INTRODUCTION:

As energy costs continue to rise in the United States, greenhouse growers are looking for more ways to curtail spending and shore up the bottom line. Fortunately for growers and retailers, there are several opportunities during a new build to shave dollars off of future energy costs related to the operation of your business. For those who plan ahead, incorporating energy-saving measures into the design of a new greenhouse or addition can reduce costs dramatically and offer paybacks in typically three to five years, depending on the heating and cooling options installed. For those who are retrofitting, there are several choices to help provide needed reduction in energy-related expenditures, too. The approximate cost of some of these options will be addressed, along with the estimated number of years required for the investment to pay back. It should be noted that the payback estimates are based on current energy costs and should only improve in the future as the expectation is for energy costs to continue to rise.

Obviously, cost and payback estimates have many variables, such as greenhouse size and configuration, crops grown, covering types, temperatures required, and geographical location. For the purposes of this white paper, we will use the central Midwest as a general point of reference and year round operation is being assumed. General costs provided are for materials only, not installation. Also, costs mentioned in this paper do not take into account grants or other state and federal opportunities.

This paper will be broken into several sections, each thoroughly covering the savings options for greenhouse growers in the following categories:

- natural ventilation
- energy/shade curtains
- heating
- partition walls
- covering and insulation
- environmental controls
NATURAL VENTILATION:

Heating isn’t the only activity where growers see costs rising. Cooling the greenhouse can add a strain to the bottom line, as well. Natural ventilation takes the work out of cooling the greenhouse by opening and closing vents in the roof, thus reducing operating costs. The following vent options can open partially during inclement weather and can close within two to three minutes to protect crops appropriately.

The Atrium, Dual Atrium and Clear Sky open roof structures use a more efficient atrium roof vent than traditional peak vents. These vents are built as pairs and hinge on a roof purlin below the peak closing and sealing together at the peak. When open, these vents will have a clear opening to the sky allowing an unobstructed path for the escaping heat, similar to a chimney.

The Zephyr and Zail use a vertical vent at the peak that allows warm air to escape at the highest point in the greenhouse. The vent is either a rigid rack and pinion style or a less expensive drop curtain.

Natural Ventilation Options include:

• Atrium Structures – Features a single atrium peak vent per greenhouse span (10’-52’ wide) running the full length for a 20 percent minimum roof opening. Using the proper controls and equipment it can stay close to ambient temperatures with a shade curtain.

• Dual Atrium Structures – Has two Atrium vented peaks per greenhouse span (24’-48’ wide), allowing for an approximate 50 percent or more roof opening, for example two 21 foot peaks in a 42 feet clear span with no columns under the middle gutter has ~20’ of vent opening. The Dual Atrium will use 50 percent less rack and pinion mechanisms and motors compared to the Clear Sky open roof to reduce initial investment costs, as well as maintenance and energy consumption. The environment in a Dual Atrium has been proven to be nearly identical to the open roof systems.

• Clear Sky Structures – Uses mini peaks (Venlo) that are 10 feet 6 inches each so a 42-foot-wide structure has four peaks and four Atrium vents for a full open roof. The Clear Sky, with its full open roof, will give you as close to an outdoor growing environment as any structure can. This is the main advantage over the Dual Atrium system.

• Zephyr/Zail – Utilizes a vertical ridge vent design at the peak. The Zephyr design is a quonset shape and allows for a very efficient and cost effective natural venting option with the choice of poly or rigid cover roofs. The Zail has a straight roof line look and uses traditional rigid roof coverings.

Along with roof vents, side or end vents are also an option, and are recommended with longer ranges or ranges with more than two houses. Two popular types of guillotine vents are available. Interior guillotine vents open within the greenhouse and can range from 4- to 5-feet high. The guillotine vent is rack and
pinion-driven, giving it a cleaner look without external mechanical or structural parts. The EDDG vent is an exterior drop-down guillotine vent that can be customized to the growers needs. Drop down curtains and rack and pinion vents are also able to provide inlet air.

Retrofitting of existing greenhouses for natural ventilation can be an option for operation cost savings depending on your environmental requirements. The quiet cooling of natural ventilation will be appreciated by your employees and customers alike.

Existing Vail greenhouses that use mechanical cooling can be retrofitted with atrium vents to achieve similar cooling effects as newer Atrium houses.

Quonset greenhouses can be fitting with a Zephyr truss adaptor that can simulate the Zephyr house with a vertical vent at the peak of the house while maintaining the original roof material.

