Braingrid Guide

ENERGY CONSUMPTION IN CANNABIS CULTIVATION

Prepared by

Nafeesa Mehboob, PhD, SMIEEE
Postdoctoral Fellow
York University

Hany Farag, PhD, SMIEEE, P.Eng
Associate Professor and Research Chair
York University

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Carbon Footprint:
the amount of carbon dioxide and other carbon compounds emitted due to the consumption of fossil fuels by a particular person, group, etc.

INTRODUCTION

Growing good-quality cannabis and maximizing production (per square foot of space and per year) is energy intensive. Energy use varies based on cultivation methodology and operational efficiency. The total energy costs for indoor cannabis operations typically vary between 20 % - 50 % of total operating costs (~150 kWh of electricity per year per square foot); in comparison, energy use in a medium - larger brewery accounts for about 6 - 12 % of total operating costs [1] . Facility type has an impact on the energy consumed for cannabis cultivation. In 2017, approximately 60 % of electricity usage in legal cannabis cultivation in the US was associated with indoor operations, while 37 % was associated with greenhouse production [2] . Furthermore, areas with extreme climate have a significant impact on the total energy consumption, because of the climate regulation needed throughout the year. Another challenge for indoor operations is the significant carbon footprint. In 2017, indoor operations contributed about 66 % of the overall electricity-based CO_2 equivalent emissions, while greenhouses contributed approximately 32 % [4] . This further highlights the need for energy efficient technologies and incentives to reduce electricity-based carbon emissions.

ENERGY CONSUMPTION IN DIFFERENT STAGES OF CANNABIS CULTIVATION

Cannabis cultivation typically has three stages: the seedling (or propagation) stage, the vegetative stage, and the flowering stage, all of which have different energy requirements based on the lighting, temperature, and humidity levels, as shown in Figure 1. Typically, for indoor and greenhouse operations, the flowering stage has the highest energy consumption, while the seedling stage has the lowest [2] .

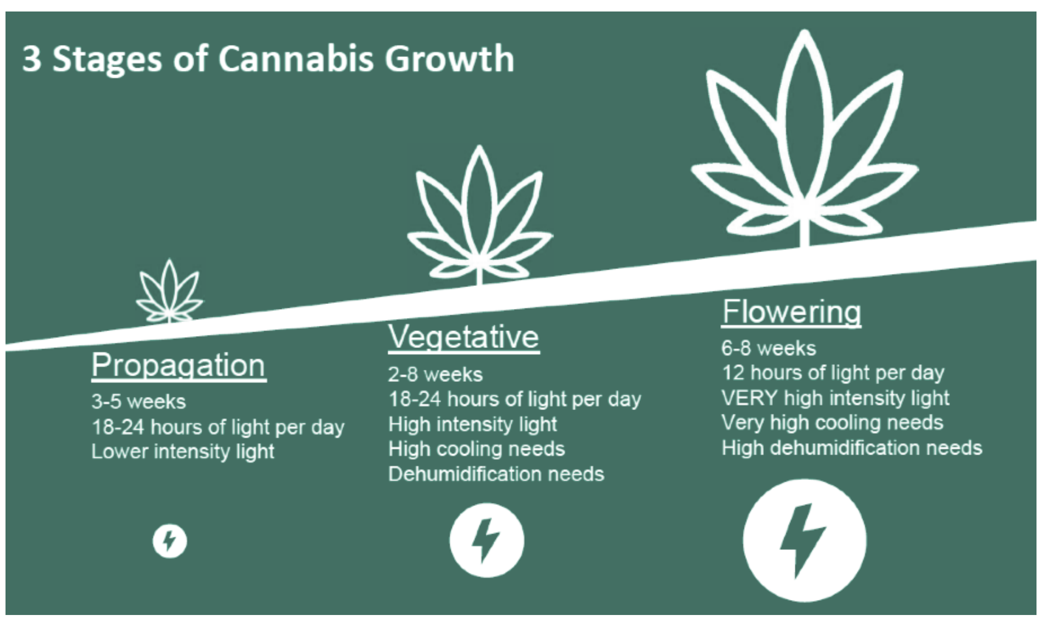

Figure 1: Lighting and HVAC needs for different stages in a Typical Indoor Cannabis Cultivation Operation [3]

