Indoor Cannabis Growing – Taming the Wild West

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ABSTRACT

With cannabis legalization spreading throughout the Northwest, utilities and program administrators are facing several challenges. Growers are racing to buildout indoor grow facilities, typically mirroring their small-scale, inefficient lighting, HVAC, and dehumidification approaches. Additionally, growers struggle to get financing and as such, are very cost-conscious. In the race to go to market, they are often unwilling to slow down and consider incorporating energy efficiency into their buildouts. Our direct experience with dozens of growers throughout the Northwest has provided mixed results and significant learnings. Over the past few years, we've had significant breakthroughs in identifying energy efficiency measures and technology solutions and are working toward understanding best practices for efficient cannabis production buildouts.

This paper will document our challenges, learnings, and technology solutions that we've discovered since Oregon's legalization of recreational cannabis in 2015. The intent of this paper is to share knowledge and accelerate the learning process for states recently legalized or facing legalization. This paper will share breakthroughs in the following areas:

- How to remove heat caused by dehumidification from the growing environment, which is typically dominated by the need to cool.
- How to mitigate challenges in balancing indoor environment plant needs, which are CO_2 enriched and clean, with traditional efficient HVAC design, which relies upon free or efficient cooling in cool weather without introducing impure air into the growing space and exhausting unacceptable amounts of CO_2.
- How to engage a historically unorthodox population of growers with little access to capital and even less time to consider efficiency.

Introduction

As more and more states legalize cannabis for recreational use, the load placed on our utility infrastructure continues to rise. Utilities in Colorado and Washington have estimated overall electric demand increases between 0.5% and 3% due to legal cannabis production since 2013 (Remillard and Collins 2017). In Colorado specifically, 50% of the overall load growth in 2015 can be attributed to cannabis grow facilities (Remillard and Collins 2017). The Northwest Power & Conservation Council has forecast a regional load for Idaho, Montana, Oregon, and Washington of between 180 MW and 300 MW for indoor grow operations by 2035 (NWPCC 2016, E-60). Utility costs are likely to rise as additional capacity is brought online to serve these loads, impacting not only the bottom line of producers but of all utility ratepayers as well.

Along with the proliferation of producers comes an oversupply of product, which has driven down the wholesale and retail prices of cannabis over the past several years in many states. In Colorado, the oldest regulated adult-use market in the United States, the wholesale price of a pound of marijuana has dropped from $2,000 in January 2015 to $1,115 in November 2017 (Schaneman 2017). Similar declines have been observed in Washington (Kennedy 2018) and, to a lesser extent, Oregon (Darling 2018). This translates into decreasing profit margins for the industry in the years to come, not to mention additional externalities such as rising labor rates and potential changes in taxation.

Growers, however, are becoming increasingly aware that they can control their energy costs - which can represent as much as 50% of overall production costs (Oldham 2015). This will only become more important as competition increases and prices inevitably fall. Early adopters of energy efficiency in the cannabis industry stand to benefit in this scenario, and will be better equipped to weather the storm than their peers. This paper will highlight some of the efficiency opportunities that we're seeing as program implementers in the Pacific Northwest. Note that this paper will focus primarily on HVAC and dehumidification, as relatively less literature exists on this topic than on efficient lighting in cannabis cultivation.

Energy Intensity of Indoor Cannabis Cultivation

Indoor cannabis cultivation facilities present a unique climate control challenge. High quality cannabis production has very specific lighting, temperature, humidity, and ventilation requirements. This makes indoor growing a very energy intensive industry, with typical Energy Use Intensity (EUI) rivaling that of a data center. It is important to note that in addition to flowering canopy, additional grow space is dedicated to the vegetative stage of growth (veg), as well as maintaining mother plants and starting new clones. For a Tier II facility in Oregon with 10,000 sqft of flowering canopy, an additional 3,000-5,000 sqft is typically dedicated to non-flowering grow space. Some facilities provide space for multiple growers, each operating on their own license. In these cases, the total facility's floor area and energy use can be much higher.

Lighting and HVAC (including dehumidification) are by far the top two energy users in these facilities, with lighting consuming roughly 70% of energy while HVAC takes the remainder. Table 1 shows typical EUI ranges for both a "baseline" and energy efficient facility, with the relative contribution of lighting and HVAC highlighted. When considering EUI, it's instructive to use the total canopy area (flowering, veg, mothering, and clone) as the denominator. Space is also dedicated to non-growing uses such as processing, storage, and office. Since these uses are much less energy intensive, they are not accounted for in the EUI figures presented in Table 1. If included, this would dilute the energy intensity over a larger floor area. As such, care should be taken to carefully define the area that is being considered when discussing EUI.

