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HEATING GREENHOUSES WITH SOLAR ENERGY

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Interest in solar energy is not new. Men have been trying to avail themselves of this apparently free source of energy for centuries. The economics of solar energy have always been unfavorable, however, due to the diffuse nature of solar radiation and the relatively low cost of fossil fuels. The 1973 oil embargo changed the economic picture, though, by causing fuel prices to rise to such staggering levels that solar energy has begun to look attractive as an alternate energy source. This is especially true for the floriculture industry in North Carolina, where annual fuel costs can run as high as $16,000 per acre of greenhouse.

What would a typical solar heating system consist of? A look at Figure 1 shows that the equipment might include a collector, an insulated storage tank capable of storing from one to three day's energy requirements, two pumps, and three heat exchangers. The collection and distribution fluids will for the purposes of this article be water, as will the storage fluid. Antifreeze will be required for the collection fluid to prevent freezing when the system is not operating due to bad weather. The choice of water for this system should not be taken as a recommendation, however, since other fluids (notably air) actually possess some real advantages over water for space heating systems. Water was chosen in this case since most commercial systems are geared for domestic hot water production where water is superior to air. Further articles will address this subject in the future. Additionally, because of space limitations, only the collector will be treated in this article. Other aspects of solar heating systems will be treated in the future.

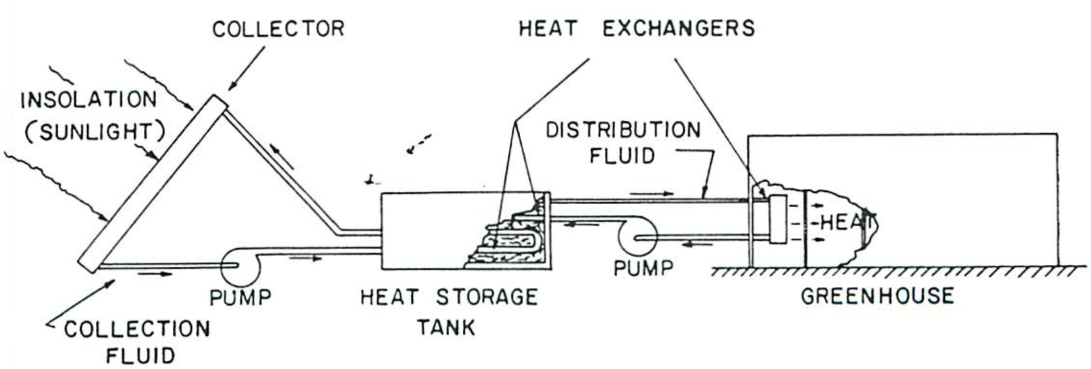

Figure 1. Typical solar heating system for greenhouses.

An essential part of any solar collection system is the solar collector. There are two types of collectors used to convert solar energy into heat energy: (1) flat plate collectors and (2) concentrating collectors. Flat plate collectors are generally less expensive than the concentrating type and are therefore more common for systems where the working fluid temperature need not exceed 200F.

Figure 2 shows the basic configuration of a flat plate collector. The incident solar insolation (sunlight) passes through the transparent cover plates (usually two), and strikes the absorbing plate (usually black) causing it to heat up. This, in turn, heats the water (or air) flowing past the plate. Typical efficiencies of flat plate collectors using water run from 65% at solar noon to zero at early morning and late afternoon. That is, at solar noon, 65% of the energy striking the surface of the collector will be transferred to the water. Typical costs for systems using flat plate collectors would presently run $6 per sq. ft. of collector area and higher depending on the complexity of the system.

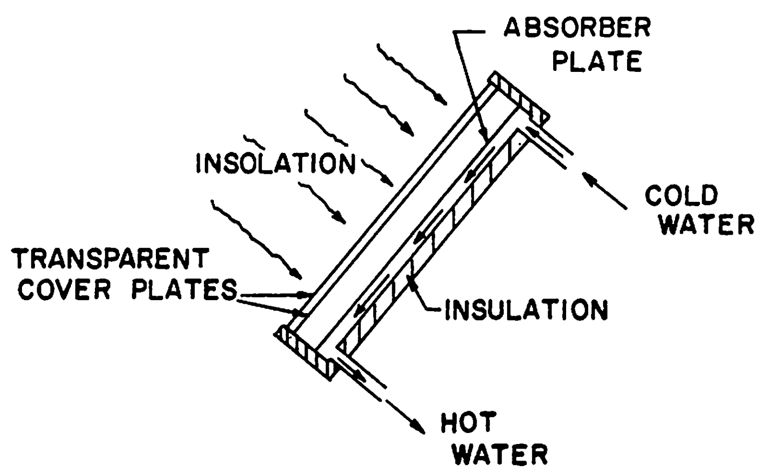

Figure 2. Typical flat plate collector.

