Trends and Observations of Energy Use in the Cannabis Industry

Jesse Remillard, PE, and Nick Collins, PE, ERS

ABSTRACT

With nine states presenting marijuana legalization measures in the 2016 election, the marijuana industry is poised to become one of the largest emerging industries in the indoor agricultural market. In recognition of the potential load growth associated with the expanding U.S. medicinal and recreational cannabis industry, this paper seeks to characterize the state of the market, including common industry practices, trends, and energy efficiency opportunities. To date, only limited research-based literature has been published on the energy consumption impacts of marijuana legalization and indoor cannabis growing. This paper seeks to build on previous investigations by presenting primary research that has been conducted on regional industry standard practices and measure costs. The authors have found LED grow lights, dehumidification, and space-conditioning end uses to be the primary energy efficiency opportunities available for the indoor cannabis industry. The authors will present an industry specific analysis of LED lighting energy savings, as well as the primary cost research for baseline and LED grow-light fixtures. The authors also conducted interviews with HVAC engineers specializing in indoor cannabis-growing operations and identified several energy savings opportunities.

Introduction

On November 8, 2016, four new states legalized cannabis for recreational use, and another three for medical use. This brought the total number of states with laws for the sale and use of recreational marijuana to eight, with another twenty-eight allowing it for medicinal use. The electrical load growth associated with new indoor grow operations because of this legislation is significant.

According to a recent study by Evergreen Economics, Seattle Light and Power estimates a 3% increase in overall electric demand as a result of legal cannabis production, and a utility interviewee from Colorado estimated that the total load growth for the state attributable to cannabis production since 2013 was between 0.5% and 1% (Evergreen Economics 2016, 9; 16). In 2015, *Bloomberg* researchers estimated that cannabis grow facilities made up almost 50% of the new power demand in Colorado (Oldham 2015).

To illustrate this impact in another way, it is estimated that between 20% (Sevcenko 2016) and 50% (Oldham 2015) of the costs of marijuana production are energy costs. The energy intensity of indoor cannabis production is known to be similar to data centers, at nearly 200 W/square foot (Crandall 2016; Mills 2012). Aluminum production consumes around 7 kWh/lb to produce, while indoor cannabis production consumes on the order of 2,000 kWh/lb to produce (Jourabchi and Lahet 2014; Mills 2012; O’Hare, Sanchez, and Alstone 2013).

The electric loads are dominated by lighting, dehumidification, and air-conditioning equipment as estimated in the widely referenced work by Evan Mills (2012), “The Carbon Footprint of Indoor Cannabis Production,” published in *Energy Policy*. Of particular merit for the report is the transparency of the detailed model that Mills uses in making his estimations. Mills calculates that it takes approximately 13,000 kWh per year to operate a standard production module that is 4′×4′×8′ (Mills 2012, 59). This is based on a production cycle of 78 days, for 4.7 cycles per year, and simple assumptions about the equipment capacities and use. A breakdown of his estimates for the energy use associated with indoor cannabis production is shown in Figure 1.

