Build and Operations, Climate Control, Commercial, Design, Ecoloop and GAHT

How To Mitigate Rising Gas Prices With Electric Greenhouses

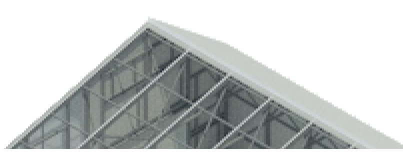
June 30, 2022

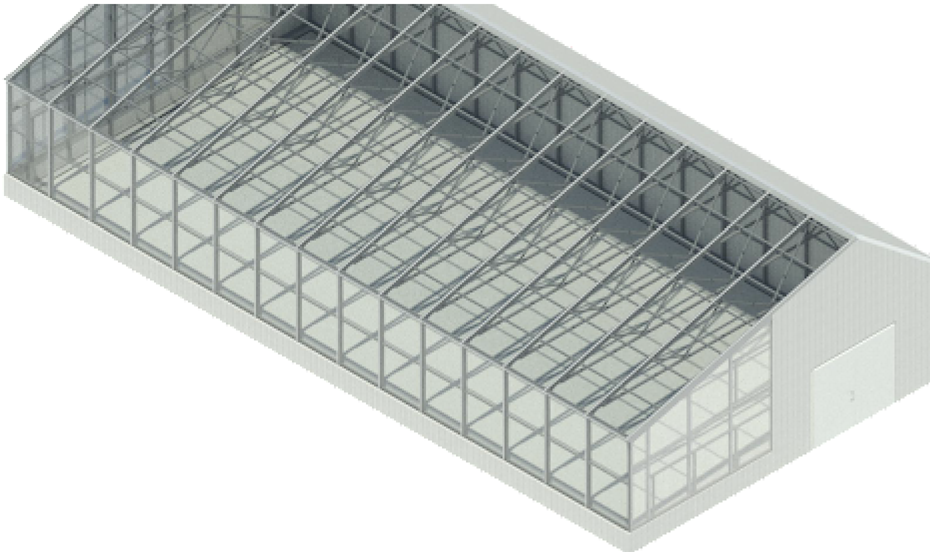
The cost of energy is rising at an alarming rate. Natural gas prices, in particular, have greenhouse growers nervous about their operational costs and questioning their business viability. This trend should act as an incentive for cultivators to look towards gas-free and energy-efficient greenhouse solutions in order to thrive. Luckily, these alternative energy solutions are more attainable than one might think and are already proving to be successful for many growers. In this blog we will discuss electric greenhouses and their equipment, and how they produce the same end result (if not higher yields and better quality) as a traditional gas-powered greenhouse.

(Markets Insider graph of natural gas prices (Henry Hub) in the US over the last 6 months (snapshot taken 6/23/22) https://markets.businessinsider.com/commodities/natural-gas-price)

The Greenhouse Envelope

While we will focus on electricity-based environmental control options, it's important to think about the thermal envelope of the greenhouse as a first step. Traditional greenhouses are poorly insulated (or not insulated at all), which means they require more heat, and more gas, to keep them operating in colder temperatures. Highly insulated greenhouses, on the other hand, can reduce heating loads by as much as 70% based on their design and materials used, reducing heating needs significantly.





From gas-powered greenhouses to electric greenhouses

Traditionally, commercial greenhouses use central gas boilers to heat water or steam that is distributed through the greenhouse via a piping system. This method of heating is similar to a radiant heating system you may have in your home. While tried and true by many commercial greenhouse operators, this method of heating is becoming less sustainable with natural gas prices reaching an all time high across the globe.

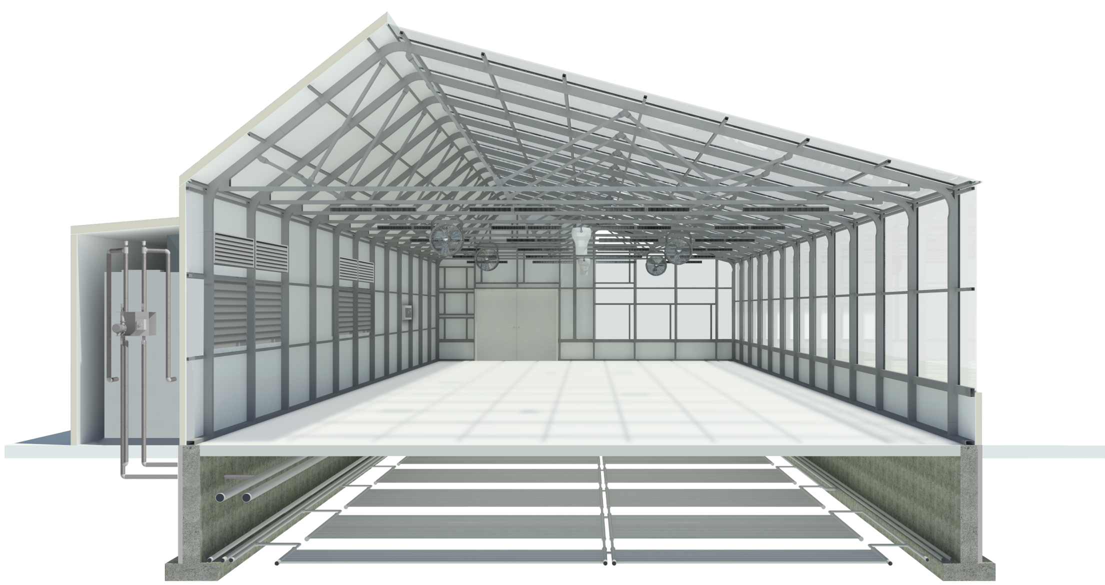
Natural gas powered boilers in a commercial greenhouse. Image from shutterstock.com

So what's the alternative? Well, just as many people are turning to electric vehicles to skip out on gasoline prices and lessen their impact on the environment, growers are turning to electric greenhouses to grow crops. You may be thinking, "well, isn't the price of electricity rising too?".

This is true, but at Ceres, we have developed energy-efficient heating, cooling, and dehumidification systems that use less electricity because they rely on heat pump technologies to condition the greenhouse environment. These energy-efficient HVACD systems are called EcoLoop™ and EcoPack™, and they enable our growers to cut their ties to natural gas and propane.

