SUNSPACES AND GREENHOUSES FOR THE HOME

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There are two types of solar heating systems. Active systems use mechanical equipment to collect, store, and distribute solar energy. They tend to be expensive to construct and to maintain. Active systems also require some degree of knowledge and effort on the part of the homeowner to operate. Since the amount of solar energy in the sections of the United States occupied by more than half the population is relatively limited by winter weather conditions, the amount of heat available to collect and use may not justify an active solar heating system.

Passive systems are built into the house and require no mechanical devices or effort on the part of the occupants to collect, store, and distribute energy from the sun. Passive systems cost relatively little to construct as a part of new construction and may be adaptable to existing houses in many instances. True passive solar design makes the whole house a solar collector. Modifications to existing houses may not go that far, but do convert some spaces to solar collection.

Because of the limited amount of energy available, a secondary goal of passive solar design is to reduce the average annual energy requirements. At the same time, the house must meet the needs of the family within the overall design goals.

While there are many ways to incorporate passive solar design into new construction, the options of adding passive solar features to an existing house are limited. One of the most feasible is to add a sunspace or solar greenhouse to the structure.

Sunspaces are defined as areas or rooms designed primarily for heating purposes as well as living spaces. A sunspace differs from most other solar heating systems in that it is a part of the house rather than a piece of equipment. Sunspaces can provide heat and save energy, and they can provide pleasant living areas.

A sunspace should:
- be weathertight.
- provide a pleasant addition to the living space.
- be capable of being closed off from the house.
- be an efficient collector of solar energy.
- have a capability of storing heat for later use.
- have a system of directing surplus heat to the remainder of the house.
- have a means of controlling solar gain during the summer.
- have a means of dissipating excess heat.

A greenhouse is a sunspace that has been adapted for growing ornamental and/or food plants. It can be used to produce food by extending the growing season or making it possible to garden year-round. It varies from a sunspace in that:
- it is designed specifically to extend the growing season.
- it may require heat to preserve plants during cold weather.
- heat storage is more important than surplus heat distribution.
- humidity control is important.

Greenhouses and sunspaces can produce heat, provide a growing environment for plants, or provide a pleasant living space. They can do any one of these things very well, but it is almost impossible to make one structure do all three well at the same time. For example, an efficient heat-gathering sunspace will get hot enough to wither most plants. A greenhouse designed to produce an abundant variety of food will not have much room to relax in, and will not produce heat consistently enough to supplement a furnace. It may even require additional heat during very cold or cloudy weather. A sunspace designed as a living area will have moderate temperatures that are too low for significant supplemental space heating and it probably will not have enough room for substantial food production.

For horticultural greenhouses, plenty of light is essential. Heating sunspaces need to gather a lot of thermal energy. Living sunspaces need to maintain moderate temperatures. These design requirements will determine how the light is let in, how thermal storage is used, and how air movement between the house and the space is controlled.

Many people hope that their sunspaces or greenhouses can be designed to be usable the year around, supply surplus heat to the rest of the house, and require no additional energy. In many parts of the country, there is not enough sunlight during the winter for the spaces to work that way. Sunspace and greenhouse performance always depends on the weather, and the very best design cannot overcome the occasional cold spell during a week of cloudy days. However, weather records indicate that the brightest winter sun often occurs on the coldest days.
The first decision to be made is what the sunspace or greenhouse is being designed to do, taking into account what seems desirable and possible now and what your needs probably will be one or twenty years from now.

Sunspaces

There are two general types of sunspaces—the attached sunspace, where the north wall is common with the rest of the building, with the other three walls free-standing, and the semi-enclosed sunspace, in which two or three walls are common with the structure.

Where space is limited, a two-story sunspace can be used to collect more solar energy. It can be designed to serve a dual function—the lower level can be used to grow plants and the upper level for heating. Heat rises in a two-story sunspace, making it essential to be able to close off the sunspace from the second floor rooms to prevent overheating them. Windows or sliding glass doors can be used to provide a feeling of openness and to help control the heat flow. A second floor deck built into the sunspace may not be practical as a living space because of the overheating. Similarly, it may be difficult to keep the lower level warm. Ducted fans work better to move warm air from the upper level to the lower level than paddle-type ceiling fans.

Before adding a sunspace to reduce heating bills, consider the following requirements:

- Your home should be energy-efficient. Money spent on roof and wall insulation, caulking, weatherstripping, and window improvements is much more effective at reducing energy bills than money spent on any type of solar retrofit.
- A sunspace addition requires good solar access on the south side of the house. It will not perform well if it is substantially shaded between 9:00 a.m. and 3:00 p.m. during the winter. Remember that the sun angle is much lower in the winter, when the space will be

A semi-enclosed sunspace, which uses two walls of the house, is the most practical for an "L" or "T"-shaped house. The flat or nearly flat roof is difficult to connect to the original roof without leakage. The projecting wing of the house on the east or west shades part of the south-facing glass except at mid-day.