Table 1. Typical energy use intensities, normalized by growing canopy area (includes flower, veg, mother, and clone)

End Use	Baseline EUI [kBtu / sqft]	Efficient EUI [kBtu / sqft]
Lighting	1,200	550 – 950
HVAC	515	300 – 400
Total	1,715	850 – 1,350

Lighting, HVAC, and Dehumidification Strategies

Most of this paper will focus on non-lighting opportunities for indoor cannabis cultivation since less information on this topic is available in the peer reviewed literature. It must be acknowledged, however, that lighting is a prime target for efficiency gains and should be addressed first, as lighting selection will have direct energy impacts on HVAC system energy consumption and sizing.

Baseline Lighting Technology

The most common lighting type in grow facilities is high pressure sodium (HPS) fixtures, which consume 1,000+ watts per fixture. HPS lights are well proven and growers trust them to provide the spectral characteristics and radiative heat to ensure maximum yield from plants. This is especially critical in the flowering stage of growth. Despite our efforts to encourage efficient lighting, the majority of the lighting selected for indoor growing remains HPS.

Energy Efficient Lighting Technology

Advanced lighting designs involve either using more efficient fixtures, and/or using rolling tables to create a "collapsing canopy" that eliminates aisles. The height of fixtures is also critical in determining how much of the lighting energy reaches the plant canopy, and how closely lights are spaced. Efficient lighting technologies include ceramic metal halide (aka CMH, also referred to as light emitting ceramic, or LEC) and LED fixtures. Both technologies can reduce fixture wattage to 600-650W; however, growers will often use additional fixtures or mix in some HPS fixtures as well. Even with the increased fixture density, lighting savings on the order of 25% are possible. When a collapsing canopy is also incorporated, savings can increase to approximately 50%. The collapsing canopy approach is most applicable to a grow method that uses many small plants and short grow cycles, commonly referred to as "sea of green." This is contrasted by medical growers who are regulated based on the number of plants and therefore encouraged to grow the largest possible plants.

Summary of Existing HVAC Technologies

As lighting loads are reduced by selecting energy efficient lights, the heat gain in the space is also reduced. This results in lower cooling loads and the opportunity to reduce the capacity of the HVAC equipment. Until recently, HVAC requirements in indoor agriculture facilities have been largely addressed through a piecemeal system of residential grade mini-split heat pumps with separate dehumidification equipment. The residential systems were well suited for the economic, security, and process needs of the formerly illicit facilities, but will not scale as the industry and producer scale grow into their new potential. In addition, it's likely that the current energy consumption and reliability of these systems will not be acceptable as the market becomes more competitive and profit margins are threatened.

The following is a summary of different HVAC system technologies ranked, approximately, from least to most efficient:

Ducted split unit, or packaged RTU (low installed cost)

- Typically, the lowest first cost option
- This is a reasonable option to use as a baseline and is the most common HVAC technology used by growers

Mini split heat pumps (low to medium installed cost)

- Commonly used, especially in smaller grows
- Equipment life may be short, as systems are not designed for high run-hours
- No free-cooling (economizer – see section below on economizers in indoor agriculture)
- Allows for a sealed grow environment, reducing risk of contamination and odor control challenges
- With limited filter capability, the resin from the plants can become airborne and accumulate on the evaporator coils, hindering heat transfer which reduces efficiency and capacity over time

VRF – Variable Refrigerant Flow (medium installed cost)

- Built in redundancy
- Heat recovery available as an option that provides an exemption to the airside economizer requirement of the Oregon Energy Efficiency Specialty Code
- Option to size system to handle dehumidification load with cooling and heating heads in the same space and the heating head serving as reheat (*this is conceptual, as we haven't seen it implemented yet)
- Good part load efficiency by utilizing inverter driven compressors and floating suction pressure
- More robust, commercial grade equipment (vs. mini split)
- Increase in performance at lower outdoor air temperature due to floating head pressure controls
- May not be cost effective for smaller scale grows (below 10,000 ft^2 of canopy)

Air Cooled Chillers (medium to high installed cost)

- May be opportunity for variable speed screw chiller improved part load efficiency
- Variable speed pumping and controls opportunities
- Can flip operation between rooms running opposite 12-hour cycles, allowing the chiller to be downsized (must consider the need for redundancy)
- Unusual in facilities below 10,000 ft^2 of canopy

