Non-Lighting EE in Indoor Cannabis Growing

Chris Smith, Energy 350
Kelson Redding, Energy 350
Eric Braddock, Energy Trust of Oregon
Kirsten Svaren, Energy Trust of Oregon

ABSTRACT

With cannabis legalization spreading throughout the northwest, utilities and program administrators are facing a number of challenges. Through 2018, growers were racing to build out facilities, typically mirroring their small scale, inefficient lighting, HVAC and dehumidification approaches from room to room. Our direct experience with dozens of growers throughout the Northwest has both captured and missed EE opportunities and has provided significant learnings. Over the past few years, we've had significant breakthroughs in identifying energy efficiency measures, technology solutions and working toward understanding best practices for efficient buildouts.

This paper will document our challenges, discoveries, and technology solutions that we've learned since legalization in Oregon in 2015. The intent of this paper is to share knowledge and accelerate the learning process for states recently legalized or facing legalization. Since lighting is a widely understood energy efficiency opportunity, we will focus on non-lighting measures. In particular, we'd like to share knowledge we've gained in the following areas:

- Unique environmental requirements of a grow room.
- Standard efficiency options most growers consider first.
- Non-lighting technology solutions that efficiently meet the requirements of a grow room.
- Case studies on innovative approaches to saving energy with HVAC & dehumidification.
- Engaging a historically unorthodox population of growers with little money and even less time to consider efficiency.
- Technical and market lessons learned from our experience.

Introduction

In late 2014, Oregon passed Measure 91, which legalized recreational marijuana use in Oregon. Following the passage of Measure 91, recreational cannabis began legal public sale in October 2015 (Measure 91 2014). As of February 1, 2019, the Oregon Liquor Control Commission (OLCC) has issued permits to over 1,100 growers (OLCC 2019).

Market Challenges to Energy Efficiency

Size Limitations

Oregon law limits grower size to less than 10,000 square feet of flowering canopy, and the average permit size is significantly smaller than this. These size limitations present a challenge to energy efficiency in that these sized operations tend to drive design to packaged systems. While higher efficiencies and efficient configuration options still exist within packaged systems, efficiency and creative solutions are more limited.

System Complexity

Many efficient solutions increase the complexity of the systems well beyond the capabilities/understanding of a typical owner. Added complexity introduces options and capability for efficient operation, but also introduces the need for controls and commissioning. Depending on operator HVAC expertise and system complexity, more complex efficient systems could trigger the need for a service contract or access to periodic technical support.

Financing Challenges

Due to the conflicting state and federal laws, owners do not have access to traditional bank financing. As such, they must either self-fund or seek private investors. In either scenario, owners are under tremendous financial pressure to complete the buildout on an aggressive budget and timeline. Private financing often comes with pressure to show a return to investors and/or a limited runway of cash availability, which necessitates the need to quickly complete the buildout to initiate income.

Limited timelines often don’t allow for a thoughtful, efficient design. In fact, we’ve seen that most buildouts bypass traditional design processes. Instead, growers lean on contractors and equipment providers to size and spec equipment with limited budget based on basic rules of thumb. This can lead to fairly basic equipment selections and often oversized equipment to allow for a significant safety factor, given the lack of design.

Additionally, limited budgets typically don’t allow for energy efficient solutions. Even though incentives are available, and paybacks can be attractive, efficient solutions still carry an incremental cost that growers typically don’t have the means to fund.

A DIY Tradition

Most of the growers are experienced, despite the fact that they’re just getting recreational licenses. This means that growers’ experience is in smaller medical grows and/or underground operations. Often in the planning phases, growers just scale the small systems that they’re accustomed to, to the detriment of energy efficiency.

A Race to Establish Early Market Share

In addition to timeline constraints imposed by the need to begin generating income, growers are driven to complete the buildout prior to market saturation. Early generation of income and capturing market share gives growers a strong advantage over their competitors that may be later to market. In addition to gaining early market share, growers face additional timeline pressure to gain sales in the higher priced markets of the early days of legalization. Figure 1 shows the dramatic price declines and low prices seen by early adopter states that have been legal for a few years. Note that Oregon and Washington have seen greater than a 50% price reduction in the past year.