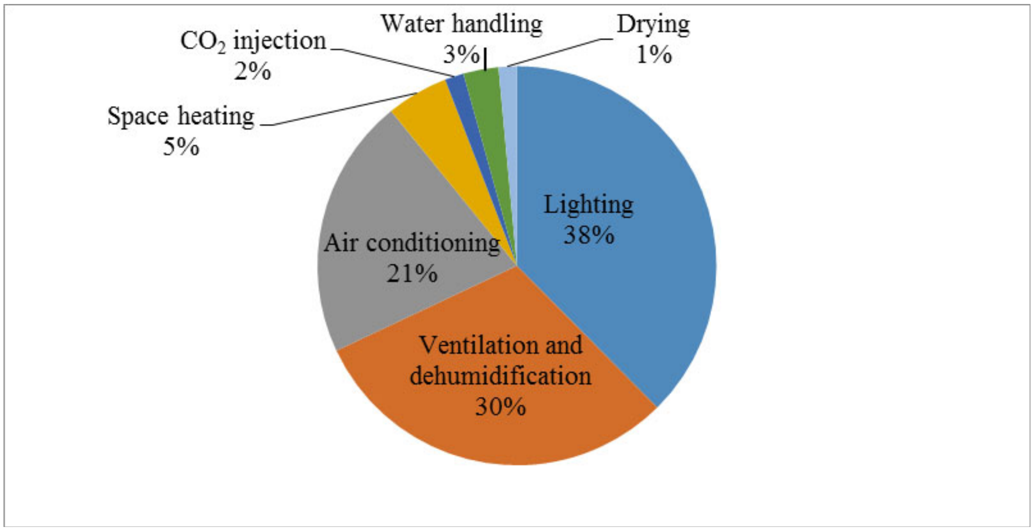

Figure 1. Breakdown of energy use for indoor cannabis production. *Source*: Mills 2012.

While high production costs are sustainable in emerging markets, more mature markets have seen a substantial reduction in product prices. Since Colorado legalized marijuana in 2014, the wholesale price of cannabis in that state has fallen from $2,500/lb. to about $1,000/lb (Borchardt 2017). Falling product prices will drive the need for more competitive operation costs, which will largely be presented in the form of energy efficiency.

For this paper, the authors interviewed owners/operators of legal medical grow facilities and equipment suppliers in the Northeast. A summary of the interviews conducted is shown in Table 1.

Table 1. Interviews with industry contacts

Type	Number
Owner/operator	7
Lighting manufacturer	3
Equipment supplier	2
HVAC equipment manufacturer	1
HVAC system designer	1

Growing cannabis is an agricultural production process where space conditions, temperature, and humidity are tightly controlled to optimize quality and mitigate crop loss due to pests, mold, and mildew. The quality and amount of light provided is the primary driver of the yield and quality once air temperature and humidity needs are met. In commercial operations, growers clone mother plants by taking small cuttings. The seedlings are usually grown in racks stacked vertically with fluorescent lighting (T5HO) until they are mature enough to be repotted and placed in grow rooms with high-intensity discharge (HID) fixtures. The plants are then grown in a vegetative state for 18 to 24 hours per day until the photoperiod is shortened, which induces the plant to begin flowering. A full cycle from clone to harvested plant takes 3 to 4 months but can vary depending on the particular strain of cannabis (Caulkins, Cohen, and Zamarra 2014).

The following sections of this report detail the industry standard practices, cost trends, and energy efficiency opportunities for lighting, dehumidification, and air-conditioning needs in the indoor cannabis industry.

Lighting

Traditional winter agriculture has taken place in greenhouses due to the high costs associated with indoor horticulture. The high value of cannabis has driven its indoor production for many years, especially in areas with shorter outdoor grow seasons. Lighting is the single most important piece of equipment for indoor growers, as it drives the photosynthesis and growth of the plants.

Industry Standard Practice for Lighting

The standard practices for each stage of the growing cycle are described below. Often, cannabis is considered to have only two growth stages, but the seedlings are shown as their own stage here in order to recognize the different type of lighting used for those plants.

- **Seedling cycle –** T5HO fluorescents are preferred for the early stages of plant growth because they can be placed close to the plant and stacked vertically, and their limited heat and light intensity reduces the chance of damaging the seedlings.
- **Vegetative cycle –** For vegetative growth, 600 W or 1000 W metal halide (MH) HID fixtures are preferred because their spectra contains more blue, but high pressure sodium (HPS) fixtures are also used. For vegetative growth, lighting is typically used for 18 to 24 hours per day. In instances where vegetative light fixtures had the capacity for variable output, interviewees indicated that plants in the vegetative state were given approximately 60% or 70% of the light used for flowering plants.
- **Flowering cycle –** The industry standard practice for the flowering cycle is the use of 1000 W HPS fixtures. HPS fixtures can be used for all stages of the growing cycle, but they are widely preferred for the flowering stage because of their concentration of yellow or red spectra. In the flowering stage, lights are typically used at their maximum output for 12 hours per day. A recent emergence to the industry is double-ended (DE) HPS lights, which output significantly more light than their single-ended counterparts. A recent study at Utah State University measured the output of traditional single-ended HPS fixtures at 1.02 µMol/sec and the output of DE grow fixtures at 1.66 to 1.70 µMol/sec (Nelson and Bugbee 2014). For an explanation of the difference between traditional lighting lumens, and micro-moles of light output, please see the section further in this report titled “Lumens are for Humans”. Interviewees indicated that the majority of growers are now purchasing DE fixtures and lamps.
    - Each DE 1000 W HPS fixture typically serves a 4′×4′ area of plant canopy (Jourabchi and Lahet 2014).
    - Each 4′×4′ of canopy contains approximately two to four flowering plants.