How the "Eco" HVACD series saves you money

The EcoLoop™ is a hybrid ground coupled heat pump system. This means it includes a ground loop component that lies underneath the footprint of the greenhouse that constantly circulates water through the underground system. The circulating water either absorbs heat from the earth surrounding the mats or dissipates heat back into the earth – depending on whether the system is in heating or cooling mode. The ground loop component transfers thermal energy to and from the heat pump component of the HVACD system which sits above ground on the exterior of the north wall of the greenhouse. Through this process, the system utilizes free geothermal energy to regulate the temperature of the greenhouse space. This energy-efficient technology is saving growers on operational costs at a time when natural gas prices are sky-rocketing.



A SunChamber™ integrated with the EcoLoop geothermal HVACD system

The EcoPack™ is a very similar system to the EcoLoop™ in that they are both use heat pumps and they combine heating, cooling and dehumidification into one system. The main difference is the EcoPack™ doesn't utilize the geothermal ground coupling, nor does it use external evaporation as part of its cooling methodology. While the EcoPack™ is slightly less efficient than the EcoLoop™, the system is simpler and cheaper to install. While it can utilize natural gas for heating, it can also be used as an electric only unit. Either way, it is significantly more efficient than traditional gas powered boiler systems.

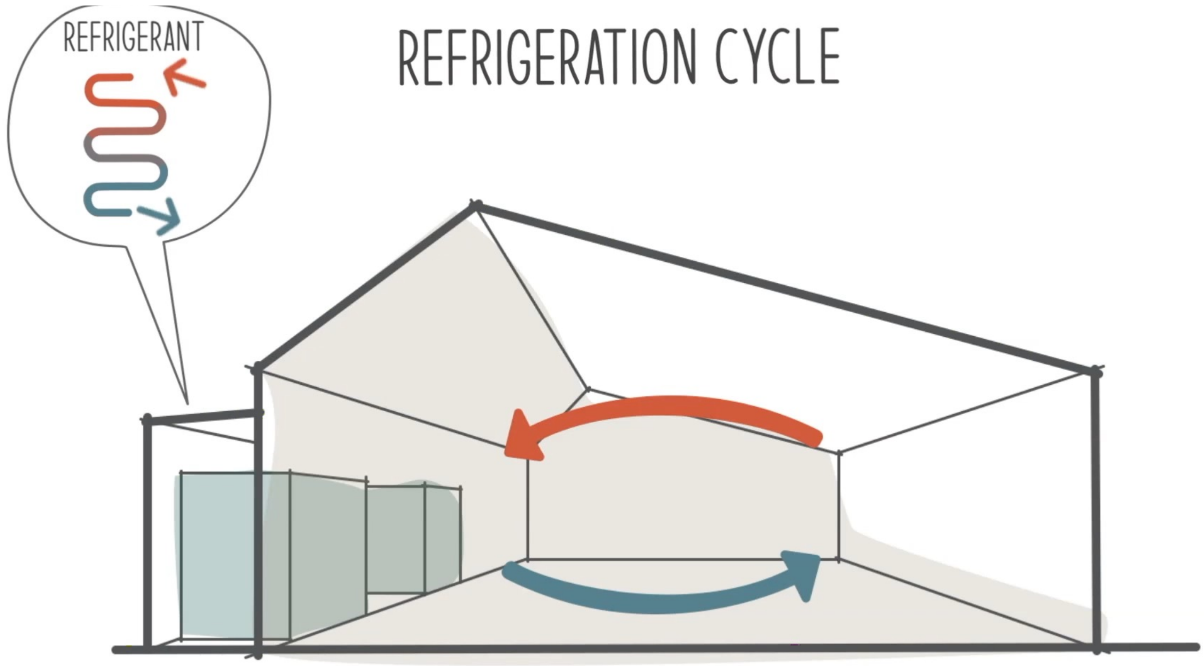
A SunChamber integrated with the EcoPack™ HVACD system

To learn more about how HVAC systems and the EcoLoop™ works, watch this informational video.

What other greenhouse systems are gas-powered?

Desiccant dehumidification systems. When plants transpire into the greenhouse space, this extra moisture in the air needs to be dealt with, either through ventilation or dehumidification. Dehumidification systems are an important aspect of a commercial greenhouse, and depending on what kind of system is used, it may use gas to function. If you are unfamiliar with how dehumidification systems work, visit our blog, "Greenhouse Dehumidification Strategies for Vented and Sealed Commercial Greenhouses".

With the EcoLoop™ and the EcoPack™, dehumidification is built into the system. The heat pump component uses a refrigerant to cool the incoming moist air to dew point, and then after condensation happens, waste heat from the heat pump reheats the dehumidified air back to a comfortable temperature suitable for plant growth before it's exhausted back into the greenhouse. By combining dehumidification with heating and cooling, we ensure that our growers can reach specified vapor pressure deficit (VPD) levels. And like we mentioned above, the Eco HVACD Series runs entirely on electricity – eliminating your reliance on gas.

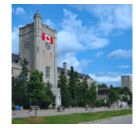


Other benefits of geothermal and electric greenhouses

The Ceres EcoLoop™ and EcoPack™ are just one component of Ceres' holistic greenhouse solution called the SunChamber™ – a sealed design with full system integration. The SunChamber™ uses the power of the sun along with innovative climate control technology to create a highly productive growing environment. With this holistic solution, you can grow higher quality crops and reduce the risk of crop failure by taking advantage of the SunChamber™'s biosecure and highly controlled environment. Combine the growing capabilities of a SunChamber™ with the lower cost it takes to operate it, and you have a growing capabilities/ abilities that will allow your business to thrive even with rising energy prices and unstable fuel markets.

Why the Ceres HighYield™ Kit is Better than Other Commercial Greenhouse Kits

Funding Awarded for Energy Efficiency Research in Ceres Greenhouse



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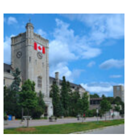

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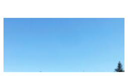

Why the Ceres HighYield™ Kit is Better than Other Commercial Greenhouse Kits

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Geothermal Greenhouses: Exploring the Potential

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Contents

This publication provides basic information on geothermal energy technology and its potential in greenhouses. It explains how geothermal heating and cooling systems may expand the features of a growing structure while maintaining minimal energy usage. This publication discusses active and passive ground-source geothermal energy systems and provides design examples for passive system design suited to agricultural operations.


