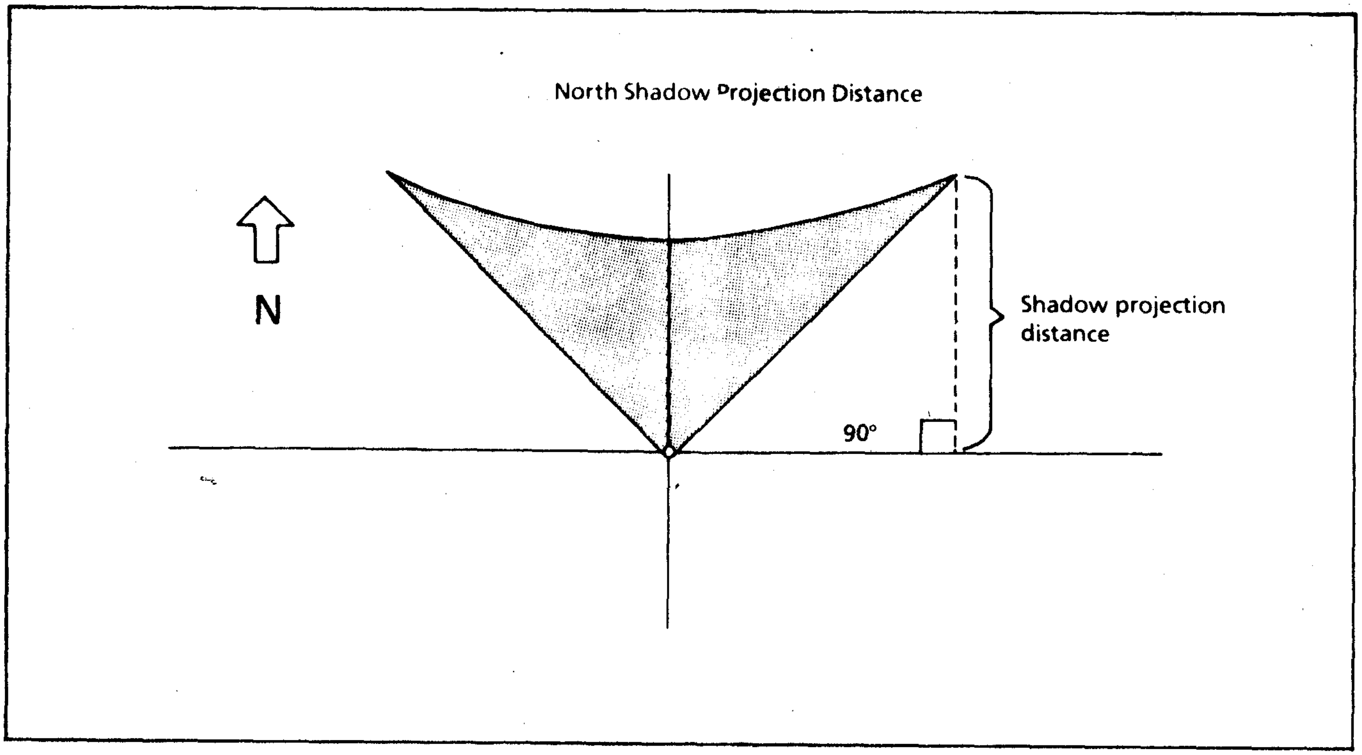
Latitude / South Slope	25%	20%	15%	10%	5%	Flat	5%	10%	15%	20%	25%	North Slope
41°15'	1.92	2.11	2.37	2.68	3.10	3.66	4.49	5.78	8.15	13.74	43.87	
41°30'	1.93	2.14	2.40	2.72	3.15	3.74	4.60	5.97	8.51	14.82	57.23	
41°45'	1.95	2.16	2.43	2.76	3.20	3.81	4.71	6.16	8.90	16.04	80.88	[SP=Sine 45°x shadow length AM]
42°0'	1.97	5.36	2.45	2.80	3.25	3.89	4.82	6.36	9.33	17.47	137.74	

Table 3: North Shadow Projection Table for 30° Azimuth Ratio of North Projection of Shadow Length to Height of Shadow Casting Object (assumes 30 degree azimuth for AM/PM shadow assessment)

Latitude / South Slope	25%	20%	15%	10%	5%	Flat	5%	10%	15%	20%	25%	North Slope
41°15'	1.53	1.65	1.81	1.98	2.21	2.47	2.83	3.29	3.94	4.91	6.51	
41°30'	1.54	1.67	1.83	2.01	2.23	2.51	2.87	3.35	4.03	5.04	6.74	[SP=Sine 30° x shadow length AM]
41°45'	1.56	1.69	1.84	2.03	2.26	2.54	2.92	3.41	4.11	5.18	7.00	
42°0'	1.57	1.71	1.86	2.05	2.29	2.59	2.96	3.47	4.21	5.33	7.26	

Figure 26



On more favorable southern slopes, it may be possible to achieve relatively high denisties of development by the careful application of solar access principles and shadow projection data. For example, taking density and solar access issues into consideration the University of Southern California School of Architecture has recently shown that passive solar design concepts can be incorporated into high density development patterns. Based on one innovative design for multi family housing, one architecture student was able to achieve densities of up to 52 units per acre without adversely affecting the solar access to any of the units on the site or any buildings off the site.

Higher denisty developments can incorporate passive solar design concepts as long as consideration is given to the solar access constraints of topography and other natural or manmade obstructions to sunlight, during the initial stages of site planning and design. A more detailed discussion of density considerations as they apply to solar access can be found in the study, Solar Envelope Concepts: Moderate Density Building Applications, prepared by the University of California School of Architecture.

Solar Easements

After all is said about the positive features of zoning as a vehicle for protecting solar access, a word of caution must be added. Zoning is subject to change. A zoning commission may have regulations limiting the maximum height of buildings to 30 feet but ten years from now it may decide to change those regulations to allow for taller buildings. Or ten years from now the town may decide to disband zoning altogether thereby dissolving any setback requirements and height restrictions limiting the development opportunities of neighboring property to the south of a solar energy system. But perhaps more importantly, zoning does not control the height of trees and other vegetation which can pose serious threats to solar access.

Because zoning is a limited vehicle for protecting solar access and because zoning is subject to change, it is important to provide other legal mechanisms to assure long term access to sunlight for all passive solar homes built under the mandate of Public Act 81-334. Perhaps the best mechanism for protecting solar access is to include a solar easement on each of the lots sold stipulating a basic level of solar access to be provided.

The State of Connecticut has not yet adopted a statute authorizing and regulating solar easements. Despite the absence of a statutory authorization for solar easements it is clear that solar easements can be established to maintain a right to solar access. Courts in this country have upheld easements for light, air and view by specific grant or reservation. Similarly easements for solar access protection can be established along the lines of easements for light, air and view. Perhaps the principal limitation created by the lack of a state authorization is that there is no model solar easement approach that courts, developers and property owners must all follow. Without a model solar easement law in Connecticut it will be up to developers to select solar easements that are simple to create and enforce.

A number of approaches to creating solar easements have been suggested in recent years only some of which are worth considering in the State of Connecticut. The approaches worth considering include a (1) non shade easement, (2) setback and height restriction easement, and (3) a vertical and horizontal angle easement.

Non Shade Easements

This type of solar easement defines a right to sunlight by prohibiting anything on adjacent property from shading the solar collector. Such a solar easement can be described using a vertical plane located at the base of the solar collector and stipulating that no shadows shall fall on the collector during the period 9 a.m. to 3 p.m. local time on any day of the year. Alternatively, the vertical plane could be delimited by indicating that the easement only applies to structures and vegetation falling within the 45 degree azimuths on either side of true south of the solar collector. Solar easements can be based on this simple type of vertical plane formula as long as the vertical plane does not result in a substantial reduction in the development potential of property to the south of the solar collector.

Setback and Height Restriction Easement

This type of easement stipulates minimum setback requirements and building height limitations similar to those customarily used in a zoning ordinance. The advantage of a setback and height restriction easement is that it is easy to establish and easy to understand. Using this approach the solar easement would uniformly restrict the maximum height of buildings or vegetation on property to the south based on a minimum setback from the solar collector. Property owners could then easily determine if the tree or building is too close to the collector or too tall based on the standards set up in the solar easement.

