Overview

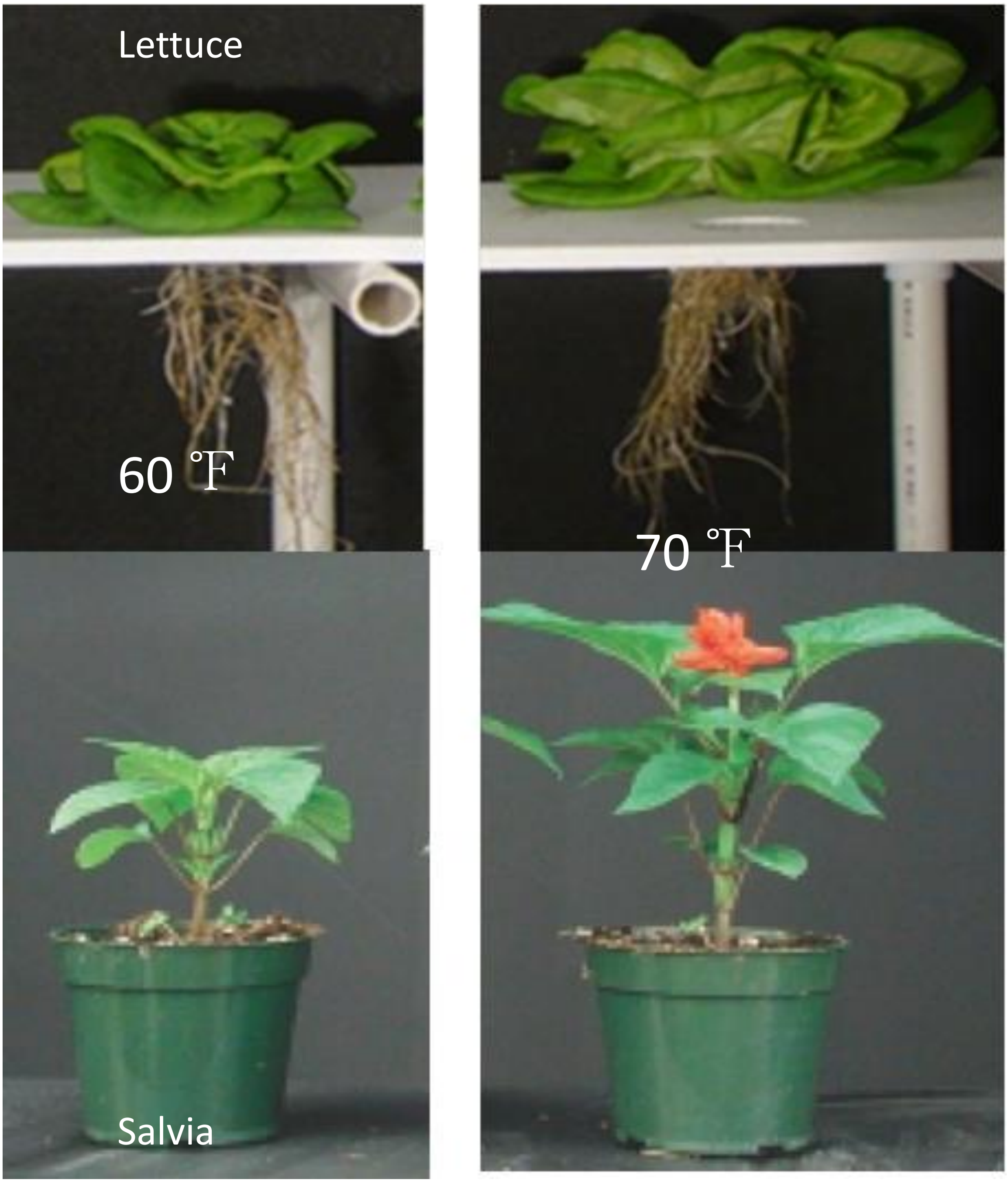
Heading and Cooling Solutions for Greenhouses

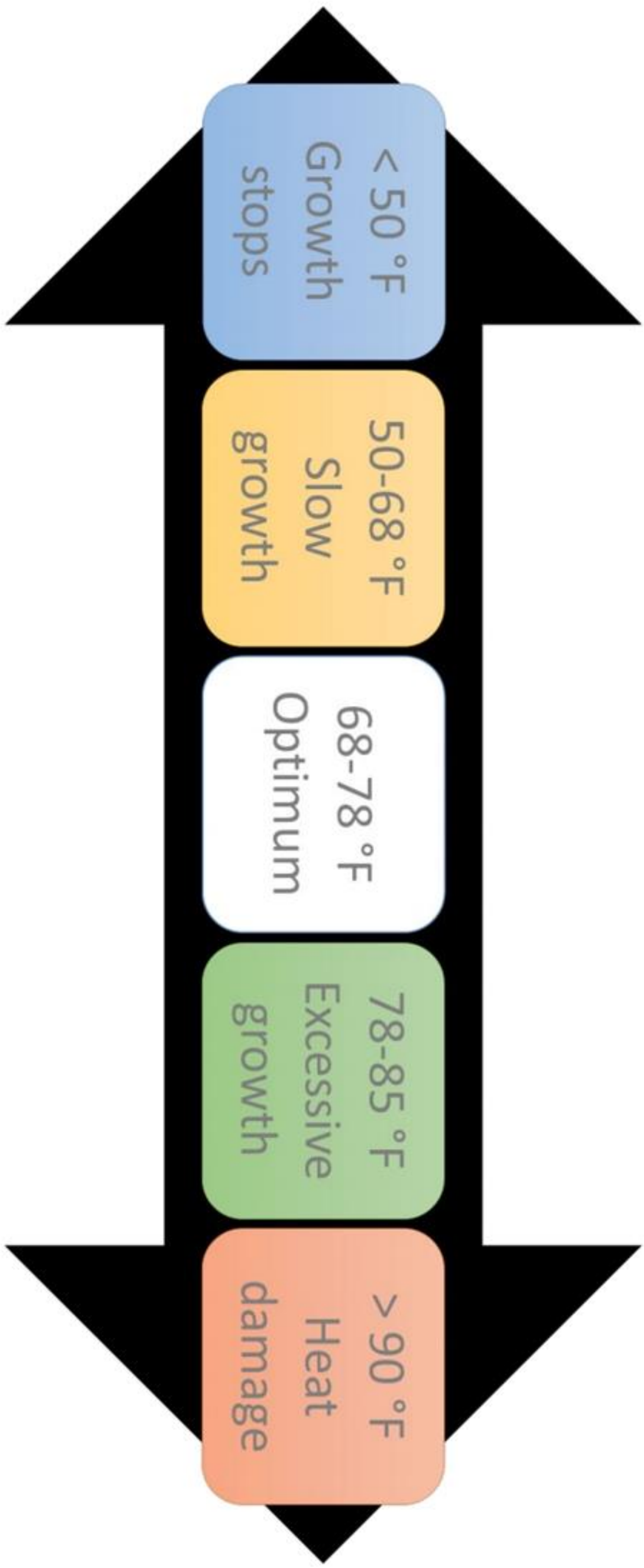
High Temperature Industrial Heat Pump Solutions for Horticulture and Industrial Agriculture

Withair Group (China) Limited
Withair (Nanjing) Industries Co., Ltd

Air temperature affects both growth and days to flowering in greenhouse plants.

