JULY 2007

Profiles in R&D

Applied Research and Development that serves society—today and tomorrow.

Solar Greenhouse Research – 06/07 Results

TEMPERATURE MONITORING AT A solar greenhouse on the outskirts of St. Francois Xavier over winter 06/07 found that a covering of conventional, air-inflated, double poly lined with argon-filled plastic kept the greenhouse warmer than bubble insulation or the poly alone.

The argon-filled lining also appeared to be an effective substitute for the thermal blanket that normally covers solar greenhouses at night to reduce heat loss.

In Elie, additional research at a 2200 sq. ft. solar greenhouse equipped with a thermal blanket showed that the greenhouse could be operated with supplementary electric heat for about $10 a day during the coldest month.

These findings are part of continuing research that seeks to improve the effectiveness of the greenhouse in Manitoba's climate. Optimum operation would reduce space-heating costs for the province's greenhouse growers. It would also set the stage for testing the greenhouses in northern communities, where their operation could offer socio-economic and health benefits for people living in the North.

Research began in 04/05 with tests of a solar greenhouse constructed in Elie. Imported from China, the 22 x 100 ft. greenhouse used a sand-filled rear wall to store the sun's heat during the day and release it at night to keep plants warm. A cotton blanket was unrolled over the single-layer, 6-mil poly covering to cut heat loss during the night.

Blanket Failure

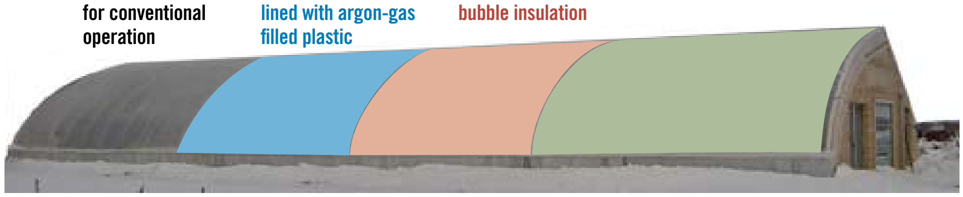
The thermal blanket failed during tests of the first solar greenhouse at Elie in 05/06. The blanket, which tore and was thought to have soaked up rainwater in fall, froze in place one night during a cold spell in January. It could not be rolled up in the morning, causing a crop failure.

When a solar greenhouse was built in St. Francois Xavier in 05/06, researchers tested an interior insulating blanket to avoid the possibility of a freeze-up or other mechanical failure. The blanket was stowed inside the greenhouse during the day, near the highest part of the roof, and unfolded at night along tracks just below the air-inflated double poly. The interior blanket proved difficult to operate and ineffective at holding heat overnight.

As a result of the blanket failure in Elie, and the ineffectiveness of the interior blanket in St. Francois Xavier,

Continued on page 2.

Open house at a solar greenhouse on Blue Lagoon Florascape Farm, St. Francois Xavier, March 31, 2007. Visitors are standing in the argon section, one of three test sections in the greenhouse. The rear wall of the greenhouse is built of 8-inch-thick concrete, painted black, to hold the sun's heat. *Below:* Section coverings used in research at the greenhouse in St. Francois Xavier.



researchers in 06/07 decided to test the effectiveness of an insulating covering that would stay in place, night and day, and have no moving parts, to avoid a mechanical failure.

St. Francois Xavier

The greenhouse was divided into four sections for the research. The first section, for conventional operation, was equipped with auxiliary electric unit heaters and electric heat mats (for keeping root zones of plants warm). The other three sections, each with different insulative coverings, were unheated.

Argon was selected as one of the insulating media because it is transparent and was expected to have an R-value that would match that of the thermal blanket. Cost of the argon in the test section was about $80.

In the second section, strips of 3-mil nylon/poly blend in tubes four-feet wide were fed between the rafters and outer greenhouse air-inflated double poly. These elongated “pillows” were filled with argon gas and the ends sealed.

Air-bubble plastic, made commercially, was used as insulation in the third section. It comes in two-foot wide rolls, which were cut into strips and installed in two layers between the rafters and the outer poly. Two layers of bubble insulation, with the bubbles facing the sky, are rated at R-2.

