

Best Practices Guide Utility & Efficiency Program

for Controlled Environment Agriculture (CEA) Program Design
& Market Engagement

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A Best Practices Guide for Utilities & Efficiency Programs

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Introduction



About Resource Innovation Institute (RII)

Resource Innovation Institute (RII) is an objective, data-driven non-profit organization whose mission is to measure, verify and celebrate the world's most efficient agricultural ideas. We cultivate a better future for all of humanity with our vision of resilient harvests for the next hundred years. Our consortium of members brings perspectives from across the field—uniting architects and engineers, growers and operators, researchers and analysts. Founded in 2016 to advise governments, utilities and industry leaders on the resource impacts of cannabis cultivation, an under-studied and resource-intensive market, we have since extended our research to other sectors in partnership with the US Department of Agriculture. To take on the challenges of our changing world, we believe that food, medicine and other vital crops demand data-driven insights, securely shared with integrity. By nurturing the human connections in our complex and dynamic industry, we can build deeply restorative systems for people and the planet.

About the American Council for an Energy-Efficient Economy (ACEEE)

The American Council for an Energy-Efficient Economy (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

About the Authors

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PHOTO: GRODAN



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efficiency-program-practices-guide-452402](http://catalog.resourceinnovation.org/item/utility-efficiency-program-practices-guide-452402).
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Overview



As an efficiency program manager designing and implementing programs for emerging industries, you may feel like the controlled environment agriculture (CEA) industry has customers that are challenging to reach and serve. Environmental systems used in cultivation facilities have energy efficiency opportunities, but capturing and verifying savings requires securing funding and supporting programs for new high-performance technologies like horticultural lighting and heating, ventilation, air conditioning, and humidity control (HVAC) equipment and controls systems.

Traditional approaches and systems used for growing are diverse and not well-documented, so baselines are difficult to create. Efficient equipment and controls strategies are still evolving and are not yet well-demonstrated, and data is scarce for utilities and implementers creating high-performance benchmarks when designing incentive programs. Creating a program from scratch may feel confusing and daunting.



**RESOURCE
INNOVATION**
INSTITUTE

We are here to help. As a non-profit organization, the Resource Innovation Institute establishes industry standards, facilitates best practices, and advocates for effective policies and incentives that drive resource efficiency. Our peer reviewed Best Practices Guides are a way of helping professionals like you understand the savings potential of resource-efficient technologies, how to quantify their benefits, and the most effective ways to deliver measures to CEA businesses.

Our membership is composed of subject matter experts with the knowledge to help your programs effectively support cultivation customers. With cost-effective and streamlined efficiency offerings, your CEA customers can build and operate the most high-performance facilities for cultivating plant life indoors.

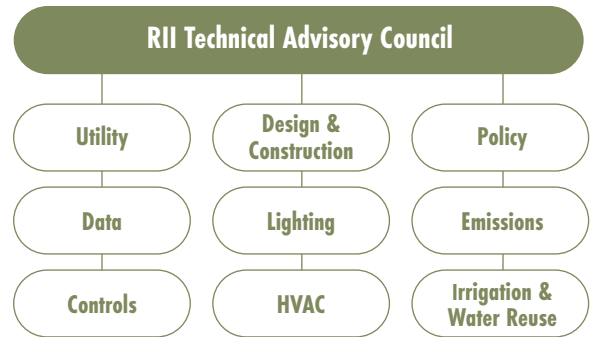
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RII Technical Advisory Council (TAC)

The TAC is a multi-disciplinary body facilitated by RII to aggregate knowledge and data to support cultivators, governments, utilities, standards bodies and other stakeholders with objective, peer-reviewed information on cultivation resource use and quantification of performance

- Provides guidance on development of standards
- Shapes tools and resources to support best practices
- Informs advocacy on policies, incentives and regulations



RII Utility Working Group (UWG)

Since 2019, the Utility Working Group of RII's Technical Advisory Council has been advancing utility best practices on program design, market engagement and savings validation for controlled environment agriculture. The UWG is composed of subject matter experts from utilities and program implementers across North America representing programs serving CEA customers in over 15 states.

