RESOURCE INNOVATION INSTITUTE

ENERGY EFFICIENCY FOR MASSACHUSETTS MARIJUANA CULTIVATORS

INCLUDING GUIDANCE FOR MARIJUANA ESTABLISHMENTS AND TREATMENT CENTERS

BY GRETCHEN SCHIMELPFENIG, PE

Part of RII's Resource Efficiency Best Practices Series

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Available online at: www.ResourceInnovation.org/Resources

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PURPOSE & INTRODUCTION

The purpose of this *Energy Efficiency Best Practices Guide for Massachusetts Marijuana Cultivators* is to support you, the Commonwealth cultivator, and your business with objective recommendations on operating an energy-efficient cultivation facility. The guide is assembled by the non-profit organization Resource Innovation Institute, funded by the Massachusetts Dept. of Energy Resources and peer-reviewed by Massachusetts-based practitioners with experience designing, constructing and operating cannabis cultivation and other horticultural facilities with energy efficiency in mind. This Best Practices Guide should not be construed as legal advice. Rather, it is intended to help you make informed decisions that consider upfront costs, operating costs, available incentives and greenhouse gas emissions impacts.

This guide is a companion to Resource Innovation Institute's peer-reviewed Best Practices Guides on LED Lighting for Cannabis Cultivation and HVAC for Cannabis Cultivation, which **help growers like you better understand resource-efficient technologies, how to use them, related terminology and metrics that can guide your efficiency tracking**.

Electricity

Resource efficiency has a direct impact on your profit. Massachusetts has some of the highest electricity rates in the country, with industrial electricity rates over $0.16 per kWh. Utility rate structures vary by facility type and region, and some rate classes for industrial customers have peak and off-peak demand charges, which can range from $9 to over $20 per kW. Depending on the consumer's total electricity costs, the savings of electric energy efficiency measures may vary. If your facility is served by a municipal utility, electric rates may be much lower, though you may also not pay into the state's Mass Save energy efficiency program and so may not be eligible for incentives offered by program administrators[1] in their service territories. While costs may vary, the state's electric grid is relatively clean and Massachusetts has legislated that the average marginal emissions rate must be at or below 200 lbs/MWh by the year 2050. If you were to compare the emissions of two facilities with identical site energy productivity, one based on Colorado and one based in Massachusetts, the Massachusetts facility would produce nearly 50% less greenhouse gas emissions (CO_{2e}).

Fuels

Historically low natural gas prices reduce the economic pressure to conserve this fuel. Strategies that reduce electricity consumption and demand often pay back faster than those that conserve gas due to the higher relative cost of electricity. Natural gas rates for cultivation facilities can range from $4.50/MMBtu in National Grid's Boston service area to as low as $1.75/MMBtu in Eversource's service area. It is important to consider the emissions impact of fuel-fired systems, and not just the economics based on the energy impacts. While gas may be cheap now, conserving natural gas and other fossil fuels is an effective way for growers to position themselves for the movement towards decarbonization. The source and deployment of back-up generation can also be an important consideration, and one that can substantially impact your operation's carbon emissions.

[1] The state's Mass Save program administrators are Berkshire Gas, Blackstone Gas Company, Cape Light Compact, Columbia Gas, Eversource, Liberty Utilities, National Grid, and Unitil.

Water

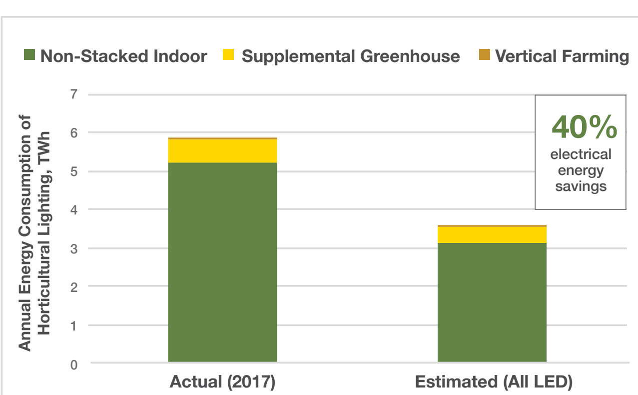
Water conservation is a key element of resource-efficient cannabis cultivation and may be critically important in certain regions. Higher water costs and anticipated clean water shortages in Boston make conservation a greater value proposition. If financial savings do not justify the expense of a water reclamation system, corporate social responsibility may become a motivating factor as time goes on.

Efficiency

Efficiency drives competitive position. While getting to market quickly is crucial, long-term decision-making will also pay off as the Commonwealth's cannabis market matures. As seen in other states, cost compression and consolidation ultimately drive competition to a place where firms with efficient and regulatorily-compliant facilities gain advantage.

A high performance lighting and HVAC system in Massachusetts could reduce total operating costs by 15% - 40% over a traditional HVAC and lighting system approach.

Figure 1: Annual Electricity Usage from Horticultural Lighting[2]



For example, the U.S. Department of Energy estimates 40% electricity savings when LED lighting systems are used in horticultural applications (Figure 1). Learn how the cost savings from LED lighting systems and efficient HVAC equipment can help your operation in the case studies on page 18.

Efficient equipment reduces maintenance costs, too. A 10,000 square foot cultivation room using fluorescent lights may incur over $50,000 in costs for replacing bulbs and reflectors.

Leverage incentives and technical assistance from Mass Save programs to shorten payback periods on efficient equipment is smart business. High performance equipment can require larger capital investment, but costs are decreasing as the horticultural equipment market matures, and incentives can buy down 20 - 50% of first costs. Pursuing incentives and employing vetted best practices will increase your odds of success.

Programs and Incentives

Many Massachusetts electric and gas customers can participate in energy efficiency programs through the Mass Save program or through their local Municipal Lighting Plant (MLP) utility. These programs provide cash incentives or rebates to offset a portion of the capital costs associated with more efficient cultivation systems, which may also help cultivators comply with the state energy requirements. Operators can also receive incentives available for on-site renewable energy generation and deploying alternative and renewable heating and cooling technology. See the **Resources** section on page 22 for links to information about efficiency and renewables programs.

After reading this document you will:

- **Increase** your understanding of Massachusetts energy regulations and best practices associated with compliance
- **Obtain** guidance on achieving resource efficiency while cultivating in the New England climate
- **Gain** resources to help you comply and benchmark energy performance

[2] Energy Savings Potential of SSL in Horticultural Applications, December 2017, U.S. DOE Office of EERE

MASSACHUSETTS ENERGY REGULATIONS

The Massachusetts Cannabis Control Commission (CCC) requires adult-use Marijuana Establishments (MEs) and Medical Marijuana Treatment Centers (MTCs) to **develop plans to adopt energy efficiency and environmental best practices, and to comply with the following state laws and regulations:**

- 935 CMR 500.000: Adult Use of Marijuana
- 935 CMR 501.000: Medical Use of Marijuana
- 935 CMR 502.000: Colocated Adult-Use and Medical-Use Marijuana Operations

The CCC published Energy and Environment Compiled Guidance (Guidance) in January 2020. The Guidance provides additional information for facilities complying with the regulations above. The Guidance also provides Best Management Practices for Water.

