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Profiles in R&D

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Solar Energy Greenhouses Update

A SECOND ROUND OF SOLAR greenhouse testing continues to support the feasibility of growing vegetables in Manitoban greenhouses over the winter, but points to the need for a source of supplemental heat to avoid losing a "crop" in extremely cold or cloudy weather.

Testing by the Biosystems Engineering department, University of Manitoba was conducted at a solar greenhouse in Elie, Manitoba from November 2005 to May 2006. Research investigated greenhouse design variations in the search for upgrades that could improve performance.

Completed in Elie in December 2004, the solar greenhouse was the setting for a first round of testing from mid-January to March 2005. Imported from China, the greenhouse measures 22 x 100 feet with a roof covered by a single layer of 6-mil polyethylene. A cotton blanket is stowed along the peak and can be unrolled across the plastic at night to help keep heat in. A vertical section of the back wall holds sand to store solar heat during the day and release it at night to keep plants warm. The design of the Elie Greenhouse has been constructed at several other sites in Southern Manitoba.

2006 Test Environment

Research at the greenhouse was conducted by prinicipal researcher Dr. Chong Zhang, Head of Biosystems Engineering at the University of Manitoba; and Dr. Eshetu Beshada, a solar energy specialist who holds a Ph.D. from Hohenheim University, Stuttgart.

In order to test variations in greenhouse design, researchers divided the greenhouse into four chambers, separated by plastic sheeting. Temperature readings from more than 40 thermistors throughout the chambers were recorded and stored on a computer in a shed attached to the greenhouse.

Solar greenhouse under construction at St. Francis Xavier, Manitoba. The rear wall is concrete, a variation of the sand-filled wall used in the greenhouse at Elie.

The first chamber was heated with solar heat only and served as a control for comparison with temperatures in the other three chambers.

In the second chamber, heated by two 5-kW agricultural GX electric unit heaters, germinating plants in pots sat on benches.

In the third chamber, germinating plants were placed on ten 130-watt heat mats resting on trestle tables. Heat mats are a type of electric heating blanket that warms the root zones of plants, permitting lower ambient temperatures. Research at

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Partially unrolled thermal blanket on the greenhouse at Elie. A problem developed with the blanket when a tear in the plastic outer layer allowed rainwater to soak the insulation. In February, the blanket froze in place after it was unrolled, making it difficult to roll up and down.

Bloomers, an experimental greenhouse near Landmark, Manitoba, from February to April 2002, showed that with appropriate root-zone heating, greenhouse temperatures could be lowered about 10˚C without having any effect on plant height, number of leaves, dry matter, and other indicators of plant performance.

Germinating plants were set out on trestle tables and warmed only by solar heat in the fourth chamber.

Results

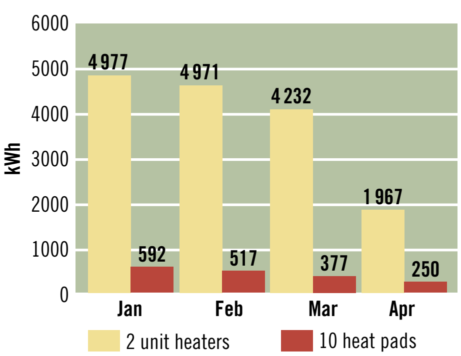
Despite a difference in power consumption of about 140 kilowatt-hours a day between the second and third chambers, testing showed that germination of the plants in both chambers was almost identical.

Percent of Plants that Germinated

	Air heated (Chamber 2)	Root zone heated (Chamber 3)	Solar heated (Chamber 4)
Chinese Broccoli	91%	94%	0%
Green Bean	92%	90%	0%

