Energy in Agriculture: Requirements for Farm Use of Solar Energy in Kentucky

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Requirements for Farm Use of Solar Energy in Kentucky

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Introduction

There is increasing interest in utilizing solar energy to supplement heating and grain drying energy needs on the farm. Many Kentucky farmers realize that their demands for heat and the orientation of certain buildings on their farms suggest solar heating potential. But most farmers are not familiar with the requirements and limitations of solar heating.

This publication discusses those factors a farmer must consider when evaluating the solar potential of agricultural structures on the farm. Solar requirements are divided into two main areas: (1) site requirements associated with the building and its surroundings and (2) load requirements associated with the use of the heat. Solar energy use on the farm can be both functionally feasible and cost effective in Kentucky, but only under a specific set of circumstances.

Evaluating Present Buildings

Before considering any of the requirements for solar utilization, evaluate the condition of farm buildings. Reinforce or replace sagging beams, truss members and loose roof and wall coverings. This will not only maintain the overall strength and useful life of the buildings, but will present a flatter, more even building surface to which clear glazing or other solar construction can be added.

Next evaluate the heat-holding capacity of the buildings. With the current cost of fuels, building materials and insulation, the first investment should be in sealing all doors, windows and other cracks which let unwanted air infiltrate the heated space. The second investment should be insulation. Bringing the insulation in the walls and ceiling up to recommended levels will reduce the amount of heat required, and therefore lower the investment in solar heating equipment. Table 1 presents the recommended insulation levels for agricultural buildings. Only after these structural and conservation measures are taken should solar utilization be considered.

Site Requirements

The site requirements that make a structure suitable for solar utilization include favorable building orientation and shape, surface angle, shading and distance from solar collector to heat load.

Orientation and Shape

As illustrated in Figure 1, during the heating season the sun travels across the southern sky, with its lowest position occurring on Dec. 21. In Kentucky this is about 30° above the horizon. By June 21, the cycle will bring the sun to its highest angle, about 70° at solar noon. The orientation of a building refers to the position of the proposed solar absorbing surface relative to true south. Both the orientation and the shape of a building affect the amount of solar radiation that can be collected. The ideal building is rectangular in shape with its long edge facing due south. Fortunately, a variation of up to 30° from due south is acceptable; in this case additional solar collecting area is used to compensate for the poor sun angle.

FIG. 1.—Winter and summer sun angles in Kentucky, lat. 40° N.
Table 1. Recommended Insulation R-Values for Various Livestock Buildings and Farm Shops

<table>
<thead>
<tr>
<th>Facility</th>
<th>Desired Temperature Range (° F)</th>
<th>R-value for -</th>
<th>Wall</th>
<th>Ceiling</th>
<th>Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Swine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestation/finishing (50 to 220 lbs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified open-front</td>
<td>45 - 85</td>
<td>13</td>
<td>20</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Shed with lot</td>
<td>Outside ± 15°</td>
<td>*</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Nursery (20 to 50 lb)</td>
<td>65 - 90</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farrowing (300 to 400 lb)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedded solid floor</td>
<td>60 - 85</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slotted floor</td>
<td>70 - 85</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dairy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total covered free-stall, cold</td>
<td>25 - 85</td>
<td>13</td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Free-stall with lot</td>
<td>Outside ± 15°</td>
<td>*</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Stanchion</td>
<td>45 - 85</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calf housing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hutch</td>
<td>Outside ± 15°</td>
<td>*</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Bedded stall</td>
<td>Outside ± 5°</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Raised stall</td>
<td>55 - 85</td>
<td>13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milking parlor</td>
<td>40 - 85</td>
<td>4-13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk house</td>
<td>40 - 85</td>
<td>4-13</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beef</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open shed with lot</td>
<td>Outside ± 15°</td>
<td>*</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Slotted floor</td>
<td>Outside ± 15°</td>
<td>*</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td><strong>Shops</strong></td>
<td>45 - 60</td>
<td>13</td>
<td>20</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

*Uninsulated.

*Source: Jones et al., 1979.
Surface Angle

The tilt angle of the proposed solar collecting surface will determine the amount of solar energy that can be collected. For solar systems incorporated into a structure, the decision is typically between the vertical south wall area of the structure, or the roof area at a predetermined roof slope. The optimum tilt angle from horizontal, strictly in terms of solar radiation absorption, is generally considered the local latitude angle plus 15°. For example, at lat. 38° N (Lexington), this is 53° from horizontal. Again, a variation of 15°-20° from this optimum angle can be easily compensated for by increasing the absorption area.

In most cases, other considerations, such as summer overheating, ease of construction and weatherability will determine where the solar energy is collected. Naturally, each system should be evaluated for its own advantages and liabilities, but the individual is encouraged to consider the vertical south wall area first for solar construction, and the roof area as a secondary location. The advantages of the south wall location include: (1) natural summer shading with a sufficient roof overhang (see Figure 2); (2) less risk of rainwater leakage; and (3) ease of installation with appropriate scaffolding.

FIG. 2.—Shading of vertical collector.

