A Budding Opportunity: Energy efficiency best practices for cannabis grow operations

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December 2017

SWEEP
SOUTHWEST ENERGY EFFICIENCY PROJECT

Acknowledgements

We would like to thank the following people for the information and data they provided, and for providing comments on drafts of the report:

Amanda Potter, Energy Trust of Oregon

Peter Meyer, Tacoma Power

David Montgomery, Puget Sound Energy

Brandy Keen, Surna

Jacob Policzer, Cannabis Conservancy

We would also like to thank Frederica Kolwey, freelance environmental journalist, for writing the "Challenges for Greenhouses in Colorado" section.

About SWEEP

The Southwest Energy Efficiency Project is a public interest organization dedicated to advancing energy efficiency in Arizona, Colorado, Nevada, New Mexico, Utah and Wyoming. For more information, visit www.swenergy.org.

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Executive Summary

Cannabis cultivation is an energy-intensive sector: energy consumption per square foot for indoor grow operations is about ten times that of a typical office building. In states with legalized recreational marijuana (such as Colorado and Nevada), the sector is also growing very rapidly. Utilities can help offset some of this growing energy demand by proactively engaging with cannabis grow operations, and by offering good-quality technical assistance, especially during the design and initial construction phase. In addition utilities can offer incentives to help offset the higher cost of more energy-efficient equipment. Three utilities/energy efficiency program administrators in the Northwest – Energy Trust of Oregon, Puget Sound Energy, and Tacoma Power -- have achieved significant energy savings through assistance provided to the cannabis sector.

For indoor grow operations, LED lighting fixtures are being successfully applied to vegetative rooms, saving up to 50% of the lighting energy compared to the standard practice. For flower rooms, double-ended, high-pressure sodium (HPS) fixtures save 20-25% compared to the standard HPS fixtures. While less common, some growers are successfully applying LED fixtures or LED/HPS hybrid designs for up to 30-40% energy savings in flower rooms. For cooling and dehumidification, smaller grow operations are saving energy by using split ductless air conditioning units in place of standard rooftop units. Medium- and large-sized grow operations are using chilled water systems to accomplish both cooling and dehumidification, with energy savings of up to 40% compared to the standard practice. By implementing all these best practices, a medium-size or larger indoor grow operation can achieve up to 30-35% energy savings compared to a standard indoor grow.

Greenhouse grow operations typically save 60-75% of the energy needed per pound of flower compared to indoor grow facilities. Generally, the decision to set up a greenhouse vs. an indoor grow facility involves many factors, and utilities may not have a lot of influence. However, local governments can encourage more greenhouse grow operations through their permitting processes.

Cannabis Challenges and Opportunities

Eight states have now legalized the consumption of recreational marijuana, including Colorado and Nevada in the Southwest region, and 28 states, including Arizona and New Mexico, allow medicinal marijuana use.[1] So far, most of this marijuana is grown indoors, with high intensities of energy consumption. For example, Colorado has more than 1,300 registered cannabis cultivators, and 75% of the grow operations are indoors (the rest are greenhouses and outdoor cannabis farms).[2] These cannabis grow operations consume a total of about 300 gigawatt-hours (GWh) of electricity per year, which is about 0.6% of Colorado's total electricity consumption.[3] In addition marijuana production in Colorado continues to expand. For example, from May 2016 to April 2017, production increased by an average of 3% per month.[4]

However, there are numerous opportunities to grow cannabis more efficiently. And there are good reasons for utilities to be proactive with the cannabis sector, such as: to prevent possible overloading of distribution systems in areas with multiple grow operations, to help the utilities achieve their energy-savings goals, and to help the growers lower their utility bills.

This paper focuses on recommendations for utility programs serving the cannabis sector and highlights the best practices of some of the leading programs. We first highlight and describe the main energy efficiency opportunities for grow operations, which may be useful to cannabis businesses and their consultants, as well as being helpful to utility programs serving these customers.

Cannabis Energy Needs

Growing good-quality marijuana and maximizing the amount of production (per square foot of space and per year) requires a great deal of energy. The total energy costs for indoor cannabis grow operations typically varies between 20-50% of total operating costs.[5] By comparison, for a typical medium-size or larger brewery, energy use accounts for about 6-12% of total operating costs.[6] Indoor grows consume up to ~150 kilowatt-hours of electricity per year per square foot, which is about 10 times as much as a typical office building in the Southwest.[7] Why does growing marijuana require so much energy?

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[1] All eight states with legalized recreational marijuana also allow medical marijuana sales.
[2] "Colorado Cannabis Grow Operations: Data and best practices," Colorado Energy Office, forthcoming.
[3] This is an estimate based on assuming an average of 1,200 kilowatt-hours of electricity per pound of flower produced, based on data from "Colorado Cannabis Grow Operations: Data and best practices," Colorado Energy Office, forthcoming, and from Jacob Policzer, President, Cannabis Conservancy, personal communication, April 20, 2017, Jacob@cannabisconservancy.com. Colorado's total electricity consumption in 2016 was 52.2 million MWh, from "2016 Utility Bundled Retail Sales – Total," https://www.eia.gov/electricity/data.php#sales.
[4] Jacob Policzer, President, Cannabis Conservancy, personal communication, April 20, 2017, Jacob@cannabisconservancy.com.
[5] "Trends and Observations of Energy Use in the Cannabis Industry," Jesse Remillard and Nick Collins, ERS, ACEEE Summer Study of Energy Efficiency in Industry, 2017.
[6] Julie Smith, Energy Manager, MillerCoors Golden Brewery, personal communication, November 8, 2017.
[7] "A Chronic Problem: Taming Energy Costs and Impacts of Marijuana Cultivation," KellyCrandall, EQ Research LLC,

Several factors contribute to this intense energy use, starting with the plants' temperature, humidity control, and intense lighting needs. Marijuana cultivation involves three main stages: the seedling stage, the vegetative stage, and the flowering stage, all of which take place in different rooms. The vegetative and flower stages consume most of the energy. (The typical desired room conditions for grow operations are shown in **Table 1**.) In addition to controlling the temperature and humidity, most indoor grow operations inject CO_2 into the vegetative and flower rooms during lights-on periods to increase the rate of plant growth and flower production.

Table 1 – Optimal Grow Room Conditions

Type of room/stage	Temperature (degrees F)	Relative humidity[8]	Hours per day of lighting	Duration of stage
Seedling	70-85	70-80%	18-24	3-10 days
Vegetative	70-85	60-70%	18-24	4-8 weeks
Flower	70-85	40-60%	12	6–10 weeks