The fourth section of the greenhouse was covered with conventional double poly without any insulative lining.

The sections were separated by double-walled plastic curtains that extended from the floor to the steel ribs of the greenhouse.

On the night of February 5, the coldest night of the season in St. Francois Xavier, outdoor temperatures plunged to –41.4˚C. Inside the greenhouse, the section with the argon-filled plastic lining kept the highest temperature of the three test sections, at –6.1˚C, versus –9.7˚C for the bubble wrap and –13.3˚C for the uninsulated section.

Most plants in the greenhouse were germinated and kept in the heated section. The argon section housed sage, rosemary, and basil, plants that could take temperatures down to –10˚C. The other sections housed even hardier plants, such as parsley. All plants survived the coldest night.

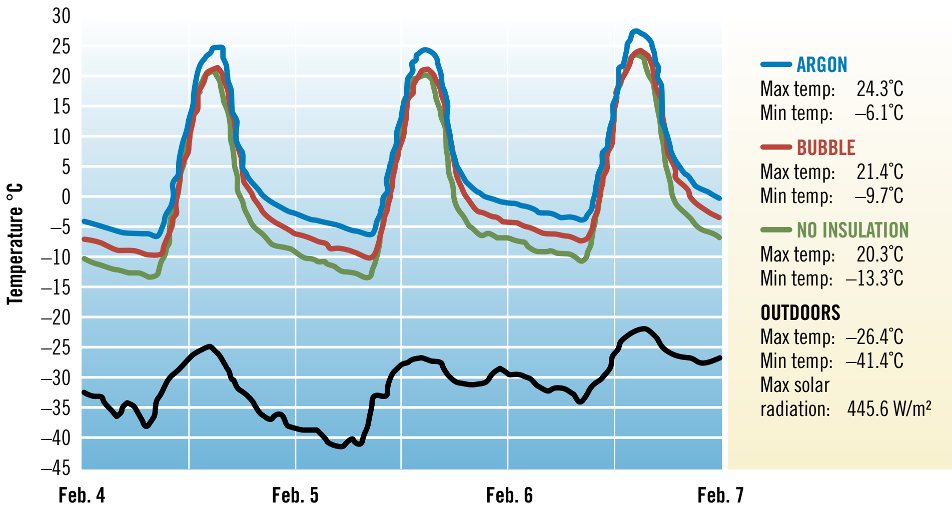
Findings point to the value of a covering filled with argon gas, or some other insulating medium, to admit enough solar energy during the day yet limit heat loss at night, while avoiding the potential mechanical problems of an interior or exterior thermal blanket.

Elie

Temperatures were monitored in two working solar greenhouses at Elie, including the greenhouse used in the first research season in 2004/05.

Continued on page 3.

Performance on Coldest Night



TEMPERATURES IN THE ARGON SECTION

	January, in ˚C			February, in ˚C		
	average	minimum	maximum	average	minimum	maximum
Indoor	4.5	–6.4	28.6	7.3	–6.1	32.7
Outdoor	–15.2	–35.3	4.8	–17.8	–41.4	–1.0
Avg. difference	19.7˚C warmer inside			25.1˚C warmer inside		

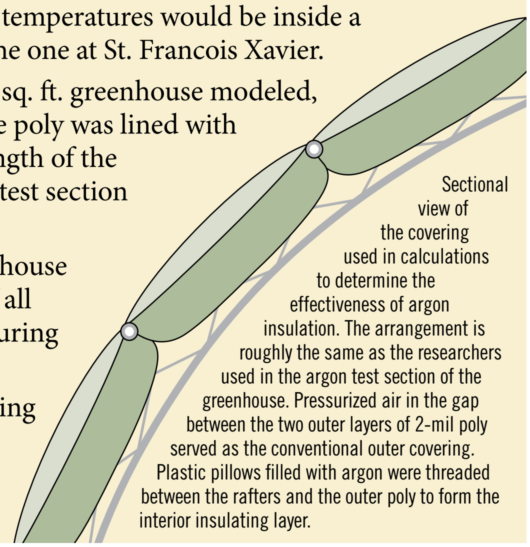
Heat Loss Calculations Confirm Effectiveness of Argon Insulation

The researchers drew on actual solar radiation and outside temperatures for February 4, 2007, to calculate what temperatures would be inside a solar greenhouse the same size as the one at St. Francois Xavier.