**SHADE AND ENERGY CURTAINS:**

A well-installed, retractable energy/shade curtain can reduce energy consumption for heating by as much as 35 percent, giving growers an easy way to save money. The curtain creates an insulated air space above the curtain and also reduces the amount of area required to be heated, thereby reducing energy costs. The efficiency of the curtain depends on the type of fabric used, the type of coverings used in the actual greenhouse construction, temperature outside and the type of environmental controls used. A typical curtain cost is very dependent on the cloth type and the number of motor drives as it can range from $1.50 - $3 per sq.ft. A return on investment for a typical energy curtain is estimated within two to three years of installation.

An energy/shade curtain can make the greenhouse more comfortable for workers or shoppers, depending on if it is a commercial or retail operation. The curtain also has a cooling effect and shades plants slowing their transpiration and the need for additional watering.

**There are several options for installing a retractable energy curtain:**

- Interior retractable shading – This is commonly used with natural ventilation and allows for even shading. The roof vents open, this shade closes and opens and the greenhouse is ventilated through the shade. Typically the open-close function is managed by an environmental control system based on required temperatures, humidity and light required.

- Interior retractable energy/shade (dual systems) – Dual curtain systems are becoming very popular. This scenario uses two curtain systems with two different cloth characteristics. By using cloths that
have different shade percentages it gives the grower a combination of available light levels for different growing conditions based on the crop needs. A shade cloth can be used during summer to cool, reducing plant stress and water consumption. A recently developed “clear” cloth is commonly used to cover the crop during cold, sunny days for heat retention during winter months. Another alternative is the use of a blackout system as the second cloth giving the option to the grower to adjust the day length for a crop and also used as a heat retention cloth at night.

As an example, if a grower is producing crops in weeks 1-12 and located in the Midwest, then they will have little sun and short days. In the past the grower might close the energy curtain to retain heat while the crops suffered from even less light. A “clear” cloth allows the growers to close this curtain system during the day while retaining heat and allowing maximum light into the greenhouse. The second cloth with the higher shade factor would typically be open in this scenario. Obviously, at night both curtain systems are closed for twice the insulation value.

- The ABRI exterior shade system – installed outside above the structures roof and does not interfere with the vents. It uses a cloth designed to breathe, allowing air as well as rain to pass between the shading and aluminized reflective components. This shade is used to cut the light from coming into the greenhouse and reduce the heat gain inside. This system is not advised in snow load regions.

A retractable energy/shade curtain is a quick way to retrofit an existing greenhouse to see some immediate energy savings. Most modern steel or aluminum greenhouses can be adapted for a curtain system fairly easy. It will not only give you a relative short payback but also give the grower a way to produce the crop in a more optimum environment. The dual curtain system is a possibility in existing houses with curtains as another way to beat the rising operating costs associated with heat loss.

HEATING:

**Boiler Units:**

The boiler is the ‘engine’ that runs the heating process in many cases, and can use traditional or non-traditional sources of fuel. Traditional sources include natural gas, propane or fuel oil. Many systems offer a dual fuel option such as oil and natural gas so growers can operate with fuel of choice based on market costs or availability of these fuels. Some boilers can be fueled with by-products such as wood chips or other biofuels, currently being used by a handful of growers in the industry (See sidebar). One thing to note is a wood burner should always have a dual fuel option.
A few examples of traditional boilers are the Atmospheric boilers and the Pressurized (Sealed) Combustion boilers. The Atmospheric boilers are most popular and they take air from the room they are in and not direct air from the outside, so they are less efficient than the pressurized-air type boilers. Because these boilers are typically in an enclosed room, they must have ventilation from fans and outside air shutters that allows them to take in fresh air. Typically they operate at between 80 percent to 82 percent efficiency. Pressurized (Sealed) Combustion boilers are around 85 percent efficient. Fresh air is piped directly from outside into the boiler and not from the surrounding room as in the Atmospheric types. They are typically not as popular, but due to better efficiency are gaining in popularity.

**Unit Heaters:**

One method of heating greenhouses for many years has involved the use of unit heaters. These heaters operate off hot water or steam (hydronic - no flame), natural gas, propane or oil (flame-fired forced air) and function by blowing hot air from the heaters into the greenhouse environment. The heated air is then mixed throughout the greenhouse by use of horizontal air flow fans (HAF) or poly convection tubing with holes (which are not used much anymore). These heaters cost approximately 50-60 cents a square foot for the typical 20,000-square-foot greenhouse and are easy and quick to install.