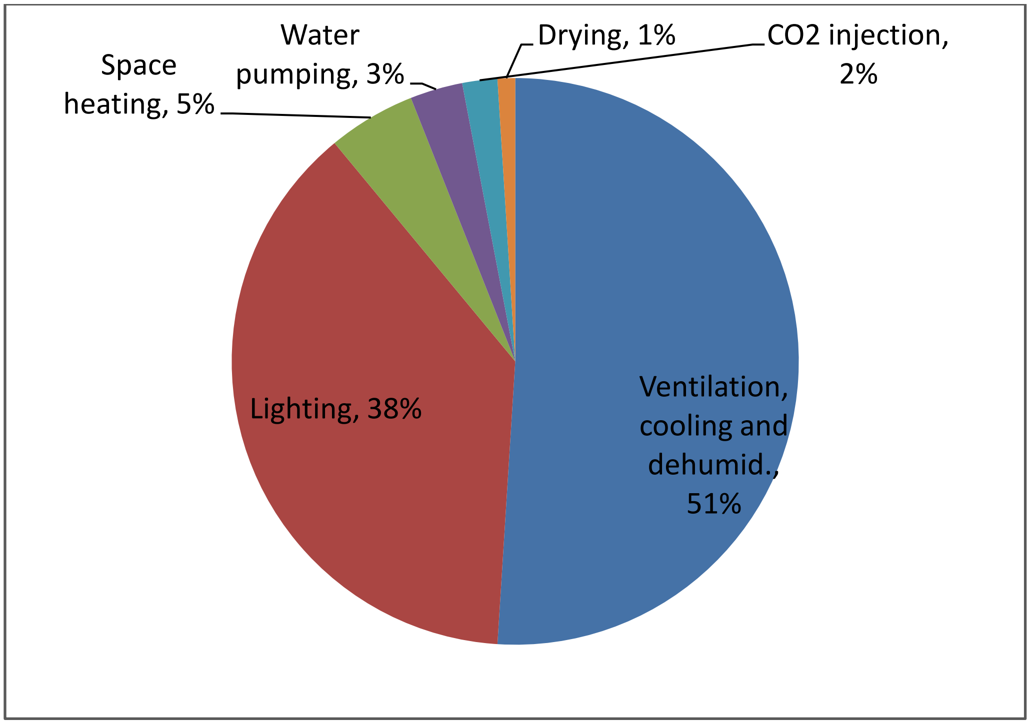
Figure 1 provides a breakdown of energy consumption for a typical indoor grow operation. As shown, most of the energy is consumed by cooling, dehumidification and ventilation (51%), and lighting (38%). In addition to the humidity control and lighting needs of indoor cannabis growing, the nature of the market has not been conducive to energy-efficient practices. When marijuana is first legalized in a state, new entrepreneurs tend to rush into the market. Rather than taking the time to carefully plan a grow operation to use energy efficiently, most new operations (especially the smaller- and medium-size ones) start out by leasing empty warehouse space and setting up the equipment using a "quick and dirty" approach, that is, by using simple, trusted technologies with low-initial equipment cost. As a result, they miss many energy efficiency opportunities in the areas of lighting, cooling, and dehumidification.

In general, the best time to take advantage of energy efficiency opportunities is during the "new construction" phase, meaning the time of designing, acquiring, and installing the equipment to transform an empty warehouse into a new grow operation. Although many grow operations already have missed this chance, many new grow operations are just getting started and could embrace best practices from the beginning. Although less common, existing grow operations can also find opportunities to perform cost-effective upgrades. (See lighting case study below.)

September 2016, http://eq-research.com/wp-content/uploads/2016/09/A-Chronic-Problem.pdf, p. 5; EIA Commercial Buildings Energy Consumption Survey, Table C20 Electricity consumption and conditional energy intensity by climate region, 2012, https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c20.php.

[8] "Ideal Humidity Level for Cannabis," https://www.zativo.com/growing-conditions-cannabis/ideal-humidity-level; and Cervantes, Jorge, "The Cannabis Encyclopedia," Van Patten Publishing, 2015, p. 234.

Figure 1 – Energy Use Breakdown for a Typical Indoor Cannabis Grow[9]



Lighting Opportunities

To achieve "optimal" plant growth and flower production, indoor grow operations use intensive lighting. The two most energy-intensive phases are the vegetative and flowering stages. As shown in Table 1, the vegetative rooms normally provide lighting 18-24 hours per day. The "standard" practice for vegetative rooms is to use 600 watts (W) of lighting for each 4-ft by 4-ft area of plants, using metal halide (MH) or high-intensity T5 fluorescent lighting fixtures.

In the vegetative stage, plants thrive with the red- and blue-dominated spectrum provided with MH fixtures, while in the flowering stage cannabis plants prefer the more yellowish frequencies of the spectrum and more intensive lighting. For these reasons, for the flowering rooms the standard practice is 1000 W of lighting for each 4-ft by 4-ft area, using high pressure sodium (HPS) fixtures. Flowering rooms are only lit for 12 hours per day, which is essential for stimulating the plants to produce flower (imitating the amount of sunlight the plants would get in the autumn if grown outdoors). The flowering stage generally takes about 6-10 weeks, compared to 4-8 weeks for vegetative growth.

For the vegetative rooms, LED lighting has been demonstrated to be very effective. A 300 W LED fixture can replace a 600 W metal halide or T5 fluorescent fixture, saving about 50% of the lighting energy required, while still providing equivalent lighting levels. However, a 300 W LED fixture also costs about

[9] "Trends and Observations of Energy Use in the Cannabis Industry," Jesse Remillard and Nick Collins, ERS, ACEEE Summer Study of Energy Efficiency in Industry, 2017.

four times as much as a 600 W metal halide fixture.[10] Nonetheless, the use of LED lighting for vegetative rooms is definitely increasing, due to the continued improvement in the quality of LED lighting, declining costs, and incentives from utility programs. In addition, growers are taking fewer risks to their production or product quality by switching to LEDs in vegetative rooms compared to flower rooms. (See case study below.) LEDs have not yet become the accepted standard practice for vegetative rooms, but will continue to become more popular through continued support from utility programs and other entities.

What are equivalent lighting levels?

Many LED lighting vendors (and some utilities and grow operations) are getting more sophisticated. Whereas *lumens* is the unit of measure for the amount of visible light produced by a light source, plants respond to other wavelengths outside the range visible to human eyes. The "lumens are for humans" slogan helps explain that plants don't see lighting levels as humans do; what matters to them is the amount of photons delivered to the plants in the photosynthetically active radiation (PAR) spectrum. So rather than using lumens, lighting fixtures for horticulture are rated in terms of their output of *photosynthetic photon flux* (PPF), measured in micro-moles per second.

Lighting fixtures are also compared in terms of *photon efficiency*, which refers to how efficiently lamps turn energy into usable light for plants and is measured in units of micromoles per kWh or micromoles per Joule.

The intensity of the light reaching a plant is measured using "photosynthetic photon flux density" (PPF density), measured in micro-moles per second per square meter. The PPF density (how many photons per second that actually reach the plants) can be measured with the proper light meter. A "lower tech" way to evaluate "equivalent lighting levels" is to perform side-by-side trials of different lighting fixtures and see how the plants respond. This technique takes longer, but avoids the challenges of trusting the manufacturers' data, obtaining the right equipment, and performing the measurements correctly.

For flowering rooms, growers have two main options for improving efficiency. They can replace the standard 1,000 W HPS fixture with a 750 W or 800 W double-ended HPS fixture to achieve 20-25% energy savings, but the double-ended HPS fixture costs about twice as much. (See **Table 2**.) The best

[10] "Trends and Observations of Energy Use in the Cannabis Industry," Jesse Remillard and Nick Collins, op. cit.

double-ended HPS fixtures also have a high photon efficiency of about 1.7 micromoles per Joule, which is as efficient as the best LED fixtures, while the standard single-ended HPS fixtures have a photon efficiency of only about 1.0 micromoles per Joule.[11] Double-ended HPS fixtures also last longer, maintaining 90% of their output at 10,000 hours of use, compared to a typical life for single-ended HPS of only 6,000 hours.[12] Because of these advantages, double-ended HPS is generally regarded as the best practice for flower rooms.