An alternative and slightly more equitable means of establishing a setback and height restriction easement is by including stepback provisions. Rather than limiting all buildings and vegetation to a specified height and a specified setback the solar easement could establish two or three setback zones within which different height limits would be established. For example, the solar easement might state that the first setback zone shall start at a line perpendicular to true south at a distance of 60 feet from the solar collector and end at a line perpendicular to true south at a distance of 80 feet. In that zone no building or vegetation shall exceed a specified height. The second and third setback zones would be similarly established with progressively less restrictive height limitations placed upon buildings or vegetation in these zones (see Figure 26).

It may also be possible to establish a more precise easement based on a consideration of the sun's movement through the sky. Using a "solar setback" approach the setback zones would be created based on the vertical angle of the sun at three specified periods of the day corresponding to the morning (9:00 a.m.) noon (12:00 p.m.) and afternoon (3:00 p.m.) sun. As can be seen in Figure 27, once delineated on the ground the solar setback zones would resemble a series of boomerangs. Within each boomerang shaped zone there would be a uniform height limitation with progressively less restrictive height limitations placed upon buildings and vegetation in each suceeding more distant zone. This approach may not be as complicated as it sounds when a developer utilizes one of the appropriate solar setback templates developed by the CNVRPA. These templates have been created at various map scales so that they can be placed over subdivision or plot plan maps to quickly delineate the shape of the solar setback zones.*

These three approaches to establishing setback and height restriction easements offer progressively greater degrees of protection for the owner of the solar collector and progressively greater degrees of equity to the owner of the property over which the easement is created.

*Copies of the solar setback templates are available from the Central Naugatuck Valley Regional Planning Agency at the one inch equals 100 foot scale.

Figure 26

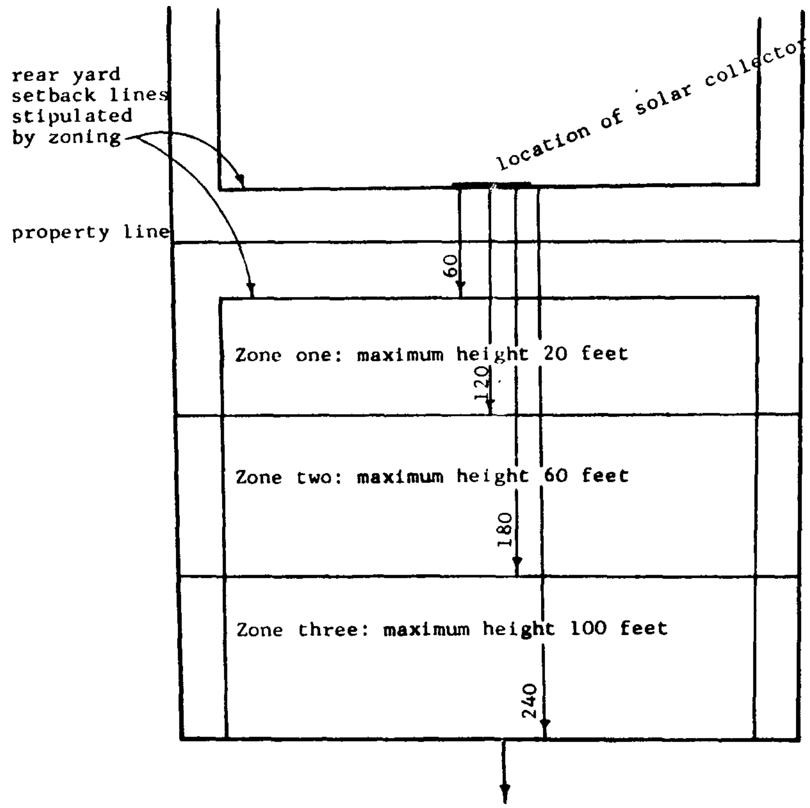
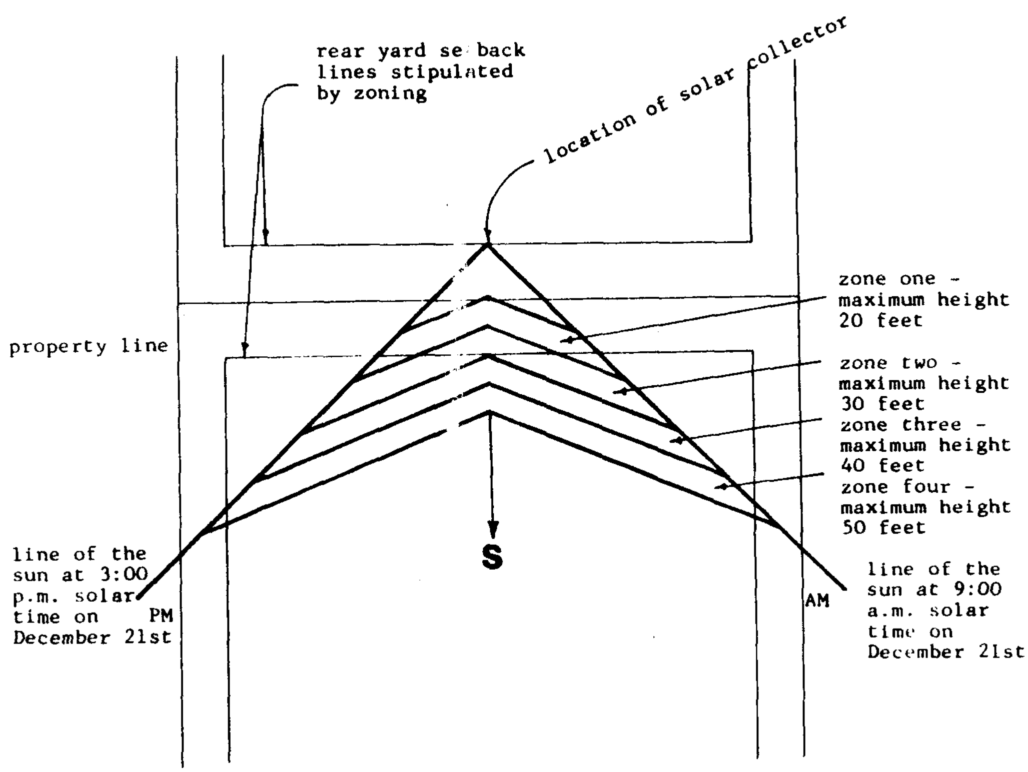


