WHITE PAPER

# HVAC Technologies For a Successful Indoor Climate

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# INTRODUCTION

The importance of HVAC systems to every layer of the cultivator's business is well understood. One of the complications with selecting the right designer or technology is that few cultivators are mechanical engineers. This really complicates the process of deciding which provider or technology is best for your facility. When it all sounds good, how do you make the right decision for your grow? The truth is, there are a number of technologies that can successfully manage the climate in an indoor facility. The trick is understanding the pros and cons of each and working with a mechanical design partner who can clearly articulate them to help you make an informed decision.

Although there are a number of options within options within the various technologies that will do the job, they generally fall into two categories: those with integrated dehumidification, and those that rely on standalone dehumidification.

# BACKGROUND

"Standalone" describes climate control systems where the cooling function is decoupled from the dehumidification function, and integrated systems describe climate control systems where the cooling and dehumidification functions are coordinated, usually with the same pieces of equipment. With standalone systems, the controls are typically on/off, which means that as soon as the temperature or humidity drifts out of a tolerance dead band (usually 4-6 degrees F), the system engages, cools or dehumidifies to below set points, and then turns off. This could use more energy than absolutely needed to perform cooling and dehumidification functions by overshooting targets or rapidly cycling the system.

From a performance standpoint, this usually means that the trend lines for temperature and humidity look more like a sawtooth than a smooth line, where the room is essentially bouncing up and down off setpoints. Some cultivators are accepting of this performance and a wider tolerance, and some prefer much tighter tolerances and trend lines. This isn't to say that a standalone system won't keep your grow within acceptable parameters, just that the temperature or humidity might fluctuate by several degrees or percentage points throughout the day.

In standalone systems, there is no direct humidity control. Simply stated, you get what you get as a byproduct of the cooling process. This means that temperature and humidity are managed independently, and additional dehumidifiers must be utilized to manage humidity to a specific setpoint, especially during lights off when there is little or no sensible heat load forcing the cooling system to run. In integrated systems, humidity and temperature control are managed simultaneously, and sensible to latent heat removal ratios within the system are managed through modulation to ensure that temperature and humidity targets are met.

Performance differences between standalone and integrated or modulating systems can be demonstrated with a car analogy. Standalone systems are the equivalent of slamming on the gas when you fall five miles an hour below the speed limit and taking your foot all the way off the gas when you are at five miles an hour above the speed limit. Modulating or integrated systems are more comparable to setting cruise control at the exact speed limit you desire and staying there.

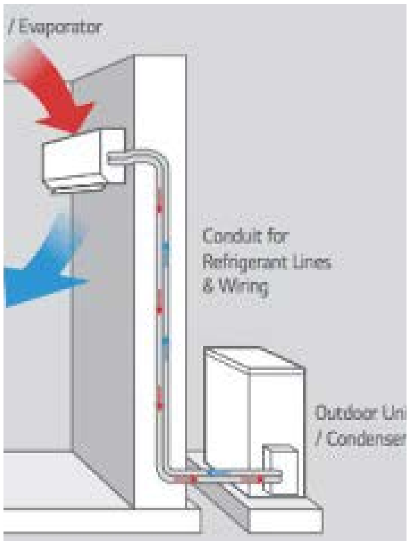
Standalone systems can be controlled with simple thermostats and humidistats mounted in the room (keep them out of direct light by using a shade or an aspirated box to ensure correct readings), or more sophisticated systems as desired. Integrated systems usually require more sophisticated controls systems, but also provide more insight into the system's performance for perfecting or troubleshooting.

# TECHNOLOGIES

## STANDALONE SYSTEMS

### DX with Standalone Dehumidification

DX with standalone systems mean the cooling and heating unit is separate from the dehumidification unit, usually located in the space it serves. The most common types of standalone DX systems are split systems, mini-splits and packaged roof top units (RTUs). Common types of dehumidifiers used are standalone electric, or desiccant in low humidity applications.




These systems typically supply cooled or heated air to a single zone in grow applications. The typical capacity is from 1 to 10 tons, but they can be larger in some applications.

Split systems are made up of two parts: an indoor fan coil unit (FCU) or small air handler, and an outside condensing unit. The FCU takes the warm air from inside your grow over cold evaporator coils, which contain refrigerant, absorbs the heat from the air inside the space, and transfers it to the condensing unit outside the grow to be rejected.