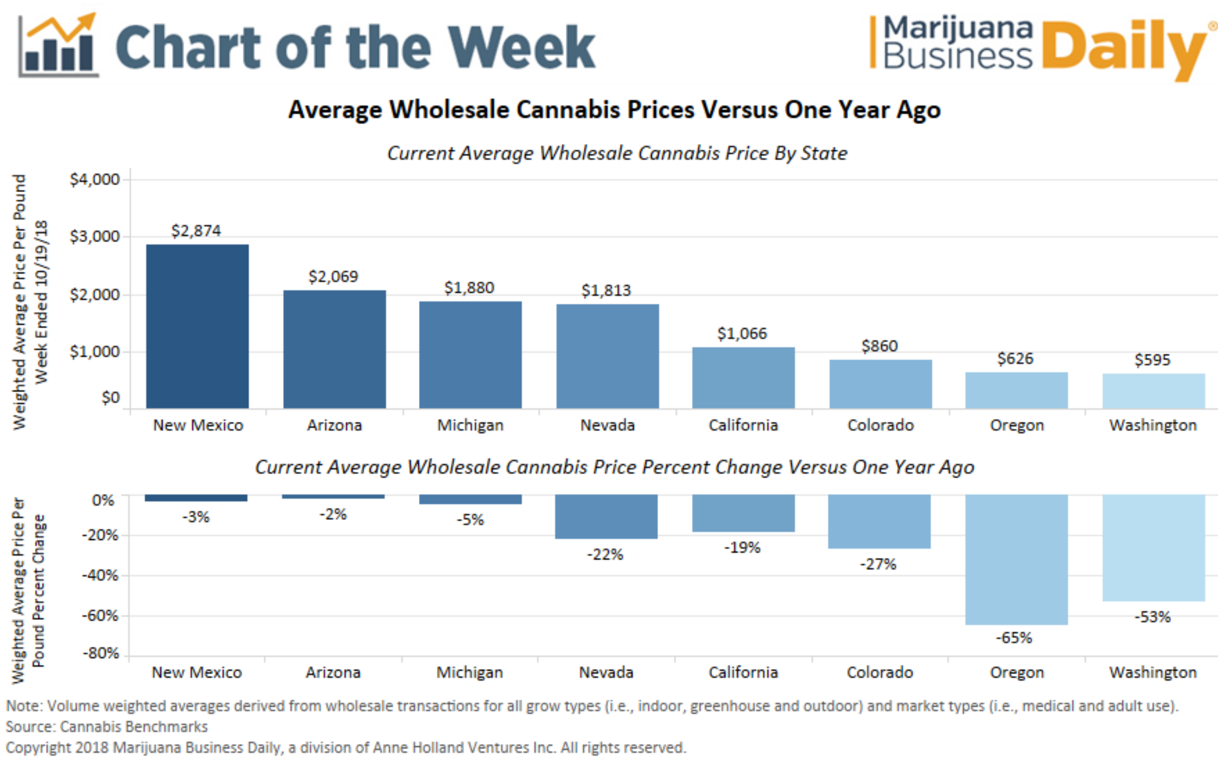

Figure 1. Wholesale cannabis market price trends. *Source:* McVey 2018.

Overcoming Market Barriers

Establish Trust in the Market

Growers are a traditionally underground group that aren't accustomed to working collaboratively with utilities and program administrators. We've had success with some strategies to overcome this reticence to collaborate.

- Embrace the legitimacy of this new market. Discuss it freely. Embrace the new market openly with targeted literature, advertisements and events. Get involved, speak at cannabis industry events, purchase booths at expos, become a part of the community. Advertise in industry publications.
- Partner with trusted industry organizations. Energy Trust partnered with Resources Innovation Institute on a series of outreach and education events. These events were heavily attended, educated growers and provided a meeting place to match growers with providers such as contractors, vendors, etc.

Offer Technical Assistance

Growers often bypass formal design efforts, relying directly on vendors, and therefore are grateful for assistance with design, sizing and equipment selection. This provides an opportunity for both parties to gain value, as design assistance helps growers move forward in a more thoughtful way while giving the utility funded technical assistance provider the opportunity to incorporate efficient selections.

Embrace Innovation

This is a new and unique market with a new set of constraints, which calls for innovative solutions. Standard building HVAC technologies can suffice, but will not maximize energy efficiency.

Grow Room Technical Requirements

Growing Cannabis indoors creates a unique set of technical needs and constraints that challenges the capabilities of existing efficient HVAC technologies. Key requirements of a productive grow room include:

- **Extremely high lighting levels and lighting power density –** Plants thrive in extremely high light levels, which has driven lighting power densities of 30-70 watt/sft. For reference, commercial buildings are in the range of 1 watt/sft or less. In addition to lighting using significant energy directly, this lighting requirement creates significant heat gain and subsequently, a large cooling load.
- **Water and nutrient delivery systems –** Obviously, the plants will require delivery of water as well as nutrients. This delivery of water introduces significant moisture into the air, both through direct evaporation of excess water and through evapotranspiration.
- **Dehumidification –** To drive evapotranspiration and the resulting plant growth, the indoor air must be kept reasonably dry, typically in the range of 45-60% relative humidity (RH). Additionally, dry air is critical in preventing mold growth, which can quickly destroy an entire crop.
- **CO_2 levels –** Plants thrive in a CO_2 rich environment. As such, growers typically inject CO_2 into the space or even burn gas or propane to create CO_2.
- **Air movement –** In addition to the significant air moved by HVAC systems, growers typically use fans to create additional air movement directly through the canopy. This strengthens the plants as well as helps prevent mold growth.
- **Airtight environment –** Given the CO_2 injection, outdoor air should not be allowed in the space, which would dilute CO_2 levels. Likely more importantly, outdoor air can introduce contaminants such as mold or even pesticides in agricultural areas. As such, grow rooms must be kept air tight with zero ventilation and low infiltration shells. This is particularly unfortunate for efficiency in that it would otherwise be an ideal scenario for an airside economizer.
- **Odor Mitigation –** While not a universal requirement, many growers install odor mitigation systems. This is typically done through carbon filters, which introduce pressure drop and the need for additional fan energy. We’ve funded ionization as

