Approximate Heating Value of Common Fuels

Natural Gas	1,030 Btu/cu ft	100,000 Btu/therm
Propane	2,500 Btu/cu ft	92,500 Btu/gal
Methane	1,000 Btu/cu ft	
Landfill gas	500 Btu/cu ft	
Butane	3,200 Btu/cu ft	130,000 Btu/gal
Methanol		57,000 Btu/gal
Ethanol		76,000 Btu/gal
Fuel Oil		
Kerosene	135,000 Btu/gal	
#2	138,500 Btu/gal	
#4	145,000 Btu/gal	
#6	153,000 Btu/gal	
Waste oil	125,000 Btu/gal	
Biodiesel – Waste vegetable oil	120,000 Btu/gal	
Gasoline	125,000 Btu/gal	
Wood		
Softwood	2-3,000 lb/cord	10–15,000,000 Btu/cord
Hardwood	4-5,000 lb/cord	18–24,000,000 Btu/cord
Sawdust – green	10-13 lb/cu ft	8-10,000,000 Btu/ton
Sawdust – kiln dry	8-10 lb/cu ft	14-18,000,000 Btu/ton
Chips – 45% moisture	10-30 lb/cu ft	7,600,000 Btu/ton
Hogged	10-30 lb/cu ft	16-20,000,000 Btu/ton
Bark	10-20 lb/cu ft	9-10,500,000 Btu/ton
Wood pellets – 10% moisture	40-50 lb/cu ft	16,000,000 Btu/ton
Hard Coal (anthracite)	13,000 Btu/lb	26,000,000 Btu/ton
Soft Coal (bituminous)	12,000 Btu/lb	24,000,000 Btu/ton
Rubber – pelletized	16,000 Btu/lb	32-34,000,000 Btu/ton
Plastic	18-20,000 Btu/lb	
Corn – shelled	7,800-8,500 Btu/lb	15-17,000,000 Btu/ton
cobs	8,000-8,300 Btu/lb	16-17,000,000 Btu/ton
Electricity	3412 Btu/kilowatt hour	

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Comparing Fuel Costs

The following formulas allow you to compare the cost of different fuels based on their heating equivalents and typical heating system efficiency.

Fuel	Heat equivalent	Burner Efficiency	Cost - $/Million Btu
Fuel Oil	138,500 Btu/gallon	75%	$/MBtu = $/gal x 9.6
Waste oil	125,000 Btu/gallon	70%	$/MBtu = $/gal x 11.4
Natural Gas	100,000 Btu/therm	75%	$/MBtu = $/therm x 13.3
Propane	92,500 Btu/gallon	75%	$/MBtu = $/gal x 14.4
Hard Coal	25,000,000 Btu/ton	60%	$/MBtu = $/ton ÷ 15.0
Hardwood	20,000,000 Btu/cord	60%	$/MBtu = $/cord ÷ 12
Softwoods	12,000,000 Btu/cord	60%	$/MBTu = $/cord ÷ 7.2
Wood Pellets	8,200 Btu/lb	80%	$/MBtu = $/ton ÷ 13.1
Wood Chips			
Green(50% m.c.)	4,000 Btu/lb	50%	$/MBtu = $/ton ÷ 4.0
Dry (10% m.c.)	7,400 Btu/lb	60%	$/MBtu = $/ton ÷ 8.8
Corn	8,200 Btu/lb	80%	$/MBtu = $/ton ÷ 13.1
Biofuels			
Vegetable oil	120,000 Btu/gal	70%	$/MBtu = $/gal x 11.9
Electricity	3,412 Btu/kilowatt-hour	100%	$/MBtu = $/kw-hr x 293

Greenhouse Energy Conservation Checklist

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Increasing energy costs make conservation and efficient use of facilities an important part of today's greenhouse operation. New greenhouse designs, better glazing, improved heating and ventilating equipment and new management systems should be included when upgrading or adding on. With typical annual energy usage being 75% for heating, 15% for electricity and 10% for vehicles, efforts and resources should be put where the greatest savings can be realized.

Reduce Air Leaks

Keep doors closed - use door closer or springs.

Weatherstrip doors, vents and fan openings. For example, a 48" fan louver that fails to close properly leaving 1" gaps, allows 23,000 Btu/hr of heat to escape costing $0.53 if you are burning $2.30 fuel oil.

Lubricate louvers frequently so that they close tight. A partially open louver may allow several air changes per hour. Additional fuel is needed to heat this air. Shut off some fans during the winter and cover openings with insulation or plastic to reduce infiltration of air.

Repair broken glass or holes in the plastic covering.

