WHITE PAPER

Climate Control Technologies

A comparison

Let's Grow Together

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INTRODUCTION

Developing the precise environment necessary for cannabis cultivation is incredibly important for healthy crops and a grower's bottom line. In fact, precise temperature and humidity control during both lights-on and lights-off photoperiods are your best defense against mold, mildew, and other biological contaminants, which improves the odds of passing inspection without reliance on pesticides and fungicides. While a robust, high-quality yield is the priority, up-front and ongoing expenses can affect cultivators' return on their investment.

Several different technologies can be used for climate control, differing substantially in functionality, reliability, and cost. Depending on the cultivator's specific goals and methodologies, one may be more applicable than other options.

Choosing the right technology for a cultivation facility can be overwhelming, as there are many considerations to take into account. This paper highlights some of the common technological choices, their application in cannabis cultivation, and the pros and cons of each, intended to take some of the guesswork out of the decision-making process.

BACKGROUND

Growing cannabis is becoming increasingly mainstream as more states legalize it for medical and adult use. Cultivators are moving out of the black and gray markets and setting up fully legal, commercial cultivation facilities. The move into legitimacy has also brought competition and regulation, making it more important than ever for cultivators to utilize the best technology and method possible to ensure high-yielding, consistent and healthy plants. Associated equipment and materials manufacturers have responded by innovating new technologies and offering products improved in quality and capacity. Cultivators are no longer obliged to use outdated, ad hoc technology not specifically intended for cultivation.

The maturation of the industry has resulted in a multitude of options for cultivation technology, which can be hard to wade through during the already complex facility design and set-up process. Selecting the right climate-control system for managing a cannabis cultivation environment is mission critical. With the exception of real estate (and sometimes not even that), a climate-control system is likely to be the largest capital expenditure associated with construction of a cultivation facility. It is an essential investment in which quality should override expense because climate control plays such a significant role in the quality of product produced. With the proper climate-control system operating at optimal efficiency, cultivators can maximize productivity, quality, and volume while simultaneously minimizing monthly expenses. Ideally, the system pays for itself.

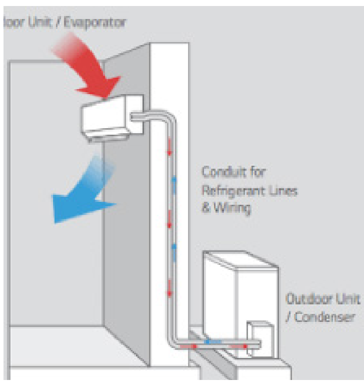
While all growers have their preferred settings, typically the optimum environment is between 78 and 84 degrees with 40 to 60 percent relative humidity. However, achieving and maintaining the correct temperature and humidity is complex. Any small change in the climate-control system's calibration or function can have disastrous effects on crop yields and profits. And, of course, choosing the wrong equipment at the outset can lead to negative consequences including significant up-front capital costs in the immediate future and long-term production chain shortfalls.

TECHNOLOGIES

UNITARY

Split Systems and Mini Splits

A mini-split system typically supplies air conditioned and heated air to one or more rooms within a single building.



Multi-zone systems are commonly ductless and condition up to eight rooms (zones) from a single outdoor unit. While these systems are often easy to use, in order to achieve ideal redundancy, excessive amounts of equipment and electrical infrastructure is needed as the compressors are tied to specific zones within the facility. Multi-zone systems typically offer a variety of indoor-unit styles including wall mounted, ceiling mounted, ceiling recessed, and horizontal ducted. Mini-split systems typically produce 9,000 to 36,000 BTUs (9,500–38,000 kJ) per hour of cooling. Multi-zone systems provide extended cooling and heating capacity up to 60,000 BTUs.

Advantages of ductless systems include smaller size and flexibility for zoning or heating and cooling individual rooms. The interior wall space required is significantly reduced. Flexible, exterior hoses lead from the outside unit to the interior; these are often enclosed in metal to look like common drainpipes from the roof. Ductless systems also offer higher efficiency, reaching above a 30 Seasonal Energy Efficiency Ratio (SEER).