an efficient alternative to carbon filters that eliminates the pressure drop of the carbon filters.

- **Temperature –** Plants thrive within a fairly tight temperature band, typically in the range of 75-80˚F. This, when considered with the intermittent use of lights, can require significant heating and cooling requirements. Keep in mind that the lights and associated heat gain are typically on for a minimum of 12 hours per day, meaning that the HVAC needs are significantly different between day and night mode. Furthermore, the light drives evapotranspiration in the plants, creating a significantly different dehumidification load between day and night. Figure 2 shows the dramatic range of loads that must be met by the HVAC and dehumidification systems throughout the course of just a 24-hour period.

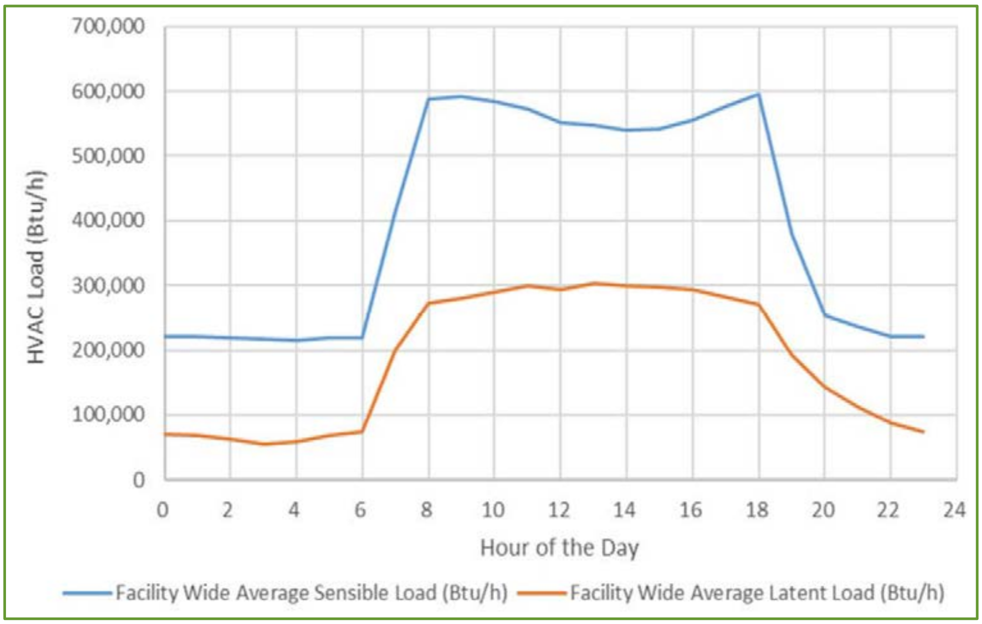

Figure 2. 24-hour grow room load profile in flower room.

Technology Solutions

There are a number of technology solutions to meet the above technical requirements efficiently, all of which have varying levels of efficiency, challenges and tradeoffs. Below is an overview of some of the technology solutions growers are using, listed in order from baseline/standard efficiency to high efficiency. All of the solutions recommended to be eligible for incentives have reasonably compelling economics, with paybacks ranging from 3-10 years prior to incentives, or 2-5 years with incentives.

Packaged RTUs and Low-Cost, Stand-Alone Dehumidifiers

We've had many lost opportunities from this difficult-to-engage market, who chose to go this route. Lost opportunities typically install packaged RTUs or ducted split systems with stand-alone dehumidifiers. This is a common practice, is done quickly and relatively cheaply, and reasonable baseline for energy savings analysis as the lowest cost solution. This solution would not be eligible for incentives.

Inverter Driven Ductless Mini Split with High Efficiency Stand-Alone Dehumidifiers

This is an incremental cost and incremental efficiency to the baseline described above. Humidifier efficiency can vary greatly, with efficiency ranges of 4-8 pints/kWh of moisture removed. We recommend that high efficiency, stand-alone dehumidifiers and higher efficiency mini splits be eligible for incentives.

