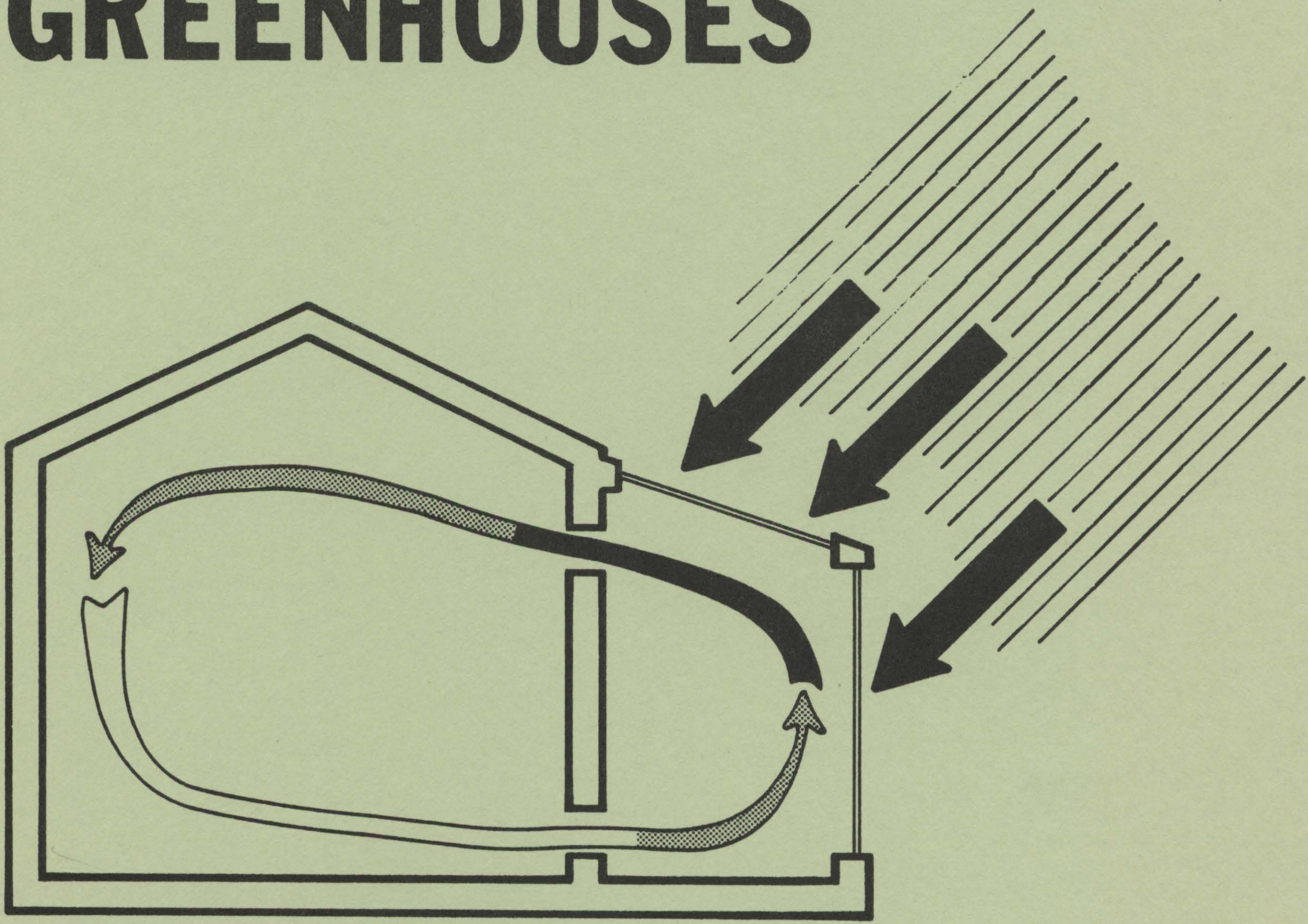
Virginia Cooperative Extension Service

ATTACHED SOLAR GREENHOUSES



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ATTACHED SOLAR GREENHOUSES

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Selected References

The Passive Solar Energy Book. Edward Mazria. Rodale Press, Emmaus, Pennsylvania, 1979.