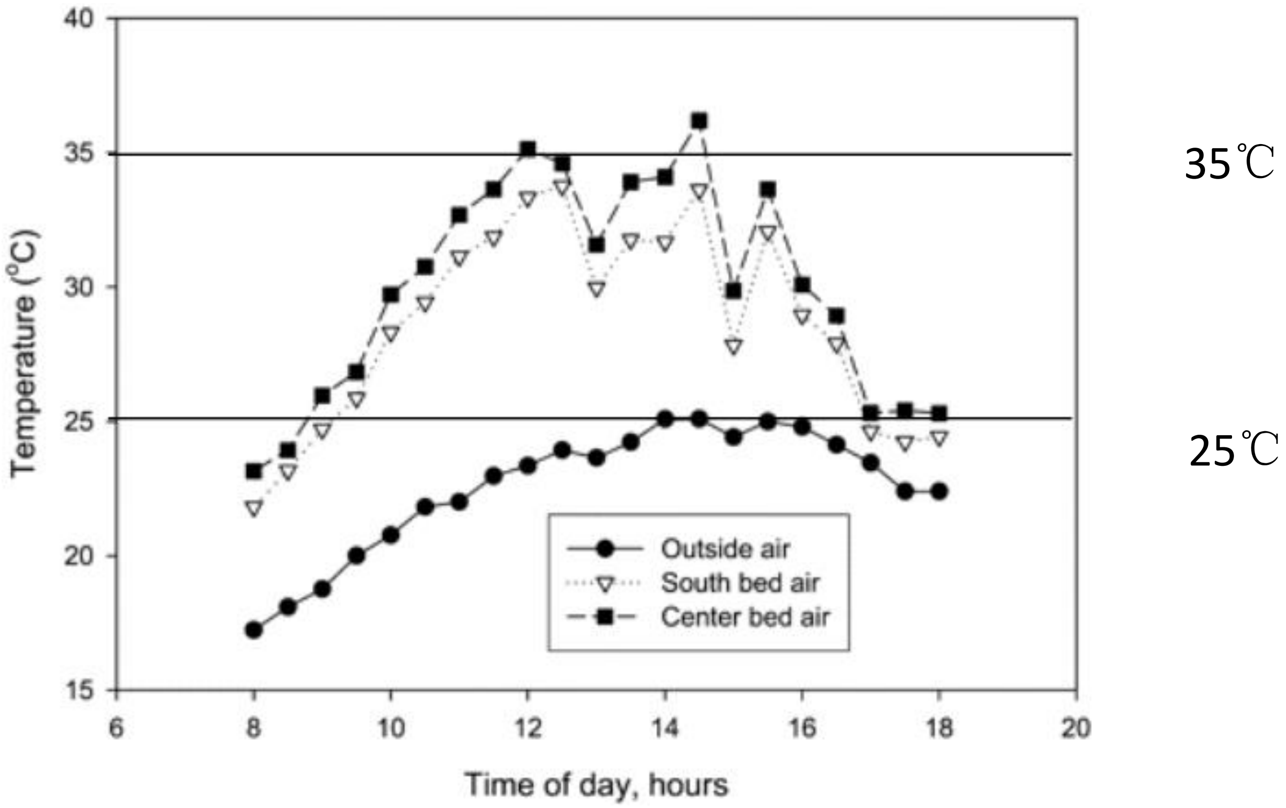
Between 10 and 27℉, plants grow faster and flower earlier, when temperature is Increased.



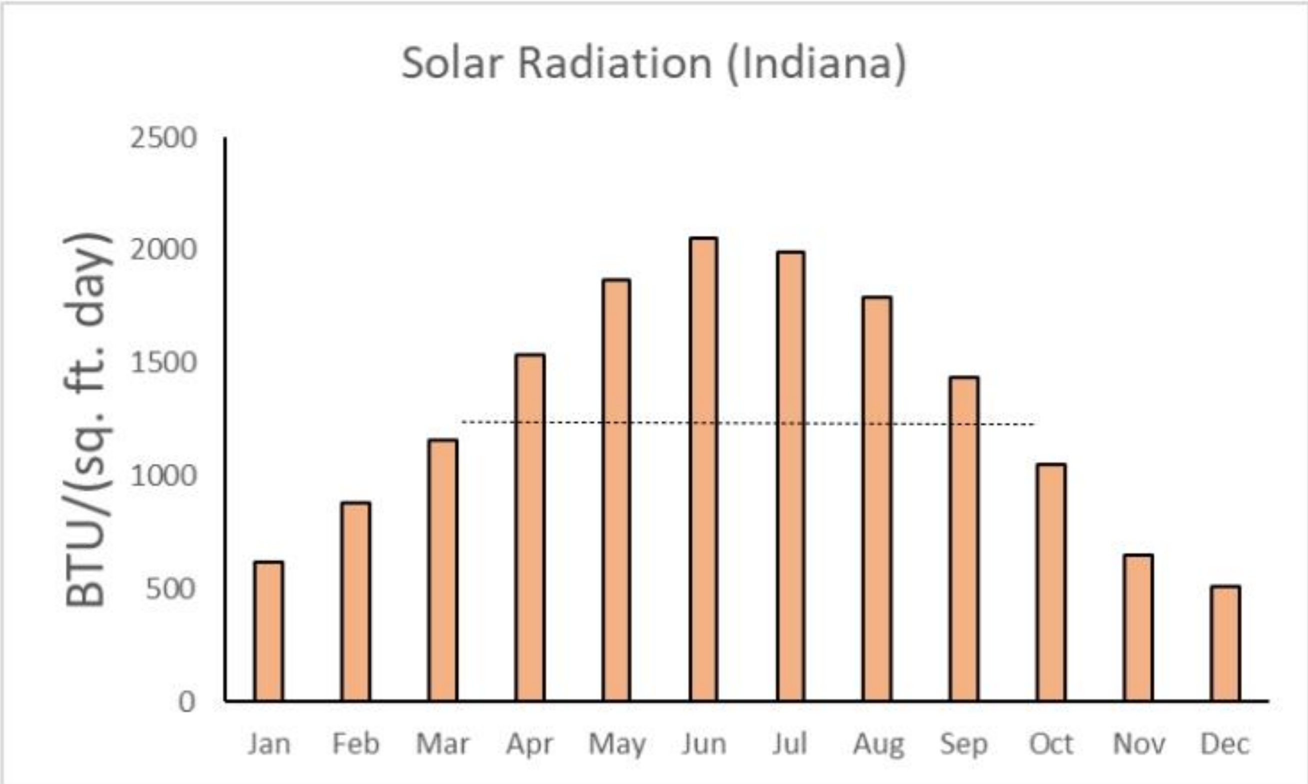


< 50 °F
Growth
stops
50-68 °F
Slow
growth
68-78 °F
Optimum
78-85 °F
Excessive
growth
> 90 °F
Heat
damage

Without ventilation and/or cooling temperature, a greenhouse can be 50 to 80℉ higher than outside



- Temperature can be lowered by shading greenhouse
- This will reduce light transmission
- Usually used when cooling by other methods does not reduce temperature to the desired level
- If the cloth is meant for shading, then it should be outside the structure for maximum reduction



- Pressure gradients due to temperature and wind create natural ventilation
  1. Hot air moves up creating low pressure and cool air moves to fill the space
  2. Wind entering greenhouse pushes air outside

- Natural ventilation can be through both side-wall and roof. The area of side-wall, roof ventilation should be similar and each accounting 15 to 20% of surface area

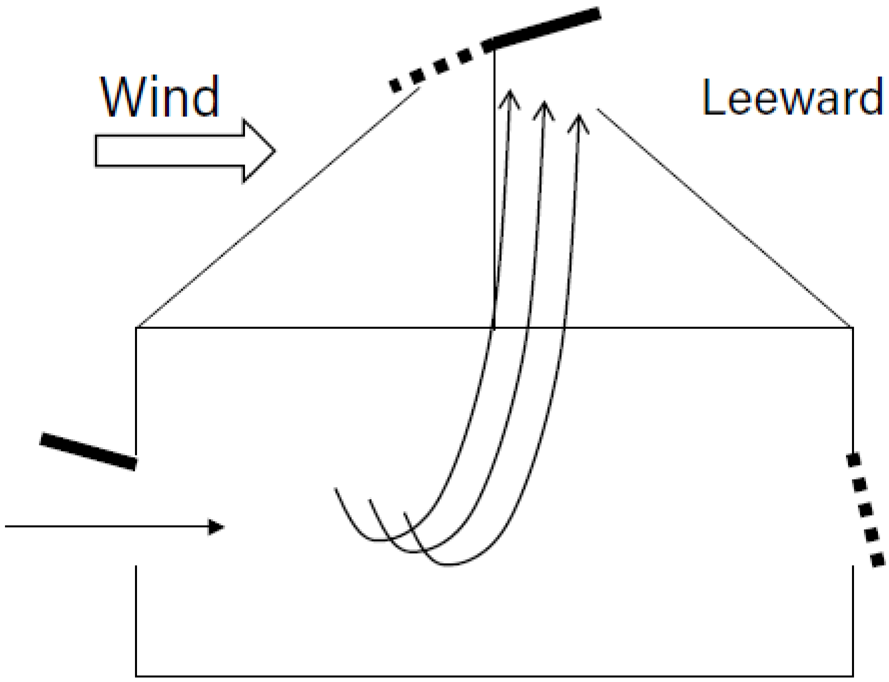
- Ridge ventilation should make 60° angle to the roof

- Wind blowing over the roof creates vacuum on the leeward side of ridge vent and air moves out

- Insect screens are used to cover openings, poses resistance to wind movement

- Tall greenhouses keep hot air above plants (gutters at 12’ to 14’ height)