"Competing lighting vendors and growers continue to discuss the real energy savings and cost-effectiveness of LEDs vs. double-ended HPS in flowering rooms."

The second energy-efficient option is to use LEDs in place of HPS, or some combination of LED and HPS. LEDS offer several potential benefits. LEDs generate less heat, and also the driver and fixture can direct the heat away from the plants, while HPS and their fixtures tend to direct the heat towards the plants, requiring more distance between the lamp and plant canopy. Since LED fixtures give off less heat, they can be mounted closer to the plant canopy, effectively increasing their PPF density. However, depending on the LED fixture design, lowering the mounting height may result in less area of canopy coverage. To provide the same canopy coverage may therefore mean that a greater number of LED fixtures are needed.[13] In addition LED fixtures are much more expensive than double-ended HPS fixtures, as shown in **Table 2**. So, competing lighting vendors and growers continue to discuss the real energy savings and cost-effectiveness of LEDs vs. double-ended HPS in flowering rooms.

In the meantime, LED products continue to improve; for example, newer products include more of the full spectrum of light rather than over-focusing on the red and blue wavelengths as the earlier LED products did. It is possible that LEDs will become the accepted best practice for flowering rooms within the next several years.

LED Lighting Case Study. Yerba Buena, a cannabis grow operation in Oregon, replaced 1,270 59-watt T5 fluorescent tubes in its vegetative room with the same number of 28-watt LED tubes. The grower was able to use the same fixtures and ballasts. The switch to LED lighting saves Yerba Buena 259,000 kilowatt-hours of electricity annually. Rick McClish, co-owner of Yerba Buena, commented, "with LED lights, our vegetative output is equivalent, and we reduced our energy costs by $22,000 a year. We're also saving on maintenance costs because LEDs have a longer life. And LED tubes generate considerably less heat, which in turn reduces our dependency on mechanical cooling." The project cost was $29,900,

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[11] Nelson and Bugbee, "Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures," Utah State University, published in PLOS One, June 2014, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0099010.

[12] "Why are Double-Ended High Pressure Sodium Bulbs Better than Single-Ended?" High Times, May 2016, http://hightimes.com/grow/grow-gear/why-are-double-ended-high-pressure-sodium-bulbs-better-than-single-ended/

[13] "Trends and Observations of Energy Use in the Cannabis Industry," Jesse Remillard and Nick Collins, op. cit.

and Yerba Buena received an incentive from the Energy Trust of Oregon of $15,000, which brought the project payback period down to only 9 months.[14]

Table 2 – Comparison of Lighting Options for Vegetative and Flower Rooms

Stage	Standard fixture	Photon efficiency (micro-moles/J)[15]	Fixture cost[16]	Efficient replace-ment	Photon efficiency (micro-moles/J)[17]	Fixture cost	Annual energy savings (kWh)[18]	Payback period[19] (yr) for: a) incremental cost at new construction;	b) retrofit
Vegetative	600 W metal halide	NA	$200	300 W LED	1.7	$850	2600	2.6	3.4
Flowering -1	1000 W std HPS	1.0	$250	750 W DE HPS	1.7	$500	1440	1.8	3.6
Flowering -2*	1000 W std HPS	1.0	$250	600 W LED	1.7	$1,300	2300	4.8	5.9

* This option is more controversial; success depends on specific LED products and lighting design.

Cooling and Dehumidification Opportunities

Growers face challenges in achieving the room conditions shown in Table 2 year-round, and in controlling humidity consistently during periods with lights on as well as with lights off. For a small or medium-sized indoor grow operation, the "standard practice" (if there is one) is to install one or several rooftop heating, ventilation and air conditioning (HVAC) units, and portable in-room dehumidifiers for the flower rooms. (See **Figure 2** below.) The rooftop HVAC units are typically designed and operated to minimize the use of outdoor air, in order to avoid the introduction of contaminants such as fungus, mildew, etc.; to minimize odor complaints from neighbors; and to maintain the enriched CO_2 levels used by most grow operations. Dehumidifiers are needed mainly for the flower rooms. Rooftop HVAC units are typically not designed to handle a significant latent heat load (the cooling required to remove excess

[14] "LEDs in Yerba Buena's Vegetative Room Deliver a 9-Month Payback," Energy Trust of Oregon, January 2017, https://blog.energytrust.org/leds-yerba-buenas-vegetative-room-deliver-9-month-payback/

[15] Nelson and Bugbee, "Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures," Utah State University, published in PLOS One, June 2014, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0099010

[16] "Trends and Observations," op. cit. Fixture costs shown are the average of the range shown in the paper. We assumed the same cost for a 750 W DE HPS fixture as the authors' shown costs for a 1,000 W DE HPS fixture.

[17] Nelson and Bugbee, op. cit.

[18] "Trends and Observations," op.cit. Annual energy savings includes cooling savings, and assumes 18 hours per day of lighting for vegetative and 12 hours per day of lighting for flower rooms. The energy savings shown assume that the fixtures require the same wattage as that shown (with no losses from the ballast).

[19] Assumes a bundled retail commercial electricity rate of $.096/kWh, the average commercial retail rate for Colorado from "2016 Utility Bundled Retail Sales – Commercial, https://www.eia.gov/electricity/data.php#sales.

moisture from the plants' transpiration), even during lights-on periods. And flower rooms have very low sensible-heat ratios during lights-off periods, when the plants continue to transpire without any sensible cooling load from lighting.[20]

Compared to the standard practice, there are many opportunities for improved energy efficiency in the design and operation of dehumidification and cooling systems. As is true for lighting opportunities, these make much more economic sense at the time of initial construction of a new grow operation.

Design for vapor pressure deficit rather than relative humidity. For design of the cooling and dehumidification system(s), which applies to all of the options discussed below (as well as the standard system), understanding the importance of vapor pressure deficit (VPD) can save grow operations up-front capital costs as well as save energy.

Healthy plants transfer moisture and nutrients from their roots for photosynthesis and growth. They transpire excess moisture through the leaves' stomata, which also helps cool the leaves. The vapor pressure deficit (VPD) is the difference between the leave's internal vapor pressure and that of the air surrounding the leaves. The VPD determines the rate of transpiration, and VPD increases with higher room temperatures and with lower relative humidity. If the VPD is too low, condensation may occur on the leaves or buds, which can lead to fungus or mildew problems. If the VPD is too high, then the plants may become too dry or heat stressed.

Many growers try to limit the relative humidity of vegetative rooms to 70 percent, and of flower rooms to a maximum of 50 percent. But this approach does not take into account the temperature. By allowing a slightly higher room temperature such as 80-85 degrees Fahrenheit (F) rather than 75 degrees F, and by considering the VPD, the HVAC system (including cooling and dehumidification) can be sized at a smaller capacity, reducing the grower's up-front equipment costs. In addition the system's energy consumption will be significantly lower. For example, for a flower room temperature of 75 F, a relative humidity of no more than 48% is needed in order to achieve a VPD of 1.2 kilo-Pascals (kPa) (an acceptable level for the flowering stage). But if the room temperature is increased to 82 degrees F (still within the acceptable range), a relative humidity of 57% will achieve the same VPD.[21] Allowing this higher temperature and relative humidity during lights-on periods will significantly lower the cooling and

[20] The sensible heat load is the energy required to cool the space to the desired temperature. The latent heat load is the energy required to control humidity by removing excess moisture from the air. The sensible heat ratio is the ratio of the sensible heat load to the combined/total sensible and latent loads.