Shading

Determine whether trees, buildings, grain structures or other tall objects are far enough from the proposed solar collecting surface that the lowest sun angle of 30° will not cast a shadow on the surface. As a rough estimate in Kentucky (lat. 38° N) the distance from the solar surface to any object south of the surface should be at least 1.75 times the height of that object (see Figure 3).

Naturally, tall narrow objects will not present as much of a problem as wide objects. Trees that shed their leaves during the heating season need not be removed from the site. The shadow cast by a bare tree should not reduce the collected solar radiation significantly, and in the summer the leaves will help shade the collection surface to prevent overheating.

Distance to Load

The location of the load and its distance from the solar collecting surface will have a great effect on solar feasibility. Obviously, the closer the load is to the collection point the fewer the losses. A practical maximum distance from collector to load is 100 feet. Unless the farmer is considering new construction, this distance is usually fixed. But in certain situations the uses of the building may be rearranged to reduce this distance. By placing the operation with the greatest heat demand closest to the solar collecting system, losses in transporting the heat to the load can be reduced. An example of this would be a farrow-to-finish swine building in which the area housing the youngest pigs could be moved to the southern side of the building to utilize collected solar radiation.

One alternative is a portable solar collector, that can be used for multiple applications on the farmstead throughout the year. In certain situations this may be a cost effective solution, but there are several considerations to this type of system.

1. To have a noticeable effect, the collector must have at least 200 square feet of collection area. The wind resistance presented by this area must be taken into consideration.

2. A portable framework must be built, adding to the cost of the system.
3. Additional insulation must be added to the back of the collector to reduce heat loss from this exposed area.

4. Ducts which bring heat from the collector to the building add to the cost and present more exposed area for heat loss.

The individual should realize that if the portable collector costs twice that of a built-in system it must have at least double the effective hours of use of a built-in system to show any advantage.

Load Requirements

The load requirements of any farming operation or enterprise are the quantity of heat needed and the temperature at which that heat must be delivered. The most efficient and least expensive solar system for any application matches the temperature output of the solar collector design to the temperature demand of the load.

Solar collectors which utilize air, rather than water, as the heat transfer medium, are recommended for most agricultural applications. This eliminates the need for heat exchangers and reduces the risk of damage due to leaks and freezing in the system. The optimum collector design is determined by identifying the heat load requirements in terms of minimum usable temperature and airflow rate. (Refer to University of Kentucky Extension publication AEES-3, Air-Type Solar Collectors for Agricultural and Residential Use.)

In addition to temperature and airflow requirements, the total number of heating hours must be sufficient that the investment in solar construction is paid for with fuel savings.

As an example, several articles have appeared in popular magazines describing solar systems, incorporated into the walls or roofs of agricultural structures, that heat air for drying grain. Most of these systems are located in states to the north or west of Kentucky, and are designed for low temperatures (10° to 10°F above outside air temperature). These systems dry the grain slowly over a period of weeks using warm air. In Kentucky, and farther south, the outside temperature and relative humidity during the harvest-drying season are typically higher than in northern and western states. As a result, grain must be dried to a safe moisture content in a shorter period of time to reduce grain spoilage, mold growth and aflatoxin formation. (See University of Kentucky Extension publication AEN-23, Low Temperature Drying—Use and Limitations.)

The time constraints imposed by the weather conditions in Kentucky put certain limitations on the operation and management of a solar grain drying system, but they do not completely eliminate its feasibility. By using the solar system to preheat the source air for grain drying before it enters the conventional heater-fan unit, a substantial amount of energy can be saved. If the collector can be built as an integral part of a new building, and if it can be used for other purposes, preheating air for grain drying with a solar system could be worthwhile.

The major considerations in solar grain drying include the following:

1. Solar assisted grain drying should be viewed as an alternate or off-season application for a proposed solar system. Currently it is not cost effective to build a solar system to be used solely for grain drying in Kentucky.
2. Due to the variability of weather and the need to dry grain rapidly, solar heat should not be relied upon as the primary heat source for drying the grain.

3. When using the existing fan to pull air through a solar system and into the bin, make sure this added resistance does not overload fan capacity.

Space Heating

The third application of solar energy is space heating. This applies to buildings on the farm where heating is required, but no animals are housed, so constant mechanical ventilation is not necessary; for example, farm shops. Unlike preheated ventilation air applications, these solar systems will require a specific level of solar radiation before air at a usable temperature can be obtained from the system. Because of these limitations, using solar energy for space heating a farm building, unless it is the farm residence, is typically not economically feasible. It should be viewed as another off-season use for the proposed solar system.

Summary

The use of solar energy to supplement or replace heating needs on the farm is limited to a specific set of conditions that are divided into two types: site requirements and load requirements. By evaluating both the building to which solar construction can be added and the load for which the heat will be used, the farmer can determine whether using this renewable energy source on the farm is mechanically and economically practical.

References


2. Loewer, Otto J., Jr., Douglas G. Overhults and Harvey E. Hamilton. 1973. Low temperature drying—use and limitations, AEN-23, Department of Agricultural Engineering, University of Kentucky, Lexington, KY.

3. Parker, Blaine F. 1980. Air-type solar collectors for agricultural and residential use, AEES-3, Department of Agricultural Engineering, University of Kentucky, Lexington, KY.