The members of the UWG:

- Identify key areas of interest
- Provide peer review
- Promote general harmony in the market



You may want to know the savings potential of greenhouse and indoor cultivation operations, motivated to reach more of these underserved and specialized customers, or looking to create a new program with an understanding of what other utilities have done in other

markets. Whatever the reason, when you are designing or implementing programs for CEA businesses, we hope you lay the groundwork with the insights offered in Resource Innovation Institute's Best Practices Guides.



A Primer Focusing on Programs for Cannabis Operations

In 2020, RII published the *Program Design & Market Engagement Primer for Energy Efficiency Utilities & Program Implementers Serving Cannabis Cultivators* to guide utilities and efficiency program administrators with recommendations for planning and creating programs for cannabis growers. This guide was developed in collaboration with the 2020 members of RII's Utility Working Group.

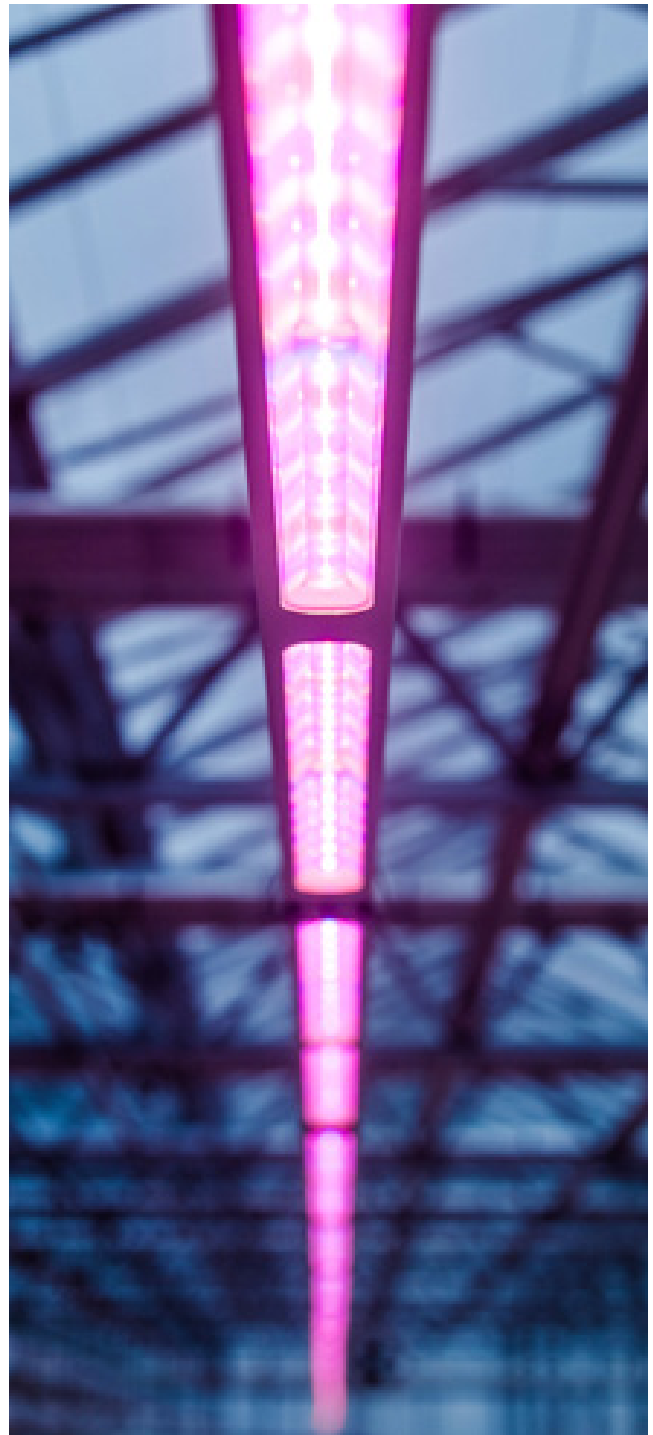
Learn more about designing programs for hemp cultivators with the [Cannabis Efficiency Program Primer](#).