Photo: Lance Cheung, USDA

Introduction: Geothermal Energy for Agricultural Growing Structures

Agricultural growing structures, such as greenhouses and high tunnels, are used for plant propagation, season extension, and to enhance and control crop production. Greenhouses and high tunnels can have the same basic structure: metal frames and plastic polyethylene, polycarbonate, or glass walls and roof. Both provide varying degrees of temperature and climate control to extend the growing season. High tunnels, sometimes called hoop houses, differ from greenhouses in that they include non-automated climate controls (like vents or roll-up sides) and are typically used for season extension rather than year-round growing. Traditional greenhouses are primarily used for plant propagation, require heat usually provided through automated climate controls, and generally built with more durable materials. This also allows for more consistent year-round growing. A third variation, passive solar greenhouses, consists of structures typically smaller than high tunnels that do not use power-generated heat sources like greenhouses do.

Traditional greenhouses protect crops in temperature extremes by using temperature, humidity, and ventilation controls to maintain

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an ideal climate (Rimol Greenhouse Systems, 2019). Generating such a climate can result in significant energy costs. Heating and electric combined is typically the third-largest cost for operating a traditional greenhouse (Penn State Cooperative Extension Service, 2020). By contrast, high tunnels and solar greenhouses are passive in design and do not require extra energy for heating and cooling, making them a more cost-effective option for certain operations. However, growers can further benefit from these structures when they are supplemented with an equally cost-effective climate-control system. Perhaps surprisingly, an efficient source of supplemental energy can be found right below our feet.

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Solar Greenhouses

Renewable geothermal energy is heat derived from the subsurface of the earth (EPA, 2016). Underground temperature becomes stable starting roughly two feet below the earth's surface and continues to stabilize at deeper depths. Underground soil maintains a constant temperature year-round, averaging 55°F throughout the United States. Geothermal systems allow us to take advantage of these stable temperatures. In general, a system is comprised of two main components: underground tubing or piping to support the flow of a fluid (either air or a glycol solution) and the mechanism to push the air or fluid in and out of the piping. These primary components work to turn over the air in the structure to meet heating or cooling needs. Movement of air or fluid is achieved in various ways, such as using a heat pump or a simple inline fan.

This publication provides basic information on geothermal energy technology and its potential in greenhouses. It explains how geothermal heating and cooling systems could expand the features of a growing structure while maintaining minimal energy usage. This publication focuses on two types of ground-source geothermal energy systems, one of which is more sophisticated in design and requires a heat pump. The other is a more "passive" system that is similar in design but does not require a heat pump. Lastly, it provides design examples for a passive greenhouse system design that best suits agricultural operations.

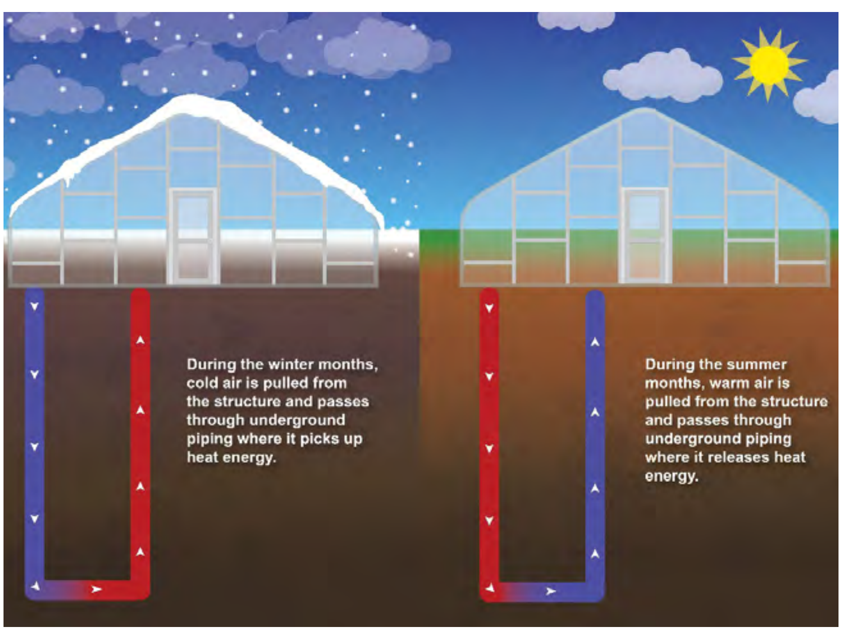

Figure 1. Flow of Heat Energy in a Geothermal System. Graphic: Marisa Larson, NCAT

How Geothermal Systems Work

The flow of heat energy within a geothermal system can be utilized to heat or cool a space, depending on seasonal needs. Air is moved from inside a building and pushed through a network of underground piping. Convection through this piping heats or cools the air, which is then exhausted back into the structure at a more desirable temperature. When the underground temperature is warmer than the ambient temperature above ground, the heat pump or fan pushes the warmer air up to the growing structure that needs to be heated. When the temperature in the growing structure is too warm, the pump or fan removes the warm air from the building and pushes it into the pipe below ground, returning cooler air to the building (Figure 1).

Active Systems

An active system utilizes a water-to-air heat pump, a liquid (either water or a glycol solution) as the medium for heat exchange, and evaporator and condenser coils. It uses the basic refrigeration cycle of evaporation, compression, condensation, and expansion to heat or cool the air before it is delivered to the space. The piping can be organized in the ground horizontally (trenches) or vertically (bore holes). Horizontal trenches are most applicable for small-scale operations because a vertical system requires drilling several deep holes (about 200 to 500 feet) to install the piping. This can become expensive because of the deep drilling that is required, although it does have greater ability to offset energy needed for heating or cooling in more sophisticated buildings and large operations (EPA, 2016). In this system, the liquid runs through piping in the ground, either absorbing or diffusing heat, depending on the temperature needs of the building above.

If the property has a private water source such as a pond, lake, or well, other options are available that do not require excavation. In these systems, water is pumped into the piping from the pond, for example, and this functions as the medium for heat exchange. These are active systems because they use a heat pump to pump the water from the water source into an exchanger, which heats or cools the air and then sends it into the building.

Standard geothermal heating and cooling systems are rated on their coefficient of performance, as a ratio of a product's heat output to the electrical energy input required (Kamoshida et al., 1990). Standard systems have efficiencies of 300 to 600%. Compare this to the efficiency of a standard fossil-fuel furnace, which varies from 75 to 90% (ASHRAE, 2018). "Geothermal systems are [at least] twice as efficient as the top-rated air conditioners and almost 50% more efficient than the best gas furnaces, all year round" (Alexander, 2018).

