Iowa
Energy
Extension
Service

Solar Space Heating

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Passive Options for Iowa: Direct Gain

System Description

In a passive solar heating system the sun's energy comes directly into the building by natural means, without the need for mechanical equipment such as pumps or fans.

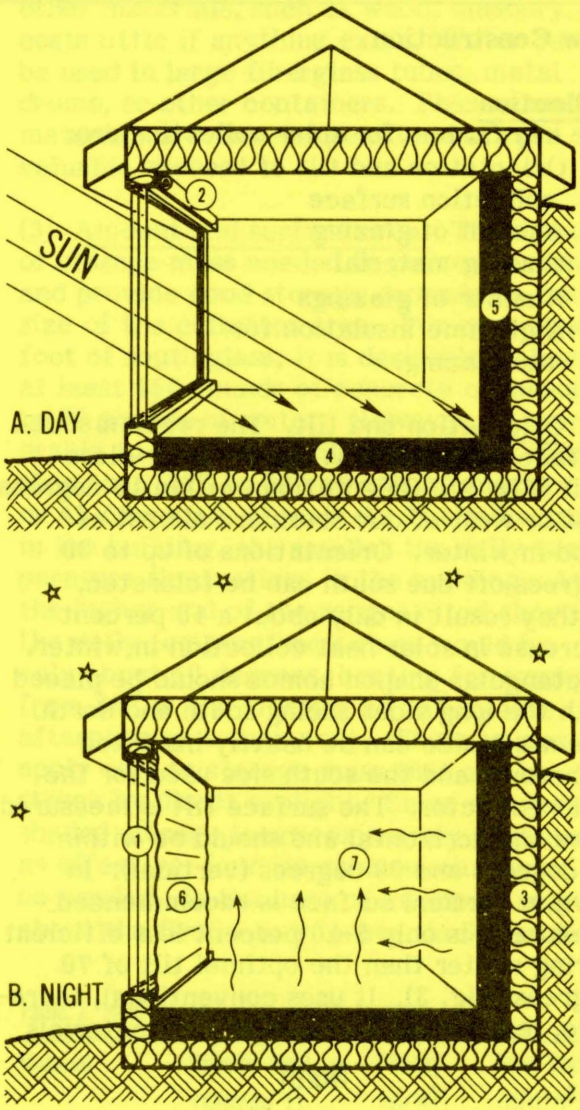
The simplest type of passive solar heating is the direct gain method, in which the solar heat gain comes directly into the actual living space of the building. The solar collector consists simply of large south-facing glass windows or doors, through which sunlight streams into the building (Fig. 1a).

Daytime overheating is prevented by having a large amount of thermal storage mass on the interior. The mass can be concrete or other masonry. The heat capacity of this mass allows excess solar heat to be stored for use at night or on cloudy days (Fig. 1b).

Heat distribution from the storage mass to the living space is by radiant heating-considered the "Cadillac" of heating systems because it provides the most comfort.

Design Recommendations

For a new building there are many ways to design a direct gain system to suit the occupants' habits and preferences. Although the choice of storage material and location is a wide one, certain rules of thumb discussed below must be followed to ensure good thermal performance and low heating bills. It is also possible to incorporate direct gain into existing buildings, but it is often difficult to do so satisfactorily.



1. Multiple glazing
2. Nighttime insulation removed
3. Insulation on outside of walls
4. Thermal storage floor
5. Thermal storage back wall
6. Nighttime insulation installed
7. Radiant heat from thermal storage

Figure 1. Direct Gain System

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Direct Gain Advantages

*Simplest in concept; easiest to design and construct.
*Building structure can serve as solar system components.
*Very little extra expense when the solar system uses glass and concrete.
*Provides occupants with radiant heat, the most comfortable heating system.
*Living space is well-lit by natural light, saving on artificial lighting costs.
*Provides a view and a natural communion with the external environment.

Direct Gain Disadvantages

*Direct sunlight can fade colored fabrics, paintings and furniture.
*Glare may be a problem on sunny days.
*Glass needs good nighttime insulation for best performance and comfort.
*Masonry floors may be objectionable.
*Privacy may be a problem as occupants are more exposed.

New Construction

Collection

The key factors for solar collection are:

(1) Orientation and tilt of the collection surface
(2) Amount of glazing
(3) Glazing material
(4) Number of glazings
(5) Nighttime insulation for the glazing.