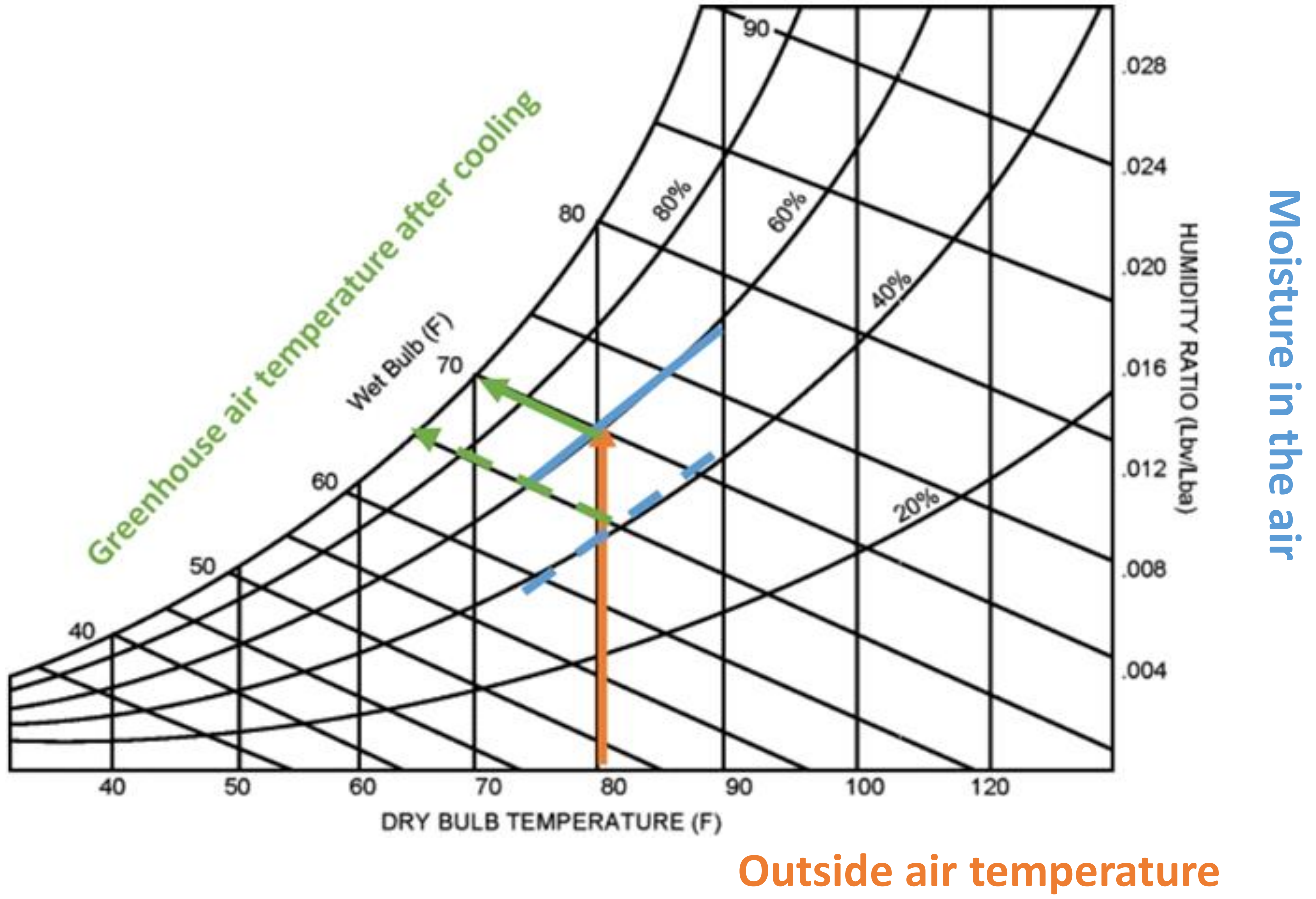
- Do not operate horizontal air flow fans when using natural ventilation



- Hot air is forced out of the greenhouse using exhaust fans
- Fans should not be spaced more than 25’ apart
- Fans should be placed on leeward side, if not add 10% to fan capacity. A clear space of 4 to 5 fan diameters to be maintained in front of fans.
- Louvers should be 1 to 1.5 times the diameter of fans
- A ventilation rate of 8-10 cubic feet of air per min for each square foot area of greenhouse is desired to keep greenhouse air within 5℉ of outside temperature (with actively growing plants)
- A 3000 square feet greenhouse requires ventilation rate of 3000 × 8 = 24000 cubic feet of air to exhaust every minute
- Exhaust fans should be sized properly to ventilate 24000 cubic feet per minute

Exhaust Fan

- Water gains temperature from air to evaporate
- This lowers air temperature
- Evaporative pads reduce air temperature by an additional 5-10℉



- Air velocity specifications:
  Aspen fiber (4-inch thick) -200 feet per min
  Corrugated cellulose (4-inch thick) -250 feet per min

- Pad area (square feet) needed will be determined by dividing air flow volume by air velocity specification

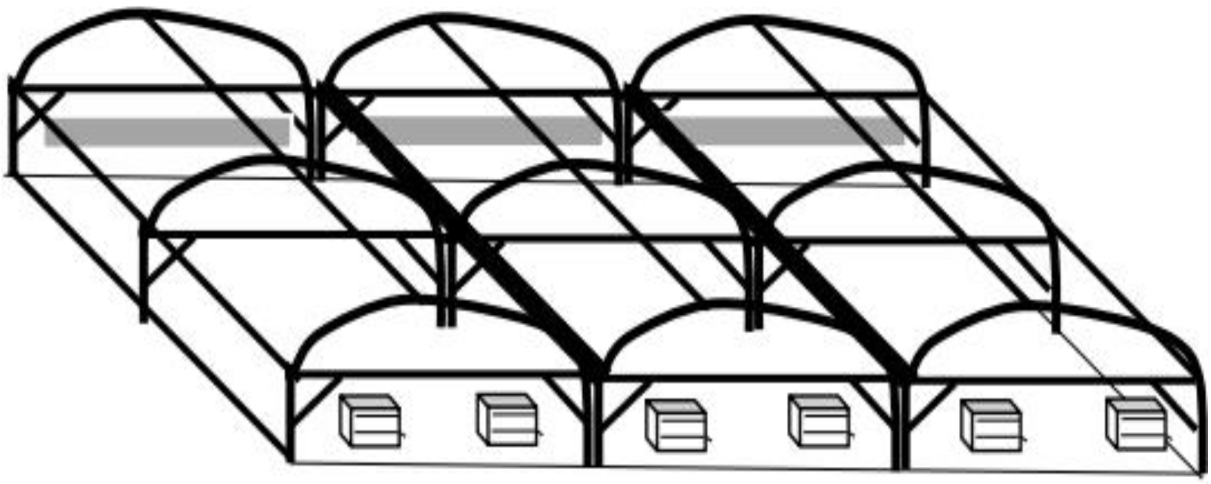
- Exhaust fans designed to ventilate 24000 cubic feet per minute

- Pad area (for Aspen fiber pads):
  = 24000 cubic feet per min / 200 ft per min = 120 square feet

- Pad vertical height is between 2-8’ but usually 4’ is preferred.
  In the above example, dimensions can be 30’ x 4’