Passive Systems

A passive geothermal system is often called an "earth battery," "climate battery," or "low-grade geothermal system." This system is comprised of piping, risers, manifolds, fans, and the insulated mass of soil. It uses the same fundamentals of thermodynamics as a ground-source system with a heat pump but has less intensive installation, which significantly reduces cost and requires only the energy needed to keep a fan or two running. Fans blow hot air from the growing structure into perforated piping that runs underground. When warm air is pushed into the piping below ground, the heat in the air traveling through the tubing is allowed to diffuse throughout the soil. This "charges" the soil with warm air that can later diffuse back into system (Osentowski and Thompson, 2021).

These passive systems rely on perforated tubing coming into contact with as much soil as possible for the maximum energy exchange to occur. Many of these systems are modified by growers who layer piping at two and four feet, or four and six feet, or six and eight feet. This piping must be organized horizontally for the system to function properly and for the growing structure to maximize its efficiency (Figure 2). Rigid foam insulation running around the perimeter of the underground portion of the system is necessary to maximize a passive system's output. This system also functions with no heat exchanger, as the cooled or heated air simply blows out of the other end of the piping, back into the growing structure.

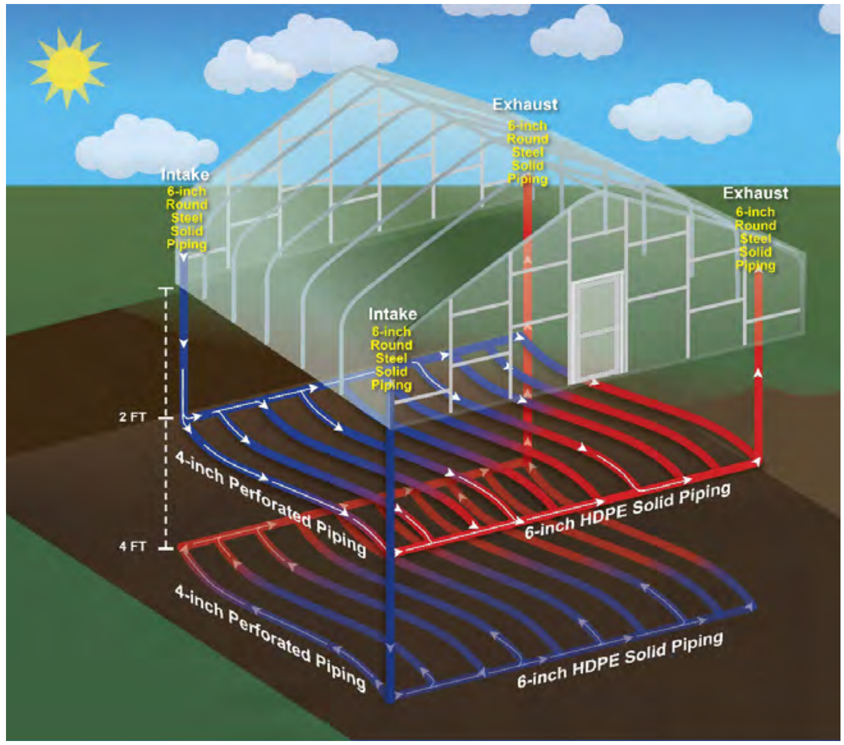

Figure 2. Example design of groundwork in a passive geothermal system. Two layers of piping are depicted here, showing the flow of heat energy. As cool air is being pulled in, warm air is being pushed out. This is organized so the flow in one layer moves inversely to the other layer. Graphic: Marisa Larson, NCAT

Geothermal Applications

Passive Solar Greenhouse

Although a passive solar greenhouse typically requires little to no energy input for climate control, using a passive geothermal system can further improve the season extension utility of the greenhouse and allow for diversity in crop production. An active system would provide the same benefits, but it would reduce the passive solar greenhouse's energy efficiency. Passive solar greenhouses tend to be small, therefore holding a small volume of air. The passive system functions most efficiently with smaller volumes of air and therefore would not need the amount of energy produced by an active system. A length-width ratio of 2:1 for any structure is ideal for energy efficiency (Bradford Research Center, no date).

Traditional Greenhouse

Traditional greenhouses are often larger than passive solar greenhouses and would most likely not be adequately heated or cooled by a passive system. An active system would be capable of providing adequate heating and cooling for greenhouses of various sizes with an appropriately sized heat pump and enough linear feet of underground piping. As well, a greenhouse of substantial size may provide the necessary payback from crops to make the expensive installation of an active system feasible. Some large-scale commercial growers have many acres of greenhouses. These settings would be most appropriate for installing active systems, because such a grower would likely see a faster payback on the investment.

High Tunnel

Heating or cooling a low-cost structure such as a high tunnel with an active system would not be cost-effective because of the tunnel's less-sturdy design with intended use of season extension only. Both the high tunnel structure and the passive system are low-cost options; however, a high tunnel is typically constructed with minimal insulation. Because the design is minimalistic, with one layer of plastic covering, climate control with a passive geothermal system would not be sustained for very long. In seasonal extremes, the "battery" that is the passive geothermal system will eventually reach its full capacity and will no longer heat or cool the space. Consequently, the passive, climate-battery system is the most feasible ground-source geothermal system for a small-scale grower, but it is primarily suited to a passive solar greenhouse or a double-walled, insulated high tunnel.

Growing structures should be oriented to maximize sunlight and with end walls facing the winter winds.

Before You Build

When designing a geothermal system, first consider your hardiness zone (USDA, 2012), the temperature variance your area experiences throughout the year, and what your temperature needs are for your crops. You should also assess the value of the additional produce the season extension would afford. Consider the marketability throughout the growing season and whether it is worth the investment of finances and labor for heating and cooling a structure, especially a low-cost structure, such as a high tunnel. Other questions to ask yourself include these:

- What are my heating and cooling needs?
- Which technologies can provide the necessary heating and cooling energy?
- How do renewable heating and cooling options compare with conventional technologies?
- What renewable resources are cost-effective in this part of the country?
- What renewable heating and cooling products should I choose?
- Who will install and maintain my system?
- How will I finance the system?
- Does the value of additional produce offset this cost?
- How much value is there in reducing the risk from freezing or overheating?
- What if fossil fuels are cheaper?

Energy Efficiency

The grower must first ensure that a structurally sound and well-insulated building is capable of keeping air inside, before installing a geothermal heating and cooling system. Otherwise, the effort and expense is wasted. In general, growing structures are more effective when constructed on well-drained, level land. Do not construct where the water table is known to be high or where you have an impermeable soil layer. Growing structures should be oriented to maximize sunlight and with end walls facing the winter winds. If these two requirements contradict, experts advise that the structure should capture as much winter sunlight as possible. It is also important to build the structures twice as far from any potential shading obstacle as the height of that obstacle (USDA, 2014).

