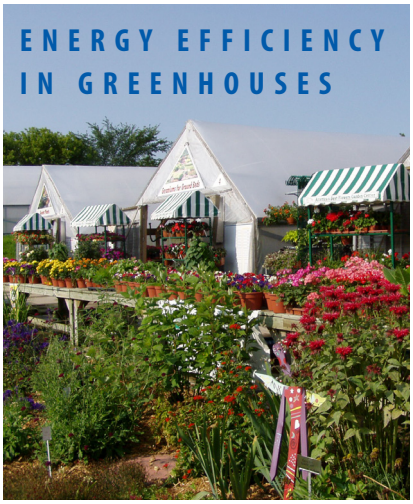


A3907-03

Using curtains to reduce greenhouse heating and cooling costs

Scott Sanford

What can you do to significantly reduce your energy costs? Consider adding curtains!

There are many things you can do to reduce greenhouse heating costs: ensure that furnaces and heaters are cleaned and adjusted to operate at maximum performance, replace old and inefficient heaters with ones rated at 90% efficiency or higher, make sure the greenhouse envelope is tight to minimize infiltration leaks, and partition off unused areas to reduce the amount of heated space. These are important steps that many greenhouse managers are already taking. So, what more can you do to significantly reduce your energy costs? Consider adding curtains!

Greenhouse curtains are not a new technology. They have been available for many years and go by many different names, including screens, thermal blankets, and night curtains. Thermal curtains are fabrics that are pulled across the roof and are sometimes used to cover the sidewalls inside the greenhouse to reduce nighttime heat loss in cold weather. The curtains retain heat by serving as a thermal barrier between the plants and the roof and, in some cases, by reducing the volume of heated space in a greenhouse. Aluminized thermal curtains are designed to reflect the infrared radiation emitted by the greenhouse structure, plants, and benches back into the greenhouse. The same curtains can also be used during warm weather to provide shading, reflect radiant heat out of the greenhouse, or control day length as blackout curtains.

There are a variety of curtain materials available to meet different crop needs, with nighttime heat loss reductions ranging from 20 to 75% and summer shading ranging from 15 to 99.9% (blackout). Since 70 to 80% of greenhouse heating occurs at night, growers can realize substantial energy savings by using thermal curtains at night. Some growers have saved 30 to 50% on their heating bills. In addition, growers who also use curtains for shading during the summer months may also save on electricity due to reduced cooling loads.

Curtain systems

Curtains can be installed in almost any greenhouse, although it's easier to install them in some types of greenhouses than in others. There are three basic types of curtain systems, named according to the location of the curtain. The first type of curtain system is flat and is supported either at the base of the truss rafter or between the gutters on a gutter-connected greenhouse. The curtain can be opened and closed across the greenhouse **gutter to gutter** (figure 1), or it can travel the length of the greenhouse. If the curtain travels lengthwise, it is generally divided into sections between each truss and is called a **truss-to-truss opening curtain** (figure 2).