Power Consumption in the Greenhouse

Chambers 2 & 3, January through April 2006



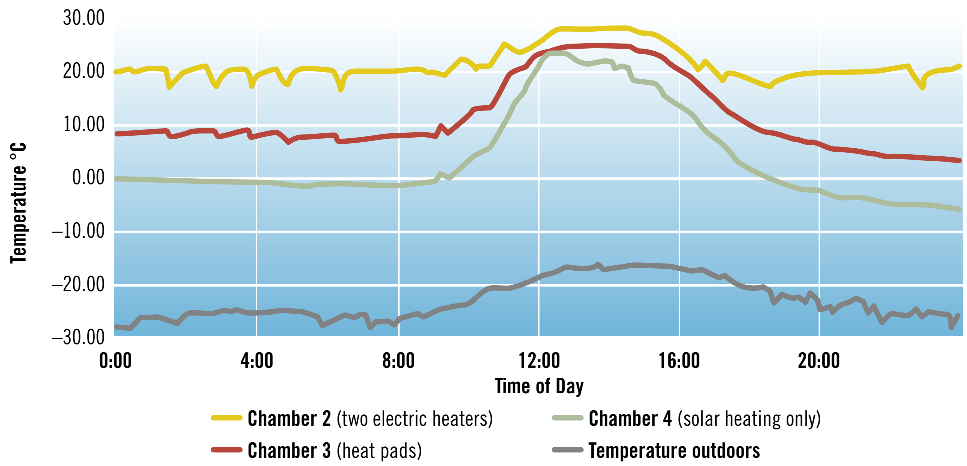
From January through April, heat pads in chamber 3 consumed roughly 90% less power than the unit heaters in chamber 2, yet germination was almost identical in both chambers. Plants on heat mats also survived the blanket problem of February 15.

In the second chamber, the two electric heaters maintained temperature at roughly 18˚C around the clock. Daily power consumption for January and February — the coldest months — was 160 kilowatt-hours.

In the third chamber, heat pads kept the root zones of the plants at roughly 13˚C around the clock, with daily power consumption at about 20 kilowatt-hours in January and February.

Temperatures Inside & Outside Greenhouse

February 15, 2006



Despite extreme cold on February 15, chambers with heat pads kept the plants from freezing. In the chamber with no supplementary heat, temperatures fell below freezing for roughly half the day, causing a "crop" failure in the chamber.

The temperature varied in the fourth chamber (solar heating only) as shown in the chart. Results indicated that temperatures below 0˚C occurred over more than half of the 24-hour period shown. This result demonstrates the need for auxiliary heat in the greenhouse when outside temperatures are extremely cold.

Unusual Conditions in 2006

Weather conditions and difficulties with the insulating blanket that occurred over the test period may have skewed results.

Higher-than-average temperatures and lower total hours of sunshine meant unusually warm and cloudy weather for Southern Manitoba, particularly during January and early February.

The insulating blanket tore and was thought to have soaked up rainwater in fall. On the night of February 14, the grower had unrolled the blanket over the plastic, but could not roll it back up the following morning because it had frozen in place. The blanket was not fully operational for several days following the freeze up, with the conclusion that the insulating blanket was not as effective as it was designed to be.

The difficulties with the blanket may account for lower than expected average temperatures in the fourth chamber, where the plants did not germinate, and where there was higher daily power consumption by the electric heaters during the test period.

Options for Improvement

Researchers are considering numerous options for improving the efficiency and reliability of the solar greenhouse based on the 2006 testing results.

Active Heating of the Rear Wall

A grower at St. Francis Xavier built solar greenhouses using materials from China. During construction, instead of building a sand-filled wall, the grower poured a concrete wall embedded with 120 metres of 25-mm diameter polyethylene pipe. The pipe could carry heated water or other heat-storage fluid from an electric heating system to supplement solar heating of the wall or compensate for falling temperatures on extremely cold nights.

Inside Thermal Blanket

A chamber of the modified greenhouse at St. Francis Xavier was equipped with thermal blankets stored