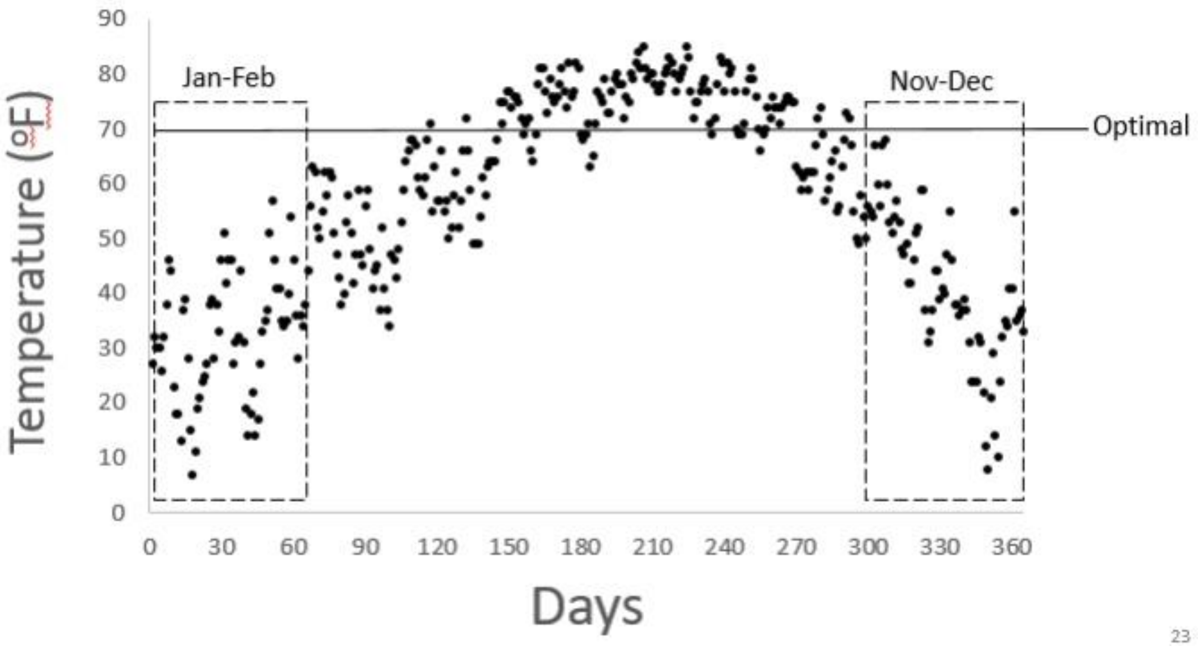
Cooling pads

- Preferred greenhouse length between fan and pad is 100 to 150 feet
- Plan 50 gallons per minute of water flow per 100 square feet of pad area
- Plan 50 GPM pump capacity per 100 feet length of pads
- Install a bleed-off to water sump to ensure that sediments are discharged
- Pads are installed on the side of prevailing winds in summer
- Fan exhaust should be at least 50 feet from adjacent pads

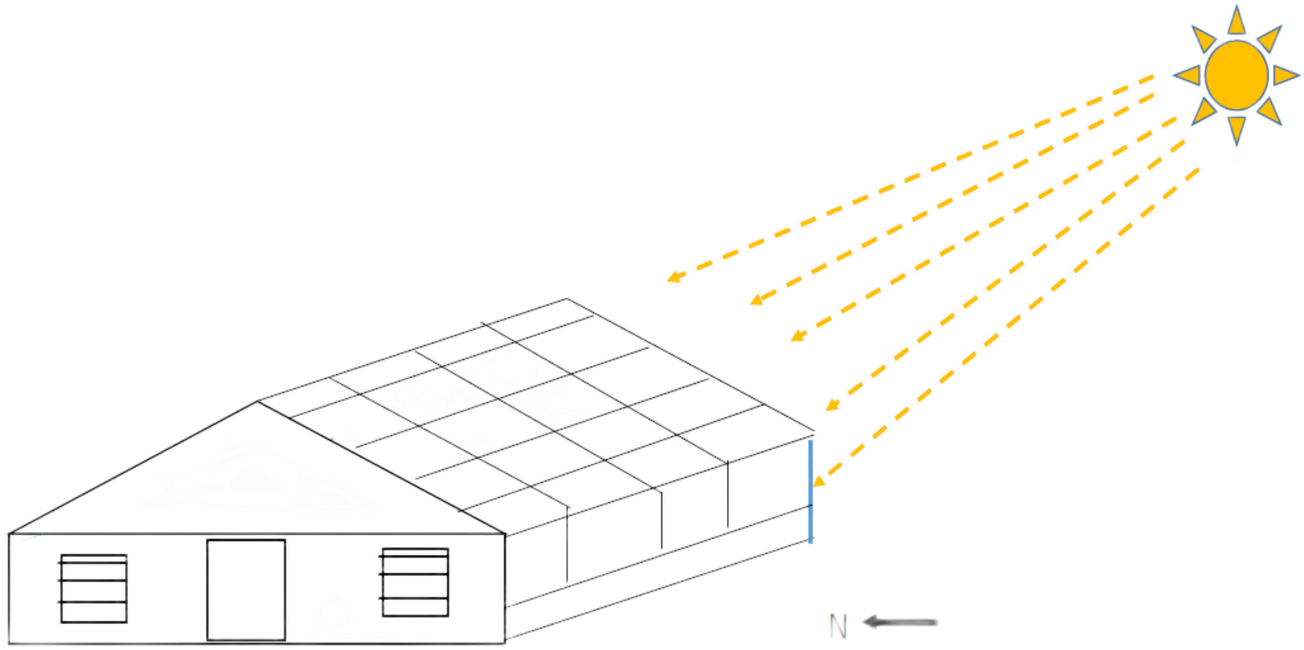


- Heating is required to produce crops during Nov – Feb

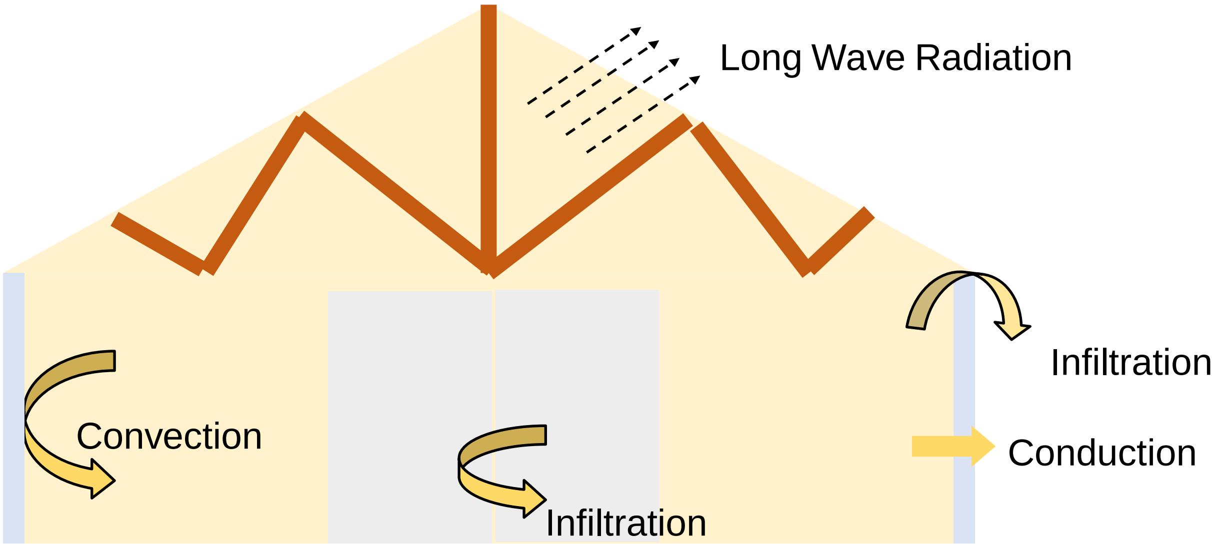
- Average winter temperatures are close to freezing (32℉) while optimal temperature for crops is around 70℉



- On coldest days, 960 BTU per square feet are needed in a day to keep optimal temperature
- Sunlight provides nearly 600 BTU per square feet in a day during winter
- Between 60 to 80 percent of heat comes from solar radiation
- Maximizing sunlight transmission into greenhouse is important to lower heating costs



1. Conduction
2. Convection
3. Radiation
4. Infiltration



- Heat requirement is calculated from heat losses due to conduction, convection, radiation and infiltration

$$QQ = UU \times AA \times (TT_{ii} - TT_{oo})$$

Q = Heat loss (BTU/hr) through conduction, convection, and radiation
U = 'Overall' heat transfer coefficient (BTU/hr ft 2 ℉)
A = Surface area of glazing (ft 2)
TT_{ii} = Inside temperature (℉)
TT_{oo} = Outside temperature (℉)

Add 10% to account for infiltration losses

- Smaller U values are better
- The value is experimentally determined for materials
- U-values can vary; representative of a normal situation are provided in the table
- Values can increase on windy and clear nights