The amount of energy a flat plate collector can collect is dependent upon the amount of energy striking the surface, which in turn is dependent upon the time of year and climatic conditions, as well as the location and orientation of the collector. During the heating season in the Northern Hemisphere, the optimum orientation of a collector is facing due south sloped at an angle from the horizontal of 15° plus the latitude of the location. For most of North Carolina the optimum inclination angle would be 50° from the horizontal (35° latitude + 15° = 50°).

The average solar insolation falling on a 50° tilted surface in North Carolina varies according to the location within the state. For most of the heating season the coastal region around New Bern receives the largest amount, followed by the Asheville area (because of its elevation) and then the Greensboro area. Typical values for December would be 39,000 BTU/mo per sq. ft. for Asheville, and 34,000 BTU/mo per sq. ft. for Greensboro.

Actual collection rates would be substantially less than the incident values, however, due to energy losses in the collector. Collection rates for December would be approximately 13,900 BTU/mo per sq. ft. for New Bern, 12,400 BTU/mo per sq. ft. for Asheville, and 12,000 BTU/mo per sq. ft. for Greensboro. Table 1 shows the average collection rates for these three locations for each month of the heating season. While viewing these numbers it must be noted that these are the values that would be expected over the long term (say 20 years), and that the values for any one year may be higher or lower than those found in the table.

Table 1. Average solar energy collection rates* for three locations in North Carolina.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April
	(thousands of BTU's/mo per sq. ft. of collector)						
New Bern	22.6	19.7	13.9	15.7	17.1	20.8	21.8
Asheville**	22.0	17.5	12.4	14.1	16.7	18.5	17.5
Greensboro	20.4	17.0	12.0	13.1	14.9	17.3	18.2

*Using a flat plate collector, with water as working fluid, having 2 glass cover plates, an overall heat loss coefficient of 0.7 BTU/hr. sq. ft. F, and a heat removal factor of 0.9.

**Estimated from cloud cover data.

Once the collection rates have been established it only remains to determine heating requirements and select an appropriate size collector that will supply that amount. The average heating requirements of a typical greenhouse per sq. ft. of floor area are listed in Table 2 for the same three locations in North Carolina. Also listed in Table 2 are the estimated annual heating costs for each of the three locations. Examination of Tables 1 and 2 points out one of the major limitations of using solar energy; that is, there is a surplus of energy in October and April and a deficit in December and January. Investigations of large systems to store energy when there is a surplus and retrive it when there is a deficit are bėing conducted by a number of people, but so far no such systems are economically feasible.

Table 2. Average heating requirements and costs for a typical greenhouse* at three locations in North Carolina.

	Oct	Nov	Dec	Jan	Feb	Mar	April	annual cost per acre**
	(thousands of BTU's/mo per sq ft of greenhouse)							
New Bern	-	5.79	12.8	14.5	11.6	7.35	-	$8,600
Asheville	3.60	14.1	20.9	21.9	18.4	14.3	4.22	$16,200
Greensboro	1.10	10.6	18.8	21.6	16.8	11.9	1.56	$13,600

*Double-covered plastic, quonset-style greenhouse with an inside design temperature of 65F.

**Based on LP gas at $0.28/gal.

The collector area required to deliver a given reduction in fuel consumption can be determined from Tables 1 and 2. Figure 3 shows this information in terms of the amount of fuel reduction that can be expected (on the average) for a given ratio of collector surface area to greenhouse floor area. The results for Greensboro and Asheville were essentially the same and were therefore plotted as one line.