NOTE: SEER DOES NOT APPLY IN CANNABIS GROWS AS A RELIABLE INDICATOR OF WHOLE SYSTEM EFFICIENCY. IT IS A SEASONAL AVERAGE FOR COMFORT COOLING WHILE CULTIVATION LOADS ARE YEAR-ROUND AND CONSTANT, NOR DOES IT TAKE DEHUMIDIFICATION CAPACITY INTO ACCOUNT.

The primary advantage of ductless air conditioners is their cost. Such systems cost about $1,500 to $2,000 USD per ton (12,000 BTUs per hour) of cooling capacity.

The main disadvantages of mini-split systems are they offer no direct control of humidity (by-product of cooling only) or flexibility as they only come on when the space is "hot" regardless of the humidity levels in the space. The dew point from the coil is set by the evaporator and condensing unit combined (designed for comfort cooling) and cannot be adjusted due to refrigerant pressures pre-engineered by the manufacturer. Additionally, mini splits only offer up to four to five tons so multiple units may be needed for any given room with multiple electrical connections. And still, no redundancy or load shifting is available.

Pros:

- ◊ Smaller size
- ◊ Zoning flexibility

Cons:

- ◊ No redundancy in most applications
- ◊ Requires a condenser for every air handler (refrigerant in grow spaces)
- ◊ Consistent dehumidification is not available
- ◊ Low life expectancy compared to other designs, 5-10 years in most applications
- ◊ Frozen evaporators are common

Self-Contained Systems (or Self-Contained Splits)

Self-contained systems are larger, more complex versions of the unitary (DX) equipment listed above. They utilize a direct refrigerant-to-air heat exchanger (evaporator) in the airstream to cool and dehumidify the space. They can easily be obtained in sizes up to 50 tons and have options small-tonnage mini splits lack, including ducting, UV lights, hot gas bypass for direct humidity control, and multiple heating options with everything usually included in one unit. These systems are sized for each space. They come in either air-cooled, "split" condenser versions (condenser located outside with refrigerant piping between) or water-cooled condenser arrangements that require connection to an evaporative-cooling tower sitting outside to reject heat. These towers will normally require maintenance and consume makeup water. Self-contained units usually tend to be on the more expensive end of the unitary spectrum due to the units' customization type as well as all the numerous components, and complexity. These units can easily cost three to four times the price of their less expensive counterparts per ton.

In most applications, these units require some floor space in the grow. As an alternative design, these units may be placed outside the grow, yet still ducted into the grow supply and return connections. Redundancy can be expensive or difficult as well with ductwork and space/sizing factors.

Pros:

- ◊ Easy to integrate into controls
- ◊ Direct humidity control when units with fully modulating, hot gas reheat are utilized
- ◊ Allows for limited structural considerations as they are placed on the floor or outside

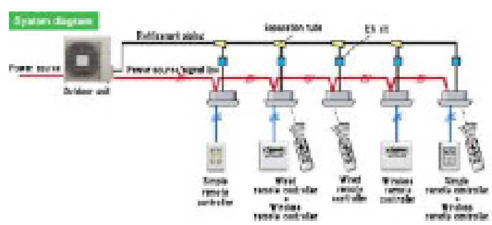
Cons:

- ◊ Usually requires ducting to uniformly distribute air into space, however ducting is a common breeding ground for mold and fungus
- ◊ Redundancy complications due to complicated ductwork, need for additional equipment
- ◊ May not work effectively in cold ambient temperatures depending on model types
- ◊ Water-cooled versions require piping indoors to the condenser and associated tower
- ◊ Frozen evaporators/air handlers
- ◊ First cost

PACKAGED

Packaged Variable Refrigerant Flow (VRF)

Also referred to as Variable Refrigerant Volume (VRV) by some manufacturers, Variable Refrigerant Flow (VRF) is an HVAC (heating, ventilation, and air-conditioning) technology that uses refrigerant for heating and cooling. Refrigerant is conditioned by an outside condensing unit and circulated in the building through multiple fan coils. VRFs are typically installed with an air conditioner inverter, which adds a DC inverter to the compressor. This design supports variable motor speed and thus variable refrigerant flow rather than simply performing on/off operation. By operating at varying speeds, VRF units work only at the needed rate, allowing for substantial energy savings at partial-load conditions.



