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REDUCE GREENHOUSE *Production Costs*

Dealing with the high cost of energy for greenhouse operations can be a challenge, but close attention to detail and a few practical changes can help keep those costs in check.

By Joyce G. Latimer

Increased fuel costs and fluctuating winter temperatures make heating costs a significant burden on many greenhouse operations. So, how can growers deal with high energy costs in the greenhouse? The problem can be addressed in several different ways. Growers can conserve energy in the greenhouse, evaluate alternative or additional fuel sources or heating systems, evaluate growing temperatures and other production practices, consolidate operations into less space, critically evaluate when to bring the next greenhouse into production and, finally, streamline operations.

Regardless of what growers do to reduce energy use, they still have to examine how to pay for increased costs related to higher fuel prices. Growers have suffered increases in the prices of pots and plastic as well as peat, pesticides and fertilizers over the past few years. In addition to the increased direct costs of heating, growers will be faced with higher transportation costs as well—not just for the products they are delivering—but also for those they receive: It's been predicted that gasoline prices will continue to skyrocket this spring. So, in addition to reducing costs in the greenhouse, how can growers adjust their production and pricing to remain profitable?

Conserving Energy in Greenhouses

The greenhouse structure

The first line of defense in efficient heating of a greenhouse is the structure itself. Losses vary depending on the greenhouse covering and the age of the structure. In general, newer structures will have better seals around the coverings and openings than older houses.

• Double polyethylene (poly) coverings reduce heating costs about 50 percent compared to single poly coverings. Different polyethylene films vary from 35 percent to 60 percent heat loss. Ask your supplier about the film's thermal value. Selecting films that reduce water condensation will enhance light transmission and improve heat retention. Maintaining proper inflation between double poly layers is critical to maximizing the insulation value of the covering.

• Consider retrofitting. A glass greenhouse can be covered with one or, preferably, a double, inflated layer of poly for extra insulation during the winter. A single layer of film over glass can reduce annual heating costs by 5 percent to 40

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percent, whereas a double (inflated) layer can reduce costs 40 percent to 60 percent. Remember that there is a trade-off between increased energy efficiency and reduced light transmission with additional layers of poly.

• Winterize openings. A tight greenhouse with few air leaks around vents, fans or doors will cost less to heat. Repair any holes in the plastic, glass or doors. Keep doors closed and caulk or weather-strip door frames and other openings.

Maximize the insulation

• Endwalls. Insulate the endwalls of the greenhouse, especially the north endwall. This wall can be constructed of a solid material like wood: Plywood (½-inch thick) will lose about the same amount of heat as a double poly wall. At least, insulate this wall for winter production. Reflective (foil backed) insulation boards provide better insulation than other rigid foam boards. Place them with the reflective side facing into the greenhouse. If possible, add windbreaks outside the greenhouse along the north wall. These may be conifers planted for screening or a temporary fence material to divert the wind over the greenhouse. The south endwall can be insulated with an extra layer of plastic.

• Foundations on new construction. On new construction, foundation heat loss can be reduced by half through the installation of 1 to 2 inches of polyurethane or polystyrene insulation. This should be installed 1.5 to 2 feet deep around the foundation wall with care given not to leave gaps or openings. This is especially important when installing any type of floor heating system.

• Existing foundation and sidewalls. If the foundation of the greenhouse was not insulated during construction, make sure that all gaps or holes below the foundation board are filled or repaired. If the greenhouse has a concrete kneewall, insulating the inside of it with insulation board can significantly reduce heat loss. Reflective insulation boards can be added to the inside of any flat greenhouse wall but should not extend above the crop or bench height. Leave a small airspace between the insulation and the sidewall to prevent freezing of the greenhouse wall. Be sure that the reflective surfaces are not in contact with perimeter heating pipes. Sidewall insulation can reduce annual heating costs 5 percent to 10 percent.

• Fans and vents. To reduce other air leaks, insulate secondary fans and vents to reduce heat loss through unused areas during the winter. Do not cover all of the vents; remember that winter ventilation is required for humidity control and to restore the oxygen/carbon dioxide balance in the greenhouse. Keep these vents in good working condition so that they close tightly when not in use.

Add a thermal blanket

Up to 85 percent of the heat loss from a greenhouse occurs at night. Using a thermal blanket to retain heat at night can be a cost efficient investment. These blankets are easier to install and create less shading in gutter-connected houses than in a Quonset house. Remember to use a porous curtain material so that condensation from the underside of the roof of the greenhouse will not pool above the plants. Use a flame-resistant material or, for growing structures, a thermal blanket that alternates flame-resistant and non-flame-resistant material. For greenhouse structures in which an internal curtain cannot be installed, external curtains are available that can reduce radiation loss from the greenhouse at night.

