FARMER & RANCHER INNOVATIONS

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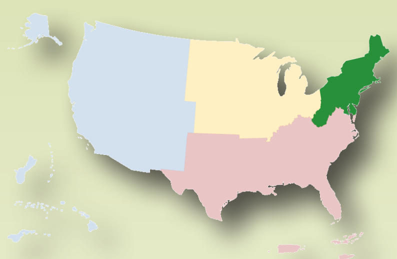

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Developing an Energy Efficient, Solar-Heated Greenhouse in Maryland

Project Summary

The lack of year-round availability of locally grown food and food processing infrastructure are the greatest barriers to increasing the consumption of local food in western Maryland. If an economical, year-round or extended food production system could be developed, it would lead to increased demand for locally produced food, which in turn would foster the growth of needed processing infrastructure.

This project sought to encourage season extension by investigating 1) the effectiveness of energy efficient greenhouse design, and 2) the ability of water-heating solar panels to heat a greenhouse as a propane alternative.

The greenhouse was built on a farm in USDA Plant Hardiness Zone 5b.

Top Findings and Lessons Learned

- Taking advantage of energy efficient design principles, the project organizers built a greenhouse that required a heat equivalent of 348 gallons of propane to maintain a 55-degree temperature—40 percent less propane than is needed to heat a hoop-style poly greenhouse of the same size.
- During the project period, the water-heating solar panels generated enough heat that propane use was reduced by 66 gallons.

COVER PHOTO: Key elements of energy efficient design include a sloping, south-facing roof and a foundation of foam insulation and concrete. The structure was built from a modified car port frame. *Photo courtesy Willie Lantz*

- The combined energy savings of improved efficiency and solar heating reduced propane use by more than 200 gallons.
- Project organizers estimated that fuel savings would pay for these design improvements in about 12 years.

Greenhouse Design

The Energy Efficient Structure

The greenhouse and solar heating system were built in 2009-2010, and data for this project was collected during the 2011 calendar year.

The roof of the greenhouse includes a long, sloped surface oriented toward the south. The foundation was set 3 feet below ground level and has an insulated north wall. The below-ground portion of the greenhouse was constructed using forms made of polystyrene foam that were stacked and filled with concrete. The total width of the wall is 12 inches, and it has an R-value of 30 (a measure of thermal resistance).

A galvanized car port frame was purchased to form the structure for the greenhouse, which is 23 feet by 25 feet. The car port frame was reconfigured to form a 2-foot high front wall (which sits atop a 4-foot concrete base), a flat, south-facing roof, and a 10-foot rear wall. Double-wall, 8-millimeter polycarbonate was selected as a glazing for the roof and above-ground walls of the greenhouse.

The Solar Water Heating System

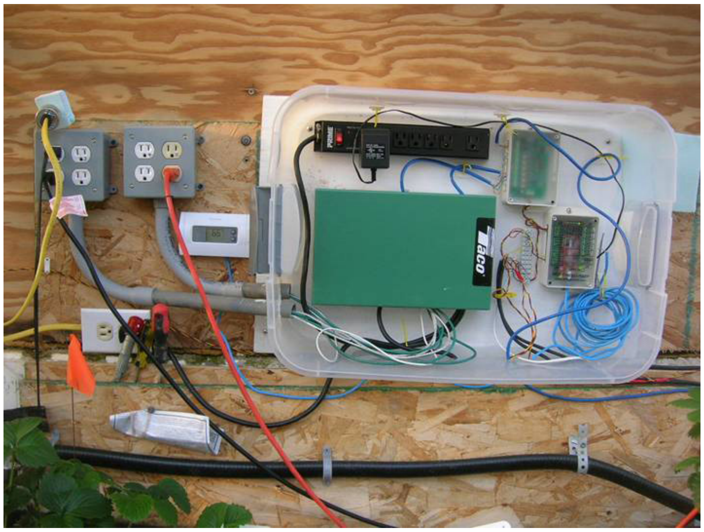
Low-cost, plastic solar panels used to heat swimming pools were donated to the project by FAFCO Solar Water Heating. These solar panels distribute water through small corrugated channels made of black polyethylene material. The 4-foot-by-8-foot panels are lightweight—filled with water, one weighs 50 pounds—and they are excellent at efficiently transferring heat. The panels are designed to heat large volumes of water compared to traditional solar panels. These panels are readily available and can be purchased by anyone desiring to do a solar heating system.