Best Practices Guides for Efficient Facility Design & Construction, HVAC, Lighting, and Controls

Throughout 2022, RII will be releasing new CEA best practices guidance with support from USDA's Natural Resources Conservation Service as part of the three-year project titled Data-Driven Market Transformation for Efficient, Sustainable CEA. Our peer-reviewed publications are a way of helping professionals like you understand things like:

- savings potential of resource-efficient technologies
- how to quantify their benefits,
- the most effective ways to deliver measures to CEA businesses.

Access all RII Best Practices Guides at <https://catalog.resourceinnovation.org/category/best-practices-guide>.



Purpose



The purpose of the Program Design & Market Engagement Best Practices Guide is to support you, the efficiency program manager, and your organization as you consider how to engage and work in the controlled environment agriculture (CEA) market space.

As a best practices guide, this document seeks to:

- Identify the range of approaches efficiency program administrators are taking as they engage the market
- Emphasize key areas of consideration for efficiency program design and implementation
- Outline opportunities for research, program design and implementation, and regional/national coordination in four key areas:
 - **Resource acquisition:** acquiring demand-side resources, often the primary goal of most utility energy efficiency programs
 - **Emerging technologies:** energy-saving

equipment, strategies, analytical tools, and information services that can be used to reduce energy use and cost in new and existing facilities

- **Market transformation:** the strategic process of intervening in a market to create lasting change in market behavior by removing identified barriers or exploiting opportunities to accelerate the adoption of all cost-effective energy efficiency as a matter of standard practice, an alternative goal of utility energy efficiency programs
- **Utility & efficiency program policy:** energy efficiency policies and programs that can help drive the implementation of projects that reduce energy use during facility operation

Whether you are new to the CEA market or simply seeking to learn more to improve your utilities position in the market, we hope you lay the groundwork with the insights offered.

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Markus Spisla

Plan CEA Efficiency Programs for Maximum Impact

PHOTO: CEA CONSULTANCY



As of 2022, in the U.S. there are 19 states with dedicated programs for CEA businesses (including producers of hemp). **Table A3** in the Appendix on **page 48** summarizes the 110 energy efficiency programs offering incentives for greenhouse and vertical farm operations growing food and floriculture products.

Efficiency programs across North America have launched programs designed for CEA cultivators since 2008¹ for a few reasons. These customers have moved cultivation under protection to benefit from increased control of environmental conditions, which requires powerful lighting systems to supplement or replace sunlight and large HVAC systems to manage airflow, temperature, and humidity. Many of these mechanical and electrical systems have already been explored by emerging

technology departments from several efficiency programs in the most mature markets.

These industrial systems add substantial electric and gas loads to the grid, and utilities and implementers have recognized that opportunities at these facilities offer pathways to reaching savings goals, as have been previously seen in other industrial operations like data centers and manufacturing plants. Unlike those buildings, cultivation facilities house plants, and the technologies used to maintain indoor environments that produce food and floriculture are unique and diverse, and require characterization and exploration before any efficiency program can be deployed to create value and result in active participation.



The Program Business Case

Creating a new efficiency program is a journey up a mountain, and most hikes benefit from a well-made map of cultivation in controlled agricultural environments (referred to in this document as CEA). Your first step in developing a program for CEA businesses is to create a map for your team to use throughout the ascent. A component of your map is your program business case, an assessment of the network of trails up the mountain. Your business case helps your team make an informed decision about whether and how to create new program offerings for CEA businesses.