Figure 27



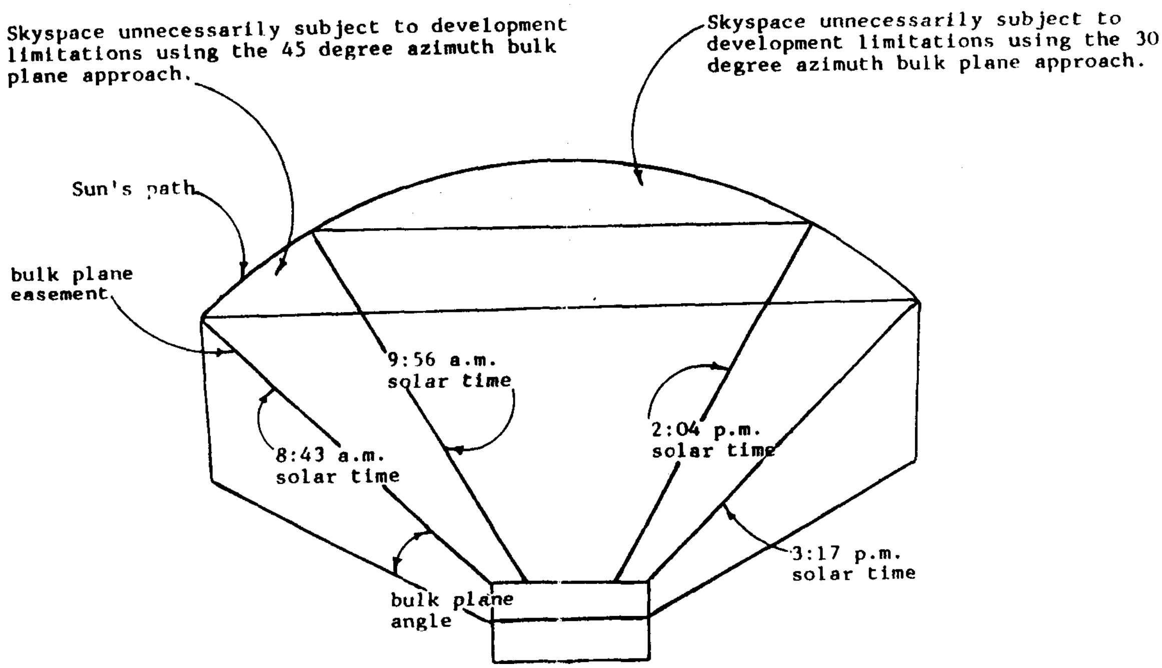
Vertical and Horizontal Angle Easement

This type of solar easement is the most complex and will probably require a survey in order to determine the limits of the solar easement. Bench marks on the ground corresponding to the points where the solar skyspace passes above the property will probably be required in order to determine the vertical and horizontal limits of the solar easement. Using this approach, the solar easement is expressed in vertical and horizontal angles corresponding to the path of the sun across the sky on December 21st. It may be simplified somewhat by creating only one or two vertical angles that approximate the path of the sun across the sky with corresponding horizontal angles delineating the location of the easement across the property to the south.

If this type of solar easement is to be used as the basis for establishing a right to sunlight it is advisable to base the vertical angle on the sun's altitude angle for the morning or afternoon hours of December 21st corresponding to the 45 degree azimuths on either side of true south. This approach simplifies the procedure for establishing a solar easement since solar access is based on one angle rather than on a series of angles corresponding to the different positions of the sun as it crosses the sky. Its disadvantage is that it unnecessarily restricts development of buildings or the growth of vegetation due south of the solar energy system where solar access problems are less of an issue. (See Figures 28 and 29). The limitations to development created by this type of easement approach will probably not pose any serious problems on flatland or south facing slopes. However, on north facing slopes, the use of the sun's altitude angle at the 45 degree azimuth positions (corresponding to 8:43 a.m. and 3:17 p.m. solar time in Connecticut) may place excessive constraints on the development of property to the south. In these cases if this easement is still acceptable it is appropriate to consider the use of the sun's altitude angle corresponding to the 30 degree azimuth positions (i.e. 9:56 a.m. and 2:04 p.m. solar time in Connecticut) as the basis for the angle incorporated into the solar easement.

While the sun's altitude angle at the 45 degree azimuth positions on December 21st may be acceptable as the solar easement angle when development occurs on flatland, the solar altitude angle must be modified when this type of easement is stipulated for land with other slopes and orientations. In effect, the solar easement angle must take into consideration the angle created by the land to the south of the solar energy system and the angle of the sun. When the land is flat that angle equals the sun's altitude at the 45 degree azimuth positions on December 21st. When the land is sloping to the south that angle becomes less restrictive and when the land is sloping to the north that angle becomes more restrictive. (See Figure 30). Appendix 3 provides suggested solar easement angles for the 45 degree azimuth and the 30 degree azimuth positions for December 21st for varying slopes, orientations and latitudes within Connecticut. These solar easement angles must be used with caution since it may not be possible to apply these solar easement angles where the density of development combined with the minimum setback requirements stipulated by the town's zoning regulations would result in an unreasonable reduction in the development potential of other lots within the development located to the south of the passive solar energy system. Nonetheless, at a minimum it is suggested that the less restrictive solar

Figure 28



Bulk Plane Solar Easements for 45 and 30 Degree Azimuth Positions

Figure 29

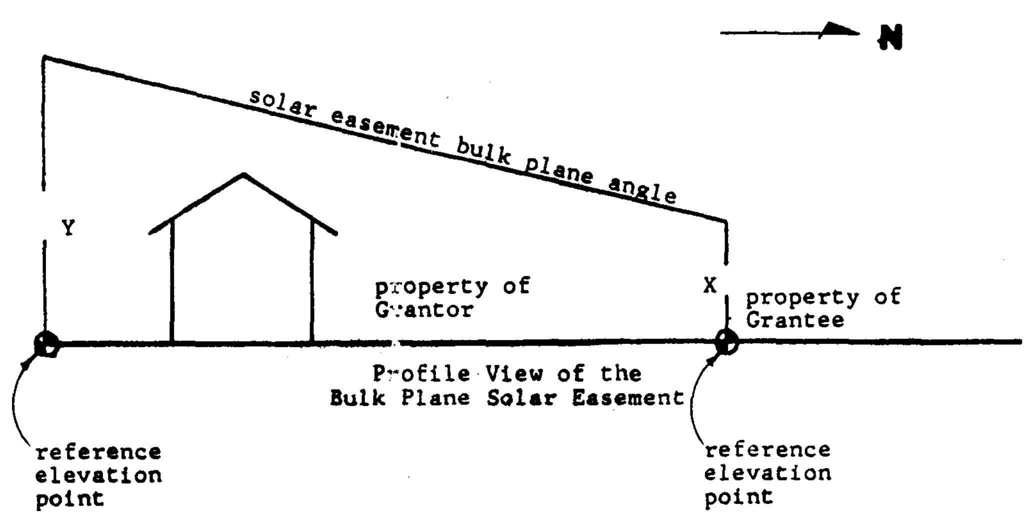
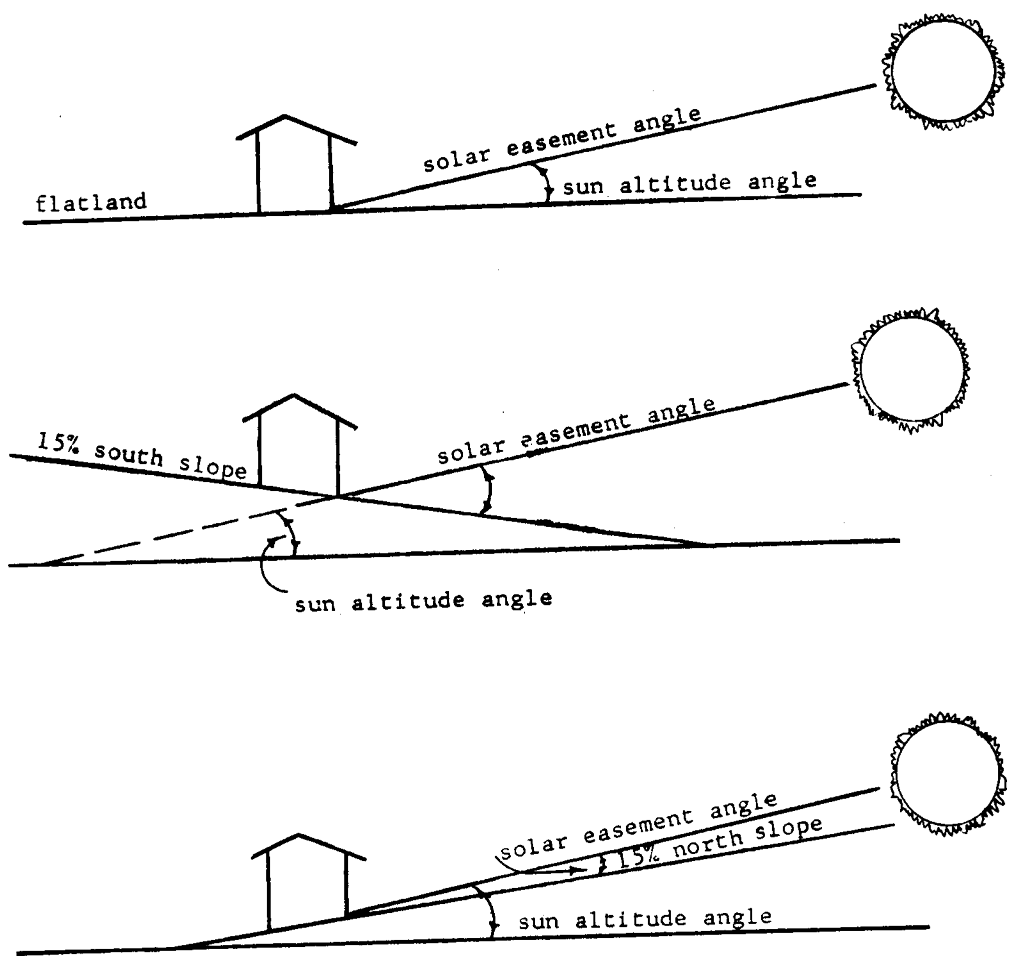


Figure 30

Impact of Slope on the
Solar Easement Bulk Plane Angle



easement angle corresponding to the 30 degree azimuth positions on December 21st be included within each deed to ensure that passive solar energy systems receive the minimum level of solar radiation required to meet the property tax exemption standards of Public Act 80-406.