The changes necessary for achieving an efficient cultivation facility may be detailed, but the up front investments for persistent resource efficiency and compliance with energy regulations can pay you back year over year in reduced operating costs.

BEST PRACTICES FOR MARIJUANA ESTABLISHMENTS, CULTIVATORS AND TREATMENT CENTERS

All applications submitted on or after July 1, 2020, if they are not otherwise exempted, must comply with energy efficiency standards and reporting requirements described in the laws and regulations listed above and outlined in the Guidance. **Existing indoor cultivation facilities must be in full compliance with standards and reporting requirements by 2021**, either January or July depending on their license type and date of licensure.

The sections below summarize the CCC's guidelines and offer you some recommendations for best practices.

The following recommendations apply to all ME/MTCs during the preparation of their Management and Operations Profile, which is one of the three main parts of the initial application for licensure. This application will be reviewed prior to grant of Provisional License and Architectural Review.

EXAMINE ENERGY-USE REDUCTION OPPORTUNITIES AND PLAN FOR IMPLEMENTATION OF SUCH OPPORTUNITIES

- **Reach out to** your Municipal Lighting Plant (MLP) utility, fuel utilities, and the Mass Save energy efficiency program administrators (PAs) early to get help identifying measures to achieve energy efficiency.
- **Evaluate incentive opportunities** and take advantage of technical assistance available through the Renewable Energy Portfolio Standard (RPS), the Alternative Energy Portfolio Standard (APS), the Solar Massachusetts Renewable Target (SMART) Program, the Massachusetts Clean Peak Energy Standard, and the Massachusetts Clean Energy Center (MassCEC).
- **Do your homework** and assemble a qualified project team. Challenge your architect, mechanical, electrical, and plumbing (MEP) engineer, and lighting designer to offer you options that can reduce your energy use in your facility.
- **Engage with energy** efficiency professionals on your team to quantify energy savings of identified energy-use reduction opportunities.
- **Read peer-reviewed** case studies to understand potential energy use reduction opportunities and technology to achieve best outcomes. See the **Case Studies** section on page 18 to learn about some strategies that have worked for Massachusetts cultivators.
- **Consider product trials** or pilots for innovative approaches to reducing energy usage.

EXPLORE ENERGY EFFICIENCY OPPORTUNITIES

- **Engage with your** local electric and gas utilities and PAs as early in your design process as possible to discuss rebates and other incentives for energy-efficient technologies.
- **Communicate early** and often with your architect, MEP engineer, lighting designer and/or energy efficiency professionals about your interest in engaging in utility energy efficiency programs. They can incorporate potential incentives into your project budget to help you understand payback periods for efficiency measures.
- **Determine what payback** period is acceptable for your operation. Include both utility bill savings as well as maintenance and labor cost savings in calculations.
    - Payback periods under 3 years are sound investments.
    - You can bundle quick-payback and longer-payback items so their blended rate of return meets your payback targets.
    - If your operation is capable of controlling systems better or increasing productivity, a 10 year payback period may be acceptable for increased yields or profit margins.

mass save®

Consider high-performance systems

Consider some of these top efficiency measures achieving success in cultivation operations and evaluate payback periods with your project team:

Indoor facilities:

- High performance building envelopes
- LED lighting systems listed on DesignLights Consortium (DLC) Horticultural Qualified Products Library (QPL)
- HVAC systems incorporating heat recovery
    - Indirect air-side economizer
- Evaporative 'free' cooling systems for existing rooftop units
- Heat pump systems
- Combined heat and power, or cogeneration
- Energy storage including batteries, thermal storage
- Additional considerations for indoor facilities Tier 3 and above:
    - Hydronic HVAC systems
    - Air- and water-side economizer

Larger greenhouse facilities:

- Lighting controls to modulate output to match target daily light integral (DLI)
- Variable frequency drives for motors driving fans and pumps
- Thermal curtains
- Shadecloth and/or light deprivation systems
- Latent heat converters
- Radiant heating systems

Some of these technologies and strategies are discussed in the following sections.

INVESTIGATE STRATEGIES TO REDUCE ELECTRIC DEMAND

Understand peak demand

- **Work with an engineer** to understand your facility's peak electric demand so you have a predictable loadshape and monthly demand charges on your electric bill.
    - Peak electric demand is the power draw from your facility during the 15-minute period of each month that you demand the greatest amount of electricity (kW).
- **Ask your engineers** and energy efficiency professionals for help understanding your demand rate billing structure and identifying strategies for reducing peak electric demand and opportunities to 'flatten' your facility's electricity demand 'spikes' and spend less each month on electric demand expenses.

Review Standard Operating Procedures

- **Review your horticultural Standard Operating Procedures (SOPs)** to determine if target light levels for various plant growth stages and environmental setpoints to be maintained by HVAC equipment are the most efficient and cost effective for your cultivars. Monitor environmental conditions to verify lighting and HVAC operation and continued product quality.

Implement demand reduction strategies

- **Implement behavioral approaches** like staggering when light fixtures (especially in flowering rooms) are turned on or performing energy-intensive like processing during off-peak hours.
- **Work with your** municipality early to understand if staff working multiple shifts are allowed.
- **Size mechanical systems** appropriately based on the expected sensible load (primarily driven by lighting) and latent load (primarily driven by plant transpiration).
- **Incorporate energy storage** to minimize demand spikes by storing energy using thermal or electric technology and determine eligibility for systems to receive incentives from Mass Save, SMART, and Clean Peak Standard programs. Thermal and battery storage devices have demonstrated success in other commercial and industrial buildings with attractive payback periods.
    - Store excess heat in water in buffer tanks or use battery banks to store energy from the grid during off-peak hours to be used when you need the most cooling.
    - See page 18 for a case study featuring Solar Therapeutics, an operation considering adding battery banks to deepen their commitment to on-site renewable energy.
- **Utilize technical approaches,** including energy efficiency measures that reduce demand, electric battery storage, thermal energy storage, or automated systems that account for peak energy demand periods and turn down equipment.
    - For example, consider installing variable frequency drives on fans and pumps to allow motors to modulate speed, allowing them to reduce demand and energy consumption.

CONSIDER OPPORTUNITIES FOR RENEWABLE ENERGY GENERATION

Determine desired fuel mix

Understand your site's energy capacity and infrastructure limitations using the details of your unique building site and existing electric and fuel service.

- **Determine the total** amperage of your site's electric service and whether it is constrained.
- **Required size of** electric service can depend on the chosen lighting system.
    - Cultivation facilities using LED need around 20% less switchgear capacity per canopy square foot than facilities using non-LED lighting systems.
- **Some operators may** be limited by amperage at their transformer, but have sufficient natural gas service or a consistent source of biomass fuel, so cogeneration can be a feasible way to satisfy energy demands.