Understand Growers - CEA cultivators face challenges such as high upfront costs, need for capital and financing, general lack of knowledge of efficient technologies, lack of trust in product performance, and limited connections to qualified professionals for efficiency projects. CEA businesses can also be underserved customers as utilities also struggle to characterize the emerging CEA markets in their service territories.

Make Connections - **Table 1** prioritizes the major touchpoints that represent opportunities for CEA market engagement. These touchpoints are all opportunities for generating customer engagement through positive interactions between utilities, programs, and customers.

Table 1: Challenges for CEA Producers Impacting Utilities and Efficiency Programs

CEA market actors are seeking	Utilities and programs are impacted by
Incentives and on-bill financing for energy efficiency	- Load reduction - Carbon emissions mitigation - Grid resilience - Electrification opportunities
Interconnections and electric service upgrades	Load growth
Integration of renewable energy infrastructure	- Load shifting - Grid resilience
Accessing trade allies	Quality and availability of supply chain
Assistance with understanding or paying their bill	- Energy efficiency opportunities - Demand management opportunities

¹ USDA NRCS programs have been supporting producers growing in protected agriculture facilities through programs like the [Environmental Quality Incentives Program \(EQIP\)](#) since 2008. Utilities and efficiency programs have served CEA producers for over a decade; Wisconsin's Focus on Energy and Arizona's Salt River Project were among the first programs to offer incentives for greenhouse efficiency measures.

Build Trust - Be proactive and engage thoughtfully at every chance to build relationships and improve business outcomes to overcome barriers with CEA growers. Some CEA producers have some distrust or a lack of understanding of efficiency programs and rebate offerings. Deliver specialized services for producers to increase awareness and improve programs to achieve optimal customer satisfaction. Invite grower champions to play an ambassador role and share the message of the benefits programs can offer.

Market Characterization: Producers

As you develop your business case for a CEA program and draw a map of the mountain, a market characterization helps your team add detail to the various routes you could take to reach your goals. Identifying the crops grown by producers, areas of development, and sizes of facilities in your CEA market give you the tools to determine your easy wins and what parts of the journey could present challenges.

Know What Grows - Many diverse products are created in controlled environments. At the start of this journey, program designers should understand common CEA crops and the typical facilities used for production. Some crops may have sprouts of seedlings grown indoors before being moved to greenhouses for later growth stages. **Figure 1** below illustrates the stages of plant growth and **Table 2** on the following page describes the ranges in length of harvest time for CEA crops.

Key: Greenhouse ● Indoor ●



Figure 1: Growth Stages for CEA Crops

Vine Crops

Cucumbers and indeterminate tomato varieties are mostly grown vertically on high wires in greenhouses.

Vegetables and Herbs

Vegetables like peppers, herbs, and edible flowers are grown in greenhouses and indoor vertical farms. Leafy greens are grown by both greenhouses and indoor facilities, while microgreens are generally grown only by indoor farms. Dwarf determinate tomato varieties are grown in greenhouses and are starting to be cultivated indoors.

Floriculture

Nursery crops (young plants), cut flowers, and finished crops (bedding plants) are often cultivated in greenhouses or outdoors.

Mushrooms

Mushrooms are primarily commercially cultivated indoors. Some greenhouses cultivate mushrooms under benches and grow vegetables or other crops above them.

Berries

Strawberries and other berries have historically been grown in greenhouses but are starting to be cultivated indoors. Dwarf blueberry and caneberry cultivars have been developed to be suitable for CEA cultivation.

What Sells - Final products grown by facilities dictate the diverse production processes that impact CEA facility energy consumption. Understand the stages of growth and associated activities performed at cultivation facilities to determine which efficient technologies and strategies will be best suited for the application.