Five panels were erected facing due south at a 36-degree angle in order to maximize wintertime solar energy collection at this latitude. The solar panels were connected to an 800-gallon underground storage tank adjacent to the greenhouse. A 750-gallon-per-hour fountain pump submerged in the tank pumps the water through the solar panels. If the system is not operating, the solar panels are plumbed to allow for complete drainage, which is important to avoid damage from frozen water.

(top) The five solar panels face due south at a 36-degree angle to maximize sunlight exposure in winter. Through a system of pipes, a storage tank and pickup truck radiators (bottom), water is heated by the panels and used to warm the greenhouse. *Photo courtesy Willie Lantz*

To distribute heat throughout the greenhouse, a second fountain pump is used to pump tank water through two pickup truck radiators installed inside the greenhouse. These radiators serve as an economical heat exchanger. A simple box-style fan, located behind the radiator, is used to move the heat throughout the greenhouse.

Fresh air is provided through two 6-inch-diameter earth tubes. The earth tubes are constructed of corrugated drainage pipe. A 4-foot-deep trench was dug for the drainage pipe, then was backfilled an additional 4 feet, to bury the earth tube a total of 8 feet deep. The external end of the earth tube was connected to a PVC stand pipe and covered with a nursery container to keep out animals. Inside the



The control system sensors and electrical outlets for the fans, pumps and other components of the solar water heating system. A long-range wireless router allows for remote control. *Photo courtesy Willie Lantz*

greenhouse, a 250-cubic-feet-per-minute duct fan was fixed to the end of the earth tube, to pull air through.

The Control System

A microprocessor control system was developed to operate the system. Similar systems are used to control geothermal home heating systems. The control system includes sensors and electrical outlets for components such as fans and pumps to plug into. Temperature sensors are located in the top and bottom of the water tank, in the return line from the solar panels, on the surface of the solar panels, outside the greenhouse, inside the greenhouse and inside the earth tube in the greenhouse. These sensors feed information to the microprocessor. A flow meter is also connected to the return line from the solar panel.

The control system turns on the pump to the solar panels whenever the temperature of the panels is greater than the temperature of the tank water by two degree, and turns it off when the temperature drops below the tank temperature. The controller also turns on the pump for the truck radiator heat exchanger whenever the temperature in the greenhouse drops below the desired set point, and if the tank temperature is warmer than the greenhouse temperature. The earth tube fan is turned on and off periodically throughout the day, based on set time intervals.

A backup propane heater is connected to a simple manual thermostat set 2-3 degrees below the solar heating system's operating temperature.

The microprocessor controller can be connected directly to a laptop, or can be operated remotely through the internet, to change the set points on various controls. A long-range wireless router is used to connect the greenhouse to a residential internet connection. For this project, the microprocessor was also developed to send data to an online system for logging energy data, which provides live data as well as automatically updated charts.

Results and Analysis

Energy Savings

The project coordinators estimated that their energy efficient greenhouse would lose 32 million British Thermal Units (BTU) of energy per year, and that a comparably sized, traditional structure would lose 44.8 million BTU of energy per year (see Fig. 1). This translates to an energy requirement equivalent to 348 gallons of propane for heating the energy efficient structure, and 486 gallons for the conventional one—or 40 percent less propane for the energy efficient structure.

The estimate was based on the number of night hours per month, the average nighttime temperature per month, and an assumption of maintaining an internal greenhouse temperature of 55 degrees. The traditional structure used for comparison was a 14-foot-by-40-foot, hoop-style greenhouse with sides of 6-millimeter double polyethylene.