Solar Greenhouses. Michael Harris. Home Energy Digest and Wood Burning Quarterly, Minneapolis, Minnesota, 1979.

The Sunspace. Larry Stains. New Shelter, Rodale Press, Emmaus, Pennsylvania, February 1980.

Suggested Low-Cost Design for Attached Greenhouses. National Center for Appropriate Technology, Butte, Montana, 1980.

Knotts Handbook for Vegetable Growers. Second Edition. Oscar A. Lorenz and Donald Maynard. John Wiley and Sons, New York, 1980.

Suggested Reading

Sunspaces for the Southeastern United States. Principles and Construction of a Passive Solar Greenhouse. United States Department of Energy - Region IV, 1655 Peachtree Road, N.E., Atlanta, Georgia 30367.

ATTACHED SOLAR GREENHOUSES

In most climates, a well constructed solar greenhouse collects more energy on a clear winter day than it needs for greenhouse heating. A portion of this extra energy can be conducted through the common wall between the greenhouse and the building. In this way, an attached greenhouse has the potential to supply a substantial amount of heat to the space adjoining it.

A building which has a south wall capable of receiving unobstructed sunlight from approximately 9:00 a.m. until 3:00 p.m. is well suited for the addition of a solar greenhouse or sunspace.

The complicated nature of thermal energy flow between an attached greenhouse and a building makes it difficult to accurately size a greenhouse and to predict its performance as a heat system. When properly sized, the attached greenhouse not only heats itself but heats the space adjacent to it (Figure 1).

The greenhouse should be extended along the south wall of the building adjoining the space you want to heat. In colder areas of Virginia, between 0.65 and 1.5 square feet of southfacing double glass (greenhouse) for each 1 square foot of (adjacent) building floor area should be used. In warmer areas of Virginia, use 0.33 to 0.9 square feet of glass for each 1 square foot of floor area. This area of glazing will collect enough heat during a clear winter day to keep both the greenhouse and adjoining space at an average temperature of 60° to 70°F during the day. Enough thermal mass to absorb direct sunlight and dampen interior temperature fluctuations should be utilized. A thermal mass wall for storing collected solar energy should be located between the greenhouse and the adjacent space. Thermal mass is the amount of potential heat storage capacity available in a given assembly or system.

Table 1. Sizing the Attached Greenhouse for Different Climatic Conditions.

Average Winter Outdoor Temp. (^{o}F)	Square feet of south facing greenhouse glass needed for each one square foot of floor area to be heated adjacent to the greenhouse.	
Temperature	Thermal Mass Wall	
	Masonry	Water in Containers
35^{o}	0.53-0.90	0.38-0.65
40^{o}	0.42-0.69	0.30-0.51
45^{o}	0.33-0.53	0.24-0.38

Temperatures are given for December and January. For a poorly insulated greenhouse or building, use slightly more glass.

When using a thermal mass wall for heat storage and transfer, the greenhouse should be positioned so it extends along the south wall exposing a large surface area of thermal wall to direct sunlight.

When the primary function of the greenhouse is to heat the building, taking heat from the greenhouse by mechanical means and storing it for use in the building will increase the efficiency of the system. For this approach to work best, the greenhouse must be allowed to drop in temperature to about 40^{o} to 45^{o}F at night. While this system is feasible in temperate and cool climates, in very cold climates most of the heat collected by the greenhouse is needed to keep plants from freezing at night.

When the principal method of heat transfer between the greenhouse and the building is an uninsulated thermal mass wall, the following table as a guide for selecting wall thickness can be used.

Table 2. Thermal Mass Walls

Material	Recommended thickness (in.)
Solid Masonry	8 - 12
Concrete	12 - 18
Water in Containers	1 cu. ft. (7.5 gal.) for each 1 sq. ft. of south facing glass

The surface of the wall should be a medium or dark color and care should be taken to not block direct sunlight from reaching it. Small vents or operable windows should be located in the wall to allow heat from the greenhouse directly into the building during the daytime. Operable exterior vents and shading devices to prevent a heat buildup in the greenhouse in the summer are required.