The attached sunspace is constructed on the south side of the house, with the north wall being part of the original house wall. A gable roof preserves the appearance of the house.

An attached sunspace can have just the south wall in glass, since the east and west walls have relatively little solar gain during the winter. The use of a low-slope shed roof will usually require roll or built-up roofing rather than shingles, and the roof line does not provide the same architectural "feel" to the appearance of the house.

A two-story sunspace can provide heat to both living and bedroom areas. While a glass roof may not be practical, operable skylights can provide both light and ventilation.
Greenhouses and sunspaces with glass roofs must have operable panels to provide ventilation during the summer. The openings into the house should be equipped with operable windows and doors to control the heat transfer into the living area.

used, than in the summer, when it is planned. Buildings and trees to the south that do not shade the area in the summer may in the winter.

- A sunspace is most likely to be a successful addition to the living space if it is adjacent to other living spaces, not bedrooms, on the south side of the home.
- There must be adequate space available on the lot within setback and zoning requirements.

Capturing the Sun

The sunspace or greenhouse addition should be located to receive the maximum amount of sun during the winter and yet be sheltered from the prevailing winds. If shaded by deciduous trees during the summer, the species of tree will have a major effect on the winter solar gain as well. Some species that have thin branches and twigs will reduce the solar energy available by only 20%, while others, such as oaks, may provide about 40% shade even after the leaves have fallen, and some species do not drop their leaves until spring. Summer shading is best provided by overhangs and controllable exterior shading devices, such as louvers or awnings.

Most sunspaces face south, but sometimes it can be better if they don’t. A greenhouse or sunspace can be oriented as much as 25 degrees off south and still collect 90% of the solar energy that it would if facing directly south. Orienting the greenhouse or sunspace so it does not face due south can be an effective way of controlling light and heat gain. A slight easterly orientation can help to gain heat in the morning and limit it in the afternoon. This may be advantageous where, in spring and fall, some heating is needed in the morning but afternoons may be too hot.

In many locations, the addition of a sunspace may significantly increase the summer cooling load of the house. Even with large ventilation air flow rates, the additional heat passing through an uninsulated masonry wall between the sunspace and the rest of the living area can be significant. Shading is more effective than venting. If the common wall between the sunspace and the house is insulated, there should be relatively little increase in the cooling load. Even though all of the additional building load may not have to be met with an air conditioner, the cooling load is a significant concern for conductive common wall systems.

Sun Porches

Many larger older homes were originally built with screened porches, most on the first floor, but some as second-floor “sleeping porches.” Converting a south-facing porch into a sunspace is a major project, requiring time, labor, and money. If the conversion is properly done, the space will be a delightful, high-quality area that will increase the value of the home. The simplest form of sunspace is to enclose a first-floor porch with vertical glazing to serve as a sheltered entryway. It cuts the force of winter winds, keeps warm air from rushing out of the house when the door is opened, and provides some solar gain. If the sun porch is built well enough, the solar heat it collects can be moved into the house through existing windows and doors. A fan will help circulate the heat into the house—natural convection may not be enough. If it is to be used as a greenhouse, the structure must be checked to see if it is capable of supporting the weight of planting beds, etc.

South-facing second-floor sleeping porches can be converted to living area by adding multiple glazing and insulation, as well as heat distribution and ventilation systems. Heat storage is difficult to add because the structure is usually not designed to carry the weight of a storage system. The space is often used as private lounging space or an office.
Many houses built in the earlier part of the century had an uninsulated second floor "sleeping porch" which can be insulated and glazed to form an effective sunspace.

Like other sunspaces, a sun porch may overheat in the summer. Some of the glazing should be removable or vents provided to let the hot air out. If cross-ventilation and some sort of shading is provided, it can be a pleasant place to spend time in the summer.

Construction

Insulation. To get the most out of heat from the sun (or back-up heat if it is used), a greenhouse or sunspace should be insulated. Both permanent and movable insulation should be considered. The important thing is to think about insulation during the design phase—insulation that is installed as an afterthought rarely works very well.

Permanent insulation may be applied to knee walls, end walls, north walls, foundations, roofs, and doors. Walls and ceilings are usually insulated with fiberglass batts, and rigid extruded polystyrene foam is typically used on the outside of foundations. The glazed areas may be insulated with double-pane glass, layers of plastic glazing, or a combination of these. Additional layers of glazing do reduce the solar gain, and various materials filter out some types of light that may be important for horticulture or heat gain.