Heat recovery VRF technology allows individual indoor units to heat or cool as required, while the compressor load benefits from internal heat recovery.

VRFs come in two system formats: two-pipe and three-pipe. In a heat pump (HP) two-pipe system, all the zones must either be in cooling or heating, limiting the ability to handle simultaneous heating and cooling loads internally on a single condensing unit. Heat Recovery (HR) systems, on the other hand, can simultaneously heat certain zones while cooling others, usually through a three-pipe design. Some manufacturers can do this with a two-pipe system by using a BC controller that distributes the refrigerant for the individual indoor evaporator zones. In this case, heat extracted from zones that require cooling is used in zones that require heating. This exchange is possible because the heating unit functions as a condenser, providing sub-cooled liquid back into the line for cooling.

While heat-recovery systems have greater initial cost, they also allow for better zoned thermal control of buildings and greater efficiency overall. In heat-recovery VRF systems, some indoor units may be in cooling mode while others are in heating mode, reducing energy consumption. If the coefficient of performance in the cooling mode of a system is three, and the coefficient of performance in the heating mode is four, then heat recovery performance can reach more than seven. However unlikely it is this balance of cooling and heating demand will happen often throughout the year, energy efficiency can be greatly improved in such circumstances.

VRF efficiencies are commonly expressed in SEER, the calculation of which by nature gives credit for varying occupancy rates and reductions in ambient temperatures for a building with a varying load profile such as schools, homes, office buildings, etc. That is where these systems are usually applied. When it comes to a grow application, however, we have a constant cooling and dehumidification load as artificial lighting and watering are used year-round and account for over 95% of the HVAC usage in grow spaces. Users should be aware SEER is therefore not an accurate representation of energy performance in a cultivation environment and should analyze full-load efficiency and dehumidification capability instead to accommodate the bulk of the operation encountered.

Pros:

- ◊ Minimizes ducting
- ◊ Small footprint
- ◊ Allows for a sealed cultivation area
- ◊ Some models can operate at low ambient temperatures

Cons:

- ◊ High up-front cost
- ◊ Requires specifically trained HVAC technicians, resulting in high installation and maintenance costs
- ◊ Requires refrigerant to be pumped to terminal units in spaces, posing a risk of leaks
- ◊ Provides minimal dehumidification as by-product of cooling (additional DHUs may be required)
- ◊ Requires complex, specialized controls
- ◊ No option for “free” cooling economization in winter months when applied in colder climates
- ◊ Redundancy issues (if there is a refrigerant leak or compressor failure in the system, all components connected could be compromised and inoperable until the system is repaired)
- ◊ Typically has a “defrost” to avoid frozen evaporators but cooling is lost during defrost mode

Roof Top Units (RTUs)

Unlike split systems, packaged units have all the components of the air conditioning system in one place. The most common packaged unit is a roof-top packaged unit, also known as an RTU.

Roof-top packaged units are more suitable for lower-lying buildings with space on the roof for installation. The units themselves require ductwork for supply and return air distribution, power lines, and drain piping.

Roof-top packaged units are commonly applied in comfort cooling and come in a vast array of efficiencies, sizes, features, and costs. A benefit of the roof-top unit is it does not use indoor space, although ducting to the space will be required as mentioned above. Most units come with a multi-zone arrangement, meaning outside and grow-space air is recirculated for both cooling and heating. These can pose odor-control and biological-contamination challenges as both bugs and nearby airborne contaminants can easily infiltrate standard damper packages even when closed. Economizing, “free” cooling is obtained by bringing in outside air when ambient temperatures are below 50 degrees Fahrenheit, which may be undesirable to most growers.