[21] "Vapor Pressure Deficit – The Hidden Force on Your Plants," http://www.just4growers.com/stream/temperature-humidity-and-c02/vapor-pressure-deficit-the-hidden-force-on-your-plants.aspx.

Figure 2 – Typical Flower Room Set-up

Note the yellowish high pressure sodium lights, and the portable dehumidifier at the end of the aisle.

dehumidification energy consumption, compared to the 75 degrees F case, without affecting quality of flower development. However, even though the VPD is the crucial parameter for maintaining healthy plants, the relative humidity of flower rooms should be kept below a maximum of 60% to prevent fungus and mildew from growing elsewhere in the room (e.g., on the walls).[22]

During lights-off periods, the room temperature should not be allowed to go below 68 to 70 degrees F, which some growers are tempted to do in order to reduce any supplemental heating needs. However, temperatures lower than 68 degrees F make the requirements for humidity control very difficult, and will actually consume more energy than the energy that would be saved from less required heating.[23]

<u>High-efficiency split ductless air conditioning/heat pump units.</u> This option mainly applies to smaller grow operations, up to about 4,000 – 6,000 square feet of canopy. (Above this size, chilled water systems or rooftop air conditioning systems with modulating hot gas reheat will save more energy and become cost-effective, as discussed in more detail below.) Although separate dehumidification units will still be required (as is the case with rooftop air conditioning units), there is some consensus among experts that using multiple split units will be more efficient and cost-effective for the smaller grow operations than using rooftop units.[24] There are high-efficiency split ductless heat pump/air conditioning systems available with seasonal energy efficiency ratings (SEER) of 25 or higher, compared to rooftop HVAC units with typical SEERs of 14-15.[25] In addition, by their design the split air conditioning units use much less fan energy compared to rooftop units.

"There are high-efficiency split ductless heat pump/air conditioning systems available with seasonal energy efficiency ratings (SEER) of 25 or higher."

These units are referred to as split systems because they include an outdoor unit (condenser, if in cooling mode) and indoor unit (evaporator), connected only by the refrigerant line. By comparison, in a standard rooftop air conditioning unit, the condenser, evaporator, and air handler are all contained in one integrated unit. The split air conditioning units are generally small in capacity (e.g., 3-5 tons of cooling capacity per unit for commercial units). Multiple units can be installed cost-effectively to provide the needed cooling (or heating if necessary) for a smaller operation. These units are also very efficient in the heating mode (down to outside temperatures of about 20 degrees F), saving energy in cooler climates (such as in Colorado). Heating will typically not be required for grow operations in Nevada or Arizona. (See case study on p. 9.)

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[22] Brandy Keen, Co-Founder, Senior Technical Advisor, Surna, personal communication (October 26, 2017), brandy.keen@surna.com.
[23] Ibid.
[24] Bryan Jungers, Lead Analyst – Technology Assessment, E Source, personal communication (September 26, 2017), bryan_jungers@esource.com; Brandy Keen, personal communication (October 17, 2017); Jack Zeiger, Energy Conservation Engineer, Tacoma Power, personal communication (August 10, 2017), Jzeiger@ci.tacoma.wa.us.
[25] Jack Zeiger, op. cit. The seasonal energy efficiency rating (SEER) of a heat pump or air-conditioning unit is the cooling energy output (in thousand Btu's) during a typical cooling-season divided by the total electric energy input (in kilowatt-hours) during the same period. The higher the unit's SEER rating, the more energy efficient it is.

Separate efficient dehumidification. A simple improvement to the portable dehumidifiers that are standard practice for smaller grows is to use a more efficient commercial dehumidifier, which can be 15% more efficient than a standard model. The energy efficiency of dehumidifiers can be compared in terms of pints of water removed per kilowatt-hour (kWh). (Note that it is important to compare dehumidifier performance curves at the same temperature and relative humidity.) However, even with a more efficient unit, the dehumidifier will still reject heat into the room, increasing the cooling load during lights-on periods.

Growers can save even more energy by choosing a "premium efficiency" dehumidifier, with a different reheat system. There are two types of dehumidifiers that fall into this category that are significantly more efficient than conventional refrigerant-based dehumidifiers; however, they are also more expensive.

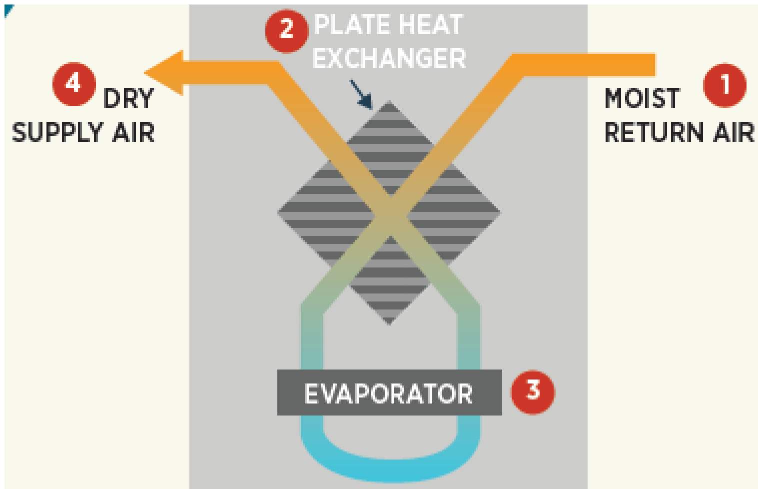
The first type incorporates a plate air-to-air heat exchanger to accomplish the reheat from the evaporative system using incoming air, which also serves the purpose of pre-cooling the incoming air before it enters the cooling coil. (See **Figure 3** below.)

The Western Cooling and Efficiency Center (WCEC) performed laboratory testing and computer modeling of the MSP Technology dehumidification system to estimate the annual energy savings, working with Xcel Energy in Colorado. WCEC found that this type of dehumidifier saves 30-65% of the energy consumed by conventional commercial dehumidifiers, while allowing 100% of the water removed from the air to be reused. According to this study, the percentage of energy savings is lower with higher latent cooling loads (more plants per square foot and more watering), when both types of dehumidifiers consume more energy.[26]

A second type of "premium" efficiency dehumidifier is a hybrid desiccant and evaporative system, such as the technology sold by Novelaire. The desiccant dehumidification system reduces the size and energy consumption of the unit's evaporative cooling system. The combination of refrigerant-based cooling with the desiccant rotor avoids overcooling and eliminates the need for reheat, saving energy during lights-on periods. Heat from the condenser is used to regenerate the desiccant, which eliminates the need for any external energy for this purpose, unlike other desiccant systems. (See diagram at https://www.novelaire.com/dehumidifiers/commercial/recirculating.html.) We are not aware of any independent testing, but Novelaire estimates that this type of system saves 30-50% of the energy consumed by conventional commercial dehumidifiers.[27]

[26] "Laboratory Testing of an Energy Efficiency Dehumidifier for Indoor Farms," Western Cooling Efficiency Center – University of California - Davis, http://wcec.ucdavis.edu/wp-content/uploads/2016/11/MSP_XCEL-Case-Study.pdf.
[27] Adrian Giovenco, Sales Engineer, InSpire Transpiration Solutions, personal communication, (September 14, 2017), agiovenco@transpiration.solutions.

