FINAL REPORT
Massachusetts Cannabis Cultivation ISP
MA19C13-B-CANISP

Date: June 10, 2020
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MASSACHUSETTS CANNABIS CULTIVATION ISP

SUMMARY

This document presents the results of the cannabis cultivation industry standard practice (ISP) study from August 2019 to March 2020. The CI Evaluation Team – including DNV GL, ERS, and DMI – conducted this study on behalf of the Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants.

Study Objective

The study's primary objective was to define industry standard practice (ISP) in indoor cannabis cultivation in Massachusetts using high rigor methods, including interviews of cultivators, facility design engineers, and vendors/contractors.

Background

The Cannabis Control Commission (CCC) has enacted rules through 935 CMR 500 regulations that dictate minimum standards for building envelopes, horticultural lighting power density, and HVAC systems for cannabis cultivation facilities. These same regulations went into effect March 23, 2018, and the CCC has set a date of January 1, 2021, for all facilities to comply with the regulations, including provisions for retroactively applying the standards to preexisting facilities. The CCC regulations require annual reporting from licensed facilities on annual electric energy use, annual fuel use, annual production values, and information on the facilities' lighting and HVAC systems.

APPROACH

The Team interviewed a random selection of 10 service providers (SPs) active in Massachusetts out of a population of 29. These service providers are architects, engineers, builders, consultants, and equipment vendors. The combined respondents have worked on 13 out of the 26 final licensed facilities in Massachusetts, and all are currently active with new projects in Massachusetts.

Interviewed service providers included architects, engineers, builders, consultants, and equipment vendors.

The combined respondents have worked on 13 out of the 26 final licensed facilities in Massachusetts, and all are currently active with new projects in Massachusetts.

RECOMMENDATION 1:
Use identified ISP for baseline.

The Team recommends the use of the ISP practices identified in this study by implementers as the baselines for projects and by evaluators when evaluating those projects. For all systems and equipment where an ISP was not identified, a site-specific baseline should be used. Please refer to Appendix D of this report, which includes all recommended baselines.

RECOMMENDATION 2:
Conduct future research.

The CCC regulations require annual reporting from licensed facilities on annual electric energy use, annual fuel use, annual production values, and information on the facility's lighting and HVAC systems. Within 12 to 18 months, the CCC should accrue a substantial body of information on the makeup and performance of cultivation and product manufacturing facilities in Massachusetts. The PAs should consider revisiting this study later to leverage the forthcoming facility data collection.
MASSACHUSETTS CANNABIS CULTIVATION ISP

PAs can no longer use a technology-based ISP but must align their baseline characterization with the regulations enforced by the CCC.

Cannabis facilities are licensed in one of eleven tiers, with each tier representing total permitted canopy area, up to a maximum of 100,000 square feet of canopy.

CONCLUSIONS

Horticultural Lighting

CCC regulations went into effect on March 23, 2018. The regulatory complexity requires defining horticultural lighting ISP for facilities both licensed before 935 CMR 500 went into effect and after. In this document, “prior to CCC regulations” refers to the period before 3/23/2018 and applies to facilities licensed before that date.

Before the CCC regulations: Massachusetts facilities followed national trends selecting specific technologies to serve the different growth phases.

After the CCC regulations: By January 1, 2021, all licensed facilities must comply with 935 CMR 500, including facilities that were designed and built before the CCC regulations. Existing facilities will have two ways to comply with the horticultural lighting power density (HLPD) requirements if their existing design exceeds that threshold: 1) facilities can retrofit high-intensity fixtures with LED fixtures, or 2) facilities can reduce the percentage of their cultivation area in active use while maintaining the existing high-intensity fixtures over that reduced footprint of the plants.

<table>
<thead>
<tr>
<th>Horticultural Lighting ISP After CCC Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivation Tier</td>
</tr>
<tr>
<td>Hierarchical</td>
</tr>
<tr>
<td>Tiers 3-11</td>
</tr>
</tbody>
</table>

Environmental Conditioning

Maintaining proper environmental conditions is critical to the productivity of a cannabis facility and to act as a primary line of defense against biological contamination such as powdery mildew (PM). There are substantial sensible heat loads from the horticultural lights and large latent loads from the transpiration of the plants.

The interview responses indicated that the CCC regulations had not impacted ISP for HVAC and dehumidification systems. The diversity in the materials and layout of the cultivation space, as well as variance in cultivation methodologies, necessitate site-specific load calculations.

Space-Cooling ISP

<table>
<thead>
<tr>
<th>Facility Canopy Area</th>
<th>HVAC Technology ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>Direct expansion (DX) type systems</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>Chilled water systems</td>
</tr>
</tbody>
</table>

Extraction Equipment

Cannabis product manufacturers prepare concentrates, edibles, tinctures, or other consumer products. Processes to extract cannabinoids and terpenes are solvent-based, and common extraction systems require dedicated air compressors and process chillers that are energy-intensive.

The interviews found no ISPs within this segment of the industry at this time. These facilities need further study to better quantify energy end use, productivity, and energy efficiency opportunities in extraction process equipment.
1 EXECUTIVE SUMMARY

1.1 Study purpose, objectives, and research questions

The DNV GL CI Evaluation Team, with ERS as lead and DMI as team member, carried out the cannabis cultivation industry standard practice (ISP) study for the Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants from August 2019 to March 2020. The study's overall purpose was to define ISP in indoor cannabis cultivation in Massachusetts using high rigor methods, including interviews of cultivators, facility design engineers, and vendors/contractors. The objectives of the study included the following:

1. Identify the ISP for processes and equipment related to the cultivation and preparation of medical and adult-use cannabis, including horticultural lighting, cultivation area HVAC, and extraction process equipment.
2. Identify variations in systems based on other characteristics, including licensure relative to 935 CMR 500.120, which set minimum efficiency standards for cultivation facilities, facility size, retrofitted facilities vs. new construction, and market served (medical or adult use).
3. Consider how regulations affect practices in the field, especially regarding the retroactive application of the energy requirement contained in 935 CMR 500.120.11.b – referred to in this report as the Cannabis Control Commission (CCC) regulations or 935 CMR 500 – and their impact on lifetime savings.

For this study, the baseline or ISP is defined as "the equipment or practice specific to the application or sector that is commonly installed absent program intervention." While this report identifies several ISPs, cannabis facility designs have proven highly variable. In accordance with the Massachusetts Commercial/Industrial Baseline Framework1, implementers and future evaluators are permitted to make use of project-specific baselines for ISP systems when "...particular circumstances render standard practice irrelevant and evidence is provided to justify [a project specific baseline]."2

1.2 Fundamental regulatory background and findings

Massachusetts is unique among states with active legal cannabis markets because the CCC has enacted rules through 935 CMR 500 in November of 2016 and updated December 16, 2019, that dictate minimum standards for building envelopes, horticultural lighting power density, and HVAC systems for cannabis-cultivation facilities. These same regulations include provisions for retroactively applying the standards to preexisting facilities. These regulations went into effect on March 23, 2018 with their publication in the Massachusetts Register. The regulatory complexity requires defining horticultural lighting ISP for facilities licensed before 935 CMR 500 went into effect March 23, 2018, and after. In this document, ‘prior to CCC regulations’ refers to the period before 3/23/2018 and applies to facilities that were licensed before that date.

The CCC has set a date of January 1, 2021, for all facilities to comply with the regulations, though a provision exists for facilities to request an extension. The CCC requires all license renewal and new license applicants to submit a statement signed by a Massachusetts licensed architect or engineer validating that the facility design complies with the CCC regulations. Two copies of drawings stamped by the Massachusetts

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2 Ibid.
licensed architect or engineer illustrating the compliant configuration must be kept at the cultivation facility for immediate surrender to the CCC upon request. Additionally, the CCC will be requiring the submission of annual facility energy use and production output data along with information on the horticultural lighting and HVAC systems serving the facility.

- **ISP for horticultural lighting for Massachusetts cultivation facilities licensed before March 2018**
  - ISP in Massachusetts followed national trends in the selection of technologies and energy intensity. However, all existing cultivation and product manufacturing facilities must comply with 935 CMR 500 by January 1, 2021. The CCC has a mechanism in place for the review, inspection, and enforcement of the requirements after that date.
  - Calculating lighting savings for facilities licensed before the CCC regulations requires a dual baseline approach to reflect an ISP baseline for the first period (which ends 12/31/2020) and a compliant baseline for the second period.

- **ISP for horticultural lighting for facilities licensed after March 2018:**
  - The adoption of 935 CMR 500 materially impacted horticultural lighting ISP in Massachusetts, nearly halving energy intensity.
  - The CCC regulations have substantial implications on demand-side management (DSM) programs. PAs can no longer use a technology-based ISP but must align their baseline characterization with the regulations enforced by the CCC. Before CCC regulations, LED horticultural lighting projects could produce savings on the order of 30 watts per square foot (sf). Cannabis facilities are licensed in one of eleven tiers, with each tier representing total permitted canopy area, up to a maximum of 100,000 sf of canopy. With the CCC horticultural lighting power density (HLPD) thresholds (see Table 1-2, below), tier 3 and larger facilities may be able to achieve savings on the order of only 3-8 watts per sf.
  - Calculated lighting savings for facilities licensed after the CCC regulations requires a single baseline with a 15 year measure life.

- There are no differences in horticultural lighting or HVAC ISP between medical and adult-use cultivation facilities.

- ISP for HVAC and envelope systems have not been impacted by 935 CMR 500.

The CCC regulations require annual reporting from licensed facilities on annual electric energy use, annual fuel use, annual production values, and information on the facilities' lighting and HVAC systems. Within 12 to 18 months, the CCC should accrue a substantial body of information on the make-up and performance of cultivation and product manufacturing facilities in Massachusetts.

### 1.3 Methods

The findings are based on interviews of a random selection of 10 service providers (SPs) active in Massachusetts out of a population of 29. The response rate was excellent, with only one replacement interviewee. These service providers are architects, engineers, builders, consultants, and equipment vendors. We note that the combined respondents have worked on 13 out of the 26 final licensed facilities in Massachusetts, and all are currently active with new projects in Massachusetts.
The responses provided by the SPs closely align with direct experience that ERS has with projects in Maine, Massachusetts, Nova Scotia, and Colorado, and are further supported by RII PowerScore data, a national self-reported cannabis facility database. The only variance unique to Massachusetts is the LPD requirement.

While the effort intended to include a survey of cultivators, asking the same basic set of questions the SPs answered, the response rate to outreach was non-existent, or 0%. Over the course of two weeks, the Team reached out to 25 (the sample quota) of 114 cultivators with either provisional or final licenses. The team made multiple attempts to reach each site using publicly available contact information – available through the CCC which typically links to the dispensary page of the associated cultivation facility instead of the cultivation facility itself. The Team has speculated that the timing of the outreach may have been too close to the forthcoming roll-out of reporting and enforcement and that cultivators may have been wary.

1.4 Conclusions

This section is organized by end use. While the study was able to identify ISP for some systems and end uses, there are many other systems where no ISP was identified through this study therefore site-specific baselines for energy efficiency projects are appropriate. The results of the interviews and the experience of the DNV GL Team in the cannabis sector illustrates the nature of a new industry with unique facility needs and loads and a wide variety of facility solutions in an attempt to meet those needs. The industry is still in its nascent stage, and data on in-situ energy use, energy end-use allocations, and energy efficiency opportunities are limited at this time. As the industry matures, the ISPs in this report are likely to change, and new ISPs are likely to emerge. In the meantime, many potential cannabis cultivation energy efficiency projects will require site-specific baselines to ensure the best representation of a specific project’s energy impact.

1.4.1 Horticultural lighting

Horticultural lighting is the primary process instrument in indoor cultivation facilities. Horticultural lighting technologies include high-pressure sodium (HPS), metal halide (MH), ceramic metal halide (CMH), fluorescent, and light-emitting diode (LED) technologies. Fixture types and run hours vary by growth phase (seedling/clones, mother plants, vegetative growth, flower/bloom). The CCC regulations substantially impacted horticultural lighting.

Aside from the date of licensing, the only other differentiator in ISP was by the size of the facility post-CCC regulations. ISP did not vary by the market served nor by whether the facility was a retrofit or new construction.

1.4.1.1 Horticultural lighting practice before CCC regulations

Before the CCC regulations, Massachusetts facilities followed national trends selecting specific technologies to serve the different growth phases. However, these facilities must now comply with CCC regulations by 2021, which require dual baseline treatment to calculate lifetime savings.

\[
\text{kWh}_{\text{savings lifetime}} = \text{first period kWh}_{\text{savings preCCC}} + \text{second period kWh}_{\text{savings postCCC}}
\]

Table 1-1 summarizes the baseline horticultural lighting practices before the adoption of CCC regulations in March 2018, which are considered the baseline for first-period savings.
Table 1-1. Horticultural lighting ISP before CCC regulations – first period savings

<table>
<thead>
<tr>
<th>Stage</th>
<th>ISP Technology</th>
<th>ISP Photoperiod - Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flower/bloom</td>
<td>1,000-watt double-ended HPS, with electronic ballast</td>
<td>12</td>
</tr>
<tr>
<td>Vegetative</td>
<td>1,000-watt single-ended metal halide</td>
<td>18</td>
</tr>
<tr>
<td>Clone/seedling</td>
<td>4LT5HO fluorescent</td>
<td>24</td>
</tr>
<tr>
<td>Mother</td>
<td>1,000-watt single-ended metal halide</td>
<td>18</td>
</tr>
</tbody>
</table>

All licensed facilities must comply with 935 CMR 500, including facilities that were designed and built before the CCC regulations. Functionally, existing facilities will have two ways to comply with the HLPD requirements if their existing design exceeds that threshold: 1) facilities can retrofit high-intensity fixtures (e.g., HPS and MH) with LED fixtures, or 2) facilities can reduce the percentage of their cultivation area in active use while maintaining the existing high-intensity fixtures over that reduced footprint of the plants. The CCC regulations define canopy as the following:

"Canopy means an area to be calculated in square feet and measured using clearly identifiable boundaries of all areas(s) that will contain mature plants at any point in time, including all of the space(s) within the boundaries, canopy may be noncontiguous, but each unique area included in the total canopy calculations shall be separated by an identifiable boundary which include, but are not limited to: interior walls, shelves, greenhouse walls, hoop house walls, garden benches, hedge rows, fencing, garden beds, or garden plots. If mature plants are being cultivated using a shelving system, the surface area of each level shall be included in the total canopy calculation."

Therefore, canopy can be defined by the area of the room, not the area or footprint of the actual plants. This path of compliance is illustrated in Appendix A.

A keyword in the above definition of canopy is "mature." The CCC defines a "mature" plant per the Massachusetts Seed-to-Sale Guidance, which defines mature plants as plants greater than 8 inches tall and immature plants as a non-flowering plant that is no taller than 8 inches and no wider than 8 inches produced from a cutting, clipping, or seedling. Under typical cultivation practices, it is recommended to define all plants in vegetative, mother, and flower rooms as mature and clones or nursery cuttings as immature.

Table 1-2 summarizes the maximum HLPD permitted after the adoption of CCC regulations in March 2018. While the pre-CCC ISP is technology-based, the post-CCC ISP is based on the maximum HLPD, in watts per square foot, permitted under 935 CMR 500. The lighting power density is calculated across all mature canopy space. Mature canopy space includes flower canopy, vegetative canopy, and mother canopy. The canopy of the clones should not be included in the overall calculation of mature canopy.

When comparing ISP horticultural lighting options against more-efficient options, it is critical to ensure that both designs provide equivalent photosynthetically active radiation (PAR) to the canopy leaf surface. The measure of PAR at the leaf surface is referred to as the PPFD. If both the ISP and more-efficient options produce equivalent PPFD, than the difference in LPD between the two options provides a more accurate
representation of the horticultural lighting equipment (HLE) wattage reduction. If the PPFD of the two options is not equivalent, then the LPD comparison will be inaccurate, as it is not based on equivalent useful light.

**Table 1-2. Horticultural lighting ISP after CCC regulations of March 2018**

<table>
<thead>
<tr>
<th>Cultivation Tier</th>
<th>Permitted Canopy Area – square feet</th>
<th>CCC Maximum HLPD – watts/sf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>1 - 10,000</td>
<td>50</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>10,001 – 100,000</td>
<td>36</td>
</tr>
</tbody>
</table>

### 1.4.2 Environmental conditioning

Maintaining proper environmental conditions is critical to the productivity of a cannabis facility and to act as a primary line of defense against biological contamination such as powdery mildew (PM). There are substantial sensible heat loads from the horticultural lights and large latent loads from the transpiration of the plants. Most of the irrigation water introduced to the plants is released into the room's atmosphere through transpiration. That moisture then must be removed from the space to maintain environmental targets. Managing these sensible and latent loads contributes to high cooling and dehumidification energy use.

The interview responses indicated that the CCC regulations had not impacted ISP for HVAC and dehumidification systems. The interview responses did demonstrate a relationship between the HVAC technology in use and the size of the facility, although not by market served or whether the facility was a retrofit or new construction. The sizing of HVAC systems should be based on the anticipated sensible and latent loads. The diversity in the materials and layout of the cultivation space, as well as variance in cultivation methodologies, necessitate site-specific load calculations.

Table 1-3 summarizes the ISP findings for environmental conditioning.

**Table 1-3. Space-cooling ISP**

<table>
<thead>
<tr>
<th>Facility Canopy Area – Square Feet</th>
<th>HVAC Technology ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>Direct expansion (DX) type systems</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>Chilled water systems</td>
</tr>
</tbody>
</table>

The Team also found a relationship between the use of supplemental dehumidification units and heat-pump-based HVAC systems, as shown in Table 1-4. ISP for supplementary dehumidification is portable unit dehumidifiers.
Table 1-4. HVAC technology and supplemental dehumidification ISP

<table>
<thead>
<tr>
<th>HVAC Technology</th>
<th>Supplemental Dehumidification Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-splits</td>
<td>Supplemental portable dehumidification</td>
</tr>
<tr>
<td>Variable refrigerant flow (VRF)</td>
<td>Supplemental portable dehumidification</td>
</tr>
<tr>
<td>Air-source or water-source heat pump</td>
<td>Supplemental portable dehumidification</td>
</tr>
<tr>
<td>Split or packaged DX systems</td>
<td>No ISP. Site-specific baselines are needed to assess the potential impact of supplemental dehumidification.</td>
</tr>
<tr>
<td>Chilled water systems</td>
<td>No supplemental dehumidification</td>
</tr>
</tbody>
</table>

The findings in Table 1-4, above, are based on the experience of the interview responders with commercial HVAC equipment designed for space cooling applications serving indoor cultivation facilities. The responses do not reflect systems specifically designed for controlled environment horticulture (CEH). There are heat-pump based systems optimized for CEH that are reported to have significantly improved humidity control compared to commercial space cooling heat-pump-based systems.

Table 1-5 presents the findings on HVAC control systems relative to the HVAC technology type.

Table 1-5. HVAC systems and controls ISP

<table>
<thead>
<tr>
<th>HVAC Technology</th>
<th>HVAC Control Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaged or split DX system</td>
<td>Operation of the HVAC unit based on the dry-bulb temperature of the space</td>
</tr>
<tr>
<td>Chilled water system</td>
<td>Automated central system</td>
</tr>
</tbody>
</table>

1.4.3 Extraction equipment

Cannabis product manufacturers prepare concentrates, edibles, tinctures, or other consumer products. Processes to extract cannabinoids and terpenes are solvent-based and typically make use of hydrocarbons (ethanol, propane, or butane) or supercritical CO₂ as the solvent. Common CO₂ extraction systems require dedicated air compressors and process chillers and are energy-intensive. Extraction-based products continue to gain market share, and energy use associated with this process should not be overlooked, as 51% of sales in Massachusetts between 11/20/18 and 06/16/19 were concentrate or infused products.

The interviews found no ISPs within this segment of the industry at this time. The raw material varies and may include flower, trim, trichomes, or fresh-frozen whole plant material. Numerous extraction techniques are used to create a wide variety of product types. While interviews indicated that system types are a function of raw material inputs and the targeted end product, none of the interview respondents had experience quantifying the energy impacts of product manufacturing facilities or potential energy efficiency measures or practices. Energy efficiency projects considering cannabis extraction and product manufacturing equipment should receive site-specific baselines.
If PAs are considering a project in a product manufacturing facility, the baseline and proposed systems should be capable of processing the same raw material into the same product to ensure a comparison of systems with similar capabilities.

These facilities need further study to better quantify energy end use, productivity, and energy efficiency opportunities in extraction process equipment.

### 1.5 Recommendations

Based on the findings and conclusions of this study, the DNV GL Team offers two recommendations:

**R1: Use identified ISP for baseline**

The Team recommends the use of the ISP practices identified in this study by implementers as the baselines for projects and by evaluators when evaluating those projects. For all systems and equipment where an ISP was not identified, a site-specific baseline should be used. A summary of the conclusions is presented in Table 1-6. Note that prior to CCC regulations applies to facilities licensed before March 2018.