(1) Orientation and tilt. The recommended surface orientation is due south or close to it (Fig. 2). Orientations within 15 degrees east or west of due south are almost as good in winter. Orientations of up to 30 degrees off due south can be tolerated, as they result in only about a 10 percent decrease in solar heat collection in winter. Rectangular-shaped homes should be placed with the long sides facing south and north. The north side can be heavily insulated or bermed and the south side used for the solar collector. The surface tilt is measured from the horizontal and should be within 60 degrees and 90 degrees (vertical). In Iowa, a vertical surface is recommended because it is only 5-10 percent less efficient during winter than the optimal tilt of 70 degrees (Fig. 3). It uses conventional, therefore, less expensive construction materials and techniques; is less susceptible to hail and water damage; and is easier to insulate during winter nights and shade during summer days. In addition, a vertical surface will collect increased solar energy during periods when there is snow cover.

(2) Amount of glazing. In a well-insulated new home (i.e. R-30 walls and R-40 roof), the amount of glazing in the collector should have a net (clear glass) area equal to about 15 to 20 percent of the heated floor area of the house; this can provide about 60 to 90 percent of the home's heating needs in Iowa. The amount of glazing may be somewhat less and still provide a significant amount of solar heating. A 2000 square foot house, for example, could reasonably have 300 to 400 square feet of south glass for a good direct gain system.

(3) Glazing material. In general, there are two types of glazing materials: glass and specially treated plastic glazings. Although direct gain systems in homes normally use glass, it is not necessary to do so. Tempered glass is desirable but is more expensive than ordinary annealed glass. Non-glass glazing is discussed in more detail in Publication EES-1a, Passive Options for Iowa: The Sunspace.

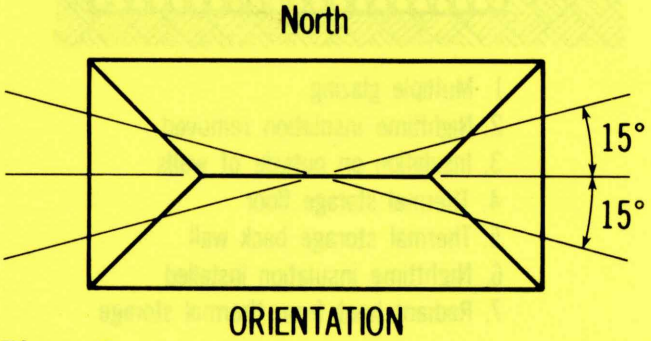

Figure 2.

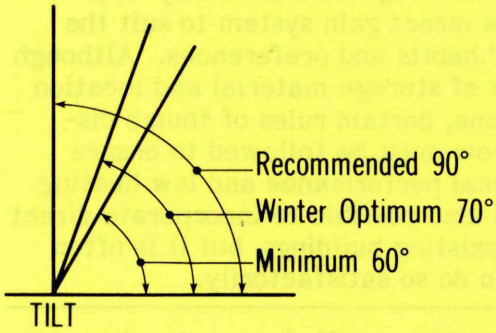

Figure 3.

(4) Number of glazings. As the number of glass layers in a window are increased from single to double to triple glazing, the amount of sunlight transmitted into the interior decreases. However, the heat loss out of the building through the glass also decreases. During mid-winter in Iowa, if no nighttime insulation is used on the glass, single glazing is a net heat loser, double glazing is a net heat gainer and triple glazing is an even better heat gainer (Table 1). Heat gain occurs when there is more solar heat gained than heat lost through the glass. If night insulation of R-5 or higher is used, single glazing is a fair heat gainer while double and triple glazing are excellent. In Iowa, the direct gain collector should be at least double glazing with night insulation or triple glazing if no night insulation is used.

Table 1. Average daily heat gain through south-facing vertical windows in Dec., Jan., & Feb.

Glazing	No Night Insulation	R-6 Night Insulation
Single	-133 BTU/ft^2	436 BTU/ft^2
Double	350 BTU/ft^2	602 BTU/ft^2
Triple	475 BTU/ft^2	625 BTU/ft^2

(5) Nighttime insulation. Night insulation consists of insulation placed over the glazing at night to reduce heat losses when there is no solar gain. It may consist of insulating shades, heavy drapes, insulating panels or shutters or other schemes. Examples are discussed in Publications Pm 811 a, b, and c. Generally speaking, if the night insulation costs less than $5 per square foot, it is a worthwhile investment. Above that amount the investment becomes less attractive.