VRF System with High Efficiency Stand-Alone Dehumidification

This is an incremental cost and incremental efficiency to the mini split scenario described above. Additionally, VRF systems tend to come with enhanced control options that allow for greater control in operation as compared to mini splits.

Integrated HVAC/Dehumidification via Hot Gas Reheat

A significant downside to stand-alone dehumidification, as described in each of the scenarios above, is that the heat is rejected into the space, where it often needs to be cooled by the HVAC system. Integrating the dehumidification into the HVAC typically allows the heat of rejection to be returned to the space when needed or rejected to atmosphere when not needed. Figure 3 shows an example of a common means of integrating HVAC and dehumidification. Dehumidification requires cooling to bring the air down to its dewpoint. With this configuration, the heat of compression caused by cooling can either be returned to the space (lights off mode), rejected to ambient (lights on mode), or both as needed to maintain temperature.

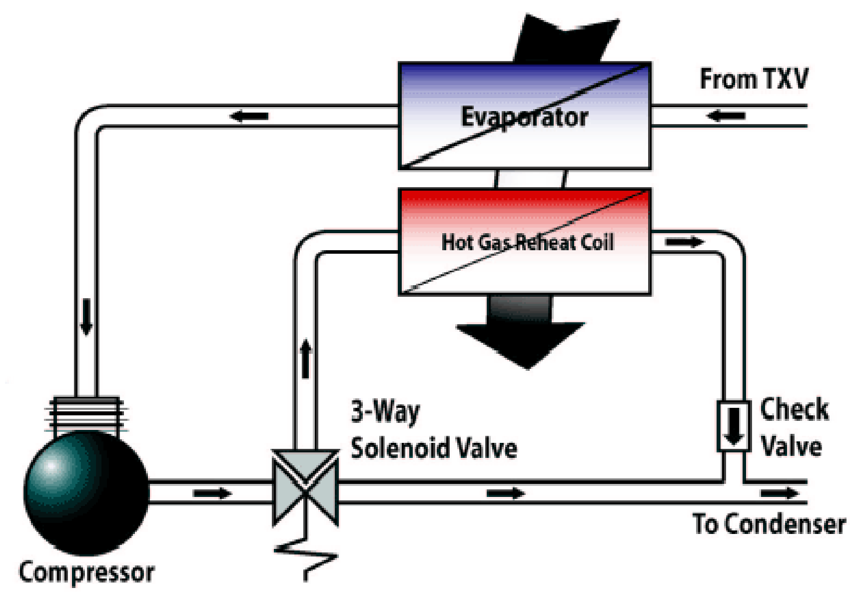

Figure 3. Integrated HVAC/dehumidification with hot gas reheat. *Source:* Enercov 2004.

Use of Energy Recovery Ventilators (ERV) for Free Cooling/Dehumidification

Indoor grow requirements are so unique that an "off the shelf" technology that enables free cooling/dehumidification in this sector does not yet exist. However, we have been able to work with custom equipment manufacturers to assemble some solutions that use modified ERV configurations for free cooling/dehumidification or heat recovery. Figure 4 shows one configuration of an ERV that is used for a combination of dehumidification and reheat.

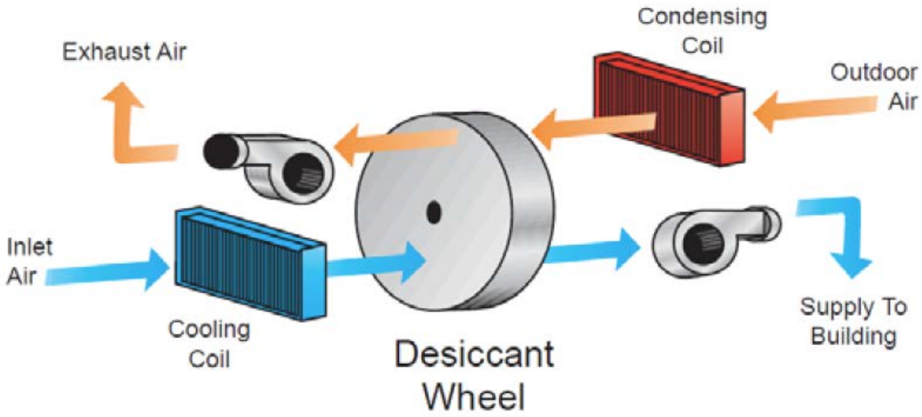

Figure 4. ERV assisted dehumidification and reheat.

Figure 5 shows an alternate ERV configuration that uses the ERV for free or pre-cooling and dehumidification. While ERVs typically recover heat from exhaust air into makeup air, grow rooms are sealed, with no exhaust or makeup air. Additionally, ERVs contain desiccant so also transfer moisture. We've configured a modified ERV that creates an outside air stream of just a few feet within the RTU to remove heat and moisture from the return air. Meanwhile, warm, humid return air is passed along the other side of the ERV, which is cooled and dehumidified by the outside air via the ERV. This configuration allows for free cooling and dehumidification in cooler weather without introducing outside air. Note that this unit also incorporates hot gas reheat to efficiently cool and dehumidify for those hours when it's too hot & humid outside for free cooling and dehumidification.