- A constant-output 1000 W HPS grow light fixture can be bought for $200 to $300. DE 1000 W HPS fixtures with dimmable or specialized output cost $400 to $600.

MH and HPS lights use interchangeable fixtures and are readily available online. Data collected from Amazon, The Grower's Warehouse, and Grower's Ace is shown in Figure 2.

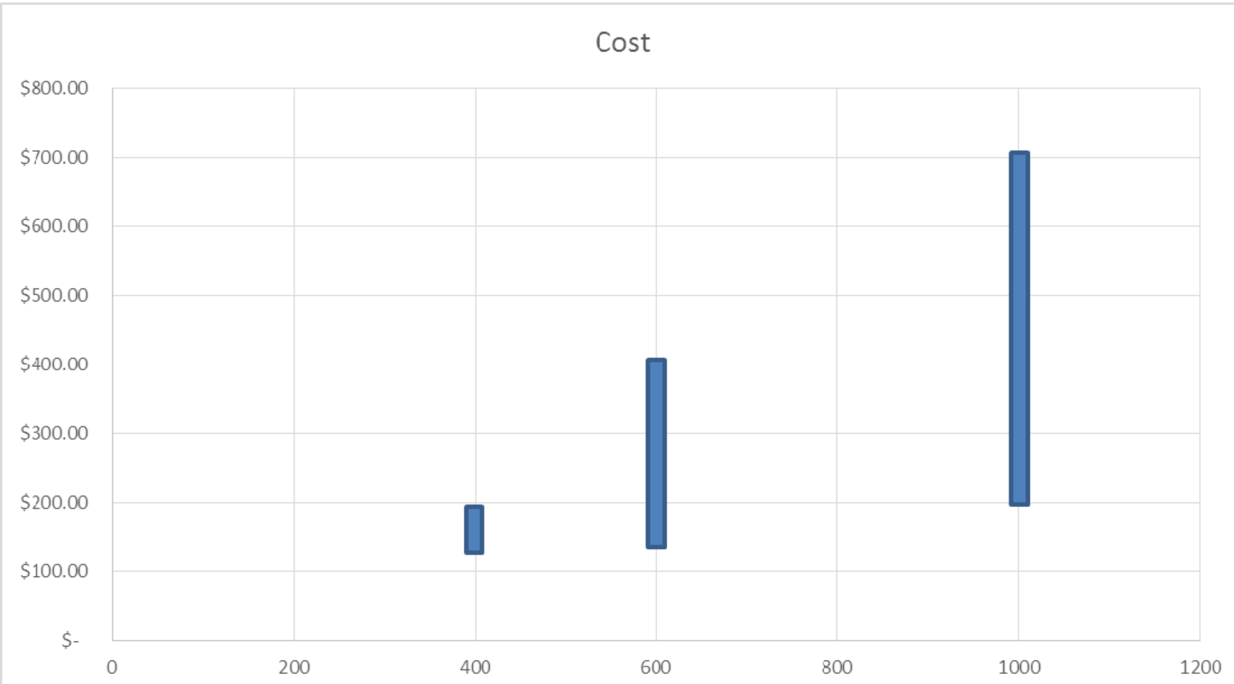

Figure 2. HID cost information

A summary of the industry standard practice results are shown in Table 2.