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**Biomass Boiler System**

Boiler systems that use alternative fuel sources are becoming increasingly popular among growers looking to shave off expenses in the energy arena. Henry Huntington of Pleasant View Gardens in New Hampshire searched for the right biomass boiler system for years until he settled upon the one that was just recently installed to heat a 4-acre range in his Pembroke facility. His boiler will mainly burn wood chips.

“Different greenhouse operations were looking at it and putting systems in,” he says. “It took a couple of years before we pulled the trigger on it. One of the biggest reasons was we wanted to make sure the fuel supply was going to be there. We didn’t want to spend a couple of million to have the fuel supply go up in price.”

Huntington’s new biomass boiler from Hurst Boiler Inc., has the option of using other sources of fuel if availability of wood chips becomes scare.

Specifically, Huntington will use whole tree chips, which can come from any variety of trees. “It’s typically when a logger goes into a forest and does some timbering, if they’re going in there for saw logs they’ll take the best part of the tree for the logs and the rest would be chipped up.”

He adds as long as the boiler is set up for a range of moisture content, a grower can burn any type of chip that falls within that moisture content range. Also, there are higher and lower grade wood chips available. The higher grade – a clean hard wood chip – is typically more expensive but the BTU content is higher.

“What we’ve learned is the BTU content tends to move with the price,” Huntington says. “For us, we felt the whole trees chips have more availability and are easier to get a hold of.”

He adds that there are several good biomass boiler manufacturers out there, so a grower interested in the investment needs to investigate which manufacturer fits their needs.

As for Huntington’s boiler, he expects it to be about 75 percent efficient as it runs on a renewable fuel source and, depending on the price of No. 2 fuel oil, the payback will be between three to four years.
Efficiency of unit heaters typically ranges from the 80 percent to 83 percent range. These units most often take air from within the greenhouse (Atmospheric). Certain manufacturers offer sealed combustion units. Sealed combustion takes required air directly from the outside, thus increasing efficiency and reducing the carbon dioxide in the greenhouse.

It is a popular option to use the less expensive unit heaters along with hot water heat such as radiant floors to keep costs down. You should consider efficiency losses between the flame gas and oil fired unit heater with vent stacks (efficiency loss) vs. the hot water (hydronic) unit with no flame and no vent and their relative costs.

**Radiant Floor:**
Depending on your growing needs such as crop locations, on floor or bench, as well as multiple zone(s) and temperatures required, hot water radiant floor could be a great value. Costs are relatively reasonable between $2.50 to $3.00 per square foot for a typical two-zone, 20,000-square-foot system. These costs do not include the concrete or other ground coverings. You should expect a payback in 3 to 5 years due to the efficient use and placement of the heat closer to the plant.

The use of hot water radiant floors allow the grower a more uniform and constant source of heat and the heat is provided at the crop, not 12 to 16 feet up in the air. If the greenhouse area is broken up into multiple zones (Typically 2 or 3 for this evaluation) multiple pumps are used along with multiple supply and return water lines. If concrete floors are used, the tubing is installed and the concrete is poured over the tubing. The concrete becomes a great source of retaining that energy and does not lose its heat instantly as you would expect with forced air heat.

Based on a 20,000 square foot operation, a typical radiant floor heating system can provide 40 to 50 percent of the heat load. However, it is estimated to be able to save a grower 30 percent on heating bills over the unit heater.

Because the radiant floor heat only supplies 40 to 50 percent of the required heat load, growers can use unit heaters to provide the balance of the design heat load on very cold days. The combination of radiant floor heat and unit heaters would be the least expensive package in regards to total system costs. Unit heaters could be the forced air flame (natural or LP gas) or hydronic unit heaters using hot water from the boiler source, which would increase efficiency over forced-air gas unit heaters.

The next step up in maximum efficiency would be 100% hot-water heating. If you are growing on the floor, use of the radiant floor is best. Then additional heat would come from either an aluminum or steel fin or 51MM steel pipe that would typically be placed along the perimeter sides and ends as well as overhead. If you are growing on benches then the fin or pipe would be installed on bench legs with
additional fin or pipe on sides and overhead. Hot water hydronic unit heaters would be a less expensive option than aluminum or steel fin systems. Typical costs per square foot for radiant floor and aluminum fin overhead would be $4.50 to $5 per square foot for a two-zone system. Fin tubing and steel piping require greater water temperatures, typically between 180 to 200 degrees.