Figure 3 – MSP Technology Dehumidifier



Caption: Warm, humid return air (1) enters the heat exchanger (2) where it is pre-cooled by contacting the cooler air leaving the evaporator. The pre-cooled incoming air is then cooled and dehumidified through passing twice over the evaporator cooling coils (3). Then the cool, dry air is drawn through the heat exchanger where it is reheated through absorbing some heat from the incoming air, and supplied to the room (4) with no additional energy input.[28]

Chilled water systems. A well-designed chilled water system offers several energy-savings advantages, compared to the standard or split air conditioning systems with separate dehumidifiers described above. Chilled water systems become cost-effective for grow operations with more than about 4,000 – 6,000 square feet of canopy.[29]

As mentioned above, standard rooftop air conditioning units are not designed to provide much latent heat removal, and the adjustments available to increase the system's latent heat capabilities are limited. With a chilled water system, one can slow the fan speed and/or reduce the water temperature to achieve more latent heat removal. Thus, with a few modifications, a relatively simple chilled water system can achieve humidity control during lights-on periods without a separate dehumidifier. As noted above, portable dehumidifiers add heat to the space, which adds to the cooling load during lights-on periods.

During lights-off periods, it is challenging to meet the requirements of the very low sensible heat-ratios. (With lights-off, there is very little sensible load, but there is still a latent load as the plants continue to

[28] "Cannabis Climate Solutions," MSP Technology, http://www.msptechnology.com/wp-content/uploads/2016/03/CCSBrochure-f.pdf. Actually, the supply air temperature is limited (by the input air conditions) and cannot be adjusted, which means that some additional heating energy (a smaller amount compared to a conventional dehumidifier) may be required in order to maintain the desired room temperature.

[29] Brandy Keen, op. cit.; Bryan Jungers, Lead Analyst, E Source, personal communication (November 7, 2017). According to Ms. Keen, above about 4,000 ft2 of canopy, the installed cost of a chilled water system will be about the same as that of a rooftop system with separate dehumidifiers. Mr. Jungers feels that the size of grow operation for which a chilled water system becomes cost-effective may be slightly larger than this (such as 6,000 ft2 of canopy or more), depending on the grow operation's lighting system design, local climate, and electricity prices.

transpire.) So with a simple chilled water system, separate dehumidifiers are still needed to control humidity during the lights-off periods. However, during lights-off periods (with a greatly reduced need for sensible cooling), the dehumidifiers' rejection of heat into the rooms generally does not add to the cooling load.

If the grow operators are willing to handle slightly more complexity, the chilled water system can be designed to accomplish the additional latent heat removal needed during lights-off periods. As the chilled water system removes humidity during lights-off periods, the space will need to be reheated to maintain the desired room temperature. The chilled water system can be designed to perform the needed reheat by using recovered heat from the system's condenser coil. (The cooled and dehumidified air is then reheated through a heat exchanger with the water heated from the condenser.) With heat recovery and a few other operating adjustments, the chilled water system can thus avoid the need for separate portable dehumidifiers for controlling humidity during lights-off periods.

Another advantage chilled water has over standard rooftop systems is that chilled water systems can be designed to allow water-side economizing, which means taking advantage of "free cooling" of the water using outdoor air, rather than the refrigerant-based water chiller, when the outdoor temperature is low enough. This process can achieve significant energy savings in cooler climates such as in Colorado. There are several reasons why economizing is more challenging with a rooftop/forced air system - the use of outdoor air wastes or dilutes the enhanced CO_2, and can lead to odor complaints.

A well-designed chilled water system with hot gas reheat/heat recovery and water-side economizing can save up to 30-40% of the total energy needed for cooling and dehumidification, compared to the standard system of rooftop units and portable dehumidifiers.[30]

<u>Modulating hot-gas reheat forced-air systems.</u> Another option that offers significant energy-saving potential is a modulating hot-gas reheat forced-air system. There are a few manufacturers of this type of system, including Desert Aire. These systems are more complex rooftop air conditioning systems with hot-gas reheat capability. Similar to the heat recovery described above for the chilled water system, this technology adds an additional condenser coil for reheat when needed. Compared to a standard dehumidifier (which has a cooling coil and a condenser coil which reheats the cooled and dehumidified air), this system adds an additional outdoor condensing coil in parallel with the reheat coil. This third coil and the associated controls allow the system to reject heat to the outdoors when cooling is required in the space, or to use the other condenser coil for reheat when there are minimal sensible cooling needs (during lights-off periods).

This promising design allows one system to be used for both cooling and dehumidification, while achieving good humidity control over a wide range of sensible heat ratios, with much higher efficiency and better humidity control than typical rooftop AC systems. We are not aware of independent testing or any available case studies for this type of system, but Desert Aire estimates potential savings of up to 34% with this type of system compared to the standard rooftop system with separate in-room

[30] Brandy Keen, op cit.

dehumidifiers.[31] However, modulating hot-gas reheat systems are only cost-effective for grow operations with more than about 14,000 square feet of canopy.[32]

Energy Management

In addition to installing more efficient equipment (lighting, cooling, or dehumidification systems), cannabis growers can control their energy costs and optimize energy performance by developing more comprehensive energy management programs. Energy management includes managing overall energy costs and reducing energy consumption through improved efficiency.

> ***"A best practice for energy management would be to track a metric such as total electricity consumption (kWh) per pound of flower."***

One way to reduce energy costs is to manage the facility's peak electrical demand. Most cannabis grow operations are large enough that their electric rates include demand charges, which are based on the maximum 15-minute peak demand (measured in kilowatts (kW)) each month. These monthly demand charges can be as much as the energy charges based on kilowatt-hours (kWh) of energy consumed during the month. To manage peak demand, facilities can install a more sophisticated electric meter (on the customer's side of the utility meter), which can provide data instantaneously (in "real-time") on the facility's fluctuating demand (in kW) as well as the facility's energy consumption (in kWh). A good meter with this capability can be purchased and installed for about $1,000-$1,500.[33] Armed with this data, facilities can see more clearly how to stagger the lights-on periods of flower and vegetative rooms, and how to manage the start-up times of other major equipment. Managing the facility's peak demand in this way can result in significant monthly energy bill savings.

Another aspect of good energy management is to develop a set of metrics for measuring and tracking energy performance over time. Most cannabis grow operations do not consistently track their energy costs or energy consumption along with production. But most grow operations do use a metric for production such as "pounds of flower per light," and achieving one or more pounds per light (in a given production cycle) is considered good or acceptable. ("Pounds per light" means pounds of flower produced per 4-ft.-by-4-ft. area typically lit by one lighting fixture.) A best practice for energy management would be to track a metric such as total electricity consumption (kWh) per pound of flower, in addition to pounds of flower per square foot (or per light).[34] Tracking this type of energy metric is a key first step towards encouraging facility managers and employees to pay more attention to energy consumption, and is essential for measuring improvements in energy efficiency over time.