SECTION 1 : PLAN CEA EFFICIENCY PROGRAMS FOR MAXIMUM IMPACT

Crop Category	Crop Type	Harvest Time ²
Vine Crops	Tomatoes	80 - 95 days
	Cucumbers	60 days
Vegetables	Peppers	75 days
	Leafy Greens	40 - 65 days
	Microgreens	7 days
Floriculture	Nursery and bedding crops, ornamentals, cut flowers	Varies (days to months)
Mushrooms	Edible mushrooms	30 - 60 days
Berries	Strawberries	110 days
Aquaponics	Fish	9 - 18 months

Table 2: CEA Crop Growth Cycles



Cultivation Approach - Just like any manufacturing process, cultivation in controlled environments comes in multiple different forms. Each method has different pros and cons. The three most common CEA cultivation approaches are:

- Traditional protected agriculture (high tunnels and ventilated greenhouses)
- Advanced greenhouse (automated greenhouses and sealed greenhouses)
- Indoor vertical farm

Note: Greenhouses and operations with outdoor canopy area (like floriculture nurseries) still have propagation spaces that may demand energy for lighting, heating and ventilation, and water pumping.

Understand Popular Approaches - Market considerations add crucial details to your program business plan. Determine the primary facility types in regions served by your programs. Investigate the three major controlled environment cultivation methods and the prevalence of each in your program's area.

² Schimelpfenig, G., Smith, D. 2021. [Controlled Environment Agriculture Market Transformation Strategy and Implementation Plan, Resource Innovation Institute \(RII\) and the American Council for an Energy-Efficient Economy \(ACEEE\), 2021.](#)



SECTION 1 : PLAN CEA EFFICIENCY PROGRAMS FOR MAXIMUM IMPACT

New and Old - Can producers retrofit existing buildings for CEA? How much new construction will happen in the next few years? Stay informed about permitting activity and develop a forecast of facilities and their locations. Understand how much your CEA program may need to cater to these different kinds of projects.

Size the Market - Cultivation approach influences facility size and demand for energy. Learn about the existing greenhouses in the region, and where new builds are happening. Understand how large typical greenhouses and warehouse cultivation operations are using guidance from **Table 3** below.

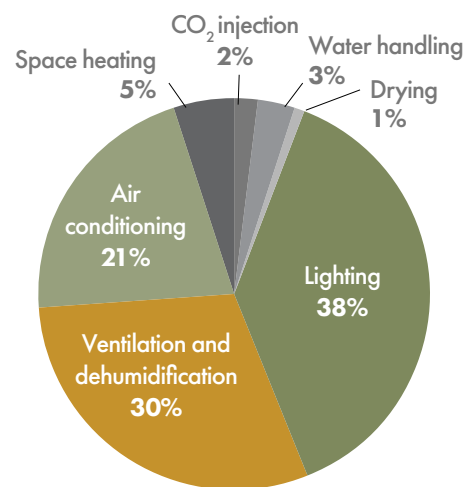


Figure 2: Electricity Usage of Indoor CEA Facilities

Facility Type ³	Minimum Canopy Area (square feet)	Median Canopy Area (square feet)	Maximum Canopy Area (square feet)
Greenhouse	13,500	348,000	5,000,000
Indoor	500 (research chamber) 5,000 (production)	60,000	280,000

Table 3: Canopy Area of U.S. CEA Facilities

Energy Sources - Understand regional energy choices available to producers. CEA facilities use diverse sources of energy depending on the facility type and the location. In addition to electrical energy, various fuels (such as natural gas and propane) are used. Electric rate structures often dictate fuel choice for CEA producers. Service capacity for electricity and natural gas can influence growers to operate using alternative energy options. Facilities using equipment like combined heat and power systems (CHP) and chillers can use buffer tanks to reduce peak demand for heating or cooling by storing heat in water.

Understand Alternative Energy Options - CEA producers also install distributed energy resources (DERs) on-site to improve operational resilience, offset grid energy consumption, and lower operating expenses from utility bills. Typical DERs on CEA sites include on-site renewable energy sources like solar, cogeneration microgrids served by natural gas, and back-up generators using a variety of fuels.