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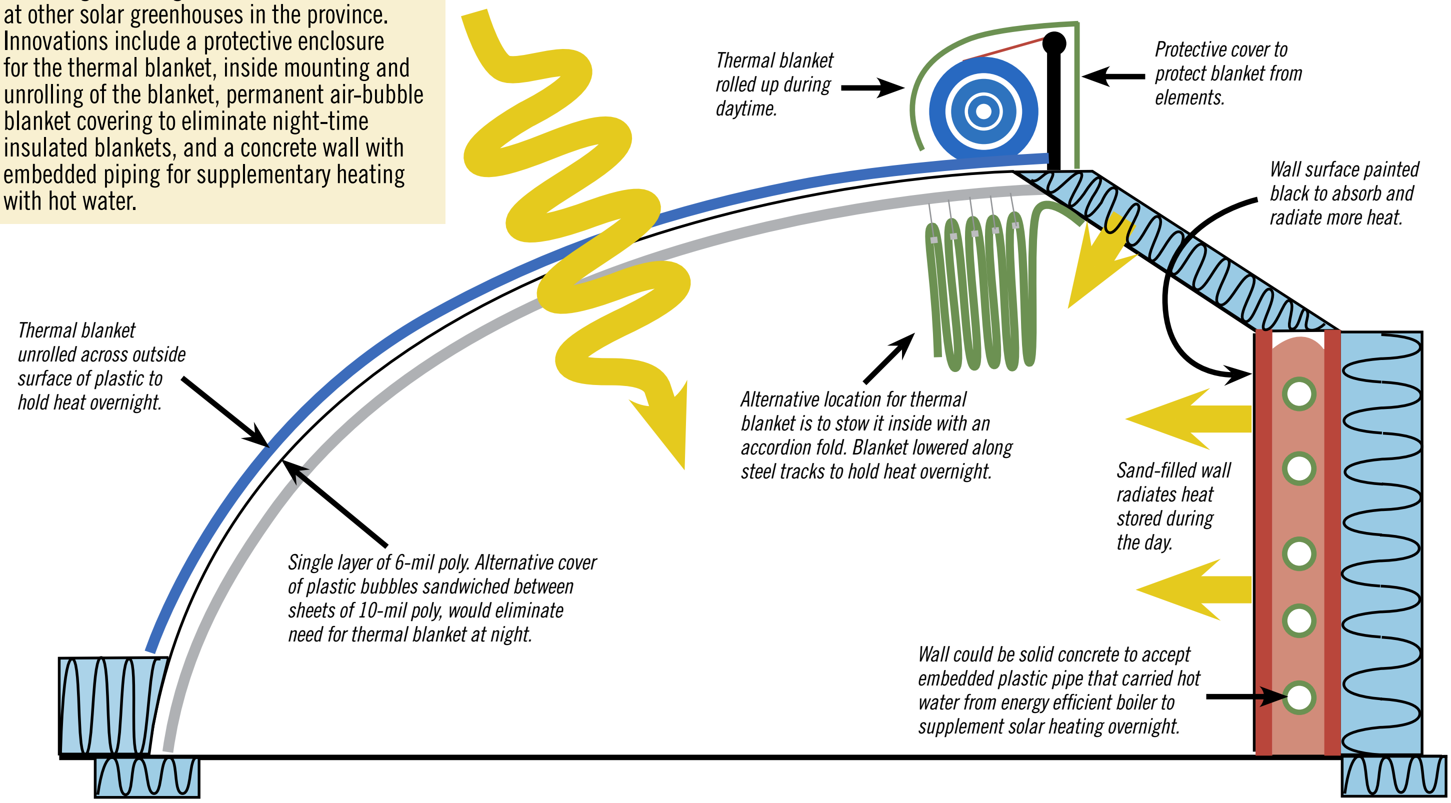
Elie design showing innovations to be tested at other solar greenhouses in the province. Innovations include a protective enclosure for the thermal blanket, inside mounting and unrolling of the blanket, permanent air-bubble blanket covering to eliminate night-time insulated blankets, and a concrete wall with embedded piping for supplementary heating with hot water.



inside the structure just underneath the plastic covering, instead of on top as in the Elie design. The inside configuration avoids problems with freezing of the blanket, as occurred at the Elie installation.

For the greenhouse at Elie, the blanket will continue to be unrolled across the outside of the plastic. When rolled up it could be stowed in a housing that shields it from the elements.

Supplementary Biomass Heating

Researchers have determined that geothermal heating of solar greenhouses is not economically feasible because of the high cost of installation and lengthy payback.

A pellet/corn-fired heating system with automatic stoker may be tested in a second solar greenhouse at Elie.

Warm Air from Hog Barns

Researchers may look into a potentially promising option for hog producers who want to operate greenhouses, where producers would duct warm air from their hog barns into the greenhouse. Air from the barn would first be circulated through a biofilter consisting of a bed of wood chips and compost to remove odours before warming the greenhouse.