Evaluate what energy mix might be right for your operation based upon environmental goals.

- **Operators interested in** sustainability should determine the fuel mix supporting their electric grid and assess the greenhouse gas emissions impacts.
    - In Massachusetts, two-thirds of electricity is sourced from natural gas and almost all the rest comes from nuclear power and renewables. There is no coal-fired electricity in Massachusetts' grid.
    - Consider electrifying process equipment to reduce carbon emissions and receive incentives from electrification programs.
- **Operations with sufficient** electric and natural gas service can decide between an all-electric heat pump HVAC system and hybrid fueled options depending on business processes and environmental goals. Some heat pump systems are eligible for incentives.
- **Greenhouse facilities can** use efficient furnaces and boilers using wood, biogas, or other biofuels as an alternative to heating with fossil fuels. Electric system alternatives include direct use geothermal and refrigerant-based ducted and hydronic heat pump systems for both heating and cooling.

Prepare for renewable energy infrastructure

- **Weigh investments in** efficiency measures before renewable energy technology to reduce the required capacity of any renewable energy equipment you install.
- **Engage with your** electric utility early to plan for interconnection of renewable infrastructure.
- **When evaluating sites**, consider properties with existing on-site renewable energy generation.
- **If you are considering** installing solar, evaluate the feasibility of ground-mounted or roof-mounted options, and the capacity you might be able to install on existing structures.
- **Consult Massachusetts DOER** resources on renewable energy opportunities for commercial and industrial businesses.
- **Engage a renewable** energy specialist who can help you assess your site for renewable energy generation.
- **In Massachusetts**, a preferred source of on-site renewable energy are solar photovoltaic (PV) panels, and business owners can take advantage of statewide policies and programs like SMART supporting installation of solar at their facilities.
- **Get in touch** with your electric utility early to discuss interconnection of renewable energy technology and get any construction work scheduled early so your timeline is not affected.
- **Talk with your** electric utility company about sourcing renewable energy from the grid to offset your facility's carbon emissions impact if you cannot install renewables at your site.

The following requirements apply to only Cultivators:

BUILDING ENVELOPE STANDARD

Comply with applicable codes

- **Review State laws** 780 CMR including 780 CMR 13.00 addressing Energy Conservation and 780 CMR 34.00 addressing Existing Structures, 935 CMR 500.120(11)(a), and 935 CMR 501.120(12)(a) with your project team to understand how they apply to your facility. Note that these standards apply to new construction as well as additions and alterations to existing buildings (retrofits). See page 13 of the Guidance for more on Building Envelope.
- **See the Resources** section on page 22 to get help understanding building codes and cannabis energy regulations, what they mean, and when code applies.
    - Cultivation facilities generally include cultivation and non-cultivation areas; understand whether all spaces must comply with State Building Code 780 CMR.
    - Additions to existing buildings are considered new construction and shall conform with 780 CMR 13.00.
    - Alterations to existing buildings significant enough to trigger a full code review for "substantial renovation" or change of use renovation may require the whole building to be brought into compliance.
    - Existing buildings shall comply with the International Energy Code (IEEC) and with the Massachusetts amendments to the IEEC as provided in 780 CMR 13.00.
    - Some greenhouses may be exempt from the requirements of 780 CMR 13.00 if they meet

certain prerequisites. Make sure to keep up to date on future code revisions, as there may be changes to 780 CMR.

- **Ensure your architect** is referring to stated Massachusetts Building Code requirements and all Massachusetts amendments for building envelope standards.

Improve building envelope integrity and quality

- **Pursue high-performance** air sealing strategies to control the movement of air and vapor through the building envelope and minimize infiltration of outside air to save energy every day.
- **Incorporate thoughtful structural** design to avoid thermal bridging.
- **Seal your cultivation** spaces to separate them from non-cultivation spaces and distribute conditioned air and water in sealed and insulated ductwork and piping.
- **Consider doing blower** door testing to establish your air leakage rate for at least one of your cultivation areas.
- **Assess insulating building** envelopes beyond code; this strategy may not prove cost-effective for cultivation operations, as internal heat loads are greater than external heat loads and higher levels of insulation may not be justified by reduced operating costs.

LIGHTING STANDARDS

Comply with applicable codes

- **Review 935 CMR 500.002**, 500.120(11)(h) and 501.120(12)(g) for definitions used in lighting standards to understand key terms and requirements.
- **Review 935 CMR 500.120 (11)(b)**; 935 CMR 501.120 (12)(b) to determine which of the two lighting compliance options your facility will use.
- **The lighting standards** require cultivators to install energy-efficient lighting equipment in their facility, measured either by Horticultural Lighting Power Density (HLPD) or by meeting a minimum photosynthetic photon efficacy (PPE) standard. Use the DLC Horticultural QPL and use the State Compliance filter to select “Massachusetts CCC Compliance” to search for fixtures compliant with Massachusetts regulations. See page 14 of the Guidance for more on Lighting.

Evaluate and conduct trials of LED light fixtures

- **Consider your light-emitting** diode (LED) options as early as possible in your design process. Read peer-reviewed case studies of facilities like yours using LED lighting systems to determine what type of LED approach will work best for you.
  - Cultivators using LED can save 15 - 30% in total operating costs when compared to high intensity discharge (HID).

- **If you remain** skeptical of LED lighting solutions, consider a phased adoption by starting with your clone and veg rooms first or designating a single flower room to LEDs while meeting the minimum requirements for compliance.
- **Overcome the learning** curve by networking with cultivators who have successfully made the transition in all phases of cultivation.
- **Running a trial** with a few plants can amplify variability. Instead, dedicate a larger space to a trial so that the resulting harvest data comes from a larger population to reduce standard deviation in your results.
- **Consider dedicating a** room to an LED trial, and maintain at a minimum, a couple tables’ worth of plants (at least 30 square feet of flowering canopy).
- **If you only test** LEDs in a part of a bay, be prepared to optimize environmental conditions for the LED plants and not the other lighting technologies in the room.
- **Consider switching an** entire area at a time instead of checkerboarding, which results in poor uniformity. If you test LEDs in checkerboard patterns with other lighting technology like HID light fixtures, you may find that you have to “split the difference” too much with your target conditions like space temperature and techniques like fertigation and watering rate.
- **When going vertical**, consider your target size of plant for each stage of plant growth. Mature plants larger than 8” in height can be closer to light fixtures when grown with LED lighting systems and lighting controls.

Evaluate and conduct trials of lighting control systems

- **Incorporate lighting controls** so you can strategically dim light fixtures at different times of the day and during various stages of plant growth.
- **Larger Massachusetts greenhouse** operations can find lighting controls systems to be a cost-effective strategy to modulate light levels to match target DLI.

HVAC AND DEHUMIDIFICATION STANDARDS

- **Review 935 CMR 500.120(11)(c)**; 935 CMR 501.120(12)(c) to understand HVAC and dehumidification requirements.
- **The regulations require** HVAC and dehumidification systems to meet Massachusetts Building Code requirements. See page 17 of the Guidance for more on HVAC and dehumidification.
- **Communicate with your architect**, MEP engineer, and/or energy efficiency professionals to make sure all parties understand the relevant standards above, and the strategies you prefer for achieving them.