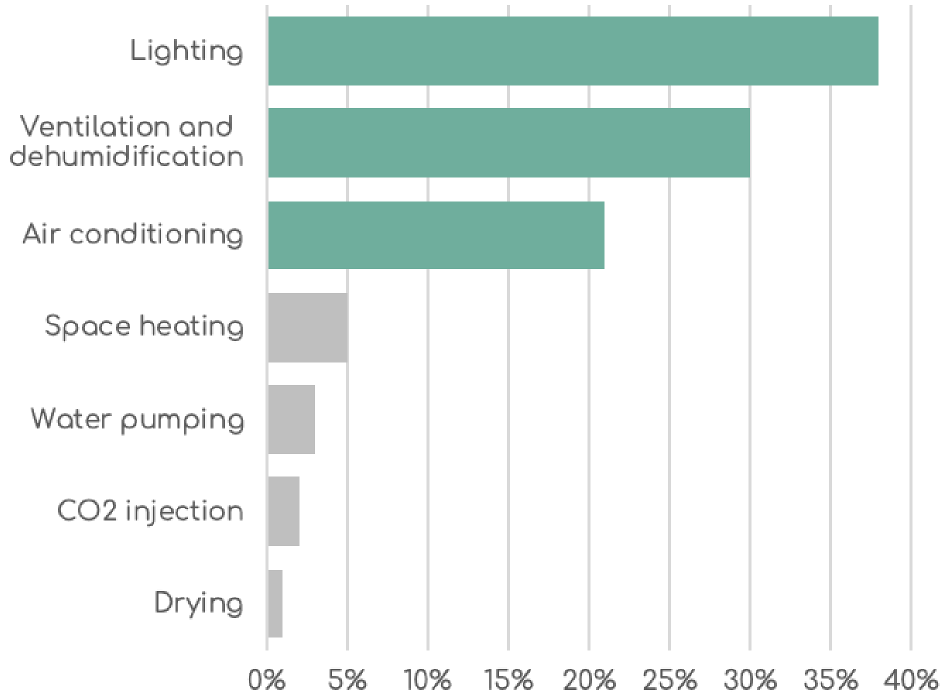

Figure 2: Energy Use Breakdown for a Typical Indoor Cannabis Cultivation Operation [3]

Seedling or Propagation stage

Clone plants are generally kept under lower- wattage lights (5-40 watts per sq. ft.) 18 - 24 hours a day for 1 - 2 weeks. This stage of the cultivation generally represents less than 5 % of overall electricity use [2]. T5HO fluorescents are preferred for this stage.

Vegetative stage

Historically, HPS lights and metal-halide (MH) lamps were preferred for the vegetative state, though now, LEDs and CMH fixtures. Depending on strain and grower preference, lights (15 - 70 watts per sq. ft.) are on for generally 18 hours a day, and consume approximately 30 - 40 % of total electricity use [2]. 600W or 1000 W MH HID lighting is preferred because their spectra contains more blue, but HPS fixtures are also used for this stage.

Flowering stage

During this stage, the light schedule is switched over to 12 hours of light per day to induce a hormonal response in the plant towards flower proliferation. During this phase of cannabis cultivation, the photosynthesis rates peak. Hence, the required lighting intensity is high (40 - 70 watts per sq. ft.), resulting in the highest energy consumption of all the stages (approximately 50 - 65 % of total facility electricity consumption) [2]. Owing to increasing cost and changing perceptions towards LEDs in this stage, the lighting mix in this stage appears to be changing from the conventional HPS lighting. 1000 W HPS fixtures are conventionally used for this stage because of their concentration of yellow or red spectra.

Sensible Heat:
Heat generated due to lighting

Latent Heat:
Heat generated due to plant evapotranspiration

HVAC ENERGY CONSUMPTION IN INDOOR CANNABIS OPERATIONS

Grow operations maintain indoor relative humidity (RH) to be around 50 - 60 %, and temperature between 70 - 80 ˚F [4]. HVAC systems are critical to maintaining plant health in grow operations by regulating temperature, RH, CO_2, and ventilation. HVAC uses energy to cool the heat gained from lighting, removing moisture from the plant's evapotranspiration process, circulation and mixing of the air, along with filtration of air for odours and contaminants. Heat generated by conventional HPS fixtures is 30 - 60 watts per square foot, and require continuous cooling while the lights are on to maintain the room at the desired temperature [5].

Poorly designed mechanical systems can increase energy consumption by up to 50 %. Temperature and RH operating setpoints majorly impact on the size of the HVAC system required. Energy consumption by HVAC can vary greatly based on geography, seasonality, facility size, layout, growing methodology, lighting system design, and watering schedule. For example, in winter, greenhouses require heating via natural gas and other fuels which drives cost higher than indoor operations.