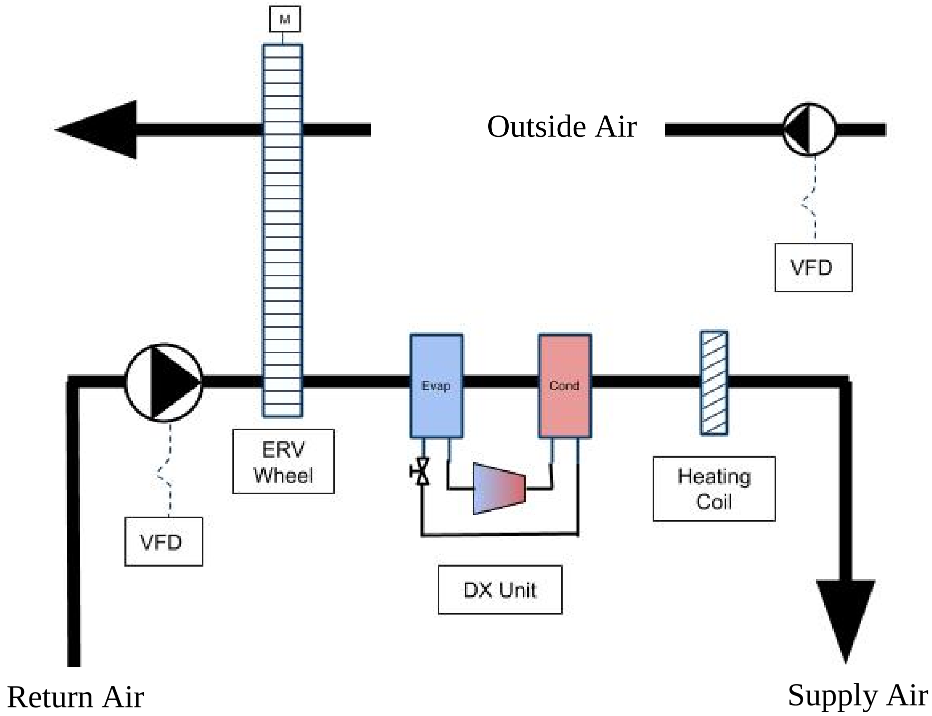

Figure 5. Free cooling/dehumidification using ERV.

Central Plant Solutions

The square footage limitations in Oregon tend to make central plant solutions impractical. However, in states that allow very large indoor operations, central plant solutions can be a practical energy efficiency option. Additionally, we have seen some central plants in Oregon in larger, multi-tenant facilities up to 160,000 square feet with shared utilities. Central plants are highly customizable and allow for a wide range of configurations. One project we developed in a multi-tenant buildout used tenant-owned water source heat pumps with owner provided water from a central plant consisting of a cooling tower, boiler, pumps, etc. Additionally, heat pumps are specified with a water side economizer to allow for free cooling without the introduction of outside air. This is an efficient solution, though requires significant capital only justified in larger buildouts. Figure 6 shows an overview of the configuration.