Select high performance HVAC and dehumidification systems

- **Think about HVAC** and lighting system interactions; new facilities using LED lighting systems can require HVAC equipment with 15 - 30% smaller capacity than HID-lit facilities, due to lower heat output.
  - Consider liquid cooled lighting systems to reduce heat loads in cultivation areas and evaluate how recovered heat can be utilized in other processes.
- **Consider purpose-built** HVAC and dehumidification technologies specifically designed for indoor horticultural applications that have the capability to maintain the dynamic environmental conditions needed for cannabis cultivation.
- **For facilities with** existing rooftop units, retrofitting them to incorporate evaporative ‘free’ cooling systems can be cost-effective and increase the cooling capacity of the equipment while also reducing operational expenses from demand charges.
- **Investigate the cost-effectiveness** of hydronic HVAC systems well-suited for larger facilities and eligible for Mass Save and Alternative Energy Portfolio Standard program incentives:
  - 4-pipe systems for cooling, dehumidification, and reheat
  - High-efficiency electric and gas-fired chiller systems with air- or water-side economizer
  - Efficient condensing boilers
- **Evaluate the feasibility** of a heat pump system and determine the type of heat pump technology that will work best depending on your cultivation process and approach. Heat pumps can be a good option for both indoor and greenhouse operations, and equipment can pay back in two to four years. Some systems well-suited to Massachusetts cultivation processes and incentivized by Mass Save program administrators and the state’s Alternative Portfolio Standard include efficient:
  - Heat pump rooftop units
  - Centrally ducted air-source heat pump systems
  - Air-to-water heat pump systems
  - Heat pump systems with Variable Refrigerant Flow controls
- **Evaluate systems that** improve efficiency and reduce cooling load by reducing unwanted waste heat production within grow rooms:
  - Remotely locate ballasts for light fixtures, in particular those with the highest wattage and/or heat output.
  - Typical portable dehumidifiers reject the heat of condensation back into cultivation spaces; consider dehumidification equipment integrated with your HVAC system.
  - Remotely locating condensers lessens heat loads on your HVAC equipment.
- **Install variable frequency** drives (VFDs) on existing fans and pumps and select new equipment with VFDs to reduce motor speeds during periods with lower demand.

Consider energy recovery

- **HVAC systems incorporating** energy recovery are best suited for cultivation applications when the heat exchanger prevents outdoor air from entering spaces with plants. Indirect air-side economizers use air- to-air heat exchange to transfer heat to a separate outdoor airstream.
  - Mass Save programs incentivize heat pipe, plate and wheel heat exchangers, and free cooling systems.

Consider efficient greenhouse HVAC equipment

- **Greenhouses in Massachusetts** can save HVAC energy by buttoning up the building envelope and reducing heat losses in cold months while minimizing solar heat gain in warmer months.
  - Thermal curtains connected to a controller can reduce heat losses seasonally and at night with paybacks ranging from six months to five years.
  - Shadecloth and/or light deprivation systems provide DLI control and can reduce cooling costs.
  - Latent heat converters convert excess water vapor in greenhouse air into liquid and allow for lower ventilation rates to reduce the heating costs while retaining CO_2-enriched air.
  - Reduce distribution temperature by 5 - 10 degrees and save energy with hydronic radiant heating under benches and in the ground, which can reduce the size of your heating equipment by 20 - 25% and pay you back in one to five years.

Review Standard Operating Procedures for environmental controls

- **Rooms with plants** grown under LED can be maintained at warmer temperature and higher relative humidity setpoints (at the same vapor pressure differential, VPD) and reduce demand for cooling, resulting in HVAC systems operating 10% more efficiently.
- **Equalize leaf temperature** when transitioning to LED by monitoring environmental conditions in cultivation spaces under new lighting systems and inform and calibrate adjustments.
  - For example, in week 4, with a room VPD setpoint of 1.4 kPa:
    - LED 82 °F / 65% RH
    - HID 76 °F / 50% RH
- **Consider incorporating airflow** control strategies to reduce energy consumption; these can be incentivized by Mass Save program administrators.

The following requirement applies only to Cultivators during the Renewal stage.