Interior thermal blanket at one end of the other solar greenhouse at St. Francis Xavier.

Air-Bubble Plastic

Air-bubble plastic (a type of oversize bubble wrap popular in shipping) would replace the conventional 6-mil poly cover. Heat loss through the plastic would be reduced and keep the plants warm through the coldest hours, replacing the thermal blanket. Developed in the United Kingdom, air-bubble plastic is said to have a very high R-value and good transmissivity for solar radiation.

Black Wall

Researchers also expect to confirm the advantage of painting the sheet metal clad interior wall of the greenhouse at Elie a flat black. Some of the walls, which are made of corrugated galvanized sheet steel with a silvery surface, were painted black this season.

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Second chamber in the greenhouse at Elie, February 7, 2006. One of two 5-kW GX agricultural electric unit heaters, top left, helped keep plants warm. Note section of rear wall, painted flat black to absorb solar heat.

Thermocouple readings in the sand-filled wall showed that painting the surface a flat black increased wall temperatures by five to six degrees Celsius compared with unpainted surfaces.

Locally Available Materials

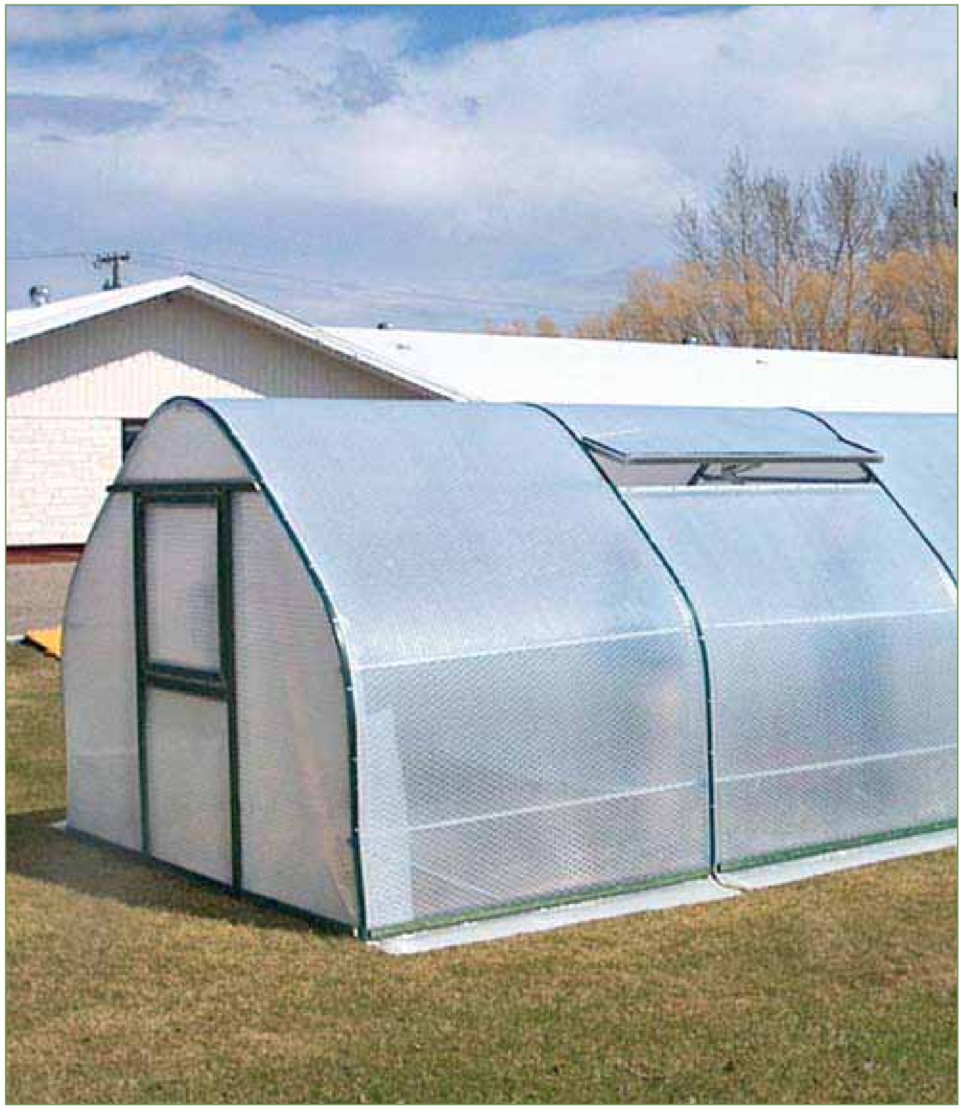
A grower near Boissevain has constructed a solar greenhouse that takes advantage of straw bales and other locally available materials in a design that could prove to be a low cost alternative to the solar greenhouse from China (see article page 6).