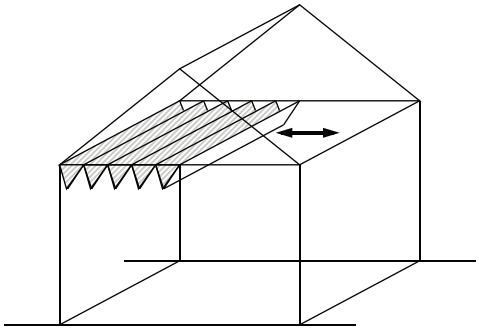


Figure 1. Gutter-to-gutter curtain layout

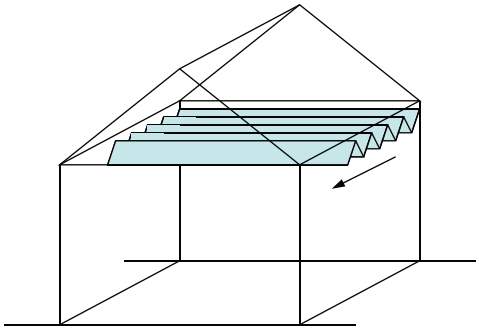


Figure 2. Truss-to-truss curtain layout

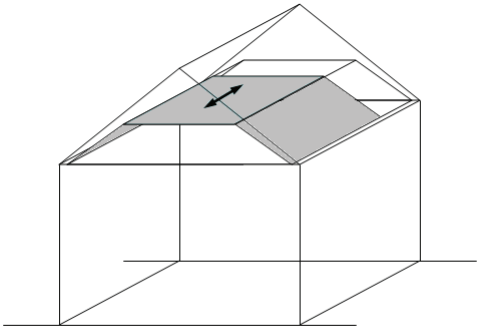


Figure 3. Slope-flat-slope curtain layout

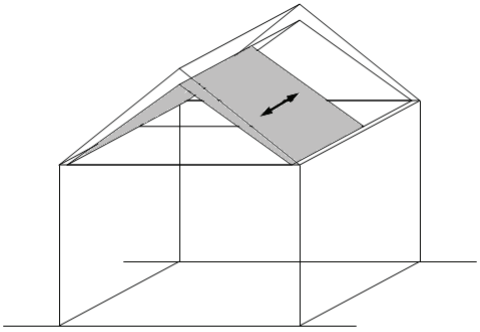


Figure 4. Slope-slope curtain layout

Flat curtains are the cheapest to install and offer the greatest reduction of heated space, but many growers like to hang things from the trusses or rafters. Moving all the lights, irrigation tubing, hanging basket holders, heaters, heating pipes, and other equipment can increase the cost of using the system. One alternative is to support the equipment from the floor instead of hanging it from the trusses. Another option is to install one of the other curtain designs that do not require the equipment to be moved.

To work around the greenhouse equipment, the **slope-flat-slope system** runs parallel to the roof and then flat across to the other side of the roof, staying above the equipment (figure 3). The curtain opens lengthwise from truss to truss. In the **slope-slope system**, which is similar to the slope-flat-slope, the curtain follows the roof and meets the other side under the roof peak (figure 4). This design traps the least amount of cold air above the curtain of any of the systems, which is an advantage when opening the curtains on cold mornings. If there are gable vents or heaters at the end walls, either the slope-flat-slope or slope-slope designs may allow the curtain to be run to the end wall. In some cases, the curtain can only be run to the last truss because of equipment located near the end wall. If that is the case, the last truss will need to be covered with plastic to seal the area above the curtain.

If you are building a greenhouse and plan to install a curtain system in the future, keep in mind that a curtain system requires approximately 12 inches of unobstructed vertical space, referred to as the **travel envelope**. In many newer, gutter-connected greenhouses, the truss beams are connected to the support poles about 12 inches below the height of the gutters. This configuration leaves sufficient vertical space for a curtain to travel above the truss beams while still allowing growers to hang lights and equipment from the trusses.

Curtain support systems

Greenhouse curtains can be supported two ways: they can slide on top of support wires or they can be suspended from wires. For a **sliding curtain**, heavy, 2.5-mm (~$^{3}/_{32}$-inch) polyester wires are strung between the trusses or gutters about 16 to 18 inches apart, and the curtain material lies on top (figure 5). The curtain slides on top of the wires as it opens and closes. The leading edge of the curtain material has a sewn-in pocket that holds a rigid tube known as the **leading edge tube**, to which the mechanical system that opens and closes the curtain is attached. As the sliding curtain opens, the material bunches up and requires a gathering device to keep the curtain behind the leading edge tube (figure 6).

Figure 5. Polyester wires supporting a sliding greenhouse curtain

Figure 6. One type of gathering device that keeps the material behind the leading edge tube as the sliding curtain opens

With the **suspended curtain** system, the curtain is suspended from stainless steel wires installed 3 to 5 feet apart. The curtain hangs from the wires by hooks, which are attached to a web sewn into the curtain. The hooks slide on the wire as the curtain opens and closes (figure 7). As the suspended curtain opens, the material folds up like an accordion (figure 8). The curtain usually hangs 6 to 9 inches from the suspension wire, depending on the hook spacing. Note that with the suspended support system, it's important to use stainless steel wire and not cable because cable will abrade the hooks, causing them to wear through before the curtain fabric has reached even half its life span. The hooks will also slide more easily on wire because it offers less resistance.