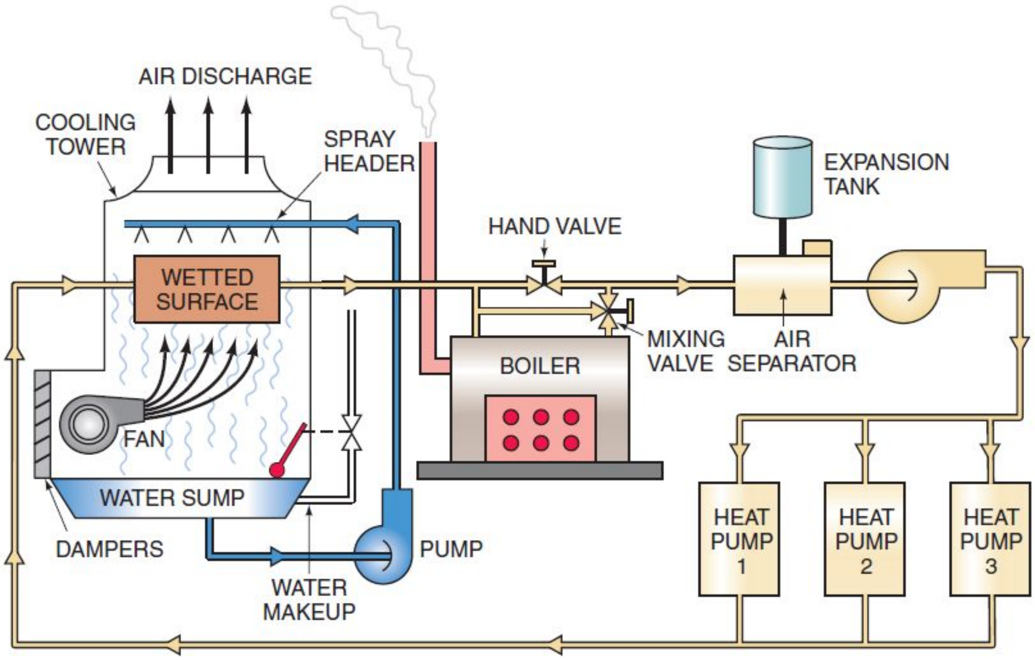

Figure 6. Central plant solution - water source heat pumps.

Case Studies

Our efforts to embrace and engage the market have led to a number of successes. Through our own events, attendance at industry events, and word of mouth, we've been able to engage a number of growers interested in both technical assistance and incentives. This has allowed us to develop a number of custom, non-lighting EE projects. This section highlights a few case studies. All of the case studies below had compelling economics, with paybacks ranging from 3-10 years prior to incentives, or 2-5 years with incentives.

Integrated HVAC/Dehumidification System. Portland Oregon Recreational Indoor Facility

This Oregon licensed indoor recreational cannabis producer installed a combined HVAC/dehumidification system. The integrated system serves a 1,026 ft^2 flower room and is comprised of two 10-ton air handling units with scroll compressors, electronic expansion valves, full capacity modulating hot gas reheat coils and remote air-cooled condensing units mounted on the roof. The system diagram shown in Figure 3 illustrates the basic layout of each of the units. The units are designed to maintain constant airflow and control suction pressure to achieve the required post cooling coil dewpoint. After the required dewpoint is met, the system modulates the hot gas reheat valve to reintroduce the heat absorbed into the refrigerant during cooling back into the supply air stream via the hot gas reheat coil as needed to meet the space temperature requirement. Any remaining heat is rejected from the condenser. Because of this control scheme the units can match the room's required sensible heat ratio across a range of plant growth conditions efficiently. This control scheme also results in precise temperature and humidity control.

After M&V, these units have been found to save 44% energy when compared to a code minimum baseline composed of packaged RTUs and low cost, stand-alone dehumidifiers. The reduction in input energy is primarily driven by the ability to control the system's effective sensible heat ratio to match that of the space, eliminating the need for stand-alone dehumidifiers. An integrated system also eliminates the simultaneous heating and cooling that occurs in independent systems. The energy impacts of the project are shown in Table 1 below.

Table 1. M&V results – integrated HVAC/dehumidification system

Energy Consumer	Code Minimum Baseline Equipment (kWh/yr)	Integrated HVAC / Dehumidification (kWh/yr)
Standalone Dehumidifiers	56,780	0
Sensible Cooling	41,846	31,881
Latent Cooling	10,176	21,631
Fans	43,858	35,040
Total	152,660	88,552
Savings	**64,109**	

Commissioning is key to realizing the intended performance of these more complex systems. Through our commissioning/M&V process, we identified that the system was initially over-dehumidifying the room and required significant commissioning of the factory controls to consistently meet the space setpoints. It was vital that the manufacturer was dedicated to the commissioning process and ensured that the equipment was performing as specified prior to signing off on the job. We have found from other integrated system installations that having full modulating hot gas reheat is necessary for the system to function without the need for an additional source of reheat such as resistance or natural gas.

Variable Refrigerant Flow (VRF) System with Variable Heat Rejection Dehumidifiers

This Oregon licensed indoor recreational cannabis producer installed a ~ 210-ton VRF HVAC system with ductless indoor units to serve the bulk of the space's sensible and latent loads. The remaining latent loads were served by (9) 5-ton dehumidifiers that had the capability to reject heat absorbed during dehumidification either through a hot gas reheat coil back into the space or through an exterior condensing unit to atmosphere. Finally, they implemented ionization odor mitigation lights into the system in order to eliminate the need for carbon odor filtration. The system served a total of 13,000 ft^2 of flower space and 3,660 ft^2 of vegetative space.

After M&V, this combined system was found to save 25% energy over the code minimum baseline system. This energy savings is primarily driven by the VRF system's floating head pressure control, electronic expansion valves and variable speed compressor, condenser fans and evaporator fans. These capabilities allow the system to operate a substantially higher efficiency than a baseline system (packaged RTUs and stand-alone dehumidifiers) when outdoor air temperatures are low and/or the system is operating at part load (most of the time). Additionally, the dehumidifier's ability to reject heat either into or out of the space depending on the space condition, eliminates any simultaneous heating and cooling that occur with traditional stand-alone dehumidifiers. A summary of the project M&V results is found in Table 2.

