



Greenhouse unit heaters— Types, placement, & efficiency

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Air temperature in a greenhouse is critical to plant growth, disease control, and plant survival. During cooler months, the sun can provide a large portion of the heating requirements during daytime hours. However, nights and overcast days require supplemental heating unless the air temperature is allowed to drop and large amounts of thermal mass are available to release stored heat. Commercial greenhouses require supplemental heating in order to meet growth schedules and maintain plant quality. To this end, many large greenhouses use a central heating system, but some large and many small greenhouses use forced-air unit heaters.

There are several types of unit heaters available for use in greenhouses. The differences among heater units may not be readily apparent, but they

Unit heater types

Unit heaters for greenhouses typically use LP gas (propane) or natural gas for fuel but may also use heating oil. Unit heaters are popular because of their low capital and installation costs, high reliability, and ease of staging multiple heaters. Using multiple heaters is recommended in greenhouses so that if one heater fails, heat is still provided by the other heaters—effectively eliminating the possibility of a no-heat situation.

There are two main types of unit heaters that are used for space heating in greenhouses: vented and unvented. The traditional vented, gas-fired unit heater transfers heat from the combustion gases to the air through a heat exchanger, and exhausts the combustion gases outside the greenhouse through a flue pipe. An unvented unit heater burns the gas and exhausts all combustion gases directly into the greenhouse, so virtually all the heat from the fuel is used to heat the air. Let's take a look at each of these technologies.

Vented unit heaters

There are four types of vented unit heaters: gravity-vented, power-vented, separated-combustion, and high-efficiency condensing heaters. Gravity-vented, power-vented, and separated-combustion heaters have thermal efficiencies of 80%. (That is, the ratio of their heat output to the heat content of the fuel input is 80% at a snapshot in time.) However, their seasonal efficiencies (their efficiencies over the entire heating season) range from 65 to 80%.¹ (Seasonal efficiencies take into account all energy losses incurred by the heater, including combustion of already-heated air, heat loss out the vent pipe, and continuously lit pilot lights.) High-efficiency condensing heaters have thermal efficiencies greater than 90%.



can have significant implications for energy consumption. This publication will explore the differences between unvented, gravity-vented, power-vented, separated-combustion, and high-efficiency condensing unit heaters, as well as how heated air distribution can affect energy usage.

Gravity-vented unit heaters

Gravity-vented unit heaters rely on thermal buoyancy and draw from wind blowing past the vent pipe to exhaust the flue gases. These heaters are typically rated at 80% thermal efficiency; however, the seasonal efficiency drops to 65% because heated air from inside the greenhouse is continuously lost out the vent pipe. These heaters use inside air for combustion, which accounts for about 2% of the efficiency loss, and some heaters use continuous pilot lights, which consume a small amount of additional energy. To meet new energy standards, gravity-vented heaters are now required to have a spark ignition system and an automatic stack damper to block the loss of heated air when the unit is off. These new requirements have made gravity-vented heaters as expensive as higher-efficiency power-vented heaters, so many manufacturers no longer sell them. However, a large number of them have been installed and continue to be used in greenhouses.

Power-vented unit heaters

A power-vented unit heater has a small blower that meters the correct amount of air for combustion and exhausts the flue gases. The blower operates only when the heater is firing. This type of unit heater uses a smaller exhaust pipe that can be run horizontally through the wall of the greenhouse, reducing installation costs and acting like a vent damper to minimize

thermal buoyancy losses. Gas-fired power-vented heaters often use an intermittent or electronic pilot, which reduces flameouts and pilot gas use. The seasonal efficiency of a power-vented unit heater is typically about 78%, with a thermal efficiency of 80%.

Separated-combustion unit heaters

The separated-combustion heater is designed for heating areas that have negative pressures or high-humidity, dusty, or corrosive environments. These heaters use a power-vented exhaust and have a separate air intake duct for combustion air. Modern plastic greenhouses are tightly constructed, with fewer seams than glass greenhouses, and therefore have low infiltration rates (the rate at which outside air leaks into the building). Due to the low infiltration rates, it is possible during times of peak heating for many types of unit heaters to use up enough oxygen in the greenhouse to cause poor combustion or to cause flue gases to be drawn into the greenhouse through the flue pipe. Back drafts of flue gases can be a problem if a greenhouse is located in a windy area or if exhaust fans and heaters are inadvertently used at the same time. Flue gases can affect plant and human health, as will be discussed in the unvented heaters section. Separated-combustion units eliminate these problems. The thermal efficiency of a standard separated-combustion heater is 80%, with a seasonal efficiency of 80%.