Water Cooled Chillers (high installed cost)

- Same as air cooled chiller, plus…
- Enables waterside economizer
- An alternate path to the code requirement of an airside economizer in some jurisdictions (including Oregon)
- Great energy savings over a non-economized system due to high internal loads and year-round cooling demand
- Allows sealed grow environment, reducing risk of contamination and odor control challenges
- Improved part load efficiencies, especially with some of the new-generation magnetic bearing chillers that operate <0.2 kW/ton at low condensing water temperatures
- Unusual in facilities below 10,000 ft^2 of canopy

A common challenge in addressing HVAC cost effectively is that facility size (in many cases and jurisdictions imposed by law, rule, or statute) limits economy of scale. In Oregon, which is where the members of this team have had the most experience studying these facilities, the largest single facility allowable by law (10,000 ft^2 of flowering canopy) will require approximately 80-300 tons of cooling, depending on lighting and other factors. This is not big enough to cost-justify chilled water systems or other elaborate HVAC configurations designed to reduce energy use. Technology innovation will be required in order to achieve significant energy savings cost effectively. We are also seeing a small number of multi-tenant buildouts that may be able to achieve economy of scale by serving tenants through a central plant system.

Dehumidification Strategies for Indoor Agriculture

The humidity levels in indoor agriculture facilities must be maintained within certain ranges to ensure good plant health and production and to prevent mold growth.[1] Irrigation systems are in place to deliver water to the plants, and some water does end up encased in plant matter; most of the water used for irrigation, however, ends up as airborne moisture. This moisture is introduced to the air space through transpiration from plant matter, evaporation from growing media, runoff, CO_2 generation, and human activity.

Dehumidification is very important in indoor agriculture facilities, and requires mechanical cooling. This is typically done with a stand-alone dehumidifier, although we are starting to see systems that are integrated with the HVAC system. Dehumidifiers are typically either compressor driven or desiccant based, as described below:

Compressor Driven Dehumidifier: A traditional compressor-based dehumidifier requires some heat in order to work. Most dehumidification is done with stand-alone dehumidifiers which consequently add sensible heat to the space that must be cooled by the HVAC system. The dehumidifier's capacity is typically rated at 80°F, if the space is near that temperature the units will perform well. However, dehumidification needs are significant at night when the temperature setpoint typically drops. If the air temperature drops to 50°F, the compressor will nearly cease to pull moisture from the space and supplemental heating may be required, driving up energy use.

- A reasonable baseline in this case is a plug-in dehumidifier from a big box store
- More efficient and quite common example: Quest™ brand https://questhydro.com/

Desiccant Based Dehumidifier: These systems use a desiccant material to absorb water instead of relying on a refrigeration-based dehumidification system. A heat source is required to "recharge" the desiccant. This technology is common for compressed air dryers and other applications that require extremely low dewpoints.

- These systems are usually more expensive up front but can be helpful with wider temperature ranges and can offer superior energy performance in some situations
- Example: http://www.ebacusa.com/desiccant/DD1200.html

Air Filtration and Odor Control

To mitigate odors, most grow facilities are required to heavily filter any air exhausted from the facility. This is traditionally accomplished with activated carbon filters, which have a large pressure drop requiring significant fan power to overcome. More efficient options (emerging) are ionizing air cleaners, ozone, and/or photocatalytic oxidation (hydrogen peroxide). If installed and working correctly, these options can be a great alternative to carbon filters

[1] We have observed that this is typically 65-75% RH for veg, cloning, and mothering. Flowering is 65-75% for the first 1-3 weeks, and 50% RH thereafter.

because they do not appreciably increase fan power and only require a small amount of input power to operate. In some local jurisdictions that have codes addressing odor control for grow facilities, a sign-off from a licensed Professional Engineer is required for these (or other alternatives to activated carbon filtration) systems.

Air Side Economizers – Opportunities and Challenges

Traditional commercial HVAC systems use airside economizers to save cooling energy when a demand for cooling exists and the ambient temperature is less than the desired supply air temperature. Economizing has the capability of reducing HVAC energy consumption by 50% depending on ambient conditions. This would be a great solution for cannabis production, but is not acceptable for two reasons.

First, contamination is a major concern for indoor growers. Nearly all growers are unwilling to allow any known outside air to be introduced into the space because it can bring pests, disease, mold, and other crop dooming contaminants. This could be mitigated by filtration, but the substantial pressure drop introduced will reduce energy savings. Additional cost for the consumables (filter changes) may well offset any energy cost savings to the grower.