Electricity - Indoor CEA facilities can have varying electric energy intensity, ranging from 40 kWh to 150 kWh per square foot based on the size, crop, and configuration of the building. Different crops and cultivation approaches have different energy impacts and opportunities for non-energy benefits. **Figure 2** above summarizes a 2021 analysis by Southern California Edison by RII member Energy Resource Integration, LLC (ERI) found that in indoor operations, horticultural lighting accounts for 38% of electricity use, with HVAC accounting for 56% of the electricity use (30% ventilation, 21% air conditioning, and 5% heating). Water handling, CO₂ injection, and drying of harvested plant material were found to account for less than 3%, 2%, and 1% respectively. Electricity demand for greenhouses is influenced by facility location and crop type, which affect facility electricity demand for supplemental lighting.

³ [Controlled Environment Agriculture Market Characterization Report: Supply Chains, Energy Sources and Uses, and Barriers to Efficiency](#), Resource Innovation Institute (RII) and the American Council for an Energy Efficient Economy (ACEEE), 2021.



Fuels - Other energy sources are used to supplement or replace electricity for both indoor and greenhouse facilities. Indoor facilities are more often located within natural gas supplier territories and some CEA facilities incorporate cogeneration systems served by natural gas, depending on electricity prices. Greenhouse facilities can have higher heating loads than indoor facilities and use more fuel; their locations and availability of energy suppliers make it more likely for them to incorporate delivered fuels like propane in their fuel mix. Greenhouses also find benefit in reusing CO₂ from flue gas for fertilizer and environmental enrichment.

Forecast - Familiarize your team with relevant policies like energy codes affecting CEA facility design or equipment used for horticultural applications to inform more accurate load growth forecasts. Consider how load growth might impact the quantity of new electrical interconnections and requests for service expansions. Communicate and coordinate between utility and efficiency program departments to collaborate on carrying out load forecasts/planning, new customer connections/service upgrades, and CEA program offerings. Reach out to coordinate with other relevant departments. Think about how cogeneration and combined heat and power could affect grid resiliency. Include load growth potential from CEA operations in your program's Integrated Resources Plan or Conservation Potential Assessment.

Overcome Barriers - Top barriers to energy efficiency for CEA producers are upfront costs of high-performance equipment, access to capital and financing, a lack of knowledge of efficient technologies, and skepticism and lack of trust in product performance. Barriers specific to emerging technologies are also prevalent and affect new construction and retrofit projects differently, may require challenging production shut-downs, and can suffer from low producer awareness and trust.

Market Characterization: Supply Chain

Enhance your market characterization with a map of the key supply chain actors influencing the CEA market in regions served by your programs. Manufacturers and service providers help your team traverse the routes to achieve your goals faster and with persistent results. Identifying the areas and sizes of the sectors of the market give you the tools to determine your easy wins and what parts of the journey could present challenges.

Qualify Services - Evaluate supply chain actors and assess the maturity of the supply chain serving regions where you may launch CEA programs. Determine relevant sectors of the design and construction community and identify trustworthy actors. Consider more clearly differentiating professionals in the supply chain that have substantial experience and knowledge about horticultural equipment and facilities.

Convey Expectations - Motivate the supply chain to specify efficient equipment and ensure market actors are set up to successfully participate in your program. Support workforce development with curriculum and training like best practices guides and workshops. Learn more about educating the supply chain in the Educational Curriculum and Training section on page 40. Clarify what project documentation project teams need to provide so you can justify utility energy savings claims to your regulators. Describe the equipment eligibility requirements suppliers must meet to receive incentives and consider requiring qualified equipment validated by certification organizations.

Trust Partners - Support the evolution of the supply chain towards efficiency and promote leaders. Vendors and manufacturers that are members of industry organizations like RII are likely to be more committed to efficiency and quality standards. As credentialing programs emerge, consider using those as a way to vet and list service providers as customers ask for help selecting qualified professionals.