For areas with mild winters (less than 4000 degree-days), the minimum insulating values for walls should be R-12, ceilings R-19, and R-8 for foundations. In colder areas, the minimum values for walls should be R-19, ceilings R-30, and R-16 for foundations. It is important to provide a vapor retarder on the sunspace side of the insulation. A 6-mil polyethylene sheet is commonly used. The kraft or foil facing on insulation will not be adequate.

Movable insulation can be very effective. It may consist of insulated drapes or shades which are pulled over windows on cloudy days and at night. It may be solid insulated panels, either removable or hinged, which close over the glass area during these periods. The main objection to any form of movable insulation is that it takes effort to use it.

The best type of movable insulation would be on the outside of the structure, because it keeps the glazed area warm enough to prevent condensation. Insulating the inside of the windows will isolate the glass from the warm room air, and allow it to get about as cold as the outdoor temperature. Since it is always difficult to get a vapor-tight seal between the movable insulation and the window frame, moisture from the room will almost certainly condense on the glass surfaces covered by drapes, shades, or panels. The minimum insulating value for movable insulation should be R-4.

Glazing. Double glazing is the minimum recommendation; triple or high-performance (R-4) glazing is better. The best is double plus R-9 movable night insulation.

When people think of greenhouses or sunspaces, they often visualize an area with near-vertical glass on the south side and a sloped glass ceiling.

The angle of glass that is most efficient for winter-time solar energy collection is 10 to 15 degrees plus the latitude of the site. A sunspace located at 40 degrees north latitude would have an optimum glass angle of 50-55 degrees from the horizontal. However, the use of the optimum winter slope may lead to overheating during the summer. A vertical south wall provides more headroom and is easier to build. Vertical glazing is easier to maintain, leaks less, and may be more durable, since rain and snow run off better. Vertical glazing is also easier to keep clean. It also works well where snow on the ground reflects additional sunlight into the sunspace. Operable windows in—

The conventional greenhouse design collects light and heat from the low sun during the winter. However, much of the solar energy is reflected from the upper section. The upper section makes a good solar collector during the summer, when additional heat is not needed.
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are subject to scratching. The advantages of plastic glazing include availability in large sheets or rolls, high solar transmittance, light weight, break-resistance, and relatively low cost.

Ordinary glass is the cheapest durable glazing, but it is subject to breakage from vandalism and hail. High-performance glass, made with a low-emissivity coating and/or the sealed space between panes filled with argon or other low-conductivity gas, is better but more expensive. Tempered glass is most resistant to breakage, and in extreme cases, safety glass can be used. Tempered glass comes in standard sizes, and cannot be cut on the job. Designing the structure to use standard replacement panels for sliding glass patio doors is a good choice because they are made of tempered glass and are available as sealed double glazing. "Seconds" are sometimes available at discount prices.

**Heat Storage.** Extra thermal mass storage is often included in the sunspace to reduce the sunspace air temperature fluctuations. Thermal mass should be integrated into the structure as much as possible. A large masonry fireplace can serve both as thermal storage and a heat source in itself.

Another common method is to use a concrete slab (sometimes finished with quarry tile) or brick floor over a bed of rock or sand. The floor and storage bed must be insulated from the foundation or surrounding soil. As the sun shines through the windows, it strikes the floor and warms the masonry and the dry sand or gravel bed below it. At night, the heat stored in the floor and storage bed will be released to the sunspace to keep the temperature more constant. Of course, no carpeting or floor covering can be used or it will insulate the storage.

A second method of heat storage is the "Trombe" wall. This is a heavy, usually masonry, wall constructed at some point inside the sunspace where it is in the direct rays of the sun. Thermal mass which does not receive direct sunlight is of little value and may contribute to midday overheating. Its greatest effect occurs when it is built just inside the glazing, but that destroys much of the utility of the space. The more common location is on the north wall of the sunspace.

If the original house had masonry veneer siding, that masonry can be used. Otherwise, masonry heat storage walls can be made of placed concrete, concrete blocks with filled cores, brick, ceramic tile, or any combination of these materials. Solid masonry walls weigh about 140 pounds per cubic foot, and the structure may not be able to carry the weight.

If additional thermal mass is desired, water is a good storage medium. On a volume basis, it will store three times as much heat as masonry, and weigh less than half as much. Also, it will absorb and release heat more rapidly than masonry. It should be placed in sealed containers, preferably black to absorb and radiate the maximum amount of heat. In the midwest, a ratio of 1 cubic foot of water (7 1/2 gallons) to each square foot of common wall seems to work well. The containers should be about twice as high as they are deep. Plastic containers are better because they will not corrode over time as metal will. The structure must be designed to carry the weight of the water or the Trombe wall.

