the SunCatcher Design Group™

Specialists in energy efficient, passively solar heated greenhouse design.

Energy efficient **passive solar greenhouses** are designed to harness the sun's energy for (1) plant photosynthesis and (2) greenhouse heating. These systems can reduce a grower's heating costs by as much as 90%. This presentation will highlight the past eight years of passive solar greenhouse research and three passive greenhouse designs resulting from it. First, the presentation will explore basic passive solar principles and then continue with the research and designs, including the conversion of a conventional hoop greenhouse into the passive hybrid hoop design.

The term **passive solar greenhouse** generally refers to greenhouses whose light and heat requirements are largely provided by the sun. Traditional greenhouses have no method of storing the heat they collect during the day and require venting to prevent overheating. The traditional greenhouse must then be heated at night and on cloudy winter days. Energy efficient passive solar greenhouses store solar energy and make it available for these situations. Unlike frequently vented traditional greenhouses, passive solar greenhouses are relatively closed systems and can also be used to sequester carbon dioxide (CO_2) from various sources and to use that CO_2 to increase food production in the greenhouse.

Benefits of Passive Solar Greenhouses

- The passive solar greenhouse will allow farmers to grow crops year-round with minimum or no heating costs thus shielding them from increases in energy costs and at the same time reduce chemical use.
- The passive solar greenhouse will help farmers meet the rapidly growing year-round demand from regional restaurants, grocers and farmers markets for fresh organic produce.
- The low heating requirements and extended growing season can significantly increase growers' profit margin.
- The passive solar greenhouse will provide protection from extreme weather conditions.

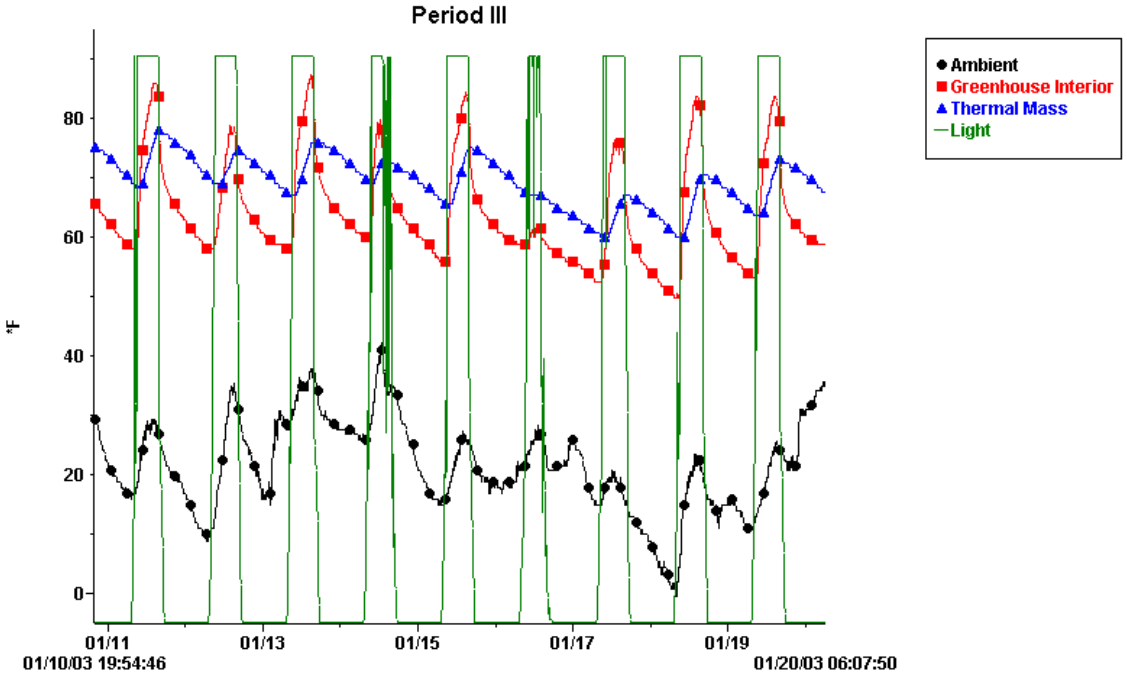
The three basic elements of passive solar greenhouses include:

An efficient collection of solar energy,
the storage of solar energy as heat, and
the prevention of heat loss during and following collection periods.

Parkway Classic Greenhouse Data
Winter of 2002-2003

Data Set / Date	Outside*	Greenhouse*	Thermal Mass*	% light**
I. 12/6-12/17	33.5°	**59.1**°	62.0°	92%
II. 12/17-1/9	34.6°	**58.9**°	63.6°	74%
III.1/10-1/20	21.9°	**63.7**°	69.3°	100%
IV.1/20-1/30	25.4°	**63.7**°	67.6°	84%

*Average temperature in degrees Fahrenheit.
**Percent sunlight entering greenhouse compared to percent recorded during the third data set (1/10 – 1/20).



The Parkway School passive solar greenhouse viewed above is a 12' x 16' research / demonstration greenhouse. The lowest temperature registered during the 2002-05 winters was 42°F and this occurred during a 10-day period of overcast weather. The interior minimum temperature is usually no lower than 50°F. During January 2003, when the average outdoor temperature was 28°F, this passive solar greenhouse maintained an average interior temperature of slightly more than 61°F. This greenhouse operated on average 33°F above the windy, cold conditions outside without the use of any heat source other than the sun itself. **If** propane prices remain $1.50 - $3.00 per gallon, this projects to approximately $150,000-$270,000 in fuel savings over a 40 year period for a commercial-sized passive solar greenhouse located in the mountains of western N.C.