• Reductions in heat loss. Blankets offered primarily for heat retention can reduce energy use by up to 50 percent, whereas blankets offered as combination thermal blanket and summer shade protection can reduce winter energy use 25 percent or more.

• Recouping installation costs. With purchase and installation costs running $2.00 to $2.50 per square foot, these systems pay for themselves in one to two years or less under high fuel prices.

• Installation details. Make sure that the blanket fits the greenhouse walls tightly to reduce heat loss above the blanket. Heating or water lines should be located below the blanket or be well insulated to reduce heat loss.

• Open slowly. Take care not to open the blankets too quickly over a chill-sensitive crop. On 10°F to 20°F nights, the temperature above the thermal blanket could be 30°F in a 60°F greenhouse. Open the blanket 6 to 12 inches for about 30 minutes to allow mixing of the air before opening it completely. Some growers wait until the sun has risen and warmed the air above the blanket before opening it, allowing that air to mix with the rest of the greenhouse air. This may be dictated by the light requirements of the crop.

• Keep it open during snowstorms. In the case of snow storms, the blanket should be left open to allow the heat to reach the roof to prevent snow accumulation on the roof of the greenhouse.

Heating system efficiency

Maintaining maximum heating efficiency of the existing heating system is critical to reducing heating costs in the greenhouse.

• Annual maintenance. Examine the equipment for physical damage to any parts of the system. Check the vent pipe and air inlet or discharge pipes for obstructions (bird nests, for example). Furnaces should be cleaned and adjusted at least once per year. Check that the boiler, burner and backup systems are operating in peak efficiency. Clean the soot from inside the furnace. *A 1/8-inch layer of soot can increase fuel consumption by as much as 10 percent.*

• Fuel choice. Use the proper fuel for the system for maximum efficiency.

• Insulation. Insulate boiler or distribution pipes in areas where heat is not needed.

• External air for combustion. Install an air inlet pipe for direct-fired heaters to provide fresh air for combustion from outside the greenhouse.

• Clean radiation surfaces. Clean heating pipes or other heat radiation surfaces frequently.

• Motors and pumps. Keep all motors and pumps properly maintained for maximum efficiency.

Warning: *Do not inhibit the fresh air supply to the greenhouse heater.* If you are using a heater that requires greenhouse air for combustion, be sure to leave about 1 square inch of opening for each 2,000 Btu/hr of heater output. If possible add an inlet pipe from outside air to serve the burner.

Add horizontal air flow (HAF) fans

Reducing air leaks and heat loss in the greenhouse will make the house "tighter," which will also tend to increase the relative humidity. Regardless of the type of heating system used, it's important to install a sufficient number of horizontal air flow (HAF) fans to adequately circulate the air inside the greenhouse. Good air circulation will improve temperature and humidity uniformity in the greenhouse, which reduces the incidence of cold pockets in the greenhouse and improves plant quality and uniformity. Monitor the humidity level in the house, generally keeping it below 80 percent to minimize disease incidence, and be sure to vent when necessary.

• Air speed. Air circulation by the HAF fans should be maintained at 2 to 3 cubic