Pros:

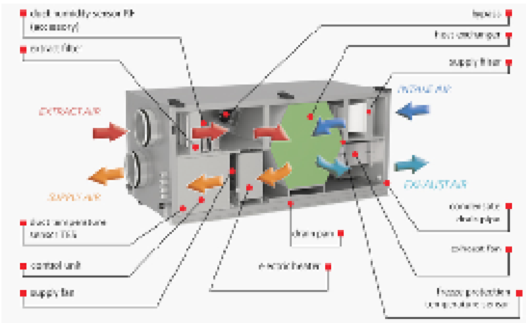
- ◊ Doesn’t use indoor space
- ◊ Can be less costly depending on features/options
- ◊ Very easy to maintain

Cons:

- ◊ Requires duct work (common breeding ground for mold and fungus) in grow space
- ◊ Low life expectancy compared to other designs, five to ten years in most applications
- ◊ Requires air to go outside of grow spaces, which can pose odor control or biological concerns
- ◊ Redundancy can be an issue with complicated ductwork

Complex Chilled Water System (AHUs)

Chiller systems are used worldwide for cooling in high-heat applications due to their top-of-the-line energy efficiency and flexibility for mechanical air conditioning. By decoupling the machine producing the cooling from the indoor environment, it is possible to move cooling to the places most in need, when they need it, thereby "right" sizing the equipment for the overall building and not oversizing individual equipment for each space based on maximum loads. Such a schema replicates smaller split-systems with DX or RTUs because the units can share chilled water for dissimilar loads (like growing on a flip), thereby conceivably reducing electrical infrastructure requirements. A chiller can be outdoor (air cooled) or indoor (water cooled). Indoor models frequently require connection to an evaporative-cooling tower outside to reject heat, which will consume water, while air-cooled models sit outside and do not require a tower. A complex chilled-water system regulates and circulates air as part of an HVAC system. This more standard HVAC chilled-water system is often seen utilized in schools, office buildings, high rises, etc. Traditionally, these systems utilize air-handler units (AHU) or different terminal units that contain a blower, heating or cooling elements, filter racks or chambers, sound attenuators, modulating dampers, and control valves. AHUs usually connect to a ductwork system that distributes the conditioned air through the building and returns it to the AHU. In some applications, AHUs discharge (supply) and admit (return) air directly to and from the space served without ductwork.



As a variation of this design, smaller air handlers can be in the space for local use and are called terminal units. These units come in many types and sizes and may or may not include air filters, coils, and fans depending on the design. These simple terminal units are commonly called blower coils or fan-coil units. A larger air handler that conditions 100 percent of the outside air and no recirculated air is known as a makeup-air unit (MAU). An air handler designed for outdoor use, typically on roofs, is known as a packaged unit or roof-top unit (RTU).

Room temperature and humidity are controlled with a combination of different heat exchangers as well as features and options inside the conditioned air stream going through the unit. These units come in many different shapes and sizes and may need to provide all or a combination of the following features and options to achieve end goals for energy efficiency and precise temperature and humidity control depending on the application and design.

In most applications, first cost, unit controls complexity, and local utility rates, as well as energy consumption, drive an owner to certain units and configurations. Common options include but are not limited to:

◊ Cooling via direct-refrigerant expansion coil (DX) and/or cooling via chilled-water coil (CW): Evaporative cooling is possible in dry climates but will increase humidity levels in the space, which may be undesirable to growers looking for precise control.

◊ Heating: Pre-heat or reheat coils are available in electric, hot water (HW), steam, or gas fired (direct and indirect options). Heat-pump heat can also be used in a DX configuration in milder climates.

◊ Heat Recovery: Flat-plate heat exchangers and heat-recovery wheels, (both sensible and enthalpy type), as well as coil run around loops, are options for heat recovery in cases where outside air is being brought into the grow environment for pre-conditioning and energy savings.

◊ Chilled water, hot water, and steam coils are typically manufactured from copper for the tubes, with copper or aluminum fins to aid heat transfer. Cooling coils also employ eliminator plates to remove and drain condensate. The hot water or steam is provided by a central boiler, and the chilled water is provided by a central chiller. Downstream temperature sensors are typically used to monitor and control "off coil" temperatures, in conjunction with an appropriate motorized, modulating control valve regulating water flow. For these reasons, a more complex computer-controlled system is desirable and a basic requirement in most cases to make split-second decisions while variables are constantly changing.

If dehumidification is required, the cooling coil is employed to over-cool so the dew point is reached and condensation occurs. In this application, one of the heating options mentioned above is placed after the cooling coil re-heats the air (known as a re-heat coil) to the desired supply temperature. This process reduces the relative humidity level of the supply air.