A conventional uninsulated wood frame and four-inch brick veneer wall is inadequate as a method of heat storage and transfer between spaces. Daily temperatures in the greenhouse will fluctuate by as much as 40° to 60°F on a clear winter day with no additional storage due to the fact that this masonry thickness alone cannot absorb and store enough heat. It is necessary that the greenhouse contain additional thermal mass such as water in containers to help dampen fluctuations (Table 2).

Active Rock Storage-Passive Heat Distribution

If the greenhouse is used primarily as a heating source, it may be advantageous to actively take heat from the greenhouse during the day and store it in the building for use at night.

Heat taken from the greenhouse by a fan is stored in a rock bed usually located in the crawl space under the floor of the building as shown in Figure 2. The advantage of this systems is that the greenhouse can be constructed of any material and need not contain a thermal mass wall. This is important when a window between the building and the greenhouse is desirable. The greenhouse should receive enough heat back from the building at night through the common wall and glass to keep it at a temperature approximately equal to the average of the indoor heated space and outdoor temperature. In any case, it is important to use operable windows or a door to assure that during periods of extremely cold weather, the greenhouse can receive direct heat from the building to keep freezing temperatures from affecting the plants.

For adequate passive heat transfer from the rock bed to the adjacent space to be heated, it is important that a large portion of the floor act as a heat transfer area. In temperate climates, this should be 50 to 75 percent of the floor's surface area. This can be accomplished by supplying warm air to the rock bed in the space between the bed and the floor, and returning cool air to the greenhouse from the bottom of the rock bed. In temperate climates, 3/4 to 1 1/2 cubic feet of fist-sized rock for each 1 square foot of southfacing greenhouse glass should be used.

Solar greenhouses in Virginia require double glazing to prevent undue heat loss. Insulating glass may be used as well as plastic products such as fiberglass or polycarbonate sheets. Plastic films are best used as the second layer of glazing inside the glass or rigid plastic glazing. The cost of glazing may account for nearly half the total cost of the greenhouse structure. The average cost of a solar greenhouse is, in most cases, one third less than standard construction.

The success of a solar greenhouse food production system is limited by the skills of the gardener who manages it. It is therefore important to cultivate your indoor gardening skills.

Vegetable Culture in a Solar Greenhouse

Plants have certain requirements for proper growth whether grown out-of-doors or in a home greenhouse. They must have adequate light, appropriate temperature, water, nutrients, and air. In a solar greenhouse intended for both home heating and food production, it may be necessary for the greenhouse owner to make decisions in the areas of light and temperature either in favor of more heat for the home or higher production for the greenhouse.

Most vegetables will produce best with 6 to 8 hours of full sun a day and will respond with increased growth up to 4,000 foot candles. However, winter sun through a double-glazed greenhouse may yield closer to 900 foot candles. To enhance light for plant growth, it is recommended that all surfaces be painted a highly-reflective color like white. However, to increase solar absorption for heat use during the night, it is recommended that storage masses (Walls, drums of water, etc.) be painted black. To minimize problems created by this dual demand, utilize the building method that allows optimum light penetration and locate plants with high light demand in areas with full exposure. If ground benches are planned, use a construction design that allows for glazing on the sides of the greenhouse.

If the greenhouse is to provide a significant amount of the household heat at night, crops must be selected which will survive and produce at night temperatures of 40° to 45°F. Table 3 provides temperature requirements on the more popular vegetable crops.

Cultural techniques may require modification from those used in the garden. Soil should be lighter, richer, and better drained than many garden soils. Whether cultivation is in ground beds, raised beds, or containers, it is necessary to mix soil especially for indoor use and change it annually.

Good drainage holes in containers are as important as light soil. Watering and fertilizing skills will have to be developed, based on the rate of plant growth which is directly related to light and temperature. Fewer pests are usually found in a greenhouse garden; however, the pests must be controlled. Due to the enclosed nature of the greenhouse, interrelated ventilation, and the proximity of family and pets, nonchemical methods are recommended.

Good air circulation is essential to reduce fungal disease buildup. If the greenhouse-to-house design does not provide for natural airflow, a small fan should be used. In late spring, additional ventilation to the outside will be necessary to prevent excessive temperature buildup. In Virginia, unless shade and ventilation are provided, the summer temperatures will be too high for comfortable cultivation of any vegetables in the greenhouse.