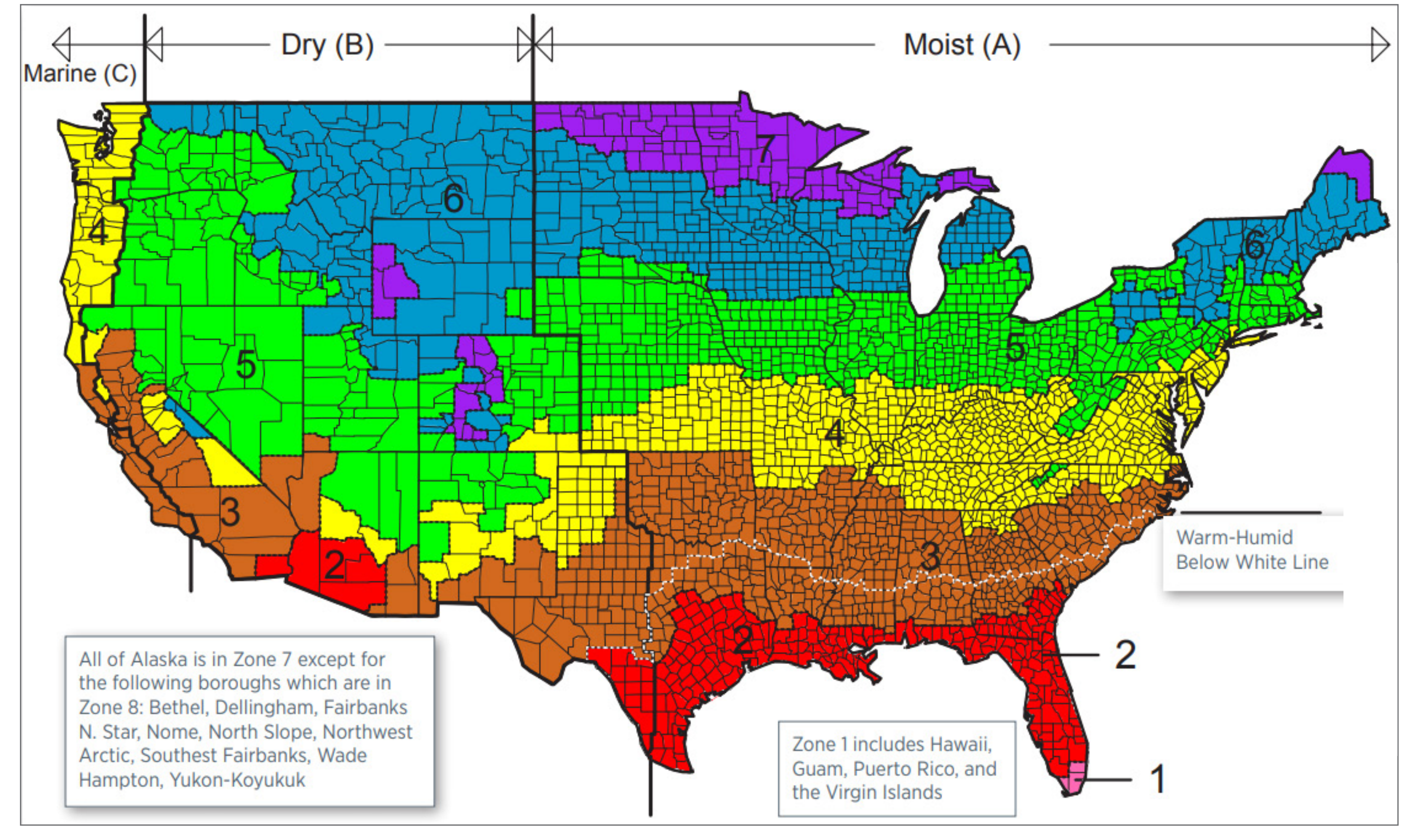
ENERGY AND WATER REPORTING

- **Review 935 CMR 500.103(4)** and 935 CMR 501.103(4) to understand energy and water reporting requirements.
- **Gather electricity**, natural gas, delivered fuels (propane, fuel oil, diesel), renewable energy production, and water bills for the prior 12 months.
- **Calculate your facility's** production of dry flower (as defined by Massachusetts METRC) for the prior 12 months.
- **Submit required annual** reporting information via RII's Cannabis PowerScore. Fill out the quick "Comply" form found at www.CannabisPowerScore.org/MA.

Benchmark to increase operational efficiency

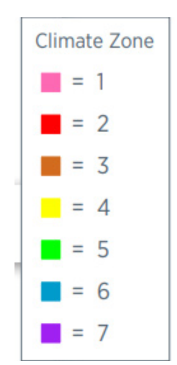
- **Gain additional insights** about how to maximize resource efficiency in your facility by completing the PowerScore "Comply & Benchmark" survey.

PHOTO: MARIJUANA VENTURE



CULTIVATING IN NEW ENGLAND

(CLIMATE ZONE 5)



Map: Climate Zones in the Continental United States

Massachusetts cultivators and their outdoor farms, greenhouses, and indoor facilities must contend with the environmental conditions of Climate Zone 5, which has relatively moist and cold conditions.

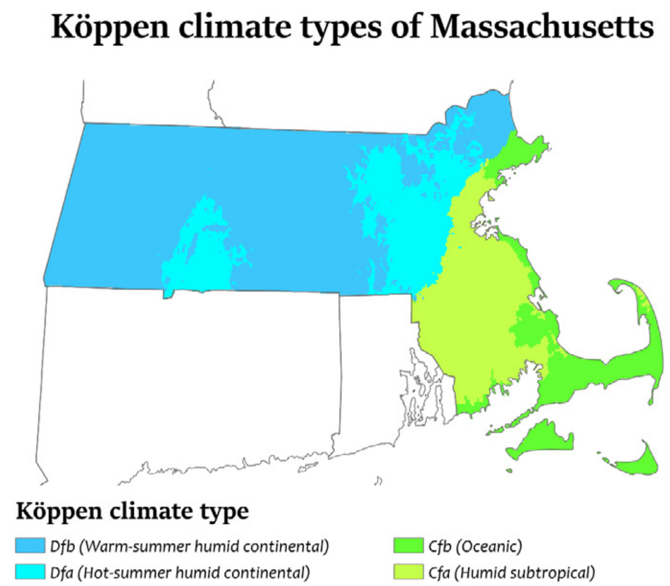
Massachusetts has a humid continental climate, with hot summers and cold, snowy winters. The state of Massachusetts has several subclimate types, with coastal regions having more oceanic and subtropical attributes. Outdoor farms in Massachusetts have shorter growing seasons averaging 140 days and may have to deal with inclement weather like thunderstorms and hurricanes. The state averages about from 40 to 60 inches of rainfall annually, and most of the state receives anywhere from 40 to 80 inches of snow a year, with coastal regions receiving less (20 - 40 inches a year). Facilities at higher elevation can get up to 100 inches of snow a year and may experience many winter days below freezing.

Cultivation facilities in cold climates range widely in their energy consumption depending on their size.

Some small operations with flowering canopy areas smaller than 5,000 square feet may use as little as 60,000 kWh, but can also consume over 2,000,000 kWh a year.

Some medium-sized facilities with flowering canopy areas from 5,000 - 10,000 square feet can use between 2 million and 3 million kWh a year.

And larger facilities with flowering canopy areas larger than 10,000 square feet can use between 2 million and 6 million kWh a year.

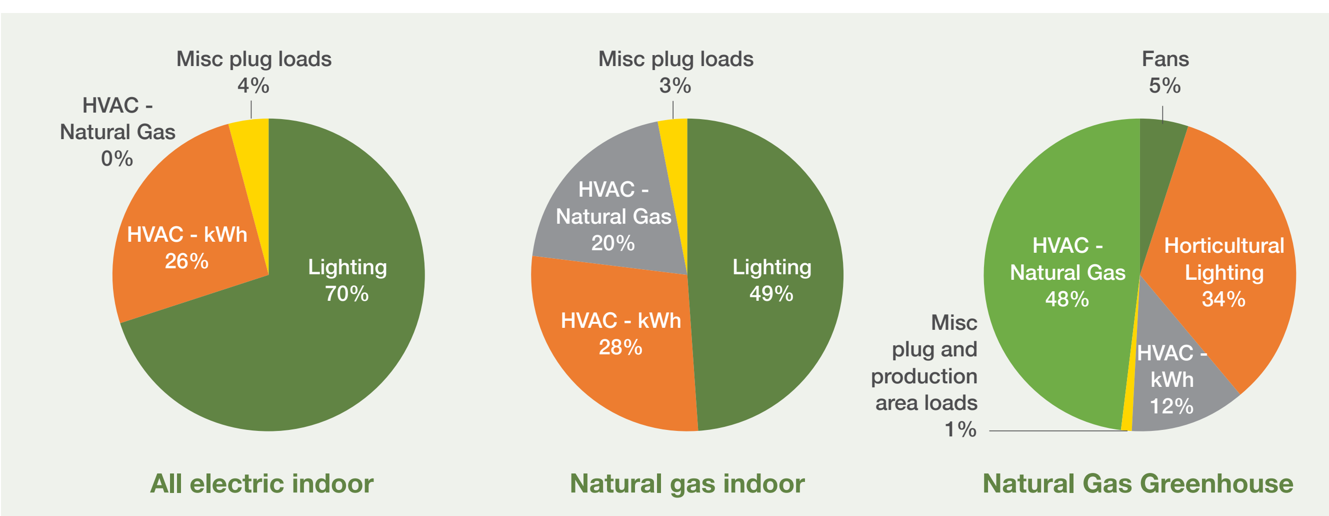


Map: Climate Types of the State of Massachusetts
Data sources: Köppen types calculated from data from PRISM Climate Group, Oregon State University, http://prism.oregon-state.edu; Outline map from US Census Bureau

The pie charts below show the proportion of electricity and natural gas used to serve various equipment for indoor and greenhouse cultivation facilities in cold climates. Lighting is still the primary source of energy use for controlled environment cannabis operations in Massachusetts and is the secondary source of energy use for greenhouses. Space conditioning provided by heating, ventilation, and air conditioning equipment is the secondary source of facility energy usage.