It is necessary to seal a high tunnel to all ambient air, so it may be heated adequately by the geothermal system. Construct your high tunnel with a double-layered wall of greenhouse plastic and inflate the space between with a blower fan to enhance insulation. As well, use twin-wall hard covering for end walls. This kind of rigid covering performs better than simple greenhouse plastic in strong winds and requires less maintenance over time. Seal or insulate doors, vents, or shutters when the high tunnel is not in use. These openings may appear tightly sealed when shut, but they are typically where these structures experience a huge loss of energy. One way to overcome this is to seal these openings with scraps of greenhouse plastic. Seal the base perimeter of the high tunnel and use frost blankets to cover crops inside the high tunnel. It is also important to install ventilation in these structures, to let in cooler air during the warm months. Many high tunnels utilize roll-up sides for ventilation during warmer months, so any type of sealing done during cold months needs to be temporary. Maximizing the efficiency of the growing structure prior to geothermal installation will only serve to maximize profits (Alexander, 2019).

Follow similar rules for constructing a greenhouse. Do not construct where you know the water table is high or where the land experiences ponding. Construct to maximize sunlight and to face end walls into the winter winds. Choose the appropriate style, doors and hardware, covering material, and ventilation system to suit your growing needs (Rimol Greenhouse Systems, 2020). Design experts advise that environmental controls be set up alongside the geothermal heating and cooling system to maximize the structure's energy efficiency.

A modification of the traditional greenhouse is the passive solar greenhouse. This type of greenhouse does not use an artificial heat source but, rather, stores solar heat within a medium to be released at colder periods, like at night or during cold months. Storage mediums are typically black barrels filled with water, situated along the north wall. Alternatively, the entire north wall can be made of concrete to create an exceptional thermal mass. The north wall is much taller than the south wall in this design, to maximize southern sun exposure to charge the storage mediums. Although the use of barrels is popular, it is worth investigating for your operation, because their heat storage capability is questionable, and they take up much space that could otherwise be used for crop production. This style of greenhouse has a large, angled south-facing wall, covered entirely in greenhouse plastic, glass, or another transparent material. Additionally, east- and west-facing inner walls can be lined with a reflective material. Pitch of the roof and overall orientation of a passive solar greenhouse are primary components of effective design and should be considered, as well as carefully calculated, to maximize efficiency for the grower's latitude. All considerations for traditional greenhouses, from location to hardware and additional systems, are necessary for this type of greenhouse, as well.

Unless the greenhouse or high tunnel is exceptionally well-insulated, significant heat loss will inevitably occur, especially in colder climates. This loss can exceed the capacity of the passive system itself. To prevent depleting the underground soil of its stored heat energy and causing the average, stable temperature to drop below 55°F, experts recommend shutting off the climate battery and using an alternative heating method during extended periods of extreme cold (Osentowski and Thompson, 2021).

Energy Needs

Conducting an energy assessment of an existing growing structure can provide you with a better understanding of current energy usage and reveal inefficiencies that may have gone unnoticed (Penn State Cooperative Extension Service, 2020). Improvement of on-farm energy efficiency can only occur from a foundational understanding of the current operation. You may hire a professional energy auditor or use an energy calculator as a "do it yourself" alternative. In an assessment, consider your building structure, its structural soundness, and any energy conservation measures (ECMs) that you may already have in place. The shape of the frame, the length of the structure, height of side walls, layers of plastic poly-film covering, air pockets between a double-layered wall, ventilating roll-up walls, energy curtains (inside of the structure), shade curtains (on top of the structure), and row coverings are all ECMs that can contribute to reaching the desired temperature for growth. If you utilize some or many of these measures, then consider a smaller geothermal system to supplement them. If these measures are not implemented yet in the operation, consider how they can be paired with this type of heating and cooling system to increase efficiency and further extend the growing season.

As part of a conference presentation, Milton Geiger from the University of Wyoming provided this calculation for heating requirements in a building:

> Square feet of structure surface x temperature difference (inside temperature minus outside temperature) x 1.2 = Heat needed in BTU/hour

A modification of the traditional greenhouse is the passive solar greenhouse. This type of greenhouse does not use an artificial heat source but, rather, stores solar heat within a medium to be released at colder periods, like at night or during cold months.

Design and Installation

Despite the relatively simple design of geothermal systems, having the right plan in place prior to installation is essential, as small mistakes could undermine the effectiveness of the system. Important preliminary steps are to ensure that tubing or piping size is appropriate for the structure and that the organization of tubing or piping is secure before the backfilling stage occurs. Hiring an excavation service is expensive and excavating the pit yourself is time consuming, so re-excavation to modify the underground system should be avoided. According to Ceres Greenhouse Solutions, fan size, pipe diameter, pipe length, proper sealing in the infrastructure, drainage, pipe blockage, fan operation in humid environments, and how long the system runs are all things to consider and adapt to the grower's operation (2015). Pipe diameter, pipe length, and air flow interact with each other and should be balanced in order to determine how much energy will be transferred between air and soil, how much air flow the grower will see, and ultimately the total heating/cooling capacity of the system (Ceres Greenhouse Solutions, 2015). Additionally, piping used for the passive system should be perforated. Condensate naturally occurs from the evaporative cooling process, so perforated piping is important to prevent water from collecting and plugging the pipe.

For maximum benefit from a climate-battery system, it should primarily run only when excess heat is in the structure or any time the structure temperature is lower than subsoil temperature.

Appropriate sizing of hardware and equipment is crucial for gaining optimal efficiency from a geothermal system. Particularly with a low-grade/earth-battery design, the pipe size and fan power should match the volume of the growing structure and therefore produce a certain number of air turnovers per hour. Five air turnovers per hour is the ideal rate for reaching optimal efficiency for any greenhouse or high tunnel (Osentowski and Thompson, 2021). Fans used in this system should generate enough cubic feet per minute (CFM) to reach five turnovers. Some calculating is needed to determine this:

$$\frac{\text{Volume (cubic feet)}}{\text{Exchange rate (minutes)}} = \text{CFM needed for system}$$

Note that a fan with a higher flow rate is going to be significantly higher in cost. Consider fan options that are rated for outdoor use because they are more likely to withstand the operating environment of an agricultural structure.