Table 2. Industry standard practices for lighting

Stage	Fixture	Hours of use	Cost
Seedling	4-foot 220 W 4 lamp T5 fluorescent	24	$100–$200
Vegetative	600 W MH	18–24	$200
Flowering	1000 W DE HPS	12	$400–$500

Lighting Efficiency Opportunities

LED grow lighting has been identified as the primary energy efficiency opportunity for indoor grow facilities, but the industry has been slow to adopt the technology due to the cost premium associated with LEDs, as well as concerns about the effectiveness of the fixtures in terms of product yield and quality.

The LED grow lighting technology is still emerging, and independent studies verifying the effectiveness of LED grow lighting compared to HID lighting are not widely available. The authors are aware that DesignLights Consortium (DLC) is in the process of developing criteria for horticultural lighting (G. Chan, Business Development Manager, Lumigrow, pers. comm., February 17, 2017). Direct comparisons between the yield of HID and LED lighting are challenging to establish since even under the exact same growing conditions and the exact same plant genetics, a 10%-20% variation in yield is to be expected (Caulkins J., Cohen, and Zamarra 2014). This makes it difficult to assess if differences in yield are due to the different lighting technologies, or are inherent to the growth of an agricultural product.

As indoor agricultural lighting matures, it is expected to become the standard for indoor cannabis operations as it has for other lighting applications. Most manufacturers market LED lights as a 40% reduction in power and energy use over traditional HID fixtures. This value represents a comparison of the connected load of the fixtures and does not include interactive savings from the reduced heat rejection into the air-conditioned space.

It is expected that 600 W LED grow lights will be the most commonly proposed measure for energy efficiency at grow facilities due to the current industry standard practice of using 1000 W MH and HPS fixtures. Through the conducted interviews and review of cannabis industry magazines, the authors have identified the following LED grow light manufacturers as industry leaders in the United States:

- Black Dog LED – www.blackdogled.com/
- Heliospectra – www.heliospectra.com/
- LumiGrow – www.lumigrow.com/
- California LightWorks – www.californialightworks.com/
- Fluence Bioengineering – https://fluence.science/
- VividGro – www.vividgro.com/

Most manufacturers list product prices and sell their fixtures directly through their websites, but additional cost information was gathered through interviews with lighting manufacturers. The costs for fixtures from the industry-leading LED manufacturers are shown in Figure 3. Most LED manufactures interviewed indicated that they offer a 10% discount for bulk purchases, which is not accounted for in these values. Similar to HID fixtures, dimmable or spectrum control features are an additional cost.