LIGHTING ENERGY CONSUMPTION IN INDOOR CANNABIS OPERATIONS

Lighting is a critical driver of energy consumption in indoor operations. Lighting combined with plant transpiration creates heat and humidity. As a result, temperature and humidity must be regulated by HVAC systems. While indoor cultivation conventionally uses High Intensity Discharge (HID) lighting, particularly HPS, recently, new products have been developed to meet preferences on intensity and spectral composition.

PPFD:
The total amount of photosynthetically active radiation (light that falls between the range needed for photosynthesis, i.e., 400-700 nanometers) that reaches the plant surface, and is measured is micromoles per square meter per second.

HPS fixtures are relatively inexpensive and support plant growth; however, they produce a great deal of heat, need frequent lamp replacement, and are not intended to be dimmable unless used with expensive solid state ballasts. LED lighting, on the other hand, is the most efficient and rapidly evolving alternative to HPS lighting [5]. The lack of lighting power density standards may be one factor hindering the adoption of LED technology by growers. For example, in Massachusetts, a lighting power density of 36 watts/ft^2 is recommended by the EEA, and the LEDs sold by the Massachusetts grow supply houses operate at an average lighting power density of 36.5 watts per sq. ft. [6].

In comparison, the industry practice for lighting power densities seems to be 33-50% more energy intensive [2]. An important horticultural lighting performance indicator is the Photosynthetic Photon Flux Density (PPFD). The industry standard practice for lighting for cannabis cultivators is shown in Table 2 [2, 7]. Data collected between 2016 and 2018 on lighting used by different growers in indoor cannabis operations shows that LED lighting has experienced the highest adoption rates by participants during this period (Figure 3 - 5).

	Indoor	Greenhouse
Cooling	• Split unit(s) • Rooftop/packaged unit(s) • Variable refrigerant flow (VRF) systems • Central chiller(s) – hydronic fan coils or air handlers • Cooling towers	• Evaporative cooling (wet wall) • Sealed environment with indoor solution
Dehumidification	• Portable units • Not dedicated – reheat (conventional) • Not dedicated – reheat (reclaimed waste heat) • Dedicated dehumidification units • Fully integrated cooling & dehumidification • Air-side or water-side economizers	• None; ventilation only • Dessicant dehumidification • Sealed environment with indoor solution
Heating	• None – sufficient heat from lighting • Natural gas – direct fired units • Natural gas – Ducted furnace • Natural gas – hydronic boiler + fancoils • Geothermal – heat pump	• Natural gas – direct fired units • Natural gas – hydronic boiler & fancoils • Natural gas – hydronic radiant floor/slab • Geothermal – ground air exchange • Geothermal – heat pump

Table 1: The six major groupings of HVAC systems used in cannabis cultivation, with their energy performance and environmental control capabilities highly dependent on the system's design, installation, operation, and maintenance [2].

Stage	Fixture	Rated Life in Hours	Intensity* in umol/m^2/s	Efficacy in umol/J	Hours of Use
Seedling / Propagation	T5 fluorescent	20,000	150-300	TBD	18-24
Vegetative	MH Ceramic MH Single-ended HPS Double-ended HPS LED Light Emitting Plasma	6000-15,000 20,000 5000-20,000 5000-20,000 50,000 30,000	500-800 800 700-900 700-900 800-1200 700-900	TBD 1.46 1.16 1.7 1.7 1	18
Flowering	Ceramic MH Single-ended HPS Double-ended HPS LED Light Emitting Plasma	20,000 5000-20,000 5000-20,000 50,000 30,000	800 700-900 700-900 800-1200 700-900	1.46 1.16 1.7 1.7 1	12

Table 2: Cannabis industry lighting standard [2, 7].

*** Intensity measured at manufacturer recommended mounting height.**

* Total may exceed 100% because respondents could select all that apply. 2017 results are based on the 294 research participants who grow only indoor and/or in greenhouses using supplemental lighting. 2016 results are based on 117 research participants who grow in indoor and/or greenhouses (with or without supplemental lighting) and/or outdoors