Single pane glass: 1.1

Double plane glass: 0.6

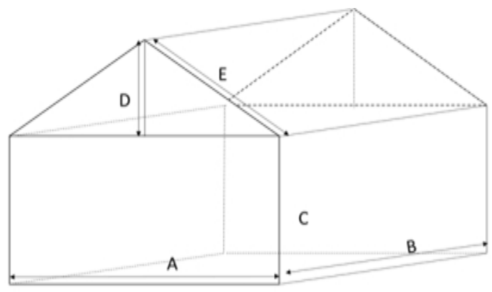
Double polythene: 0.7

Polythene (IR coated) : 0.50

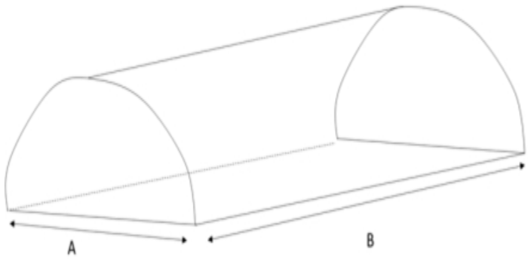
Polycarbonate: 1.1

Double polycarbonate: 0.56

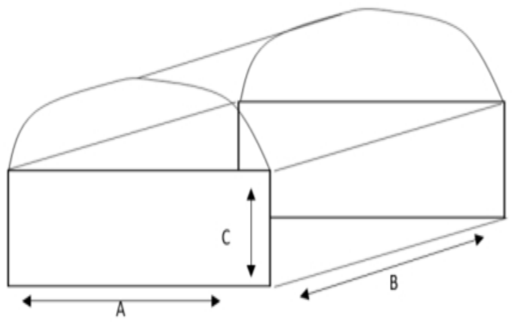
Concrete: 0.75



$$Surface\ area = 2(A \times C) + 2(B \times C) + 2(E \times B) + AD$$



$$Surface\ Area = \frac{\pi}{2}(A \times B) + \pi(\frac{A^2}{4})$$



$$Surface\ Area = 2(A \times C) + 2(B \times C) + \frac{\pi}{2}(A \times B) + \pi(\frac{A^2}{4})$$

- Propane: 91,000 BTU/gal
- Gasoline 124,000 BTU/gal
- Wood (dry): 8,600 BTU/lb
- Electricity: 3,410 BTU/KWh
- Oil (#2): 140,000 BTU/gal
- Natural gas: 1000 BTU/ft^3

Unit Heater

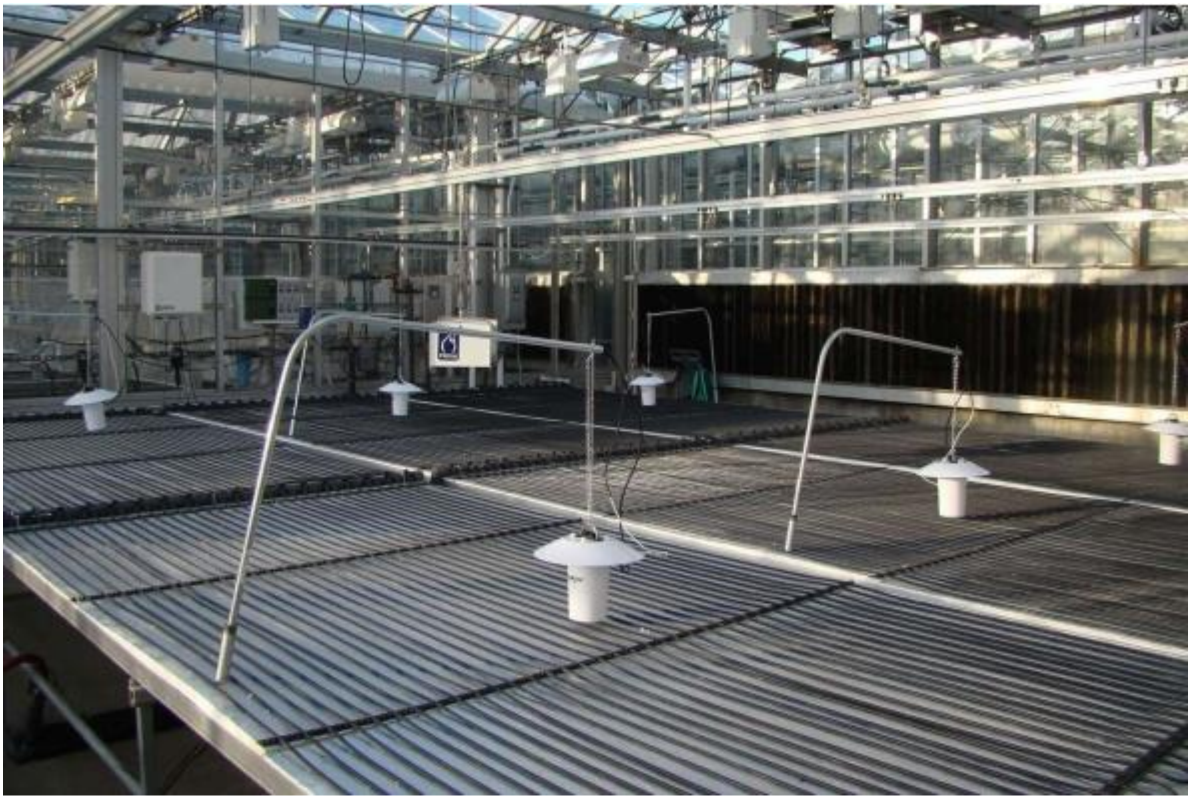
How much heat (BTU/hr) is needed to maintain 70℉ in a greenhouse when outside air temperature is 36℉.

The greenhouse is arch-shape with a surface area of 5000 square feet and covered with a double-polyethylene with IR coating on inside. Propane is used as fuel to heat the greenhouse.

$$Q = U \times A \times (T_i - T_o)$$

1. Q = 0.5 × 5000 × (70 – 36)
2. Q = 0.5 × 5000 × (34)
3. Q = 85000 BTU/hr
4. Add 10% for infiltration losses
5. Q = 85000 + 8500 = 93500 BTU/hr
6. 1 gal of propane provides 91000 BTUs
7. Therefore, 93500/91000 = 1.03 gal of propane is used every hour

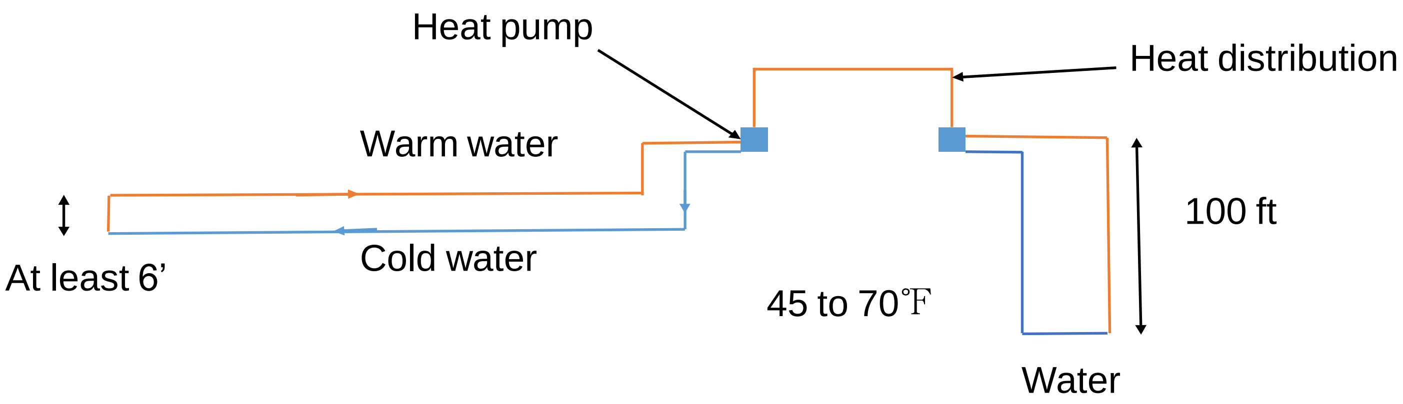
- Used to provide optimal temperature to root zone for germination, propagation and plant growth
- Hot water at 35 to 40℃(95 to 104℉) is circulated through 0.5 inch polyethylene tubing
- Flow rate should be high enough to minimize difference between supply and return sides and avoid sedimentation
- Tubing can be placed on the bench. A polystyrene sheet at the bottom ensures heat is directed towards roots
- Usually 4-inch spacing between tubes, less spacing if more temperature uniformity is desired



- Greenhouse was maintained at 55℉ but heated solution at 70℉ was used to grow lettuce
- This reduced greenhouse heating requirement but maintained good crop growth

Heated Solution (70℉) **Unheated Solution(60/50℉)**

- Both passive and active systems exist
- About 54℉ is geothermal temperature between 6-10’ in the ground
- Passive method can’t increase air temperature beyond 50-55℉
- Active method uses a heat pump. About 6-8 ton pump is needed
- Overall cost of installation can be close to $20000 for a 3000 to 5000ft² area
- Add electrical energy cost of running heat pumps to monthly bill



When comparing your alternatives, don't forget to factor in the following:

• Cost of energy

• Cost of installation

• Cost of maintenance

The possibilities for Ground and Air Source Heat Pumps in the Horticultural, Industrial Agricultural industry is enormous.

Whether you are looking to heat a farmhouse, large scale greenhouse or industrial warehouse, a ground or air source heating system will help keep your running costs low and protect your business from the volatility of fossil fuel prices.