Double Covering

Line sidewalls and endwalls of greenhouse inside with poly or bubble wrap to achieve the thermopane effect. Install double wall polycarbonate structured sheets to get insulation effect and reduce recovering labor.

Use poly with an infrared inhibitor on the inner layer for 15% savings. Payback is 2-3 months.

Add a single or double layer of plastic over older glasshouses to reduce infiltration and heat loss by 50%.

Energy Conserving Blanket

Install a thermal blanket for 20%-50% savings. Cost is $1.00 - $2.00/sq ft. Payback is 1-2 years. Tight closures should be maintained where curtains meet sidewalls, framing or gutters. Use a U-shaped trap to prevent heat from escaping overhead. Heat and water lines should be insulated or located below the blanket.

Foundation and Sidewall Insulation

Insulate the foundation - place 1-2" polyurethane or polystyrene board to 18" below ground to reduce heat loss. This can increase the soil temperature near the sidewall as much as 10 degrees during the winter.

Insulate the kneewall or sidewall to bench height. Use 1" to 2" of insulation board. Applying 2" of foam insulation to a 3' high kneewall on a 28' x 100' greenhouse will save about 400 gallons of fuel oil/year.

Insulate behind sidewall heat pipes - Use aluminum faced building paper or insulation board behind to radiant heat back into the growing area. Leave air space next to wall to prevent frost damage to wall.

Site Location

Locate new greenhouses in sheltered areas to reduce wind-induced heat loss, if this does not reduce light.

Install windbreaks on the North and Northwest sides of the greenhouse. The windbreak can be a double row of conifer trees or plastic snow fence.

Space Utilization

Increase space utilization to 80% - 90% with peninsular or movable benches.

Install multi-level racks for crops that don't require high light levels.

Grow a crop of hanging baskets on overhead rails or truss-mounted conveyor system.

A roll-out bench system can double growing space. Plants are moved outside during the day.

Efficient Heating System

Installation of floor or under-bench heat will allow air temperature to be set 5° - 10°F lower.

Yearly maintenance - Check boiler, burner and backup systems to make sure they are operating at peak efficiency. Have furnaces cleaned and adjusted and an efficiency test run before heating season. A 2% increase in efficiency for a 30' x 150' greenhouse will save about 200 gallons of fuel oil.

Clean heating pipes and other radiation surfaces frequently.

Check accuracy of thermostats – correcting a reading that is 2°F high will save $100-$200.

Install electronic thermostats or controllers with a 1° F accuracy. Potential yearly savings of 500 gallons of fuel oil in a 30' x 100' greenhouse when changing from a mechanical to electronic thermostat or controller.

Aspirate thermostats or sensors for more uniform temperature control. Differential between on and off can be reduced as much as 6°F.

Install horizontal air flow (HAF) fans to get more uniform temperature in the growing area.

Insulate distribution pipes in areas where heat is not required.

Check and repair leaks in valves, steam traps and pipes.

Efficient Cooling System

Build new greenhouse with open-roof design to eliminate the need for fans.

Install roll-up or guillotine sides to reduce the need for fan ventilation.

Use shading to reduce the need for mechanical cooling.

Install evaporative cooling to get better temperature control during the summer.

Select fans that meet AMCA standards and have a Ventilation Efficiency Ratio greater than 15.

Use the largest diameter fan with the smallest motor that meets ventilation requirements.

Keep doors closed when fans are operating. Locate intake louvers to give uniform cooling.

Conserve Electricity

Have wiring system inspected for overloading, corroded parts and faulty insulation.

Replace 3 hp or larger motors with high efficiency ones to reduce electric consumption by 2-5%.

Check for proper belt tension and alignment.

Replace incandescent bulbs with low wattage fluorescent or HID bulbs. Save 2/3rds on electricity.

Install motion detectors to control security lights so they are not on all the time.

Trucks and Tractors

Regularly scheduled tune-ups can save 10% on fuel usage. Keep tires properly inflated.

Avoid lengthy idling. Idling can consume 15-20% of the fuel used.

Train drivers in truck operation. The difference between the poorest and best drivers is 30% savings.

Water Systems

Locate hot water tanks as close as possible to the largest and most frequent use. Insulate pipes.

Heat water to the lowest temperature needed, usually 120°F is adequate.

Use pipe size large enough to supply necessary water at minimum friction loss.

Eliminate water leaks – A dripping faucet at 60 drops/min. will waste 113 gallons/month.

Management

Lower night temperature – Fuel consumption is reduced 3% for each 1°F night temperature is lowered.

Delay starting the greenhouse by a week or more. Build a germination/growth chamber to start seedlings.

Keep growing areas full at all times.