Mechanical drive systems

The mechanical system that moves the curtain is usually the most expensive part of a curtain system, but it can be very simple. In a freestanding greenhouse, the system may consist of three or more tracks, similar to the tracks from which hospital privacy curtains hang. If three tracks are used, one is set on each side and one in the center of the greenhouse, and rollers with clips ride in the tracks and attach to the curtain. A simple system can be opened and closed by hand or can be fully automated to open and close based on outside temperature, amount of solar radiation, and/or time of day.

Two types of drive systems are used in commercial operations: the **cable drive** and the **rack-and-pinion drive.** The cable drive has several cable loops that run the length of the greenhouse. A gearbox drive turns a drive shaft (usually a 2- to 3-inch pipe) that runs the length or width of the greenhouse, depending on the type of curtain system. A cable is wrapped around the drive shaft and as the shaft turns, the cable winds onto it on one side and unwinds off the other side, advancing the curtain (figure 9). For truss-to-truss curtain systems, the cable must advance the curtain the same distance as the truss spacing, typically 6 to 12 feet. The leading edge tube of each curtain section attaches to the cable by a clamp or bracket.

Figure 7. Suspended curtain support system

Figure 8. Suspended curtain folding as it is opened

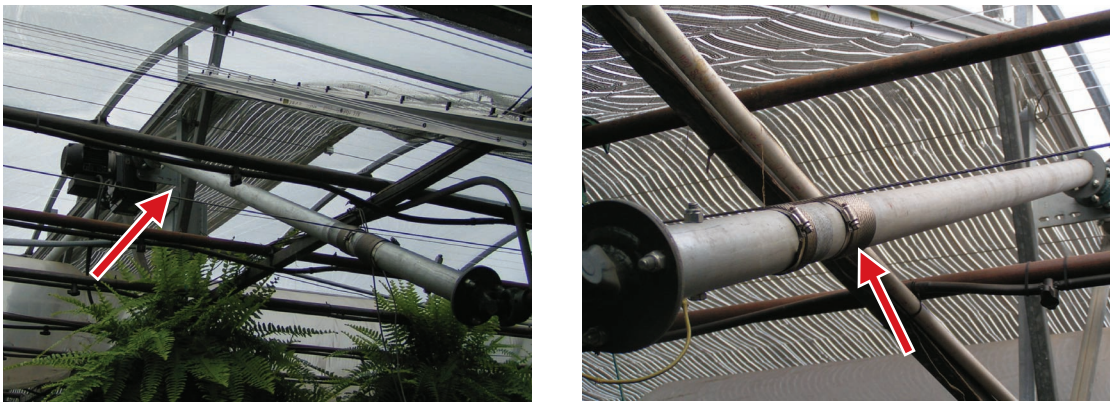
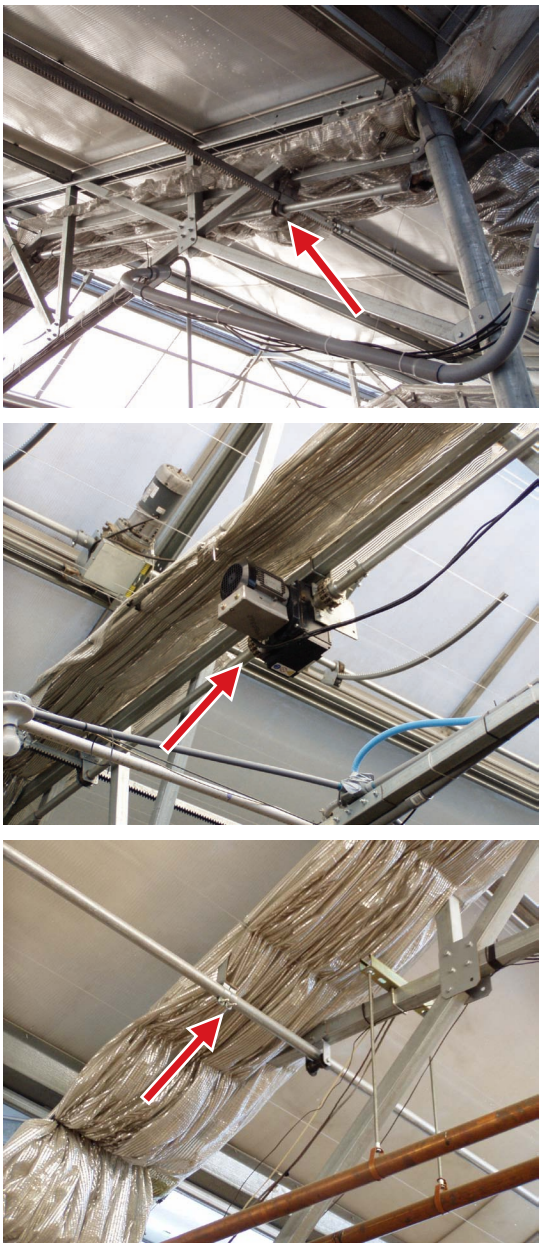