Pros:

◊ Allows for good air homogenization
◊ Energy efficient
◊ May allow for condensate reclamation in many applications
◊ Longer life expectancy if maintained properly
◊ Allows for many different biosecurity options, MERV/HEPA/UV/PCO options

Cons:

◊ Expensive first cost
◊ May require significant amounts of water outside of plant irrigation (evaporative cooled or units with cooling towers)
◊ Controls are more complex than other systems and may increase first cost
◊ Ductwork can pose a biological risk as it is a place for mold and mildew to propagate

Modular Chilled Water (CW) System

The Modular Chilled-Water System is a common application of the air-cooled, chilled-water system approach mentioned above, offering many of the benefits but eliminating much of the complexity and first cost. In a Modular CW system, a bank of air-cooled chillers sits outside the facility to offer operational redundancy. The compressors inside the chillers operate to maintain a

precise temperature in a water/glycol mix that is then pumped around the building to fan coil units (FCUs) of varying sizes, controlled by a simple wall thermostat or control unit with on/off control. Here, warm/moist room air is circulated over the coils, transferring heat and humidity from inside the room to condensate in the unit drain pan as well as warm water for the closed chilled-water loop, which then goes back to the chiller via pumps, for the process to start again.

Modular chilled-water systems refer to a sub-grouping of chilled-water system designs where multiple chillers and FCUs are utilized both inside and outside the grow to maximize redundancy. In fact, for a minor cost addition, N+1 redundancy in each space can be built into the design, offering complete redundancy without doubling equipment cost. These systems utilize multiple chillers organized into a bank and multiple fan coils all tied back to the collective chiller bank. This distribution allows flexibility for the system to grow and cooling capacity to be added as needed. Built-in redundancy is inherent since grow spaces use multiple chillers and fan coils. Because no fan coil is tied to one specific chiller directly via the chilled-water loop, any malfunction of either piece will not cause complete loss of cooling capacity. Due to this, facilities can ensure they always have some or even full cooling if going with an N+1 design concept.

Because these units consist of multiple pieces of equipment and 99% of the indoor equipment is hung from the ceiling, having a large space dedicated entirely to climate control indoors is unnecessary. The use of multiple fan coils also ensures more homogenized air due to distributed, ductless airflow.

Pros:

◊ Redundancy
◊ Ability to easily expand operations
◊ No ductwork, allowing for a sealed cultivation environment
◊ Greater efficiencies than packaged units
◊ Flexible tonnage
◊ 24-hour dehumidification even when compressors are off
◊ Simple Controls - on/off via thermostat is available or can be combined with computer control systems

Cons:

◊ Initial expense can be slightly higher the packaged DX or split units
◊ Engineering work is required to design the water-piping loop properly

CONCLUSION

With so many choices, selecting the correct climate-control system for your facility can be daunting. However, picking the right one to meet your goals is critical for obtaining healthy, high-yielding plants that maximize profits. A climate-control system can be the largest capital expenditure associated with a cultivation facility outside of the real estate itself, making it even more important that it be done right the first time.

At Surna, we have been designing cannabis-cultivation equipment and facilities for over a decade and have the necessary experience to understand the best options for obtaining specific cultivation goals. We've seen facilities of all shapes and sizes and have provided ideal systems for each. We work with cultivators to understand their goals and design the best systems for their individual needs. After familiarizing yourself with the options listed in this paper, reach out to us so we can help you choose the right system for your facility.

ABOUT SURNA

Surna provides the expertise and application-specific climate control for cultivation environments, including automation and biosecurity systems that produce greater yield, more security, and better energy efficiency—resulting in practical and timely ROI.

Our deep expertise is not something you can achieve overnight. It requires years of experience. Hundreds and hundreds of projects. Tens of thousands of hours. As a true expert in cultivation environments, Surna is the first call any cultivator, investor, engineer or consultant should make when planning and designing a controlled-environment cultivation.

We're laser focused on producing better energy efficiency for you, moving heat and humidity out of your environment as practically as possible. As cross-disciplinary experts, we take time to fully understand your business goals, climate conditions and facility before building a system that will meet your business and cultivation goals.

Surna was created to address the increasingly complex financial, marketing and operational challenges faced by indoor cultivators.

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