Second, growers keep elevated levels of CO_2 in the growing environment during illuminated hours and the addition of outdoor air would hinder this practice. Additional CO_2 would have to be generated or introduced to overcome the dilution from outside air, adding cost and/or additional energy use.

One lesson we've learned is that in many jurisdictions, an airside economizer may be required by building code in new construction. Much ambiguity exists regarding the applicability of these codes to indoor cannabis grows, since these mechanical systems are serving process loads, not space conditioning. Regardless, we have seen several instances where an airside economizer is essentially forced into the design of the system to satisfy code, only to be disabled by the customer once the system has been inspected for code compliance. This has large implications for utility programs and evaluators that are assuming these savings to be real and persistent over time.

Emerging Technology

Given the relative immaturity of the recreational cannabis market, there is still a lot of potential for emerging technology. This could be truly new technology, or the adaption, application, and integration of existing technologies to the cannabis industry. Some promising technologies that have been proposed for various custom projects include:

Ducted Lighting: Cool outdoor air can still be used to effectively reduce HVAC energy by ducting it directly through sealed lighting fixtures and then out of the space. This solution allows the outdoor air to be used without threat of introducing contaminants into the controlled environment. The latest lighting fixture technology addresses bulb cooling and maintenance concerns with a two-chamber design. The fixture is separated into two chambers: the lower chamber houses the bulb and reflector while the cooling air is ducted through a sealed upper chamber, effectively removing heat without cooling the bulb or dirtying the glass. Ducted lighting is most cost effective when the heat removed from lights can be used to offset heating energy use in adjacent spaces.

Water Cooled Lighting: Some manufacturers are now offering water cooled lighting fixtures. Similar to the ducted lighting described above, the goal of this system is to remove sensible heat directly from the lighting fixtures. This design would be most efficient in facilities that are large enough to already be using a central cooling plant, ideally with some form of water side economizer. Compared to ducted lighting, it may be more feasible to make use of waste heat.

Ground Source Heat Pumps (GSHP): Similar to traditional commercial applications, GSHPs can improve both cooling and heating efficiency by relying on the relatively steady ground temperature to provide a heat source/sink. The barrier to GSHPs is typically their higher initial cost. However, some grow sites located in rural areas may have sufficient land area to install a horizontal system. The cost for such installations can be drastically reduced if site excavation is already required, or if the business owner already has access to the required excavating equipment.

Energy Recovery Ventilation (ERV): To allow airside economizing without introducing outside air to the grow space, one can use an ERV as a heat exchanger to transfer latent and sensible heat from inside to out. An ERV can also offset dehumidification load using a desiccant wheel. If using a flipped schedule (multiple grow rooms in the facility are a requirement for this), you can take advantage of free heat in the rooms that have lights off.

Heat Exchanger Assisted Dehumidification: One equipment manufacturer, MSP Technology, currently offers a dehumidifier that uses an air-to-air counterflow heat exchanger to pre-cool and then reheat air. Water is recaptured for use in irrigation, providing additional cost savings. The Western Cooling Efficiency Center (WCEC) at UC Davis has performed some interesting laboratory trials using this technology, sponsored by Xcel Energy (Pistochini et al. 2017). This is a promising technology, but initial cost estimates have been too high to meet some incentive programs' cost effectiveness criteria.

Integrated HVAC/Dehumidification: Another promising existing HVAC technology is an integrated HVAC/dehumidification system utilizing hot gas reheat. These systems, from firms such as Desert Aire™, were originally designed for the HVAC requirements of indoor pool facilities. The systems are designed to provide heating and cooling along with dehumidification and water recovery in a single system. A traditional dehumidifier uses two coils: a cooling coil to remove moisture and a reheat coil which transfers the heat extracted from the incoming air back into the air exhausted from the dehumidifier. A hot gas reheat system adds an outdoor condensing coil in parallel with a third reheat coil. This third coil and associated controls allows the system to reject heat to the outdoors when cooling is required in the space, or to send heat into the reheat coil when space cooling loads are low. This is a promising and efficient design that allows one system to be used for both cooling and dehumidification without the need for supplemental dehumidifiers. The following schematic, courtesy of Desert Aire, may help illustrate how a hot gas reheat system works.