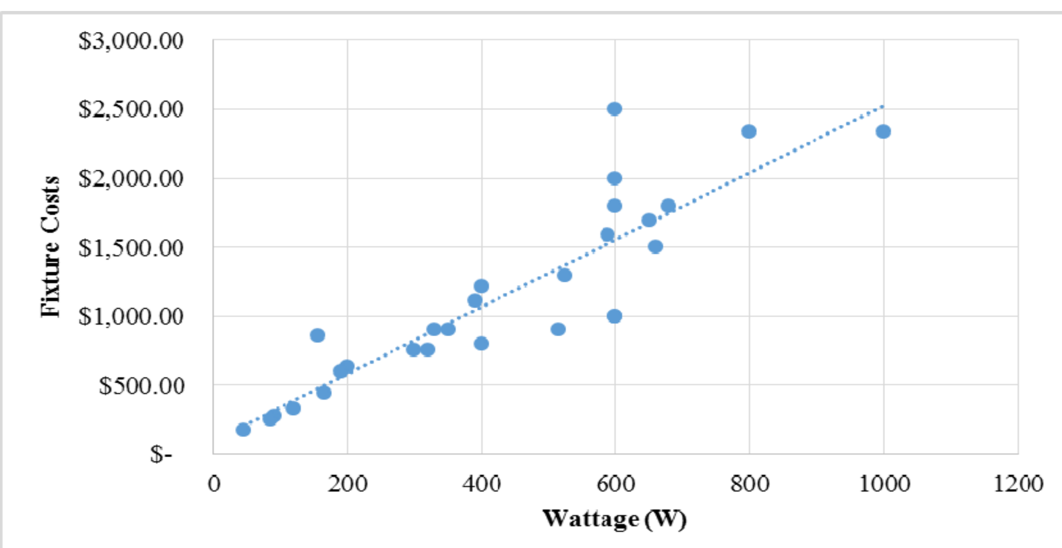

Figure 3. LED fixture costs

Lighting Energy Savings

The annual energy savings for implementing LED lighting in a grow operation can be calculated through the following formula.

$$kWh\ savings = Lighting\ kWh\ savings + HVAC\ Interactive$$

where,

$$Lighting\ kWh\ savings = (HID\ wattage - LED\ wattage) \times Annual\ Operating\ Hours$$

and,

$$HVAC\ Interactive = Lighting\ kWh\ savings \times \frac{3412\ Btus}{kWh} \div 12{,}000 \frac{tons}{Btu} \times HVAC\ kW/ton$$

The typical energy savings per fixture in vegetative and flower rooms can be calculated using the following assumptions, as shown in Table 3. The annual operating hours are calculated as the daily operating hours multiplied by 365 days.

- Vegetative room lights are on for 18 hours per day.
- Flower room lights are on for 12 hours per day.
- Fixtures are assumed to operate 365 days a year
- HID wattages from Table 2, above
- LED wattages of 300 W and 600 W for vegetative and flower rooms, respectively
- HVAC efficiency of 1.2 kW/ton or 10 SEER
- Cooling in the grow room is assumed to be required year round while lights are on
- Blended electric rate of $0.12/kWh

Table 3. LED energy savings summary

Stage	HID wattage	LED wattage	Demand impact	Annual energy savings	LED fixture costs	Simple payback[1]
Vegetative	600 W	300 W	300 W	2,600 kWh	$700–$1,000	2-3 years
Flowering	1000 W	600 W	400 W	2,300 kWh	$1,000–$1,600+	3-4 years

For simplicity, the nameplate wattages are used in the above calculations. The actual input wattages for both fixture types vary. HID input wattages are greater than the nameplate wattage, and LED input wattages could be greater than or less than their nameplate wattage depending on the manufacturer.

The above calculations also assume that LED fixtures can truly replace HID fixtures one-for-one. This assumption may be invalid.

“Lumens are for Humans”

The above quote is a phrase often heard when discussing agricultural lighting. It indicates that lumens, the typical measure of light output associated with interior or exterior space lighting,

[1] Assumes a retrofit scenario where incremental cost is not a factor

is not an appropriate measure of light output for agricultural applications. What matters to plants and photosynthesis is the amount of photons delivered to the plants within the photosynthetically active radiation (PAR) spectrum from 400 to 700 nanometers. Photon delivery is expressed as photosynthetic photon flux (PPF) in the unit of µMol/sec. The µMol/sec of LED fixtures varies by manufacturer and is typically 40%–50% less than the µMol/sec output of a DE 1000 W HPS fixture. This comparison can't be made so directly or easily, however.

The output of a given fixture does not directly equate to the amount of µMol/sec delivered to the plant. By varying the mounting height of a fixture, the output can be "concentrated" on a smaller area of canopy, yielding a greater density of µMol/sec delivered for a given fixture. This value is referred to as photoactive photon flux density (PPFD). This value appears to be the key metric for comparing effective PAR output from various fixture technologies. Since LED fixtures give off substantially less heat than HID fixtures, they can be mounted much closer to the plant canopy, effectively increasing their PPFD. Depending on the LED fixture design, lowering the mounting height may result in canopy coverage of less than the standard of 4′×4′, which in turn may result in a greater number of LED fixtures being required to provide sufficient coverage at the desired level or HID-equivalent PPFD value. This is a topic of ongoing discussion between the authors and various LED manufactures and medicinal cannabis producers.