High-efficiency condensing heaters

Several manufacturers make high-efficiency unit heaters with thermal efficiencies exceeding 90%, to get every Btu (British thermal unit) possible out of the fuel with a vented heater. These heaters condense some of the moisture out of the flue gas to squeeze out more energy. This technology has been around for many years and is used in most residential furnaces sold today. High-efficiency condensing heaters use a power-vented exhaust and a separate air intake so heated greenhouse air is not used for combustion, and they require a drain or other way to dispose of the acidic condensate. Both the thermal and seasonal efficiencies are typically about 93%. High-efficiency condensing heaters are more expensive than other types, but they provide more heated air per unit of fuel.

Unvented heaters

Small, unvented heaters have been used for carbon dioxide (CO₂) enrichment in greenhouses, but higher-capacity, direct-fire heaters are also available for heating. These units are unvented, so all the products of combustion are transferred into the greenhouse for heating. Many people assume that unvented heaters are nearly 100% efficient, which is appealing in a climate of increasing fuel costs. However, when fuels such as LP gas and natural gas combust, water forms and is then vaporized by the heat of combustion, reducing the net energy by 8%. Also, if the heater does not have a combustion air intake, fresh air must be drawn into the greenhouse to replace oxygen used by the heater for combustion. The fresh air is heated and then used for combustion, which reduces the overall heater efficiency. When the water vapor and air exchange are factored in, the seasonal efficiency of the unvented heater drops to about 80%—about the same as a power-vented heater. And the colder the outside air, the lower the heater efficiency will be.



Gravity-vented unit heater

Some unvented heaters are designed with a fresh-air intake duct so that air inside the greenhouse is not used for combustion. This increases the heater efficiency to about 90%. Unvented heaters without air intake ducts must have the heater interlocked with an exhaust fan and inlet louver so that fresh air enters the greenhouse when the heater is firing.

There are some disadvantages along with the CO₂ enrichment and higher energy efficiency that some unvented units offer. The water vapor formed by burning LP gas or natural gas may increase the potential for fungal disease among certain plant varieties and will block sunlight if it condenses on the glazing. For every gallon of LP gas that is burned, approximately 1½ pounds of water are added to the air. For a 250,000 Btu/hr heater, almost 4 pounds of water (about ½ gallon) would be added to the air per hour of heater operation.

Other by-products of combustion (e.g., ethylene, sulfur dioxide, nitrous oxide, and carbon monoxide) can be harmful to plants and humans, depending on the concentration. Heating oil produces these gases in higher quantities than LP gas and natural gas. Colorless and odorless ethylene gas can seriously affect plants in very low concentrations, and the subtle effects may not show until 1 or 2 weeks after an ethylene release. Tomatoes, cucumbers, lettuce, melons, peppers, tobacco, flowers, and bedding plants are all susceptible to ethylene gas.^{2,3,6} Sulfur dioxide exposure can cause

leaf curling and necrotic spots on leaves. Malfunctioning vented heaters can also cause problems with ethylene and sulfur dioxide due to flue gases entering the greenhouse.

In addition, if unvented heaters are installed for heating and CO₂ enrichment, the plants are unlikely to fully utilize the CO₂ because 80% of the heating in greenhouses occurs at night when the plants are not using CO₂. In a greenhouse with multiple heaters, it may be effective to have one unvented heater for CO₂ enrichment and have the others vented. The unvented unit would be the primary heater during the day, when plants are using CO₂, and the vented heaters would be the primary heaters at night.

Portable unit heaters

Portable unit heaters are often used for temporary or emergency heating and operate on kerosene, heating oil, or LP gas. These unvented units are not suited for use in enclosed structures because they do not have air intake venting. If using portable units for emergency or temporary greenhouse heating, use only LP gas-fired units, and open a vent or prop open a door to replace the oxygen burned by the heater.