One of the main disadvantages of a typical light commercial split system is it offers no direct control of humidity as it only comes on when the space is "hot" regardless of the humidity level in the space. Because of this, split systems will need to be paired with standalone dehumidifiers. These dehumidifiers can be fairly inexpensive, depending on their capacities. It's also common for growers to have a few extra dehumidifiers on hand to supplement for additional capacity or in case of mechanical failures.

Pros:

- ◊ Low cost.
- ◊ Smaller size (split units) common.
- ◊ Installation requirements well understood.
- ◊ Common, don't require significant building alterations.
- ◊ Short lead times.

Cons:

- ◊ Lower life expectancy (3-10 years depending on selection) as they are designed for light commercial or residential vs industrial applications.
- ◊ Higher maintenance costs as they are not intended for heavy duty operation.
- ◊ Consistent dehumidification is not available.
- ◊ Temperature and humidity fluctuations due to staged on/off operation and tendency for the DX units and DHU to "fight" each other and operate independently.
- ◊ Usually less energy efficient than other options
- ◊ Many points of electrical connection required.
- ◊ Electrical infrastructure costs may be greater due to large HVAC loads being spread throughout the building as opposed to being centralized at the plant.
- ◊ Limited free cooling or economization options.
- ◊ Requires additional standalone dehumidifiers.

**Packaged Units**

Packaged units operate similarly to split systems. The primary difference is that packaged units have all the components of the air conditioning system in one place. The most common packaged unit is an RTU. With these systems, the unit is typically placed on the roof (however, they can be placed on a grade outside the building) and the dehumidifiers are placed inside the grow rooms.

Roof top packaged units are more suitable for buildings with space on the rooftop to install the unit. The unit itself requires duct work for distribution to the space for supply and return air, a power line and drain piping.

Roof top packaged units are commonly applied in comfort cooling and have a vast array of efficiency, sizes, features, and costs. Packaged units do not require indoor space like split units, but they do have substantial ductwork requirements. Most units can come with either gas or electric heat options so they can be used for heat as well. Since the unit does sit outside and grow space air is recirculated for both cooling and heating, they can pose a challenge from an odor control and biological contamination perspective as both bugs and nearby airborne contaminants have the opportunity to infiltrate through exterior ductwork. Airside economization ("free" cooling) is achieved by bringing in outside air when ambient temperatures are below 50 degrees Fahrenheit, which may be undesirable to many growers as this creates biosecurity, odor, pressurization and $CO_2$ enrichment concerns. As a result, the economizer function is often disabled, missing an opportunity for OPEX energy savings in colder and dryer climates.

Pros:

- ◊ Does not use indoor space (except for the dehumidifiers).
- ◊ Can be lower in cost depending on features/options.
- ◊ Widely available with short lead times.
- ◊ Relatively easy to install and maintain.

Cons:

- ◊ Higher maintenance costs as they are not intended for industrial use operation.
- ◊ Temperature and humidity fluctuations due to staged on/off operation and tendency for the DX units and DHU to "fight" each other and operate independently.
- ◊ Usually less energy efficient than other options.
- ◊ Many points of electrical connection required.
- ◊ Electrical infrastructure costs may be greater due to large HVAC loads being spread throughout the building as opposed to being centralized at the plant.
- ◊ Requires duct work in the grow space adding to odor and biosecurity concerns.
- ◊ Lower life expectancy (3-10 years) in most applications.
- ◊ Requires air to go outside of grow spaces which can pose an odor control or biological concern, or loss of $CO_2$.
- ◊ Rooftop or ground mounting can be a problem if the building cannot bear the weight of the unit(s) or there is no ground level onsite space.
- ◊ Redundancy more costly than with central plants.
- ◊ Ductwork can complicate redundancy options.

