4104

ATTACHED SOLAR GREENHOUSES AND SUNSPACES

FACTSHEET

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Attached solar greenhouses and sunspaces remain one of the most popular designs for both new and existing homes. They can produce heat, provide an environment for intensive food production, and offer a very pleasant living space; but a greenhouse or sunspace can seldom do all three things well. Consequently one of the most important first steps in designing and building a solar greenhouse or sunspace is to develop a very clear idea of the purpose of the space.

We may choose to design our space as an area whose primary purpose is aesthetic--a pleasant living space. It would be a space designed for light, beauty and visual contact with the environment. It may contain houseplants or garden starts and it may gain considerable warmth from the sun. But it is not primarily designed to intensively produce food or maximize solar energy gains. Though it would pay an increased energy penalty for facing directions other than south it could do so and still fulfill its purpose.

On the other hand we could design our space as one whose purpose is to maximize the benefits of solar energy gain. It would have more restrictive design requirements than a purely aesthetic space. For example it would have to face south, or nearly so, in order to gain the most solar energy. While this space might often times provide a very aesthetic space, it might also be often too hot for comfortable living and so bright that one might have to squint uncomfortably. At night it could be closed off from the house and allowed to get uncomfortably cold. It might have plants, but fewer types of plants would tolerate the temperature extremes, and it certainly could not produce tomatoes in the winter.

If our purpose is to maximize the production of plants for food, then we will have little space for easy chairs and other pleasantries of a living space, and we may have to sacrifice some solar gains in order to moderate high temperatures or ventilate excess humidity. At night we may have to provide some supplemental heat in order to keep plants healthy.

None of these three purposes is entirely exclusive of the others. Through compromise it is possible to blend them in many ways to suit our individual purposes. For example, an exquisitely refreshing living space; one with flowers, fragrance and light; providing net energy benefits to the home; and extending the growing season for herbs and food plants is achievable. But it is important to understand the technical requirements of each purpose in order to succeed in obtaining the kind of space we desire.

In this factsheet we shall use the term solar sunspace to refer to spaces designed for any blend that emphasizes living and heating purposes. Solar sunspaces may even have a zone set aside for starting food plants for the summer garden, but they stop short of becoming a full production greenhouse. The term solar greenhouse shall refer specifically to those spaces designed to maximize plant production.

WISE USE OF RESOURCES THROUGH EDUCATION

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Solar greenhouses and solar sunspaces can be quite complex. Maximizing their performance potential requires a sophisticated analysis, a thorough grasp of a number of basic principles, and an in-depth knowledge of a wide range of available materials. However, the ability to design, construct and manage an adequately performing, net energy gaining, and personally satisfying solar sunspace or solar greenhouse is within the grasp of those of us who haven't the time or inclination to first become experts. Fortunately there exists a well developed body of literature addressing the subject, and by using these resources you can learn to design and build your own solar sunspace or solar greenhouse. If you would like to learn more about designing and building your own solar sunspace or greenhouse, we suggest you begin by obtaining the WEES Factsheet (FS-1606) titled "Designing and Building a Solar Greenhouse or Sunspace." What follows is an introduction to the topics covered in that publication.

SITING

Attaching the solar sunspace or solar greenhouse to the new or existing home can reduce the cost of heating the home, but it is critically important that the attached space is located where it will have adequate solar availability. A solar site survey can assist in that determination and is advised in all but the most obviously complete solar exposures (see The Solar Site Survey Factsheet, FS-1601).

GLAZING

The optimum orientation for solar sunspace and solar greenhouse glazing is due south, though solar sunspaces and solar greenhouses perform well when the glazing faces within about 25° of true south (not magnetic south). Within this range 90 percent or more of the solar energy that would be obtained with an exact south orientation will be available. Beyond 25° the amount of available solar energy falls off rapidly and thermal performance will be impaired.

Tilt refers to the angle between the northern horizon and the plane of the glazing. The optimal tilt for maximizing heating season solar performance in Washington is about 60° to 70°. However any tilt ranging between 60° and 90° will perform reasonably well.