**Table 1-6. Summary of ISP findings**

<table>
<thead>
<tr>
<th>Horticultural lighting ISP prior to CCC regulations - technology-based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stage</strong></td>
</tr>
<tr>
<td>Flower/bloom</td>
</tr>
<tr>
<td>Vegetative</td>
</tr>
<tr>
<td>Clone/seedling</td>
</tr>
<tr>
<td>Mother</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Horticultural lighting ISP after CCC regulations - LPD based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cultivation Tier</strong></td>
</tr>
<tr>
<td>Tiers 1-2</td>
</tr>
<tr>
<td>Tiers 3-11</td>
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</tbody>
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<table>
<thead>
<tr>
<th>HVAC technology by building size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facility Building Area – square feet</strong></td>
</tr>
<tr>
<td>Tiers 1-2</td>
</tr>
<tr>
<td>Tiers 3-11</td>
</tr>
</tbody>
</table>
### Dehumidification practice by associated HVAC technology

<table>
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<td>Chilled water systems</td>
<td>No supplemental dehumidification</td>
</tr>
</tbody>
</table>

### HVAC system control types by associated HVAC technology

<table>
<thead>
<tr>
<th>HVAC Technology</th>
<th>HVAC Control Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaged or split DX system</td>
<td>Operation of the HVAC unit based on the dry-bulb temperature of the space.</td>
</tr>
<tr>
<td>Chilled water system</td>
<td>Automated central system</td>
</tr>
</tbody>
</table>

### R2: Future research

The CCC regulations require annual reporting from licensed facilities on annual electric energy use, annual fuel use, annual production values, and information on the facility’s lighting and HVAC systems. Within 12 to 18 months, the CCC should accrue a substantial body of information on the make-up and performance of cultivation and product manufacturing facilities in Massachusetts. The PAs should consider revisiting this study later to leverage the forthcoming facility data collection. Various levels of access to the anonymous data will be available through the RII PowerScore tool.

In the creation of this document, stakeholders identified some unresolved questions that implementers are dealing with to support measures. With the post-CCC baselines defined by regulatory compliance, there is no basis for determining the incremental cost of the baseline system without modeling a valid counterfactual design that precisely matches the mandated LPD performance. A collective agreement on the method to presume incremental costs would expedite the implementation of energy efficiency measures.
2 INTRODUCTION

2.1 Study purpose, objectives, and research questions

The DNV GL Team carried out the cannabis cultivation ISP study for the Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants from August 2019 to March 2020. The study's overall purpose was to define ISP in indoor cannabis cultivation in Massachusetts using high rigor methods, which entailed interviews of cultivators, facility design engineers, and vendors/contractors. The study included the following objectives:

1. Identify the ISP for processes and equipment related to the cultivation and preparation of medical and adult-use cannabis, including horticultural lighting, cultivation area HVAC, and extraction process equipment.
2. Identify variances in systems based on other characteristics, including facility size, retrofitted facilities vs. new construction, market served (medical or adult-use), and the CCC regulations, which set minimum efficiency standards for cultivation facilities.
3. Consider how regulations affect practices in the field, especially regarding the retroactive application of Cannabis Control Commission (CCC) efficiency standards and their impact on lifetime savings.
4. For this study, the baseline or ISP is defined as "the equipment or practice specific to the application or sector that is commonly installed absent program intervention."

2.2 Organization of report

The remainder of this report is organized as follows:

- Section 3: Methodology and approach
- Section 4: Data sources
- Section 5: Analysis and results
3 METHODOLOGY AND APPROACH

This section presents a succinct summary of the study methodology and approach (additional details are provided in the appendices).

3.1 Sample design

ERS, as part of the DNV GL Team, constructed three study populations: cultivators, manufacturers (extractions and concentrates), and the design community (including architects, facility design engineers, consultants, and contractors/vendors) using various data sources to capture the full range of market actors in each population.

The source of the cultivator population was the Massachusetts CCC list of cultivation facilities covering the medical and recreational markets and includes both cultivation and extraction facilities. The list includes licensed and provisional facilities that have been built, are in construction, are in the design phase, and/or are still in the development phase. The list of licensed facilities provides the location and size of each facility, and the provisional list provides the name and location of the proposed facility. ERS included the licensed facilities in the population to provide data on how facilities were actually built, and they included those in the provisional stage so that potential trends over time can be identified in the newest facility designs if such a trend exists. The final population is described in Table 3-1, below, and includes facilities that were licensed or submitted for a license on or prior to 09/02/2019.

To identify architects, engineers, and vendors serving this industry, ERS and DMI conducted outreach to architects, engineers, contractors, and vendors to generate lists of firms serving the cannabis market nationally and in Massachusetts. The Team also performed internet research to identify additional interview targets. ERS engaged the National Cannabis Industry Association (NCIA) and the Resource Innovation Institute (RII) to identify key stakeholders and firms serving the cannabis market in Massachusetts.

The Team sampled the cultivator, manufacturer, and service providers separately, with an allocation of 15, 5, and 10 interviews, respectively. Although there were a large number of extraction facilities in the CCC list, the cultivation facilities are more energy-intensive, thus accounting for the allocation. There is no further weighting or segmentation of the population; thus, each sample unit within a segment was selected randomly.

Table 3-1, below, shows the sample group and general population for cultivators, manufacturers, and facility designers, engineers, and contractors/vendors.
### Table 3-1. Sample design summary

<table>
<thead>
<tr>
<th>Metric</th>
<th>Cultivators</th>
<th>Manufacturers</th>
<th>Facility Designers, Engineers, and Contractors/Vendors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source of population</strong></td>
<td>Massachusetts CCC list of licensed and pending licensed facilities as of 09/02/2019</td>
<td>Professional contacts, internet searches, and NCIA and RII outreach</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-profit: 1 Vendor: 8 Total: 29</td>
</tr>
<tr>
<td><strong>Targeted sample size</strong></td>
<td>15</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td><strong>Final sample disposition</strong></td>
<td>0</td>
<td>0</td>
<td>Architects: 2 Cannabis Facility Consultant: 2 MEP Engineer: 3 GC/Engineer: 1 Vendor: 2 Total: 10</td>
</tr>
</tbody>
</table>

### 3.2 Interview guides

The Team developed the interview guides to cover each broad category of interest and to methodically review the design choices and motivations behind key decisions for all areas of interest. The interview guide sections were as follows:

- **Familiarity with Cannabis Technology** – This section allowed interviewers to use skip logic to avoid sections of the survey that interviewees were not proficient with.

- **Horticultural Lighting** – For each room type, interviewers asked about typical fixtures, wattages, LPDs, and target PPFD, as well as controls equipment. Additionally, they asked questions probing for experience and feedback on LED lighting, changes in typical practice, the rationale for design decisions, and program influence.

- **Mechanical Systems and Dehumidification** – These questions covered typical air-side systems, cooling equipment, heating equipment, and dehumidification equipment. Additionally, interviewers asked questions probing for experience and feedback on advanced HVAC equipment configurations, the rationale for design decisions, and program influence.
- **HVAC Controls** – These questions covered typical control systems for HVAC as well as questions probing for experience and feedback on HVAC controls best practices, the rationale for design decisions, and program influence.

- **Extraction Equipment** – This section covered typical extraction equipment and the rationale for design decisions and program influence.

- **General Questions** – The interviewers asked broader questions on the most important facets of facility design, barriers to greater energy efficiency, and the industry's biggest challenges.

The full interview guides are attached in Appendix B.
4 DATA SOURCES

Data sources on this project include expert interviews from cannabis professionals with experience working in Massachusetts facilities. These fall into two groups: cultivators/manufacturers and service providers. Service providers consist of all supporting vendor and consulting professionals that assist in the design and construction of a cannabis facility.

Some gaps exist in the available population of interviewees. Most notably, no cultivators responded to the request for an interview. The Team collaborated with the CCC to identify accurate contact information and conducted web searches and networking to identify quality contact information for the cultivators. Based on the Team's experience in the industry, we can suggest this was partly attributable to the high degree of secrecy that is pervasive in the industry. Industry professionals, especially cultivators, place a high value on their intellectual property related to all facets of the growing process. In these early years of the legal cannabis market, this intellectual property is indeed a valuable asset over potential competing cultivators and manufacturers.

The Team employed data screening during the execution of the service provider interviews. A service provider may have been selected based on their firm's involvement with designing facilities but have no first-hand experience with certain areas of the facility design. By allowing interviewers to focus on parts of the interview guide that were most relevant, the interviews collected the best available insights from the interviews while minimizing dead-end questions and weak responses. For example, cannabis extraction equipment was an area for which several facility designers had little first-hand experience; they simply procured equipment based on the requests of their clients. Interviewers would screen questions based on the interviewee’s stated familiarity with the technology and focus on questions that would generate the most valuable information given the interviewee’s particular experience and skill set. In this example, the interviewer would choose to ask about what types of systems they have observed in facilities and who made those design decisions, rather than the nature of how a particular type of extraction machine was selected. This process was also used for lighting designs with some of the interviewees who had no first-hand experience with lighting selection but merely designed the facility for the given lighting loads specified by their client or lighting designer.

Some deviation from the interview guide was also permitted during interviews. Interviewers were given license to ask follow-up questions that were not included in the interview guide to probe prior responses for unanticipated findings. This also led to a more engaging and personal conversation for the interviewees, which in turn increased the quality of responses.
5 ANALYSIS AND RESULTS

5.1 Horticultural lighting

Horticultural lighting is the primary production process in indoor cultivation facilities and typically represents 50%–70% of a facility’s total electric energy use. Horticultural lighting technologies include high-pressure sodium, metal halide, ceramic metal halide, fluorescent, and LED fixture types. Fixture types and run hours vary by growth phase (seedling/clones, mother plants, vegetative growth, flower/bloom) and by cultivator preference. The flower/bloom stage is by far the most energy-intensive phase of the growth cycle due to the high lighting levels, large sensible and latent loads on the HVAC systems associated with the lighting, and the release of water vapor through plant transpiration.

The service providers were asked what the standard lighting technology was for all cultivation phases prior to the CCC regulations. Table 5-1 summarizes the responses. Percentages represent the total number of projects installed for a given technology based on their experience designing or building a combined total of 18 cannabis cultivation facilities in Massachusetts.

Table 5-1. Horticultural lighting ISP prior to CCC regulations

<table>
<thead>
<tr>
<th>Technology</th>
<th>Flower</th>
<th>Veg</th>
<th>Clone</th>
<th>Mother</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>0%</td>
<td>17% (n=1)</td>
<td>29% (n=2)</td>
<td>13% (n=1)</td>
</tr>
<tr>
<td>HID</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-ended HPS</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Double-ended HPS</td>
<td>90% (n=9)</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Ceramic MH – 315 watts</td>
<td>10% (n=1)</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Metal halide</td>
<td>0%</td>
<td>50% (n=3)</td>
<td>0%</td>
<td>63% (n=5)</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>T5</td>
<td>0%</td>
<td>33% (n=2)</td>
<td>71% (n=5)</td>
</tr>
</tbody>
</table>

The above findings are consistent with the low penetration of flowering LED fixtures presented in the 2016 State of the Cannabis Lighting Market report by the Cannabis Business Times. The 2016 report responses are presented in Figure 5-1.

3 ERS data on indoor cultivation facilities and Resource Innovation Institute data from the PowerScore tool.
4 https://www.cannabisbusinesstimes.com/article/types-of-lighting/
5.1.1 Other ISP considerations

Translation to ISP requires consideration of three other factors relevant to recent project activity: ballast configurations, PAR light equivalency expressed as PPFD, and baseline technology assignments to reflect ISP.

5.1.1.1 Ballast configurations

High-intensity discharge fixtures, including double-ended high-pressure sodium fixtures, are operated with ballasts, and those ballasts can be magnetic or electronic. Magnetic ballasts are less efficient, which brings about the question of whether magnetic ballasts are ISP, particularly for double-ended (DE) HPS flower fixtures.

DE fixtures have contacts at either side of a horizontally mounted lamp, while single-ended (SE) fixtures connect to this fixture in one location and may be oriented vertically or horizontally. Figures 5-2 and 5-3 show a DE and SE lamp, respectively.
As shown in Table 5-1, above, the interviews identified DE HPS fixtures as the ISP for the flower phase prior to CCC regulations. The identification of DE fixtures as the baseline is relevant, as DE fixtures are all but synonymous with electronic ballasts.

The ISP Team conducted internet research to identify the existence and availability of DE magnetic ballasts. The Team was able to find one type of DE magnetic ballast on the market, the Sun System Hard Core 1000-Watt DE HPS Magnetic Ballast. While this ballast is still available through retailers that have it in stock, it is no longer manufactured.

Metal halide (MH) fixtures are similar; the study could not find any DE MH magnetic ballasts available in the market. SE MH fixtures can operate with either magnetic or electronic ballasts, and the study did not identify ISP associated with SE MH ballasts.

5.1.1.2 PAR light equivalency and photosynthetic photon flux density

Photosynthetically active radiation (PAR) is the spectrum of light that drives photosynthesis in plants. Academic studies on non-cannabis crops have shown a strong (nearly one-to-one) relationship between intensity of PAR light and photosynthesis. Since PAR is a major factor in photosynthesis and plant growth, it is important to ensure that comparisons between lighting technologies or designs produce equivalent PAR delivered to the canopy. PAR at the canopy is expressed as photosynthetic photon flux density (PPFD, μmol/m²/s) and is the appropriate metric for comparing lighting designs in terms of equivalent light intensity. While numerous factors influence plant growth, including the different spectrum output of various lighting technologies, establishing equivalent PPFD for baseline and proposed systems currently provides the best method for ensuring the equivalency of light intensity delivered to the plants.

A comparison of different horticultural lighting designs requires modeling to ensure equal PPFD at the canopy, considering the lighting technology and its unique light distribution, fixture spacing, mounting height, and the canopy footprint.

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5 Bugbee, “Effects of Radiation Quality, Intensity, and Duration on Photosynthesis and Growth,” International Lighting in Controlled Environments Workshop
5.1.1.3 Pre-CCC technology baselines

Service providers indicated a mix of technologies servicing the less energy-intense vegetative, clone, and mother stages; however, certain technologies were predominant for each phase of growth. For these scenarios, it may seem appropriate to create a blended baseline, which would require modeling the base case using the mix of technologies appearing in the market. The models take into account the specific fixtures' PAR output, lighting layout in terms of mounting height and fixture spacing, and the resulting photometrics. As noted previously, base-case and proposed/as-built designs must achieve equivalent PPFD at the canopy to make a like comparison. The need for equivalent PFFD and the unique performance of technology types will often result in base-case and proposed designs that do not have an equal quantity of fixtures.

Table 5-2 provides baseline fixture technology for the vegetative and mother phase reflecting the technology blend without LEDs to align with the Baseline Framework, which states: "[the] baseline is the condition that would have existed absent the installed measure." The Team used responses to the interviews and ERS project data to normalize the area of canopy served by each fixture type (T5HO fixtures cover less canopy area than 1,000-watt MH fixtures.) In the vegetative stage, the weighted average wattage normalized to the area of canopy and based on the weight of the responses is 544 watts. The wattage of the predominant fixture used in this stage, 1,000-watt metal halide, is 593 watts. Given that the difference between the wattage of the two technologies used in this phase is only 8% and they perform similarly, we recommend assigning a single technology as the baseline for each growth phase to simplify modeling. The same recommendation is made for the mother phase, where the difference is only 6%.

Table 5-2. Vegetative and mother phase blended baseline wattages

<table>
<thead>
<tr>
<th>Lighting Technology</th>
<th>Weight</th>
<th>Input Wattage</th>
<th>Canopy Cover (sf per fixture)*</th>
<th>Wattage Normalized to 13.5 sf Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000-watt SE metal halide</td>
<td>50%</td>
<td>1055</td>
<td>24</td>
<td>593</td>
</tr>
<tr>
<td>8LT5HO fluorescent</td>
<td>33%</td>
<td>468</td>
<td>13.5</td>
<td>468</td>
</tr>
<tr>
<td><strong>Weighted average baseline vegetative fixture wattage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000-watt SE metal halide</td>
<td>63%</td>
<td>1055</td>
<td>24</td>
<td>593</td>
</tr>
<tr>
<td>8LT5HO fluorescent</td>
<td>25%</td>
<td>468</td>
<td>13.5</td>
<td>468</td>
</tr>
<tr>
<td><strong>Weighted average baseline mother fixture wattage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Based on project data, typical

Given the predominance of SE MH fixtures in survey responses and national data, and the relatively close wattages of the two primary technology types identified, SE 1,000-watt MH fixtures are considered the baseline technology type for vegetative and mother phases.

5.1.2 Pre-CCC horticultural lighting ISP

Based on the survey responses and the findings noted above, ISP for each stage of growth is presented in Table 5-3.
Table 5-3. ISP conclusions for horticultural lighting prior to CCC regulations

<table>
<thead>
<tr>
<th>Stage</th>
<th>ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flower/bloom</td>
<td>1,000-watt double-ended HPS, with electronic ballast</td>
</tr>
<tr>
<td>Vegetative</td>
<td>1,000-watt single-ended metal halide</td>
</tr>
<tr>
<td>Clone/seedling</td>
<td>4LT5HO fluorescent</td>
</tr>
<tr>
<td>Mother</td>
<td>1,000-watt single-ended metal halide</td>
</tr>
</tbody>
</table>

5.1.3 Post-CCC horticultural lighting ISP

Table 5-4, below, summarizes baseline horticultural lighting practices after the adoption of CCC regulations. While the pre-CCC ISP is technology-based, the post-CCC ISP is based on the maximum horticultural lighting power density (HLPD), in watts per square foot, permitted under 935 CMR 500. There are no prohibitions on any given lighting technology or requirements surrounding DesignLights Consortium (DLC) compliance paths. "Canopy space" and "mature" are defined below, as per CCC guidance.

"Canopy means an area to be calculated in square feet and measured using clearly identifiable boundaries of all areas(s) that will contain mature plants at any point in time, including all of the space(s) within the boundaries, canopy may be noncontiguous, but each unique area included in the total canopy calculations shall be separated by an identifiable boundary which include, but are not limited to: interior walls, shelves, greenhouse walls, hoop house walls, garden benches, hedge rows, fencing, garden beds, or garden plots. If mature plants are being cultivated using a shelving system, the surface area of each level shall be included in the total canopy calculation."

Therefore, the canopy can be defined by the area of the room, not the area or footprint of the actual plants. This path of compliance is illustrated in Appendix A.

The CCC defines a "mature" plant per the Massachusetts Seed-to-Sale Guidance, which defines mature plants as plants greater than 8 inches tall and defines "immature" plants as a non-flowering plant that is no taller than 8 inches and no wider than 8 inches produced from a cutting, clipping, or seedling. Under typical cultivation practices, it is recommended to define all plants in vegetative, mother, and flower rooms as mature and clones or nursery cuttings as immature.

As a secondary compliance path, the CCC regulations allow a facility to forgo the HLPD approach and calculations and instead install fixtures that are listed by the DLC Horticultural Qualified Products List (HQPL) and which exceed the DLC HQPL minimum qualifying photosynthetic photon efficacy (PPE) requirement by 15%. The DLC has a specific filter on its products website for listed fixtures that meet Massachusetts CCC requirements.6 This secondary compliance path does not impact the ISP findings or the recommended approach for post-CCC energy impact calculations. The path simplifies the process for the cultivator while providing reasonable assurance to the CCC of efficient lighting.

When comparing ISP horticultural lighting options against more-efficient options, it is critical to ensure that both designs provide equivalent PAR to the canopy leaf surface. As stated before, the measure of PAR at the

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6 [https://www.designlights.org/horticultural-lighting/search/](https://www.designlights.org/horticultural-lighting/search/)
leaf surface is referred to as the PPFD. If both the ISP and more-efficient options produce equivalent PPFD, then the difference in LPD between the two options provides a more accurate representation of the HLE wattage reduction. If the PPFD of the two options is not equivalent, then the LPD comparison will be inaccurate as it is not based on equivalent useful light.

Table 5-4. Horticultural lighting ISP after CCC regulations

<table>
<thead>
<tr>
<th>Cultivation Tier</th>
<th>Permitted Canopy Area – square feet</th>
<th>CCC Maximum HLPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>1 – 10,000</td>
<td>50 watts/sf</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>10,001 – 100,000</td>
<td>36 watts/sf</td>
</tr>
</tbody>
</table>

5.1.3.1 Tiered cultivation

Of the respondents familiar with tiered cultivation in the flowering stage (n=5), each provided one of three responses regarding ISP lighting technology. Respondents indicated that tiered cultivation is either only done with LED fixtures (2 responses); done with LED or 315-watt ceramic metal halide (CMH) fixtures (1 response); or done with LED, CMH, or DE HPS provided there was enough ceiling height to allow for the necessary spacing between the hot HPS fixtures and the canopy (2 responses).

The CCC regulations mandate the baseline through the prescribed HLPD requirements, but given the varied responses and relatively new approach of flowering in tiers or vertical levels, the study recommends site-specific assessments for tiered cultivation. The ISP for tiered cultivation in the flowering stage is the same as non-tiered, with the additional qualification that the height of the grow room must be able to accommodate the height of the racks, the grow media/container, the height of the mature plant, appropriate spacing between the mature canopy and the bottom of the fixture, and the technology and height of the fixture itself.

5.1.3.2 Horticultural lighting controls

Survey respondents were asked what the ISP is for horticultural lighting controls. All respondents indicated that simple timers were the ISP for HID lighting technologies and LED fixtures. These measures are not addressed by the CCC regulations.

Survey respondents were asked about alternative control strategies such as dimming and adjustable light racks. The following discussion summarizes their responses.

Dimming – Those respondents familiar with HPS and LED horticultural lighting indicated that dimming strategies with HID fixture types were manually operated, uncommon, and inconsistently deployed. Dimming strategies for LED systems were noted as more common due to the simplicity of dimming the fixture through a simple 10-volt signal but still not widely adopted in practice. Where dimming is used, it is used to transition the plant between stages to minimize the shock of moving from a lower PPFD to a higher PPFD.

Considering dimming as an efficiency measure presents an issue of light equivalency. During the transient dimming period, less light is delivered to the plant than in a non-dimming system over that same period. Light intensity is a prime factor in plant growth, and so on the surface, the comparison does not appear to be "apples to apples." Those who advocate for dimming, however, believe that any reduction in delivered
light during the dimming period is made up for by eliminating the shock of a hard transition from a lower to a higher PPFD.

The study found no ISP for dimming. Where projects proposed dimming horticultural light fixtures as an energy-saving mechanism, the savings calculations should make use of site-specific baselines.