2007 Test Season

Problems with the insulating blanket at Elie and unusual weather in the province in 2006, underscore the importance of a third test season for the greenhouse. Researchers would factor in a range of improvements to determine their effectiveness in Manitoba's climate.

Ray Boris, an agricultural engineer with Manitoba Hydro, says the corporation supports research on solar greenhouses because it presents an opportunity to benefit the province's greenhouse growers by lowering their space-heating energy costs.

"The greenhouse may also be tested in northern communities, where successful operation would offer socio-economic and health benefits for people living in the North," Boris says.



This greenhouse, located in Neepawa, is the first of its kind in Canada. It uses a specially designed plastic that the manufacturers say has an insulation value equivalent to R19. Its specialised galvanised steel structure, is capable of withstanding wind speed in excess of 140mph. The performance of the greenhouse will be monitored in upcoming research to determine its capabilities in all weather conditions. The plasic material is also undergoing tests at the Department of Agriculture. Greenhouse ventilation is provided automatically using a temperature sensitive fluid to operate an actuator to open and close a vent near the peak.

WHO'S WHO ON THE PROJECT

Greenhouses owned & operated by:
- Wenkai Oriental Vegetables, Elie
- Blue Lagoon Florascape, St. Francis Xavier
- Room to Grow, Boissevain
- Growing Technologies Inc. – Neepawa

Solar greenhouse designed by:
- Yanlin Science and Technology Service Centre, Shengyan, China

Heat mats supplied by:
- Alternative Heating Systems Inc.

Funders:
- Manitoba Hydro
- ARDI
- NRCan

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Ashern Solar Greenhouse

JEANNIE'S GREENHOUSE HAS OPERATED a solar greenhouse similar to the one in Elie since the end of February 2006. Tim Cameron, who operates Jeannie's Greenhouse just outside Ashern, Manitoba, created modifications to the design to achieve optimum effectiveness.

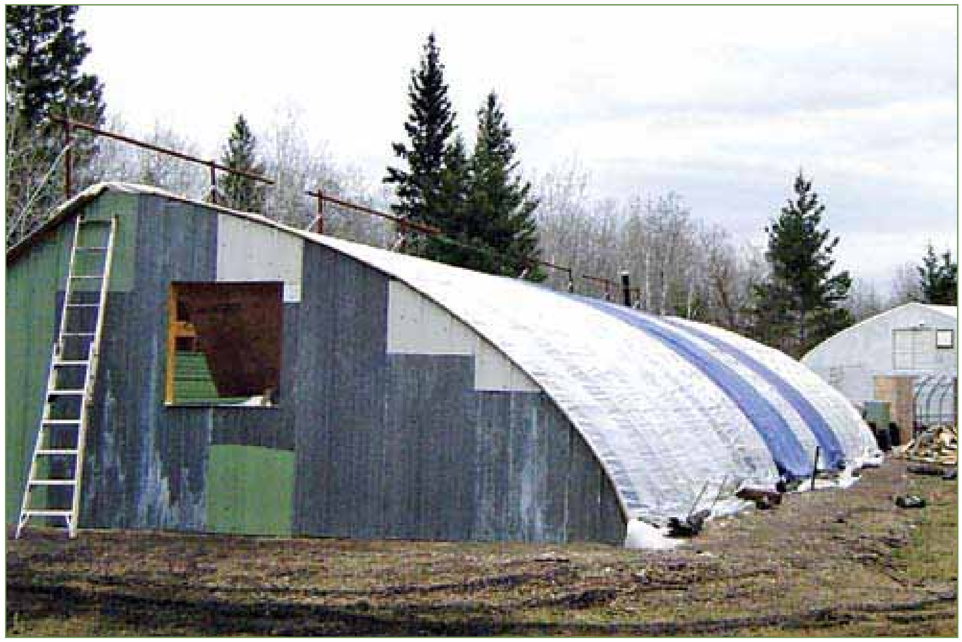
A wood stove, located just inside the entrance to the greenhouse, supplements heat from the solar wall to keep temperatures up early in the season. A furnace fan distributes heated air by blowing the air through a poly duct strung along the base of the rear wall of the greenhouse.