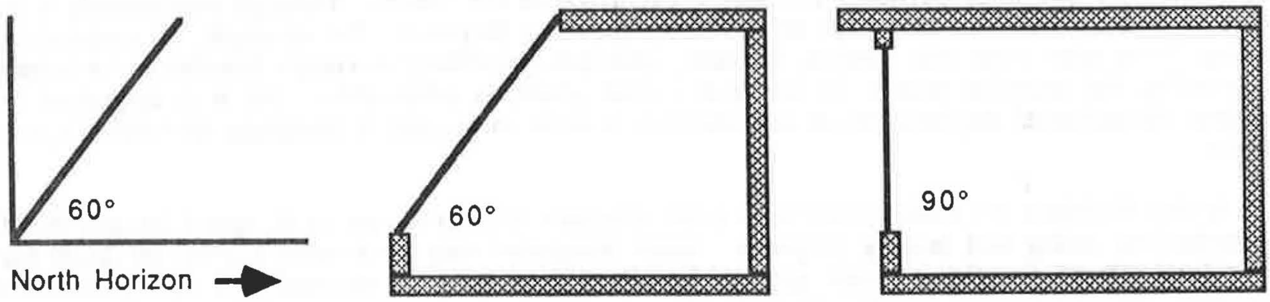


Figure 1. Optimum Range of Glazing Tilt Is Between 60°-90°

Vertical glazing has a number of advantages over sloped glazing, and though there is an energy penalty, vertical glazing may be the tilt of choice for many solar sunspace applications. Vertical glazing is easier to install than sloped glazing, is much less likely to leak, easier to clean, and significantly reduces the difficulty of avoiding summer overheating. In many solar sunspace applications vertical glazing with an insulated roof may be quite sufficient and is technically the least complex. If some overhead light and view is desired one or two skylights can be included and the difficulties of overhead glass avoided.

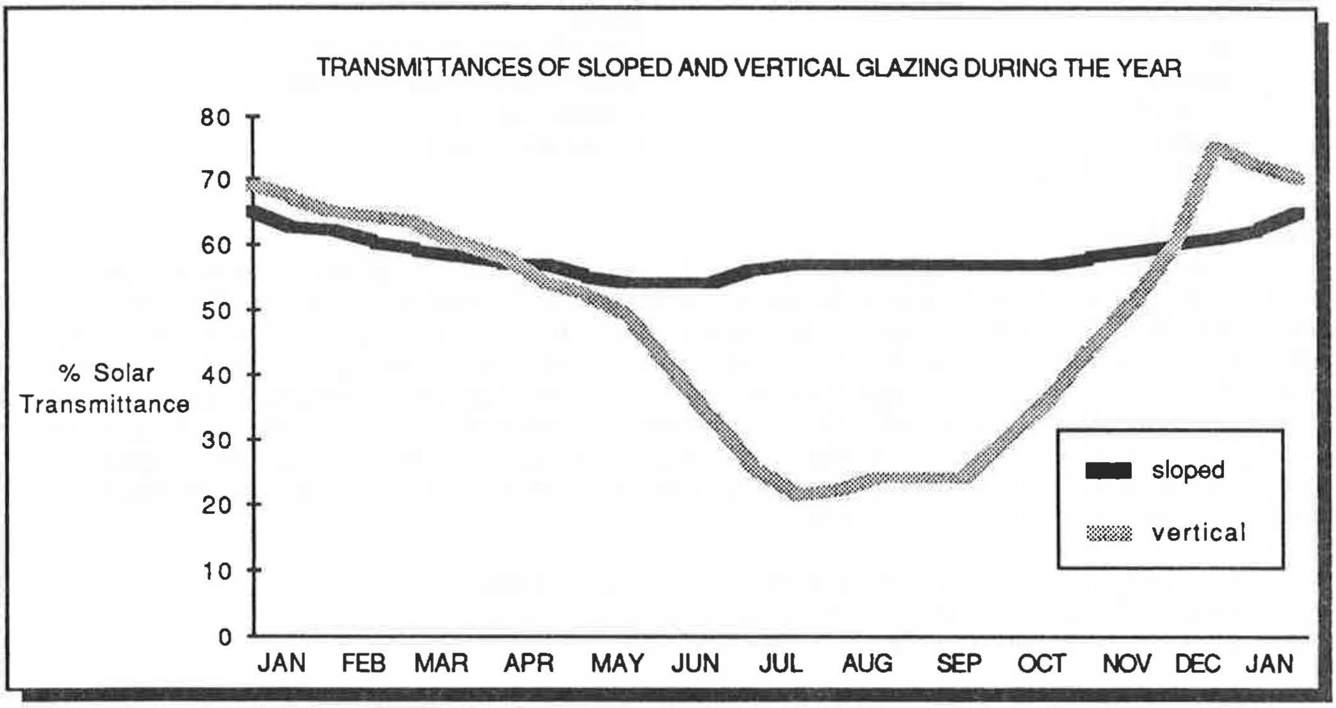


Figure 2. Sloped versus Vertical Glazing

Solar greenhouses, on the other hand, have more rigid design requirements. They need to maximize both the quality and quantity of light available to plants, and overhead glazing is required in most cases. Vertical glazing in combination with sloped overhead glazing is a common compromise. One can expect reasonably good energy performance if the sloped glazing is tilted 30^{o} or more. There will also be increased headroom near the south wall.