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[31] "Indoor Grow Room Energy Flow," Desert Aire white paper, July 2017, www.desert-aire.com.
[32] Keith Coursin, President, Desert Aire, personal communication, August 2, 2017, keith@desert-aire.com.
[33] Brody Wilson, Site Energy Coordinator, IBM, personal communication, Nov. 3, 2017. Another option is to buy a slightly cheaper meter (for approximately $750) and obtain interval data (including the demand data) from the utility for a monthly fee such as $75.
[34] Jacob Policzer, op. cit.

The next step in good proactive or "strategic" energy management is to set a three- to five-year goal for improving energy efficiency, and to develop a plan for achieving this goal. The goal-setting process would involve identifying possible ways to reduce energy consumption, such as the opportunities mentioned above, and deciding which ones are feasible. Based on the possible energy efficiency improvements identified, and a baseline year measurement of kWh per pound of flower, the facility could then develop a percentage improvement goal over a multi-year period, as well as a plan for implementing new energy efficiency projects to achieve the goal.

Summary of Energy Savings Potential for Indoor Grows

For a medium-size (e.g., 10,000 ft^2 of canopy or larger) new indoor grow operation, what would be the total potential savings through implementing all of the opportunities listed above? For lighting, the facility could save up to 50% in the vegetative rooms through installing LEDs, and 25-30% in the flower rooms through a hybrid of HPS and LEDs, for total lighting savings of 35-40%. For cooling and dehumidification, the facility could save up to about 35% by installing a well-designed chilled water system. Using the approximate breakdown of total consumption shown in Figure 1, this would result in total potential savings of about 32% compared to a standard grow operation, as shown below. An indoor grow operation in Colorado, with 10,000 ft^2 of canopy and producing 3,000 lb of dried flower per year would save about 1,250 MWh per year by implementing all these energy-efficiency best practices.[35]

Total potential energy savings for indoor grows

Lighting: savings of 37% x 38% of total energy use = 14.1% energy savings

Cooling and dehumidification: savings of 35% x 51% of total energy use = 17.8% energy savings

Total = ~32% energy savings

Greenhouses

Greenhouses in Colorado save 60% to 75% of the energy required per pound of flower compared to typical indoor grow facilities.[36] This large reduction in energy consumption stems mostly from the reduced need for artificial lighting. As shown above, indoor grow operations require between 18 and 24 hours per day of artificial light during the vegetative stage, and 12 hours during the flowering stage. Greenhouses only require up to six hours per day of supplemental artificial lighting for the vegetative stage (depending on the geographic location), and may not require any supplemental lighting for the flowering stage. In addition greenhouses are typically designed for much more air circulation than an indoor grow, which allows greenhouses to use evaporative cooling systems, which save up to 75% of the energy needed compared to refrigerant-based cooling and dehumidification.

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[35] This assumes the standard indoor grow operation consumes about 1300 kWh/lb of flower, based on "Energy and Water Use for Marijuana Cultivation in Colorado," Colorado Energy Office, forthcoming.

[36] "Energy and Water Use for Marijuana Cultivation in Colorado," op. cit.

However, greenhouses' energy needs depend largely on the climate in which they are located. They work well in Colorado with its relatively mild climate, and present more challenges in very hot climates such as Arizona or southern Nevada.

> ***"Greenhouses in Colorado save 60% to 75% of the energy required per pound of flower compared to typical indoor grow facilities."***

Challenges for Greenhouses in Colorado

In 2016, Colorado sold more than $1 billion of legal marijuana. Seventy-five percent of Colorado's marijuana is grown indoors, and 20% is grown in greenhouses. Denver, which has most of Colorado's market for marijuana, currently has only one cannabis greenhouse.

As explained above, greenhouse grow operations use much less energy than indoor grow operations, so theoretically cannabis growers, already challenged with high energy costs and increasing competition, should be rushing to start more greenhouse grows. However, so far in Colorado, that hasn't been the case. Several factors inhibit cannabis growers from pursuing greenhouses.

In Denver, until recently it has mainly been a question of space. When marijuana was first legalized, the city had lots of empty warehouses left over from the 1960s and 1970s, so the infrastructure to support indoor grow operations already existed.[37] That wasn't the case for greenhouses.

Now some cannabis growers are becoming more interested in greenhouses, but investors are reluctant to fund greenhouse grows because they're not as versatile as warehouses. According to Jacob Policzer, President of the Cannabis Conservancy, "Investors are more willing to put up money to own a building that can be used for a multitude of purposes if the business fails, whereas a greenhouse can only be used for a few things."[38]

Even if growers can find and pay for a space to be used as a greenhouse, getting a greenhouse cannabis permit from the City and County of Denver can be very challenging. The permitting process for greenhouses is still in its infancy. Whereas city permits and inspections of warehouse spaces are very common, city officials are not as knowledgeable or comfortable with greenhouse grows. Because of this, Policzer feels that "permitting a greenhouse in Denver is going to be a very slow, methodical process with a lot of bumps along the road."[39]

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[37] Sammy Reifer, Research and Outreach Associate, Colorado Energy Office, personal communication, (July 26, 2017), Sammy.reifer@state.co.us.
[38] Jacob Policzer, personal communication, July 25, 2017.
[39] Jacob Policzer, personal communication, July 25, 2017.

Greenhouse grow operations are much more energy-efficient than indoor grows, but require growers to adjust their way of thinking.

Some of the reluctance to permit greenhouses might come from misconceptions about what greenhouses today actually look like. Modern greenhouses are solid-walled buildings with a special roof to allow light to enter. They do not pose the security risks that might make people wary, and they comply with Denver's requirement that cannabis grow facilities be contained in a "secure, fully-enclosed location."

On the other hand, building a new greenhouse may cost more than retrofitting a warehouse to grow marijuana. High start-up infrastructure costs become even more of a deterrent when combined with the risk involved in greenhouse operations. According to Policzer, "With an indoor grow, people have more control and have more confidence they'll have a successful first harvest. But it [shifting to a greenhouse] really is just a learning curve. If you can grow indoors, you can definitely grow good-quality marijuana in a greenhouse."[40]

The cannabis industry in general may be naturally moving toward more greenhouse cultivation. In Colorado, the shift will happen as local government officials becoming more familiar with the greenhouse permitting process. It is also likely that the majority of the state's greenhouses will develop in areas outside of urban centers, such as on the outskirts of Denver, Fort Collins or Pueblo. Increasing the number of permits for greenhouse grow operations could play a significant part in reducing the overall energy use (and associated greenhouse gas emissions) for producing cannabis in Colorado.

[40] Jacob Policzer, personal communication, July 25, 2017.

Utility Energy Efficiency Programs

What are utilities doing to serve cannabis grow operations? What are some best practices in this area? We found four utilities and an energy-efficiency organization, Energy Trust of Oregon[41] (who for the purpose of this report we will refer to as a "utility" going forward), with programs/efforts to help their cannabis-grow customers. These are highlighted in **Table 3**. These utilities are located in states with legalized recreational and medical marijuana. Other utilities in these states are also beginning to develop cannabis-targeted programs.

All of the utilities we spoke with agree that the best opportunity to influence energy efficiency projects is at the time of "new construction," meaning when the warehouse, abandoned manufacturing space, or other converted commercial building is leased and the cannabis entrepreneur is preparing to install new equipment to start the grow operation. Once an operation is up and running, it is much more difficult to affect any major changes in lighting or other equipment.