Factors in unit heater performance

Combustion air inlets

As previously mentioned, modern plastic greenhouses are tightly constructed and have relatively low infiltration rates. Relatively little cold air leaks into the building, so there is relatively little cold air that requires heating and displaces already-heated air. While low infiltration rates contribute to energy efficiency, they can also be problematic because little fresh air is entering the building. The smell of flue gases inside a greenhouse, which typically happens on cold nights when many heaters are running at once, is a sign of insufficient air inlets to replace the air combusted by the heaters. A good solution is to provide a fresh-air duct to each heater to ensure ample air and complete combustion. The general recommendation is 1 square inch of inlet opening per 2,000 to 2,500 Btu/hr of heating capacity, but always follow the manufacturer's recommendations.^{5,9} The fresh-air vent should ideally be positioned within 12 inches of the combustion unit and should be outfitted with a power damper so it is open only when the heater is operating. Using this recommendation, a heater rated at 250,000 Btu/hr would require a vent opening of 100 to 125 square inches, or approximately the equivalent of a 12-inch-diameter pipe.



Unvented unit heater



Portable unit heater

Heat exchanger material

Because of the high-humidity environment and the pesticide chemicals used in many greenhouses, the heat exchanger material can affect the unit heater's life span and warranty. The standard heat exchanger material for unit heaters is aluminized steel, while the optional material is stainless steel. In high-humidity environments such as greenhouses, the aluminized steel heat exchangers have reduced life spans. Stainless steel heat exchangers have longer life spans, and the manufacturers' warranties reflect that. The standard warranty from a leading manufacturer is 10 years for an aluminized steel heat exchanger, but if used in a high-humidity environment such as a greenhouse, the warranty is reduced to 1 year. Under the same conditions, the manufacturer provides a 10-year warranty on a stainless steel heat exchanger. The cost of a stainless steel heat exchanger for a 250,000 Btu/hr unit heater is about \$450 more than an aluminized steel unit, but the stainless steel heat exchanger extends the unit's expected life span by 9 years.

Heated air distribution

The heat distribution location in a greenhouse can decrease total energy usage and increase growth and yields at the same time. Using hydronic floor heating and growing plants on the floor can save 20 to 30% in heating costs.^{7,8,10} However, unit heaters will still be needed. On very cold nights, a heated floor system will not be able to keep up with the high rate of heat loss from the greenhouse.

Forced air under-bench heating can provide an effect similar to floor heating, and similar savings. The effect can be created by connecting a unit heater with a blower (instead of a propeller fan) to a duct or poly tube positioned under the growing benches. Installing skirts around the sides of the bench will help keep the heat under the bench.

Heat rises, so heat distributed above the plants will not drop to the plant zone until all of the air above the plants is heated. Therefore, when the heat is discharged overhead, more air must be heated (and thus more energy must be used) than when the heat is distributed below the plants.

When plants are grown on a heated floor or bench, a microenvironment is formed, warming the plants and the immediate surroundings—but not the entire greenhouse—to the desired growing temperature. Using floor or under-bench heating reduces the greenhouse air temperature at 6 feet by about 10°F and still maintains proper growing temperature at the plant level.⁴ Studies of floor heating have reported increased production, faster root growth, and reduced disease pressure, along with energy savings. A study of greenhouse tomatoes at Louisiana State University showed a 28% savings in fuel and a 7% increase in yields with heated air distributed via poly tubes positioned between the rows of tomatoes at the floor level.

If floor or under-bench heating is not a viable option, using poly tube overhead and horizontal airflow fans can help provide more uniform air temperature distribution. Typically, horizontal stirring fans are used to push heat down to the plant level, mix the air to reduce temperature stratification, eliminate dead air spots, and reduce condensation formation on the glazing.

Case study— Vented heater type versus heating cost

This example uses a 30- x 96-foot greenhouse with a double polyethylene infrared-inhibiting cover and double-wall polycarbonate end walls in Madison, Wisconsin. The greenhouse has an average infiltration rate of 0.75 air changes per hour and is heated with two 250,000 Btu/hr LP gas unit heaters with propeller fans. The growing season lasts from February 1 through June 1. Except for heater efficiencies and costs, all conditions and costs are assumed to be the same (including installation costs).



Unit heater ducted for under-bench heating

Table 1 shows the efficiencies and costs of four different types of vented unit heaters. Note that the capital costs listed are the manufacturers' suggested retail prices (MSRPs) but that typically, units can be purchased for less.