**Heat Distribution.** In general, sunspaces that have an uninsulated masonry wall on the north deliver relatively large amounts of heat to the living space during the day. However, at night, a significant amount of energy is conducted from the living space through the wall and lost through the sunspace glass and walls. Insulated common wall systems have a lower passive daytime delivery but minimal nighttime losses. The best design depends upon location.

Nearly any house that relies on a sunspace as a source of heat will benefit from the use of fans to move the air from the sunspace. Fairly simple systems that use small fans can be effective and low in both initial and operating cost.

Many sunspace system designs include vents in the common wall to allow gravity circulation of warm air from the sunspace into the building. In the case of an uninsulated masonry common wall, the venting air flow rate has little effect on the auxiliary heating load of the building. This is because a large portion of the heat transferred from the sunspace to the building is by conduction through the wall. However, for insulated common wall systems, the air flow rate has a large impact on the auxiliary heating requirement because very little heat is transferred through the wall. Thermal air circulation vents should total about 6% of the north wall area, with the high and low vent areas in the ratio of 4 to 3.
Greenhouses

An attached solar greenhouse is often used as a sunspace for sitting and growing a few plants. In this case, the operation of air vents and movable night insulation usually requires a minimum of time and effort. For the more serious gardener, the solar greenhouse can be used to extend the growing season of the outdoor garden. This usually involves transplanting vegetables in and out of the greenhouse on a seasonal basis.

In the spring, tomatoes, melons, broccoli, and celery are some plants which might be started in the greenhouse for transplanting to the outdoor garden after the last frost. Most healthy garden vegetables can be brought into the greenhouse to stretch their growing season into the winter. Hardy vegetables, such as lettuce, spinach, beets, carrots, onions, radishes, and herbs should grow well through most if not all of the winter.

Traditional greenhouses, prefabricated or site-built, are usually designed as free-standing structures. They are seldom designed for specific climates and solar conditions. They often demand the use of additional fuel to maintain growing conditions. Many manufacturers have developed units which appear as half-greenhouses to be attached to an existing structure. Since these structures were designed as commercial or semi-commercial plant-growing units, being watertight is not a major concern, and most of them have minor leaks. For that reason, a site-built unit is usually more suitable for an attached greenhouse.

If the sunspace is to be used as a greenhouse in the winter, and is insulated to the standards given above, is double-glazed, and has an uninsulated masonry common wall with the house, very little auxiliary heat will be needed to maintain it above 40 degrees. A significant amount may be needed to maintain it at 65 degrees. Not all of the auxiliary energy added to the sunspace is lost to the atmosphere—by increasing the sunspace temperature, less heat is lost from the house, and auxiliary heat requirements for the house are somewhat reduced. The glass area and the amount of thermal storage required is usually larger for a horticultural greenhouse than for a sunspace.

Rules of Thumb. The amount of glass area needed to maintain a growing greenhouse will vary with the local climate and the hours and intensity of sunlight available. In areas having less than 4000 heating degree-days, \( \frac{3}{4} \) to \( \frac{1}{4} \) square feet of south-facing glass should be allowed for each square foot of heated floor area. The heated floor area should include the greenhouse and any adjoining area in the house which is to be heated. In climates to 6500 degree-days, 1 to \( \frac{1}{2} \) square feet of glass per square foot of floor area would be desirable.

For thermal storage, about 2\( \frac{1}{2} \) gallons of water or 1\( \frac{1}{2} \) cubic feet of rock or masonry storage is recommended for each square foot of glass in the milder climate. In colder climates, up to 3 cubic feet of rock or masonry or 5 gallons of water per square foot may be needed.

Two venting systems are needed in a working greenhouse—one which vents warm air into the house in the winter and a second which exhausts hot, humid air outside in the summer. An upper and lower vent is required for both applications, with provisions for closing each vent. If gravity vents are used rather than fans, the total area of vent openings should be equal to \( \frac{1}{5} \) to \( \frac{1}{6} \) of the greenhouse floor area. In some cases, the existing doors and windows can be used for venting air into the house.

Construction Materials. Wood used in greenhouse construction should be naturally durable species, such as cedar, redwood, or cypress, since it is an area of high humidity and frequent water usage. Pressure-treated wood treated with CCA or ACA preservatives can be used. Wood treated with creosote or "penta" should not be used. Cut ends of pressure-treated wood should be brushed with a solution of copper napthenate. Cut ends of all wood should be sealed to prevent moisture absorption. Only hot-dipped galvanized or stainless steel nails should be used. Screws should be brass, aluminum, or stainless steel. Ordinary steel nails or screws will deteriorate quickly in the humid atmosphere of a greenhouse, particularly when used in redwood.

There is the same choice of glazing materials as was listed for sunspaces, with essentially the same advantages and disadvantages.