More and more gardeners are looking for ways to operate their greenhouses in a most eco and cost-effective manner. Not only is there a growing desire to garden in a more sustainable fashion, but fuel costs are also rising considerably. If you need tips on heating your greenhouse more efficiently, continue reading.

Eco-Friendly and Efficient Greenhouse Heating Ideas

Use an electric fan heater

Buying an electric fan heater may help if you do want to heat your greenhouse more efficiently. Fan heaters are well known for circulating heat effectively, even when they are used in medium and large structures. These models tend to be built from robust stainless steel, and all you normally need to do to get started is to plug in the heater. Most of these systems come with integrated thermostats to give you control over the temperature. If you don’t have much floor space, buy one that you can mount to your ceiling.

If you do decide to buy one of these heaters, you’ll need an electrical outlet in your greenhouse. This should be installed by a professional. You could consider adding external lighting to your structure once the heater is in place. This will allow you to use the heater after dark to garden or simply unwind.

Use an air or ground source pump

Air and ground source heat pumps are becoming increasingly popular. Although you will need electricity to run a ground source heat pump, it will take warmth from the ground to transform it into heat that you can use in your greenhouse. An air-source pump takes heat from the outdoor air. It can either transfer it to your greenhouse air or to water in pipes to keep your greenhouse warm. An air-source heat pump is a less expensive option than a ground source heat pump. This is because no excavation is required.

Specialise in reducing the heating costs of greenhouses and agricultural buildings

Types of Heat Pumps

There are four types of pumps for environmentally-friendly greenhouse heating:

• **Ground Source Heat Pumps** - These draw the heat energy from the Earth to your greenhouse.

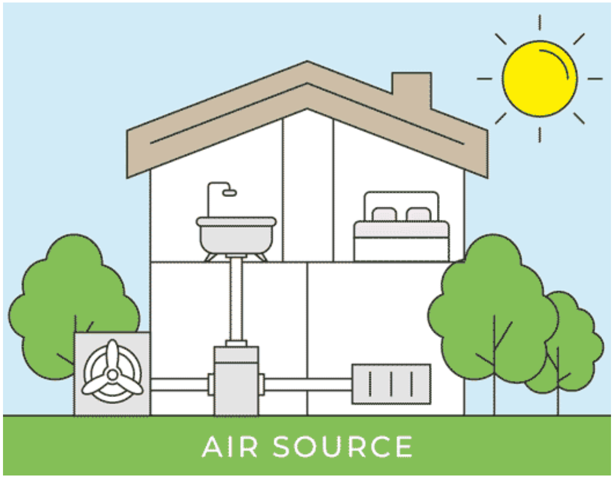
• **Air Source Heat Pumps** - These are the ideal pumps for greenhouse growers, providing a versatile system that efficiently heats and cools the greenhouse.

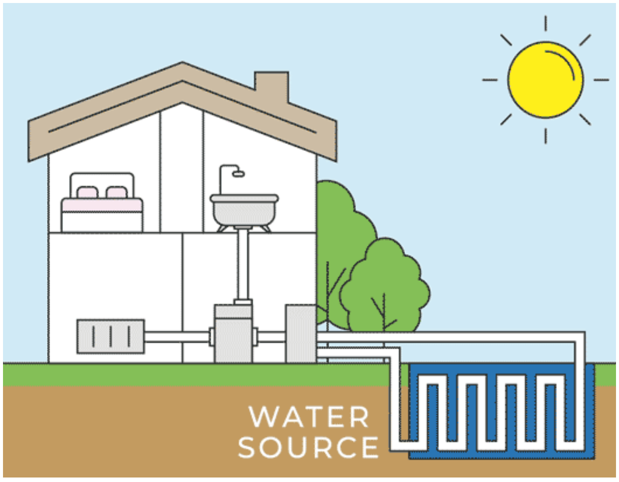
• **Water Source Heat Pumps** - These pumps draw heat from the water and transform it into heat for your greenhouse.

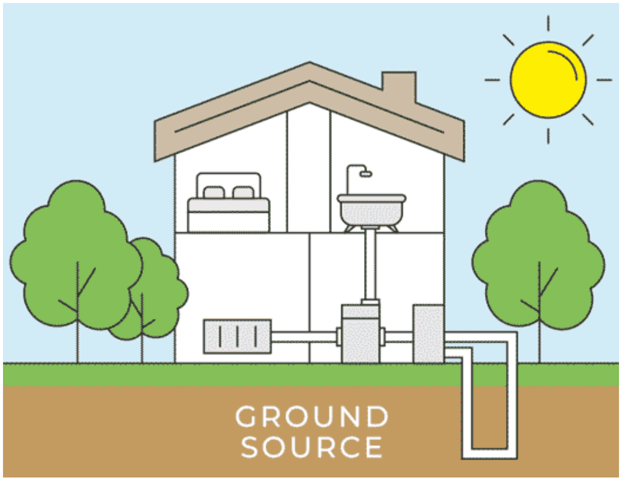
• **Heating & Cooling Systems** - These all-in-one pumping systems serve as an air-conditioner, a boiler, a radiator to offer underfloor heating and fan coil services.

What Are the Three Major Types of Heat Pumps?

There are three significant subtypes of heat pump systems – ground source heat pumps, air-source heat pumps, and water source heat pumps. Let us discuss each type to further your understanding of each.







Air Source Heat Pumps

Air source heat pump work great in moderate climates. You will usually find an air source heat pump on the side of the building, where it takes the air from the outside and transfers it through compression and two conductive copper tubing-made coils.

Whenever there is a requirement for any heating, the liquid refrigerant in the other coil takes the heat from the air and vaporisers, passing it into the inner coil. In air-to-air heat pumps, this gas turns into liquid form and produces all the warmth you need for the household heating system.

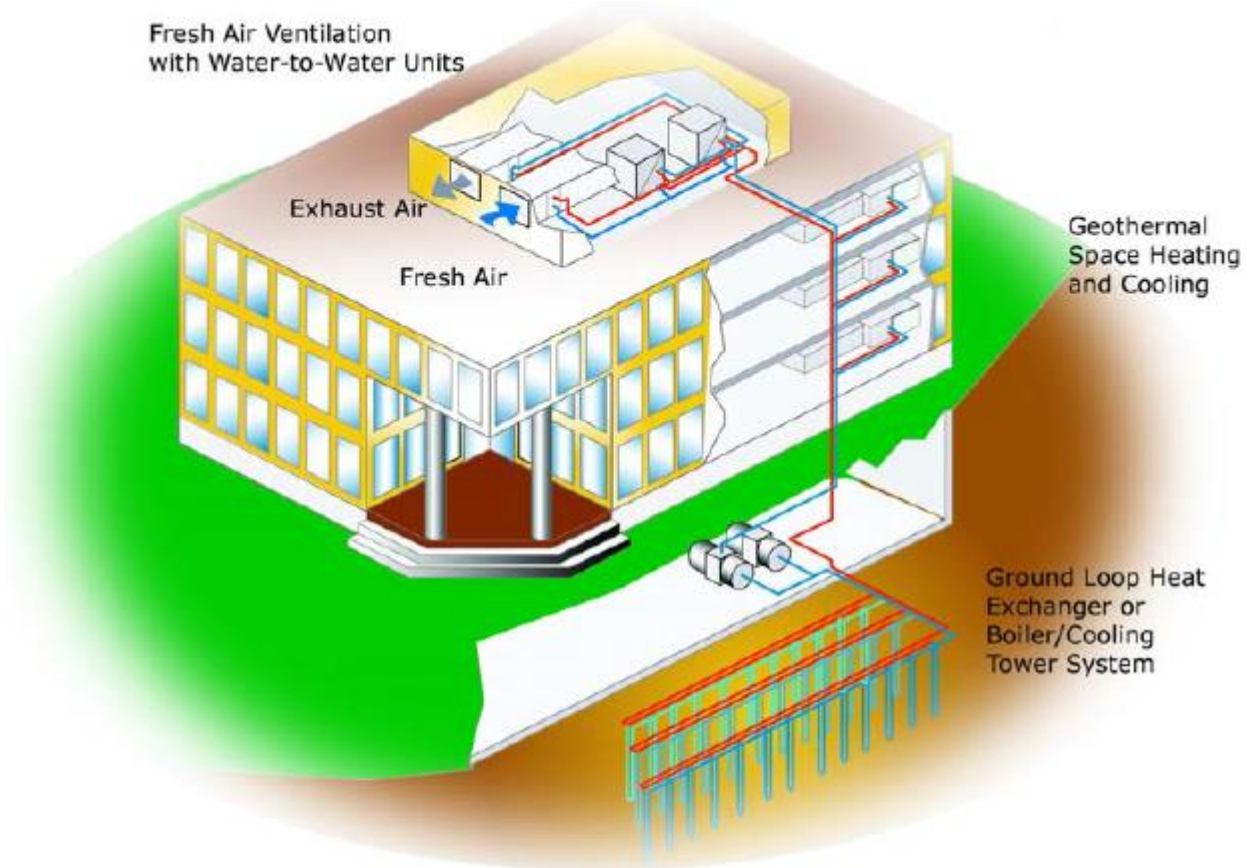
Air source heat pumps extract energy from the air even as low as -25℃. Extracting this low grade heat at this temperature is still enough for the heat pump to multiple or amplify this heat to 65℃(max 90℃). Therefore, satisfying your heating and hot water demands.