For maximum benefit from a climate-battery system, it should primarily run only when excess heat is in the structure or any time the structure temperature is lower than subsoil temperature. Use a two-stage thermostat, or an integrated control system if other automated systems are being controlled, in order to avoid depleting the climate battery of its stored heat. When the structure's temperature becomes equal to the subsoil "battery" temperature, heat transfer is no longer occurring; therefore, the fans do not need to be running.

The installer should note that because of the design of the passive earth-battery system and its interaction with surrounding soil, it is crucial that the area in which the underground tubing is laid is insulated around its perimeter. Two-inch-thick rigid foam insulation serves to contain the heat stored underground and prevents heat energy from being leached into the cooler surrounding soil. Additionally, soil type plays a role in installation and maintenance of this system. Sandy, loam soil is ideal for this, not to mention its effectiveness for plant growth. Too much clay in the soil can harden around the tubing from the wetting and drying cycles, eventually plugging the system. If your soil is high in clay, consider replacing the soil during excavation or amending the soil to lower clay content (Osentowski and Thompson, 2021).

Hot air flowing through the pipes in a passive system will heat up the soil for about a foot surrounding the piping on all sides. Consequently, allow two feet of space between each row and each level of piping to ensure the soil is "charging" at its maximum capacity. If you are able to install a geothermal system and its groundwork prior to installing the actual high tunnel or greenhouse, the piping or tubing system would sit directly underneath the structure. If a structure is already in place, the underground piping for a retrofitted geothermal system should be buried next to the north or south-facing wall. This system would still require the same amount of linear feet of piping to be effective, and this pipe also needs to be spaced two feet away from the next pipe on all sides. Below, we will further explain calculating energy needs and the expense of installing a low-cost version of a geothermal system.

Costs and Payback

Remember to include operating costs in project cost calculations. A small amount of energy is needed for the heat pump in an active system, to drive the heating and cooling processes, but as much as five times this much energy is being brought up from the ground, resulting in a net gain of energy for the system. Fans in a passive system need even less energy to run.

Cost can vary widely, depending on system mechanics and design. Parts and installation can range from $1,200 to $25,000, depending on the system. There can be significant variation in upfront costs because, as this technology becomes more understood and utilized in agriculture, growers are developing and implementing passive systems that require less sophisticated equipment and fewer parts. Additionally, growers may already have access to equipment, like an excavator or tractor, whose rental or hire typically accounts for the majority of system installation cost. An example of costing a passive geothermal system is described in the first case study, below.

On the other hand, in an active system, the heat pump itself can represent as much as 60% of the system cost (Stimson, 2016). The size of the heat pump, as well as the design of the underground piping, will vary from one application to the next. Because of the sophistication of the system and extensive design requirements, an active system should be designed by an engineer and installed by a professional. A heat pump may further accommodate your seasonal and operational needs by providing you with a more direct means of climate control, provided it is financially appropriate. Contact your local HVAC equipment provider or a geothermal systems vendor for sizing and pricing.

Case Studies

Dave McCarson, Alpine Organic Farms, Montana

Dave McCarson specializes in design and construction of passive solar greenhouses and has expertise in horizontal open-loop, ground-air geothermal systems. He explains that this low-cost, climate-battery type of system is particularly effective in agriculture and farming. Systems he has designed and installed are typically small, 10 feet by 20 feet, and are comprised of piping layered at two feet and at four feet deep in the earth. For McCarson's own system, installation was cheap because he had excavation equipment available, and he has general knowledge of using the hardware. He has seen success with installations and overall efficacy of this type of system in Plant Hardiness zones 3 and 4.

McCarson suggests that unless a high tunnel has double-layered, insulated walls, any geothermal system would be cost-inefficient for this

The two-foot layer of perforated piping and insulation in a passive system. Photo: Dave McCarson

application. This is because a typical uninsulated high tunnel will quickly release heat energy. Conversely, geothermal systems can generate a significant amount of energy, and an active system will produce too much energy for a single-layered high tunnel and its crops. McCarson points out that the nature of a high tunnel is to become too hot in the summer but not stay warm enough for the winter. Without double-layered insulated walls, the same problem would continue, even with a geothermal system.

Because of the sophistication of the system and extensive design requirements, an active system should be designed by an engineer and installed by a professional.

The dimensions of McCarson's structure and the hardware used can provide a cost estimate. Ten feet by 20 feet by 8 feet (typical height at the ridgeline for a high tunnel this size) constitutes 200 square feet of floor space and 1,600 cubic feet of volume. Using the calculation above, 133 CFM from inline fan(s) is needed for this size structure to achieve five air turnovers per hour. To get cubic feet per minute, the structure's volume in cubic feet is divided by 12 minutes, since we desire five turnovers per hour (12 × 5 = 60).

$$\frac{(1{,}600 \text{ cu ft})}{(12 \text{ min})} = 133 \text{ CFM needed for system}$$

The groundwork involves two layers of piping, one at four feet deep and the other at two feet deep, running the length of the structure. To create a bidirectional air flow between the two layers, two intake pipes (one for each layer) are situated at opposite ends of the structure and pull air from near the ridgeline. Four-inch perforated pipe is used for the lengthwise tubing. Six-inch perforated pipe is used for the manifolds at opposite ends of the system for each layer. Table 1 breaks down the costs of a geothermal system for a high tunnel this size. Keep in mind that the grower may not need to hire an excavator.

Table 1. Cost Breakdown of a Passive Geothermal System.
Source: Gordian, 2020

Hardware	Quantity	Unit Price	Cost
Inline Fans, rated for outdoor use, 133 CFM	2	$150	$300
Perforated HDPE piping (4-inch for lengthwise 20 ft) X 12 rows, six at each level (6-inch for manifold 10 ft) X 4 manifolds, two at each level	240 ft. 40 ft.	$0.83/ft. $2/ft.	$199 $80
Corrugated wyes, 6”	12	$15	$180
Reducers, 6” × 4”	24	$17	$408
Subsoil insulation: (4 ft deep X 20 ft long) X 2 walls = 160 (4 ft deep X 10 ft wide) X 2 ends = 80	240 sq. ft.	$2	$480
Hired excavation (soil with clay and rock will increase the price)	20 ft.	$5/linear ft.	$100
			Total: $1,747

Russ Finch, Greenhouse in the Snow, Nebraska

Russ Finch specializes in passive solar greenhouse design complemented with open-loop, ground-source passive geothermal systems. The original unit attached to Finch’s home runs 78 feet long and 17 feet wide. However, this is smaller than the typical size of the units Finch commercially produces, which range up to 138 feet long, although efficiency is maximized at 102 feet. At his home greenhouse in eastern Nebraska, Finch grows large crops of citrus, figs, feijoa, grapes, and dozens of flower varieties. A typical lemon tree will produce 125 pounds per year, fetching $4.30 a pound at farmers market prices. It is notable that Finch is able to grow these crops in this part of Nebraska, an area that is rated at Plant Hardiness zone 4 or 5. In the winter, the temperature can drop to -27°F, and in the summer, it can climb to 105°F.