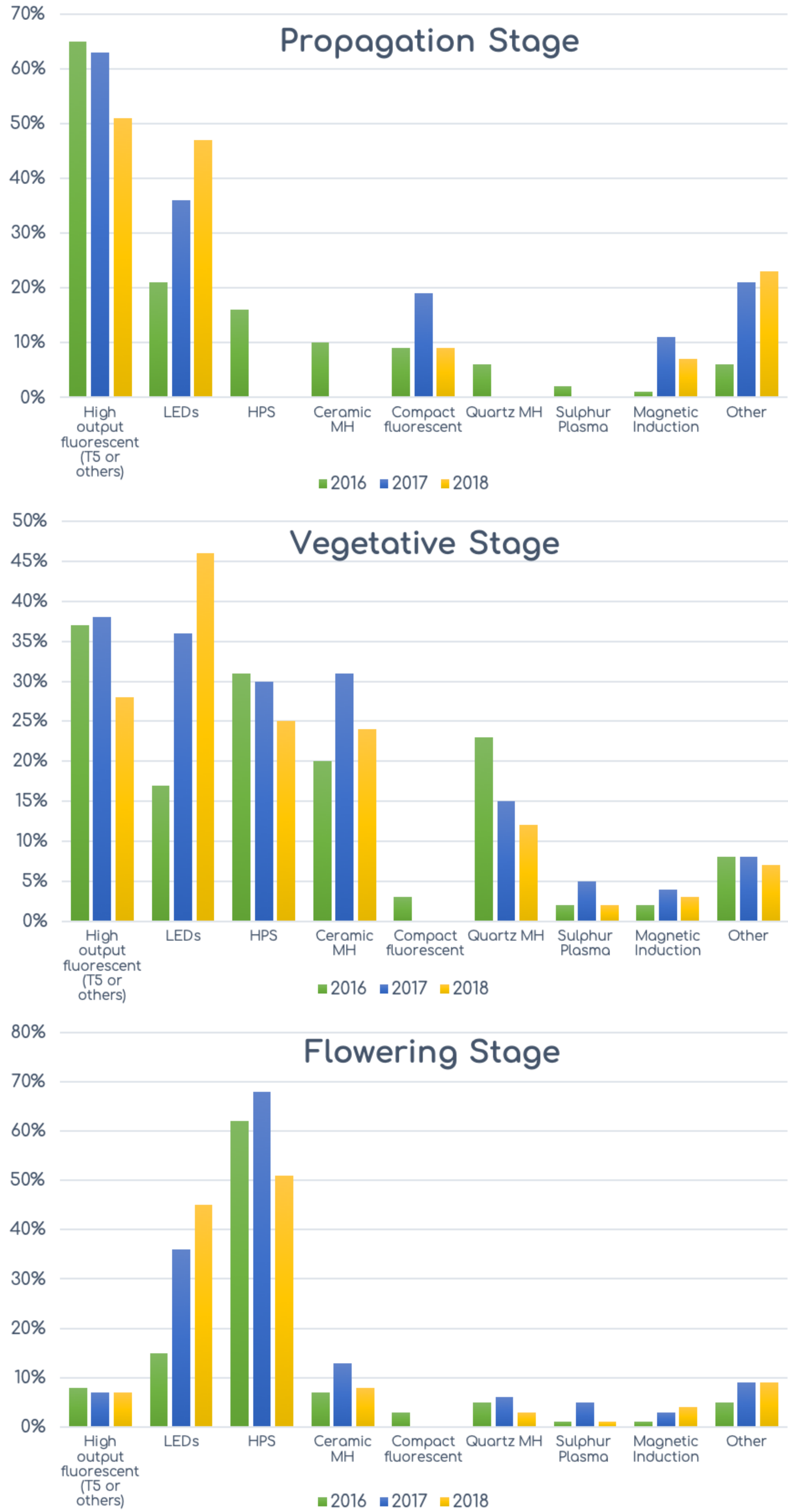

Figure 3 - 5: Lighting used in different stages of indoor cannabis grow operations [8].

CONCLUSIONS

Indoor cannabis operations are highly energy intensive, with lighting and HVAC responsible for the majority of the energy demand. Therefore, it is crucial for indoor cannabis operations to find efficiencies in HVAC and lighting to maintain feasibility in this competitive market, as well as for long term sustainability of this industry as a whole.

REFERENCES

1. N. Kowley, "A Budding Opportunity: Energy efficient best practices for cannabis grow operations," Southwest Energy Efficiency Project, 2017.
2. New Frontier Data, "The 2018 Cannabis Energy Report," 2018.
3. E. Mills, "The Carbon Footprint of Indoor Cannabis Production," Energy Policy, no. 46, pp. 58-67, 2012.
4. N. C. Jesse Remillard, "Trends and Observations of Energy Use in the Cannabis Industry," ACEE Summer Study on Energy Efficiency in Industry, 2017.
5. D. J. L. Duane L. Jonlin, "A Low-Energy High Managing Energy Use for Commercial Indoor Cannabis Cultivation," Association of Energy Engineers.
6. Massachusetts Department of Energy Resources, "Cannabis Energy Overview and Recommendations," 2018.
7. Denver Public Health & Environment, "Cannabis Environmental Best Management Practices Guide," Denver, 2018.
8. http://magazine.cannabisbusinesstimes.com/article/november-2018/facility-lighting.aspx

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