Additional information can be found in **Energy Conservation for Commercial Greenhouses** – NRAES-3, 100 pages, $20.00 available from the Department of Natural Resources Mgt. & Engr., 1376 Storrs Rd., UConn, Storrs CT 06269-4087. Make check payable to UConn. Price includes postage and handling.

Ten Low-cost Energy Savers

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Fuel and electric bills are at the forefront of our minds as we get into the winter season. It seems that there is no limit to how high the cost of fuel and electricity will go. This is influencing the way we plan our production and operate our greenhouses.

As I travel around visiting growers, I still find that some of the simplest conservation measures have not been put in place. Questions on alternate energy systems or expensive retrofits are common but looking around the greenhouse the large gaps under the door or simple insulation measures are overlooked as a way to achieve significant savings.

Check your greenhouses for the following energy savers that cost very little to implement:

1. **Reduce infiltration** – gaps under exterior doors, in shutters or vents and around the foundation can allow a considerable amount of heated air to escape. For example, a 48" fan shutter that fails to close properly leaving 1" gaps allows 23,000 Btu of heat to escape each hour costing $0.45 with $2.00/gal. fuel oil or $1.38/ therm natural gas. A little time spent installing weatherstripping, foam crack sealer or placing insulation board over the vents will reduce this to a minimum.
2. **Insulate the kneewall to bench height** – Heat loss from a greenhouse is directly related to the surface area, insulation value of the glazing and the temperature difference between inside and outside. Although the sidewall surface of a greenhouse is less than 20% of the surface of the greenhouse, the heat loss can be significant. I have measured temperature reductions in kneewall surface temperatures of 40°F when an inch of insulation board or a piece of aluminum foil was placed between the heat pipes and the wall.
3. **Pipe insulation has a good payback** – Whether it's the ¾" pipe that supplies the sink or the 4" line from the boiler, there is considerable heat loss from hot water pipes. This heat loss continues every day the system is operating. Payback for insulating pipes usually takes less than two years. Using the above fuel cost figures, the approximate annual savings for installing 1" thick fiberglass or foam pipe insulation on the ¾" pipe will be $2.50/ft and $10.15/ft for the 4" pipe.
4. **Service the heating system each year** – A thorough cleaning and adjustment of the burner can increase efficiency at least 5% on most heating units. The most important adjustment is the air supply setting. Too little air results in incomplete combustion, too much air carries some of the heat up the chimney. On oil burners, other areas to check are the oil pressure, nozzle type and angle and electrode spacing. On gas burners check for blocked gas orifices, gas leaks and obstructions in the vent system. On both types adjust the barometric damper. Provide at least 15 cu.ft. of makeup air/1000 Btu of heat.

5. **Calibrate the heating system sensors for better temperature control** - Thermostats loose their accuracy over time. The calibration can be checked by placing an accurate thermometer next to a thermostat and slowly turning the dial until the heater comes on. If the reading is not the same temperature as the thermometer, mark the thermostat accordingly. A 1°F to 2°F difference could save over $100 in fuel costs/year. Better sensing of temperature in the greenhouse can be achieved by placing the thermostats inside an aspirated box (a wooden box with a muffin fan that pulls air past the sensors). Tests at Rutgers University showed that the temperature fluctuation between the on and off position was reduced from 8°F to 2°F by using an aspirated box.
6. **Modulate boiler water temperature for savings** – A radiator filled with 180°F water when the thermostat shuts off the circulator pump will continue to provide heat for some period of time overheating the greenhouse and increasing the heat loss. Installing a 3 or 4-way mixing valve and temperature sensor will lower the water temperature in the radiators as the setpoint is being reached. This reduces the redundant heat and saves fuel.
7. **Install root zone heat** – Providing heat where it is need by the plants can save considerable energy. For most plants the root zone temperature is more important than the air temperature. Adding heat in the floor or under the benches can provide a first stage of heating. As the heat rises, it then heats the air. For hoophouses and small gutter-connected houses, a domestic hot water heater can supply adequate hot water for the root zone at low cost.
8. **Add a germination chamber to start seedlings** – A germination chamber in the headhouse or basement will allow you to keep the greenhouse closed for an extra two or three weeks in early spring. Installing 25 – 30 watts of fluorescent lighting per square foot of growing area will provide both the light and heat needed for good germination and seedling light requirement.
9. **Check fan belt tension and alignment** – Loose belts and pulleys that are out of alignment reduce fan output considerably. Use a straight edge to check alignment of the pulleys and adjust the belt so that it has no more than ½" depression between the pulleys.
10. **Install a motion detector to activate security lighting** – Research has found that vandals are scared off more by lights that come on when they enter an area than by continuous lighting. This can save considerable electricity over the year.

Small savings in energy add up over the year. Simple conservation measures are often easy to install or implement and require only a small investment.