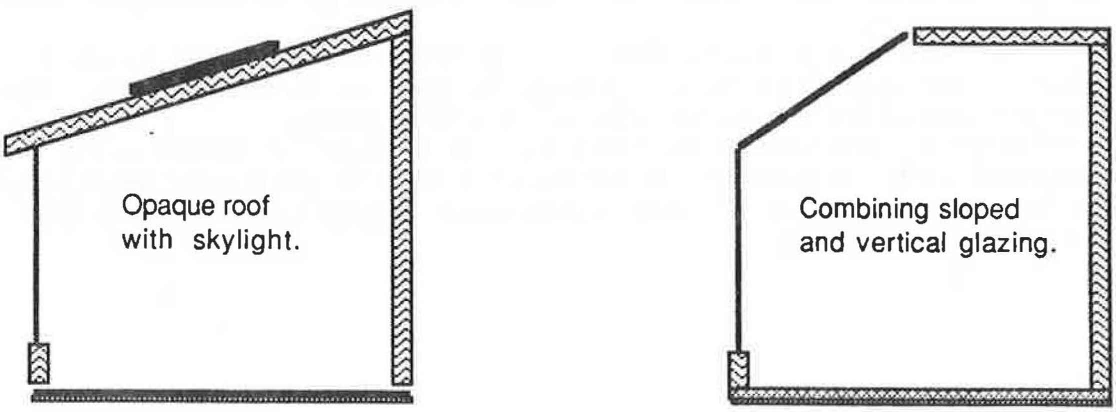


Figure 3. Design Shape

Selection of the type of glazing to be used is one of the most difficult decisions in the design of a solar sunspace or solar greenhouse, because there are many different glazing materials and many different qualities to consider. There is no single complete source of information detailing the costs and benefits of all the glazing options. The field is changing very rapidly, as new products continue to surface and the properties of existing products continue to change.

Some of the major aspects to be considered when making the glazing choice include:

- Availability
- Cost
- Durability
- Weatherability
- Strength
- Ease of installation
- Safety
- Light Transmitting Qualities
- Solar Transmitting Qualities
- Appearance
- Insulating Ability

THERMAL MASS

Thermal mass is a material or combination of materials that has the ability to absorb or release a relatively large quantity of heat while undergoing a relatively small temperature change. Solar energy is typically delivered to a solar sunspace as an intense "pulse" of energy lasting only a few hours. The energy delivered in those hours is often in excess of what it takes to heat the space. As the space gets increasingly warmer, a properly designed thermal mass will absorb an ever increasing quantity of heat. This helps to moderate the temperature increase and prevent overheating. At night the space cools and eventually its temperature drops below that of the mass. The mass then begins to release its relatively large quantity of heat, this time serving to moderate the temperature drop and preventing "overcooling". The mass has performed three very valuable functions:

1. it stored solar energy that would otherwise have been useless,
2. it released that energy later, when it was most valuable, and
3. it limited the temperature swings within the space.

Extensive cloudy periods during Washington winters make long term heat storage less practical, so a good approach is to design the mass to minimize the daily temperature swings. In order to do this we want the mass to be able to quickly absorb and release heat, and this is best accomplished by increasing the surface area of the mass in relation to its volume. For example, five gallon water containers would be more effective than 55 gallon drums.