Technical assistance. As noted in the table, National Grid and Xcel Energy will pay for 75% of the cost of a study of energy-saving opportunities, and Energy Trust will pay for up to 100%, which has been a valuable tactic for reaching this market as it addresses growers' reluctance to fund energy studies out of pocket. National Grid encourages its cannabis customers to request a study of integrated lighting and HVAC options to capture the synergies of integrated design and potentially achieve greater energy savings. Tacoma Power provides technical assistance and free engineering-design review and analysis with the grow owners and their design team.

Puget Sound Energy (PSE) leaves it up to the growers and lighting or HVAC vendors to develop a proposal for more efficient equipment. Energy Trust uses this same approach for lighting proposals. This approach saves the utility money, but relies on the vendors and customers to be proactive in developing more efficient systems/designs. In addition, PSE and all the utilities above will perform a free analysis of the energy savings vs. the standard practice/design, and provide an estimate of incentives.

Incentives. As shown in the table, all of the above utilities offer incentives for more efficient lighting or HVAC systems. The utilities offer various incentive rates such as $0.25/kWh of first year savings, and all have limits on the total incentive amount as a percentage of the program's approved incremental cost of the more efficient alternative compared to the "standard" system or equipment. The incremental cost is the applicable metric for new construction projects, since we are talking about incentives for different alternatives for new equipment. For retrofit projects, which are less common, the applicable metric is the total cost of the retrofit project. Puget Sound Energy and Tacoma Power's incentives are the most generous, potentially covering up to 100% of the incremental cost of a more efficient system compared to a standard system.

[41] The Energy Trust of Oregon is a state-wide independent energy efficiency program administrator, which receives ratepayer funding collected by utilities in the state.

Table 3 – Utility Cannabis Energy Efficiency Programs

Utility	Technical Assistance	Incentives for new construction projects
Energy Trust of Oregon	Will pay for up to 100% of cost of custom non-lighting studies. For lighting technical support, Energy Trust will provide a free analysis of the savings compared to standard practice.	$0.25/kWh of first year savings, up to 50% of incremental cost of more efficient equipment.
National Grid - MA	Will pay for 75% of cost of study of HVAC, lighting, or integrated study.	Up to 75% of incremental cost of more efficient equipment.[42]
Puget Sound Energy - WA	If customer/vendor develops a proposal, then PSE will provide a free analysis of the savings compared to standard practice.	$0.20/kWh of first year savings, up to 100% of the incremental cost of more efficient equipment.
Tacoma Power - WA	Provides technical assistance and free design review to analyze energy savings compared to standard practice or the applicable energy code.	$0.20/kWh of first year savings, up to 100% of incremental cost.
Xcel Energy – CO	Will pay 75% of cost of study for HVAC or lighting. And will do free analysis of savings for a customer's proposal.	$400/kW of savings, up to 60% of incremental cost.

Projects. Of the five programs highlighted above, two utilities and the Energy Trust of Oregon were able to provide data on numbers of energy efficiency projects completed with estimates of energy savings. (See **Table 4**.) National Grid is just getting started and chose not to share any preliminary results of its cannabis efforts, and Xcel Energy told us they do not track energy savings specifically for the cannabis grow sector.

Of the lighting projects, most involve upgrades to LED lighting in the vegetative rooms. As discussed above, there is less risk (and less perceived risk) of affecting the rates of growth/maturity or product quality by switching to LEDs in the vegetative rooms vs. the flower rooms.

Another fairly common type of lighting project has been the use of lower-wattage, double-ended high pressure sodium (DE HPS) fixtures (e.g., 750 W or 800 W) for flower rooms in place of the standard 1,000 W single-ended HPS. DE HPS light fixtures cost about twice as much as single-ended HPS, so incentives that pay for most of the incremental cost are helpful in getting grow operations to make this choice. Energy Trust, Xcel Energy, and National Grid provide incentives for DE HPS lighting for flower rooms, but Puget Sound Energy and Tacoma Power only provide incentives for LEDs.

[42] National Grid negotiates the incentive rate with its customers, and would not specify the typical range.

Table 4 – Energy Efficiency Projects and Energy Savings

Utility/program	Number of Projects		Energy Savings[43]
	Lighting	HVAC	
Energy Trust of Oregon	55	0	7.8 GWh
Puget Sound Energy - WA	70	1	35-40 GWh
Tacoma Power - WA	1	4	1.3 GWh
Xcel Energy - CO	30	0	No data

A few of the above projects involve the use of LEDs in the flower rooms, or hybrid systems using LEDs combined with HPS. Energy Trust has analyzed HPS DE fixtures in hybrid systems in conjunction with LED, ceramic metal halide, or light-emitting plasma (LEP) lighting fixtures, and has found these projects have significant energy-saving potential. As LED products continue to improve, there will likely be more successful applications in flower rooms.

As shown in Table 4 above, only about 4% of the total projects (or 5 of the projects so far) involved HVAC or dehumidification. One of the challenges with providing incentives for HVAC projects is establishing the "baseline" with which to compare the more efficient alternative, since there is no clear "standard practice." For Tacoma Power, the largest project involved a central chiller with use of heat recovery from the condenser coil for reheat/dehumidification (as described above in the opportunities section). The project also included water-side economizing. This project saves about 1,000 MWh per year. Two other projects, both for smaller grow operations, involved high-efficiency, ductless split air conditioning systems. (See case study below.)

Split air conditioning system case study. A medium-size (6400 square feet) grow operation in Tacoma, Washington installed high-efficiency "split system" air conditioning units, rather than the standard code-compliant units, during its initial "construction" (set-up in an existing warehouse). The grow operation chose to install 12, 3-ton Daikin split air conditioning units with a SEER of 17.9, which was compared to units with the minimum efficiency (in the applicable building code) SEER of 13.0. Tacoma Power also commented that the customer's proposal could have been compared with a system involving rooftop air conditioning units, since that could also be considered standard practice, but the utility chose the more conservative and straightforward approach of comparing it to the same type of system with the minimum efficiency. (In this case, the split units are not set up to also provide heating, because the facility assumes that no heating of the grow rooms will be required.)

The initial cost of the high-efficiency air conditioning units was $5,340 more than the standard efficiency units; and the facility's utility, Tacoma Power, provided an incentive of $5,340 to cover 100% of the incremental cost. Tacoma Power estimated the annual energy savings to be 51,300 kWh, but post-

[43] Data from: Amanda Potter, Section Lead – Industry and Agriculture, Energy Trust, Amanda.potter@energytrust.org; Peter Meyer, Commercial-Industrial Conservation Manager, Tacoma Power, pmeyer@ci.tacoma.wa.us; David Montgomery, Business Energy Manager, Puget Sound Energy, david.montgomery@pse.com.

installation measurements show that the customer's actual energy consumption was much lower than expected (and energy savings were greater than expected).[44]

Clearly, there is a lot of potential HVAC savings that is not being captured by growers or energy efficiency programs. This is mainly because at least up until now, the grow operations have been less willing to take the time to understand the HVAC energy efficiency options available. However, this could be changing as grow operations become more interested in reducing their energy costs in order to stay competitive. The Energy Trust has recently completed several studies of more efficient HVAC systems. One study involves the use of energy recovery ventilation (ERV) systems, a type of air-to-air heat exchanger that allows economizing without introducing outside air into the grow rooms. While this system will require a non-traditional installation and some additional controls in order to properly condition the grow environment, Energy Trust estimated energy savings of 50% compared to a traditional ducted rooftop air conditioning and auxiliary dehumidifier system. Additionally, Energy Trust has completed multiple studies of modulating hot-gas reheat systems, with increased latent heat capacity as described above, eliminating the need for separate in-space dehumidification units.