Principles of Passive Solar Greenhouse Design

a) **Orientation** - the site must be located where there is no shadow on the greenhouse glazing three hours before and after local solar noon (in Boone that is 9:30-3:30). Unlike many all-glass north-south oriented conventional greenhouses, passive solar greenhouses have an **east-west orientation** of the long axis of the greenhouse. This orientation optimizes the collection of the sun's low-angle rays in the winter by increasing the area of the glazing facing the southern sky. It is estimated that *changing even a conventional greenhouse from a north-south to an east-west axis can save up to 25% of the energy needed* to heat the space.

b) **Angled glazing** - enhances daytime solar gain in the winter when the sun is at a low angle to the southern horizon while reflecting much of the high angle summer sun to reduce overheating. (*Talk about looking in a pond critical angle*)

c) **Thermal storage** - lowers daytime temperatures and provides heat at night and on overcast days. Black 55 gallon barrels filled with water are used as **thermal mass** to collect and store energy from the sun during the day. It releases it as the greenhouse temperature begins to drop at night and on overcast days. The thermal energy stored in the greenhouse's thermal mass keeps the interior greenhouse temperature well above the

outdoor temperature. This thermal mass reduces temperature fluctuations inside the greenhouse, nearly eliminating the need for daytime venting and nighttime reheating.

d) **Well-insulated walls and roof** - areas that receive little or no direct solar gain in the winter. The greenhouse roof, the north-facing wall and frequently the east- and west-facing walls are **well-insulated** in this design to keep the heat loss to a minimum. These walls and roof cannot collect much sunlight in the wintertime, but certainly can lose a lot of heat if not well insulated.

e) **Silver or white non-transparent interior walls** - reflect sunlight onto plants and the thermal mass.

f) **Light colored exterior walls and roof** - reduce nighttime heat loss and summertime over-heating.

Energy efficient passive solar greenhouses are designed to use **thermal mass**, **insulation**, **glazing**, and **orientation** to collect, convert, and store the sun's energy for heating the greenhouse 24 hours a day. *The passive solar process minimizes greenhouse temperature fluctuations without venting excess solar energy during the day and stores that energy to use at night instead of using expensive, nonrenewable fossil fuels.*

Because many growers will be unable to design and build new greenhouses from scratch, look to see how one can modify an existing "conventional" greenhouse into a passive solar greenhouse. By adding inexpensive insulation on the north wall and thermal masses inside the structure, energy costs may be *greatly* reduced (although possibly not completely eliminated) by considering these important design aspects.

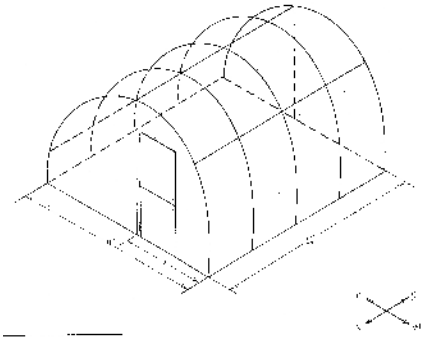
Four Passive Solar Greenhouse Designs

Recycling Existing Hoops using low cost enhancements.

*East / West orientation of greenhouse = 25% increase in winter sun

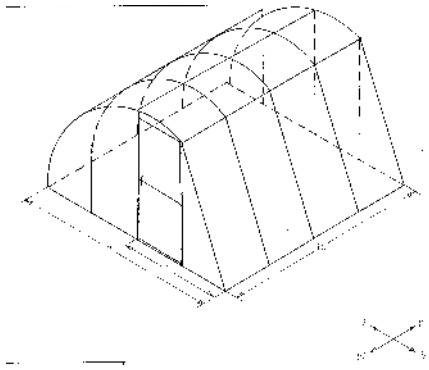
Modified Hoop

E←→W with North Wall Insulation & Thermal Mass



Hybrid Hoop

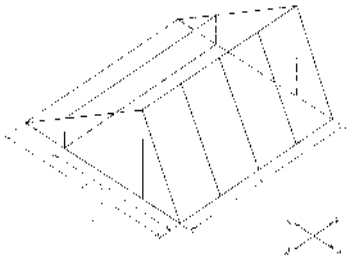
Cut long ways & double length +1/2 width
Growers could get tax credits for this.



New Construction

A-frame

Much lower initial cost of construction and with Tax Credit and may cost less than a conventional hoop greenhouse for initial construction.
Insulation can be easily added.



Classic

Excellent performance but high initial cost of construction.
Virtually no heating costs.

Reading Materials

Clegg P., & Watkins D., 1979. *The Complete Greenhouse Book.* Garden Way Publishing.

Fisher R., & Yanda B., 1980. *The Food and Heat Producing Solar Greenhouse: Design, Construction, Operation.* John Muir Publications, Inc.

Mazria E., 1979. *The Passive Solar Energy Book.* Rodale Press.

McCullagh J., 1978. *The Solar Greenhouse Book.* Rodale Press.

The **SunCatcher Design Group** can help growers with design and construction of new passive solar greenhouses, as well as retrofitting existing hoop greenhouses. For more information, design services, turn-key projects, presentations and workshops, please contact:

suncatcherdg@gmail.com