**Adjustable/Moving Lights** – All respondents were familiar with the concept of moving lights vertically to maintain a consistent distance from the fixture to the canopy, but very few have seen it in practice. Individually adjusting hundreds of light fixtures every week is not practical. Where respondents had seen this, lights were mounted to frames, and the frames were moved up and down.

The study concludes that adjustable or moving lights are not ISP.

### 5.1.4 Compliance enforcement

Based on the CCC 935 CRM 500 regulations, and the recently released CCC *Energy and Environment Compiled Guidance*, the CCC intends to enforce the requirements through several mechanisms:

- During license application, the applicant must submit drawings stamped by a Massachusetts licensed architect or mechanical engineer, and the architect or mechanical engineer must submit a signed narrative attesting that the design meets the CCC requirements.
- Cultivators must keep two copies of stamped drawings on-site, which document the horticultural lighting systems and the canopy areas. These drawings are to be surrendered immediately to CCC inspectors upon request.
- The CCC has the authority to inspect a cultivation facility at any time.
- Cultivators are required to submit annual energy consumption data, annual production data, and facility equipment details every year that they reapply for a license.

### 5.2 HVAC systems

The responses to the questions on HVAC ISP were varied and included packaged and split direct expansion (DX) systems, heat pumps and mini-splits, variable refrigerant flow (VRF), air and water-cooled chillers, and gas-fired chillers.

All respondents indicated that the CCC regulations on HVAC had not impacted ISP. The regulations state that facilities must meet the State building code.

> Heating Ventilation and Air Condition (HVAC) and dehumidification systems must meet Massachusetts Building Code requirements and all Massachusetts amendments (780 CMR: State Building Code), IECC Section C.403, or ASHRAE Chapter 6 as applied or incorporated by reference in (780 CMR: State Building Code).

The referenced code impacts non-process areas of cultivation facilities, but the cultivation spaces are exempt from the code as they are considered process spaces.

Table 5-5 summarizes the survey responses. Percentages represent the total number of times survey respondents (n=10) indicated they had experience with a given technology in Massachusetts. For example, a respondent may have indicated that they had experience with DX-based systems and chiller systems. Some respondents only had experience with one technology type, while others had experience with multiple
technology types. These individual projects were summed across all survey respondents that had experience with the technology installed at a facility.

Table 5-5. Environmental conditioning ISP practices

<table>
<thead>
<tr>
<th>System Type</th>
<th>Percent of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-splits</td>
<td>7% (n=1)</td>
</tr>
<tr>
<td>Chiller</td>
<td>Electric 33% (n=5)</td>
</tr>
<tr>
<td></td>
<td>Gas-fired 13% (n=2)</td>
</tr>
<tr>
<td>DX units</td>
<td>36% (n=5)</td>
</tr>
<tr>
<td>Water source heat pumps</td>
<td>7% (n=1)</td>
</tr>
<tr>
<td>VRF</td>
<td>7% (n=1)</td>
</tr>
</tbody>
</table>

The above responses indicate that most facilities operate with DX HVAC systems or chilled water systems. Further probing did reveal a correlation between HVAC system type and the size of the facility being served. Respondents indicated that tier 1 and tier 2 facilities typically use DX units or chilled water systems, while tier 3 and larger facilities nearly exclusively make use of chilled water systems.

5.2.1.1 Natural gas-fired chillers

The interview specifically asked about gas-fired chillers and what alternatives were considered for facilities with gas-fired chillers. Interview responses stated that electric chillers were the most common alternative to gas-fired chillers. Facilities pursuing gas-fired chillers had already decided to use a chiller-based system and were weighing the capital and operating costs of an electric chiller against a natural-gas-fired chiller. Other factors cited in the pursuit of gas-fired chillers include the facility proximity to natural gas and the electric service capacity at the facility location. Facilities that do not have ready access to sufficient electrical service may weigh the economics of electric service upgrades and electric chiller operation against the capital and operational costs of gas-fired chillers.

5.2.2 Dehumidification

Substantial dehumidification is required in indoor cultivation facilities. The plants constantly release moisture through transpiration. The majority of that moisture is released as water vapor during the period when the lights are on, with smaller quantities released when the lights are off. Indoor facilities attempt to introduce as little outdoor air as possible, meaning all HVAC loads, sensible and latent, must be removed mechanically. The unusually high dehumidification loads experienced at many facilities exceeds the capacity of commercial duty equipment designed for typical space-cooling applications. As a result, many facilities require supplemental dehumidification in addition to their primary HVAC systems.

The survey respondents were asked where supplemental dehumidification was needed. Of the ten respondents, six had experience with supplemental DH systems. Each of their responses is provided in Table 5-6.
Table 5-6. Use of supplemental dehumidification

<table>
<thead>
<tr>
<th>Where is supplemental dehumidification used?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always with heat pumps</td>
</tr>
<tr>
<td>Always with VRF</td>
</tr>
<tr>
<td>Only with mini-splits</td>
</tr>
<tr>
<td>For facilities under 30,000 sf served by DX systems</td>
</tr>
<tr>
<td>20% of DX facilities</td>
</tr>
<tr>
<td>In most facilities after they start up and can't control conditions [responder works with many mini-split facilities]</td>
</tr>
</tbody>
</table>

All respondents surveyed who had experience with heat-pump-based technologies (mini-splits, water source heat pumps, VRF) indicated poor performance, particularly with maintaining relative humidity. This stands to reason, as most heat pump-based systems are designed for general comfort cooling and have high sensible heat ratios (SHR). SHR indicates how much of a unit's total cooling capacity is sensible (cooling), as opposed to latent (dehumidifying). Though interview respondents did not have experience with ground source heat pumps (GSHPs), these systems typically have high SHRs relative to cannabis facility loads. A high SHR indicates that a unit is not well suited for dehumidification applications. SHR in flower rooms can reach as low as 0.4 during lights-off conditions. It is important to note that the core technology itself, the heat pump, is not a poor fit by virtue of the technology but by the applications those systems on the market have been designed to serve. Commercial heat-pump-based systems are typically designed for cooling of human-occupied spaces and are therefore designed to meet those loads. There is no fundamental reason that heat-pump technology can't be used to develop efficient applications in controlled environment horticulture, and, in fact, some vendors are offering heat-pump based systems designed for the loads of cultivation facilities.

The common theme is that heat-pump-based systems most often require supplemental dehumidification. This is achieved through portable units, such as Quest7 and Anden,8 that are marketed to the indoor cultivation industry. Outside of this observation, each facility is unique in layout, lighting loads, transpiration loads, and primary HVAC systems, all of which impact the dehumidification needs of the space.

5.2.2.1 Dehumidification cycling

The survey probed further on the question of dehumidification to understand whether systems were dehumidifying continuously or were cycling. All respondents agree that plant transpiration is continuous, though rates of transpiration vary, so there is a constant need for dehumidification.

For DX systems, dehumidification cycles. As discussed below, survey respondents indicated that simple thermostat-based controls are ISP for DX-based systems. The DX system operates continuously if there is a call for cooling. If all dehumidification is managed through the primary DX system, then the humidity will

---
7 https://www.questclimate.com/
8 https://www.anden.com/product_category/dehumidifiers/
begin to rise as soon as the unit cycles off and will continue to rise until there is another call for cooling. If the facility makes use of portable DH units, then the units, operating on humidistat control, will run until they satisfy the relative humidity space setting. When the units shut off, they typically have a 10-minute window where they will not restart for compressor safety. During this time, the humidity will rise until there is a call for dehumidification and the 10-minute off cycle is complete.

All respondents who have experience with chilled water-based systems indicated that dehumidifying should be happening continuously, with little to no cycling. By varying system parameters such as fan speed and cooling and reheat coil valve positions, the supply air conditions can be tuned to the dehumidification needs of the space. The respondents indicate that this provides a more stable environment without spikes in temperature and humidity and that running at part-load conditions is more efficient than cycling equipment on and off.

5.2.3 HVAC controls

The survey investigated ISP for HVAC control systems, and a strong relationship emerged between HVAC system type and basic HVAC control type, as shown in Table 5-9, farther below. Further discussion on the responses indicates that chilled-water-based systems are served by central automated systems, while split and packaged DX systems are served by simple thermostat control. While some DX systems are tied into central control systems, those systems do not provide the sophisticated and dynamic control strategies that can be achieved with chilled water systems.

Respondents with direct controls experience, both consultants and vendors, indicated that sophisticated control strategies presented the opportunity for precise control and energy efficiency, but if they were not set up properly and monitored regularly, the performance would suffer. One controls engineer stated "[HVAC controls are a] terrible part of this industry."

This respondent went on to discuss issues with equipment and controls system compatibility, equipment-based controls overriding central control system logic, and other challenges encountered. All respondents indicated that environmental control was the primary concern related to HVAC system operation, with energy efficiency lower on the priority list. Respondents indicated that opportunities for improved control systems represented an area for energy efficiency.

The Team also found a relationship between the use of supplemental dehumidification units and heat-pump-based HVAC systems, as shown in Table 5-7.

Table 5-7. HVAC technology and supplemental dehumidification ISP

<table>
<thead>
<tr>
<th>HVAC Technology</th>
<th>Percent of Projects Requiring Supplemental Dehumidification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-splits</td>
<td>100%</td>
</tr>
<tr>
<td>Variable refrigerant flow (VRF)</td>
<td>100%</td>
</tr>
<tr>
<td>Air-source or water-source heat pump</td>
<td>100%</td>
</tr>
<tr>
<td>DX systems</td>
<td>30%</td>
</tr>
<tr>
<td>Chilled water systems</td>
<td>0%</td>
</tr>
</tbody>
</table>
The findings in Table 5-7, above, are based on the experiences of the interview responders with commercial HVAC equipment designed for space-cooling applications serving indoor cultivation facilities. The responses do not reflect systems specifically designed for controlled environment horticulture (CEH). There are heat-pump based systems optimized for CEH that are reported to have significantly improved humidity control compared to commercial space-cooling heat-pump based systems.

### 5.2.4 HVAC ISP summary

The findings on HVAC system type and controls indicate that ISP for HVAC systems can be assigned as per Table 5-8. This is based on the relationships between facility HVAC type, and HVAC type and HVAC control types as identified in the surveys.

**Table 5-8. Environmental conditioning ISPs**

<table>
<thead>
<tr>
<th>Facility Size – Square Feet</th>
<th>HVAC Technology ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>Direct expansion (DX) type systems</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>Chilled water systems</td>
</tr>
</tbody>
</table>

Table 5-9 reports the relationships identified in the interviews between HVAC system type and HVAC control type. Note that this table largely reflects control equipment and not control strategies.

**Table 5-9. HVAC systems and controls ISP**

<table>
<thead>
<tr>
<th>HVAC Technology</th>
<th>HVAC Controls ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaged or split DX system</td>
<td>The operation of the HVAC unit is based on the dry-bulb temperature of the space served. No hot-gas reheat for humidity control. Fixed speed supply fans.</td>
</tr>
<tr>
<td>Chilled water system</td>
<td>Automated central system. Site-specific baseline for control strategies.</td>
</tr>
</tbody>
</table>

The responses for split and packaged DX systems indicate that ISP control systems for these unit types are simple thermostats responding to the dry-bulb temperature of the space. There is no further coordination or optimization of these unit types as part of the ISP. ISP control for supplemental dehumidification should be based on static lights-on and lights-off relative humidity setpoints, as detailed in the facility design.

While the responses for chilled water systems indicate that central automation is ISP for these system types, the study did not find ISP as related to HVAC control strategies. A central automation system does not indicate a sophisticated or optimized control strategy. Therefore, ISP for HVAC control strategies for chilled water systems should be based on a central automated system, but the baseline control strategy should be site-specific and based on a strategy that allows the baseline system to maintain the same environmental setpoints as the proposed higher-efficiency control system or strategy.

### 5.3 Extraction equipment

Marijuana product manufacturers prepare concentrates, edibles, tinctures, or other consumer products. Processes to extract cannabinoids and terpenes are solvent-based and typically make use of hydrocarbons.
(ethanol, propane, or butane) or supercritical CO$_2$ as the solvent. Common CO$_2$ extraction systems require dedicated air compressors and process chillers and are energy-intensive. Extraction-based products continue to gain market share, and energy use associated with this process should not be overlooked, as 51% of sales in Massachusetts between 11/20/18 and 06/16/19 were concentrate or infused products.

The interviews found no ISPs within this segment of the industry at this time. The raw material varies and may include flower, trim, trichomes,$^9$ or fresh-frozen whole plant material. Numerous extraction techniques are used to create a wide variety of product types. While interviews indicated that system types are a function of raw material inputs and the targeted end product, none of the interview respondents had experience quantifying the energy impacts of product manufacturing facilities or potential energy efficiency measures or practices.

The study concludes that there is no ISP for cannabis extraction and product manufacturing processes or equipment at this time, and site-specific baselines should be used. If PAs are considering an energy efficiency project associated with cannabis extraction or cannabis product manufacturing equipment, a product manufacturing facility, the baseline, and proposed systems should be capable of processing the same raw material into the same product to ensure comparison of systems with similar capabilities.

These facilities need further study to better quantify energy end use, productivity, and energy efficiency opportunities.

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$^9$ A small outgrowth from the epidermis of a plant
APPENDIX A. MASSACHUSETTS CANNABIS CONTROL COMMISSION ENERGY AND ENVIRONMENT COMPILED GUIDANCE
Energy and Environment
Compiled Guidance

January 2020

Massachusetts Cannabis Control Commission:

Steven J. Hoffman, Chairman
Kay Doyle, Commissioner
Jennifer Flanagan, Commissioner
Britte McBride, Commissioner
Shaleen Title, Commissioner
Shawn Collins, Executive Director
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I. Overview and Applicability

This guidance is not legal advice. It is meant to assist licensed Marijuana Establishments (MEs) with developing energy efficiency and environmental best practices, and to comply with state laws and regulations. Please consult an attorney if you have any questions regarding the legal requirements that apply.
II. Energy

A. Guidance on Basic Energy Efficiency Practices & Reporting for Marijuana Establishments

The following guidance is provided to assist applicants seeking to be licensed as an adult-use ME under 935 CMR 500.000: Adult Use of Marijuana. This guidance also applies to Medical Marijuana Treatment Centers (MTCs, formerly known as Registered Marijuana Dispensaries), seeking to be licensed under 935 CMR 501.000: Medical Use of Marijuana. Please note that Cultivation Facilities, whether licensed as an ME or MTC (ME/MTC), must also comply with additional requirements set forth in Guidance on Energy Efficiency Standards & Reporting for Cultivation Facilities [see page 10].

All applications submitted on or after July 1, 2020, if they are not otherwise exempted, must comply with the energy efficiency standards and reporting requirements described in this guidance. This guidance is not legal advice. If you have questions regarding the legal requirements for licensure in the Commonwealth, you are encouraged to consult an attorney. An ME/MTC is responsible for complying with any revisions to this guidance that may be issued if legal or regulatory requirements change.

Applicants

Consideration of energy efficiency and conservation should occur during the application process and throughout the operational life of a facility. During the application process, an ME/MTC must submit a summary of their written operating procedures regarding energy efficiency and conservation as part of their Management and Operation Profile in accordance with 935 CMR 500.101(1)(c)10. and 500.105(15), or 935 CMR 501.101(1)(c)10. and 501.105(15). As part of the Architectural Review process, additional information should be submitted at the same time as building plans after receipt of a Provisional License. Please note that applicants seeking a Transporter or Delivery license have different issues, which are addressed in a separate section below.

An ME/MTC is required\(^1\) to engage in:

\[(1) \text{Identification of potential energy-use reduction opportunities (such as natural lighting and energy efficiency measures), and a plan for implementation of such opportunities;}\]

\(^1\) 935 CMR 500.105(1)(q) & 500.105(15); 935 CMR 501.105(1)(q) & 501.105(15).
Consideration of opportunities for renewable energy generation, including, where applicable, submission of building plans showing where energy generators could be placed on the site, and an explanation of why the identified opportunities were not pursued, if applicable;

Strategies to reduce electric demand (such as lighting schedules, active load management, and energy storage); and

Engagement with energy efficiency programs offered pursuant to M.G.L. c. 25, § 21, or through municipal lighting plants.

The guidance will go through each item above.

Identification of potential energy-use reduction opportunities and a plan for implementation of such opportunities.

There are many opportunities in an ME/MTC to reduce energy usage and costs through energy efficient equipment and operations. Lighting is a major energy user in everything from retail spaces, to cultivation, and back-office operations. Heating and air conditioning are also large drivers of energy use for all buildings in the Northeast. It is recommended that the design team for an ME/MTC include energy professionals who will review facility and equipment needs and make recommendations for optimal facility equipment choices based on energy usage.

The applicant must address how its written operating procedures in the Management and Operations Profile packet will incorporate the following elements:

- Description of how the ME/MTC will monitor energy consumption and make adjustments to operations based on energy-usage data;
- Procedures for identifying energy savings opportunities as part of any facility upgrades, renovations, or expansions; and
- Procedures for identifying energy savings opportunities when equipment fails and needs to be replaced.

At the Architectural Review stage, further information should be submitted to demonstrate actual consideration of energy reduction opportunities, including a list of energy reduction opportunities that were considered. Information should include whether opportunities are being implemented, will be implemented at a later date, or not planning to be implemented. An ME/MTC should also include a summary of information that was considered to make the decision (i.e. costs, available incentives, and bill savings). As a general matter, submission of a Mass Save® or municipal light plant (MLP) audit report or rebate applications should suffice to demonstrate compliance with this item.
Consideration of opportunities for renewable energy generation, including, where available, submission of building plans showing where energy generators could be placed on the site, and an explanation of why the identified opportunities were not pursued, if applicable.

Renewable energy such as solar panels, wind turbines, and renewable thermal can reduce and stabilize energy costs for an ME/MTC. The applicant must address how its written operating procedures in the Management and Operations Profile packet will incorporate the following elements:

- Description of how the ME/MTC will make energy supply decisions and regularly evaluate renewable options;
- Procedures for identifying renewable or alternative energy opportunities as part of any facility upgrades, renovations, or expansions; and
- Procedures for identifying renewable or alternative energy opportunities when equipment fails and needs to be replaced.

At the Architectural Review stage, further information should be submitted to demonstrate actual consideration of renewable energy generation opportunities, including a list of renewable or alternative energy reduction opportunities that were considered. Information should include whether opportunities:

- are being implemented;
- will be implemented at a later date; or
- are not planned to be implemented.

An ME/MTC should include a summary of information that was considered to make a decision (i.e. costs, available incentives, and bill savings). ME/MTCs should consider incentives through programs which can help offset costs of renewable and alternative energy installation, such as:

- Massachusetts Department of Energy Resources’ Solar Massachusetts Renewable Target (SMART) (http://masmartsolar.com/);
- Renewable Portfolio Standard (https://www.mass.gov/guides/rps-class-i-and-class-ii-statement-of-qualification-application); and
**Strategies to reduce electric demand (such as lighting schedules, active load management, and energy storage).**

Demand is how much electricity an ME/MTC can use at a given time in its facility – more demand means more electricity capacity is needed, and an ME/MTC pays for this capacity on electricity bills.

The applicant must address how its written operating procedures in the Management and Operations Profile packet will incorporate the following elements:

- Description of how the ME/MTC will monitor energy demand and make adjustments to operations based on data; and

- Procedures for participation in load curtailment, energy storage, or other active demand management programs (as applicable).

At the Architectural Review stage, further information should be submitted to demonstrate actual consideration of demand reduction opportunities, including whether opportunities are being implemented, will be implemented at a later date, or not planning to be implemented. Include a summary of information that was considered to make a decision (i.e. costs, available incentives, and bill savings). As a general matter, submission of a Mass Save® or MLP audit report or rebate applications should suffice to demonstrate compliance with this item.

**Engagement with energy efficiency programs offered pursuant to M.G.L. c. 25, § 21, or through municipal lighting plants.**

The Mass Save® programs ([https://www.masssave.com/en/saving/business-rebates/](https://www.masssave.com/en/saving/business-rebates/)) provide financial incentives for energy efficiency and demand reduction measures, including efficient lighting, heating ventilation and air conditioning (HVAC), and other equipment. These programs are available to homes and businesses across the Commonwealth. For communities where Mass Save® is not available, please engage with the local MLP ([http://www.mmwecgoprogram.org](http://www.mmwecgoprogram.org), [https://www.ene.org/energy-efficiency/](https://www.ene.org/energy-efficiency/)).

The applicant must address how its written operating procedures in the Management and Operations Profile packet will incorporate regular engagement with energy efficiency programs (account representative, vendors, etc.) to ensure awareness of new opportunities and incentives. At the Architectural Review stage, further information should be submitted to demonstrate actual engagement with energy efficiency (Mass Save® or MLP) programs and any financial incentives received. As a general matter, submission of a Mass Save® or MLP audit report or rebate applications should suffice to demonstrate compliance with this item.
Transporters and Delivery

Transporters and delivery operators are different from other license types because their energy use is derived primarily from vehicles instead of buildings.

Vehicles that use alternative fuels – such as biodiesel, electricity, and natural gas – help to reduce carbon emissions and increase our energy security. In the Management and Operations profile, the applicant must describe how it will make fleet decisions and affirm that it will regularly evaluate alternative fuel vehicle options. At the Architectural Review stage, the applicant must submit a narrative describing the process the Transporter or Delivery operation used to select vehicles to be used in operations, and if alternative fuel vehicles are not being used, a detailed explanation of why other vehicle fuel sources were selected. A description of any other energy and water conservation strategies employed at the physical facility for transportation and delivery (e.g. garage, dispatch) should also be included.