Figure 9. Cable drive system, which includes the gear drive and motor (left) and cable-wrapped drive shaft (right)

Figure 10. Rack-and-pinion drive system, which includes the rack-and-pinion drive (top), gear drive and motor (middle), and push-pull tube and connection to the curtain's leading edge (truss-to-truss curtains only) (bottom)



The rack-and-pinion drive system resembles the cable system, but instead of having cable loops, a tube supported by rollers runs the length of the greenhouse and connects to a rack-and-pinion drive (figure 10). The rack-and-pinion drive is the same length as the truss spacing and the pinion gear fastens to a shaft that is connected to a gear drive. For a truss-to-truss curtain system, three or four pipes are spaced along the width of the curtain. The curtain sections are connected to the push-pull pipe by a clamp or bracket that is connected to the leading edge tube.

The cable or rack-and-pinion drive is usually located below the curtain system but in some cases may be located above a suspended curtain. A gear drive and motor system can power multiple bays in a gutter-connected greenhouse; a joint allows the drive shaft to cross under a gutter to the next bay (figure 11).

A gear motor in a cable or rack-and-pinion system can damage the greenhouse should a limit switch fail or the cable become jammed. This is because of the motor's low speed and high torque. As a result, a typical system has over-travel safety switches that are designed to stop the system if either the open or closed travel-limit switches should fail. The motor should also be wired with a thermal overload to sense if the drive system has higher-than-normal torque load (as in the case of a cable or pinion jam). It is very important that the safety switches remain intact and that if a travel-limit switch fails, the system is not used until the faulty travel-limit switch has been replaced.

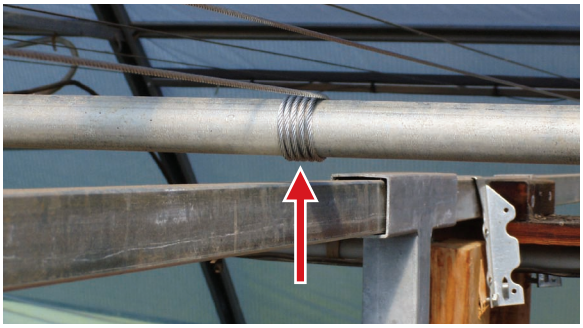
Figure 11. Cable drive shaft crossing to the next bay of a gutter-connected greenhouse via a universal joint

In small greenhouses, the curtain can be opened and closed with a hand-crank device to reduce costs. Figure 12 shows a side-to-side curtain installed in a freestanding, gothic-style greenhouse. A drive shaft runs half the length of the greenhouse, with a crank handle attached to the end. Cables run the width of the greenhouse and are spaced 12 feet apart along the width of the curtain. The cables wrap around the shaft and are connected to the leading edge tube of the curtain. As the crank handle is turned, the cable spools on and off the drive shaft, opening or closing the curtain.

Edge seals

All curtain edges must be sealed when the curtain is closed to prevent warm air from moving to the cold side of the curtain and cold air from displacing the warm, creating a chimney effect. Such an effect can cause localized crop damage as the cold air falls to the floor. The seals don't have to retain any pressure, so they can be as simple as the edge of the curtain material overlapping the edge of another object. One method for sealing the sides of a curtain is to form a trough using curtain material: Keep one edge tight against the greenhouse wall and fold and fasten the other edge over a stainless steel or polyester wire. Leave a generous amount of material between the two edges, forming a pocket in which the curtain edge can lie (figure 13).