Table 2 lists for each heater type the fuel consumption, fuel savings, and simple payback, assuming that the fuel cost savings would pay for the incremental purchase cost of the higher-efficiency heater. According to the information in table 2, purchasing a power-vented unit heater is a better choice than purchasing a gravity-vented heater due to the short payback from energy savings.

The case study greenhouse can be heated with one heater about 80% of the time, but on cold nights, two heaters are needed to meet the temperature specifications. A high-efficiency condensing heater has a long payback if two of them are used. But if one high-efficiency condensing heater is used as the primary heater (providing 80% of the heating) and a power-vented unit heater is used as the secondary (providing 20%) for the few cold times when a single heater cannot keep up, the overall payback would be reduced to about 2 years in relation to using gravity-vented heaters.

If comparing high-efficiency condensing heaters to power-vented heaters, then the incremental capital cost is \$3776 to generate a fuel savings of \$502 per year for a simple payback of 7.5 years—a marginal investment. However, if a high-efficiency condensing heater is the primary heater and is paired with a power-vented heater as the secondary heater (running only if the primary heater cannot keep up), the incremental investment drops to \$1888 for a fuel savings of \$400 and a simple payback of 4.7 years—a 21% return on investment.

Conclusions and recommendations

Growers should evaluate the annual cost of ownership and not solely the purchase price when purchasing energy-consuming equipment such as heaters. Considering the energy and capital costs presented, growers should consider upgrading existing gravity-vented heaters to high-efficiency condensing heaters or purchase a kit to convert gravity-vented heaters to power-vented heaters. Using a high-efficiency condensing heater as the primary heater with a power-vented heater as the secondary can provide almost the same energy savings and a higher return on investment than using two high-efficiency condensing heaters.

Growers should consider a few key pieces of information to help improve unit heater performance:

- Properly sized air inlets are necessary to ensure heaters receive enough oxygen for complete combustion.
- Stainless steel heat exchangers are recommended because of their longer expected life span (10 to 15 years, versus just a few years for an aluminized steel heat exchanger).
- Moving the heat distribution system under-bench or using floor heating could save an additional 20% or more in heating costs and may increase yield and plant quality.

Table 1. Heater efficiencies and costs of vented unit heaters with propeller fans and stainless steel heat exchangers and burners

Heater type	Efficiency		Capital cost (MSRP) ^a	Incremental capital cost
	Thermal	Seasonal		
Gravity-vented ^{b,c}	80%	65%	\$3,640	\$0
Power-vented ^c	80%	78%	\$3,820	\$180
Separated-combustion ^d	80%	80%	\$6,886	\$3,246
High-efficiency condensing ^d	93%	93%	\$7,596	\$3,956
High-efficiency condensing & power-vented	90% ^e	90% ^e	\$5,708	\$2,068

^a Manufacturer's suggested retail price for two unit heaters, in 2010 U.S. dollars. Where two types of heaters are listed, value is combined cost for one heater of each type. ^b This type of heater is no longer manufactured, so cost is based on historical price difference. ^c 250,000 Btu/hr input rating. ^d 215,000 Btu/hr input rating. ^e Efficiency is weighted based on percentage of heating supplied.

Table 2. Fuel savings and payback of vented unit heaters with propeller fans and stainless steel heat exchangers and burners

Heater type	Incremental capital cost	Estimated fuel (gallons) ^a	Fuel savings	Fuel cost savings ^b	Simple payback (yrs)
Gravity-vented	\$0	2,494	0%	\$0	0.0
Power-vented	\$180	2,078	16%	\$624	0.3
Separated-combustion	\$3,246	2,026	19%	\$702	4.6
High-efficiency condensing	\$3,956	1,743	30%	\$1,126	3.5
High-efficiency condensing & power-vented	\$2,068	1,810	27%	\$1,026	2.0

^a Calculated using LP gas, a by-product of the petroleum distillation industry, and based on the 30-year average weather data for Madison, Wisconsin as determined by a heat-loss model. ^b LP gas cost, which follows the world market price for oil, assumed to be \$1.50/gallon.

Energy prices are expected to continue to increase due to increasing world energy consumption, so purchasing heaters with 90%-plus efficiencies today, despite their higher cost, may be one of the best long-term investments growers can make for their business.

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Resources

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

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