Conclusion

Application sections pertaining to energy are reviewed for compliance with 935 CMR 500.000 & 501.000 and for completeness. The regulations and guidance are designed to ensure that an ME/MTC considers how to optimally use energy early in the facility design process, and continually assess new opportunities for reduced energy usage and costs. Licensees should use best management practices to reduce energy and water usage, engage in energy conservation, and mitigate other environmental impacts. Licensees are also required to meet all applicable environmental laws, regulations, permits, and other applicable approvals, including those related to water quality and solid and hazardous waste management, prior to obtaining a final license. At this time, the Cannabis Control Commission (Commission) deems compliance with the operational requirements of the regulations, as described above, to constitute best management practices as related to energy usage and conservation. Cultivation facilities should maintain policies and procedures addressing all efforts to mitigate environmental impacts, as required under 935 CMR 500.120(12)(e) and 935 CMR 501.120(13)(e). Applicants will be responsible for complying with any revisions to this guidance that may be issued if legal or regulatory requirements change.
Other Resources

License applicants can use this guidance to learn more about how to comply with the energy usage requirements set forth in the following sections of 935 CMR 500.000 and 501.000:

- 935 CMR 500.040(3)(c) – Energy and Environmental Leader Award
- 935 CMR 500.103(1)(b) & 501.103(1)(a) – Architectural Review, Energy Letters
- 935 CMR 500.103(1)(f) & 501.103(1)(e) – Provisional License, Energy Letters
- 935 CMR 500.103(4)(c),(d) & 501.103(4)(c),(d) – Renewal, Energy Letters
- 935 CMR 500.105(1)(q) & 501.105(1)(q) – Written Operating Procedures
- 935 CMR 500.105(13)(h) & 501.105(13)(h) – General Operating Requirements / Transporters
- 935 CMR 500.105(15) & 501.105(15) – General Operating Requirements / Energy Efficiency and Conservation
- 935 CMR 500.120(11) – Marijuana Cultivators
- 935 CMR 501.120(11) – Additional Operational Requirements for the Cultivation, Acquisition, and Distribution of Marijuana
- 935 CMR 500.130(3) & (5)(e) – Marijuana Product Manufacturers
- 935 CMR 501.130(3) – Additional Operational Requirements for Handling and Testing Marijuana and for Production of Marijuana-Infused Products (MIPs)
B. Guidance on Energy Efficiency Standards & Reporting for Cultivation Facilities

The following guidance is provided to assist indoor cultivation facilities, whether they are licensed as a Craft Cooperative, Microbusiness, or Marijuana Cultivator under 935 CMR 500.000: Adult Use of Marijuana, or as an MTC to cultivate cannabis under 935 CMR 501.000: Medical Use of Marijuana. All relevant entities are referenced as “Cultivation Facilities” in this guidance. Indoor operations associated with outdoor cultivation are also subject to these requirements. Please note that Cultivation Facilities must also meet the requirements in the Guidance on Basic Energy Efficiency Practices & Reporting for Marijuana Establishments [see page 4].

This guidance, in conjunction with applicable regulations, establish the requirements for licensure in the Commonwealth. This guidance is not legal advice. If you have questions regarding the legal requirements for licensure in the Commonwealth, you are encouraged to consult an attorney. Cultivators are responsible for complying with any revisions to this guidance that may be issued if legal or regulatory requirements change.

Applicability

All applications for initial licensure or renewal submitted on or after July 1, 2020, if they are not otherwise exempted, must comply with the energy efficiency standards and reporting requirements described in this guidance. A co-located ME and MTC with a final Certificate of Licensure before November 1, 2019 shall have until July 1, 2020 to comply with 935 CMR 500.120(11), except that any additions to or renovations to a facility must comply with 935 CMR 500.120(11). An MTC with a final Certificate of Licensure before November 1, 2019 and that is not co-located with an ME shall have until January 1, 2021 to comply with 935 CMR 501.120(11), except that any additions to or renovations to a facility must comply with 935 CMR 501.120(11). An ME or MTC may apply for an additional six-month extension beyond the date applicable to it, if it agrees to install meters to monitor energy usage, water usage, and other data determined by the Commission, as well as provide reports on energy usage, water usage, waste production and other data in a form and manner determined by the Commission.
Overview

Cannabis cultivation uses significant energy, primarily because of three energy uses: (i) horticultural lighting; (ii) dehumidification; and (iii) HVAC. To mitigate the impact of increased energy usage, and associated costs and greenhouse gas emissions, specific operational requirements have been adopted for Cultivation Facilities in the adult-use and medical-use marijuana regulations.²

To document compliance with the energy efficiency requirements of the regulations, materials must be submitted at three different points in the licensure/renewal process and be maintained throughout operations:

- **Application:** A Cultivation Facility must maintain written operating procedures that demonstrate compliance with the energy efficiency standards in the regulations. A summary of such procedures must be submitted as part of the Management and Operations Profile³;

- **Architectural Review:** As part of the Architectural Review process, building and equipment information should be submitted at the same time as building plans after receipt of a Provisional License;⁴ and

- **Operations & Renewal:** A Cultivation Facility must continue to maintain written operating procedures on energy usage for the duration of its operations. When it comes time for renewal, a Cultivation Facility must provide information regarding its energy and water consumption usage.⁵ This information must be included every year that a renewal application is submitted.

² 935 CMR 500.120 (11) & (12); 935 CMR 501.120 (11) & (12).
³ 935 CMR 500.101(1)(c)(10) & 500.120(12)(e); 935 CMR 501.101(1)(c)(10) & 501.120(13)(e).
⁴ 935 CMR 500.103(1); 935 CMR 501.103(1).
⁵ 935 CMR 500.103(4)(c) & 120(11); 935 CMR 501.103(4)(c) & 120(11).
Application: Demonstrating Compliance with Energy Efficiency Standards in the Management and Operations Profile

Cultivation Facilities must, in addition to the other materials submitted as part of the Management and Operations Profile, submit a summary of their written operating procedures that demonstrate compliance with energy efficiency standards. Please complete the basic summary required in the Guidance on Basic Energy Efficiency Practices & Reporting for Marijuana Establishments [see page 4]. In addition to the basic summary required of all MEs, a Cultivation Facility must address how its written operating procedures will incorporate the following additional elements:

1. How the cultivator will ensure on a regular basis that equipment is maintained, calibrated and operating properly, including maintain operations manuals and operating procedures for all major energy using equipment, including, but not limited to horticultural lighting, HVAC systems, dehumidification systems.

2. How the cultivator regularly assesses opportunities to reduce energy and water usage, which should include:
   
   a. Identification of potential energy use reduction opportunities (such as natural lighting and energy efficiency measures), and a plan for implementation of such opportunities;
   
   b. Consideration of opportunities for renewable energy generation, including, where applicable, identification of building plans, available upon inspection, showing where energy generators could be placed on the site, and an explanation of why the identified opportunities were not pursued, if applicable;
   
   c. Strategies to reduce electric demand (such as lighting schedules, active load management, and energy storage); and
   
   d. Engagement with energy efficiency programs offered pursuant to M.G.L. c. 25, § 21, or through municipal lighting plants.

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6 935 CMR 500.101(1)(c)(10) & 500.120(12)(e); 935 CMR 501.101(1)(c)(10) & 501.120(13)(e).
Architectural Review: Letters and Supporting Documentation

As part of the Architectural Review process, Cultivation Facilities must document compliance with the energy requirements by submitting an energy compliance letter prepared by a Massachusetts Licensed Professional Engineer or Massachusetts Licensed Registered Architect with supporting documentation, together with submission of building plans.

For a Microbusiness or Craft Marijuana Cooperative with a cultivation location sized as Tier 1 or Tier 2, or such other Cultivation Facilities meeting the requirements of 935 CMR 500.850: Waivers, there are additional options. They may demonstrate compliance with any of the requirements of 935 CMR 500.120(11) through an energy compliance letter or updated energy compliance letter prepared by one or more of the following energy professionals:

1. A Certified Energy Auditor certified by the Association of Energy Engineers;
2. A Certified Energy Manager certified by the Association of Energy Engineers;
3. A Massachusetts Licensed Professional Engineer; or

In addition, all facilities regardless of compliance path shall provide third-party safety certification for lighting products by an Occupational Safety and Health Administration (OSHA), Nationally Recognized Testing Laboratory (NRTL), or Standards Council of Canada (SCC)-recognized body, which shall certify that the products meet a set of safety requirements and standards deemed applicable to horticultural lighting products by that safety organization.

The following paragraphs provide guidance regarding the necessary components of the contents of the Energy Compliance Letter.

Building Envelope

A building envelope is what separates the outside from the inside of a building. Building envelope items include insulation, roofs, windows, doors, walls, etc. Having a tight building envelope is fundamental to good energy performance. Poor performing building envelopes results in wasted energy, increase energy costs, and may have ancillary impacts like neighbor smell complaints.

The regulations identify specific ways to demonstrate compliance regarding a Marijuana Establishment’s building envelope as follows:7

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7 935 CMR 500.120(11)(a); 935 CMR 501.120(12)(a).
The building envelope for all facilities, except greenhouses, must meet minimum Massachusetts Building Code requirements and all Massachusetts amendments (780 CMR: State Building Code), International Energy Conservation Code (IECC) Section C.402, or The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Chapters 5.4 and 5.5 as applied or incorporated by reference in 780 CMR: State Building Code, except that facilities using existing buildings may demonstrate compliance by showing that the envelope insulation complies with code minimum standards for Type Factory Industrial F-1, as further defined in guidelines issued by the Commission.

An Energy Compliance Letter submitted as part of the Architectural Review must include a narrative confirming compliance with the building envelope requirements and the output from COMcheck™ software used to show building envelope compliance with Massachusetts Building Code, 780 CMR.

**Lighting**

When discussing horticultural lighting, it is helpful to be aware of the following definitions in the regulations:

- **Canopy** means an area to be calculated in square feet and measured using clearly identifiable boundaries of all area(s) that will contain mature plants at any point in time, including all of the space(s) within the boundaries. Canopy may be noncontiguous, but each unique area included in the total Canopy calculations shall be separated by an identifiable boundary which include, but is not limited to: interior walls, shelves, greenhouse walls, hoop house walls, garden benches, hedge rows, fencing, garden beds, or garden plots. If mature plants are being cultivated using a shelving system, the surface area of each level shall be included in the total Canopy calculation.

- **Horticultural Lighting Equipment (HLE)** means any lighting equipment (e.g. fixtures, bulbs, ballasts, controls, etc.) that uses energy for the cultivation of plants, at any stage of growth (e.g. germination, cloning/mother plants, propagation, vegetation, flowering, and harvest).

- **Horticulture Lighting Square Footage (HLSF)** means Canopy.

- **Horticulture Lighting Power Density (HLPD)** is a measure of total watts of HLE per total Horticulture Lighting Square Footage (HLE / HLSF = HLPD), expressed as number of watts per square foot.

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8 935 CMR 500.002, 500.120(11)(h) and 501.120(12)(g).
Indoor and some greenhouse cultivators use HLE to grow plants. These lights are very powerful and have significantly higher energy use and light intensity compared to typical screw-in light bulbs. As there are numerous horticultural lighting technology options, the regulations set forth two lighting compliance options to provide flexibility for Cultivators to make technology decisions that meet the requirements.\(^9\)

It is important to note that long-term exposure to horticultural lighting may impact vision. Eye safety protocols must be established prior to the time of initial operations and regularly updated and implemented as part of the Cultivation Facility’s detailed written operating procedures.

These eye protection requirements are in addition to any other safety protocols required under state, federal, or local law (e.g. OSHA).

Cultivators must demonstrate compliance with either: (1) the HLPD standard; or (2) the Horticultural Lighting Qualified Product List (Horticultural QPL):

1. **HLPD**: HLPD must not exceed 36 watts per gross square foot, but for Tier 1 and Tier 2 which must not exceed 50 watts per square foot.

   HLPD is a measure of total watts of Horticultural Lighting Equipment per total Horticulture Lighting Square Footage, expressed as number of watts per square foot.
   
   \[ \text{HLE} / \text{HLSF} = \text{HLPD} \]

2. **Horticultural QPL**: All horticultural lighting used in a facility must be:
   a. listed on the current Design Lights Consortium Solid-State Horticultural QPL or other similar list approved by the Commission as of the date of license application, AND
   b. lighting Photosynthetic Photon Efficacy (PPE) is at least 15 percent above the minimum Horticultural QPL threshold rounded up to the nearest 0.1 micromoles per joule (\(\mu\text{mol/J}\)).

The HLPD Energy Compliance Letter submitted as part of the Architectural Review must contain the following regarding horticultural lighting:

1. The letter must include the calculations that show compliance with the HLPD requirements;

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\(^9\) 935 CMR 500.120 (11)(b); 935 CMR 501.120 (12)(b).
2. Narrative explanation of how the facility complies with 935 CMR 500.120(11)(b) or 501.120(12)(b), supported by copies of the facility lighting schedule, square footage of canopy, description of HLE, number, type, and wattage of all HLE;

3. Cutsheets for all HLE to be submitted as part of the Architectural Review;

4. Detailed identification of the stamped plans showing the layout of all HLE, which means any lighting equipment (e.g. fixtures, bulbs, ballasts, controls, etc.) that uses energy for the cultivation of plants, at any stage of growth (e.g. germination, cloning/mother plants, propagation, vegetation, flowering, and harvest), such plans must be available immediately upon inspection and two copies of the plans must be available for immediate surrender upon request;

5. Detailed identification of the stamped plans showing the areas considered as HLSF, such plans must be available immediately upon inspection and two copies of the plans must be available for immediate surrender upon request;

6. Description of an eye safety plan that includes the following:
   a. Safety protocols related to eye safety for those exposed to horticultural lighting;
   b. Communication plan for how eye safety protocols will be communicated to employees;
   c. Description of how protective eyewear will be provided for anyone coming in to contact with active horticultural lights;
   d. Description of signage that will be used to remind workers of eye safety;
   e. Affirmation that the safety protocols will be reviewed and updated by the Cultivation Facility on an annual basis.

The Horticultural QPL Energy Compliance Letter submitted as part of the Architectural Review must contain the following regarding horticultural lighting:

1. Narrative explanation of how the facility complies with 935 CMR 500.120(11)(b) or 501.120(12)(b), supported by copies of the facility lighting schedule, square footage of canopy, description of HLE, number, type and wattage of all HLE;

2. Cutsheets for all HLE to be submitted as part of the Architectural Review;
3. Description of an eye safety plan that includes the following:
   a. Safety protocols related to eye safety for those exposed to horticultural lighting;
   b. Communication plan for how eye safety protocols will be communicated to employees;
   c. Description of how protective eyewear will be provided for anyone coming in to contact with active horticultural lights;
   d. Description of signage that will be used to remind workers of eye safety;
   e. Affirmation that the safety protocols will be reviewed and updated by the Cultivation Facility on an annual basis.

**HVAC & Dehumidification Systems**

HVAC as well as dehumidification are primary drivers of energy use in a Cultivation Facility. Air conditioning is used to cool the air to offset heat generated from lighting. Dehumidification is necessary to remove water, used by plants, from the air.

The regulations require HVAC and dehumidification systems to meet Massachusetts Building Code requirements, 780 CMR, which in turn incorporates Chapter 403 of the International Energy Conservation Code (IECC) and Chapter 6 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook. To demonstrate compliance, a Cultivation Facility must provide a certification from a Massachusetts Licensed Mechanical Engineer that the HVAC and dehumidification systems meet the Massachusetts State Building Code as specified in the regulations and that such systems have been evaluated and sized for the anticipated loads of the facility.

The Professional Engineer (PE) providing the Energy Compliance Letter may also serve as a Licensed Mechanical Engineer, if the PE license covers mechanical engineering. The letter must include the following information:

- Certification from a Massachusetts Licensed Mechanical Engineer that the HVAC and dehumidification systems meet the Massachusetts State Building Code, and that HVAC and dehumidification equipment have been evaluated and sized for the loads of the facility;

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10 935 CMR 500.120(11)(c); 935 CMR 501.120(12)(c).
• Total of tons of refrigeration (TR), thousands of British thermal units (BTUs) per hour (MBH), and a listing of all HVAC equipment to be installed. The information provided in the letter must be supported by equipment data sheets available immediately upon request.

• Total of tons of dehumidification (TD), and a listing of all dehumidification equipment to be installed, supported by equipment data sheets.

• Details about energy recovery equipment installed as part of the ventilation system.

• A listing of all odor mitigation equipment to be installed. The information provided in the letter must be supported by equipment data sheets available immediately upon request.

Exemptions

Indoor cultivation facilities may be exempt\textsuperscript{11} from the regulatory requirements for horticultural lighting, HVAC, and dehumidification systems if they are generating 80% or more of the total annual onsite energy use for all fuels (expressed on a MWh basis) from:

1. a clean or renewable generating source; or

2. renewable thermal generation.

A “clean or renewable resource” should be understood to refer to renewable energy generating sources, as provided in M.G.L. c. 25A, § 11F and regulations promulgated thereunder, or renewable thermal generating sources, as provided in M.G.L. c. 25A, § 11F½ and regulations promulgated thereunder.

As of September 2019, acceptable renewables technologies include the following:

1. Renewable Generation Unit as defined by 225 CMR 14
   (\url{https://www.mass.gov/guides/rps-class-i-and-class-ii-statement-of-qualification-application})
   a. Solar photovoltaic or solar thermal electric energy
   b. Wind energy
   c. Ocean thermal, wave, or tidal energy

\textsuperscript{11} 935 CMR 500.120(11)(e); 935 CMR 500.120(12)(e).

e. Landfill methane gas

f. Hydroelectric

g. Low-emission, Advanced Biomass Power Conversion Technologies using Eligible Biomass Fuel

h. Marine or hydrokinetic energy

i. Geothermal energy

2. Renewable Thermal Generation Unit as defined by 225 CMR 16
   (https://www.mass.gov/guides/aps-renewable-thermal-statement-of-qualification-application)

   a. Air-Source Heat Pump

   b. Ground Source Heat Pump

   c. Deep Geothermal Heat Exchange

   d. Solar Thermal

   e. Woody Biomass

   f. Biogas

   g. Liquid Biofuels

   h. Compost Heat Exchange System

Additionally, the Cultivation Facility must document that renewable energy credits or alternative energy credits representing the portion of the Licensee’s energy usage not generated onsite has been purchased and retired on an annual basis.

In order to demonstrate eligibility for the exemption, a Cultivation Facility must submit an Energy Compliance Exemption Letter, demonstrating exemption as part of Architectural Review.

The letter must be provided by someone with the same qualifications as for the Energy Compliance Letter and include:
1. Description of clean or renewable energy system, including an attestation that the system meets eligibility requirements above. This requirement can be satisfied by providing an RPS or APS Conditional Statement of Qualification approved by the Department of Energy Resources.

3. Energy usage calculations for the facility, supported by building plans and energy models, including inputs and outputs by end use.

4. Clean or renewable energy generation calculations for the facility, supported by building plans and energy models, including inputs and outputs by end use.

5. Written plan on how Renewable Energy Certificates (RECs) or Alternative Energy Credits (AECs) will be generated and retired on at least an annual basis. Note that the option of retiring RECs and AECs is available only to demonstrate the portion of energy usage not generated for onsite use (maximum of 20% of total onsite energy usage).

6. HVAC information, including:
   a. Certification from a Massachusetts Licensed Mechanical Engineer that the HVAC and dehumidification systems meet the Massachusetts State Building Code, and that HVAC and dehumidification equipment have been evaluated and sized for the loads of the facility.
   b. Total of TR, thousands of BTUs per hour (MBH), and a listing of all HVAC equipment to be installed. The information provided in the letter must be supported by equipment data sheets available immediately upon request.
   c. Total of TD, and a listing of all dehumidification equipment to be installed, supported by equipment data sheets.
   d. Details about energy recovery equipment installed as part of the ventilation system.
   e. A listing of all odor mitigation equipment to be installed. The information provided in the letter must be supported by equipment data sheets available immediately upon request.

7. Description of an eye safety plan that includes the following:
   a. Safety protocols related to eye safety for those exposed to horticultural lighting;
b. Communication plan for how eye safety protocols will be communicated to employees;

c. Description of how protective eyewear will be provided for anyone coming in to contact with active horticultural lights;

d. Description of signage that will be used to remind workers of eye safety.

e. Affirmation that the safety protocols will be reviewed and updated by the Cultivation Facility on an annual basis.

Operations & Renewal

A Cultivation Facility shall continue to maintain written operating procedures on energy usage for the duration of its operations. Cultivation Facilities should continuously re-evaluate opportunities for energy conservation and the mitigation of their environmental impact as their operations are ongoing.

A Cultivation Facility, whether operated by a Marijuana Cultivator or an MTC, must provide energy and water reporting as part of the annual license renewal requirement. All Cultivation Facilities are subject to this requirement, regardless of whether they file a Letter of Compliance or a Letter of Compliance Exemption. This guidance document outlines the steps that Cultivation Facilities should take to be in compliance with this reporting requirement.

Requirements: Based on the previous 12-month period, a Cultivation Facility must provide energy consumption by fuel (monthly, including consumption and demand), water consumption (gallons per month), on-site energy generation (monthly), and cannabis yield by weight (annual).

Timing: The required information must be included as part of the licensee’s completed renewal application as outlined in 935 CMR 500.103(4)(c) and 935 CMR 501.103(4)(c). This information must be included every year that a renewal application is submitted. Please note that if a Cultivation Facility has filed its renewal application prior to July 1, 2020, without complying with the documentation requirements for renewal as described in the regulations and this guidance, but the Commission acts upon the renewal application after July 1, 2020, a condition will be placed on its renewal that the documentation must be filed within 60 days, unless the licensee has applied for an Energy Reporting Extension (if eligible). All applications for renewal filed on or after July 1, 2020 must include the required documentation.

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12 935 CMR 500.103(4) and 935 CMR 501.103(4).
Annual Energy and Environmental Reporting

1. Facilities should use the Cannabis PowerScore for annual reporting for electricity consumption. If non-electric fuels, such as natural gas consumption, other delivered fuels or clean or renewable energy generation are not yet available on the Cannabis PowerScore at the time of renewal, facilities may submit monthly usage information in a separate format.