Table 3. Approximate Monthly Temperatures for Best Growth and Quality of Vegetable Crops.*

Some crops can be planted as temperatures approach the proper range. Cool-season crops grown in the spring must have time to mature before warm weather. Fall crops can be started in hot weather to ensure a sufficient period of cool temperature to reach maturity. Within a crop, varieties may differ in temperature requirements; hence this listing provides general rather than specific guidelines.

Temperatures (^{o}F)			
Optimum	Minimum	Maximum	Vegetable
55-75	45[1]	85	Chicory, chives, garlic, leek, onion, salsify, scolymus, scorzonera, shallot
60-65	40[1]	75	Beet, broad bean, broccoli, Brussels sprouts, cabbage, chard, collard, horseradish, kale, kohl-rabi, parsnip, radish, rutabaga, sorrel, spinach, turnip
60-65	45[1]	75	Artichoke, cardoon, carrot, cauliflower, celeriac, celery, Chinese cabbage, endive, Florence fennel, lettuce, mustard, parsley, pea, potato
60-70	50	80	Lima bean, snap bean
60-75	50	95	Sweet corn, Southern pea, New Zealand spinach
65-75	50	90	Chayote, pumpkin, squash
65-75	60	90	Cucumber, muskmelon
70-75	65	80	Sweet pepper, tomato
70-85	65	95	Eggplant, hot pepper, martynia, okra, roselle, sweet potato, watermelon

*Knotts Handbook for Vegetable Growers. Second Edition. Oscar A. Lorenz and Donald Maynard. John Wiley and Sons, New York, 1980.