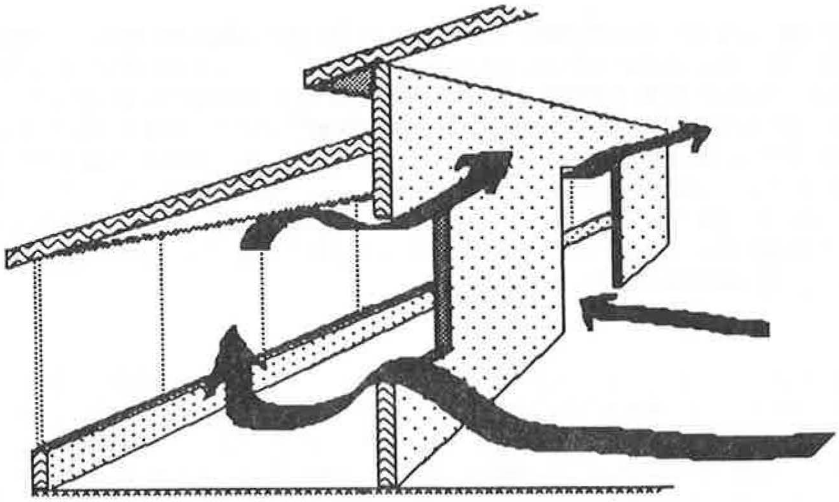
DISTRIBUTION

Distribution refers to the delivery of excess heat from the attached solar sunspace or solar greenhouse to the house, and on occasion, delivery of heat from the house to the space. Thermal mass and a distribution system can work well together to maximize the energy and comfort potential of a solar sunspace or solar greenhouse.

The simplest and least expensive distribution system is that of natural convection through window and/or door openings. Warm air flows through the upper portions of door openings and through upper window openings while cooler air flows through the lower openings.

A mechanical fan can increase the convenience of a distribution system as the fan can be controlled automatically by a thermostat. The optimal location for the fan is in the upper portion of the space where the highest temperature will occur. The minimum recommended capacity is 3 to 4 CFM for each single Ft^2 of sunspace glazing.

Figure 4. Ventilation Patterns



VENTILATION

Keeping the solar sunspace or solar greenhouse from overheating in the summer months is of fundamental importance if the space is to be used and enjoyed. Ventilation and shading are the primary strategies and can be effective when properly combined.

Natural ventilation can perform well but requires relatively large vent openings. Vents should be sized to prevent overheating under "worst case" conditions. Depending on the design of the solar sunspace or solar greenhouse these conditions will occur in late summer (overhead glazing and little shading) or fall (vertical glazing and overhang shading). The necessary size of the vents is a function of a number of factors including available shading, the tilt of the glazing, the size of the glazing relative to the size of the sunspace, the vertical separation between vents, and the increase over outdoor temperatures you are willing to accept in the space.

It is important to vent at two levels. The inlet vents should be low and the exhaust vents high. The vertical separation or "stack height" between high and low openings helps determine the airflow. More separation is better. Cross ventilation is also important and openings should be placed to maximize it. Here wind can be a very helpful ally. The low vents should face into the prevailing winds during the hotter months in order to complement and enhance the stack effect.

Natural ventilation requires frequent opening and closing of vents, especially in the spring and fall. One can purchase automatic temperature-activated vent operating devices from a number of sources listed in the references. Though more expensive, they offer the convenience of automatic operation.

Mechanical ventilation also offers the convenience of automatic temperature (and/or humidity)-activated ventilation. The strategy of using natural ventilation as a primary ventilation strategy with a mechanical backup to limit extreme temperatures can greatly reduce fan operating costs and allow use of lower capacity fans which are less expensive.

SHADING

For some applications deciduous trees may be appropriate for shading south facing glazing, though their use will result in a winter energy penalty.

Solid Roofs with properly sized overhangs readily solve the most difficult problem of summer shading and are excellent when appropriate. Solar greenhouses will need direct light to plants and generally cannot use this option.

Exterior shades have flexibility as they can be operated seasonally or more frequently. They are made of a number of different materials of varying cost and durability including aluminum, fiberglass, and bamboo. They can be mounted as rigid panels or as roll-up mechanisms. They can be difficult to mount and must withstand wind, rain and ultraviolet light.

Paint on shading may be appropriate for some solar greenhouse applications. Some paint-on compounds gradually wear off while others must be washed off. Some may not be compatible with plastic glazings. Information can be obtained from commercial greenhouse suppliers.

Interior shades are generally less expensive but less effective. They too can be roll-up or rigid, and are made of a number of different materials. The limitations of interior shades is that the insolation has already entered the space when it contacts the shade, and a portion of the light will be absorbed by the space and contribute to heating the space. The interior shade acts somewhat like a poorly designed solar collector. Still they can be effective. Generally the more reflective they are the better they perform as more light gets returned to the outside.

CONSTRUCTION

One option is to purchase a solar sunspace in kit form. A number of prefabricated solar sunspace kits are available that can be site assembled by either contractors or do-it-yourselfers. Another option is the custom designed and built solar sunspace or solar greenhouse. This will require careful planning and several building skills. One of the most reliable rules of thumb is that it will always take longer than you think. Unanticipated weather and logistical difficulties will occur and should be allowed for in planning the construction sequence. Nonetheless the project can be as rewarding as it will be as a completed space.