Dehumidification and Air Conditioning

Because plants release water vapor through transpiration, indoor grow facilities require substantial dehumidification to maintain approximately 50% to 60% relative humidity. If excess humidity is left unregulated, it can cause mold or mildew, potentially ruining a crop. Dehumidification is generally achieved mechanically by sub-cooling the air to remove water and then reheating the air to the desired supply air temperature through traditional dehumidification units or by absorbing moisture in the air through a desiccant dehumidifier. Hot, dry air – typically produced by fuel-burning or electric-resistance heaters – is then used to "recharge" the desiccant wheel.

Closed-ventilation systems appear to be common in commercial cannabis enterprises and represent the industry's fear of mold, mildew, mites, and uncontrolled fertilization. With proper air filtration (MERV 14 or greater), outside air can be used without introducing outside contaminants. Closed-ventilation systems also require supplementary CO_2 from either direct combustion or liquid systems. Conversely, operations that introduce CO_2 into the grow space are all but required to employ closed-loop systems since the introduced CO_2 would be exhausted from the space with an open-loop configuration.

Cannabis plants grow best in the 70°F to 80°F temperature range. Due to the use of closed-ventilation systems and HID lights, which reject large amounts of heat within the production space, indoor grow rooms are cooling-dominated environments. Household mini-splits are common in smaller operations, while rooftop units, computer room air conditioners, or air-cooled chillers are typically used for larger operations.

The authors have observed a trend toward lowest first cost options for HVAC systems serving grow spaces. The interviews conducted also indicate that HVAC systems are not being thoughtfully designed for the unique conditions for the grow spaces, resulting in difficulty controlling the environment, frustration with the installed systems, and a "Band-Aid" approach to fixing the problem where more and more standalone dehumidifying equipment is added until the desired conditions are met, which ultimately increases the energy use associated with production.

Dehumidification and Air-Conditioning Efficiency Opportunities

After LED grow lighting, dehumidification and air conditioning represent the largest opportunities for energy savings (Figure 1). Two approaches are currently known to minimize the energy consumption associated with maintaining indoor grow space conditions: 1) utilization of outdoor air economizing through the supply of filtered outdoor air or a dry cooling tower, and 2) high efficient dehumidification through air-to-air heat exchangers.

High efficiency dehumidification is accomplished by circulating air in a closed loop through a heat exchanger before and after mechanical cooling. Heat is exchanged between the same air stream to both precool the incoming air and preheat the outgoing dehumidified air.

The Western Cooling Efficiency Center at the University of California, Davis, performed research on such a system made by MSP Technology and found savings between 30% and 50% over traditional systems without heat recovery (Pistochini et al. 2016).

The authors present the following additional potential efficiency measures for maintaining humidity and air conditioning in indoor grow rooms:

- Reheating needs can be served by heat recovery off the condenser side of cooling equipment.
- If waste heat is available, it can be used to recharge (fully or partially) desiccant wheels for efficient dehumidification.

Conclusions

Lighting, cooling, and dehumidification are the largest energy end uses and represent the primary areas for potential improvements in energy performance for indoor grow facilities.

- **Lighting –** The industry appears poised to accept LED lighting for the vegetative stage as some interview respondents indicated that LEDs perform as good as or better than HIDs for this stage. The industry does not appear ready to accept LED lights for the flowering period, however, as anecdotes indicate reduced yields compared with HPS fixtures. Additionally, the perception of growers has been tainted by early low-quality versions of LED grow lighting, and there are not enough published field trials proving the effectiveness of modern LED equipment. Although LED manufacturers claim equal or superior flowering performance, definitive data in support of these claims appears to be lacking. The emergence of a DLC category for LED grow lighting is expected in the next 12 to 18 months and would provide a much-needed third-party verification of LED grow light performance. Due to the value of the product they produce, cannabis growers are widely focused on yield and production over energy use, which severely hinders the adoption of energy efficient equipment.
- **HVAC and dehumidification –** The primary opportunity identified for dehumidification and HVAC systems lies in the use of high efficiency equipment coupled with detailed site-specific design. These spaces have very specific requirements and loads, and an improperly designed system could require additional equipment to meet space conditions that would likely consume more energy than is required for the task.