"The stove works well," Cameron says, "But you have to sleep with one eye open to stoke the stove to keep the temperature up throughout the night." For 2007, Cameron is thinking of installing a small electric furnace to provide any supplemental heat needed.

Cameron also says that looking back, other modifications he would have made are to build the rear wall slightly higher and increase the steepness of the front of the greenhouse. With a steeper slope on the steel ribs, any snow on the roof would be easier to push off.

In the future, Cameron also plans on using a traditional double layer of plastic, with air flowing between the sheets, to eliminate the problem of tearing and increase the insulating value of the covering. The single layer of 6-mil poly tends to snap in the wind and cause tears in the plastic.

Sections of the thermal blanket that came with the greenhouse are used by Cameron to shade plants and protect them from sunburn — not to hold temperatures in the greenhouse overnight. But Cameron says that the sections of blanket have already developed small tears and suggests that the traditional black poly or knitted shade fabric would be a less expensive option for shading the plants.



Solar greenhouse at Jeannie's Greenhouse just outside Ashern. Strips of thermal blanket, ordinarily used to hold heat in the greenhouse overnight, are draped over the plastic to shade the plants. Opening in end wall is set to take a conventional vent for greenhouse ventilation.

A wood stove supplements heat in cold weather. Heat from the stove is circulated to the greenhouse by a furnace fan that blows the hot air through a poly duct.

The steel ribs, the sand-filled rear wall, and sloping section of wall shown here are all standard features of the solar greenhouse at Ashern. Steel ribs are handy for hanging plants. The sloping section of wall will be clad in white or silver roofing tin to reflect sunlight onto the plants.

The Ashern greenhouse does not use an opening in the plastic along the top for ventilation. Instead, a fan in the wall at the front door draws air through the structure. Cameron plans to install a 4-foot x 4-foot standard greenhouse vent in the wall at the far end for full ventilation.

Boissevain Design Uses Local Materials

ROOM TO GROW NURSERY HAS BUILT a solar greenhouse using locally available materials where possible to keep costs down and avoid long delivery times.

