Grower 101:

Understanding (And Avoiding) Heat Loss

With costs on the rise, growers need to examine energy conservation options in relation to the basic mechanisms for greenhouse heat loss and look at energy conservation.

By George Elliott

Fuel prices are again, you should pardon the expression, a hot topic. This past heating season was relatively mild, but growers still experienced fuel-cost increases of 50 percent or greater, and this summer has seen fuel prices reach new heights. I hope your spring sales were profitable enough to invest in energy savings for next year, because there is little hope that fuel costs will decrease and next winter may not be as mild as the last.

With costs on the rise, it is important for those in the industry to examine energy conservation options in relation to the basic mechanisms for heat loss from greenhouses and look at energy conservation in the context of crop production.

Understanding Heat Loss

Heat loss is driven by the difference in temperature between the inside and outside of a structure. The overall rate of heat loss is expressed as Btu per hour. A Btu (British thermal unit) is the amount of heat required to raise the temperature of 1 lb. of water by 1° F. The heat transfer coefficient for a covering material is expressed in Btu per hour per square foot per degree Fahrenheit. The rate of heat loss for a structure is related to the difference of temperature, the heat transfer coefficient of the covering material and the surface area.

The primary mechanism of heat loss is conduction — movement of thermal energy through the covering material. Conductive heat loss (U) values for covering materials range from about .7 Btu per hr. per sq.ft. for double-layer polyethylene to 1.2 Btu per hr. per sq.ft. for single-layer corrugated polycarbonate. In the greenhouse, air movement is responsible for heat convection to the inside surface of the covering. Outside the greenhouse, air movement is responsible for heat convection away from the outside surface.

Air exchange — the outward movement of warm air and inward movement of cold air — is the second major mechanism of heat loss. Air exchange is expressed in terms of the number of exchanges per hour; it ranges from about one-half for new, tight double poly houses to two or more for old, leaky glass houses. Most heat loss is the result of the water vapor in the air.

Finally, heat may be lost by the direct emission of infrared energy from inside the greenhouse through the covering. Radiant heat loss is expressed as a percentage of the incident radiation, that is, the proportion of infrared energy that goes through the covering. Glass transmits about 4 percent, while polyethylene transmits about 70 percent.

Reducing Heat Loss

Growers can use different methods to reduce heat loss from their greenhouses. Often, small investments in energy efficiency can pay off more quickly than purchasing big-ticket items.

Insulation. Conductive heat loss can be reduced by insulation. For example, the U value of 1-inch rigid board insulation is about .14. However, the use of insulation is limited because of the need to avoid blocking light. If crops are grown on benches, insulating the walls below the bench is worthwhile. Even if crops are grown on the floor, it is worthwhile to insulate the foundation and the perimeter at ground level. Insulating the north wall used to be recommended, but the loss in indirect light may outweigh the advantage of reduced heat loss.

Double-layer coverings. Using double-layer coverings also decreases conductive heat loss. With a double-layer covering, the dead air space between the layers reduces heat transfer. Over-inflating double poly can negate this effect if the gap is large enough to allow convective heat transfer between the inner and outer layers.

Plugging leaks. Reducing air exchange is often simply a matter of plugging leaks. Any opening in the greenhouse surface has the potential for leaks: Doors, fan housings and vents are all apt to have gaps or fail to close tightly. Proper maintenance, caulk and weather stripping are simple solutions to excessive air exchange. Covering fan housings and vent louvers can also reduce air exchange. However, some air exchange is necessary to avoid depleting carbon dioxide and increasing humidity in the greenhouse atmosphere.

*Top: Reducing air exchange is often simply a matter of plugging leaks. The gap between this door and sill could easily be blocked with weather stripping. **Middle:** Inaccurate and imprecise controls will waste heat by failing to maintain temperatures at the appropriate level for a crop. An electronic temperature control is more accurate and precise and can reduce heating costs. **Bottom:** Under-bench heat creates a warmer microclimate in the growing area. This greenhouse uses skirts on the bench to further confine the heat. (Photos: George Elliott)*

Energy/shade curtains. Energy curtains can reduce radiant heat loss. Energy curtains also reduce convective heat transfer to the roof — in effect, the curtain creates an attic with a cooler temperature than the growing area, thereby reducing the difference in temperature. The curtain has to fit tightly to trap warm air in the growing space; otherwise, warm air will rise into the "attic" and reduce its effectiveness.