Storage

The key factors for storage are:
(1) Location
(2) Type
(3) Amount and surface area
(4) Surface treatment

(1) Location. Solar heat can be transferred to the thermal storage mass either by direct absorption of solar radiation that strikes it or by absorption of heat from air that is warmer than the storage mass. Direct absorption is preferable, and thermal storage mass located where direct sunlight can strike it during part of the day is more useful than storage located in the shade all day. Floors, side walls, and interior partitions make good storage, while north walls are usually less useful.

(2) Type. Good storage materials for direct gain systems are concrete or masonry (stone, brick, tile, etc.) or water in containers (Table 2). Masonry materials have an advantage because they can be used as part of the structure—as floors, exterior walls, partitions or fireplaces. Since they replace other materials, such as wood, masonry costs little if anything extra. Water can be used in large fiberglass tubes, metal drums, or other containers. Phase change materials are more expensive, but save valuable space.

(3) Amount and surface area. The amount of storage mass needed to prevent overheating and provide good storage depends on the size of the collector area. For each square foot of south glass, it is desirable to have at least 150 pounds of concrete or masonry or 30 pounds of water. However, it is preferable to have about 50-100 percent more than that (225 to 300 pounds of masonry or 45-60 pounds of water). The more storage in the building, the smaller the daily temperature fluctuations in the building. At the higher end of the ranges cited above, the daily temperature swings would be only about 10 degrees, heating for example from 65° in the morning to 75° by late afternoon on a sunny day. These values apply only to storage mass that can be struck by direct sunlight. Since constantly-shaded storage is approximately 25 percent as effective, four times as much would be needed. In the case of masonry, only about the first 4 to 8 inches thickness from

Table 2. Heat capacities of various materials

Material	Specific Heat (BTU/lb/°F)	Density (lb/ft^3)	Heat Capacity (BTU/ft^3/°F)
Water	1.00	62.5	62.5
Concrete	0.27	140	38
Brick	0.20	140	28
	Heat of Fusion (BTU/lb)	**Density (lb/ft^3)**	**Heat Capacity (BTU/ft^3)**
Eutectic salts	80	100	8000

any air surface is very effective as storage on a daily basis. Therefore, any masonry located more than 8 inches from an interior air surface should not be considered storage. It is best to have as large a surface area of masonry storage as possible. A given mass spread over 500 square feet is more effective than the same mass spread over 400 square feet. It is desirable to have at least 3 and preferably 8 square feet of masonry storage surface area for every square foot of south glazing.

(4) Surface treatment. Masonry storage can be painted, plastered, or even dry-walled if the dry wall is thin and bonded directly to the masonry. Carpeting or similar materials are undesirable because they insulate the storage and reduce its effectiveness. Moderate amounts of area rugs can be used on a concrete storage floor, but wall-to-wall carpeting should be avoided. Many such floors are tiled or given an exposed aggregate topping; these types of floors have often proved very satisfactory to occupants of direct gain homes. The color of the storage mass is not critical. It should not be very light, because that would inhibit absorption of solar radiation, but it does not need to be dark. Medium colors such as light brown will work satisfactorily though darker floors would have a slight advantage in performance.

Distribution

The thermal storage mass acts not only as an absorber of solar heat to prevent daytime overheating, but also as the distribution system. As such, the thermal storage releases heat to the living space automatically when the air temperature cools below the storage mass temperature. The radiant heating (Fig. 1b) provided by direct gain storage is extremely comfortable, generally more so than forced air systems. When the air temperature in a direct gain house drops to the lower 60's Fahrenheit, the home still feels comfortable. Conventional homes with cooler walls and floors can feel cold even when the air temperature is in the upper 60's or lower 70's.

The storage mass should have a large surface area and be located adjacent to the living space. For this reason, masonry back and side walls, room partitions, and floors perform excellently. If a hard floor is not desirable, sufficient storage mass can be placed in walls, partitions, fireplaces, and other interior design elements to meet the requirements discussed earlier. Large surface areas are most desirable for better comfort and performance. A rule of thumb for good distribution is to have at least 3 and preferably closer to 8 square feet of surface area of storage for each square foot of collector glazing.

Retrofit

If an existing home has a good southern exposure, with no buildings or other obstructions to block winter sunlight, it may be possible to add a direct gain system. This is not an easy task, as it involves removing part of the existing south wall and replacing it with glazing. If a substantial amount of glazing is added, it is necessary to add thermal storage mass, a task often difficult to accomplish in existing homes. If there is room, a better approach would be to retrofit a sunspace addition (see Publication EES-1a). This would provide additional living space.

Iowa Energy Policy Council

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