Anyone of the three solar easements suggested may be acceptable depending upon the degree of precision required in creating the solar easement. In some cases title insurance companies, banks or local planning and zoning commissions may require greater precision in the creation of the solar easements when the solar collectors installed have substantial value or provide a significant portion of the space heating needs of the dwelling unit. In these cases it is advisable to consult the bank, title insurance company or planning and zoning commission before creating the solar easement. Regardless of the approach taken, in describing the solar easement, it is recommended that the solar easement include provisions for (1) permissible shading caused by existing structures or vegetation (the solar access requirements of PA-80-406 should be consulted in establishing this standard); (2) methods available to the owner of the solar collector for maintaining the solar easement against encroachments by vegetation; (3) enforcement mechanisms available to the owner of the solar collector stipulating how the cost of enforcement will be born; and (4) stipulations that the easement runs with the land.

These provisions, of course, should be developed after consulting an attorney familar with Connecticut's solar access law and solar easements.

It is important to recognize that if a solar easement is not included as part of the deed of each lot it is very unlikely that future homeowners will ever be assured of permanent solar access. Clearly, the purchase of a solar easement may be expensive or prohibitive in an existing development when an adjoining landowner has no interest in cooperating or in losing any of his rights to future development. For this reason, solar easements are most likely to be effective in new developments where a developer takes the time to include a solar easement within each deed thereby eliminating all transaction costs between neighbors. The solar easement is simply one of the conditions that each homeowner accepts when buying the lot or the house.

4. Site Planning for Energy Conservation

The microclimate of the site and the characteristics of the land can have an important bearing upon the overall energy requirements of the proposed development. Ambient air temperature, humidity, wind speed, and wind direction are most significant factors affecting the microclimate of a site. To a large degree these factors are fixed by the forces of nature. However, these microclimatic factors can be modified to a degree through the use of "energy conscious" site planning principles. For example, site planning can modify wind patterns, ambient air temperatures and humidity levels surrounding a building. By changing the microclimate of the site it is possible to exert a positive impact upon the energy requirements of the building and therefore improve the effectiveness of passive solar energy design concepts.

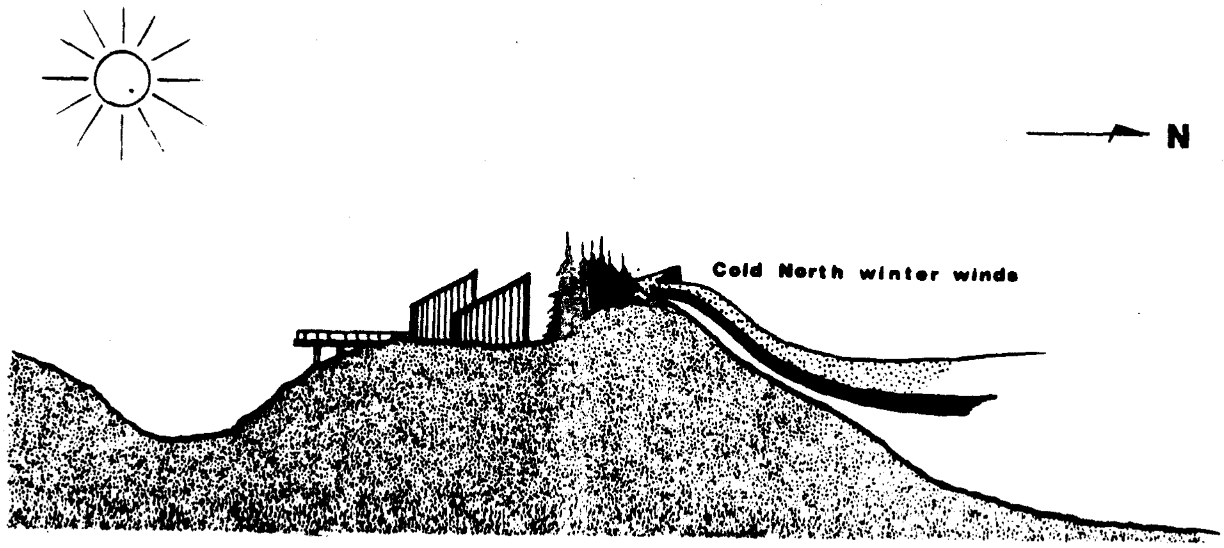
In evaluating the energy conservation opportunities available on a tract of land, it is important to identify, (1) prevailing wind patterns, (2) the grade and orientation of slopes, (3) vegetation, (4) soils, (5) surficial geology and (6) ambient air temperatures. These factors when evaluated as a whole determine the optimum location for siting buildings and solar energy systems. A site planner can have a considerable degree of infuence upon the energy requirements of individual dwelling units by taking advantage of (1) south facing slopes for wind protection, (2) using evergreen trees as windbreaks, (3) locating proposed dwelling units below exposed hilltops and out of cool valley bottoms where space heating requirements are greatest, (4) designing street systems which block winter winds and channel cool summer winds and (5) designing dwelling units which minimize exposure to the north and maximize south wall solar access.

Each of these factors is discussed below:

1. South Facing Slopes for Wind Protection

South facing slopes not only offer greater solar access, they provide protection from prevailing winter winds. In Connecticut ridgelines tend to follow a north-south pattern with the bulk of the land in many towns facing either east or west. Under these circumstances, development on southeasterly slopes is preferable since these sites offer the greatest protection against prevailing northwestern winter winds. Southern slopes, while less frequently found are the ideal location since these sites offer both wind protection and solar access protection. (See Figure 31).