Table 2. M&V results – VRF system with variable heat rejection dehumidifiers

Efficiency Measure	Code Minimum Baseline Equipment (kWh/yr)	Verified Energy Consumption (kWh/Yr)	Verified Annual kWh Savings	Verified % Savings
VRF System	1,664,239	1,339,393	324,846	20%
3-Coil Dehumidifiers	1,339,393	1,288,890	50,503	4%
Plasma Odor Mitigation	1,288,890	1,245,767	43,123	3%
TOTALS:			**418,472**	**25%**

During M&V data logging period, it was found that the low ambient efficiency of the VRF system was actually better than the manufacturer specified over the observed operating range. During the monitoring period, the VRF units were operating at lower than expected power even when applying the manufacturer's low ambient correction and capacity correction factors. For the verified annual energy savings, however, the manufacturer's provided performance specifications were used, because in order to claim additional savings, a much more intensive and lengthy data logging effort would have been needed to cover a broad set of operating conditions.

An interesting note about the commissioning process for this project is that the site was initially having trouble with the system handling the full latent load. After attempting multiple strategies to improve airflow and reduce stratification, they finally solved the issue by slowing the evaporator fans to low speed during the lights on period. This effectively increased the coil contact duration of the airstream which allowed more moisture to condense on the coil. This resulted in an improved sensible heat ratio that more closely matched the requirement of the space, while increasing energy savings.

Integrated HVAC and Dehumidification with ERV for Free-Cooling/Dehumidification

To our knowledge, this project is the first of its kind. In addition to the hot gas reheat used on many other projects, the primary energy savings feature is the custom use of an ERV for free cooling and dehumidification. This is a custom configuration shown conceptually in Figure 5 above, along with an as-built configuration shown in the graphics screenshot in Figure 7.

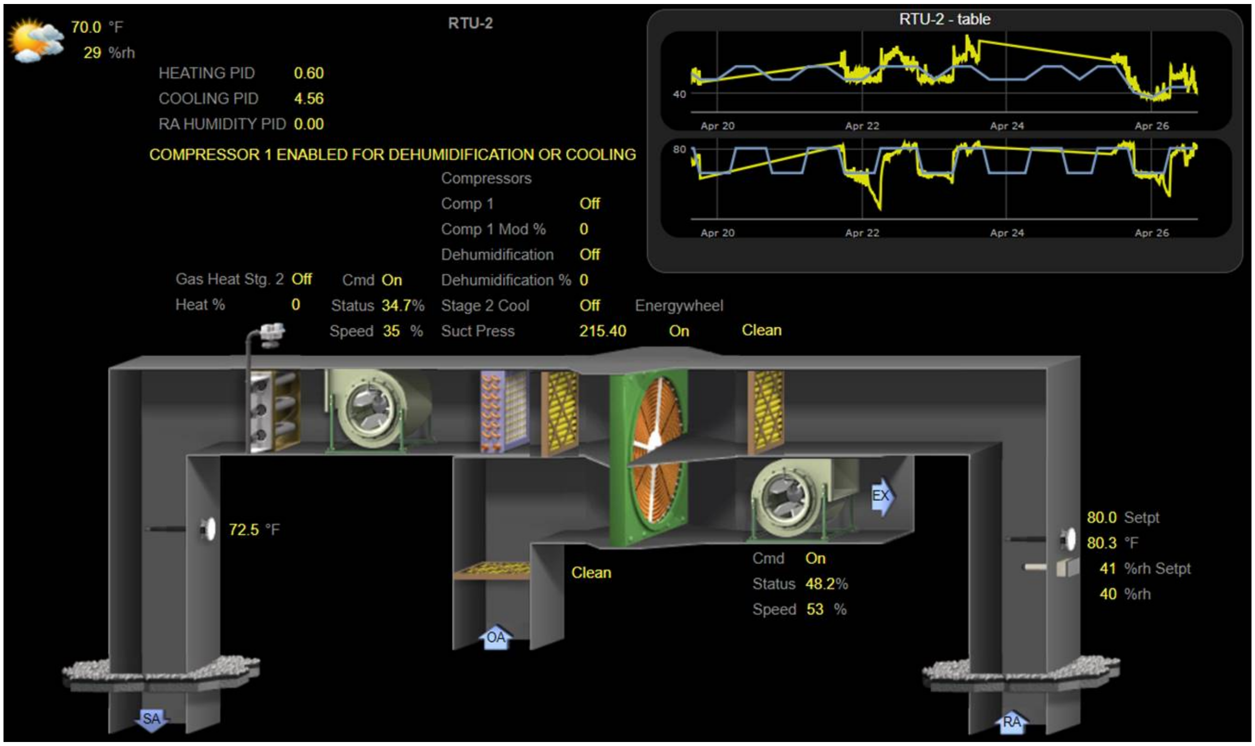

Figure 7. Controls Graphic of ERV system with hot gas reheat

The hot, humid return air passes through an ERV before it hits the heating or cooling coils. On the other side of the ERV is a small fan and a short duct run to move "scavenger air" across the other side of the ERV. When outside air is cooler and less humid than return air (which is the case most of the hours in a year), this allows the ERV to reject heat and moisture from the return air into the outside airstream. Most importantly to growers, this allows for free cooling and dehumidification without introducing outside air, which is laden with contaminants and would dilute the high carbon conditions they create in the grow space.