While there are twice as many hours in the year with cool weather as warm weather, HVAC energy use for indoor Massachusetts cultivation facilities is still predominantly from cooling and dehumidification loads, the energy being continuously stored in the air in your grow rooms as heat and humidity, due to heat from sun and light fixtures, as well as moisture from plant transpiration and watering. Greenhouses in western Massachusetts have higher heating loads than those in more southern or eastern regions, experiencing more extreme fluctuations between day and nighttime temperatures.

New England gets less sunny hours than much of the rest of the nation, which means less insolation for renewable energy generation by solar photovoltaic (PV) panels. It also means that greenhouses will need to provide supplemental lighting to achieve desired plant growth due to the high light intensity needs of cannabis. Greenhouses in Massachusetts that produce year-round cannot properly function without supplemental lighting. In months with shorter days, not only do facilities need supplemental lighting to maintain proper light cycle hours, but midday light intensity is often very low.



Graphs from left: Energy Mix of All-Electric Indoor, Natural Gas Indoor, and Greenhouse Facilities in a Cold Climate

As well - not every day is a sunny one. Massachusetts' solar resources require that a large percentage of the light in a greenhouse needs to come from electric lighting to reach a daily light integral (DLI) value equivalent to an indoor facility. An appropriate DLI value for cannabis is 40. Note - The DLI values on the chart are for outdoors - these values need to be reduced by approximately 1/3 to account for transmission loss through greenhouse glass / polycarbonate.

For example, even in June, the month with the highest average solar radiation, after accounting for losses from greenhouse glass, there will be a DLI of about 25 mol/day. About 15 mol/day of light will need to be supplemented on average to hit a DLI of 40. In December, more than 75% (30 mol/day or more) of light will need to be supplemented. Consideration of the economics of a greenhouse operation will need to account for the light coming into the greenhouse vs. the fuel needed to heat it.

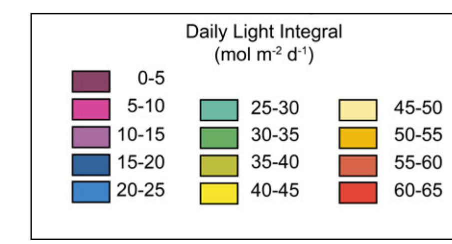
For many months of the year in Massachusetts, the cost of fuel needed to heat the interior of the greenhouse during dark hours may be greater than the cost of electricity saved from getting less than 10 Mol/day of natural light. This calculation depends on the exact location, insulation R-value of the greenhouse covering, and the cost of both electricity and fuel for heat (usually natural gas) at the particular site under consideration.

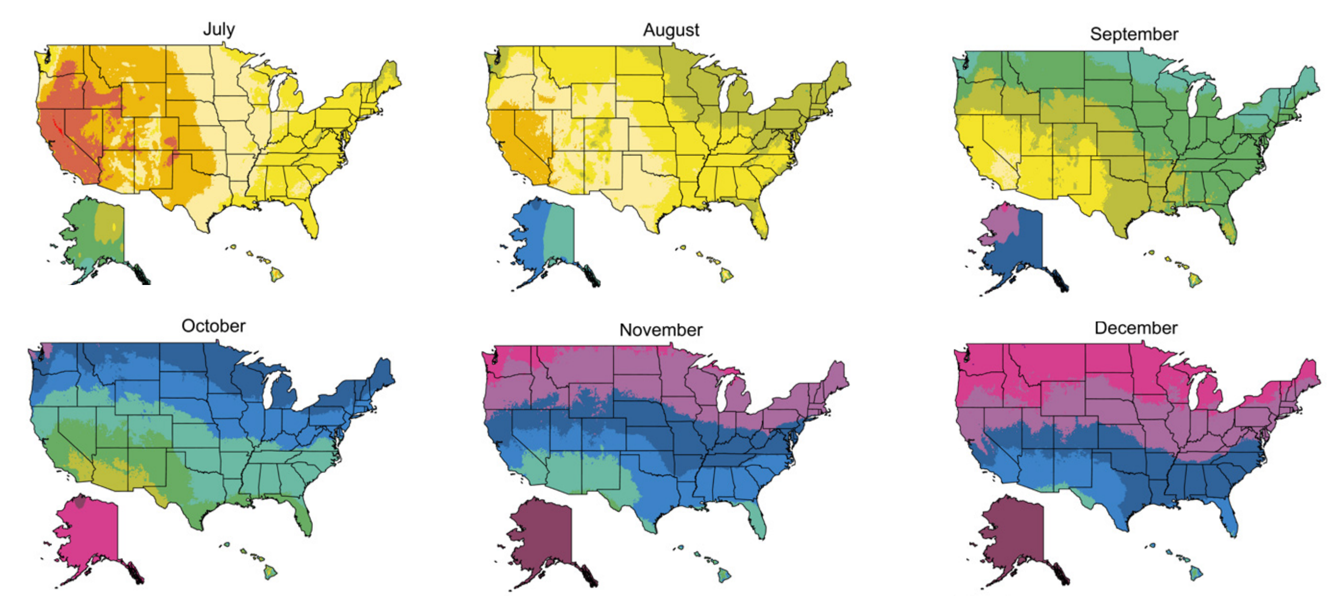
If you are running a greenhouse for cannabis in New England it is likely that the cultivars you grow under glass are either only in the vegetative stage, or are being processed for extract products, and may not require the higher DLI necessary for a top-tier product grown indoors for flowering growth stages.

A greenhouse growing cannabis in Massachusetts is not necessarily more profitable than an indoor operation, due to these cost considerations.

Reference daily light integral maps (www.endowment.org/dlimaps) to understand available, ambient light at different times of the year. It is possible to estimate supplemental lighting needs at the various times of the year with some light calculations, but these are not guaranteed to be accurate nor should be used for purchasing decisions. You can determine the transmission rate (consider loss from structures, equipment and greenhouse coverings) to estimate the light penetration at crop level. Use hourly solar data from Typical Meteorological Year (TMY3), and carefully consider your assumptions.

Given the outdoor conditions in Massachusetts, indoor cultivation facilities and greenhouses should incorporate region-specific architectural considerations like designing structures to handle snow and wind loads, insulating and air sealing building envelopes to minimize outside air infiltration and moisture intrusion, and incorporating stormwater management techniques to return precipitation to the water table. Indoor cultivation facilities should consider energy-efficient (higher) cooling, dehumidification, temperature and relative humidity targets to reduce overall HVAC energy consumption.