2. It is recommended to create an account on https://www.cannabispowerscore.org by clicking the “sign up” link, this will allow you to save work and return to it later. Creating an account is not required.

3. Complete information about your facility. The more information provided, the more you will learn in comparing to other facilities.

4. On the annual totals page, a Cultivator will provide the following information:
   a. Monthly
      i. Electricity consumption (kWh and KW)
      ii. Natural gas consumption (Therms) (if available)
      iii. Other delivered fuels (specify fuel, gallons) (if available)
      iv. Water consumption (gallons)
      v. Clean or renewable energy generation (kWh) (if available)
   b. Annual
      i. Total cannabis flower and byproduct (grams)

5. Complete your submission.

6. Print final Cannabis PowerScore report and include as part of renewal application. Please ensure the following information is included on the printed submission:
   a. Cannabis PowerScore report number
   b. Production efficiency – grams per kwh
   c. Monthly energy consumption/generation and water usage breakdown
Update Energy Compliance Letter or Energy Compliance Exemption Letter

If any information reflected in the Energy Compliance Letter or Energy Compliance Exemption Letter, including plans or other technical information, has changed, an updated letter and any required supporting documentation must be filed together with the renewal application.

NOTE: Cultivation Facilities that did not submit an Energy Compliance Letter or an Energy Compliance Exemption Letter as part of initial licensure must submit these letters and any other required documentation explained in this guidance at the time of the renewal application, subject to the timing allowances explained above.

Conclusion

Application sections pertaining to energy are reviewed for compliance with 935 CMR 500.000 or 935 CMR 501.000, as applicable, and for completeness. The regulations and guidance are designed to ensure that Cultivation Facilities consider how to optimally use energy early in the facility design process, and continually assess new opportunities for reduce energy usage and costs. Current regulations require that Cultivation Facilities use best management practices to reduce energy and water usage, engage in energy conservation and mitigate other environmental impacts. At this time, the Commission deems compliance with the operational requirements, as described above, to constitute best management practices as related to Cultivation Facilities. Cultivation facilities should maintain policies and procedures addressing all efforts to mitigate environmental impacts, as required under 935 CMR 500.120(12)(e) and 501.120(13)(e).

Applicants will be responsible for complying with any revisions to this guidance that may be issued if legal or regulatory requirements change.

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13 935 CMR 500.120(11) and 935 CMR 501.120(11) & (12).
Other Resources

License applicants can use this guidance to learn more about how to comply with the energy usage requirements set forth in the following sections of 935 CMR 500.000 and 501.000:

- 935 CMR 500.040(3)(c) – Energy and Environmental Leader Award
- 935 CMR 500.103(1)(b) & 501.103(1)(a) – Architectural Review, Energy Letters
- 935 CMR 500.103(1)(f) & 501.103(1)(e) – Provisional License, Energy Letters
- 935 CMR 500.103(4)(c),(d) & 501.103(4)(c),(d) – Renewal, Energy Letters
- 935 CMR 500.105(1)(q) & 501.105(1)(q) – Written Operating Procedures
- 935 CMR 500.105(13)(h) & 501.105(13)(h) – General Operating Requirements / Transporters
- 935 CMR 500.105(15) & 501.105(15) – General Operating Requirements / Energy Efficiency and Conservation
- 935 CMR 500.120(11) – Marijuana Cultivators
- 935 CMR 501.120(11) – Additional Operational Requirements for the Cultivation, Acquisition, and Distribution of Marijuana
- 935 CMR 500.130(3) & (5)(e) – Marijuana Product Manufacturers
- 935 CMR 501.130(3) – Additional Operational Requirements for Handling and Testing Marijuana and for Production of MIPs
C. Grandfathering & Energy Extension Reporting

Grandfathering

For adult-use cultivation facilities, the requirement to comply with the energy efficiency and equipment standards has been in effect as of March 23, 2018. MTCs with a final certificate of registration before March 15, 2018 who sought an adult cultivation license were given an additional 12 months to comply, until March 23, 2019. The regulations were amended again to give these operators an additional 9 months to comply, until January 1, 2020. The Commission has voted to delay enforcement until July 1, 2020 to allow additional time for implementation. The same date applies to cultivation facilities that are co-located medical and adult use. Facilities that are only medical have until January 1, 2021 to comply.

The regulations also permit licensees to apply for a 6-month extension to the deadline if they agree to submit reports to the Commission regarding their energy and environmental impact.
III. Best Management Practices

A. Guidance on Best Management Practices for Water Use

Cannabis, whether in the form of industrial hemp or marijuana, has varying requirements in water and nutrient levels based on the method of cultivation. This document aims to compare the water needs and differences between all methods of cultivation, including removing the plant entirely from natural systems and growing in sealed indoor environments, and the considerations that a grower should be taking into account when locating their facility and establishing watering operations for plant growth and facility maintenance.

**It should be noted that given the lack of research on hemp and marijuana growth in the United States, there is conflicting information on cultivation practices, and the vast differences between methods leads to high amounts of variability. The following numbers are cited but subject to change upon the release of more current regional data.**

Location of Facility and Source of Water

An important consideration for siting of a facility is the availability of water for production. Typically, water for a greenhouse or indoor facility would come from local municipal water or from a regional water supplier like the Massachusetts Water Resources Authority (MWRA). In the case of local municipal water, attention should be paid to whether the water supplier has enough capacity to supply the water both from a source and infrastructure perspective. Depending on the watershed and the specific town the facility is located in, the additional volumes may not be available within the town’s registered or permitted amounts, or an Interbasin Transfer approval may be required.

Increased demand on the system may cause a community to seek a new permitted volume which may have additional mitigation requirements. If a grower chooses to develop their own local water supply such as a new well, it is recommended that they contact the local Massachusetts Department of Environmental Protection (MassDEP) office for guidance on new source approval. A marijuana cultivation facility could trigger the Water Management Act’s permitting requirements if it pumps from its own water sources more than an average of 100,000 gallons per day or more for three consecutive months of the year, or more than nine million unregistered gallons over any three-month period. In addition, an ME that is supplying its own potable water and has a restroom that is accessible to 25 or more people 60 or more days per year is considered

14 For information about the Interbasin Transfer Act and Application materials: [https://www.mass.gov/interbasin-transfer-act](https://www.mass.gov/interbasin-transfer-act)
a Public Water System and would need to obtain an approval. A permit application will need to be filed with MassDEP before operations commence.

**Water Use**

It is also important to know and understand that prior to establishing your facility, you will need to consider how much water you may use. If your water source is public then you must consider that the city or town you are operating in has a limited amount of water it is allocated to use per year. This information may be useful when you are preparing for and going through the state licensing process and local permitting and/or licensing process.

**Seeds vs. Clones**

Literature does not currently provide an in-depth analysis of the water necessities of an individual plant, but there is significant evidence to indicate that seeds require less water than clones regardless of the cultivation setting. Seeds are harder and more resistant to stress and disease, and even though they need more water initially, the growing period for seeds is shorter than that of clones. Clones, while providing insurance for an exact chemical profile upon maturity, require more nutrients which are usually mixed in a water solution.

**Outdoor Cultivation**

Water requirements for outdoor cultivation vary widely by region, variety, and planting date. As outdoor large-scale cultivation of cannabis is new to Massachusetts, there is no data yet to confirm exact amounts of water required.

Notably, cannabis requires that most of its water be received by the plant within the first six weeks of cultivation, while metrics generally list watering averages over the lifespan of the plant.

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Flowering of the plant significantly decreases water uptake. Within that six-week period, it is critical that the plant experience neither drought nor flooding. Dry conditions hasten maturity and stunt the growth of the plant, whereas puddled areas of a field will kill seedlings within two days if not drained appropriately. Soil composition and conditions play a critical role in this. It should also be noted that varieties respond differently across agricultural regions, with variability in height, biomass, and chemical composition. It has been found that it may take up to three years to develop a localized strain that is acclimatized to the conditions set forth in the region.

**Indoor Cultivation**

Indoor cannabis cultivation is generally referred to as the process of removing the crop completely from natural conditions such as sunlight, soil, and air and substituting those elements with artificial alternatives. The benefit of indoor growing lies in being able to control the elements of the plant’s environment and be able to produce multiple harvests in a year. This method of growing is much more intensive in its usage of energy, water, and chemicals. There are many different methods of cultivating the plants themselves. These methods include:

- Hydroponics (water medium)
- Pots/trays (soil medium)
- Aeroponics (plant suspended on wall, not as common)

In the more typical methods of cultivation (namely soil and hydroponics), medical marijuana studies have estimated that indoor grows require watering in quantities of 98”/room-year, or 40 gallons/room-day (one room = 250 sq. ft.).\(^{19}\) Hydroponically grown cannabis is much more water intensive than other crops. When grown indoors, however, facilities have the capacity to set up recycling systems that clean and filter used water to be recycled back into irrigation; which helps negate the amount of freshwater input into the system. Treating water and reusing treated water are activities that are regulated by MassDEP and require permits.\(^{20}\) This water would need to be changed periodically, and nutrient levels can reach unusable points for the plants if not applied correctly.

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\(^{19}\) O’Hare, M., et. al. (7 September, 2013). *Environmental Risks and Opportunities in Cannabis*, [https://lcb.wa.gov/publications/Marijuana/SEPA/5d_Environmental_Risks_and_Opportunities_in_Cannabis_Cultivation.pdf](https://lcb.wa.gov/publications/Marijuana/SEPA/5d_Environmental_Risks_and_Opportunities_in_Cannabis_Cultivation.pdf)

Generally, for non-cannabis crops, indoor cultivation facilities with natural sun and/or ventilation present appear to provide a more balanced method of cultivation, as they are less energy and water intensive than a sealed indoor facility.

**Monitoring and Reporting**

Water is a crucial resource in the growth of cannabis and in the functioning and operations of cannabis growing facilities. In addition to plant needs, water is also used for heating, processing, sanitary purposes, and landscaping on the property. Minimizing water loss from leaks as well as monitoring total water use as a compliment to instituting best management practices help advance the water conservation goals of the Commonwealth.

Growers should:

- install water meters;
- conduct regular water audits to determine the amount and location of water use;
- develop and implement a water savings strategy; and
- repair all leaks as quickly as possible.

**Water Application Methods**

Several different methods of water application are used as standards in the horticultural industry. Whereas outdoor fields rely mostly on rainfall or irrigation in cases of drought, indoor facilities must install their own application systems. The most commonly used methods are as follows:

*Flood tables* utilize large, shallow tables that flood usually on an automated system and provide a layer of water and/or nutrients to plants growing in hydroponic mediums. Large amounts of water are used for this method, but the water can be recycled through the system and used again after treatment via filtration and cleaning.

*Drip watering* involves irrigation systems that feed directly to each plant through thin drip tubes. The amount of water can be controlled directly or on an automated schedule, and virtually eliminates excess water waste or runoff from the plants.

*Wick systems* employ a reservoir that provides water and nutrients for a plant via capillary action through wicking material. Seedlings and newly vegetating plants are occasionally watered with this method since it is a simple system that does not require machinery or electricity. However, it is insufficient in supplying large plants with greater water needs.

*Hand watering* is one of the most common practices used since it requires relatively little equipment and expense initially or in maintenance. However, the amount of applied water varies
greatly between applicators and there is a much larger potential for water being wasted through either over application or by missing the plant root systems. If hand watering is being used, the facility should have a good operating procedure on how to hand water.

*Aeroponics* uses spray nozzles to mist the stem or roots with nutrients. Larger operations will put the stem/root in a channel and have the spray nozzles line the channel, while others may use the bucket system in which the nitrified water and air are maintained in buckets.

*Nutrient film technique (NFT) Systems* use very shallow nutrient solution that runs downward in a tube or tray toward the reservoir where it is reused. It is best used on smaller plants with short crop cycle.

*Water culture systems* are systems where plants are suspended so roots hang down in nutrient solution and the reservoir is continually aerated.

**Wastewater Disposal**

Many indoor facilities utilize water recapture methods to save money and energy in their operations. Depending on the system in place this could be done through drain pipes and lines, ditches, dehumidifiers, or condensation recapture modules. The recaptured water requires treatment if it is to be reapplied to plants to prevent the growth and spread of microbial pathogens and to reduce the amount of ionic and toxic elements that can be introduced to the water through the addition of nutrients. Common practices include carbon filtration, which neutralizes salinity and other inorganic materials in the water, and reverse osmosis, which allows for close to 97% reuptake but produces a brine that is difficult to dispose of. Other chemicals may be added to clean the water before reapplication to reduce microbe levels. Facilities may also employ the use of an aerobic treatment unit to reduce chemical and microbial levels in the returned water to a satisfactory level. Studies have shown that there is no significant difference in plant growth between the use of recycled water versus the use of fresh water.

Even with recapture methods, however, systems need to be flushed on occasion and new water introduced, especially in the event of pathogen outbreaks or from the presence of high levels of salts or ions that could be detrimental to crop growth and development. Water which is not reused must be discharged to a sewer or collected and stored in a certified holding tank for disposal at an approved facility. Note that water which is being disposed of cannot be discharged to an on-site septic system. If wastewater is being discharged out of the facility (e.g., to a Title 5 system, a sewer system, the ground, or surface waters), the proponent must contact their local

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MassDEP office to determine if a discharge permit is required. If wastewater is being stored, it must be kept in a holding tank that is permitted by MassDEP (Transmittal Form DEP01).

In other states, this waste has traditionally been disposed through landfills (often with unused cannabis waste material such as leaves and stems chopped up and mixed in to form a slurry) or is considered industrial waste, depending on the method the waste was created and the definition of industrial/hazardous waste by law. In Massachusetts, however, this waste may not be disposed in a landfill. If the waste is combined with unused cannabis waste, it may be composted or sent to an anaerobic digester. As a last resort, if such slurry is sufficiently dewatered, it may be disposed at a landfill so long as the remaining sludge does not contain free-draining liquids and contains a minimum of 20% solids (note that the disposal facility will need advance notice in order to submit the required documentation to MassDEP). If wastewater is being discharged out of the facility (e.g., to a Title 5 system, a sewer system, the ground, or surface waters), the proponent must contact their local MassDEP office to determine if a discharge permit is required. If wastewater is being stored, it must be kept in a holding tank that is permitted by MassDEP (Transmittal Form DEP01). For more information on waste disposal, please refer to the Commission’s Guidance on Cannabis Waste Management Requirements (https://mass-cannabis-control.com/wp-content/uploads/2019/04/Guidance-on-Cannabis-Waste-Management-Requirements.pdf).

Best Management Practice Guides

Water use on a crop should strike an appropriate balance between both agricultural needs for water and the need to conserve water. Examples of conservation approaches include proper irrigation scheduling in both timing (daily and seasonal) and volume, control of runoff, the uniform application of water, irrigation technologies, such as drip irrigation (where appropriate), and automated irrigation systems. The Massachusetts Water Conservation Standards (WCS) outline many approaches and best management practices that an agricultural entity should adopt that are environmentally and economically appropriate for their specific operation and site conditions. In addition, the WCS outlines standards and best approaches for indoor water use to ensure high levels of efficiency in structural items such as toilets and other water fixtures. Based on the information gathered above, there are three best management practice categories listed below that are considered high priority and should be implemented, to the greatest extent practicable, by all cannabis growers. These practices, along with some others, can help reduce or mitigate strains to disposal and environmental systems and improve water and energy efficiency as a whole.

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1. Soil health

- Determine the soil needs and develop a soil health management system to improve the health and function of the soil. Soils are an ecosystem that can be managed to provide nutrients for plant growth, absorb and hold rainwater for use during drier periods, filter and buffer potential pollutants from leaving fields, serve as a firm foundation for agricultural activities, and provide habitat for soil microbes to flourish.

- Consider using compost to help promote the health of the soil.

- Maintain adequate soil moisture based on crop needs for optimum plant growth without causing excessive water loss, erosion, or reduced water quality.

2. Watering methods

- Use water in a targeted, planned, and efficient manner with appropriate amounts and frequency to meet the needs of the crop without excessive water loss.

- Automation of watering systems is critical to reducing water waste and decreasing variability in plant health through overwatering. If automation is not financially feasible, water nozzles and other flow-reducing systems should be put in place to monitor and check flow rates.

- Micro-irrigation systems, such as subsurface drip irrigation, should be adopted if the facility is designed to be compatible for it.

- Establish an irrigation schedule based on the specific needs of the crop.

- Irrigation system efficiency should be evaluated on an annual basis.

- Where sprinkler systems are used for irrigation, the systems should be capable of uniform application of water with minimal evaporative loss and minimal surface run-off.

3. Water capture and reuse

- A water recapturing system should be used to recycle and reuse water so as to reduce the total amount of water used. Systems can include ones that capture water from watering the plant and reusing and/or capturing water condensation from the HVAC system.

- Explore the options of capturing and using rainwater.
4. Other

- Be knowledgeable of the municipal and state laws relative to water use.

- Choose a site that is capable of managing the amount of water that will be used and will not impact other water users.

- Cultivators should consider utilizing greenhouses and outdoor settings to reduce the amount of energy and water required to maintain plant health.

- Monitor and document your water use.

- If cultivating outdoors, growers should be mindful of all other relevant agricultural and environmental protection regulations in place regarding watershed areas, buffer zones, irrigation runoff, erosion control, and soil amendments.

- Ensure that the appropriate dilution rates and application schedules are followed for any nutrients or cleaning solutions that are being used during cultivation or in treating water. Over application can lead to unnecessary contaminant levels in the water or poor plant health and require further treatment, more frequent system

Managing Solid Waste Materials

Like any other business, MEs generate a variety of common waste materials. While some materials need to be disposed of in the trash, others should be recycled or composted. Massachusetts has waste disposal ban regulations (310 CMR 19.017, available at https://www.mass.gov/regulations/310-CMR-19000-solid-waste-facility-regulations) that ban the disposal of certain materials in the trash. Commonly generated waste that is banned from disposal include cardboard, bottles and cans, paper, and leaves and yard waste. You can see more information on the waste bans and what materials are banned from disposal at https://www.mass.gov/guides/massdep-waste-disposal-bans.

Under the waste ban regulations, MassDEP considers cannabis plant material to be “commercial organic material.” This material is banned from disposal in the trash if a business generates one ton or more per week for disposal. If an ME generates one ton or more of commercial organic material per week for disposal, it would need to divert this material from disposal, typically to a compost or anaerobic digestion (AD) operation. If an ME generates less than one ton of plant material per week, the material may be disposed of in the trash, although MassDEP still encourages this material to be composted where possible.

Composting or AD

According to 935 CMR 500.105(12), cannabis plant parts and associated materials sent for composting or AD must first be ground and mixed with other organic materials such that the cannabis material is rendered unusable. Other organic materials may include growing media, soil, mulch, food waste, or agricultural material such as manure or other plant materials.

There are no unique requirements for hauling this material to a compost or anaerobic digestion facility. MassDEP does not license or grant permits to waste haulers. The best place to start is to check with the haulers that currently service businesses in the area, though ideally an ME should work with a hauler that has experience hauling other similar organic materials. If you need to find a new hauler, you can search for haulers by material type and location at Recycling Works Massachusetts (https://recyclingworksma.com/about-recyclingworks).

Once on the webpage, select the material type “Food-Waste/Compostables” for cannabis plant materials (note: you can also use this webpage to search for recycling service providers). A hauler can help you determine which facility to deliver your material to, as well as the number and size of containers you need to meet your needs. You can also search for compost or AD facilities that can accept that material using that same link, or by referring to MassDEP’s list of sites accepting diverted food material (https://www.mass.gov/doc/map-list-of-massachusetts-sites-accepting-diverted-food-material-june-2019/download).
On-site composting: In some cases, it may work well for an ME to compost materials on site. Composting on site requires sufficient space to construct and maintain a compost pile, as well as additional materials to mix with cannabis plant material to compost successfully. For general guidance on composting practices, please refer to the Massachusetts Department of Agricultural Resources’ Composting Guidebook (https://www.mass.gov/files/documents/2017/12/11/Guide%20to%20Agricultural%20Composting.pdf). Under MassDEP’s regulations, a business can compost up to 20 cubic yards of material per week on site, but must complete and submit a one-time notification form to MassDEP and your local board of health. If you are interested in composting on site, you can receive free assistance and guidance through the RecyclingWorks in Massachusetts’ Compost Site Technical Assistance Program (https://recyclingworksma.com/learn-more/compost-site-technical-assistance).

Solid waste disposal: The requirements under 935 CMR 500.105(12) for disposing of cannabis waste are similar to those for sending it to composting or AD. The cannabis waste must be ground and mixed with other solid wastes so that the material is rendered unusable. Suitable materials for mixing cannabis wastes for disposal include food waste, coffee grounds, manure, sawdust, or growing media. The best approach is to work with your existing waste hauler to provide this collection service. Cannabis wastes mixed with other solid waste can be brought to any permitted transfer station, landfill (https://www.mass.gov/files/documents/2018/02/06/actlf.pdf), or municipal waste combustion facility (https://www.mass.gov/files/documents/2018/02/06/actcf_0.pdf) for disposal. Your solid waste hauler will typically determine the best nearby facility to deliver the waste to for disposal. A hauler can also help you determine what number and size of containers you need to meet your needs.

Storage, documentation, and recordkeeping: Cannabis wastes should be stored in a secure and locked container and location prior to collection. Under 935 CMR 500.105(12), at least two ME agents must witness and document how the marijuana waste is handled. The same regulation requires your business to develop and maintain records for at least three years that include:

1. How the cannabis waste is secured prior to collection;
2. The date the material is sent for composting, anaerobic digestion, or disposal;
3. The type and amount of material managed;
4. The name, location, and type of facility to which the material was delivered;
   - (The facility can provide a scale or load ticket that includes all of this information.)
5. The manner of disposal or handling; and

6. The names and signatures of the two agents who witness the material management.

This three-year period is extended for the duration of any enforcement action and also may be extended by an order of the Commission.