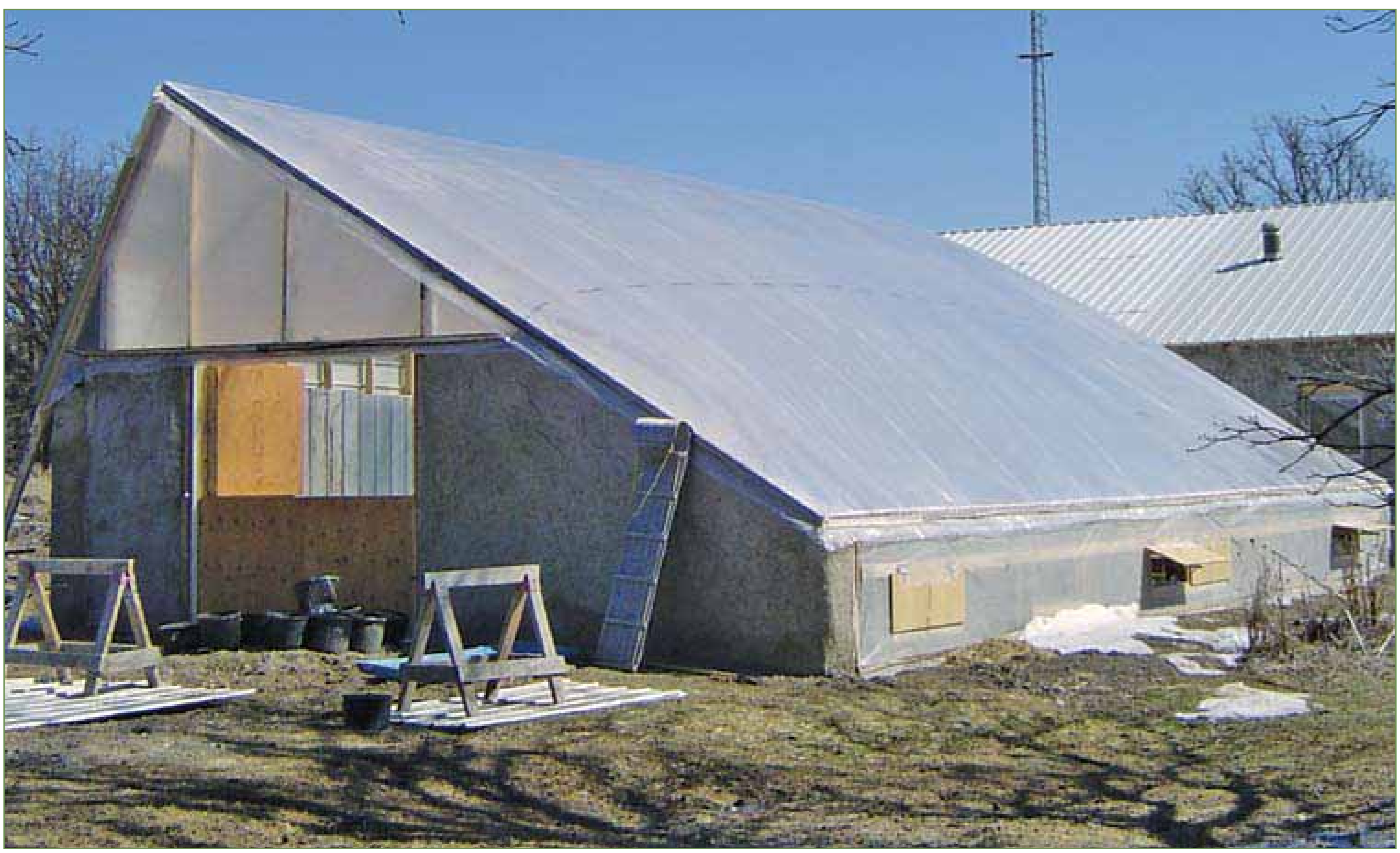
Two by six spruce rafters support the plastic covering of the greenhouse which is framed with wood. The rear wall is insulated to R-50 with stacked straw bales sandwiched between protective layers of stucco. Sheets of roofing tin form an inner wall, four inches from the stucco, to hold gravel that stores heat during the day and releases it at night to help keep plants warm. A wood-fired boiler provides supplemental heat, and a small fan circulates air between double sheets of poly covering the front half of the greenhouse.

David Neufeld who operates the nursery near Boissevain, is a certified organic greenhouse grower and advises on solar greenhouse operation. Neufeld plans on building a small barn for goats and chickens along the rear wall of the greenhouse. Barn walls would be of straw bale and stucco construction, for well-insulated livestock housing. A duct from the barn into the greenhouse would supply plants with warm, carbon-dioxide-laden air.

Another plan would collect warm air from the greenhouse during the day, and circulate it though pipes in the floor slab of the adjoining workshop. At night, air flow would be reversed to return heat from the slab to the greenhouse.

Neufeld may look into the use of metal halide, high pressure sodium, or other high-efficiency supplementary lighting for year-round operation of the greenhouse.

Inside, 2x6 spruce rafters support double 6-mil poly with an air gap. Roofing tin on the rear wall, to be painted flat black, is 4 inches from the inner face of a wall of straw bales encased in concrete. The 4-inch gap is filled with gravel to store heat during the day. Upper section of rear wall will be insulated and clad in roofing tin to reflect heat onto plants, important at low sun angles.



Solar greenhouse designed by David Neufeld of Boissevain. Walls use stacked straw bales protected on both sides by layers of stucco.