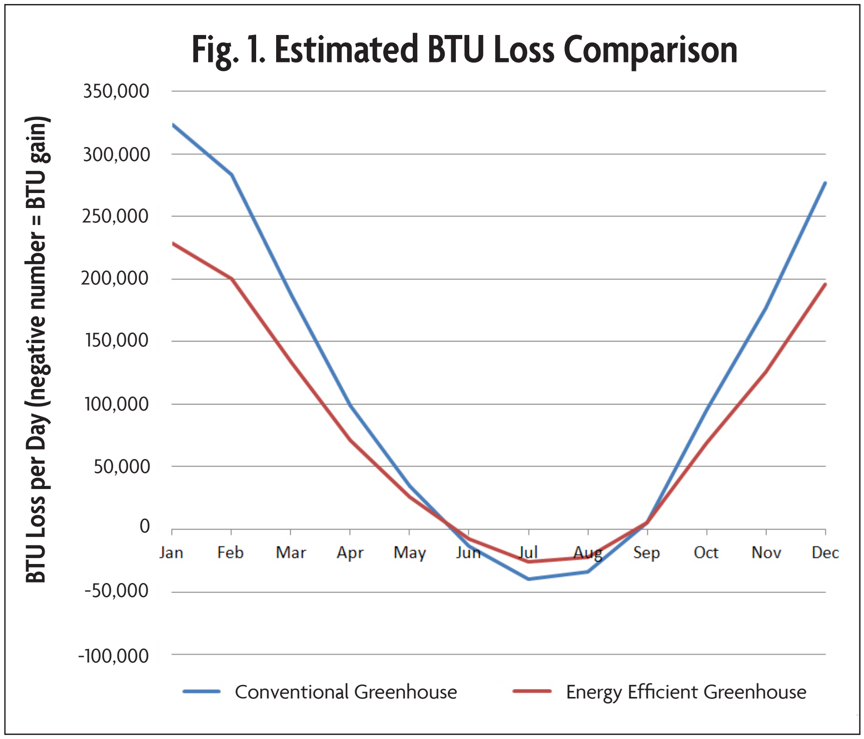
The solar water heating panels worked very well to heat water in the storage tank. During sunny days, even when the temperatures outside were cold (20-40 degrees), the solar panel temperatures were often over 100 degrees. The temperature of the water in the 800-gallon tank was often raised by 20 degrees in a single day. Based on flow meter readings and increased temperatures in the tank, the solar panels were able to create over 150,000 BTU on many sunny days. This is equivalent to nearly two gallons of liquid propane per day. With three to five sunny days in a row, the water tank temperature would often increase to around 100 degrees. This amount of stored heat was able to heat the greenhouse for three to four cloudy days with daytime highs of 40 degrees and nighttime lows of 20 degrees.

Over the course of a year, the energy efficient greenhouse and solar heating system reduced the amount of propane used by over 200 gallon. The system worked effectively throughout the fall, late winter and early spring. The system provided many days' worth of heating without the need for propane. The system provided a majority of the heat in October and November. It also reduced the amount of propane required to maintain 50 degrees during April and May.

Cost Savings

The cost of constructing the energy efficient greenhouse was compared to the cost of a traditional hoop-style greenhouse. The conventional greenhouse would have a construction cost of $3,000. It would also require new plastic once every four years, at a cost of $200. The yearly cost of ownership for the conventional greenhouse, given a life of 15 years, would equal $250 per year. The energy efficient greenhouse cost $7,000 to construct, not including the solar heating system. Given a 15-year life, the yearly cost of ownership equals $467.

The conventional greenhouse would require 486 gallon of propane for winter heating, which at the cost of $2.40 per gallon, would equal $1,166 per year. Without factoring in the solar heating system, the energy efficient greenhouse would require 348 gallon of propane, which equals $835 per year. So, savings of $331 per year in reduced propane use would pay for the additional construction cost ($4,000) of the energy efficient greenhouse in 12 years.



Separately, the solar water heating system used in this project cost $2,000. This includes the solar panels, panel support, pumps, water tank, control system, radiators, and necessary electrical and plumbing, but not installation. The solar heating system was operated from Feb. 1, 2011 until Dec. 31, 2011. The system generated nearly 6 million BTU of heat, equal to 66 gallons of propane, or $158.40 at $2.40 per gallon. The solar heating system did not eliminate the need for propane: 128 gallons were needed to maintain a minimum of 50 degrees. The fuel savings would pay for the solar heating system in 12.5 years.

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