Many greenhouses use an energy curtain that also serves as a shade curtain in the summer. However, shade curtains are inevitably less efficient than single-purpose heat retention curtains ➧

— after all, a shade curtain has to let in some light! Completely opaque curtains provide greater energy savings. These curtains can also be used as blackout curtains for photoperiod control. Some growers install a double-curtain system — one for shade and one for energy conservation/photoperiod control.

Infrared-reflecting additives. Polyethylene film with infrared-reflecting (IR) additives that reduce radiant heat loss can be used for the inner layer of a double-poly covering. However, these films also transmit less photosynthetically active radiation. Since the net light transmission of double poly is already relatively low, the use of IR films is restricted to crops with a low light requirement.

Windbreaks. Outside the greenhouse, a windbreak can reduce infiltration of cold air and convection of heat away from the greenhouse. Proper design is essential — an incorrectly designed windbreak can actually increase heat losses.

This covering is not properly attached, allowing a large gap for air exchange.

Maintain/Update Systems

On average, about 15 percent of the potential heat in fuel is wasted because of heating system inefficiencies. While some loss is inevitable, an efficient system for generating heat and transferring it to the crop will reduce fuel consumption. Poorly maintained furnaces or boilers will burn more fuel to deliver the same amount of heat. Regularly scheduled service will reduce fuel consumption. At some point, it will be worthwhile to replace older heating units with modern, more efficient heaters.

Inaccurate and imprecise controls will waste heat by failing to maintain temperatures at the appropriate level for a crop. Mechanical thermostats are notoriously inaccurate and imprecise and should be replaced, at the very least, with electronic controls. More sophisticated temperature controls will pay off in both reduced energy consumption and improved crop production.

Transferring heat to the crop can also offer opportunities for energy conservation. Root-zone heating (either in the floor or under the bench) puts heat where the plants are. If the crop temperature is at the desired point, the bulk air temperature can be maintained a few degrees lower. Dr. A.J. Both at Rutgers University, New Brunswick, N.J., has shown that growing crops on a heated floor and dropping the bulk air temperature from 60 to 55° F can reduce fuel costs by more than 25 percent.

Managing Crops

Crop management is the third component in energy conservation. It may be tempting to lower the temperature for crop production, but it is definitely not advisable. Crop growth and development rates are directly related to temperature, so growing cooler means growing slower. Increased growing time means lower productivity. To have crops ready in time for spring sales, they have to be started earlier in the winter. Dr. ➧

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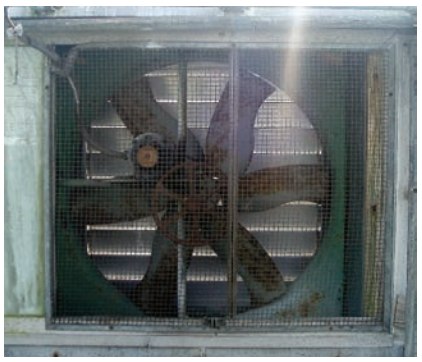
Erik Runkle (Michigan State University, East Lansing, Mich.) and Dr. Paul Fisher (University of Florida, Gainesville, Fla.) have shown that cooler temperatures with an earlier start can actually increase the overall heating requirement for the crop. Growers will usually be better off delaying the start of the crop and growing at warmer temperatures under more favorable weather conditions.

The average daily temperature (ADT) determines crop growth rates. Within limits, maintaining the same ADT with warmer days/cooler nights can reduce heating costs. On a sunny day, it is cheaper to keep a greenhouse warm during the day because solar energy is free. However, there are limits to this approach: Some crops have minimum night temperature requirements, excessively high daytime temperatures may be stressful and a higher day/night difference (positive DIF) will cause some crops to stretch.



Fan or vent louvers that do not close tightly should be adjusted for proper operation.

Management Is Key

The key to heating energy conservation is careful management. Greenhouse operators must first take steps to minimize heat loss and maximize heating system efficiency. Second, they must optimize the greenhouse environment for plant growth.

Heating is one of many costs incurred in producing crops. Trying to reduce heating costs at the expense of productivity would be penny-wise and pound-foolish. Small investments in energy efficiency like insulation or weather stripping can pay off more quickly than big-ticket items like a new heating system or energy curtain. However, with continued high energy costs, it may be worthwhile to replace inefficient systems sooner rather than later.

It is worth reflecting that this is not the first time that a rapid increase in energy prices has had serious financial impact on greenhouse operations. Whatever the causes may be for the current petroleum price situation, it appears that it may not be a "spike" that will be as quickly forgotten as in the past. Furthermore, the energy-conserving innovations that became available as the result of demand from earlier energy crises have been widely adopted in the greenhouse industry. It remains to be seen if there are additional opportunities for significant reductions in energy use. GPN

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