Hazardous waste management: MEs may also generate some wastes that need to be managed as hazardous wastes. This may include: spent lighting, pesticides, solvents, used oil, or other chemicals used in facility operation and maintenance.

Massachusetts hazardous waste regulations (314 CMR 30.000, https://www.mass.gov/regulations/310-CMR-30000-massachusetts-hazardous-waste-regulations) include provisions governing storage (how much material and for how long), labeling, manifest, transportation, and final management and disposal. If you generate hazardous waste, you will need an EPA ID (https://www.mass.gov/guides/hazardous-waste-generation-generators#obtain-or-modify-an-id-number). Your hazardous waste generator status (https://www.mass.gov/guides/hazardous-waste-generation-generators#obtain-or-modify-an-id-number) determines how much waste you may accumulate at your site at one time, and how quickly you need to ship it off site for recycling or disposal. Please see the MassDEP Hazardous Waste Generation web page (https://www.mass.gov/guides/hazardous-waste-generation-generators) for more information and guidance.

Managing liquid wastes: Liquid waste containing marijuana or by-products of marijuana processing shall be disposed of in compliance with all applicable state and federal requirements. These requirements will depend on how liquid waste from a facility is being managed, whether discharged via a sewer connection, holding tank, or to groundwater or surface water. For more information on the applicable regulations and points of contact for each, please see the links in the Regulation Links and Contacts section below.

Packaging: It is recommended that recyclable and compostable packaging be used for marijuana products. Existing resources relative to packaging include the following:

- For recycling, MassDEP maintains a website with educational guidance: www.RecycleSmartMA.Org. This website summarizes what types of packaging are recyclable at our recycling facilities. For general guidance, see https://recyclesmartma.org/smart-recycling-guide. For more specific questions, you can search the “recyclopedia” using the search bar at the top of the page.
For compostable packaging, search the internet for organizations that certify compostable packaging. Specifications relative to labeling are available at:

- [https://www.astm.org/Standards/D6400.htm](https://www.astm.org/Standards/D6400.htm)
- [https://www.astm.org/Standards/D6868.htm](https://www.astm.org/Standards/D6868.htm)
Other Resources

 Regulation Links & Contacts

For any facility-specific permitting questions, please contact your MassDEP regional office. You can find which MassDEP region you are in using MassDEP’s list of environmental protection locations (https://www.mass.gov/orgs/massachusetts-department-of-environmental-protection/locations?_page=1). Links to relevant regulations are as follows:

Massachusetts Waste Ban Regulations – 310 CMR 19.017
(https://www.mass.gov/guides/massdep-waste-disposal-bans)

Massachusetts Hazardous Waste Regulations – 314 CMR 30.000

Surface Water Discharge Permit Program – 314 CMR 3.00
(https://www.mass.gov/regulations/314-CMR-3-surface-water-discharge-permit-program)

Groundwater Discharge Program – 314 CMR 5.00 (https://www.mass.gov/service-details/the-groundwater-discharge-permitting-program)


Sewer System Extension and Connection Permit Program – 314 CMR 7.00
(https://www.mass.gov/regulations/314-CMR-7-sewer-system-extension-and-connection-permit-program)

Industrial Wastewater Holding Tanks and Containers – 314 CMR 18.00

For assistance with recycling, running a compost operation, and solid waste management, please contact the RecyclingWorks in Massachusetts Program at (888) 254-5525, by email at Info@RecyclingWorksMA.com, or visit the program website at www.RecyclingWorksMA.com. RecyclingWorks in Massachusetts is funded by MassDEP and administered under contract with MassDEP by the Center for EcoTechnology. The program provides free assistance to Massachusetts businesses on waste reduction, recycling, composting, and best management practices.

Licensed marijuana cultivators must comply with 935 CMR 500.120(9), which states:

*The cultivation process shall use best practices to limit contamination including, but not limited to, mold, fungus, bacterial diseases, rot, pests, pesticides not in compliance with 500.120(5) for use on marijuana, mildew, and any other contaminant identified as posing potential harm.*

To help licensed cultivators establish best practices in preventing pests and contamination, this guidance serves to assist growers in creating an integrated pest management plan.

**The Plant – *Cannabis sativa L***

Cannabis can be grown outdoors as a field crop, indoors in greenhouses, or in grow rooms. Each cultivation method has specific pest and disease problems that may arise due to the different conditions presented by each setting. For example, the high humidity environment of a grow room provides ideal conditions for fungal pathogens. Cannabis grown outdoors may be susceptible to vertebrate pests such as deer and mice as well as larger insect pests, such as stem borers. Whether the cannabis crop is grown indoors or outdoors, cultivators should be prepared with the knowledge to prevent, identify, and control pests using Integrated Pest Management.

**Integrated pest management (IPM)** is an approach to pest control that applies a combination of methods to manage pest problems. The primary objective of IPM is to prevent, reduce, or maintain pest populations at non-damaging levels by utilizing mechanical, physical, and biological controls to reduce the need for reliance on chemical pesticides. In Massachusetts, IPM is defined under 333 CMR 14.02 as:

> A comprehensive strategy of pest control whose major objective is to achieve desired levels of pest control in an environmentally responsible manner by combining multiple pest control measures to reduce the need for reliance on chemical pesticides; more specifically, a combination of pest controls which addresses conditions that support pests and may include, but is not limited to, the use of monitoring techniques to determine immediate and ongoing need for pest control, increased sanitation, physical barrier methods, the use of natural pest enemies, and a judicious use of lowest risk pesticides when necessary.

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23 Hemp and marijuana are different varieties of the same plant species, *Cannabis sativa L*. For the purposes of this document, the term *Cannabis* refers to marijuana only.
IPM takes advantage of all available pest management strategies. It does not rely on a single pest control method, but rather establishes a way of evaluating the situation and determining the most environmentally safe or ecological solution.

The basic concepts that comprise an effective IPM strategy include:

1. **Knowledge**
   - Identify the pests: accurate identification of pests is critical in determining the proper methods of control.
   - Establish thresholds to determine when and if action is required to control pests before they reach damaging levels.

2. **Prevention**
   - Inspect/quarantine plants entering closed environments to ensure you are not bringing in pests.
   - Maintain controlled environments to inhibit growth of plant pathogens.
   - Reduce habitat for potential pests such as poor drainage, standing water, or overgrown vegetation/weeds.

3. **Monitoring**
   - Scout crops for evidence of pest damage. Use pest traps (like pheromone traps or yellow sticky cards) to determine presence and levels of insect pests.

4. **Intervention**
   - If intervention is required to control pests, evaluate all the options to determine the least risky and most effective controls available, including cultural, mechanical, biological, and/or chemical methods.

This document is not intended to provide comprehensive IPM recommendations for every cannabis pest; rather, it should serve as a basic guideline and assist cultivators with development of an IPM plan for their crop.
Pesticide Use in Cannabis

As cannabis remains prohibited by federal law, the United States Environmental Protection Agency (EPA) does not allow for the use of any registered pesticides in cannabis. Massachusetts pesticide laws follow federal laws, and thus registered pesticides cannot be applied to cannabis in Massachusetts. The Massachusetts Department of Agriculture has published an advisory (https://www.mass.gov/files/documents/2018/10/19/Pesticide%20Advisory.pdf) regarding the use of pesticides on cannabis. As a result, cannabis cultivators must rely more heavily on other methods of management, as they have fewer available tools for use in pest control.

Indoor Cannabis Pest Prevention

Growing cannabis indoors is unique from other cultivation practices in that environmental factors such as ventilation and light are not naturally occurring. Instead, these inputs are produced and controlled by equipment. As with other crops, however, IPM starts with pest prevention. It is recommended to design and operate facilities to prevent the introduction and spread of pests.

Recommendations for indoor pest prevention include:

1. Keeping plants healthy: Healthy plants are more readily able to fight off pests or infections.

2. Sanitation: Keep your facility clean and organized. Seal potential points of entry for pests including cracks, crevices, and voids. Establish protocols to prevent pests from entering the facility on workers’ clothing, shoes, or equipment.

3. Quarantine: Inspect all new plant material entering your facility for signs of infestation. Keep new plant material in a separate space for several days to ensure that signs of infestation do not present.

4. Maintain environmental conditions to minimize optimal pest habitat: Ensure humidity levels are appropriate and do not promote pathogen growth. Prevent standing water from forming and ensure that any reservoirs are sealed and filtered.

5. Inspections/monitoring: Regularly inspect plants for signs or symptoms of pest infestations. Place traps like yellow sticky cards in strategic locations to help detect early infestations of flying insect pests.
Outdoor Cannabis Pest Prevention

Cannabis grown outdoors is susceptible to a wide variety of pests including deer, insects, and fungi. Outdoor environments, by nature, are not as well controlled as indoor, and exclusion/prevention practices may be less effective against certain pests. In addition, the use of chemical controls is restricted, so cultural, mechanical, and biological controls have increased importance.

Recommendations for outdoor cannabis pest prevention include:

1. Keeping plants healthy: Healthy plants are more readily able to fight off pests or infections.
2. Exclusion: Use fencing or netting to keep out unwanted pests like deer or birds.
3. Sanitation: Inspect all new plant material for signs of infestation. Keep new plant material in a separate location for several days to ensure that signs of infestation do not present.
4. Maintain field conditions to minimize optimal pest habitat: Remove any overgrown vegetation that may harbor insect pests. Prevent standing water and promote plant health.
5. Inspections/monitoring: Regularly inspect the crop for signs or symptoms of pest infestations. Place traps like yellow sticky cards in strategic locations to help detect early infestations of flying insect pests like moths or aphids.

Cannabis Pest Control Actions

Even with a solid preventative program implemented, it is still possible for a cannabis crop to develop a pest problem. The first step once you’ve discovered a pest problem is to identify your pest. Proper identification of the pest is vital to determining the most effective control strategy.

There are four primary strategies available in a pest management program:

1. Cultural controls: Cultural controls modify the environment to make the cultivation operation an unaccommodating habitat for pests. They involve practices such as adjusting the irrigation schedule to combat root disease, reducing humidity to make the environment less hospitable to pathogenic fungus and shaping the canopy to facilitate superior airflow, or companion plantings to boost the populations of beneficial insects.
2. Mechanical controls: Mechanical controls use physical methods to trap, exclude, and remove pests, such as putting filters on air intakes, placing sticky traps in strategic locations to trap flying pests, removal of diseased plant material, or removal of weeds.

3. Biological controls: Biological controls utilize natural enemies (predators and parasites that deplete the health of a pest population) to directly attack pests. Biological control organisms can be extremely effective at maintaining pest populations below economic thresholds, and preventing infestations from reaching damaging levels.

4. Chemical controls: Chemical controls should be used judiciously in any IPM program. Cannabis cultivators are limited in their options for chemical controls since Massachusetts prohibits the use of any pesticide with an EPA registration number. While there are minimum-risk (25(b)) pesticides available for use in cannabis cultivation, pesticides in general should not be used as a primary pest control method in cannabis.

Questions? If you have additional questions regarding the Energy and Environment Compiled Guidance, please contact the Commission at Commission@CCCMass.com or (774) 415-0200.
IV. Appendices

A. Appendix A: Checklists for Energy Compliance

I. Application

a. Basic Requirements for Applicants Other than Transporters & Delivery

1. Identification of potential energy-use reduction opportunities (such as natural lighting and energy efficiency measures), and a plan for implementation of such opportunities;

   • Description of how the ME/MTC will monitor energy consumption and make adjustments to operations based on energy usage data;

   • Procedures for identifying energy savings opportunities as part of any facility upgrades, renovations, or expansions; and

   • Procedures for identifying energy savings opportunities when equipment fails and needs to be replaced.

2. Consideration of opportunities for renewable energy generation, including, where applicable, submission of building plans showing where energy generators could be placed on the site, and an explanation of why the identified opportunities were not pursued, if applicable;

   • Description of how the ME/MTC will make energy supply decisions and regularly evaluate renewable options;

   • Procedures for identifying renewable or alternative energy opportunities as part of any facility upgrades, renovations, or expansions; and

   • Procedures for identifying renewable or alternative energy opportunities when equipment fails and needs to be replaced.

3. Strategies to reduce electric demand (such as lighting schedules, active load management, and energy storage); and

   • Description of how the ME/MTC will monitor energy demand and make adjustments to operations based on data; and

   • Procedures for participation in load curtailment, energy storage, or other active demand management programs (as applicable).
4. Engagement with energy efficiency programs offered pursuant to M.G.L. c. 25, § 21, or through municipal lighting plants.

- Description of how the applicant will incorporate regular engagement with energy efficiency programs (account representative, vendors, etc.) to ensure awareness of new opportunities and incentives.

b. Basic Requirements for Transporters & Delivery

- Applicant must describe how it will make fleet decisions and affirm that it will regularly evaluate alternative fuel vehicle options.

c. Additional Requirements for Cultivation Facilities

- How the cultivator will ensure on a regular basis that equipment is maintained, calibrated, and operating properly, including maintaining operations manuals and operating procedures for all major energy-using equipment – including, but not limited to, horticultural lighting, HVAC systems, dehumidification systems.

II. Architectural Review

a. Basic Requirements for Applicants Other than Transporter & Delivery

1. Identification of potential energy-use reduction opportunities (such as natural lighting and energy efficiency measures), and a plan for implementation of such opportunities;

- Information demonstrating actual consideration of energy reduction opportunities, including a list of energy reduction opportunities that were considered.

- Information about whether opportunities are being implemented, will be implemented at a later date, or are not planned to be implemented.

- Summary of information that was considered to make the decision (i.e. costs, available incentives, and bill savings). NOTE: submission of a Mass Save® or MLP audit report or rebate applications is sufficient to demonstrate compliance.
2. Consideration of opportunities for renewable energy generation, including, where applicable, submission of building plans showing where energy generators could be placed on the site, and an explanation of why the identified opportunities were not pursued, if applicable;

- Information should be submitted to demonstrate actual consideration of renewable energy generation opportunities, including a list of renewable or alternative energy reduction opportunities that were considered.

- Information about whether opportunities are being implemented; will be implemented at a later date; or are not planned to be implemented.

- A summary of information that was considered to make a decision (i.e. costs, available incentives, and bill savings).

3. Strategies to reduce electric demand (such as lighting schedules, active load management, and energy storage);

- Information should be submitted to demonstrate actual consideration of demand reduction opportunities.

- Information about whether opportunities are being implemented, will be implemented at a later date, or not planning to be implemented.

- A summary of information that was considered to make a decision (i.e. costs, available incentives, and bill savings). NOTE: submission of a Mass Save® or MLP audit report or rebate applications is sufficient to demonstrate compliance.

4. Engagement with energy efficiency programs offered pursuant to M.G.L. c. 25, § 21, or through municipal lighting plants.

- Information should be submitted to demonstrate actual engagement with energy efficiency (Mass Save® or MLP) programs and any financial incentives received. NOTE: submission of a Mass Save® or MLP audit report or rebate applications is sufficient to demonstrate compliance.

b. Basic Requirements for Transporter & Delivery

- Narrative describing the process the Transporter or Delivery operation used to select vehicles to be used in operations.

- If alternative fuel vehicles are not being used, detailed explanation of why other vehicle fuel sources were selected.
• A description of any other energy and water conservation strategies employed at the physical facility for the Transporter and Delivery operation (e.g. garage, dispatch) should also be included.

c. Additional Requirements for Cultivation Facilities: Energy Compliance & Energy Compliance Exemption Letters

1. Who needs to sign the letter?

For Indoor Marijuana Cultivators, Medical Marijuana Treatment Centers – the letter must be signed by a:

• Massachusetts Licensed Professional Engineer; or
• Massachusetts Licensed Registered Architect.

For Microbusinesses or Craft Marijuana Cooperatives with a cultivation location sized as Tier 1 or Tier 2, or such other Marijuana Cultivators meeting the requirements of 935 CMR 500.850 for a waiver:

The letter must be signed by a:

• Massachusetts Licensed Professional Engineer;
• Massachusetts Licensed Registered Architect;
• Certified Energy Auditor certified by the Association of Energy Engineers; or
• Certified Energy Manager certified by the Association of Energy Engineers.

Please note: The HVAC & dehumidification systems portion of the letter must be separately completed and signed by a:

• Massachusetts Licensed Mechanical Engineer; or
• Professional Engineer with license that covers mechanical engineering.

2. What needs to be in the letter?

Energy Compliance Letters or Energy Compliance Exemption Letters must include, at a minimum, the information required below.
• Letter Demonstrating HLPD Compliance

The letter must include the following information:

  o **Building Envelope**

    ▪ Narrative confirming compliance with 935 CMR 500.120(11)(a) or 935 CMR 501.120(11)(a), as applicable; and

    ▪ The output from COMcheck™ software used to show building envelope compliance with State Building Code, 780 CMR.

  o **HLPD Lighting (you should select either HLPD or HQPL, not both)**

    ▪ If the applicant chooses the HLPD compliance path, the letter must include the calculations that show compliance with the HLPD requirements;

    ▪ Narrative explanation of how the facility complies with 935 CMR 500.120(11)(b) or 501.120(12)(b), supported by copies of the facility lighting schedule, square footage of canopy, description of horticultural lighting equipment, number, type and wattage of all HLE;

    ▪ Cutsheets for all HLE to be submitted as part of the Architectural Review;

    ▪ Detailed identification of the stamped plans showing the layout of all HLE, which means any lighting equipment (e.g. fixtures, bulbs, ballasts, controls, etc.) that uses energy for the cultivation of plants, at any stage of growth (e.g. germination, cloning/mother plants, propagation, vegetation, flowering, and harvest), such plans must be available immediately upon inspection and two copies of the plans must be available for immediate surrender upon request;

    ▪ Detailed identification of the stamped plans showing the areas considered as HLSF, such plans must be available immediately upon inspection and two copies of the plans must be available for immediate surrender upon request;

    ▪ Description of eye safety plan that includes the following:

      □ Safety protocols related to eye safety for those exposed to horticultural lighting;
□ Communication plan for how eye safety protocols will be communicated to employees;

□ Description of how protective eyewear will be provided for anyone coming in to contact with active horticultural lights;

□ Description of signage that will be used to remind workers of eye safety; and

□ Affirmation that the safety protocols will be reviewed and updated by the Marijuana Cultivator or MTC on an annual basis.

○ HQPL Lighting (you should select either HLPD or HQPL, not both)

- Narrative explanation of how the facility complies with 935 CMR 500.120(11)(b) or 501.120(12)(b), supported by copies of the facility lighting schedule, square footage of canopy, description of horticultural lighting equipment, number, type and wattage of all HLE;

- Cutsheets for all HLE to be submitted as part of the Architectural Review;

- Description of eye safety plan that includes the following:
  
  □ Safety protocols related to eye safety for those exposed to horticultural lighting;
  
  □ Communication plan for how eye safety protocols will be communicated to employees;
  
  □ Description of how protective eyewear will be provided for anyone coming in to contact with active horticultural lights;
  
  □ Description of signage that will be used to remind workers of eye safety; and
  
  □ Affirmation that the safety protocols will be reviewed and updated by the Marijuana Cultivator or MTC on an annual basis.
HVAC & Dehumidification Systems

- Certification from a MA Licensed Mechanical Engineer that the HVAC and dehumidification systems meet Massachusetts building code, and that HVAC and dehumidification equipment have been evaluated and sized for the loads of the facility;

- Total of TR, thousands of BTUs per hour (MBH), and a listing of all HVAC equipment to be installed, supported by equipment data sheets;

- Total of TD, and a listing of all dehumidification equipment to be installed, supported by equipment data sheets;

- Details about energy recovery equipment installed as part of the ventilation system; and

- A listing of all odor mitigation equipment to be installed, supported by equipment data sheets.

Letter Demonstrating Compliance Exemption

- Eligible Technologies

  - Renewable Generation Unit as defined by 225 CMR 14:
    - Solar photovoltaic or solar thermal electric energy;
    - Wind energy;
    - Ocean thermal, wave or tidal energy;
    - Fuel cells using eligible RPS Class I renewable fuel;
    - Landfill methane gas;
    - Hydroelectric;
    - Low-emission, Advanced Biomass Power Conversion Technologies using Eligible Biomass Fuel;
    - Marine or hydrokinetic energy; or
    - Geothermal energy.
Renewable Thermal Generation Unit as defined by 225 CMR 16:

- Air-Source Heat Pump;
- Ground Source Heat Pump;
- Deep Geothermal Heat Exchange;
- Solar Thermal;
- Woody Biomass;
- Biogas;
- Liquid Biofuels; or
- Compost Heat Exchange System.

Narrative Contents of Letter

- Description of clean or renewable energy system, including an attestation that system meets eligibility requirements above. This requirement can be satisfied by providing an RPS or APS Statement of Qualification approved by the Department of Energy Resources.

- Energy usage calculations for the facility, supported by building plans, energy models, and energy model outputs, including inputs and outputs by end use;

- Clean or renewable energy generation calculations for the facility, supported by building plans and energy models, including inputs and outputs by end use; and

- Written plan on how RECs or AECs will be generated and retired on at least an annual basis. Note that the option of retiring RECs and AECs is available only to demonstrate the portion of energy usage not generated for onsite use (maximum of 20% of total onsite energy usage).

- Description of eye safety plan that includes the following:
  - Safety protocols related to eye safety for those exposed to horticultural lighting;
Communication plan for how eye safety protocols will be communicated to employees;

Description of how protective eyewear will be provided for anyone coming in to contact with active horticultural lights;

Description of signage that will be used to remind workers of eye safety; and

Affirmation that the safety protocols will be reviewed and updated by the Marijuana Cultivator or MTC on an annual basis.