Installing and sealing glazing onto a wood framed solar sunspace is one of the more difficult construction procedures, but careful attention to detail can lead to success. Many wood framed solar sunspaces have leaked because they attempted to use wood as a sealing component of the glazing system. Wood makes a poor exterior glazing cap. It will require frequent maintenance and will be difficult to keep from leaking.

CONSERVATION/EFFICIENCY

The impact of a solar sunspace or solar greenhouse will be much greater in a well-weatherized and well-insulated home, and increasing the efficiency of the home's energy use will often dramatically lower the cost of home heating, increase comfort, and optimize the value of your solar sunspace or solar greenhouse. As well the solar sunspace or solar greenhouse should itself have well-insulated floors, walls, ceilings and doors, and should be of tight well-sealed construction. Levels of insulation should at least match those of the house. In the case of older homes, cost-effective solar sunspace insulation levels might often exceed those of the house. Some reasonable insulation levels for solar sunspaces and solar greenhouses in Washington are listed in the table below

REASONABLE SUNSPACE INSULATION R VALUES FOR WASHINGTON

Component	R value
Walls	19 - 30
Ceilings	30 - 40
Perimeters	10 - 20
E, W, & N Windows	(double - triple glazing or equal)

• R value is a measure of resistance to heat transfer. One pane of glass has an R value of 1. 5.5" of fiberglass has an R value of 19.

• Higher values are reasonable for colder areas and areas with higher fuel cost. Lower values are reasonable for warmer areas and areas with lower fuel costs.

Figure 5. Sunspace Insulation R-Values

BUILDING CODES, SAFETY, AND ZONING

Building codes are meant to ensure structural soundness and prevent health and fire hazards, and code officials have a responsibility to enforce these. Usually if they sense a cordial builder who respects their role, relations will be much more productive. Since the addition of a solar sunspace or solar greenhouse requires a building permit, lengthy delays in construction can often occur if the space design must be readjusted to meet building codes. Determining the zoning and building code requirements early in the planning process only makes sense.

The use of glass, especially overhead is another major area worthy of attention. Exact codes vary for different jurisdictions but are all very restrictive about the types of glazing that can be used overhead.

The use of electricity in high moisture areas, such as near hot tubs, water storage containers, and in solar greenhouses requires special attention. Ground fault interrupting circuits are an excellent idea, as are high quality materials and skilled installation.

All solar sunspace and solar greenhouse designs should consider the potential entry of soil gas containing radon, an inert radioactive gas linked to lung cancer. Radon is generated by the decay of radium, a radioactive metallic element present to some degree in all soils. As an inert gas radon is quite mobile and can be drawn into the space by the pressure differences occurring between the solar sunspace air and the soil gas. Currently a site cannot be reliably tested for radon before construction, and radon exposure can only be determined after the house has been built. It is wise to include certain preventive and anticipatory mitigation measures during construction. You can contact your local health department for health information, and WEES or your local Building Department for appropriate building design and construction information.

Increasingly, jurisdictions have solar access laws that protect solar availability to a lot. Your community's planning department can help you determine if such protection is available to you. If not, investigating the need for negotiating a legal solar easement with southerly neighbors may be warranted.

COST AND PERFORMANCE

In Washington, the energy performance of solar sunspaces and solar greenhouses can range from providing a modest amount of daytime heat to one that provides over 50 percent of a well-insulated home's annual heating energy. The "comfort" performance of the space can also range from one seldom used to one used on a daily basis.

An index of approximately 30 prefabricated solar sunspace and solar greenhouse in 1985 reported costs ranging from $10/Ft^2 to slightly over $100/Ft^2.

The cost of a custom solar sunspace or solar greenhouse will depend on its size, materials used, and labor costs. An extremely basic space with polyethylene or vinyl glazing and recycled lumber for framing might cost about $5/Ft^2. A more finished solar sunspace or solar greenhouse with quality wood or aluminum framing and higher quality glazing will be more expensive and costs may be similar to the costs of any other type of home addition. In other words they will range considerably. An owner built addition might cost $15 to $35/Ft^2. A similar scale project that is contractor installed might cost between $35 and $55/Ft^2. An elaborate solar sunspace or solar greenhouse could easily soar over $75 to $100/Ft^2.

Written by Mike Nuess and Chuck Eberdt.

REFERENCES

WEES Factsheets.

Designing and Building an Attached Solar Greenhouse or Sunspace, WEES Technical Publication.

National Center for Appropriate Technology, Solar Greenhouses and Sunspaces, Washington State Energy Office, Olympia, WA. 1985.

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