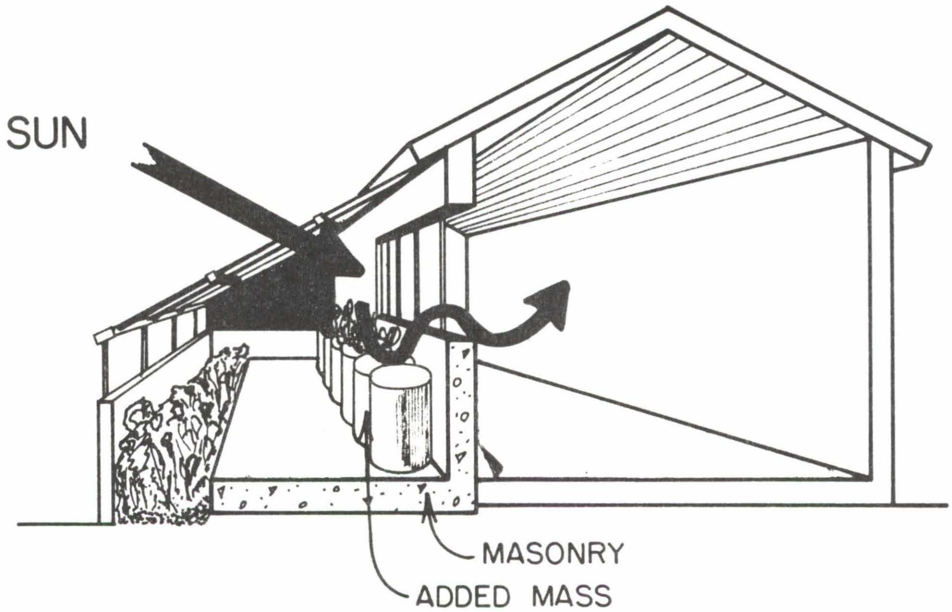


FIGURE ONE

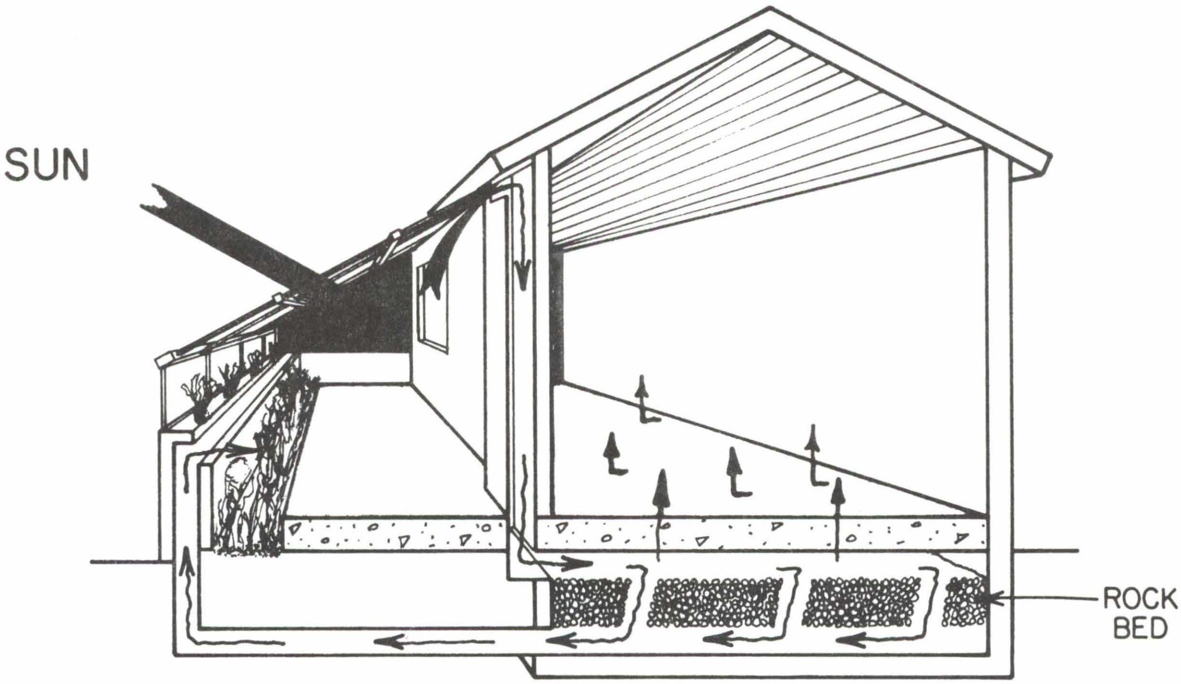