Finch’s system utilizes the stability of soil temperature at eight feet below the earth. Along with this system, Finch also utilizes a unique passive solar greenhouse design that minimizes the volume of air that needs to be heated or cooled. Finch suggests that these systems are not feasible for hoop houses (high tunnels) or even for traditionally sized greenhouses. Both contain a large volume of air and conditioning this much air could potentially raise costs to the point where they would exceed the benefits of the system.

The greatest accomplishment of the systems Finch designs is their simplicity. The systems can easily be installed by anyone with access to a backhoe and the ability to do the labor. In an 8-foot-deep trench, extending from one end of the greenhouse to another, a series of perforated pipes are laid. Finch states that for every six feet of

Construction of Finch’s passive solar greenhouse. Photo: Russ Finch

Citrus grown on Russ Finch’s operation. Photo: Russ Finch greenhouse length, an additional tube is required. For instance, a 96-foot greenhouse would require 16 tubes. Finch arrived at the numbers purely through trial and error and notes that it is difficult to set up hard calculations for this. This system regularly delivers a temperature difference of 35 to 40°F between the air being put into the ground and the air coming out. To develop estimates for your greenhouse and geothermal system, you can use an online climate battery calculator such as the one provided by Eco Systems Design (ecosystems-design.com/climate-battery-calculator.html).

Conclusion

The use of growing structures for season extension and the application of geothermal heat technology impact the sustainability of a growing operation. Unheated high tunnels can extend the growing season at minimal cost to the grower. With the help of structures that extend the growing season, the grower has more capacity for production and can grow their market and promote local food security. Adding a geothermal system can provide enhanced protection to crops and extend the growing season even further. Geothermal heating and cooling systems require very little dependence on conventional energy sources such as oil and gas, resulting in reduction of greenhouse gas emissions and air pollutants.

Geothermal energy is a renewable energy source, and with simple but durable design, a system can last a long time. A geothermal system is easy to maintain and requires little ongoing maintenance when built properly. There are many considerations regarding the economics of a geothermal system, but in some cases the investment can be worth it. A passive design variation in the form of a "climate battery" or other type of low-grade geothermal system is most feasible in agriculture when paired with an insulated high tunnel or passive solar greenhouse. Tapping into this renewable energy tool that is cost-effective and long-lasting can be invaluable for extending the growing season, increasing capacity for providing fresh produce, and contributing to the sustainability of food and energy systems.

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Notes

Notes

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UMass Extension Greenhouse Crops and Floriculture Program (/greenhouse-floriculture)

Geothermal Heat for Greenhouses

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°F)

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°F with a variation of about 6°F 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°F 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°F)

Thermal wells and springs in some parts of the world including the west coast of the U.S. provide hot water that can be used directly for heat. There are currently over 40 greenhouse operations in Oregon, California and Washington 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 geysers in California, Nevada and Utah is being tapped for power generation. Currently there are about 20 sites in operation with several more under construction. These produce power for 5-8 cents/kW hr.

Greenhouse heating systems

In New England, 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 Massachusetts varies between 60°F in early Fall to 46°F in early March. To increase the temperature to 80°F - 90°F 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. (#2 fuel oil =

$2.50/gal) Additional information is available at: [Mass.Gov (https://www.mass.gov/)](https://www.mass.gov/)

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Climate Control, Ecoloop and GAHT

Introducing The EcoLoop™: Ceres Most Energy-Efficient Heating And Cooling System Yet

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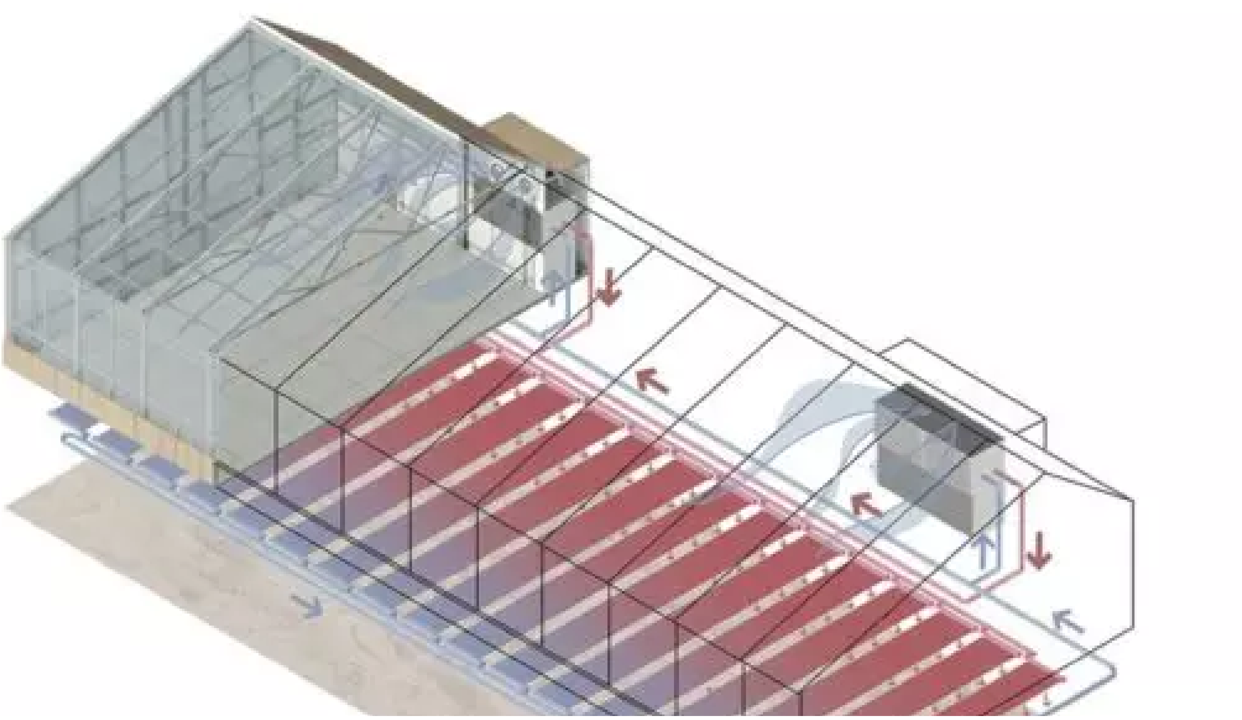
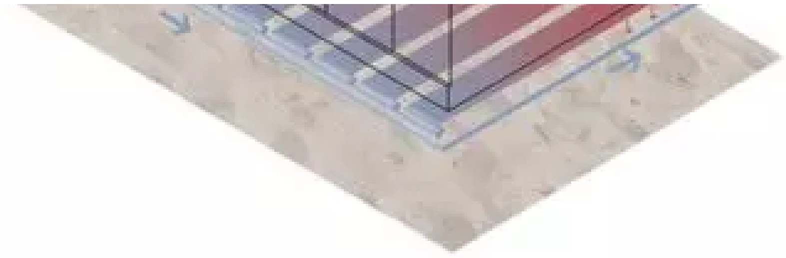