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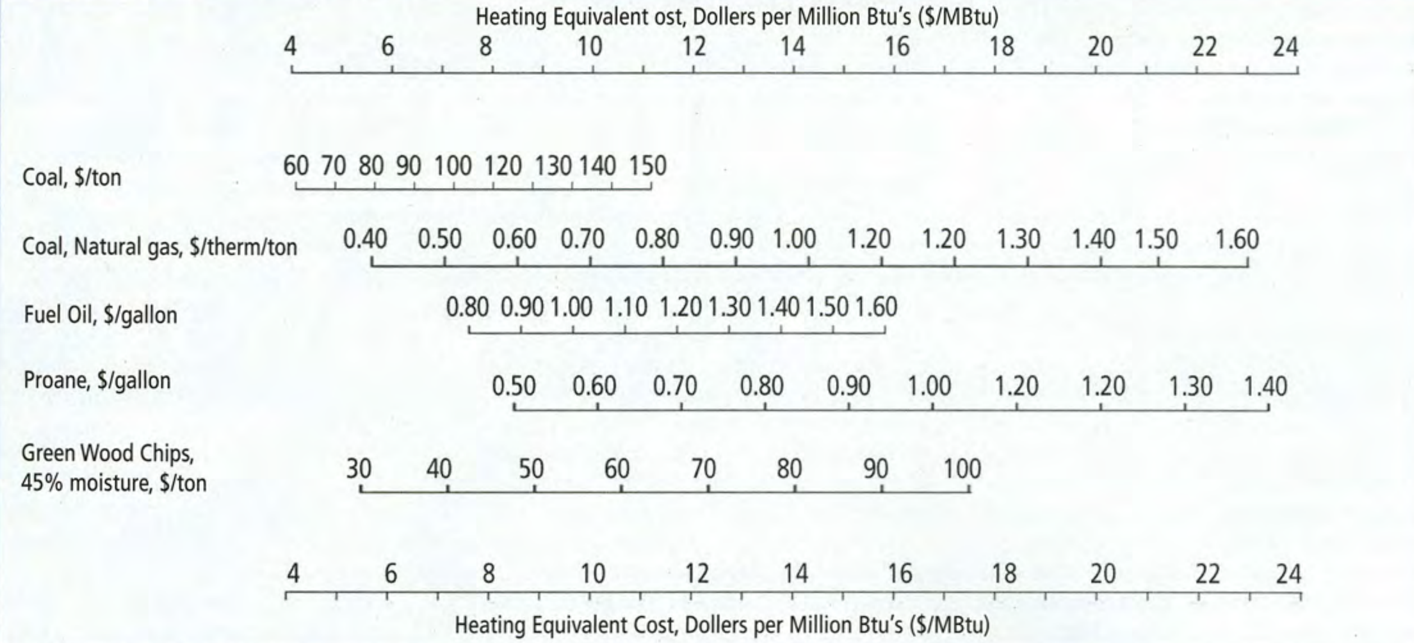
Figure 1: Fuel cost comparisons



ASSUMPTIONS:

COAL – 13,000 Btu/lb. 60% efficiency. $/MBtu = $/ton ÷ 13.8
NATURAL GAS – Therm = 100,000 Btu. 70% efficiency. $/MBtu = S/therm × $/gallon ×14.3
FUEL PIL (Average #2 & #6) - 145,000 Btu/gallon 70% efficiency. $/MBtu = $/gallon x 9.8
PROPANE – 85,000 Btu/Gal. 70% efficiency. $/MBtu = $/gallon × 16.8
WOOD CHIPS – 45% moisture. 3800 Btu/lb. 75% eficiency. $/MBtu = $/ton ÷ 5.7

(Source: Adapted with perimission from NRAES-3, Energy Conservation for Commercial Greenhouses.)

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feet per minute over the floor surface of the greenhouse.

For example, a 28-foot by 96-foot greenhouse requires an airflow of 5,376 cubic feet per minute (28 x 96 x 2 cubic feet per min per square foot = 5,376 cubic feet per minute). This greenhouse would require four HAF fans capable of moving air at 1,440 cubic feet per minute. This could be provided by four 16-inch fans with 1/15-horsepower motors at 1,600 revolutions per minute. Horizontal air flow fans are generally available in two air flow capacities, but check the fan specifications to determine that they meet the calculated needs.

• Fan location. The HAF fans should be located 2 to 3 feet above the plants and aligned parallel to the sidewalls of the greenhouse so that the air is circulated around the house in a rotational pattern.

• Winter operation. The HAF fans should be run continuously during the winter to improve temperature and humidity uniformity in the greenhouse.

Environmental control

• Use aspirated thermostats. Thermostats should be aspirated with greenhouse air and be placed near the plant canopy in locations representative of the rest of the greenhouse (not near sidewalls, fans or doors). *Aspirated thermostats save 2 percent to 3 percent of the total fuel bill by improving fan and heater operation.*

• Electronic thermostats. Switching to solid-state electronic thermostats can also improve efficiency by reducing the differential between the on and off modes, usually down to 1°F instead of the 3°F to 4°F of mechanical thermostats.

• Calibrate sensors. Calibrate the sensors regularly to maintain proper environmental temperatures. If you are lowering greenhouse growing temperatures, sensors must be accurate to avoid chilling damage to the crop.

Alternative fuels

With significant increases in the per unit cost of natural and LP gases, many growers seek to evaluate alternative fuel sources. Some growers who had previously "upgraded" to natural or LP gas furnaces still had working oil, wood or coal-fired furnaces or boilers connected to their greenhouses, and switched back to those fuel sources.