Figure 12. Manual curtain system, which includes the drive shaft (top), cable spool (second), clamp connecting curtain and cable (third), and crank handle (bottom)



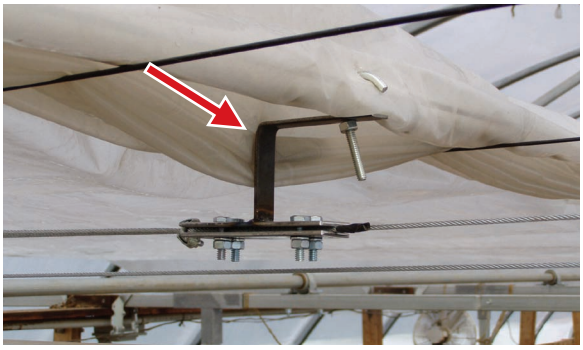


Figure 13. Side edge seal formed by a pocket of curtain material

The leading edge of the curtain can be sealed in a number of ways. Some companies offer aluminum extrusions with a pocket and rubber seals for the leading edge tube to rest against when the curtain is closed (figure 14). In some cases, a piece of curtain material is left hanging and the leading edge slides under the flap of material, allowing the flap to lie on top of the curtain and creating a seal when the curtain is fully closed.

The back edge of the curtain is anchored and sealed to the wall or a truss, depending on the type of curtain system. Companies that sell curtain systems have extrusions or brackets to which the curtain material can be fastened with clips for fast installation. If there are many objects to work around such as rafters or poles, it may be easier to use a starter strip. The starter strip can be cut to get around objects, and it is wide enough that there is a straight edge to attach the curtain to. The curtain can be attached by lapping the starter strip and curtain material, aligning the edges, folding it over twice to form a 1-inch hem, and then putting a stainless steel staple in the hem to hold it together.

Figure 14. Extrusion with rubber seal, one option for sealing the leading edge

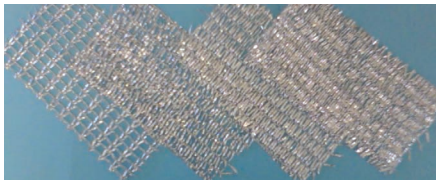


Figure 15. Porous curtain material, with shade factors of (from left to right) 30, 40, 50, and 60%

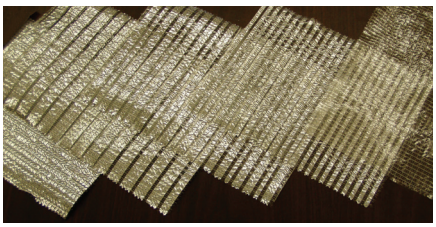


Figure 16. Semi-porous curtain material, with light transmission of (from left to right) 0, 25, 35, 45, and 85%

Any place the curtain has to go around an obstruction such as a post or vent, the curtain material needs to be sealed to the obstruction so no air will leak past. Any other holes, such as those around U-shaped truss components, also need to be sealed or plugged. Gaps can be sealed by taping the curtain or starter strip to the object, and holes can be plugged with foam rubber.

Curtain materials

Almost any type of cloth or sheet material can serve as a thermal barrier, but not all aid in reflecting heat into or sunlight out of the greenhouse. Several materials on the market are made specifically for greenhouse curtain applications.

The main types of curtain materials are nonporous, porous, and semi-porous. Greenhouse film is an example of a nonporous material. The disadvantage of nonporous materials is that when condensation drips off the roof onto the curtain, it puddles and can eventually add enough weight to cause the curtain support to fail. Therefore, nonporous materials are not recommended for greenhouse curtains.

Aluminet® (a registered trademark of Polysack Plastic Industries) is an example of a porous material, which is typically used for shading (figure 15). Porous materials allow condensation to drip through, but they also allow significant air exchange between the underside and topside of the curtain—precisely what thermal curtains try to stop. Porous materials provide approximately 20% heat retention, and the lower the light transmission (or higher the shade factor), the less air movement they allow and the higher the energy savings (see table 1).

Semi-porous materials offer the best alternative for both heat retention and shading without retaining condensation (figure 16). These fabrics are made of alternating strips of clear and aluminized polyester or acrylic fabric tightly woven together, similar to the blue tarps used to cover outdoor items. However, the material is not waterproof, so it resists air movement through the curtain but allows condensation to penetrate. The aluminized strips reflect unneeded light out of the greenhouse during summer and reflect heat back into the greenhouse at night during cold weather.