"Clearly, there is a lot of potential HVAC savings not being captured by growers or energy efficiency programs."

National Grid has also studied a few projects involving the efficient dehumidifier technology described above that uses a heat exchanger to accomplish reheat without the need for an external energy source, and without adding additional heat into the space. National Grid commented that this technology seems very promising. With a separate, efficient dehumidification system, grow operations can size a smaller, more efficient cooling system to handle the sensible cooling load.

Summary and Recommendations

We summarize the opportunities for improved energy efficiency for cannabis grow operations in the next section. And we make several recommendations for utility programs that would like to better serve this important and expanding sector.

Summary of Energy Efficiency Opportunities

Cannabis grow operations have many cost-effective opportunities to save energy and reduce operating costs. These make the most business sense when implemented during initial set-up of a new grow operation, but opportunities also exist for cost-effective retrofit improvements.

Energy Management

- Install a more sophisticated meter that provides demand as well as usage data, and use it to manage peak demand, such as by alternating lights-on periods for flower and vegetative rooms.

[44] Jack Zeiger, Tacoma Power, personal communication, September 19, 2017, jzeiger@ci.tacoma.wa.us.

- Monitor total electricity consumption per pound of flower on a weekly or monthly basis, in addition to other metrics such as pounds of flower per square foot or per light.
- Set a goal to reduce energy consumption per pound of flower, develop and implement an action plan to meet the goal, and track progress towards the goal.

Lighting Opportunities

- Use LED lighting for vegetative rooms, which will save up to 50% of lighting energy compared to metal halide or fluorescent lighting.
- For flower rooms, install efficient double-ended, high-pressure sodium lighting fixtures.
- As LED products continue to improve, consider installing LEDs or LED/HPS hybrid systems in flower rooms.

Cooling and Dehumidification Opportunities

Here are some improvements over the standard rooftop air conditioning units with separate portable dehumidifiers.

- For small grows, install ductless split air conditioning/heat pump units, which provide cooling (or heating) more efficiently than rooftop HVAC units. These units still require separate dehumidifiers for the flower rooms.
- For medium-size grows, install a relatively simple chilled water system accompanied by dehumidifiers set up to operate only during lights-off periods.
- For other medium- and large-size grows with more sophistication, install a well-designed chilled-water system with heat recovery that can provide both cooling and dehumidification without separate dehumidifiers. Chilled-water systems can also be designed for water-side economizing for greater energy savings.
- Another option for the larger and more sophisticated grows is to install a rooftop system with modulating hot-gas reheat, to provide both cooling and dehumidification. This type of system can also be set up with energy recovery ventilation for greater energy savings.

Greenhouses

Greenhouses offer potential savings of 60-75% of total energy consumption compared to an indoor grow. Greenhouses take advantage of natural lighting and evaporative cooling. Greenhouses for cannabis require a change in thinking compared to indoor grows, but can achieve equal product quality with significantly lower operating costs.

Recommendations for Utility Programs

Utilities in states with legalized marijuana should be proactive with cannabis grows to avoid overloading of distribution systems, or paying for expensive system upgrades. In addition, utilities should be proactive in helping these customers save energy, in order to help the utilities achieve their energy-saving goals and to increase customer satisfaction. Here are some lessons from the leading utilities.

Technical Assistance

Grow operations need support to take advantage of the evolving energy efficiency best practices, and utilities can help encourage this by staying on top of new technologies and best practices, which most customers will not do on their own. In addition many grow operations are hesitant to trust equipment vendors, even those with good-quality products.

1. If utilities currently offer or co-fund energy efficiency studies for new construction (and retrofits) of commercial and/or industrial facilities, they should do the same for the cannabis sector. They should also hire knowledgeable contractors with expertise in cannabis production to provide these studies. (If they do not offer or co-fund such studies, they should consider providing this type of assistance for all commercial and industrial customers.)
2. Choose well-qualified contractors. For cooling and dehumidification, choose a contractor with expertise in mechanical systems for indoor agriculture/cannabis cultivation.[45]
3. Make it easy/user-friendly for customers to request a study of energy efficiency opportunities, and consider offering an integrated approach to looking at lighting and cooling/dehumidification opportunities at the same time, to capture the synergies.

"Utilities should not assume that cannabis growers and their consultants are familiar with utility energy efficiency programs and services. "

Incentives

Utilities typically provide prescriptive incentives for common energy efficiency measures and custom incentives for more complex or specialized measures, based on the estimated level of energy and/or peak demand savings. Most utilities already have custom incentive programs for commercial and industrial/agricultural customers. For new construction, if custom incentives do not already cover at least 75% of the incremental cost of more energy-efficient equipment, utilities should consider bringing incentives up to that level. If necessary, they can add contractors or provide training for utility staff on the improvements listed above, to make their evaluation and approval more user-friendly for cannabis sector customers.

For cannabis grow facilities, custom incentives should assume that the baseline system is either: a) the preliminary design proposed by the customer (if the customer has one), or b) the standard practice. For HVAC systems, the custom analysis should assume standard practice is the use of basic, code-required minimum efficiency rooftop HVAC units, with portable, in-room dehumidifiers for flower rooms. For lighting, the standard practices for vegetative and flower rooms are described above.

[45] There may be a need for more training of contractors in this area. In the meantime, there are three engineering firms we know of that specialize in mechanical systems for cannabis and indoor agriculture: Surna, Delta T Solutions, and Grow2Guys.

Marketing and Outreach

Utilities should not assume that cannabis growers and their consultants are familiar with utility energy efficiency programs and services. Therefore, utilities should proactively reach out to the cannabis sector to market the technical assistance and incentives being offered. Utilities should also consider coordinating with local governments to reach out to newly licensed grow operations, to help the growers make better, more efficient choices as they design their new operations.

Since cannabis grow operations can add a large, new load and potentially overload (or contribute to overload) of distribution system feeders, utilities should consider geo-targeting outreach. This outreach could be combined with technical assistance and incentives to cannabis producers and other customers on such feeders, in order to defer or possibly even eliminate the need for costly distribution system upgrades. This geo-targeting could include expanded marketing as well as higher incentive amounts for energy efficiency projects that reduce peak demand on the targeted feeders. Geo-targeting of DSM efforts in this manner has been successfully deployed by utilities in California, New York and a few other states,[46] and has been proposed by Xcel Energy in Colorado.

[46] C. Neme and J. Grevatt. 2015. *Energy Efficiency as a T&D Resource: Lessons from Recent U.S. Efforts to Use Geographically Targeted Efficiency Programs to Defer T&D Investments.* Report prepared by the Energy Futures Group for the Northeast Energy Efficiency Partnerships (NEEP). http://www.neep.org/sites/default/files/GeotargetingExecutiveSummary_Final%20%282%29_0.pdf