Source: Faust, J. E., and J. Logan. 2018. "Daily Light Integral: A Research Review and High-Resolution Maps of the United States," HortScience 53(9):1250-1257.

Solar Therapeutics,
Somerset facility

ENERGY EFFICIENCY CASE STUDIES

SOLAR THERAPEUTICS

This 70,000 square-foot indoor cannabis cultivation facility in Somerset features five grow rooms with 42,500 square feet of flowering canopy, utilizing three tiers with mobile racking inside a retrofitted concrete and steel building.

The existing building was served by a 5,000 amp service and the cost of expanding service to include 500 more amps was prohibitive, meaning on-site energy generation was a cost-effective strategy. The facility is served by a 1.7 megawatt (MW) gas-driven combined heat and power (CHP) system with waste heat recovery, a 1.5 MW microgrid, and a 750 kW solar PV array net metered with their electric utility. The team is also considering battery storage to further reduce peak electric demand.

The facility was retrofitted to use LED light fixtures to substantially reduce lighting and cooling energy consumption. The cultivation team at Solar Therapeutics uses light meters to measure *actual photosynthetic photon flux density (PPFD)* to understand the light their plants actually receive in the grow rooms of their facility before switching to LED. Measuring before and after retrofitting to LED gave the team a comparison of target intensity levels.

PHOTO: OPPOSITE PAGE: SOLAR THERAPEUTICS;.THIS PAGE: REVOLUTIONARY CLINICS,

The cultivation team is very happy with their results, both in terms of DLI achieved and resulting plant growth. Transitioning to LED lighting systems involved a learning curve; as they moved from high pressure sodium (HPS) to LED, the team had to feed their plants twice as much. Switching to LED can require modifications to your cultivation approaches; this is critical for all cultivators to understand when making their own transition.

New LEDs are better designed and now that there has been more real research, there is real competition.

"**LED lights can flower** as well as HPS. We learned that dimming LEDs for certain stages of growth was necessary to avoid leaf burning. We run lights at higher intensity on the top tier of our racks to save time later in the plant's growth cycle."

Understand that switching to ***cultivating with LED lighting offers more broad or evenly distributed light over the PAR range****. Some product offerings can be tuned to certain wavelengths, for certain crops or growth phases. fixtures supply the plants with a targeted spectrum rather than a broad one. When you match photosynthetic photon flux density (PPFD) between high pressure sodium (HPS) and LED fixtures, plants served by LEDs receive the same intensity of light but may not receive the same quality of light.*

Not all photons are created equal! *LED fixtures can provide more or less photons of different light spectra than HPS and the distribution of photons is dependent on the specific model you select. Consult spectral quantum distribution graphs to understand what range of the spectrum has what quantity of photons.*

It is common for growers who have historically used HPS to switch to LED lighting systems and make no changes to other elements of their cultivation approach, which may increase stress for plants and can appear to result in lower yield. Some new LED growers may find they need to feed plants more or adjust output of their LEDs with dimming controls, like Solar Therapeutics, but ***every facility is different and the modifications made by one grow operation may not be necessary or suitable for others.***

The HVAC equipment at the facility was retrofitted to incorporate high performance motor technology to serve fans at a fraction of the amperage and power, though at three times the first cost of a traditional fan motor. The team uses a building automation system (BAS) with digital environmental controls that use in-room sensing equipment to monitor temperature, relative humidity, and CO_2 which report to the cultivation team on a controls dashboard that they check throughout the day. The BAS was commissioned by a third party and the team works with a controls contractor periodically to update sequences of operation.

Plants are grown hydroponically and water efficiency is front of mind. Condensate is reclaimed from HVAC equipment and the cultivation team also collects runoff from fertigation.

The Solar Therapeutics team continuously benchmarks their resource consumption to track usage and identify trends. They define their business' success using the following key performance indicators (KPIs) and monitor them for operational health:

- Production efficiency: **g/kWh** *Higher is better*
- Electricity efficiency: **kWh/sq ft** *Lower is better*
- Water efficiency: **gallons/year** *Lower is better*

REVOLUTIONARY CLINICS

This 250,000 square foot indoor cannabis operation in the Boston area includes 150,000 square feet of grow rooms and 50,000 square feet of flowering canopy, featuring two to three tiers of vertical racking in clone and veg rooms inside a retrofitted industrial and educational building built in 1893.

The existing building participated in an energy efficiency incubator "Go Green" program to install a geothermal heat pump system for heating and cooling, meaning energy consumption for the facility is largely from electricity.

The facility uses a fully integrated lighting, HVAC, and controls solution that includes liquid-cooled LED light fixtures to substantially reduce lighting and cooling energy consumption. Handheld and permanently installed light meters are used in the plant canopy to measure actual PPFD and provide feedback to the HVAC and lighting controls systems.

Revolutionary Clinics,
Boston area facility

Revolutionary Clinics,
Boston area facility

Liquid-cooled lighting systems directly remove most waste heat generated by light fixtures, reducing the amount of cooling required to maintain a target indoor environmental conditions. This type of system also allows fan-cooled water-to-air heat exchangers to reject waste heat directly to outside air, reducing the need for energy inputs to cool cultivation spaces further.

The HVAC equipment at the facility was purpose-built for cultivation which means the sensible heat ratio can modulate when lights are on and off, as well as by stage of plant growth. Large oscillating industrial fans are used to increase airflow in grow rooms. The team uses a building automation system (BAS) with digital environmental controls that use in-room sensing equipment to monitor temperature and relative humidity and maintain target setpoints for plant development. The BAS was not functionally performance tested by a third party.

Plants are irrigated using drip irrigation and an automated fertigation system. Green waste is composted off-site.

The Revolution Clinics team does not yet proactively benchmark their resource consumption to track usage and identify trends. They define their business success using the following key performance indicators (KPIs) and monitor them for operational health:

- Production efficiency **g/sq ft** *Higher is better*
- Fuel efficiency **kBtu/year** *Lower is better*

TRIPLE M

This indoor operation is housed in a 46,000 square foot building in Plymouth and uses 25,000 square feet of the space for cannabis cultivation. Six grow rooms and 6,440 square feet of flowering canopy, featuring two to three tiers of vertical racking are contained within a structure built in 1969 and retrofitted in 2017.

LED lighting is used throughout the facility. Each 660 watt fixture serves 16 square feet of canopy module. This works out to 41 watts per square foot, which is less than the 50 watts per square foot limit in 935 CMR 500.120 (11)(b) for a Tier 2 cultivation facility. As shown in the table below, using LED light fixtures saves Triple M over $57,000 a year on their utility bills from both energy usage (kWh and therms) and demand (kW) savings.

Room lighting is staged on and off at different times to provide an even electric load so that no more than half of the light fixtures for cultivation are on at a time, further reducing peak demand. Automatic dimming controls are used to modulate output, which can be an important capability for LED light fixtures.