Flame-resistant fabrics are recommended and may be required for public greenhouses. Check with your local building inspector to determine local code requirements.

Greenhouse curtains typically last 8 to 12 years.

Table 1. Properties of common curtain materials

Curtain material	Ave. % light transmission	% energy savings
Porous fabrics		
XLS 14 F	58	20
XLS 15 F	49	20
XLS 16 F	38	25
XLS 17 F	27	30
Aluminet® R-50%	50	20
Aluminet® R-70%	30	50
Semi-porous fabrics		
XLS 14	55	52
XLS 15	45	57
XLS 16	35	62
XLS 17	25	67
XLS Obscura	<0.1	75

Source: Material manufacturers' data.

Shade factors

If you want both summer shading and cold-weather heat retention, which semi-porous curtain material will be most effective? To answer that question, it's important to know that most plants can use light levels of only 500 to 635 µmol/m^2s (4000 to 5000 foot-candles), but on a June or July day, the sunlight level may be 1250 µmol/m^2s (10,000 foot-candles). If the greenhouse has a double poly glazing, then about 80% of the sunlight, or about 1000 µmol/m^2s (8000 foot-candles), will enter the greenhouse—still more than the plants can use. If a 55% light transmission (45% shade) curtain is used, then about 550 µmol/m^2s (1000 µmol/m^2s x 0.55, or 4345 foot-candles) of light will reach the plants, which is in the middle of the usable range. This curtain will provide a 52% energy savings.

Considerations for open-roof and peak-vented greenhouses

If the thermal and shade curtain system is closed in an open-roof or peak- or gable-vented greenhouse, it will restrict the air flowing out of the vents. There are a few options to avoid problems. The first option is to use an open weave or porous curtain material so air can freely move through the curtain even if the curtain is closed. Curtain materials such as Aluminet® and Svensson® XLS F will reflect sunlight out but have an open weave that allows air through. (Svensson® is a registered trademark of AB Ludvig Svensson.) These materials can be used during the winter for heat retention but reduce heat loss by only 20 to 30%, versus 50 to 75% for semi-porous materials with the same light transmission. Another option is to use a semi-porous material but either leave the curtain partly open or remove a section of curtain so that air can travel around it. Other options include changing the curtain material seasonally (using a semi-porous material in winter and a porous material in summer), or installing two curtain systems, one with a semi-porous curtain and the other with a porous curtain.

Curtain maintenance and management

A curtain system requires a certain amount of maintenance to keep it operating. The edge seals should be checked weekly to make sure the edge is staying in the pocket and maintaining a seal. Wires may need to be tightened now and then, and wear spots on the curtain and hooks should be located and repaired or replaced. The gear motor, rollers, and any universal joints need to be checked and lubricated routinely.

Following some basic curtain management practices will help avoid problems. During periods of snow, the curtain system should be left open to allow the heat from the greenhouse to melt the snow off the roof, avoiding snow buildup that will block light and possibly stress the greenhouse structure. Also, it's best to open the curtain in stages. Cold air is trapped above a closed curtain, and when the curtain is opened, this cold air falls into the growing space and can stress the plants. To avoid problems, open the curtain in stages so the air above and below the curtain have time to mix slowly. Another option is to delay opening the curtain until the sun warms the air above the curtain to some minimum temperature.

Curtain controls

Greenhouse curtains can be controlled manually or automatically, by a time clock or smart controller that can detect solar levels (figure 17). The advantage of a clock or a controller is that no one has to be present to have the curtain open or close. The smart controller has an advantage over a clock because it detects the outside solar level and can control the curtain to optimize heat retention on an overcast day. It also can be programmed to open the curtain in stages to minimize potential cold stress on the plants.

Using curtains for shading

A semi-porous curtain made of aluminized materials and used for shading can reduce the temperature in the greenhouse by about 10°F. This reduces the cooling costs of using fans or evaporative cooling and may improve plant quality. If the shade curtain is installed between the growing space and the roof or gable vents, the curtain should be a porous type or be left partly open to allow some air movement. Some growers install a second curtain to allow flexibility for several crops. The second curtain might be porous for summer shading if it is used in a greenhouse with gable or roof vents, or one curtain might be used for day-length control (100% light block) while the second curtain provides 55% light transmission for normal summer light control. A porous shade curtain closed at the same time as a heat retention curtain reduces the air temperature an additional 4 to 7°F when used for cooling. A second curtain system also increases the amount of heat retention when used in cold temperatures.