HVAC & Dehumidification Systems

- Certification from a MA Licensed Mechanical Engineer that the HVAC and dehumidification systems meet Massachusetts building code, and that HVAC and dehumidification equipment have been evaluated and sized for the loads of the facility;

- Total of TR, thousands of BTUs per hour (MBH), and a listing of all HVAC equipment to be installed, supported by equipment data sheets;

- Total of TD, and a listing of all dehumidification equipment to be installed, supported by equipment data sheets;

- Details about energy recovery equipment installed as part of the ventilation system; and

- A listing of all odor mitigation equipment to be installed, supported by equipment data sheets.

d. Additional Requirements for Cultivation Facilities: Third-Party Safety Certification

- Third-party safety certification for lighting products by an OSHA, NRTL, or SCC-recognized body, which shall certify that the products meet a set of safety requirements and standards deemed applicable to horticultural lighting products by that safety organization.
III. Renewal

- Cannabis PowerScore
- Update Energy Compliance Letter or Energy Compliance Exemption Letter
B. Appendix B: DLC Horticulture QPL Process

Finding qualified lighting products on the DLC Horticultural QPL
Draft date: November 5, 2019

The Commission recently updated its regulations so that qualified LED lighting fixtures on the DesignLights Consortium (DLC) Horticultural Qualified Products List (QPL) can be used to comply with the minimum Commission Photosynthetic Photon Efficacy (PPE) metric.

The current baseline PPE for LED lighting fixtures on the DLC Horticultural QPL is 1.9 micromoles per Joule (µmol/J). The Commission regulations stipulate that the “lighting Photosynthetic Photon Efficacy (PPE) is at least 15% above the minimum Horticultural QPL threshold rounded up to the nearest 0.1 µmol/J (micromoles per joule).” This equates to a minimum Commission PPE requirement of 2.2 µmol/J (1.9 x 1.15 = 2.19, which rounds up to 2.2).

To find products that are on the DLC Horticultural QPL with PPEs of at least 2.2 µmol/J, follow these steps:

1. Go to http://www.designlights.org
2. Click on “Horticultural Lighting”
3. On the left side of the web page, click on the “Horticultural Lighting QPL” link.

4. All qualified lighting products will be shown in the Tile format by default. To filter products for Massachusetts state compliance, click on “State Compliance.” Click out of the pop-up form to apply the filter.
5. Alternatively, to filter products by a specific minimum PPE, first click on the “Product Function” filter on the left side of the web page, then in the pop-up form, change the minimum PPE Filter Value to 2.2. Click out of the pop-up form to apply the filter. The number of qualifying products that meet or exceed the minimum PPE = 2.2 will be shown (26 as of November 5, 2019).

6. In the Tile view, the tested PPE for each qualifying product is shown in the Basic Function tab. You can change the Tile display order by sorting by various QPL metrics (click the “Sort By” button to see a pop-up list).
7. To review all the PPE values in a list format, click on the “Display as List” button on the upper right portion of the QPL web page. The qualifying products will be displayed 10 at a time. To see more products at once, change the “Results per Page” value to 20, 50, or 100.

8. To view the tested PPE value for each product, click on the “Customize Columns” button. From the pop-up form, click on “Show More… link.” Then, click on the PPE option to add this column to the list. Click out of the pop-up form to apply the changes.
9. You can change the sort order of the columns by clicking on the column title. You can see more about each product by clicking on the Show button.
**INTRODUCTORY SCRIPT**

We are conducting research for the Massachusetts Electric and Natural Gas Utilities (also referred to as the Program Administrators, or PAs) to understand current design and installation practices for cannabis cultivation facilities in Massachusetts.

Our initial research has identified you as a representative of *insert contact company here* as someone who is familiar with the new construction and major renovation of cannabis cultivation facilities in Massachusetts. We are hoping you can share some general information that will assist with our effort to better understand the current design of these unique facilities and their installation practices.

Do you have 0.5 - 1 hour to answer a series of questions? If not, is there another time that works better for you? *Record time and phone number for future interview then thank and send interview invite.*
Date and Time of interview:

Housekeeping Questions - Confidentiality and Recording
First, the information you provide may be shared with the Massachusetts PAs (NGrid, Eversource, Cape Light, Unitil etc.). Can we identify you as an interviewee in this study or would you like your identity to remain anonymous?

Second, I would like to record this interview for my note-taking purposes to make sure I’m capturing everything in this survey. Do I have your permission?

SECTION 1: FAMILIARITY WITH CANNABIS CULTIVATION TECHNOLOGIES

G.1. What is your background, and your company’s background with cannabis cultivation facilities in Massachusetts? [If not mentioned, ask]: Have you or anybody else in your firm designed/installed cannabis cultivation facilities or the systems serving these facilities in Massachusetts? (If no, thank and end survey; if yes, check all that apply and ask about each of these technologies in the sections that follow – may need to call another person in the firm who is more familiar to answer questions)

Key dates: Medical cannabis use was legalized in Massachusetts in July of 2013, with recreational use laws passed in November 2016 and recreational sales starting July of 2018. On March 7, 2018, the Commission promulgated final regulations at 935 CMR 500. Those regulations were published in the Register on March 23, 2018.

G.2 Have you designed/installed cannabis cultivation facilities in states other than Massachusetts?
G.2.1 What is the typical size of the facilities you work on?
G.2.2 Do you have experience with extraction equipment?

G.3 IF YES to G.2, Has/have the project(s) received incentives from utilities in States other than Massachusetts?
G.4 IF YES to G.3, What did the project receive incentives for?

G.5. For any technologies with which your firm has worked with: How many times have you designed/installed each type of system in the last 5 years in Massachusetts
cannabis cultivation facilities? *(Ask them to distinguish between number or percent of facilities before and after CC regulations, 3/23/18)*

- Full facility
  - # projects / % projects
- Horticultural lighting systems
  - # projects / % projects
- HVAC systems (including dehumidification)
  - # projects / % projects
- HVAC controls
  - # projects / % projects
- Envelope systems
  - # projects / % projects
- Cannabis extraction systems
  - # projects / % projects
- Other: ______________________
  - # projects / % projects

G.6. For any technologies with which your firm has worked: What building types have you installed these systems in (indoor/warehouse, greenhouse, hybrid)?

G.7. How often does the design for these systems change as a function of building type? Why does it change, or does not change?

G.8. For any technologies with which your firm has worked: What percent of cannabis cultivation facility projects were ground-up new construction vs. renovation of existing buildings?

TECHNOLOGY #1: HORTICULTURAL LIGHTING

Next, I’d like to gather some lighting information about your experience designing/installing horticultural lighting. I’d like to walk through each room in a typical cannabis cultivation facility, thinking about projects where you designed/installed horticultural lighting over the last 5 years in Massachusetts.

General design/installation questions

HL.1 Flower Rooms

Starting with the flower rooms, what is the range of square footage of these rooms, and what is the range of square footage of the canopy space?
Are there typical lighting fixtures you install here? If yes, what are they?
Is there a typical wattage of these fixtures installed? If yes, what is it?
Can you estimate the LPD (lighting power density) of a typical canopy space? OR
Can you estimate the target PPFD (PPFD (Photosynthetic photon flux density [µMol/s/m²]) in typical flower rooms?

Flower rooms – Area sq. ft. range ______ Canopy sq. ft. range ________

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light technology</strong> (distinguish between single ended and double ended HPS)</td>
<td></td>
</tr>
<tr>
<td>Lighting Wattage</td>
<td></td>
</tr>
<tr>
<td>LPD/ Number of Fixtures per sq. ft of canopy</td>
<td></td>
</tr>
<tr>
<td>Target PPFD (Photosynthetic photon flux density [µMol/s/m²])</td>
<td></td>
</tr>
</tbody>
</table>

HL.2 Vegetative Rooms

Moving to the vegetative rooms, what is the range of square footage of these rooms, and what is the range of square footage of the canopy space?
Are there typical lighting fixtures you install here? If yes, what are they?
Is there a typical wattage of these fixtures installed? If yes, what is it?
Can you estimate the LPD (lighting power density) of a typical canopy space?
Can you estimate the target PPFD (PPFD (Photosynthetic photon flux density [µMol/s/m²]) in typical vegetative rooms?
**Vegetative rooms** – Area sq. ft. range _______ Canopy sq. ft. range ________

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light technology</strong> <em>(distinguish between single ended and double ended HPS)</em></td>
<td></td>
</tr>
<tr>
<td>Lighting Wattage</td>
<td></td>
</tr>
<tr>
<td>LPD/ Number of Fixtures per sq. ft of canopy.</td>
<td></td>
</tr>
<tr>
<td>Target PPFD (Photosynthetic photon flux density [µMol/s/m²])</td>
<td></td>
</tr>
</tbody>
</table>

**HL.3. Clone/seedling/propagation rooms**

For the clone/seedling/propagation rooms, what is the range of square footage of these rooms, and what is the range of square footage of the canopy space?

Are there typical lighting fixtures you install here? If yes, what are they?

Is there a typical wattage of these fixtures installed? If yes, what is it?

Can you estimate the LPD (lighting power density) of the typical canopy space?

Can you estimate the target PPFD (PPFD (Photosynthetic photon flux density [µMol/s/m²])) in typical clone/seedling/propagation rooms?

**Clone/seedling/propagation rooms**

Area sq. ft. range _______ Canopy sq. ft. range ________

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light technology</strong> <em>(distinguish between single ended and double ended HPS)</em></td>
<td></td>
</tr>
<tr>
<td>Lighting Wattage</td>
<td></td>
</tr>
<tr>
<td>LPD/ Number of Fixtures per sq. ft of canopy.</td>
<td></td>
</tr>
<tr>
<td>Target PPFD (Photosynthetic photon flux density [µMol/s/m²])</td>
<td></td>
</tr>
</tbody>
</table>
HL.4. Mother Rooms

For mother rooms, what is the typical range of square footage of these rooms, and what is the typical range of square footage of the canopy space?

Are there typical lighting fixtures you install here? If yes, what are they?

Is there a typical wattage of these fixtures installed? If yes, what is it?

Can you estimate the LPD (lighting power density) of the typical canopy space?

Can you estimate the target PPFD (Photosynthetic photon flux density [µMol/s/m²]) in typical mother rooms?

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light technology</strong> <em>(distinguish between single ended and double ended HPS)</em></td>
<td></td>
</tr>
<tr>
<td>Lighting Wattage</td>
<td></td>
</tr>
<tr>
<td>LPD/ Number of Fixtures per sq. ft of canopy.</td>
<td></td>
</tr>
<tr>
<td>Target PPFD (Photosynthetic photon flux density [µMol/s/m²])</td>
<td></td>
</tr>
</tbody>
</table>

**Mother rooms - Area sq. ft. range __________ Canopy sq. ft. range __________**

**Lighting Controls**

**HL5.** What are the typical lighting controls you design/install?

**HL6.** What lighting photoperiods do your facilities operate with?

<table>
<thead>
<tr>
<th>Space</th>
<th>Hours/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flower Room</td>
<td></td>
</tr>
<tr>
<td>Vegetative Room</td>
<td></td>
</tr>
<tr>
<td>Clone/seedling/propagation rooms</td>
<td></td>
</tr>
</tbody>
</table>
HL.7. Have you designed/installed dimming systems?

HL.8 IF YES, How are the systems used? In what stage of growth?

HL.9. Have you designed any other lighting control systems such as track lights or vertically adjustable lights?

**HL.10. Non-Cultivation Spaces**

Lastly, we would like to gather some information on the non-cultivation spaces you typically see in cannabis cultivation facilities:

What is the proportion of non-cultivation area to cultivation area in facilities you have worked on?

Are there typical lighting fixtures you install here? If yes, what are they?

Is there a typical wattage of these installed fixtures? If yes, what is it?

Can you estimate the LPD (lighting power density) of these spaces?

**Non-Cultivation Spaces Area sq. ft. range ____________**

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light technology</td>
<td></td>
</tr>
<tr>
<td>Lighting Wattage</td>
<td></td>
</tr>
<tr>
<td>LPD/ Number of Fixtures per sq. ft.</td>
<td></td>
</tr>
</tbody>
</table>

HL.11 What percent of your projects included the following lighting technologies for at least some portion of the space? *(Record general response and then fill in the percentages; if unable to provide a percentage, and then ask them to rank the technology types from least to most prevalent)*

Lighting Overview:
<table>
<thead>
<tr>
<th>Lighting Type</th>
<th>Percentage/Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single ended high-pressure sodium</td>
<td>%________/#_______</td>
</tr>
<tr>
<td>Double ended high pressure sodium</td>
<td>%________/#_______</td>
</tr>
<tr>
<td>Metal Halide</td>
<td>%________/#_______</td>
</tr>
<tr>
<td>LED</td>
<td>%________/#_______</td>
</tr>
<tr>
<td>Ceramic metal halide</td>
<td>%________/#_______</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>%________/#_______</td>
</tr>
<tr>
<td>Plasma</td>
<td>%________/#_______</td>
</tr>
</tbody>
</table>

**HL.12 If they have experience with LED:** What has been your experience with LEDs in terms of performance (yield, quality) and learning curve (did you have to adjust cultivation techniques or environmental parameters?)

**HL.13 Are you aware of any potential interactions between LED fixtures and the operation or productivity of cannabis facilities?**

**HL.14 Would you recommend LEDs to cultivators based on your experience with quality and yield?**

**Changes in Practices**

**HL.15 Have your horticultural lighting design/specification/installation practices changed over the last 5 years in Massachusetts? (If no, then no need to distinguish between past and current practice in the questions that follow; if yes, ask remaining questions)**

**HL.16 If yes, how does the design today compare to how these systems were designed 5 years ago? What prompted the change? How much experimentation in design is still taking place?**

**HL.17 How has the knowledge of cultivators/cultivation facilities you’ve worked with changed over the last 5 years? Probe: What specific areas are they more knowledgeable on, or focused on?**
Factors influencing design/installation practices

HL.18 What are the three most important factors that affect the type of horticultural lighting you design/install starting with the most important? *(Indicate relative influence of each factor below, rating the 1st, 2nd, and 3rd most important factors in the table below. Capture any factors the interviewee mentions that is not in the table).*

<table>
<thead>
<tr>
<th>Category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of growth served (flower, veg, etc.)</td>
<td></td>
</tr>
<tr>
<td>Installation cost</td>
<td></td>
</tr>
<tr>
<td>Operating cost</td>
<td></td>
</tr>
<tr>
<td>Energy savings</td>
<td></td>
</tr>
<tr>
<td>Availability of utility incentives</td>
<td></td>
</tr>
<tr>
<td>Cannabis control commissions requirements</td>
<td></td>
</tr>
<tr>
<td>Client interest in sustainable design generally</td>
<td></td>
</tr>
<tr>
<td>Client request regarding technology</td>
<td></td>
</tr>
<tr>
<td>Speed of design/construction</td>
<td></td>
</tr>
<tr>
<td>Desired PPFD</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

HL.18 Comments:

Ask HL.19-HL.21 for all factors identified as significant. After asking more generally, probe for specific conditions that dictate differences in design.

HL.19 How do lighting designs differ for different cultivation spaces – for example, flower versus vegetative spaces?
How do lighting designs differ for different project types - for example, new construction vs. major renovation?

Have the Cannabis Control Commission LPD requirements changed lighting designs in terms of technology, layout, or PPFD?

If energy savings are identified as a factor per HL.16 How do the lighting designs differ when energy savings are a factor? These differences may include fixture technology, mounting heights, fixture layout, dimming schedules, “checker boarding”

Program influence

What percentage of the projects you work on receive financial incentives from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, Unitil, etc.) for lighting measures in cultivation facilities?

What percent of the projects do you work on receive technical assistance (a comprehensive, consultative resource where the Massachusetts’s PA’s help you identify energy saving opportunities that will decrease your energy costs) from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, etc.) for lighting measures in cultivation facilities?

Is there any consistency in the lighting systems you specify for projects that receive incentives/assistance for lighting? Are there any consistencies in the systems you specify for projects that do not receive utility incentives or technical assistance?

When utility incentives are available, what percent of time do you recommend the following technologies? (Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank the lighting from least to most prevalent)

Percent change in installation with incentives: [Negative indicates a reduction. For example, if incentives caused design changes of switching from HPS to LED, the table would indicate -100% for HPS, +100% for LED.]
<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure sodium</td>
<td></td>
</tr>
<tr>
<td>Metal Halide</td>
<td></td>
</tr>
<tr>
<td>LED</td>
<td></td>
</tr>
<tr>
<td>Ceramic metal discharge</td>
<td></td>
</tr>
<tr>
<td>Fluorescent</td>
<td></td>
</tr>
<tr>
<td>Plasma</td>
<td></td>
</tr>
</tbody>
</table>

**HL.27** In the absence of utility incentives, what percent of time would you recommend the following technologies? *(Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank the lighting from least to most prevalent)*

**Percent of installations without incentives:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure sodium</td>
<td></td>
</tr>
<tr>
<td>Metal Halide</td>
<td></td>
</tr>
<tr>
<td>LED</td>
<td></td>
</tr>
<tr>
<td>Ceramic metal discharge</td>
<td></td>
</tr>
<tr>
<td>Fluorescent</td>
<td></td>
</tr>
<tr>
<td>Plasma</td>
<td></td>
</tr>
</tbody>
</table>

**HL.28** *If they have worked outside of Mass*, how do your Massachusetts design practices for lighting compare with your practices in other jurisdictions?
TECHNOLOGY #2: MECHANICAL (HVAC) AND DEHUMIDIFICATION SYSTEMS

I’d like to ask you a series of questions about your experience designing/installing mechanical (HVAC) and dehumidification systems in cannabis cultivation facilities in Massachusetts.

General design/installation questions

M.1 In projects where you designed/installed HVAC systems over the last 5 years, what types of cooling systems/equipment did you install/design? *Record general response then check all that apply in M.1*

**General Response:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop units</td>
<td></td>
</tr>
<tr>
<td>Heat pumps/mini splits</td>
<td></td>
</tr>
<tr>
<td>Air cooled chiller</td>
<td></td>
</tr>
<tr>
<td>Water cooled chillers</td>
<td></td>
</tr>
<tr>
<td>Gas-fired chiller</td>
<td></td>
</tr>
<tr>
<td>Other (list several if applicable)</td>
<td></td>
</tr>
</tbody>
</table>

M.2 What proportion of your projects are [insert technology from below here]? *Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank the system types from least to most prevalent. Ensure in the interviewee’s response that the percentages given add up to 100%.*

**General Response:**
M.3 What types of air-side systems did you design/specify/install?

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop unit (constant volume)</td>
<td></td>
</tr>
<tr>
<td>Rooftop unit (variable volume)</td>
<td></td>
</tr>
<tr>
<td>Air handling units</td>
<td></td>
</tr>
<tr>
<td>Fan coil units</td>
<td></td>
</tr>
<tr>
<td>Mini-split</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

M.4 What heating systems do you see in cultivation facilities?? Select more than one if applicable.

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td></td>
</tr>
<tr>
<td>Furnace</td>
<td></td>
</tr>
<tr>
<td>Recovered heat</td>
<td></td>
</tr>
<tr>
<td>Heat pump/Mini split</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>
**M.5** What fuel or energy source is used for heating in cultivation facilities you have worked on?

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td></td>
</tr>
<tr>
<td>Oil</td>
<td></td>
</tr>
<tr>
<td>Propane</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

**M.6** What is the primary dehumidification equipment for cultivation facilities you’ve worked on?

**At the HVAC system**

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooftop unit</td>
<td></td>
</tr>
<tr>
<td>Mini-split/heat pump</td>
<td></td>
</tr>
<tr>
<td>Air handling unit</td>
<td></td>
</tr>
<tr>
<td>Fan coil unit</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>

**Stand-alone system**

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable dehumidifier (example: Quest brand)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>
**Advanced HVAC strategies or equipment**

**M.7** In projects where you designed/installed HVAC systems over the last 5 years, what percentage of the time did you install advanced or efficient systems/strategies? What were those efficient systems/strategies? *(Record general response then check all that apply below)*

**General Response:**

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dehumidification</strong>- Desiccant wheel air handling unit</td>
<td></td>
</tr>
<tr>
<td><strong>Dehumidification</strong> - Wrap around heat exchangers (e.g. MSP)</td>
<td></td>
</tr>
<tr>
<td><strong>Dehumidification</strong> - Variable discharge air temperature (DAT)</td>
<td></td>
</tr>
<tr>
<td>Direct or indirect airside economizing</td>
<td></td>
</tr>
<tr>
<td>Evaporative condenser pre-coolers</td>
<td></td>
</tr>
<tr>
<td><strong>Horticulture specific HVAC products</strong> – (e.g. Growaire or Surna Systems)</td>
<td></td>
</tr>
<tr>
<td><strong>Horticulture specific HVAC products</strong> – Other</td>
<td></td>
</tr>
<tr>
<td>Water side economizing or dry coolers (for water cooled chillers)</td>
<td></td>
</tr>
<tr>
<td>Gas fired chillers, if yes, ask what the alternative would be to the gas-fired chiller (electric chiller, RTU, etc.)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

**M.8** Who is typically driving the decision to consider energy efficient systems/strategies in cultivation facility equipment in Massachusetts?
Factors Influencing Design

M.9 What are the top three most important factors that affect the type of HVAC systems you design/install starting with the most important? (Indicate relative influence of each factor below, rating the 1st, 2nd, and 3rd most important factors in the table below. Capture any factors the interviewee mentions that is not in the table.)

<table>
<thead>
<tr>
<th>Category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of growth served (flower, veg, etc.)</td>
<td></td>
</tr>
<tr>
<td>Installation cost</td>
<td></td>
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<tr>
<td>Operating cost</td>
<td></td>
</tr>
<tr>
<td>Energy savings</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
</tr>
<tr>
<td>Ability to maintain precise control</td>
<td></td>
</tr>
<tr>
<td>Availability of utility incentives</td>
<td></td>
</tr>
<tr>
<td>Cannabis Control Commissions requirements</td>
<td></td>
</tr>
<tr>
<td>Client interest in sustainable design generally</td>
<td></td>
</tr>
<tr>
<td>Client request regarding technology</td>
<td></td>
</tr>
<tr>
<td>Speed of design/construction</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
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</tbody>
</table>

M.9 Comments:

Ask M.10 - M.13 for all factors identified as significant. After asking more generally, probe for specific conditions that dictate differences in design.