The cultivation areas of the facility are served by several air handling units (AHUs) that operate with ~1% outside air and do not use economizer due to strict CO2 management procedures. One AHU serves each grow room, and there are separate units used for drying and trimming areas. The AHUs are connected to a central heating and cooling plant served by two 800 MBH condensing boilers and a high performance 200-ton natural-gas-driven chiller with heat recovery. The facility uses a natural gas-fueled backup generator if the facility experiences electricity outages.

Triple M uses a building automation system to monitor operations and control their HVAC equipment including their air handling units, rooftop units, chilled water, boiler, and CO_2 systems.

The facility follows a water use policy based on the Cannabis Control Commission's "Best Management Practice for Water Use" publication. A drip watering system feeds directly into each plant using an automatic schedule, and lines are inspected daily to identify and repair leaks. Water is reclaimed from the dehumidification system to be reused for watering.

PHOTO: THIS PAGE: REV CLINICS; OPPOSITE PAGE: TRIPLE M

ECM #	DESCRIPTION OF ENERGY CONSERVATION MEASURE (ECM)	ANNUAL UTILITY BILL SAVINGS Electric kWh	Gas therms	Cost Savings $	MAX PEAK DEMAND REDUCTION kW	INCREMENTAL COST $	PAYBACK PERIOD YEARS
1	*LED Grow Lights*	382,642	7,358	$57,028	82.6	$206,375	3.6
2	*Exhaust Fans with EC Motors*	1,251		$163	0.5	$1,350	8.3
3	*Gas-Driven Chiller with Heat Recovery*	286,674	-18,199	$19,251	49.3	$97,240	5.1
4	*Condensing Boilers*		1,565	$1,549		$20,018	12.9
5	*VFDs on HWS & CW Pumps*	16,114		$2,095	2.7	$7,093	3.4

The cultivator worked with their utility to receive incentives for various energy conservation measures (ECMs) when they renovated their facility. The building is served by Eversource, and has a blended rate of around $0.13 per kWh and $0.99 per therm.

The table below is a summary of information from the engineering study conducted by Eversource for five of the ECMs involved in the horticultural lighting and HVAC systems serving cultivation spaces in the building. ***The payback periods shown in the table do not include utility incentives and just show the effect of annual utility bill savings.***

Before utility incentives, ECM #1 (LED grow lights) would pay back in under four years. After incentives, the project could pay back much more quickly, which is a great reason to ***work with efficiency utility representatives to assess projects for potential support and further improve payback periods.***

Triple M,
Plymouth facility

For additional case studies of cultivation facilities and their efficiency features, check out https://ResourceInnovation.org/Case-Studies/

RESOURCES

ORGANIZATION	RESOURCE	DESCRIPTION	LINK
Cannabis Control Commission	Massachusetts cannabis enabling legislation, statues, and regulation	Web page with links to key legal documents pertaining to the Massachusetts cannabis.	https://mass-cannabis-control.com/the-laws/
	935 CMR 500.000: Adult Use of Marijuana	Statute implementing St. 2017, c. 55, An Act to Ensure SafeAccess to Marijuana and M.G.L. c. 94G.	https://mass-cannabis-control.com/wp-content/uploads/2019/11/Fall_2019_Adult_Regs_500.pdf
	935 CMR 501.000: Medical Use of Marijuana	Statute implementing St. 2017, c. 55: An Act to Ensure SafeAccess to Marijuana; M.G.L. c. 94G and M.G.L. c. 94I. Replaces former DPH regulations and 105 CMR 725.000: Implementation of an Act for the Humanitarian Medical Use of Marijuana.	https://mass-cannabis-control.com/wp-content/uploads/2019/11/Fall_2019_Medical_Regs_501.pdf
Department of Energy Resources	Massachusetts Department of Energy Resources' Solar Massachusetts Renewable Target (SMART)	Landing page provides information about the Massachusetts solar incentive program.	https://www.mass.gov/solar-massachusetts-renewable-target-smart
	Qualified Generation Units	Web page provides information about those technology types that qualify for the onsite clean energy generation exemption.	https://www.mass.gov/service-details/qualified-generation-units
	energyCENTS: Commonwealth Energy Tool for Savings	Landing page with information about energy saving opportunities for all Massachusetts residents, businesses and institutions.	http://public.dep.state.ma.us/Doer/mesa/#/home
Board of Building Regulation and Standards	Massachusetts State Building Code	A collection of all versions of the Massachusetts State Building Code, which consists of a series of international model codes and any state-specific amendments.	https://www.mass.gov/massachusetts-state-building-code-780-cmr
Energy Efficiency Programs	Mass Save	Landing page for the statewide energy efficiency program, supported by the state's largest gas and electric utilities.	https://www.masssave.com/en/saving/business-rebates/
	Municipal Light Plant Programs	Web pages for programs with energy efficiency opportunities for electric and gas customers whose utilities do not participate in Mass Save.	http://www.mmwecgoprogram.org https://www.ene.org/energy-efficiency/

ORGANIZATION	RESOURCE	DESCRIPTION	LINK
Massachusetts Clean Energy Center	Clean Energy for Business	Resources available to all Massachusetts businesses for adopting clean energy technologies.	https://www.masscec.com/get-clean-energy/business
DesignLights Consortium	Horticultural Qualified Products Library	Database of third-party certified LED light fixtures suitable for horticultural applications.	https://www.designlights.org/horticultural-lighting/search/
Resource Innovation Institute	LED Lighting for Cannabis Cultivation & Controlled Environment Agriculture Best Practices Guide	Document with best practices for growing cannabis with LED technology with definitions of common terms, detail to understand the technology and considerations when selecting, installing and operating successful LED lighting solutions.	https://ResourceInnovation.org/Resources
	HVAC for Cannabis Cultivation & Controlled Environment Agriculture Best Practices Guide	Document with best practices for choosing, installing and operating an appropriate HVAC solution for your cannabis cultivation facility.	https://ResourceInnovation.org/Resources
	Published Resources	Landing page with links to publications produced by RII and other organizations; featured publications include the LED and HVAC best practices guides, and Public reports about resource efficient cannabis cultivation. Water best practices are expected to be published in 2021.	https://ResourceInnovation.org/Resources
	Cannabis PowerScore	CCC-specified energy and water reporting and performance tracking tool for cannabis cultivators.	https://www.CannabisPowerScore.org/MA

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RESOURCE INNOVATION INSTITUTE

The Resource Innovation Institute (RII) is a non-profit organization whose mission is to advance resource efficiency to cultivate a better agricultural future. RII provides best practices guidance on resource efficient cultivation technologies and techniques via peer-reviewed reports and curated events. RII's performance benchmarking service, the Cannabis PowerScore, enables cultivators to gain insights about how to reduce energy expenses and improve their competitive position. Resource Innovation Institute is funded by foundations, governments, utilities and industry leaders. For more information, go to ResourceInnovation.org.