Figure 31

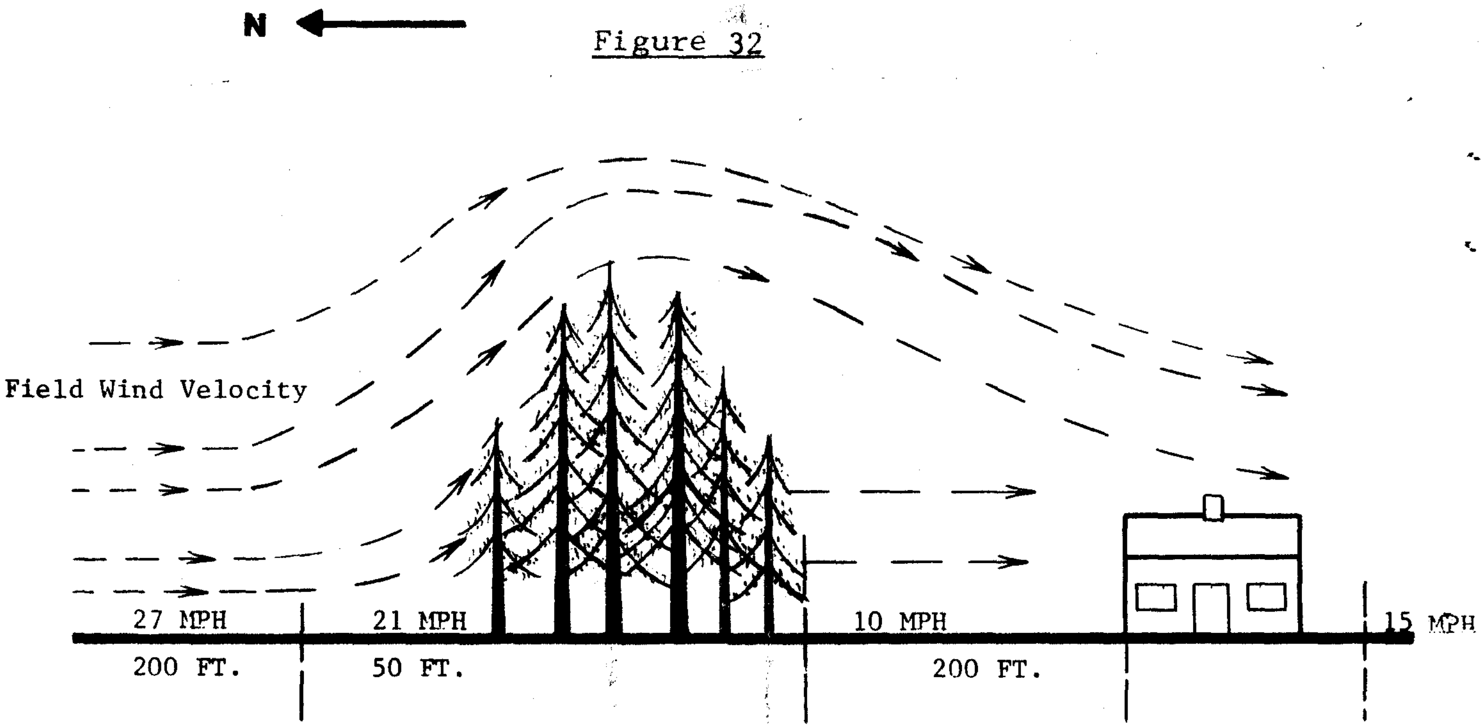


2. Windbreaks

For developments which are not located on southern slopes, a fair degree of protection from winter winds can be achieved through the use of evergreen windbreaks on the north side of the house (see Figure 32). Several studies have found that an evergreen windbreak can reduce wind velocities by 50% over the prevailing velocities of the unimpaired wind. In turn less severe winds can save on fuel bills. The heating bill for an unprotected house with a 20 mile per hour wind is approximately 2.4 times as great as that for a 5 mile per hour wind under the same temperature conditions. In one case, reduction of wind velocities saved a protected house 22.9% in fuel over an identical house exposed to the wind when indoor temperatures were maintained at 70°F.* Even greater energy savings can be achieved by building the house partially or wholly underground, earth sheltered housing is even less susceptible to winter winds than above ground housing.

* See Victor Olgay, Design with Climate - Bioclimatic Approach to Architectural Regionalism, pg. 99.

Figure 32



(not to scale)

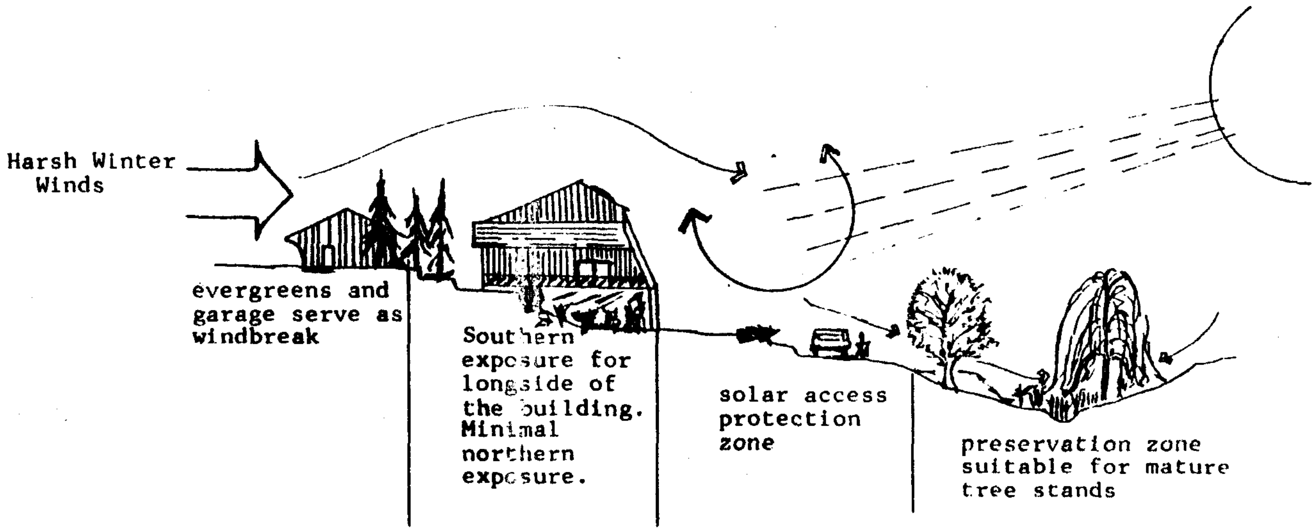
Moreover, an earth sheltered house takes considerably longer to react to outside air temperatures when earth mass is used as an insulation along the walls and on the roof of the building. One recent study found that the maximum rate of heat loss for one prototype earth sheltered house was less than 1.8°F per day even when no allowance was made for any internal heat gain such as from people inside the building.*

3. Avoiding Exposed Hilltops and Valley Bottoms

From an energy conservation standpoint, hilltops and valley bottoms should be avoided. Hilltops are generally more exposed to winter winds and valley bottoms tend to collect cool air. Both of these factors will increase the space heating requirements of the building thereby limiting the effective use of solar energy for space heating. Generally, locations mid way up the hill on gentle south facing slopes are the ideal location. (See Figure 33).

*The Underground Space Center, University of Minnesota, Earth Sheltered Housing Design: Guidelines, Examples and References, P.91.

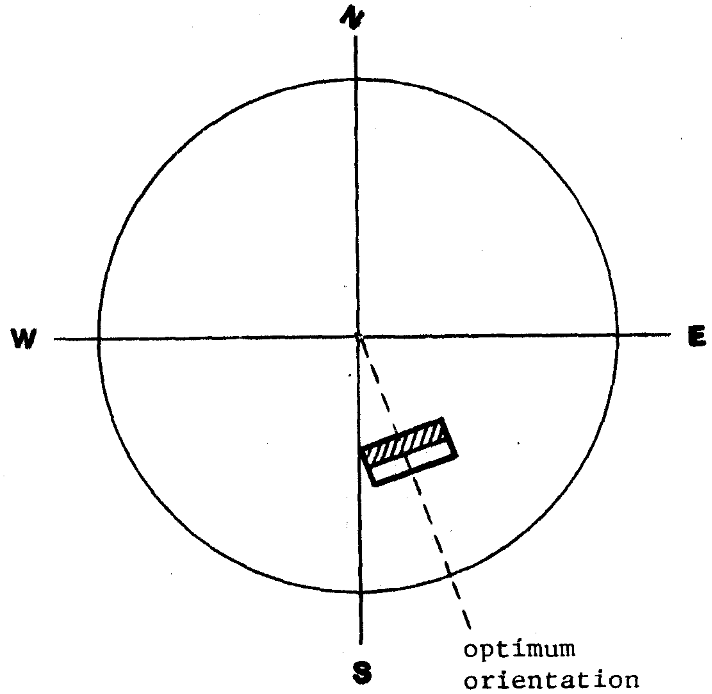
Figure 33



4. Sol-Air Street Pattern

East-west streets are ideal for those building passive solar homes. Under this street pattern solar homes can be sited just like conventional houses fronting on a public street. However, east-west streets may not always be ideal in all locations especially in areas where the prevailing winter winds may often come from the west or northwest. One suggested means of avoiding the channeling of winter winds down east-west streets is to orient the street perpendicular to the prevailing winter wind. Where winter winds are from the northwest a street with a southwest to northeast orientation would be the most appropriate. This street orientation is often called the sol-air street orientation since it attempts to balance the need for winter wind protection with the need for year round exposure to the sun. Houses built on a sol-air street system will have the northerly side facing the prevailing wind and the southerly side facing about 17.5 degrees east of true south. (See Figure 34).