As the controls show, when outdoor air is dry, this allows us to carry 100% of the cooling and dehumidification load without compressors. In Portland, OR, outdoor air is dryer than return air for approximately 80% of the hours in a year.

Conclusion

As legalization continues to roll out, program administrators will continue to face the challenges and opportunities created by indoor grow buildouts. Given the unique challenges, both market-based and technical, we recommend a custom approach with performance-based incentives to serving the market. While this market is unique, we don't feel that cannabis needs its own program. We feel that most custom programs should be able to serve this market, provided they can minimize turnaround times. We've learned a significant amount about serving this market, and quite honestly, have had more missed opportunities than successes as growers race to complete buildouts on a shoestring. Below are some key lessons learned that we believe can help capture savings within this challenging market:

- Lead with lighting – Lighting typically represents over half of the energy use within a grow facility. With the advancement of LED lighting specifically designed for plants, lighting has both the largest savings opportunity and lowest technical challenges. In fact, Massachusetts has set a code required lighting power density of 36 watts/sft. While this eliminates the ability to receive incentives for efficient lighting, this code requirement will result in significant energy savings from a 100% adoption rate of LED lighting, whereas incentives would only capture a portion of that resource's potential. While they don't explicitly require LEDs, this effectively drives the market to LED lighting as the only viable means of meeting the lighting power density requirement. Additionally, an early decision to use efficient lighting allows for a significant downsizing of HVAC equipment.

- Embrace the market – We recommend that program administrators let go of any historic stigma around cannabis use and fully embrace the market. Attend Cannabis events, join industry associations and create cannabis targeting outreach events. We have found partnerships with key industry players, such as Resource Innovation Institute, to allow us to gain trust in the industry and form meaningful connections with growers and cannabis specific contractors and vendors. As an example of fully embracing the market, Energy Trust of Oregon advertised in Dope and Grow Magazines. We recommend that other program administrators follow suit and immerse themselves in this now legitimate market.
- Offer strong technical assistance that embraces innovation. However, it is important to keep in mind that this service must be provided quickly to keep up with planning and buildout schedules. This will help overcome multiple barriers:
    1. As a result of a rush to complete the buildout and limited cash flow, growers typically skip the design phase. Technical assistance can help bring a thoughtful approach to design and equipment selection that is often lacking.
    2. Grow rooms have unique technical requirements that most traditional efficient HVAC solutions struggle to meet. Meeting the unique technical requirements of a grow room efficiently requires significant technical expertise and innovation.
    3. While most growers are well informed of lighting solutions, they're often overwhelmed by HVAC. Growers may embrace technical assistance more to gain sound advice than energy efficiency. However, the trust built through this interaction can offer both sound advice and incorporate efficiency.
- Act Fast – In Oregon, so much supply has come online that prices have dropped significantly, signaling a lack of need for more growers to come online. The market has responded and buildout of new facilities has all but halted. Due to the marginal economics of non-lighting retrofits, we expect limited participation from this market going forward. The key takeaway here is act fast to get in front of the wave of buildouts as this opportunity is rare and only available for a limited window.
- Commissioning is key – With these, or any other complex systems, we rarely approve the project when the owner and contractor consider it done. We typically are able to squeeze out significant additional energy savings through commissioning. We highly recommend a robust commissioning and M&V process to ensure that the full savings potential is realized.

References

Enercov. 2004. *Products Catalog.* Enercov.com. www.enercov.com/cuh2.html

McVey, E. 2018. "Chart: Declines in Wholesale Prices Hammer Major Recreational Cannabis Markets." Marijuana Business Daily, October 29. www.mjbizdaily.com/chart-declines-in-wholesale-prices-hammer-major-recreational-cannabis-markets/

Measure 91 (Control, Regulation, and Taxation of Marijuana and Industrial Hemp Act). 2014. Accessed February. www.oregon.gov/olcc/marijuana/Documents/Measure91.pdf

Milton, S. 2018. "Recent Cannabis Regulations Take Energy Efficiency to a Higher Level." Climate Action Business Association. March 7. cabaus.org/2018/03/07/recent-cannabis-regulations-take-energy-efficiency-higher-level/

OLCC (Oregon Liquor Control Commission). 2019. *Marijuana Business Licenses Approved as of 2/1/2019.* www.oregon.gov/olcc/marijuana/Documents/MarijuanaLicenses_approved.pdf