**2-Pipe Chilled Water (also-known-as hydronic cooling and dehumidification)**

Hydronic cooling is simply the removal of heat and moisture from a space utilizing chilled water as the heat exchange medium. People sometimes confuse chilled water systems with evaporative cooling which introduces humidity into the space and consumes water to cool, but they are quite different. Hydronic cooling systems are completely closed loop meaning no water is added to the space much like the radiator in a car. In hydronic cooling, water is chilled by a chiller, dry cooler, or cooling tower and circulated via pump through the system into heat exchanger units in the space (air handlers or fan coils) and then back to the chiller to be recirculated again. Air handlers and/or fan coil units utilize a fan to pull warm air in and over the heat exchanger inside. As warm air in the room moves over the heat exchangers, heat is transferred from the air into the cool water inside the coils, pulling heat and humidity from the room and returning cool,

dry air to the space. Since pumps keep water inside the system constantly moving, the warm water leaving the heat exchanger is immediately returned to a chiller, dry cooler or cooling tower. These units may sit inside or outside the facility. While indoor chillers are more efficient, for the added cost, complexity and floorspace required, most facilities prefer them outside so they don't have to give up space inside for equipment.

One of the primary benefits of chilled water systems is that for a minor cost addition, N+1 redundancy in each space can be built into the design, offering complete redundancy without doubling the equipment cost. These systems utilize multiple chillers organized into a bank and multiple fan coils that are all tied back to the collective chiller bank. This allows for 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 air handlers or 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. in this way, facilities can ensure they always have some manner or even full cooling if going with an N+1 design concept.

Chiller systems are used worldwide for cooling in high-heat applications because of their top-of-the-line energy efficiency and flexibility for mechanical air conditioning and dehumidification. By decoupling the machine that is producing the cooling away from the indoor environment, it is possible to move cooling to the places that need it, 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 in each.

In a 2-pipe chilled water system, the fan coil or air handler only has one supply pipe and one return pipe, so the system uses the chiller loop for sensible cooling and passive assist to standalone dehumidifiers; the dehumidification is not integral, so there is no direct humidity control.

2-pipe chilled water systems provide the ability to economize via a dry cooler in colder climates saving significant amounts of energy by turning off the compressors in the chiller, which are the single largest energy consumer in the HVAC system.

Pros:

- ◊ Flexible air handling options (ducted, ductless, multiple sizes and configurations available).
- ◊ Minimal indoor space requirements.
- ◊ Usually results in lower overall electrical infrastructure than DX units.
- ◊ Flexible air handling options can result in better room air homogenization.
- ◊ N+1 redundancy possible at a minimal cost addition.
- ◊ Ability to easily expand operations if phasing plan is identified ahead of time.
- ◊ Flexible tonnage.
- ◊ Share equipment between rooms without sharing air between rooms (great for flips).
- ◊ Lower ongoing maintenance.
- ◊ High longevity (~20+ years).
- ◊ Significant economization (free cooling) options.

Cons:

- ◊ Initial expense can be slightly higher than packaged DX or split units.
- ◊ More engineering work is required to design the water piping loop properly than simpler systems.
- ◊ More complicated to install than most DX systems.
- ◊ Requires a mechanical room in the building (small).
- ◊ Standalone dehumidifiers are required.

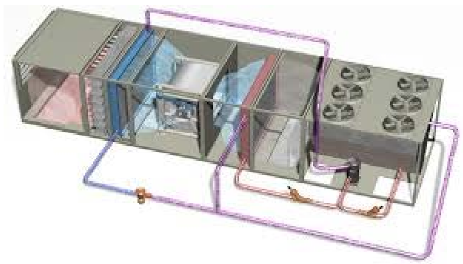
## INTEGRATED SYSTEMS

### Refrigerant Based Systems (also-known-as DX)

The main difference between a DX (direct expansion) unit and a chilled water unit is that the DX system's cooling, dehumidification and heating all happen directly to the airstream serving the space, whereas with chilled water systems, the unit producing the cooling (the chiller) is decoupled and cools a recirculated water loop that is pumped to terminal units for heat exchange. The DX system uses a refrigerant vapor expansion and compression cycle to cool and dehumidify the air coming from the space and returns it to the room after conditioning. DX based systems described in the stand-alone section are different from the DX units described here, where dehumidification is coordinated with cooling functions.

### Complex DX with Integrated Dehumidification via Hot Gas Reheat

As noted previously, in this type of system, cooling, dehumidification and heating all happen directly to the airstream serving the space. The system uses a refrigerant vapor expansion and compression cycle to cool and dehumidify the air coming from the space and returns it to the room after conditioning. Here we will discuss the complex integrated system with the dehumidification/cooling/heating all in one unit which may be undesirable to most growers.



These unit's cooling and heating functions are the same as standalone DX systems, however the dehumidification function is combined into the same unit, so they work in concert. There are two forms of hot gas reheat. There is an on/off type with poor discharge air temperature control (but cheaper) and complex modulating which offers better discharge air but is more expensive.