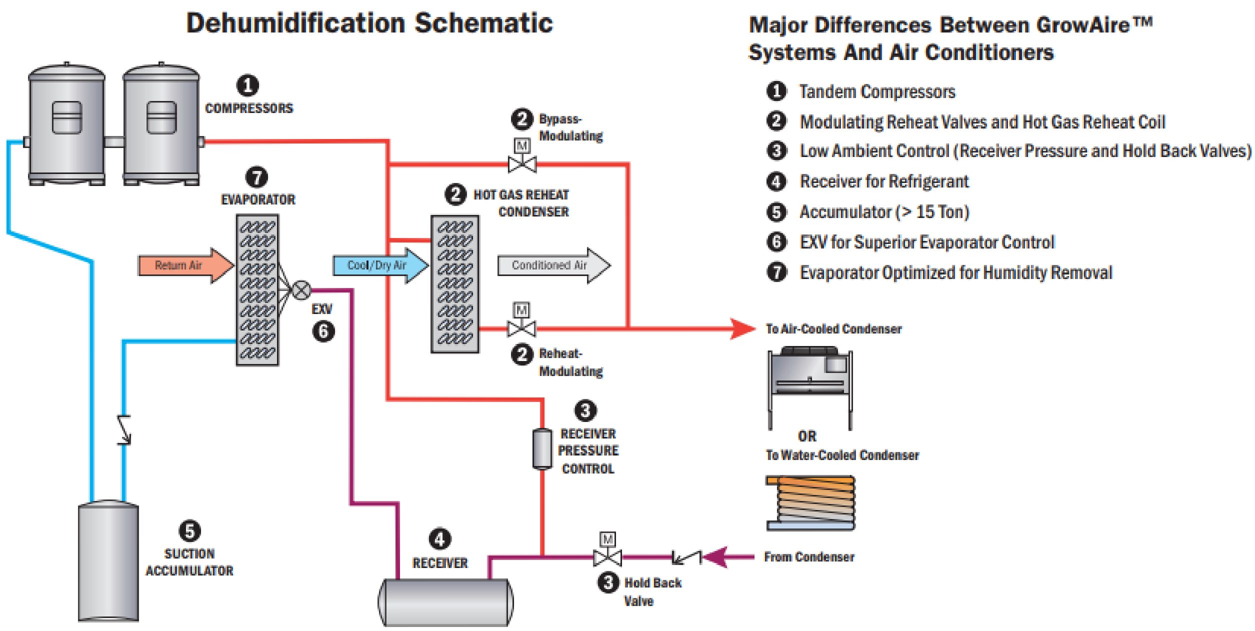

Figure 1. GrowAire™ Dehumidification Schematic. *Source*: https://www.desert-aire.com/dehumidification-systems-growaire?term-bread=growaire%E2%84%A2-systems

Case Studies of Interactive Effects

To better understand the interactive effects of various energy efficiency measures, Table 2 compiles data from three comparable facilities in the Portland, OR metro area where a custom energy efficiency study was conducted through a utility incentive program. While the number of incentivized cannabis lighting projects is much higher, these are three representative projects that included measures beyond lighting. Each customer chose to pursue a different degree of HVAC/dehumidification energy efficiency utilizing some of the advanced technologies discussed in this paper. In each case, the assumed baseline technology is 1,000W HPS lighting, packaged HVAC (EER of 11- 12) and stand-alone dehumidification (4.5lb/kWh) consistent with code minimums for Oregon. Savings shown below are net of direct lighting savings and represent additional savings attributable to the HVAC and dehumidification upgrades directly.

Table 2: Example of three efficiency tiers (savings % measured unless noted)

Measure	Customer #1	Customer #2	Customer #3
Reduced lighting HVAC load*	Y	Y	Y
Integrated HVAC/ Dehumidification	Y	Y	N
VRF HVAC	N	N	Y
Ducted Lighting	N	Y	N
Plasma Odor Mitigation	N	N	Y
Collapsing canopy	N	N	Y
Net Energy Savings	**55%**	**50%**	**38%**
Payback w/ Incentive	**>1 yr.**	**2.5 yrs.**	**2.7 yrs.**

*All customers used a mix of different fixture types, but included at least some CMH and/or LED fixtures.

Customer #1 is a medical cannabis grower that expanded their existing facility by 3,000 ft^2 to support recreational cannabis production. In addition to a cooling load reduction due to LED lights, the customer selected an integrated HVAC/dehumidification design that included hot gas reheat and an outdoor condensing coil.

Customer #2 is a 6,300 ft^2 new construction project for a recreational grow. Beyond upgrading to efficient CMH lighting, this design utilizes ducted fixtures with heat recovery. This means that a portion of the heat rejected by the lights can be used to offset space heating in the adjacent office and workspaces whenever a concurrent load exists. Like Customer #1, this facility also selected an efficient, integrated HVAC/dehumidification system. Savings shown here are estimates from the energy study, as this project is not yet complete.