Geothermal Heat Pumps

Ground source or geothermal heat pumps are instrumental in extracting heat from sources other than the outside air. These heat pumps take up the natural heat in the ground and use them to run their system. Moreover, these heat pumps work with multiple heat pipes laid in the ground.

However, **geothermal heat pumps** would be more efficient than air-source heat pumps. A simple reason behind this is that the ground temperatures are much more fixed than the air. The only negative with ground source heat pumps is that they would be much more expensive than the other options.

Ground source heat pumps efficiently extract energy from the ground at around 10℃ and using compression are able generate temperatures of around 80℃– Satisfying your heating and hot water demands.



Water Source Heat Pumps

A **water source heat pump** works just like its name– it extracts heat from the lakes, rivers, ponds, springs, boreholes, or wells to heat your home or office. This sourced heat is increased in temperature through electricity and is then sent to taps, geysers, and the underfloor heating in your home.

So, it is an excellent option to replace your original home gas boiler with these pumps, given their effectiveness and low power consumption. As such, more and more people are edging towards the use of a water source heat pump.

Is an Air Source Heat Pump the Ideal Choice for a Greenhouse?

Yes, air source heat pumps are far more environmentally friendly than traditional gas boilers. Installing a heat pump could cut your carbon emissions by more than 23 tonnes of CO2 over 10 years.

With the increasing trend of environmentally friendly efforts, heat pumps have successfully replaced old oil-fired boilers. The air energy heat pumps are now used in various fields as a part of energy conservation and emission reduction policies.

Now, not only thousands of households but agricultural specialists also do heat pump greenhouse heating to get effective results.

An air-source heat pump absorbs heat from the outside environment and releases it into the greenhouse's interior. These devices are of two types depending on their functions:

• **Air-to-Air Systems** - They deliver warm air that heats the entire greenhouse.

• **Air-to-Water Systems** - They heat water that provides both heating and hot water for the greenhouse through radiators, fan coil units, air handling units or an underfloor heating system.

How Does Air Source Heat Pump Greenhouse Heating Work?

The heat pump has three parts that ensure adequate heating to your greenhouse, including:

• **Evaporator Coil** - It draws heat from the outside.

• **Compressor -** It then pumps a refrigerant type with the heat pump and compresses the gaseous form to the ideal temperature for heat distribution.

• **Heat Exchanger -** This part then transfers the heat energy obtained from the refrigerant to air or water.

The air-to-air and air-to-water systems then transfer this heat to the greenhouse for effective and energy-sufficient vegetation.

Soil and water below ground contains a vast reservoir of thermal energy. Geothermal heating systems recover this energy and convert it to heat that can be utilized in greenhouses and other buildings. Geothermal heat can be classified into three categories.

Low temperature (50℉)

They heat water that provides both heating and hot The soil temperature at the surface varies considerably over the year and closely follows the air temperature. At the 10-12' depth it is more uniform averaging about 50℉ with a variation of about 6℉ above and below this level. There is also a lag time of about 8 weeks between the maximum surface temperature and the maximum soil temperature at the 12' level which is helpful in winter heating and summer cooling. For the greenhouse production of perennials, herbs, nursery stock and some vegetables that require a temperature from 32-45℉ this low grade soil heated air or water can be used directly. For heating the greenhouse to a higher temperature, a heat pump is necessary. These are available as air to air, air to water, water to water or water to air systems.

Medium temperature (140-300℉)

Thermal wells and springs in some parts of the world provide hot water that can be used directly for heat. There are currently over 500 greenhouse operations in the world that are heated by geothermal energy. The heated water that comes from the ground is distributed through fin radiation or root zone heating.

High temperature (>300℉)

The steam from somewhere is being tapped for power generation. These produce power for 5-8 cents/kWhr.

Greenhouse heating systems

In somewhere, the only choice that we have for geothermal heating is with low temperature heat. There are several systems that appear to be feasible that have a reasonable payback. Before considering the installation of one of these systems, it is important to address energy conservation. Reducing infiltration, installing energy curtains, insulating sidewalls and the foundation perimeter, making good use of growing space and installing electronic controls should be done first. This will save considerable heat and reduce the size of the heating system needed.

Air systems

Earth tubes are piping that is buried 6' to 12' below the soil surface. The simplest and least expensive systems gather heat during the winter by drawing air through corrugated plastic tubes and direct it into the space to be heated. The air passing through the tubes is warmed by the soil that has a higher temperature than the air. During the summer the system can be used to cool building space by drawing the heated air in the greenhouse through the buried tubes and then returning it to the building. The heat is absorbed by the cooler earth.

In the above system the air can be warmed or cooled to near the soil temperature. For example, the average soil temperature 8' below the surface in central China varies between 60℉ in early Fall to 46℉ in early March. To increase the temperature to 80℉ - 90℉ for air heating for ornamentals or bedding plants, an air to air heat pump could be employed. This process is similar to what happens in a refrigeration system.

Water systems

Liquid systems utilize either the soil heat to warm a liquid, such as water or antifreeze or directly use water from ponds or well and extract the heat. There are several systems that have been used successfully.

Closed-loop systems circulate water or an antifreeze solution through loops of small diameter underground pipes. In cold weather this solution absorbs heat from the ground and carries it to a heat exchanger that extracts it. In may also go to a heat pump that amplifies it so that the temperature is warmer.

Horizontal loops may be used where adequate land is available. Pipes are placed in trenches in lengths to 400'. Multiple loops are used to capture the amount of heat needed to heat the greenhouse. Vertical loops are an alternative were land area is limited. Well drilling equipment is used to bore small diameter holes from 75' to 500'; deep. The hole may be filled with a grout to transfer the soil heat to the pipes.

Pond or lake loops are economical to install when a body of water is nearby. This system eliminates the excavation cost. Water or antifreeze is circulated through coils of pipe that are placed in the bottom of the pond or lake. A depth of at least 12' is needed to avoid the influence of the freezing that occurs on the surface during the winter.

An open loop system utilizes ground water directly. Water is usually pumped from one well and returned to a second, adjacent well. The distance between wells has to be far enough so that the return water doesn't influence the intake water. The water may also be pumped out of a pond or lake at one location and returned a distance away. Open loop systems can be economical if the source of water is located nearby.

Conclusions

The use of ground heat is becoming more popular for residential and commercial applications. Due to the high temperature needed for conventional greenhouse heating, a heat pump is needed. Today's equipment is more reliable at a lower cost than a few years ago. Where low temperature heat is needed, such as maintaining an air temperature just above freezing, direct use of the heat is possible.

As the cost of fossil fuels increases, the payback for alternative heating systems shortens. For most geothermal systems the payback is in less than ten years with energy prices at $25/MBtu.

The GCHP system to heat, cool and dehumidify greenhouses

A ground coupled heat pump system that heats, cools and dehumidifies our sealed greenhouses. It acts as an innovative geothermal HVAC system that utilizes the Earth's steady temperature (between 45℉- 60℉) to create precise climates in each greenhouse environment.

To break it down, the GCHP system is made up of two primary components: a ground source heat pump and a ground loop. The ground source heat pumps are attached to the North wall of the greenhouse, above ground. The pumps filter and condition CO2 rich air from inside the sealed greenhouse environment. The ground loop component transfers thermal energy to or from the greenhouse heat pumps. This is achieved by recirculating water through subsurface piping. The recirculating water will either absorb heat from the ground (GCHP system in heating mode) or disperse heat back into the ground (GCHP system in cooling mode). The two components together make up a completely closed-loop system.

We should probably mention the fluid coolers as they are on the diagram and are an integral part of the GCHP system. The fluid coolers are basically there to add an extra boost of cooling when the ground alone cannot handle the cooling load. The fluid coolers are there to dump excess heat into the air, via evaporative cooling, before it enters the ground to ensure our ground temperature does not increase over time year after year. Basically the fluid coolers are our “Turbo” when we really need it.