M.10 How do HVAC designs differ for different cultivation spaces – for example, flower versus vegetative spaces?
M.11 Do HVAC designs differ for new construction vs. major renovation of facilities? If so, how and why?

M.12 Do HVAC designs differ relative to the Cannabis Control Commission requirements, If so, how and why?

M.13 If energy savings are identified as a factor per M.9 How do the HVAC designs differ when energy savings are a factor? These differences may include HVAC technology, control strategies, etc.

Program influence

M.14 What percentage of the projects you work on receive financial incentives from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, Unitil, etc.) for HVAC measures in cultivation facilities?

M.15 What percent of the project you work on receive technical assistance (a comprehensive, consultative resource where the Massachusetts’s PA’s help you identify energy saving opportunities that will decrease your energy costs) from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, Unitil, etc.) for HVAC measures in cultivation facilities?

M.16 Is there any consistency in the HVAC systems you specify for projects that receive incentives/assistance? Are there any consistencies in the systems you specify for projects that do not receive utility incentives or technical assistance?

M.17 When utility incentives are available, what technologies or strategies do you recommend? What percent of the time do you recommend each?

<table>
<thead>
<tr>
<th>Technologies or Strategies</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>
M.18 In the absence of utility incentives, what technologies or strategies do you recommend? *(Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank from least to most prevalent)*

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
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<tbody>
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</tbody>
</table>

M.19 *If they have worked outside of Mass*, how do your Massachusetts design practices for HVAC compare with your practices in other jurisdictions?

**TECHNOLOGY 3: HVAC CONTROLS QUESTIONS**

HC.1 What type of controls have you designed/installed on your HVAC systems? *(Record general response then circle all that apply)*

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</tbody>
</table>
General Response:

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermostats</td>
<td></td>
</tr>
<tr>
<td>Humidistats</td>
<td></td>
</tr>
<tr>
<td>Central, automated control</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

**HC.2** What proportion of your projects are [insert technology from below here]? *(Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank the control types from least to most prevalent. Ensure in the interviewee’s response that the percentages given add up to 100%).*

General Response:

- Thermostats %_________/#_______
- Humidistats %_________/#_______
- Central automated control %_________/#_______
- Other %_________/#_______

Other:

**HC.3** Are certain control systems more often associated with certain HVAC systems types (e.g. do RTU based systems generally use thermostats, but chiller-based systems use automated central systems)? *(Record general response)*

**HC.4** For control systems you have installed, can you provide an overview of the sequence of operation? *(Possible strategies include, fan VFD control, setting up dehumidifiers with varying setpoints so they stage based on load, over cooling/reheating at constant fan speed)*
Factors influencing design/installation practices

HC.5 What are the top three most important factors that affect the type of HVAC control systems you design/install starting with the most important? *(Indicate relative influence of each factor below, rating the 1st, 2nd, and 3rd most important factors in the table below. Capture any factors the interviewee mentions that is not in the table).*

<table>
<thead>
<tr>
<th>Category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage of growth served (flower, veg, etc.)</td>
<td></td>
</tr>
<tr>
<td>Installation cost</td>
<td></td>
</tr>
<tr>
<td>Ability to maintain set points</td>
<td></td>
</tr>
<tr>
<td>Ease of use</td>
<td></td>
</tr>
<tr>
<td>Tracking/trending ability of system on key parameters</td>
<td></td>
</tr>
<tr>
<td>Operating cost</td>
<td></td>
</tr>
<tr>
<td>Energy savings</td>
<td></td>
</tr>
<tr>
<td>Availability of utility incentives</td>
<td></td>
</tr>
<tr>
<td>Cannabis control commissions requirements</td>
<td></td>
</tr>
<tr>
<td>Client interest in sustainable design generally</td>
<td></td>
</tr>
<tr>
<td>Client request regarding technology</td>
<td></td>
</tr>
<tr>
<td>Speed of design/construction</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

HC.6 Comments:
Ask HC.7 - HC.10 for all factors identified as significant. After asking more generally, probe for specific conditions that dictate differences in design.

HC.7 How do HVAC control strategies differ for different cultivation spaces – for example, flower versus vegetative spaces?

HC.8 Do HVAC control designs differ for different project types - for example, new construction vs. major renovation? If so, how and why?

HC.9 Do HVAC control designs differ relative to the Cannabis Control Commission requirements? If so, how and why?

HC.10 If energy savings are identified as a factor per HC.5 How do the HVAC designs differ when energy savings are a factor?

Program influence

HC.11 What percentage of the projects you work on receive financial incentives from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, Unitil, etc.) for HVAC control measures in cultivation facilities?

HC.12 What percent of the project you work on receive technical assistance (a comprehensive, consultative resource where the Massachusetts’s PA’s help you identify energy saving opportunities that will decrease your energy costs) from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, Unitil, etc.) for HVAC control measures in cultivation facilities?

HC.13 Is there any consistency in the HVAC control strategies you specify for projects that receive incentives/assistance? Are there any consistencies in the systems you specify for projects that do not receive utility incentives or technical assistance?

HC.14 When utility incentives are available, what control technologies or strategies do you recommend? What percent of the time do you recommend each? (Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank from least to most prevalent)
In the absence of utility incentives, what control technologies or strategies do you recommend? What percent of the time do you recommend each? *(Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank from least to most prevalent)*

<table>
<thead>
<tr>
<th>Control technologies or strategies</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>control technologies or strategies</th>
<th>Percentage</th>
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<tbody>
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</tr>
</tbody>
</table>
TECHNOLOGY 3: CANNABIS EXTRACTION EQUIPMENT

CEE.1 What type of cannabis extraction systems have you designed/installed? (Record general response then circle all that apply)

General Response:

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ based</td>
<td></td>
</tr>
<tr>
<td>Propane based</td>
<td></td>
</tr>
<tr>
<td>Butane based</td>
<td></td>
</tr>
<tr>
<td>Ethanol based</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

CEE.2 What proportion of your projects are [insert technology from below here]? (Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank from least to most prevalent. Ensure in the interviewee’s response that the percentages given add up to 100%)

General Response:

- CO₂ based %_______/#_______
- Propane based %_______/#_______
- Butane based %_______/#_______
- Ethanol based %_______/#_______
- Other %_______/#_______

Other:
Factors influencing design/installation practices

CEE.3 What are the top three most important factors that affect the type of extraction systems you design/install starting with the most important? *(Indicate relative influence of each factor below, rating the 1st, 2nd, and 3rd most important factors in the table below. Capture any factors the interviewee mentions that is not in the table).*

<table>
<thead>
<tr>
<th>Category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating cost</td>
<td></td>
</tr>
<tr>
<td>Ease of use/level of operator expertise</td>
<td></td>
</tr>
<tr>
<td>Installation cost</td>
<td></td>
</tr>
<tr>
<td>Quality of extract</td>
<td></td>
</tr>
<tr>
<td>Quantity of extract</td>
<td></td>
</tr>
<tr>
<td>Availability of utility incentives</td>
<td></td>
</tr>
<tr>
<td>Client preference or client’s previous experience</td>
<td></td>
</tr>
<tr>
<td>Energy efficiency</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

CEE.3 Comments:

*Ask CEE.4 and CEE.5 for all factors identified as significant. After asking more generally, probe for specific conditions that dictate differences in design.*

CEE.4 Do extraction system designs differ for different products (e.g. edibles, concentrates for vaping, topicals)? If so, how and why?

CEE.5 If energy savings are identified as a factor per CEE.3 How do the extraction systems differ when energy savings are a factor?
Program influence

CEE.6 What percentage of the projects you work on receive financial incentives from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, etc.) for extraction equipment in cultivation facilities?

CEE.7. What percent of the projects you work on receive technical assistance from the Massachusetts PAs (e.g. National Grid, Eversource, Cape Light, etc.) for extraction equipment in cultivation facilities?

CEE.8 Is there any consistency in the extraction systems you specify for projects that receive incentives/assistance? Are there any consistencies in the systems you specify for projects that do not receive utility incentives or technical assistance?

CEE.9 When utility incentives are available, what extraction systems do you recommend? What percent of the time do you recommend each? (Record general response and then fill in the percentages; if unable to provide a percentage, then ask them to rank the lighting from least to most prevalent)

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
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<tbody>
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<td></td>
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</tbody>
</table>

CEE.10 In the absence of utility incentives, what extraction systems do you recommend? What percent of the time do you recommend each? (Record general response and then
fill in the percentages; if unable to provide a percentage, then ask them to rank the lighting from least to most prevalent)

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
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<tbody>
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<td></td>
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</tbody>
</table>

**SECTION 2: GENERAL CANNABIS CULTIVATION QUESTIONS**

**G1.** What are the top factors you typically focus on when designing cultivation facilities?  
*Probe: do you focus on maximizing crop yield, cost, speed of design and construction, energy efficiency options?*

**G2.** What are the top factors cultivators typically focus on when designing cultivation facilities? *Probe: Maximizing crop yield, cost, speed of design and construction, environmental control, energy efficiency options?*
G3. What are the biggest barriers to implementing energy efficiency measures for cultivation facilities?

<table>
<thead>
<tr>
<th>Category</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>New laws</td>
<td></td>
</tr>
<tr>
<td>Lack of background in cannabis equipment and available options</td>
<td></td>
</tr>
<tr>
<td>Lack of background in facility management or design</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>

G4. When projects involve elements of energy efficiency, who typically initiates the conversation about energy efficiency in the design of a cultivation facility?

G5. In the next five years, where do you see the design/operation of cultivation facilities headed in regards to energy efficiency regionally, nationally, and internationally?

Regionally:
Nationally:
Internationally:

G6. What are the biggest challenges you expect to see?
Additional Market Players

MP.1 Who else do you suggest we contact for this study who installed/design cannabis facilities in new construction and major renovation projects in MA in the last 3-5 years?
SECTION 3: SURVEY IMPRESSIONS AND THOUGHT CATCHER

Did you find this responder credible? Why or why not?

Was there anything in similar questions that are in disagreement with other comments made by the responder?

Was the information provided by the respondent consistent?
APPENDIX C. COMPLIANCE PATHWAY EXAMPLE

The canopy is defined by the area of the room, not the area of the biomass. This path of compliance is illustrated in Figures C-1 and C-2.

Figure C-1. Illustrative PPFD map at 36 watts/sf

<table>
<thead>
<tr>
<th>Calculation Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Label</strong></td>
</tr>
<tr>
<td>RoomEst_1_Workplane</td>
</tr>
</tbody>
</table>

Specify Desired Calculated

- **Illuminance**: 3796. ft
- **# Luminaires**: 28
- **LPD**: 36.85 W/ft²

The desired criterion is the:
- Minimum Allowable
- Target (find nearest)
- Maximum Allowable

This arrangement produces an average PPFD of 512 µmol/s/m², which is well below typical target values of 800-1,000 µmol/s/m².

Figure C-2 models a scenario where the same quantity of fixtures is concentrated over a smaller area (30' x 15') within the 20' x 40' room. This model yields an LPD that is nearly double the LPD in Figure C-1 and produces PPFD values that are in line with typical targets. It also provides more consistent light across the canopy. Per the CCC definition of canopy, both of these rooms would meet the LPD requirement since the connected lighting load is the same, and the canopy, as defined by the boundary of the walls, is also the same.
Figure C-2. Illustrative PFD map at 36 watts/sf, reduced footprint

This example illustrates the need to ensure that any comparative lighting designs achieve equivalent PPFD. While both designs above meet the CCC LPD requirements, one delivers substantially less useful light.
APPENDIX D. IMPLEMENTER'S GUIDE

This appendix summarizes the relevant findings for program implementation staff in Massachusetts and Rhode Island. For facilities in Massachusetts, data from the post-CCC regulations constitute the findings that define ISP. For facilities in Rhode Island, data from the pre-CCC regulations constitute the findings that define ISP. Table D-1 shows what end uses concluded actionable findings for implementers, and those findings are summarized in more detail below.

While this report identifies several ISPs, cannabis facility designs have proven highly variable. In accordance with the Massachusetts Commercial/Industrial Baseline Framework\(^\text{10}\), implementers and future evaluators are permitted to make use of site-specific baselines for ISP systems when "...particular circumstances render standard practice irrelevant and evidence is provided to justify it."\(^\text{11}\)

### Table D-1. Summary of baselines for implementers

<table>
<thead>
<tr>
<th>System</th>
<th>Baseline definition (ISP or Site-Specific, or CCC Regulation)</th>
<th>ISP Report Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horticultural lighting LPD, non-tiered:</td>
<td>ISP, dual baseline treatment in MA</td>
<td>Section 5.1.2</td>
</tr>
<tr>
<td>Pre-CCC or Rhode Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horticultural lighting LPD, tiered:</td>
<td>Site-specific</td>
<td>Section 5.1.3.1</td>
</tr>
<tr>
<td>Pre-CCC or Rhode Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horticultural lighting LPD: Post-CCC</td>
<td>CCC regulation</td>
<td>Section 5.1.3</td>
</tr>
<tr>
<td>Horticultural lighting dimming</td>
<td>Site-specific</td>
<td>Section 5.1.3.2</td>
</tr>
<tr>
<td>HVAC system type</td>
<td>Site-specific or ISP based on tier</td>
<td>Section 5.2.4</td>
</tr>
<tr>
<td>Supplemental dehumidification</td>
<td>ISP – except DX systems</td>
<td>Section 5.2</td>
</tr>
<tr>
<td>HVAC controls equipment</td>
<td>ISP</td>
<td>Section 5.2</td>
</tr>
<tr>
<td>Extraction equipment</td>
<td>Site-specific</td>
<td>Section 5.3</td>
</tr>
</tbody>
</table>

Below is a summary of findings for each system geared toward implementation baselines. More details on the findings can be found in the corresponding sections of the report.

**Horticultural lighting LPD, non-tiered: Pre-CCC or Rhode Island**

In Massachusetts, projects at facilities licensed before March 2018 require dual baseline treatment. The first period applies the Pre-CCC baseline for the period from the licensing date of the facility to 1/1/2021. The second baseline applies the Post-CCC baseline for the balance of the measure life of 15 years.

---


\(^{11}\) Ibid
Table D-2. ISP conclusions for horticultural lighting prior to CCC regulations

<table>
<thead>
<tr>
<th>Stage</th>
<th>ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flower/bloom</td>
<td>1,000-watt double-ended HPS, with electronic ballast</td>
</tr>
<tr>
<td>Vegetative</td>
<td>1,000-watt single-ended metal halide</td>
</tr>
<tr>
<td>Clone/seedling</td>
<td>4LT5HO fluorescent</td>
</tr>
<tr>
<td>Mother</td>
<td>1,000-watt single-ended metal halide</td>
</tr>
</tbody>
</table>

Horticultural lighting LPD tiered: Pre-CCC or Rhode Island

There is no ISP technology for tiered lighting LPD at this time. There is sufficient variability within tiered grows in the available height between tiers that allow for many different lighting technologies to be utilized. Baselines should be site-specific with consideration to the CCC HLPD requirements.

Horticultural Lighting LPD non-tiered: Post-CCC

The Post-CCC baseline applies to facilities licensed after March 2018.

Table D-3. Horticultural lighting ISP after CCC regulations

<table>
<thead>
<tr>
<th>Cultivation Tier</th>
<th>Permitted Canopy Area – square feet</th>
<th>CCC Maximum HLPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>1 – 10,000</td>
<td>50 watts/sf</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>10,001 – 100,000</td>
<td>36 watts/sf</td>
</tr>
</tbody>
</table>

The ISP study team notes that there is a secondary compliance path using a minimum fixture PPE. This secondary compliance path is more stringent than the LPD compliance path and is therefore not recommended for use as the baseline case for programs (analogous to a performance compliance pathway in the energy code).

The ISP study team also notes that the findings for tiered cultivation spaces remain true for the post-CCC designed facilities; those facilities were still designed to meet or exceed the CCC-regulated LPDs, so the CCC-regulated LPDs remain as expected for tiered grows.

Horticultural lighting dimming

There is no ISP for lighting dimming at this time. The application of dimming and its effects on plant growth are not sufficiently understood for a standard practice to have emerged. Site-specific baselines should be used if dimming at a facility is considered an energy-efficiency measure.
**HVAC system type**

Table D-4. Environmental conditioning ISPs

<table>
<thead>
<tr>
<th>Cultivation Tier</th>
<th>HVAC Technology ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiers 1-2</td>
<td>Split or packaged direct expansion (DX) systems such as rooftop units (RTUs) and mini-split heat pumps</td>
</tr>
<tr>
<td>Tiers 3-11</td>
<td>Chilled water systems</td>
</tr>
</tbody>
</table>

**Supplemental dehumidification**

Table D-5. HVAC technology and supplemental dehumidification ISP

<table>
<thead>
<tr>
<th>HVAC Technology</th>
<th>Supplemental Dehumidification Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-splits</td>
<td>Supplemental portable dehumidification</td>
</tr>
<tr>
<td>Variable refrigerant flow (VRF)</td>
<td>Supplemental portable dehumidification</td>
</tr>
<tr>
<td>Air-source or water-source heat pump</td>
<td>Supplemental portable dehumidification</td>
</tr>
<tr>
<td>DX systems</td>
<td>No ISP. Site-specific baselines are needed to assess the potential impact of supplemental dehumidification.</td>
</tr>
<tr>
<td>Chilled water systems</td>
<td>No supplemental dehumidification</td>
</tr>
</tbody>
</table>

**HVAC control equipment**

Table D-6. HVAC systems and controls ISP

<table>
<thead>
<tr>
<th>Facility size</th>
<th>HVAC ISP</th>
<th>HVAC Controls ISP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1-2</td>
<td>Packaged or split DX system</td>
<td>The operation of the HVAC unit is based on the dry-bulb temperature of the space served. No hot-gas bypass for humidity control. Fixed speed supply fans.</td>
</tr>
<tr>
<td>Tier 3-11</td>
<td>Chilled water system</td>
<td>Automated central system</td>
</tr>
</tbody>
</table>

**Extraction equipment**

There is no ISP for extraction equipment at this time. These processes are varied and highly dependent on the facilities' final products and techniques.

**Additional systems**

The table below provides a summary of system types that implementers may encounter in the course of program activity. These systems were not part of the study and are specified here for implementer reference and for future research.
Table D-7. Additional systems for future investigation

<table>
<thead>
<tr>
<th>System</th>
<th>ISP</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouses and mixed light facilities</td>
<td>ISP was not identified in this study. Site-specific baseline recommended at this time</td>
<td>Greenhouses and their associated systems were not studied.</td>
</tr>
<tr>
<td>Odor mitigation</td>
<td>ISP was not identified in this study. Site-specific baseline recommended at this time</td>
<td>Facilities install equipment to mitigate odors produced by the plants. Several technologies are available including carbon filters and ozone-based systems.</td>
</tr>
</tbody>
</table>

Dual baseline lighting savings calculation approach

Below is a recommended process for calculating the potential savings of retrospective compliance horticultural lighting projects. The lifetime savings of the measure will have a dual baseline, with a portion of the measure life occurring prior to the CCC regulations, and the balance of the measure life occurring after CCC regulations.

\[
kWh_{savings\text{\ lifetime}} = first \ period \ kWh_{savings\ preCCC} + second \ period \ kWh_{savings\ postCCC}
\]

To calculate savings for pre-CCC phase:

1. Identify the phase of cultivation and select the appropriate baseline technology per Table 1-1.
2. Identify the project’s target photosynthetic photon flux density (PPFD) for that phase of growth. This value will differ based on the cultivator’s preference for lighting design.
3. Model the base case using the technology identified in Table 1-1, and model the proposed case to validate PPFD equivalency of the two designs. Most LED vendors and many service providers can generate this modeling. Modeling can be performed or validated with AGi32 lighting analysis software.
4. Calculate the connected wattage of the PPFD-equivalent base-case and proposed designs. The difference in wattage is the demand reduction.
5. Calculate the annual lighting energy impacts based on fixture run hours, a value specific to each phase and project, and referred to as the photoperiod. The flower phase photoperiod is 12 hours. The vegetative and mother photoperiods are 18 hours, and the clone photoperiod is 24 hours.
6. Calculate the interactive HVAC impacts of the proposed lighting design.
7. Calculate the first-period savings as the product of the sum of the first-period annual savings and the first-period measure life. The first-period measure life is the time between the project installation and January 1, 2021. The calculation should use a fractional measure life if possible.
To calculate savings for post-CCC phase:

Post-CCC operation:

- Lifetime use is based on a 15-year measure life with a single baseline.
- The baseline LPD is now based on the CCC watts/sf based on facility tier.

To calculate the savings for the post-CCC phase:

- Select the appropriate LPD threshold based on the tier of cultivation and Table 1-2, above.
- Model the base-case and the proposed case, demonstrating equivalent PPFD in each cultivation space and the HLPD as defined by the CCC regulations. Most LED vendors and many service providers can generate this modeling. Modeling can be performed or validated with AGi32 lighting analysis software.
- Calculate the difference between the CCC mandated LPD and the proposed case LPD.
- Apply the difference in LPD to the canopy area value used in the calculations to find the reduction in connected wattage.
- Calculate the annual lighting energy impacts based on fixture run hours, a value specific to each phase and project and referred to as the photoperiod. The flower phase photoperiod is 12 hours. The vegetative and mother photoperiods are 18 hours, and the clone photoperiod is 24 hours.
- Calculate the interactive HVAC impacts of the proposed lighting design.
- Calculate the second-period savings as the product of the sum of the second-period annual savings and the second-period remaining measure life. The second-period measure life is the full measure life less the first-period measure life. The calculation should use a fractional measure life if possible.
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