Typical payback for investing into 100 percent hot water heat vs. forced-air unit heaters is 3 to 5 years based on a year round operation.

Mixing valves are a component of a hot water heating system that increases its efficiency. Simply put a mixing valve smooths out water temperatures. When a boiler receives water from its source, which is usually cold ground water, the mixing valve has the ability to take warmed return water and mix it with the colder water enabling the boiler to make hot water that is at a warmer temperature. The mixing valve can also lower the water temperature by adding colder water when the demand for heat is low. Mixing valves are common place when the boiler(s) supplies heat for radiant floors.

When considering hot water heat you should never consider having only a single source of heat. With unit heaters other than hot water hydronic style, you typically have more than one, so if one fails you have enough heat to provide a minimum acceptable temperature in an emergency. The same applies to radiant floor and unit heaters. If you have just one boiler and it was to fail, you still have the gas or oil forced-air unit heaters for redundancy. When considering all hot water heat, be sure you have multiple boilers (two or more). In the event one boiler was to fail, the other - when hooked in series - would carry you at minimum temperature until repairs can be made.

PARTITION WALLS:

Another way to increase efficiency in the greenhouse is to plan ahead during the design phase for better space utilization. Installing partition walls can provide multiple zones that can be independently heated, irrigated and covered with shade or energy cloth to give growers multiple options during growing and non-growing seasons.

For example, a greenhouse 200 feet long can have a 200-foot-long wall between greenhouse zones two and three under the gutter. The wall can be either corrugated polycarbonate or a less expensive roll-up curtain. Certain zones can be used and heated during the winter while the others remain cold until production begins on later product in the spring, resulting in an energy savings.

In a retail garden center you can have unheated canopy space that is used in the busier, warmer spring and summer months but vacant in the slow, cold winter months.
COVERINGS:

The heat loss through the exterior coverings and particularly the roof is an area that needs particular attention when designing an energy efficient greenhouse. There are different products on the market that will decrease this loss. Energy curtains that we discussed earlier are one of those products, but there are also covering materials that will have higher R-values resulting in cost savings even if only used on the exterior walls. Double and triple wall extruded sheets are on the market that have minimal cost effects and paybacks of one to two years.

In terms of site location, it is recommended that the northern wall be fitted with an aluminum knee-wall panel all the way up to the peak for maximum efficiency since the north wall is usually the coldest.

Those growing product on the ground may only want to insulate a knee-wall up to about two feet to avoid shade on the plants. Those growing on benches can insulate up to 30 to 36 inches for maximum efficiency.

Along with the heat savings aspect other coverings are available that will help shade the greenhouse and reduce the heat gain. Some of these coverings have a variety of shade percentages and others have physical characteristics that will reflect the infrared light that causes heat build up and still allow the visible PAR light in for the plants.

ENVIRONMENTAL CONTROLS:

All of the systems discussed with the exception of coverings can be controlled via environmental control devices that allow growers to easily manage their greenhouse surroundings. In fact, it is highly recommended that a grower utilize an environmental control system if he or she invests in extensive efficient heating and cooling systems, shade curtains, partition walls and other cost-saving measures. The computerized controls can work each of the systems to their maximum potential and automate the greenhouse to reduce labor and time involved in setting and controlling vents for heating and cooling, curtains, irrigation, plant feeding and other tasks.

Many controllers include weather stations, which monitor the weather conditions outside the greenhouse and report back to the environmental control systems, prompting it to shut the vents during inclement weather. The controls also can control the zones separately, allowing growers to set a variety of climates, irrigation requirements and curtains for each zone.

An environmental control system for a 20,000 square-foot, two- to four-zone greenhouse will likely run between $5,000 and $10,000, depending on the sophistication of the system.
ALTERNATIVE POWER SOURCES:

New technology for alternative power is being developed throughout the world and we need to be on top of the new designs as they become available and more affordable. Many research and development projects are ongoing to find systems that are adaptable to the size and power range needed for greenhouse operations.

Unconventional Power Sources include:

• Wind power. Added benefit would be that the extra electricity produced could be sold back to the utility at retail prices and not at wholesale.

• Solar power. For this to be an option, the location of the greenhouse and the slope of the roof are critical to success, as is the glazing.

For all of the systems discussed above, as well as the biofuel boilers in the prior sections, grant money is available from various United States government departments and other sources for material costs and installation. These programs change rapidly in our current political environment and should be monitored for the best conditions.