Cooling

When the GCHP system is in cooling mode during peak summer months, hot air will enter the heat pumps and refrigerants inside will absorb and transfer heat to the water recirculating underground in the ground loop. The earth surrounding the ground loop acts as a heat sink and will disperse the heat back into the ground. To add an extra boost of cooling on especially hot days, the GCHP system is equipped with fluid coolers to dump excess heat into the outside air via evaporative cooling. This is done before the air enters the ground to ensure the ground temperatures do not increase over time year after year.

When the heat pump is in this cooling mode, it pulls moisture out of the air and this moisture can be collected in a reservoir and used on site for irrigation purposes. In this way the GCHP system is recycling water by taking moisture transpired by the plants, collecting it and then giving it back to the plants at a later time when it is needed.

Heating

When the GCHP system is in heating mode it absorbs heat from the ground through the water recirculating in the ground loop. The heat pumps concentrate and transfer absorbed heat to the air recirculating in the grow environment. The GCHP system also recovers waste heat from the compressors for reheating dehumidified air. Traditionally HVACs need additional energy to reheat dehumidified air to the desired temperature but the GCHP system recycles energy from the heat compressors via heat exchangers. This innovative concept contributes to its low operational costs.

Dehumidification

In most greenhouses, the HVAC and dehumidification systems are two separate entities working together (or sometimes against each other) to create the perfect growing environment. With the GCHP system we have combined these two systems so growers can easily achieve exact VPD levels. The GCHP system dehumidifies the greenhouse environment by intaking air and cooling it to dew point inside the heat pump. The heat pumps then reheat the air with waste heat recovery to bring the air back to the desired temperature. The system can dehumidify the air down to 40% relative humidity.

"The GCHP system is designed exclusively for our sealed high yield kit design and is a perfect solution for growers seeking heightened biosecurity and precise climate control. Also, the GCHP system is designed for all climate zones and can be built in redundancy for modular expansion. And unlike traditional HVAC systems that create unwanted shading, the GCHP system takes up no room inside the greenhouse which increases the potential for optimal sun harvesting."

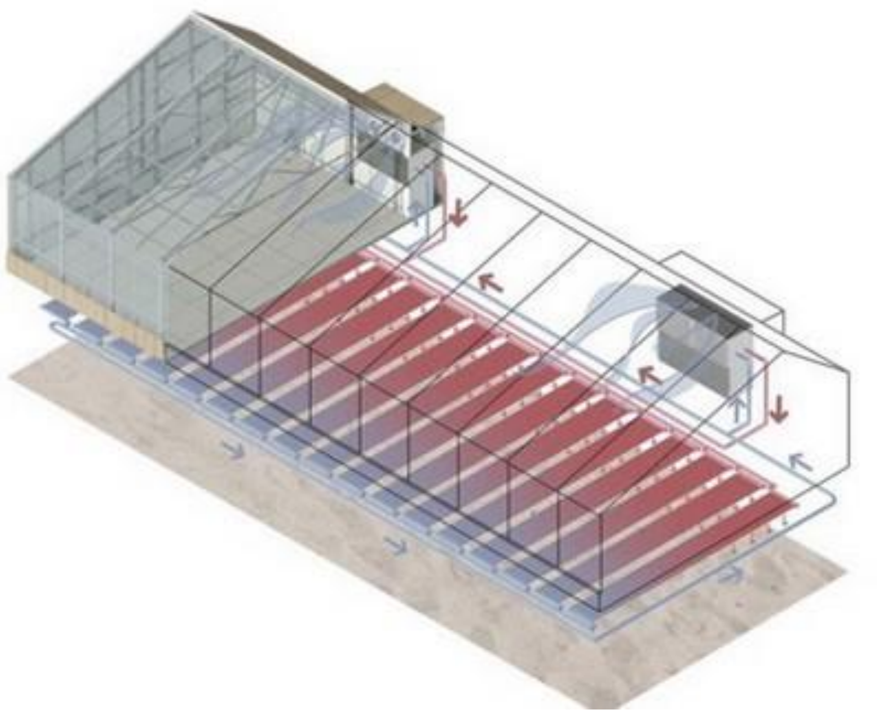
The geothermal qualities of the GCHP system classifies it as a renewable energy source and thus qualifies growers for rebate offers from state and utility programs. GCHP systems have a comparable upfront cost to chillers but GCHP system's life expectancy is longer and its energy consumption is significantly lower.

The Numbers

We crunched the numbers and determined that growers can expect to save more than 60% on energy costs compared to a traditional HVAC system. A traditional HVAC system uses 87.5 kilowatts of energy per square foot per year whereas the GCHP system uses 35 kilowatts. To translate that to dollars, growers will spend about $10.50/ sq ft/ year to use their HVAC system and they could be spending $4.20/ sq ft/ year with the GCHP system.

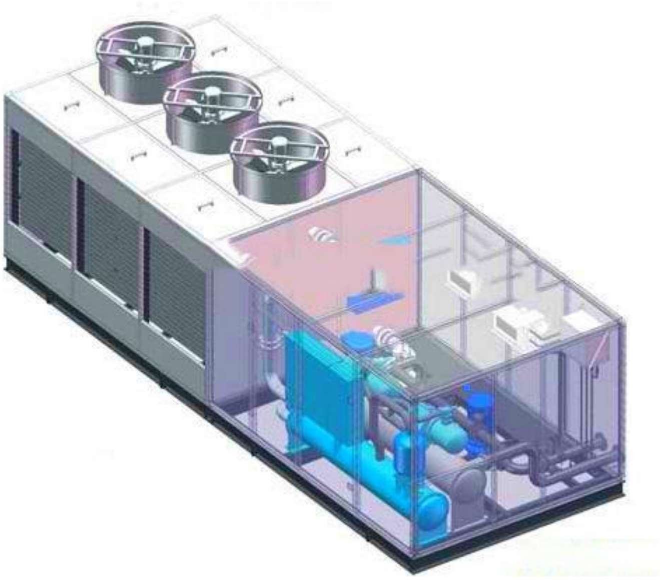
Permanent glass house structures are often ideal to take advantage of the benefits of a heat pump heating system. The heat also enables clients the option to grow a wider variety of plants more profitably. In addition to this the "dry heat" that is produced through the ground and through the fan coil heaters can help reduce disease developing on the plants.

The possibilities for ground and air source heat pumps in the agricultural industry is enormous. There are so many sectors within agriculture where this can benefit the customer, both financially and productively.




Withair


Withair



Air-conditioning System for Modern Agricultural Production of Mushroom

Air-conditioning System for Litch Storage

Ultralow Temperature Air Source Heat Pump (Ambient Temp. from -25℃ to 45℃) in Armenia

President of Armenia visited greenhouses projects on 31th,Jan,2013

Bulgaria greenhouses (Geothermal Source Heat Pumps) for Extension Greenhouse Crops and Floriculture

Benefits At A Glance

Withair® designed the complete line of Heat Pumps for high efficiency, individually-zoned comfort control in offices, schools, assisted living facilities, manufacturing facilities and other commercial buildings. Our reputation for outstanding reliability and quiet operation has been reinforced in thousands of successful installations.

Using feedback from building owners, consulting engineers, contractors and service engineers, we designed the latest version Water Source Heat Pumps to give you maximum flexibility to design, install, operate and maintain the ideal water source heat pump system for your building project. And we incorporated non-ozone depleting R-410A refrigerant, which–along with high Energy Efficiency Ratios (EER's)–helps preserve our environment and precious energy resources.

For Building Owners and Managers

• Quiet operation
• Easy to maintain
• Reliable operation
• Reduces operating expenses
• Environmentally sound refrigerant
• Building automation system compatible

For Consulting Engineers

• HFC refrigerants
• High-efficiency optimization
• Ideal for replacement projects
• Compliant local code requirements
• Quick response technical support services

For Contractors

• 100% run-tested
• Compact footprint
• Diagnostic controls
• Easy to break down
• Ideal for replacement
• Reliable performance
• Reduces installation expenses

Premium manufacturer in HVACR products
for Heating,Cooling and Indoor Air Quality.

Learn more at www.withairgroup.com
or follow us info@withairgroup.com

About Withair ®

Withair® is the premium manufacturer in sustainable energy solutions supplying HVACR products & services for heating, cooling, hot water, indoor air quality, industrial refrigeration, and heat recovery that reflect today's demand for sustainable construction, comfortable indoor climate and industrial cooling & heating process application.