Customer #3 is a larger, more mature company with multiple facilities in Oregon and Colorado. This project added multiple rooms (totaling 17,000 ft^2) to an existing small medical grow within a large, open warehouse space. This project was very unique in that it employed a mix of efficient lighting types together with a collapsing canopy incorporating rolling tables. This design eliminates isles to provide a solid, or “sea of green,” canopy which requires fewer lights. Unlike the previous two case studies described above, this customer opted for a VRF system and a separate, but efficient, dehumidification system. This decision to go with VRF was driven mainly by the building layout, which would have required a complicated ductwork layout and lacked the structural requirements necessary for RTUs. The customer also opted for Plasma Odor Mitigation, which saves fan energy compared to the baseline (activated carbon filters).

The key to success in each of these projects was the owner's decision to hire a mechanical design firm specializing in HVAC and in some cases cannabis room design explicitly. Often it is the individual designer that steers most of the decisions for the customer, either based on preference, familiarity, or commission. Connecting that individual with the utility incentive program early in the design process is critical for influencing the final equipment selections.

Barriers to Serving this Market

While we have seen promising results with some projects, there have been an even larger number of cases where owners are hesitant to pursue energy efficiency. Now, as the size and number of recreational and medical cannabis facilities increase and operational cost becomes more important, growers will need to investigate new approaches if they are going to continue to innovate and remain competitive over the long term.

High Upfront Costs

Perhaps the most challenging barrier is the large initial capital investment that commercial/industrial grade HVAC equipment requires. This challenge is typically intensified when considering energy efficient equipment options because, as the efficiency of equipment increases, so does its initial cost. Access to traditional financing mechanisms isn't generally an option due to the federally illegal status of cannabis, so many projects are self-financed. In addition, publicly owned utilities in the Pacific Northwest that purchase power from the Bonneville Power Administration (BPA – a federal agency) are prohibited from providing energy efficiency incentives for cannabis cultivation (Crandall 2016, 9). These constraints on capital and cash assistance often means that even if growers would like to invest in efficiency now, they simply may not be able to bear any additional upfront costs and must defer to a future year for an efficiency retrofit.

Business Model

Cannabis businesses are more likely to be owned by a single entrepreneur or a few individuals, often family and/or friends, which means fewer decision makers are involved (Forrest 2017, 8-9). This leads to a faster, less structured business decision-making process than what is typically encountered when working with other industry sectors. These growers are often unwilling to slow down the buildout process with a proper design and informed equipment selection process. There is often a sense of urgency to get into the market as quickly as possible to generate revenue now, with significant uncertainty about future market conditions.

Resistance to Change

A key barrier that energy efficiency programs face is the fact that many growers simply trust that their current approaches yield the desired results. They have been creative in evolving their approaches over time; however, they were evolved to fit a broader set of needs than just environmental process control. Beyond the cash incentive, an often-overlooked benefit of working with a utility incentive program is the technical services provided by a custom energy study. Customers are often skeptical of claims made by vendors. Therefore, a key selling point for engaging this market is that a 3rd party energy study will help vet manufacturers' efficiency claims and let growers make a more informed investment decision (Forrest 2017). Very few cannabis customers we've worked with have solicited the design assistance of a mechanical design firm, as is the norm with complex HVAC systems in a commercial building or industrial facility. A utility-funded ASHRAE level 2 or equivalent energy study may be the best information a grower has in order to make an educated decision on equipment lifecycle costs.

Conclusion

If growers plan to be competitive over the long term, the operational cost of equipment must be considered when making capital investment decisions. Utility incentive programs stand to benefit by creating a tailored approach to serving this market, taking into consideration the non-traditional characteristics of these customers. Our recommendations for those interested in fully realizing the potential energy savings from this sector are as follows:

- The approach that worked when growing illicitly or in small facilities will not scale effectively as facility size increases
- Utility incentive programs have a valuable role to play beyond financial incentives by offering 3rd party technical expertise to growers who are often skeptical of equipment manufacturers' claims
- Engage cannabis growers early and often – as soon as license is applied for
- Pursue efficient lighting first to reduce cooling loads as much as possible since this reduces the size and upfront costs of HVAC equipment
- Integrated HVAC/dehumidification strategies are emerging that provide energy efficiency and water recovery in one package

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