Examination of Figure 3 shows that to achieve total solar heating, a grower in New Bern would need 0.925 sq. ft. of collector per sq. ft. of floor area, while a grower in Greensboro or Asheville would need 1.68 sq. ft. per sq. ft. In the latter case, this means 1.68 acres of collector for every acre of greenhouse. Using an estimated cost of $6 per sq. ft. of collector, the system would run about $439,000 per acre of greenhouse. This is a very large investment, especially considering that the savings in fuel costs would only be about $16,000 per acre per year, even for Asheville. Even considering that systems costs might be reduced to as low as $3 per sq. ft. through mass production techniques and that fuel costs might double every three years, the inclusion of depreciation, maintainence, land and operating costs combine to make total solar heating an unattractive investment.

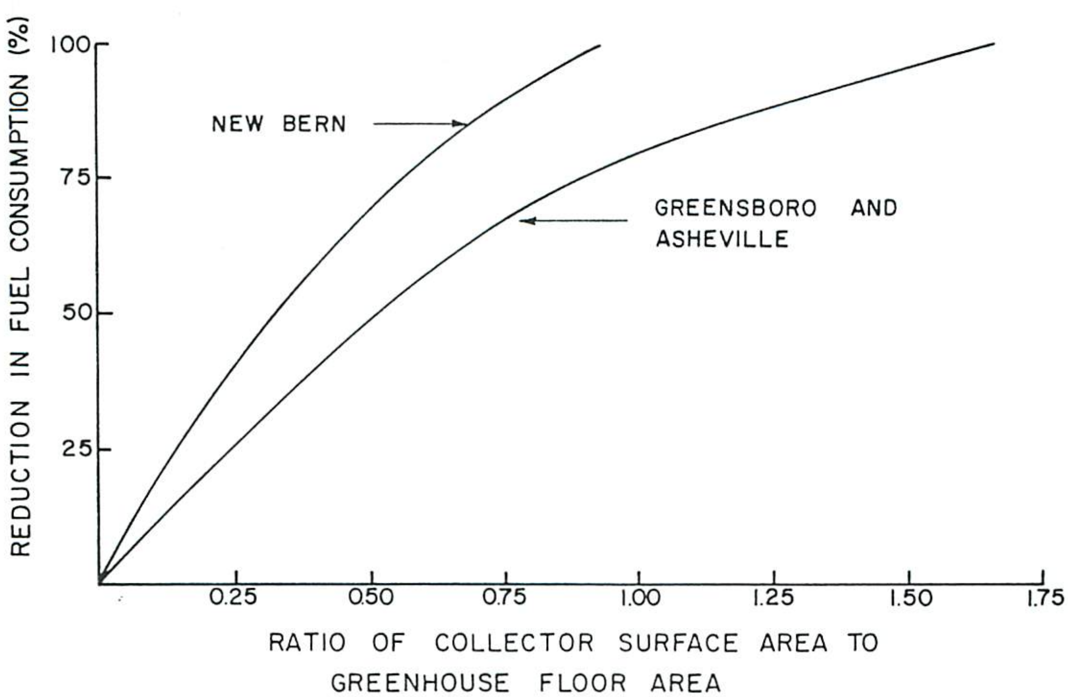

Figure 3. Average reduction in fuel consumption versus collector size and greenhouse area for three locations in North Carolina.

What about supplemental heating with solar energy? The economics are marginal, even here. To achieve a 50% reduction in fuel consuption in Asheville, for example, a ratio of 0.5 sq. ft. of collector per sq. ft. of greenhouse is needed, or 1/2 acre of collector for every acre of greenhouse. Even using the projected mass production costs of $3 per sq. ft., the heating system would run about $65,000 per acre of greenhouse. Whether or not this would be an attractive investment would depend upon the economic situation of the individual involved. If present costs of $6 per sq. ft. are used, however, the system becomes economically unfeasible.

In summary, the following conclusions can be drawn:

(1) Total solar heating for greenhouses will probably not be economically feasible for North Carolina within the near future.

(2) Supplemental heating with solar energy shows promise, provided that costs can be reduced.

(3) A great deal of work remains to be done, especially on solar storage systems. If surplus energy from summer can be stored and used in the winter, supplemental solar heat may become competitive with fossil fuels.

A word of caution must be interjected here. All of the information in this article is based on average conditions for the three North Carolina locations over the last 20 years. This information should not be taken as a guarantee of future performance for a system of the type discussed in the article, but rather it should be used as an aid to general planning. Use of this information for areas other than North Carolina should be undertaken only by competent engineers.