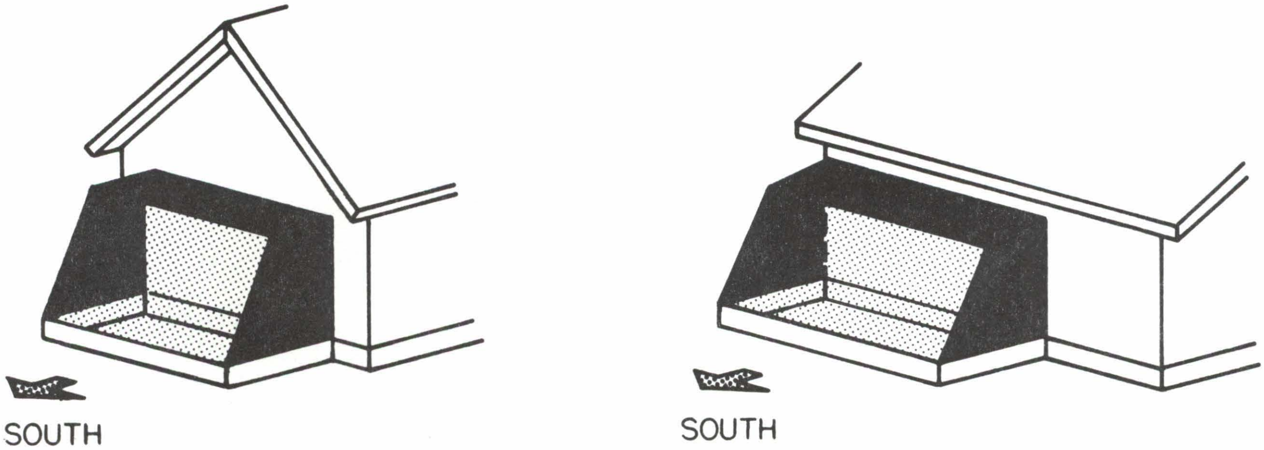
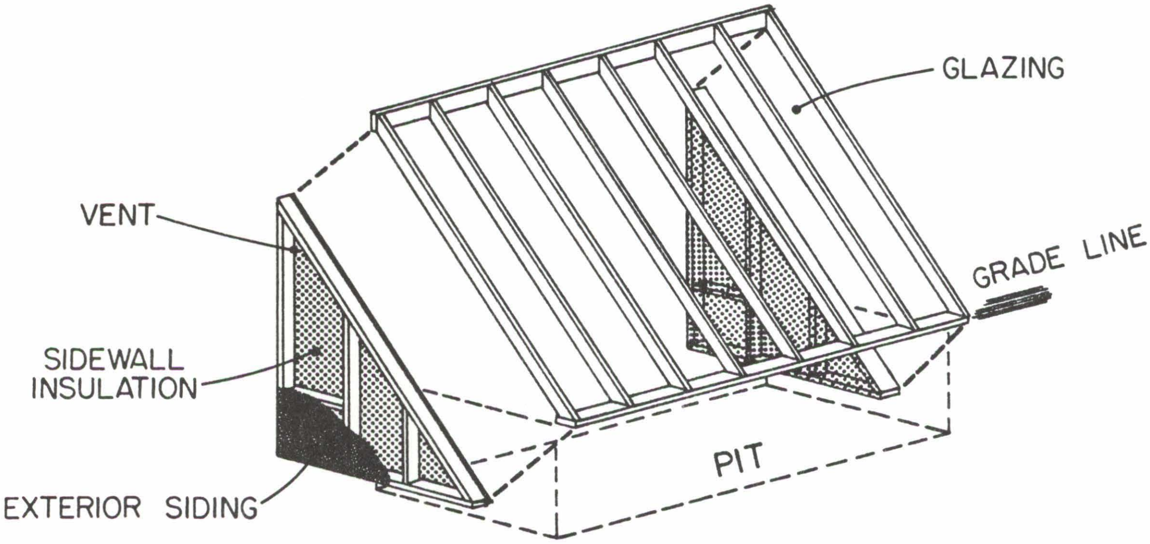