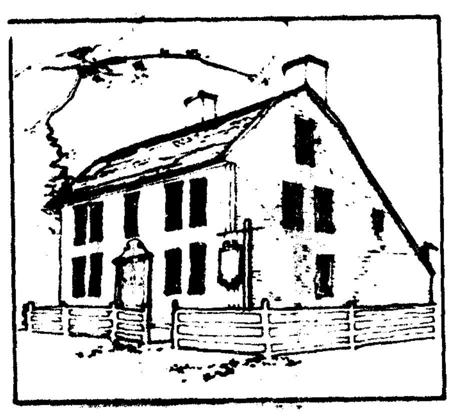
Figure 34



5. Building with Minimum Northern Exposure

The shape and orientation of the building itself can also have considerable influence upon its heating requirements. In particular, passive solar homes should not merely feature increased south facing glass area: there should be a reduction in the amount of north facing glass and less exposed north wall surface area. Typically, many modern day solar builders are returning to the traditional colonial salt box design with a long slanting northern roof virtually eliminating the north wall exposure of the dwelling unit. This building design technique tends to channel winter winds over the dwelling unit. Moreover, north wall heat loss from wind infiltration can be further reduced by adding evergreen windbreaks on the north side of the dwelling unit (see Figure 35).

Figure 35



Appendix 1

Shadow Length Tables for December 21st for a One Foot Pole for Varying Latitudes and Slopes in Connecticut.
(Assumes Morning and Afternoon Evaluations Correspond to 45 Degree Azimuths)

41° 15' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	5.18	2.11	5.18	5.18	2.11	5.18	5.18	2.11	5.18	5.18	2.11	5.18	5.18	2.11	5.18	5.18	2.11	5.18	5.18	2.11	5.18	5.18	2.11	5.18
5%	6.35	2.36	6.35	5.18	2.28	7.00	4.38	2.11	6.35	4.12	1.97	5.18	4.38	1.91	4.38	5.18	1.97	4.12	6.35	2.11	4.38	7.00	2.28	5.18
10%	8.18	2.67	8.18	5.18	2.48	10.77	3.79	2.11	8.18	3.41	1.84	5.18	3.79	1.74	3.79	5.18	1.84	3.41	8.18	2.11	3.79	10.77	2.48	5.18
15%	11.52	3.09	11.52	5.18	2.72	23.31	3.35	2.11	11.52	2.92	1.73	5.18	3.35	1.60	3.35	5.18	1.73	2.92	11.52	2.11	3.35	23.31	2.72	5.18
20%	19.43	3.66	19.43	5.18	3.01	***	2.99	2.11	19.43	2.55	1.63	5.18	2.99	1.49	2.99	5.18	1.63	2.55	19.43	2.11	2.99	***	3.01	5.18
25%	62.04	4.47	62.04	5.18	3.37	***	2.71	2.11	62.04	2.86	1.54	5.18	2.71	1.38	2.71	5.18	1.54	2.86	62.04	2.11	2.71	***	3.37	5.18

41° 30' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	5.29	2.14	5.29	5.29	2.14	5.29	5.29	2.14	5.29	5.29	2.14	5.29	5.29	2.14	5.29	5.29	2.14	5.29	5.29	2.14	5.29	5.29	2.14	5.29
5%	6.50	2.40	6.50	5.29	2.32	7.19	4.46	2.14	6.50	4.18	1.99	5.29	4.46	1.93	4.46	5.29	1.99	4.18	6.50	2.14	4.46	7.19	2.32	5.29
10%	8.44	2.72	8.44	5.29	2.52	11.22	3.85	2.14	8.44	3.46	1.86	5.29	3.85	1.76	3.85	5.29	1.86	3.46	8.44	2.14	3.85	11.22	2.52	5.29
15%	12.04	3.15	12.04	5.29	2.77	25.55	3.39	2.14	12.04	2.95	1.74	5.29	3.39	1.62	3.39	5.29	1.74	2.95	12.04	2.14	3.39	25.55	2.77	5.29
20%	20.96	3.74	20.96	5.29	3.07	***	3.03	2.14	20.96	2.57	1.64	5.29	3.03	1.50	3.03	5.29	1.64	2.57	20.96	2.14	3.03	***	3.07	5.29
25%	80.93	4.60	80.93	5.29	3.44	***	2.73	2.14	80.93	2.28	1.55	5.29	2.73	1.39	2.73	5.29	1.55	2.28	80.93	2.14	2.73	***	3.44	5.29

41° 45' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	5.39	2.16	5.39	5.39	2.16	5.39	5.39	2.16	5.39	5.39	2.16	5.39	5.39	2.16	5.39	5.39	2.16	5.39	5.39	2.16	5.39	5.39	2.16	5.39
5%	6.66	2.42	6.66	5.39	2.34	7.38	4.53	2.16	6.66	4.25	2.01	5.39	4.53	1.95	4.53	5.39	2.01	4.25	6.66	2.16	4.53	7.38	2.34	5.39
10%	8.71	2.75	8.71	5.39	2.55	11.69	3.90	2.16	8.71	3.50	1.87	5.39	3.90	1.78	3.90	5.39	1.87	3.50	8.71	2.16	3.90	11.69	2.55	5.39
15%	12.59	3.19	12.59	5.39	2.80	28.15	3.43	2.16	12.59	2.98	1.76	5.39	3.43	1.63	3.43	5.39	1.76	2.98	12.59	2.16	3.43	28.15	2.80	5.39
20%	22.68	3.80	22.68	5.39	3.11	***	3.06	2.16	22.68	2.59	1.65	5.39	3.06	1.51	3.06	5.39	1.65	2.59	22.68	2.16	3.06	***	3.11	5.39
25%	114.4	4.69	114.4	5.39	3.49	***	2.76	2.16	114.4	2.30	1.56	5.39	2.76	1.40	2.76	5.39	1.56	2.30	114.4	2.16	2.76	***	3.49	5.39

42° 0' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	5.50	2.18	5.50	5.50	2.18	5.50	5.50	2.18	5.50	5.50	2.18	5.50	5.50	2.18	5.50	5.50	2.18	5.50	5.50	2.18	5.50	5.50	2.18	5.50
5%	6.82	2.45	6.82	5.50	2.37	7.59	4.60	2.18	6.82	4.31	2.03	5.50	4.60	1.97	4.60	5.50	2.03	4.31	6.82	2.18	4.60	7.58	2.37	5.50
10%	8.99	2.80	8.99	5.50	2.58	12.21	3.96	2.18	8.99	3.55	1.89	5.50	3.96	1.79	3.96	5.50	1.89	3.55	8.99	2.18	3.96	12.21	2.58	5.50
15%	13.19	3.25	13.19	5.50	2.84	31.34	3.47	2.18	13.19	3.01	1.77	5.50	3.47	1.65	3.47	5.50	1.77	3.01	13.19	2.18	3.47	31.34	2.84	5.50
20%	24.70	3.88	24.70	5.50	3.16	***	3.09	2.18	24.70	2.62	1.67	5.50	3.09	1.52	3.09	5.50	1.67	2.62	24.70	2.18	3.09	***	3.16	5.50
25%	194.8	4.81	194.8	5.50	3.56	***	2.79	2.18	194.8	2.32	1.58	5.50	2.79	1.41	2.79	5.50	1.58	2.32	194.8	2.18	2.79	***	3.56	5.50

Note: The a.m. time refers to 8:43 solar time, the p.m. time refers to 3:17 solar time and the noon time refers to 12:00 Noon solar time. The a.m. and p.m. times correspond to 45 degree azimuths that are used to define the day's period of usable radiation. About 95% of the total available sunshine on December 21st will f on a vertical wall between 8:43 a.m. and 3:17 p.m. solar time. The table gives the shadow length on December 21st of a one (1) foot pole for varying slopes and orientations. Approximate shadow lengths for slopes not listed in the table may be interpolated.

***Afternoon shadow lengths on Northwast slopes of 20% or greater and morning shadow lengths on Northwest slopes of 20% or greater do not offer any solar access opportunities.

	Noon Altitude	A.M./P.M. Altitude	Hour Angle
41° 15'	25.34	10.91	49.16
41° 30'	25.05	10.71	49.20
41° 45'	24.85	10.51	49.25
42° 0'	24.60	10.31	49.30

$$SP = \frac{H}{\text{Tan}\ (A_1) + S_1 \times \text{COS}\ (A_z - w)}$$

Where: A_1 = solar altitude (see tables)

A_z = solar azimuth (a.m. = -45°, p.m. = 45°, noon = 0°)

H = height of the object (the table assumes an object one foot tall)

W = orientation (0 = south; 90° = west; -90° = east; 180° = north, etc.)