**Modulating Hot Gas Reheat**

Modulating Hot Gas Reheat (MHGRH), the more complex form of reheat, allows precise control of the HVAC system discharge air temperature and is typically used during dehumidification mode. During dehumidification, mechanical cooling lowers the temperature of the air to a specific dewpoint in order to lower the moisture content of the air. MHGRH is then used to temper (raise) the temperature of the air to a desired setpoint that is equal to the room's temperature setpoint. A common solution is a sophisticated RTU with integral dehumidification via modulating hot gas reheat.

These RTUs have a vast array of efficiency, sizes, features, and costs. Another benefit of the rooftop unit is that it does not use up indoor space, although ducting to the space will be required as mentioned earlier. Most units can come with either gas or electric heat options so they can be used for heat as well. 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 as this creates biosecurity, odor and pressurization concerns and is oftentimes disabled, eliminating any chance for economization or "free" cooling in colder climates.

Controls in complex MHGRH systems are far more complex than those in standalone systems. Modulating systems require modulation of fan speeds, refrigerant, pressures and temperatures. This level of sophistication can be both a blessing and a curse. The downside is the greater expense for controls and equipment cost of a modulating system. The upside is the extreme visibility the cultivator has into the operation of his or her climate control system, which allows for immediate detection and faster diagnosis of potential equipment problems, immediate detection and faster response and correction of any failure to meet temperature and humidity setpoints, and significant opportunities for optimization of both energy use and overall performance.

Pros:

- ◊ Does not use indoor space.Energy efficient.
- ◊ Easy to install.
- ◊ Usually among the most energy efficient options.
- ◊ Unit arrives packaged and ready to go with controls so it is "plug and play."
- ◊ Supplemental standalone dehumidifiers not required.
- ◊ Greater precision of climate parameters over standalone systems when modulating option is selected.

Cons:

- ◊ Highest equipment cost per ton (although overall installation costs may be less expensive than a chilled water system).
- ◊ Requires duct work in grow space.
- ◊ Lower life expectancy compared to other designs, 5-10 years in most applications.
- ◊ Requires air to go outside of grow spaces which can pose an odor control or biological concern, or loss of $CO_2$.
- ◊ Redundancy and its associated electrical infrastructure will be required to oversize every room's tonnage (as opposed to a chiller system that can provide similar redundancy at a lower overall tonnage).
- ◊ Lacks ability to economize for energy as compressor cannot be turned off when it's cold outside.
- ◊ Cannot benefit from flipped loads.
- ◊ Lack of flexibility. If grow conditions change in the future, you "have what you have" and would need to purchase more equipment to accommodate growth.
- ◊ Can require specialized techs for maintenance.

**4-Pipe Chilled Water**

The 4-pipe chilled water system is also a hydronic cooling and dehumidification system as previously described. As the name suggests, four pipe systems have four pipes going to multiple heat exchangers inside of the building consisting of two supply and two return lines. One set is dedicated to chilled water, typically kept between 40 degrees F and 60 degrees F. Another set of pipes is dedicated to hot water, generally kept between 130 degrees F and 200 degrees F. The pipes run to terminal fan coils or air handlers, which use chilled or hot water to change the air temperature by cooling, heating or by dehumidifying. The main benefit of using a 4-pipe system over a 2-pipe system is that standalone dehumidifiers are not required as the system provides temperature and humidity control simultaneously in a single unit when controlled properly.

Traditionally these systems utilize air handler units (AHU's) or fan coil units (FCU's) which contain a blower, heating or cooling elements, and control valves (and optionally, filter racks, and modulating dampers) . AHU's and FCU's can either:

a. be connected to a ductwork system that distributes the conditioned air to the area served and reside outside the space, or
b. reside directly in and condition the space served without ductwork.

4-pipe chilled water systems provide the ability to economize via a dry cooler in colder climates saving significant amounts of energy by turning off the compressors in the chiller, which are the single largest energy consumer in the HVAC system. The most energy efficient 4-pipe designs utilize heat recovery on the chiller plant to minimize or eliminate dehumidification reheat costs.