FIGURE TWO



COMMON ATTACHMENT LOCATIONS

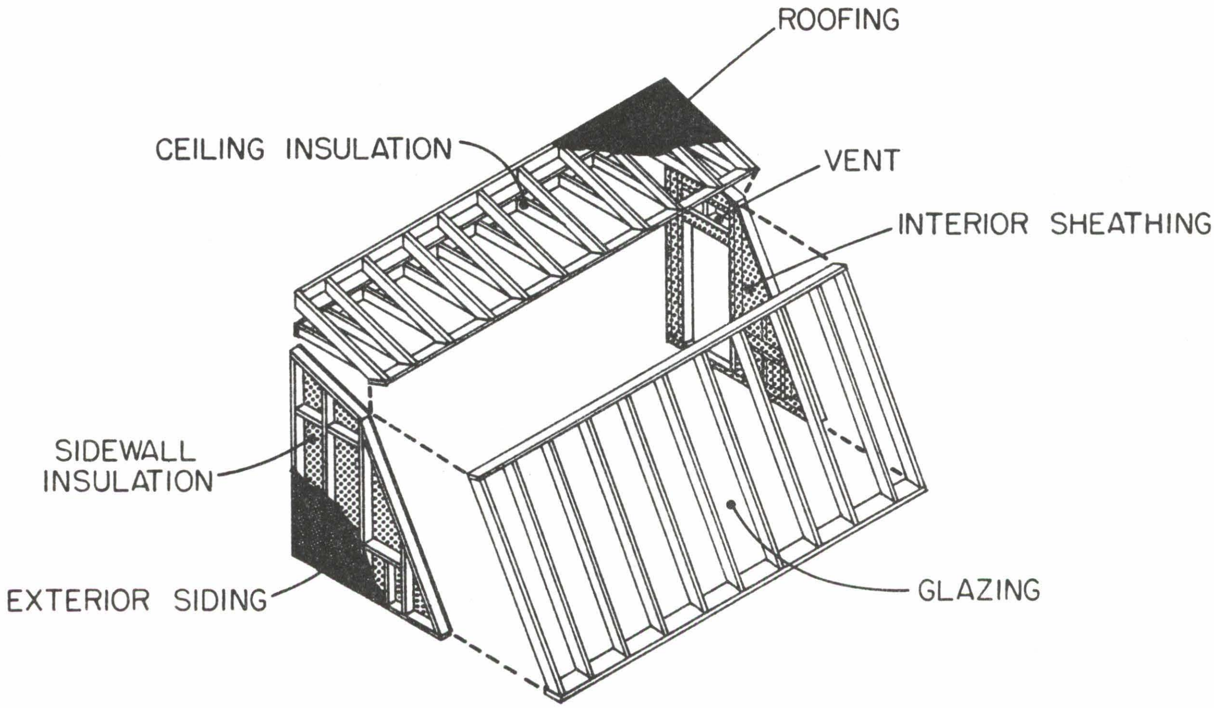


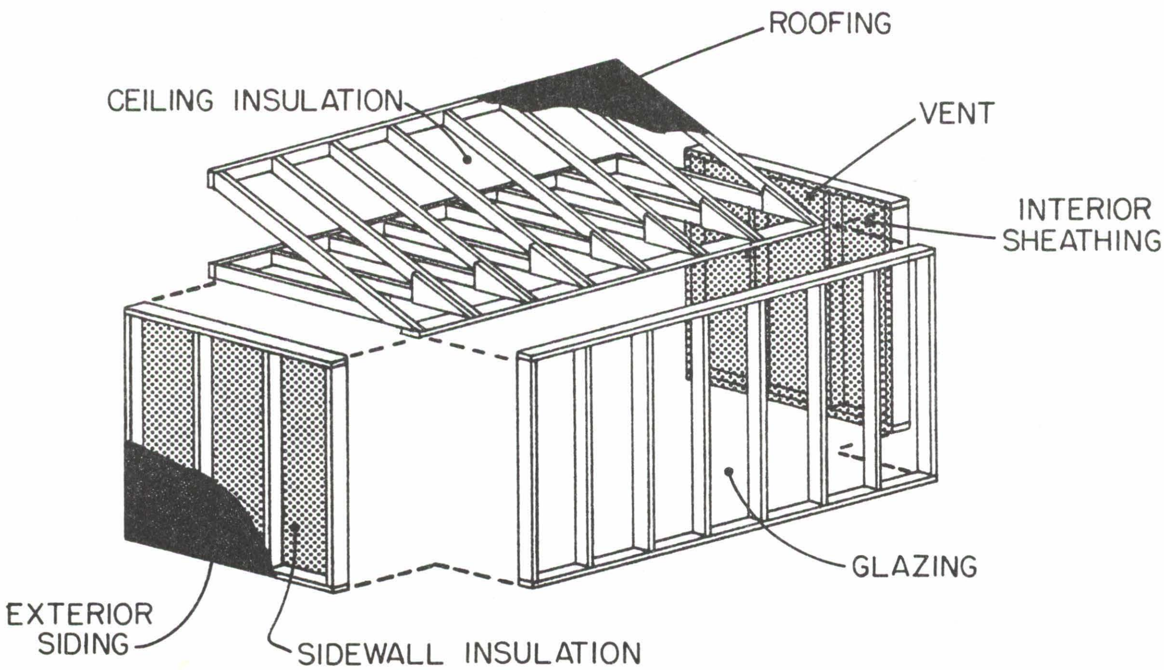
LEAN-TO SUPERSTRUCTURE

FOUNDATION IS REQUIRED

General Notes

- Comply with all local building and zoning codes.
- Provide proper roof drainage and weatherproofing.
- Ensure adequate vapor barriers for insulation.
- Use conventional wood frame construction techniques.
- Use conventional masonry construction techniques for foundation, foundation walls, and floor slab.
- Provide access to interior of structure based on specific needs.
- No single particular design will be suitable for every situation, since regional climate and availability of materials, labor, and skills will vary. Foundation and superstructure needs will vary considerably depending on specific application.





SUPERSTRUCTURE ALTERNATES

FOUNDATION IS REQUIRED

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