S_1 = slope (in percent)

Shadow Length Tables for December 21st for a One Foot Pole for Varying Latitudes and Slopes in Connecticut.
(Assumes that Morning and Afternoon Evaluations Correspond to 30 Degree Azimuths)

41° 15' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	2.86	2.11	2.86	2.86	2.11	2.86	2.86	2.11	2.86	2.86	2.11	2.86	2.86	2.11	2.86	2.86	2.11	2.86	2.86	2.11	2.86	2.86	2.11	2.86
5%	3.27	2.36	3.27	2.97	2.28	3.32	2.67	2.11	3.08	2.51	1.97	2.76	2.55	1.91	2.55	2.76	1.97	2.51	3.08	2.11	2.67	3.32	2.28	2.97
10%	3.80	2.67	3.80	3.09	2.48	3.95	2.50	2.11	3.34	2.24	1.84	2.66	2.29	1.74	2.29	2.66	1.84	2.24	3.34	2.11	2.50	3.95	2.48	3.09
15%	4.55	3.09	4.55	3.22	2.72	4.89	2.36	2.11	3.64	2.02	1.73	2.50	2.09	1.60	2.09	2.58	1.73	2.02	3.64	2.11	2.36	4.89	2.72	3.22
20%	5.67	3.66	5.67	3.36	3.01	6.40	2.23	2.11	4.01	1.84	1.63	2.49	1.91	1.49	1.91	2.49	1.63	1.84	4.01	2.11	2.23	6.40	3.01	3.36
25%	7.58	4.47	7.58	3.51	3.37	9.26	2.11	2.11	4.45	1.69	1.54	2.41	1.77	1.38	1.77	2.41	1.54	1.69	4.45	2.11	2.11	9.26	3.37	3.51

41° 30' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	2.90	2.14	2.90	2.90	2.14	2.90	2.90	2.14	2.90	2.90	2.14	2.90	2.90	2.14	2.90	2.90	2.14	2.90	2.90	2.14	2.90	2.90	2.14	2.90
5%	3.31	2.40	3.31	3.01	2.32	3.37	2.70	2.14	3.13	2.54	1.99	2.79	2.58	1.93	2.58	2.79	1.99	2.54	3.13	2.14	2.70	3.37	2.32	3.01
10%	3.87	2.72	3.87	3.13	2.52	4.03	2.53	2.14	3.39	2.26	1.86	2.70	2.32	1.76	2.32	2.70	1.86	2.26	3.39	2.14	2.53	4.03	2.52	3.13
15%	4.65	3.15	4.65	3.27	2.77	5.00	2.38	2.14	3.70	2.04	1.74	2.61	2.11	1.68	2.11	2.61	1.74	2.04	3.70	2.14	2.38	5.00	2.77	3.27
20%	5.82	3.74	5.82	3.41	3.07	6.59	2.25	2.14	4.08	1.86	1.64	2.52	1.93	1.50	1.93	2.52	1.64	1.86	4.08	2.14	2.25	6.59	3.07	3.41
25%	7.78	4.60	7.78	3.57	3.44	9.66	2.13	2.14	4.55	1.71	1.55	2.44	1.78	1.39	1.78	2.44	1.55	1.71	4.55	2.14	2.13	9.66	3.44	3.57

41° 45' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	2.94	2.16	2.94	2.94	2.16	2.94	2.94	2.16	2.94	2.94	2.16	2.94	2.94	2.16	2.94	2.94	2.16	2.94	2.94	2.16	2.94	2.94	2.16	2.94
5%	3.37	2.42	3.37	3.05	2.34	3.42	2.74	2.16	3.17	2.57	2.01	2.83	2.61	1.95	2.61	2.83	2.01	2.57	3.17	2.16	2.74	3.42	2.34	3.05
10%	3.94	2.75	3.94	3.18	2.55	4.10	2.56	2.16	3.44	2.29	1.87	2.73	2.34	1.78	2.34	2.73	1.87	2.29	3.44	2.16	2.56	4.10	2.55	3.18
15%	4.75	3.19	4.75	3.32	2.80	5.12	2.41	2.16	3.77	2.06	1.76	2.64	2.13	1.63	2.13	2.64	1.76	2.06	3.77	2.16	2.41	5.12	2.80	3.32
20%	5.98	3.80	5.98	3.47	3.11	6.80	2.27	2.16	4.16	1.87	1.65	2.55	1.95	1.51	1.95	2.55	1.65	1.87	4.16	2.16	2.27	6.80	3.11	3.47
25%	8.08	4.69	8.08	3.63	3.49	10.11	2.15	2.16	4.64	1.72	1.56	2.47	1.80	1.40	1.80	2.47	1.56	1.72	4.64	2.16	2.15	10.11	3.49	3.63

42° 0' North Latitude

	N			NE			E			SE			S			SW			W			NW		
Slope	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.	A.M.	NOON	P.M.
0%	2.99	2.18	2.99	2.99	2.18	2.99	2.99	2.18	2.99	2.99	2.18	2.99	2.99	2.18	2.99	2.99	2.18	2.99	2.99	2.18	2.99	2.99	2.18	2.99
5%	3.42	2.45	3.42	3.10	2.37	3.48	2.77	2.18	3.22	2.60	2.03	2.87	2.64	1.97	2.64	2.87	2.03	2.60	3.22	2.18	2.77	3.48	2.37	3.10
10%	4.01	2.80	4.01	3.23	2.58	4.18	2.59	2.18	3.50	2.31	1.89	2.77	2.37	1.79	2.37	2.77	1.89	2.31	3.50	2.18	2.59	4.18	2.58	3.23
15%	4.86	3.25	4.86	3.37	2.84	5.24	2.43	2.18	3.84	2.15	1.77	2.67	2.15	1.65	2.15	2.67	1.77	2.15	3.84	2.18	2.43	5.24	2.84	3.37
20%	6.15	3.88	6.15	3.52	3.16	7.01	2.30	2.18	4.24	1.97	1.67	2.58	1.97	1.52	1.97	2.58	1.67	1.97	4.24	2.18	2.30	7.01	3.16	3.52
25%	8.38	4.81	8.38	3.69	3.56	10.61	2.17	2.18	4.74	1.73	1.58	2.50	1.81	1.41	1.81	2.50	1.58	1.73	4.74	2.18	2.17	10.61	3.56	3.69

Note: The a.m. time refers to 9:56 solar time, the p.m. time refers to 2:04 solar time and the noon time refers to 12:00 Noon solar time. The a.m. and p.m. times correspond to 30 degree azimuths that are used to define the day's period of usable radiation. About 75% of the total sunshine on December 21st will fall on a vertical wall between 9:56 a.m. and 2:04 p.m. solar time. The table gives the shadow length on December 21st of a one (1) foot pole for varying slopes and orientations. Approximate shadow lengths for slopes not listed in the table may be interpolated.

	Noon Altitude	A.M./P.M. Altitude	Hour Angle
41° 15'	25.34	19.26	30.95
41° 30'	25.05	19.03	31.00
41° 45'	24.85	18.79	31.05
42° 0'	24.60	18.56	31.10

$$SP = \frac{H}{\text{Tan}(A_1) + S_1 \times \text{COS}(A_z - w)}$$

Where: A_1 = solar altitude (see Tables)

A_z = solar azimuth (a.m. = -30°, p.m. = 30°, noon = 0°)

H = height of the object (the table assumes an object one foot tall)

W = orientation (0 = south; 90° = west; -90° = east; 180° = north, etc.)