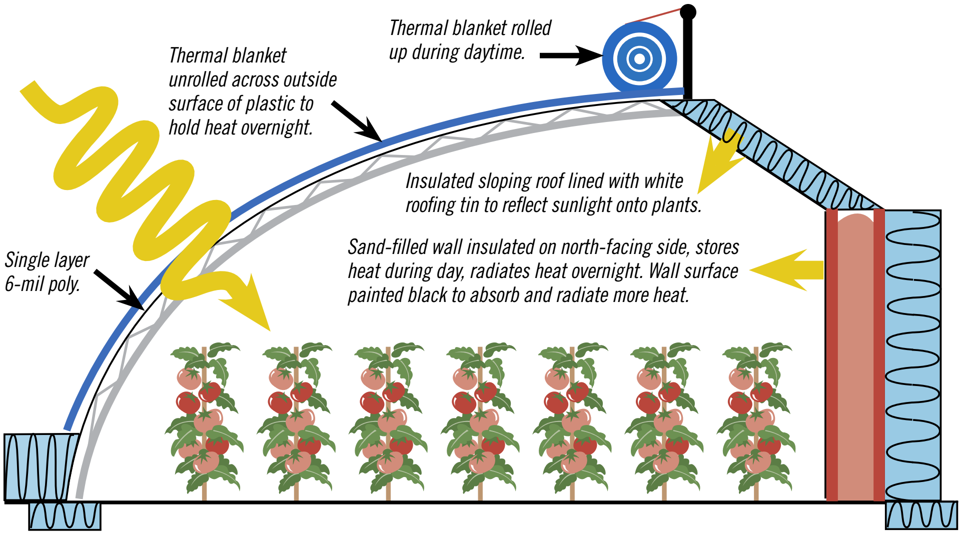
The difference was that in the 2000 sq. ft. greenhouse modeled, the conventional air-inflated double poly was lined with argon filled plastic along the full length of the greenhouse, rather than in a single test section as in the research.

Calculations showed that the greenhouse would stay above 10˚C overnight if all available solar energy is captured during the hours of daylight.

They suggest that argon is a promising solution to replace the thermal blanket covering during the night in a solar greenhouse.



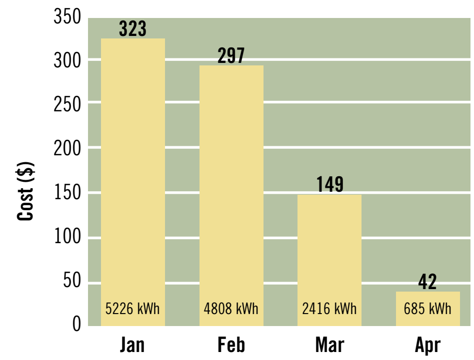
Sectional view of the covering used in calculations to determine the effectiveness of argon insulation. The arrangement is roughly the same as the researchers used in the argon test section of the greenhouse. Pressurized air in the gap between the two outer layers of 2-mil poly served as the conventional outer covering. Plastic pillows filled with argon were threaded between the rafters and the outer poly to form the interior insulating layer.



Design of solar energy greenhouses at Wenkai Oriental Vegetable Farm in Elie.

Cost of Supplementary Heating in the Electrically Heated Greenhouse at Elie

Supplementary heating supplied by two 5-kW agricultural GX heaters, set for a minimum temperature of 13˚C. Cost of electricity: 6.18¢/kW.h.



The insulating blanket on each was sandwiched between protective layers of plastic to seal out moisture that could freeze and render the blanket inoperable.

Supplementary heat was provided by two 5-kW agricultural GX heaters along the rear wall in the first greenhouse, and by a small wood stove at one end of the second.