• Compare unit costs of fuels. When considering switching to alternative fuels, remember to compare apples to apples. In other words, look at all fuel sources on a cost per heating equivalent; for instance, dollars per million Btu's ($/MBtu). Figure 1 shows a comparison of the costs of different fuels based on $/MBtu, which were calculated using the heat value and efficiency rating stated under the "assumptions." To use this chart, draw a vertical line through the price of the fuel being considered to the Heating Equivalent Cost line. This line shows the price per MBtu. For example, if the cost of LP gas is $1.30/gal, the unit cost for a 70 percent efficiency furnace is $21.84/MBtu.

• Consider dependability of the fuel source. In evaluating alternative fuels, also consider the dependability of the source of the fuel. Make sure that sufficient quantities of an acceptable quality fuel will be available when needed.

• Conversion and operation costs. In addition to actual fuel costs, calculate the cost of converting to the new heating

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system and the labor involved in operating the new system. Remember that coal and wood-fired boilers or furnaces require additional labor investments, and you will also need a means of disposing of the ashes.

Alternative heating systems

If costs are continuing to be a challenge, you may consider changing the primary heating system. Alternatively, growers should evaluate the efficiencies of different heating systems (Table 1) and consider using combinations of different types of heating systems for the greenhouse. Evaluate the newer, more energy efficient heating systems to determine the "pay-back" period for individual operations. It may be worth the investment.

• Zone for higher temperatures. Consider adding higher efficiency bench or floor heating systems in root zones of areas that require higher temperatures, such as propagation or seedling and plug production areas. These systems consist primarily of electric cable or mat systems for small-scale implementation. For larger areas, hot water piping, on or under benches or in the floor, provides excellent growing conditions for roots while reducing air temperatures. In general, less than optimum temperatures have a greater effect on plant roots than on plant shoots.

• Hot water boilers. Modular, low-mass, hot water boilers that are very energy efficient are now available for individual greenhouse heating. They heat smaller amounts of water combined with the more efficient heat delivery capacity of aluminum pipes, fins and plastic tubing. Hot water heat provides more gentle, uniform heat than hot air heaters. In addition, these systems are very flexible, allowing the grower to zone the heat for different locations or purposes within the greenhouse.

• Hot water unit heaters. Hot water, forced-air, unit heaters also are available. Improvements in efficiency in heat exchangers and low-volume tubing have increased the efficiency of these units as well.

• Infrared radiant systems. Infrared radiant heat systems are available that provide warming of plants, people and surfaces without heating the air. These heating systems are very economical, with reports of up to 30 percent fuel-cost savings over forced-air unit heaters. Some Virginia growers have reported paying for the system in energy savings in less than two winter heating seasons.

Table 1. Estimated efficiencies of several greenhouse heating systems.

Heating system	Estimated efficiency
Warm insulated floor	90 percent
Warm uninsulated floor	80 percent
Hot water pipes near floor	85 percent
Steam pipes near floor	80 percent
Hot air heaters	60 percent

(From: E. Runkel. 2001. Michigan State University Greenhouse Alert, Issue 1, Jan. 16, 2001.)

Changing growing practices

It is logical that reducing the greenhouse temperature, especially at night, would reduce heating costs. In fact, reducing the night temperature by just 1°F can reduce a greenhouse heating bill by 2 percent to 3 percent. So, how low can we go? Greenhouse temperatures affect plant growth and flowering. In particular, they affect the time required to finish the crop. Be aware that some plants are more sensitive to lower temperatures and may cease to grow when a base temperature is met. This base temperature is lower for cool-season crops than for warm-season crops. In addition, growth is more strongly affected as the temperature approaches that base temperature.

Also, be aware that lowering the greenhouse temperatures can cause additional disease problems. You may want to run plants at optimum temperatures until the roots reach the edges of pots. Then lower the temperatures and run the plants drier to prevent root rot. Avoid overcrowding and provide horizontal air movement to ensure uniform temperatures and dry foliage. Use temperate irrigation water in the morning so the medium warms up faster and there is better nutrient uptake.

• Impact of temperature on crop finish time. Table 2 shows the estimated delay in finishing bedding plants when the nighttime temperature is reduced from a normal air temperature of 68°F or 63°F. To use this table, determine the normal air temperature, 68°F or 63°F, of the greenhouse. Then, estimate the base temperature of the crop in question. The 41°F base temperature is for more cold-tolerant, warm-season crops. Check previous records for the normal production time for the crop and determine how many days would be added by growing the crop at the lower night temperature.