Pros:

- ◊ When connected to a heat recovery chiller plant, can recover heat from that process, rather than generating new heat through the consumption of electricity or natural gas.
- ◊ Usually among the most energy efficient options.
- ◊ Flexible air handling options (ducted/ductless, with multiple sizes and configurations available).
- ◊ Long life expectancy if maintained properly (over 20 years).
- ◊ Very flexible biosecurity options (MERV/HEPA/UV/PCO).
- ◊ Ability to economize via a dry cooler in colder climates saving significant amounts of energy by turning off the compressors in the system.
- ◊ When controls are properly applied, flexibility to adjust to changing room parameters and insight into system operation (for perfecting operation and troubleshooting where required) are unmatched.
- ◊ Standalone dehumidifiers not required.
- ◊ Greatest precision of all options in varying conditions.

Cons:

- ◊ Controls and installation are more complex than other systems and may increase first cost.
- ◊ Longer lead times for engineering and equipment production due to the complexity and custom nature of the design and machines themselves.
- ◊ Not as common as DX units (usually utilized in true industrial applications).

# CONCLUSION

With so many choices, selecting the correct climate-control technology 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.

To ensure you are choosing the right technology for your grow, work with a mechanical design team that has expert knowledge of the different available technologies. They shoould also be capable of assisting you in getting to the right choice for your very first grow or help you pivot later if necessary.

# ABOUT SURNA

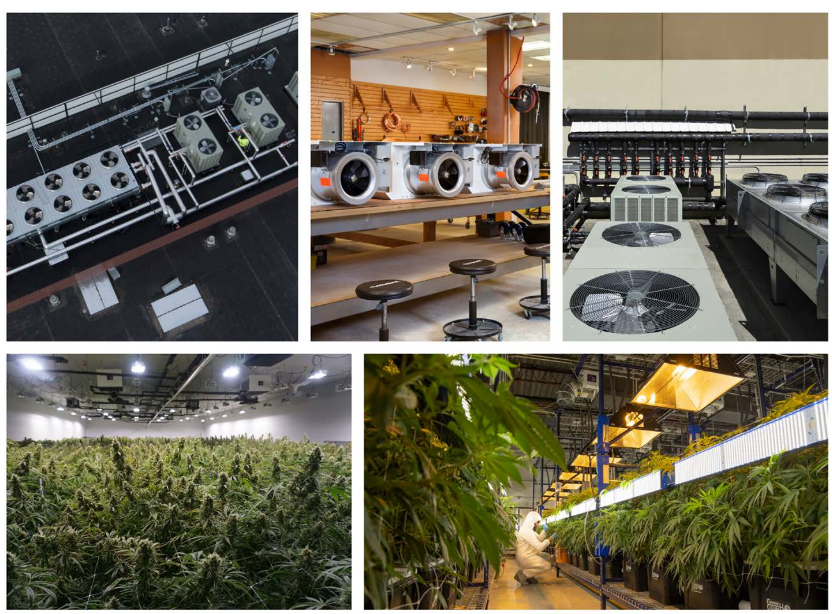
At Surna, our deep engineering expertise and direct experience with every imaginable approach to cannabis cultivation and climate control makes us uniquely qualified to handle all of the mechanical, electrical and plumbing (MEP) design requirements of any cannabis facility. But we are so much more. Not just an engineer, not just an equipment manufacturer, Surna is a solutions provider. Just as the cannabis industry has evolved over the years, so have we. We were ahead of the curve in hydronic cooling systems 14 years ago and we're ahead of the curve now with our ability to design and provide virtually any climate control system. Our ultimate goal is to provide whatever HVAC design is the best fit for the circumstances, regardless of of the system chosen. From MEP design to equipment and controls to commissioning, we can help you with any or all of the steps associated with designing and implementing a perfect cannabis environment. Our longevity in this industry means we have a deep understanding of the unique challenges that come with constructing a cultivation facility. Take advantage of our experience and contact us to learn how we can help you grow today.Our experience serves to provide you with a custom design that you can rely on.

Whatever your goals are, we can sit down together and create a solution:

Cultivation Technologies
- ◊ Controlled Climate Systems
- ◊ Controls
- ◊ Biosecurity

Grow Room Services
- ◊ MEP Engineering
- ◊ Odor Control
- ◊ Installation Support

*We've been growing our business for over 14 years and we can help you grow yours too.*



SURNA®
Let's Grow Together™


A 1780 55th Street
Boulder, CO 80301

P 303.993.5271

E info@surna.com


SURNA.COM