The 5-kW heaters were set for a minimum temperature of 13˚C. They ran about 18 hours a day during the coldest days.

The unit heaters kept the first greenhouse warm for $10/day in the coldest month. On average, energy consumption of the heaters was roughly 20 per cent of what it would have been in a conventional greenhouse.

The wood stove in the second greenhouse was stocked with firewood each night. It helped keep temperatures above 1˚C overnight.

Plants in both greenhouses thrived.

Looking Ahead

Results continue to support the feasibility of growing vegetables in solar greenhouses over the winter months in Manitoba, but point to the need for a source of supplemental heat to avoid losing a "crop" in extremely cold or cloudy weather.

Upcoming research is expected to look at ways of minimizing supplementary heating by improving the thickness and configuration of insulative coverings filled with argon.

Continued on page 4.

March 22, 2007: Tomato plants seeded in December 2006 in the greenhouse. A wood stove supplied supplementary heat.

February 16, 2007: Chinese broccoli growing in the greenhouse. Two 5-kW agricultural GX heaters supplied supplementary heat.

An experimental hog finishing barn and partially constructed solar greenhouse on the grounds of the University of Manitoba's Glenlea Research Station. A new study is set to test the feasibility of supplementary heating for solar greenhouses using warm, biofiltered air from the hog barn.

Researchers may look into the use of very high-efficiency lighting using light emitting diodes, for extending the growing season in the greenhouse during the winter months.

A hot water heating system using a boiler that burns wood pellets could be tested for its effectiveness as a supplementary heat source.

These and other findings would be of value to solar greenhouse operation in the north, where winter sun angles are lower and daylight hours shorter.

Meanwhile, research is expected to begin in summer 2007 on the effectiveness of warm air drawn from livestock housing as a form of supplementary heating for solar greenhouses. Warm, carbon dioxide-laden air from a hog barn would be circulated through a biofilter of wood chips to scrub odours, then ducted to plants in the solar greenhouse.

Root Zone Heating Popular in the Solar Greenhouse

Plant pots germinating on suspended flats in a solar greenhouse in Elie. The pots are sitting on heat mats to keep root zones warm.

Jack Maendel of Oakbluff Colony points to heat mats that were used earlier this year in a new greenhouse at the colony. "They worked perfectly," he said. High-pressure sodium lighting has given an orange cast to the mats.

Plant clusters in the geranium/heat mat experiment at Bloomers in Landmark. The green heat mats are clearly visible, projecting from underneath the plant pots in the foreground.

GROWERS AT BOTH RESEARCH locations used heat mats in their solar greenhouses to keep germinating plants warm. Heat mats are a type of electric heating blanket that warms the root zones of the plants, permitting lower ambient temperatures in the greenhouse.

Earlier research at an experimental greenhouse at Bloomers, Landmark, showed that with appropriate root-zone heating, greenhouse temperatures could be lowered about 10˚C without having a significant effect on plant height, number of leaves, dry matter, and other indicators of plant performance.

The mats are two feet long by four feet wide and about an inch thick. Their heating elements and temperature sensing circuitry are encapsulated in a rugged, waterproof fibreglass skin. The mats run off 120 volts and are rated at 130 watts. They can be temperature controlled.

WHO'S WHO ON THE PROJECT

Solar greenhouses in Elie owned and operated by **Wenkai Oriental Vegetables**

Solar greenhouse in St. Francois Xavier owned and operated by **Blue Lagoon Florascape Farm**

Heat mats supplied by **Alternative Heating Systems Inc.**

Funders:

- Manitoba Hydro
- ARDI

Researchers:

- **Dr. Chong Zhang**, P.Eng., Principal Researcher, University of Manitoba
- **Ms. Jordan Langrell**, Biosystems Engineer, Research Assistant, University of Manitoba

To find out more about this project, please call:

Dr. Chong Zhang, P.Eng.
Biosystems Engineering
University of Manitoba
204-474-9819
or
Ray Boris, P.Eng.
Business Engineering Services
Manitoba Hydro
204-474-3582

Manitoba Hydro