Virtually all of the growers that the authors spoke with are adding grow rooms or expanding their operations in response to the rising demand for medical cannabis, and in anticipation of increasing cannabis demand in states that recently passed legalization laws such as Maine, Massachusetts, Nevada, and California. Utilities from the SDG&E study report a lag time of 6 to 12 months before seeing the impacts of legalization on energy grids, and growers express a need to expedite facility set up. Growers are also not typically experienced in facility management, which often leads to poor HVAC and lighting design choices. Efficiency programs have the opportunity to influence the choices and direction of this emerging industry toward more efficient designs by engaging growers and providing guidance and incentives.

References

Borchardt, D. 2017. "Marijuana Prices Fall In 2016 As Growers Flood The Market With Pot." *Forbes*. https://www.forbes.com/sites/debraborchardt/2017/01/31/marijuana-prices-fall-in-2016-as-growers-flood-the-market-with-pot/#46f9192b2f7f

Caulkins, J., M. Cohen, and L. Zamarra. 2014. *Estimating Adequate Licensed Square Footage for Production.* Washington State Liquor and Cannabis Board. lcb.wa.gov/publications/Marijuana/BOTEC%20reports/5a_Cannabis_Yields-Final.pdf.

Crandall, K. 2016. *A Chronic Problem: Taming Energy Costs and Impacts from Marijuana Cultivation.* EQ Research. eq-research.com/wp-content/uploads/2016/09/A-Chronic-Problem.pdf.

Evergreen Economics. 2016. *SDG&E Cannabis Agriculture Energy Demand Study.* Prepared for the San Diego Gas & Electric Company. http://www.calmac.org/publications/SDG%26E_Cannabis_Ag_Energy_Demand_Final_Report_071516ES.pdf

Jourabchi, M. and M. Lahet. 2014. *Electrical Load Impacts of Indoor Commercial Cannabis Production.* Presented to the Northwest Power and Conservation Council. www.nwcouncil.org/media/7130334/p7.pdf.

Mills, E. 2012. "The Carbon Footprint of Indoor Cannabis Production." *Energy Policy* 46: 58–67. http://evanmills.lbl.gov/pubs/pdf/cannabis-carbon-footprint.pdf

Nelson, J. and B. Bugbee. 2014. "Economic Analysis of Greenhouse Lighting: Light Emitting Diodes vs. High Intensity Discharge Fixtures." *PLOS ONE*. http://cpl.usu.edu/files/publications/publication/pub__8264567.pdf

O'Hare, M., D. Sanchez, and P. Alstone. 2013. *Environmental Risks and Opportunities in Cannabis Cultivation.* Washington State Liquor and Cannabis Board. lcb.wa.gov/publications/Marijuana/SEPA/BOTEC_Whitepaper_Final.pdf.

Oldham, J. 2015. "As Pot-Growing Expands, Electricity Demands Tax U.S. Grids." *Bloomberg*. http://www.bloomberg.com/news/articles/2015-12-21/as-pot-growing-expands-power-demands-tax-u-s-electricity-grids.

Pistochini, T., R. McMurry, D. Ross, and P. Fortunato. 2016. *Laboratory Testing of an Energy Efficient Dehumidifier for Indoor Farms*. UC Davis: Western Cooling Efficiency Center. wcec.ucdavis.edu/wp-content/uploads/2016/11/MSP_XCEL-Case-Study.pdf.

Sevcenko, M. 2016. "Pot is Power Hungry: Why the Marijuana Industry's Energy Footprint is Growing." *The Guardian*. www.theguardian.com/us-news/2016/feb/27/marijuana-industry-huge-energy-footprint.