S_1 = slope (in percent)

Appendix 2

Solar Position Data for 1977 (values of declination and Equation of Time will vary slightly for specific dates in other years).*

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	D
Date													
	Year Day	1	32	60	91	121	152	182	213	244	274	305	335
1	Declination	−23.0	−17.0	−7.4	+4.7	+15.2	+22.1	+23.1	+17.9	+8.2	−3.3	−14.6	−21.9
	Eq of Time	−3.6	−13.7	−12.5	−4.0	+2.9	+2.4	−3.6	−6.2	+0.0	+10.2	+16.3	+11.0
	Year Day	6	37	65	96	126	157	187	218	249	279	310	340
6	Declination	−22.4	−15.5	−5.5	+6.6	+16.6	+22.7	+22.7	+16.6	+6.7	−5.3	−16.1	−22.5
	Eq of Time	−5.9	−14.2	−11.4	−2.5	+3.5	+1.6	−4.5	−5.8	+1.6	+11.8	+16.3	+9.0
	Year Day	11	42	70	101	131	162	192	223	254	284	315	345
11	Declination	−21.7	−13.9	−3.5	+8.5	+17.9	+23.1	+22.1	+15.2	+4.4	−7.2	−17.5	−23.0
	Eq of Time	−8.0	−14.4	−10.2	−1.1	+3.7	+0.6	−5.3	−5.1	+3.3	+13.1	+15.9	6.5
	Year Day	16	47	75	106	136	167	197	228	259	289	320	350
16	Declination	−20.8	−12.2	−1.6	+10.3	+19.2	+23.3	+21.3	+13.6	+2.5	−8.7	−18.8	23.3
	Eq of Time	−9.8	−14.2	−8.8	+0.1	+3.8	−0.4	−5.9	−4.3	+5.0	+14.3	+15.2	+4.4
	Year Day	21	52	80	111	141	172	202	233	264	294	325	355
21	Declination	−19.6	−10.4	+0.4	+12.0	+20.3	+23.4	+20.6	+12.0	+0.5	−10.8	−20.0	-23.4
	Eq of Time	−11.4	−13.8	−7.4	+1.2	+3.6	−1.5	−6.2	−3.1	+6.8	+15.3	+14.1	2.0
	Year Day	26	57	85	116	146	177	207	238	269	299	330	360
26	Declination	−18.6	−8.6	+2.4	+13.6	+21.2	+23.3	+19.3	+10.3	−1.4	−12.6	−21.0	-23.4
	Eq of Time	−12.6	−13.1	−5.8	+2.2	+3.2	−2.6	−6.4	−1.8	+8.6	+15.9	+12.7	−0.5

*From ASHRAE Standard 93-77. Units for declination are angular degrees; units for Equation of Time are minutes of time.

Appendix 3

Table 1

Suggested Solar Easement Bulk Plane Angles for the 45 Degree Azimuth Positions of the Sun on December 21st

41° 15' North Latitude								
Slope	N	NE	E	SE	S	SW	W	NW
0%	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
5%	8.9	8.0	8.9	10.9	12.9	10.9	8.9	8.0
10%	6.9	5.2	6.9	10.9	15.0	10.9	6.9	5.2
15%	4.8	2.3	4.8	10.9	17.0	10.9	4.8	2.3
20%	2.7	0.0	2.7	10.9	19.1	10.9	2.7	0.0
25%	0.0	0.0	0.0	10.9	21.1	10.9	0.0	0.0

41° 30' North Latitude								
Slope	N	NE	E	SE	S	SW	W	NW
0%	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7
5%	8.7	7.8	8.7	10.7	12.7	10.7	8.7	7.8
10%	6.7	5.0	6.7	10.7	14.8	10.7	6.7	5.0
15%	4.6	2.1	4.6	10.7	16.8	10.7	4.6	2.1
20%	2.5	0.0	2.5	10.7	18.9	10.7	2.5	0.0
25%	0.0	0.0	0.0	10.7	20.9	10.7	0.0	0.0

41° 45' North Latitude								
Slope	N	NE	E	SE	S	SW	W	NW
0%	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
5%	8.5	7.6	8.5	10.5	12.5	10.5	8.5	7.6
10%	6.5	4.8	6.5	10.5	14.6	10.5	6.5	4.8
15%	4.4	1.9	4.4	10.5	16.6	10.5	4.4	1.9
20%	2.3	0.0	2.3	10.5	18.7	10.5	2.3	0.0
25%	0.0	0.0	0.0	10.5	20.7	10.5	0.0	0.0

42° 0' North Latitude								
Slope	N	NE	E	SE	S	SW	W	NW
0%	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
5%	8.3	7.4	8.3	10.3	12.3	10.3	8.3	7.4
10%	6.3	4.6	6.3	10.3	14.4	10.3	6.3	4.6
15%	4.2	1.7	4.2	10.3	16.4	10.3	4.2	1.7
20%	2.1	0.0	2.1	10.3	18.5	10.3	2.1	0.0
25%	0.0	0.0	0.0	10.3	20.5	10.3	0.0	0.0

Source: Prepared by the staff of the Central Naugatuck Valley Regional Planning Agency, July 1981.

Table 2

Suggested Solar Easement Bulk Plane Angles for the 30 Degree Azimuth Positions of the Sun on December 21st

Slope	N	NE	E	SE	S	SW	W	NW
41° 15' North Latitude								
0%	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2
5%	16.7	16.4	17.8	19.9	21.7	19.9	17.8	16.4
10%	14.2	13.7	16.3	20.7	24.2	20.7	16.3	13.7
15%	11.7	10.9	14.9	21.4	26.7	21.4	14.9	10.9
20%	9.2	8.1	13.4	22.2	29.2	22.2	13.4	8.1
25%	6.7	5.2	12.0	23.0	31.7	23.0	12.0	5.2
41° 30' North Latitude								
0%	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
5%	16.5	16.2	17.6	19.7	21.5	19.7	17.6	16.2
10%	14.0	13.5	16.1	20.5	24.0	20.5	16.1	13.5
15%	11.5	10.7	14.7	21.2	26.5	21.2	14.7	10.7
20%	9.0	7.9	13.2	22.0	29.0	22.0	13.2	7.9
25%	6.5	5.0	11.8	22.8	31.5	22.8	11.8	5.0
41° 45' North Latitude								
0%	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
5%	16.3	16.0	17.4	19.5	21.3	19.5	17.4	16.0
10%	13.8	13.3	15.9	20.3	23.8	20.3	15.9	13.3
15%	11.3	10.5	14.5	21.0	26.3	21.0	14.5	10.5
20%	8.8	7.7	13.0	21.8	28.8	21.8	13.0	7.7
25%	6.3	4.8	11.6	22.6	31.3	22.6	11.6	4.8
42° 0' North Latitude								
0%	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
5%	16.1	15.8	17.2	19.3	21.1	19.3	17.2	15.8
10%	13.6	13.1	15.7	20.1	23.6	20.1	15.7	13.1
15%	11.1	10.3	14.3	20.8	26.1	20.8	14.3	10.3
20%	8.6	7.5	12.8	21.6	28.6	21.6	12.8	7.5
25%	6.1	4.6	11.4	22.4	31.1	22.4	11.4	4.6

Source: Prepared by the staff of the Central Naugatuck Valley Regional Planning Agency, July 1981.

Footnote to Tables 1 and 2 of Appendix 3:

Each of the suggested solar easement bulk plane angles within Table 1 protects solar access to the same degree on December 21st. However, because of changing slopes and orientations of slopes it is much more difficult to protect the same level of solar access on a north facing slope as on a south facing slope. As solar easement bulk plane angles become smaller there is a greater and greater risk that solar access objectives will conflict with the development objectives of property owners to the south. Consequently, it is recommended that solar easement bulk plane angles not be utilized if the solar easement angle is less than that suggested in Table 1 for flatland. Solar easement angles for land with orientations of north, northwest, northeast, east and west having a slope of 5% or more have been placed in a box in Table 1 to signify that these angles are not recommended. In those cases where development occurs on these less desirable tracts of land, it is suggested that the less restrictive solar easement bulk angles shown in Table 2 be utilized. Although, the solar easement angles suggested in Table 2 offer less solar access protection, they are less likely to limit the development opportunities of land to the south of the solar energy system. The only cases where problems will emerge with the use of the 30 degree position table are on northerly facing slopes of 20% or more where protection of solar access will probably result in restrictions on the development of land to the south. Unless development occurs at extremely low densities it will probably not be possible to include effective solar easements on these steep northerly slopes.

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