Hoop house shade curtains

Sliding or suspended moveable curtains for hoop houses are usually too expensive to use for shading only. Shading in hoop houses can be accomplished inexpensively by installing a shade cloth over the exterior of the greenhouse or by hanging a cloth inside the greenhouse. These curtains are usually installed once and remain in place for the summer months. They are not used for energy conservation during the heating months.

Figure 17. Smart controller, which can detect the outside solar level and control the curtain to optimize heat retention

Energy grants

Thermal curtains reduce the amount of heating required to produce a crop and usually qualify for energy-efficiency grants. If you heat with natural gas, your gas utility should be able to tell you about any utility or state energy-efficiency grants that pertain to your facility. If you heat with propane or heating oil, it is unlikely that any state or local grants are available.

If you are a small, rural business as defined by the Rural Development Program of USDA, you may apply for a REAP (Rural Energy for America Program) grant or loan. All types of heating fuels are included in the program. The REAP program is competitive and requires applicants to submit an application before starting the proposed project or purchasing any materials. The highest-scoring projects are funded with the allocated funds.

Information on energy-efficiency incentives can be found at www.dsireusa.org. For state and utility grants, click on the state where the facility is located; for federal programs, click on the US flag in the upper right section of the page. There are also tax credits for investing in energy-efficiency projects.

Curtain sources

Screen systems and fabrics are available from a number of suppliers; consult your local greenhouse equipment supplier, trade magazines, or the National Greenhouse Manufacturers Association (www.ngma.com) for a list of vendors and products. When installed and used correctly, greenhouse curtains can improve plant growth and reduce both heating and cooling costs with paybacks of 2 to 4 years for an average greenhouse.

Resources

For more information on greenhouse curtains, see the following resources, some of which were used in the preparation of this publication:

"Curtain Systems." National Greenhouse Manufacturers Association. www.ngma.com/standardpdf/curtainsystems2010.pdf.

Energy Conservation for Commercial Greenhouses (NRAES-3). John Bartok, Jr. Ithaca, NY: Natural Resource, Agriculture and Engineering Service, 2001. www.nraes.org.

Greenhouse Engineering (NRAES-33). R.A. Aldrich, J.W. Bartok, Jr. Ithaca, NY: Natural Resource, Agriculture and Engineering Service, 1994. www.nraes.org.

"Save Fuel and Electricity with Energy/Shade Screens." John Bartok, Jr. *Greenhouse Management & Production,* Sept. 2009.

"Selecting a Greenhouse Curtain for Better Environmental Control." Kurt Parbst. *Greenhouse Management & Production,* Dec. 2009.

"Using Shading for Greenhouse Temperature Control." Kurt Parbst. *Greenhouse Management & Production*, Apr. 2010.

Tools

Energy Self Assessment–Greenhouse Self Assessment Tool. USDA–Natural Resources Conservation Service. www.ruralenergy.wisc.edu.

Includes a calculator that can help estimate the amount of energy you could save with a thermal curtain.

Virtual Grower Software. USDA–Agricultural Research Service. Download at: www.ars.usda.gov/services/software/download.htm?softwareid=108.

Build a virtual greenhouse, determine energy use, and see potential savings from energy-efficiency measures.

References to brand names in this publication are included for the convenience of the reader. They are not an endorsement or condemnation of any product, whether included or excluded from the list.

Author: Scott Sanford is senior outreach specialist with the department of Biological Systems Engineering, College of Agricultural and Life Sciences, University of Wisconsin–Madison. Cooperative Extension publications are subject to peer review.

This publication was funded in part by the Wisconsin Focus on Energy program and the North Central Region Sustainable Agriculture Research and Education Professional Development Program of USDA.

This publication is available from your county UW-Extension office (www.uwex.edu/ces/cty) or from Cooperative Extension Publishing. To order, call toll free: 1-877-947-7827 (1-877-WIS-PUBS) or visit our website: learningstore.uwex.edu.