At Ceres we are challenging the idea that “high tech” means “expensive” when it comes to greenhouse design. Between our patented passive solar structural design and our Ground to Air Heat Transfer (GAHT™) System, innovation is at our core and we aim to provide growers with the most energy-efficient growing solutions. We help our growers achieve the most productive growing environments possible while simultaneously saving them money on operational costs. This year has been a big year in developments for Ceres and we’d like to introduce our newest climate control greenhouse system to date: the Ecoloop™.

Function

The Ceres Ecoloop™ is 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°F) to create precise climates in each greenhouse environment.

To break it down, the Ecoloop™ 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 (Ecoloop™ in heating mode) or disperse heat back into the ground (Ecoloop™ 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 Ecoloop™ 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 Ecoloop™ 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.

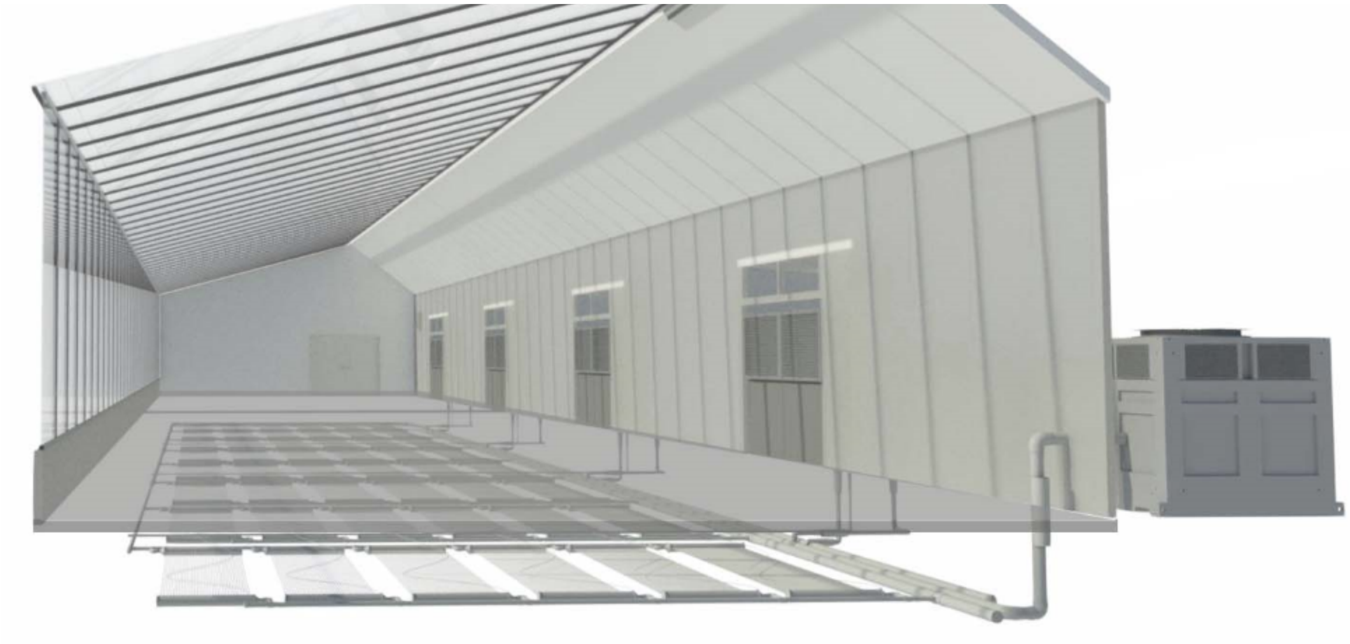
When the heat pump is in this cooling mode, it pulls moisture out of the air and this moisture can be collected in a reservoir and used on site for irrigation purposes. In this way the Ecoloop™ is recycling water by taking moisture transpired by the plants, collecting it and then giving it back to the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

Heating

When the Ecoloop™ 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 Ecoloop™ 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 Ecoloop™ 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 Ceres Ecoloop™ we have combined these two systems so growers can easily achieve exact VPD levels. The Ecoloop™ 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.



Why go with a Ceres Ecoloop™?

The Ecoloop™ is designed exclusively for our sealed HighYield Kit™design and is a perfect solution for growers seeking heightened biosecurity and precise climate control. Also, the Ecoloop™ 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 Ceres Ecoloop™ takes up no room inside the greenhouse which increases the potential for optimal sun harvesting.

The geothermal qualities of the Ecoloop™ classifies it as a renewable energy source and thus qualifies growers for rebate offers from state and utility programs. Ground coupled heat pump 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 Ecoloop™ 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 Ecoloop™.

The development of this product forced us to go back to our roots and come up with a solution that would be revolutionary in terms of energy-efficiency but also be simplistic in terms of concept. A smart grow operation starts with smart design. Contact a greenhouse expert today to discuss your energy-efficient greenhouse project.

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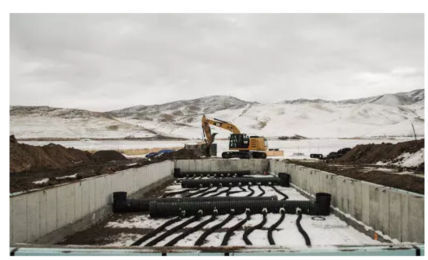

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