• Temperature reduction example. A grower normally grows his vinca (a warm-season crop, base temperature 40°F) at 68°F and finishes that crop in 12 weeks (84 days). This year he wants to grow the crop at 64°F, so he can expect to take an additional 13 days (15 percent of 84 days) to finish that crop, for a total of 13.8 weeks. Table 2 provides a guideline for scheduling bedding plant crops under lower energy inputs, but be aware that other factors like light level, specific crops and other environmental conditions will affect crop scheduling as well.

• Utilize space wisely. Plan the spring production schedule carefully. Maximize the use of heated greenhouse space. Don't bring the next greenhouse on-line until absolutely necessary.

• Group plants. Group plants according to temperature tolerances so that some houses are run cooler than others. Plan for maximum efficiency.

• HAF fans. Keep the HAF fans running constantly to keep air temperatures uniform and reduce the incidences of cold pockets in the greenhouse.

Recovering the costs

• Increased fuel costs. Whereas fuel costs normally account for about 7 percent to 10 percent of the costs of production, in the 2000-2001 heating season that cost was close to 20 percent to 25 percent of the total. Most greenhouse grower profit margins are less than 10 percent. So how can growers recover the "loss" of this much money? First, growers must recognize that in order to stay in business, they must recover at least some of these costs. Very few growers are financially able to absorb these costs and remain in operation. This industry is traditionally one of the last to raise prices or add surcharges to their products, but it is an option.

• Increased input costs. As fuel costs increase, the costs of pots, plastics, chemicals, fertilizers and media components also increase. Availability issues of some fertilizer sources also contributes to increased input costs.

Table 2. Estimated delay in crop finishing time for bedding plants grown under reduced nighttime air temperatures.

Crop base temperature	Cooler air temperature	Approximate delay in crop timing
Normal air temperature of 68° F		
36° F (cool-season crops)	64° F	11 percent
	61° F	13 percent
41° F	64° F	13 percent
	61° F	15 percent
45° F (warm-season crops)	64° F	15 percent
	61° F	18 percent
Normal air temperature of 63° F		
36° F (cool-season crops)	59° F	13 percent
	55° F	15 percent
41° F	59° F	17 percent
	55° F	20 percent
45° F (warm-season crops)	59° F	20 percent
	55° F	25 percent

(From: Eric Runkle. Michigan State University's Greenhouse Alert Issue 3, February 15, 2001)

• Costs of production. Growers must know their costs of production. Put pencil to paper and calculate all of the costs. Develop a budget for the greenhouse operation and specific seasonal crops that will allow determination of the likelihood of making a profit and allow determination of the breakeven points. This will allow you to determine the relationship between the minimum volume sold and the minimum selling price per flat.

• Prepare an enterprise budget. Dr. Forrest Stegelin, extension agricultural economist for the University of Georgia, prepared an enterprise budget for bedding plants. Based on that budget, he calculated the expected results of changes in different factors of production. For example, a 1 percent increase in the utility rate for heating with natural gas decreased profit by 2 percent. However, a 1 percent increase in the selling price of a flat of bedding plants will increase profit by 16 percent; or, a 10 percent increase in the selling price of a flat will increase profit by 160 percent. In addition, a 1 percent increase in the percentage of the crop sold as marketable—for example, reducing your waste from 10 percent to 9 percent—results in a 25 percent increase in profit. To summarize, growers can have significant impacts on their profits by managing production to maximize marketability and by making modest increases in the selling price.

• Add fuel surcharges. Economists tell us that most consumers do not remember what they paid for plants last year and are not likely to notice a 50¢ increase per pot. So if your calculations determine that you must raises your prices to keep up with your costs, do so.

In many cases, growers are not comfortable adding a price increase sufficient to recover significant increases in fuel costs. In other cases, prices were set for many customers prior to fuel increases, and growers want to honor those commitments. In previous fuel crises, many growers across the country added fuel surcharges to their product prices. After doing the cost of production calculations, several growers found that adding a fuel surcharge to everything they sold during the spring would reverse their losses and restore a profit. They passed the fuel charges on to their customers, who in turn passed it on to the consumer.

Remember, you must determine your costs—and plan how to recover excessive costs due to high energy costs—so that you can afford to stay in business.

• Recover delivery costs. Also consider delivery of greenhouse products. Most industries charge for the delivery of their products. On the whole, the greenhouse industry provides this as a free service. How long can growers afford that? Strongly consider adding delivery charges, or at least fuel surcharges, to delivery services.

The costs of doing business in the green industry are ever changing, but it's unlikely we'll see a *reduction* in expenditures. Careful consideration of infrastructure and production practices can help keep those dollars in check—and put more of them in your pocket.

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