Connect Customers - Consider how you will work with key actors in the supply chain like designers, manufacturers, contractors, distributors, and retailers. CEA customers may not be well served by your existing commercial and



industrial (C&I) vendor networks. To ensure efficiency projects achieve their full energy savings potential, recommend customers work with credentialed supply chain actors recognized by third-party industry organizations like RII. In 2022, RII will launch a trade ally network for CEA design and construction professionals supported by continuing education curriculum and training.

Market Characterization: Key Market Actors

Fill in your map of the CEA market by identifying and connecting to key market actors active in your program regions. Governments and industry organizations craft policies, enact energy codes, and establish standards that affect measure design and savings claims of CEA programs. Learn how evolving regulations and equipment standards may alter your path up the mountain.

Know Who Must Comply - Government agencies, regulators, and industry groups are important market actors to understand and engage. Be aware that equipment used to grow crops in CEA environments may have to comply with minimum efficiency requirements. Determine the applicable codes for your major types of CEA customers. Understand which agencies are most strategic for you to work with: agencies of Agriculture, Energy, and/or Public Utility Commissions are common stakeholders. Consider how you will reach out and engage as policies are developed and implemented to address the CEA industry. Know when the next code update cycle starts and how you can be involved to provide feedback.

Be Aware of Baselines - Anticipate the impacts energy codes may have on your customers and your savings claims. Understand relevant local building and energy codes to determine if there are any minimum performance requirements affecting systems and equipment your program could support. Learn how codes apply to greenhouses and indoor farms and how they impact potential CEA program baselines. Some entities at the local level may seek to enact ordinances which aim to limit or curtail energy consumption from growing in controlled environments. Be informed and calculate how grower

requirements impact baseline CEA facility efficiency and savings.

Evolve Programs - Decarbonization policies in states, counties, and municipalities may impact both your customers and your programs. In certain states, Utility Working Group program administrators are no longer able to incentivize combined heat and power systems as they result in increased greenhouse gas emissions from energy use. Emerging technologies for HVAC processes offer electric heat pump options for CEA producers as an alternative to fossil fuel-consuming systems.

Connect to Industry - Connect with CEA business operators and their supply chain partners. Identify industry associations for growers, as well as organizations for specialized engineers and construction partners. Foster trust with educational programming like resources and events.

Lean On Each Other - Know the market influencers active in your area such as Regional Energy Efficiency Organizations (REEOs), Rural Energy for America Program (REAP) implementers, and Regional Technical Forums.



PHOTO: GRETA HOFFMAN



Level of Program Engagement

After your team has added detail to your program business case, it is time to determine what level of engagement is prudent at this stage of your state's CEA market. Determine your level of engagement and how you use subject matter experts as the CEA market is not homogeneous and your program needs to be crafted based on savings opportunity.

Determine Your Approach - Find the swim lane which best aligns your program's needs and goals with your perceived market size and appetite to engage. Table 4 below describes the three major levels of engagement.

RII's Utility Working Group members representing CEA programs across the United States share that 20% of CEA programs are passive, 60% are reactive and 20% are proactive.

Category	Perceived Opportunity to Program Goals	CEA Efficiency Program Approach
Passive	Small	- No investment in CEA-specific resources. - Some incentives offered for CEA customers via existing C&I or Ag programs. - Staff have limited experience processing structured custom projects. Staff are directly involved in project management. No subject matter experts (SME). - No proactive engagement in the CEA market. - Higher exposure to realization rate impacts during program evaluation due to lack of SME and rigor.
Reactive	Medium	- Some intermittent program investments in cost share opportunities that provide access to tools and resources. Resources develop cultivators to get more projects in the pipeline. - Variety of incentives offered for CEA customers via existing and emerging C&I and Ag programs. - Staff have some experience processing structured custom CEA projects. Staff are directly involved in project management and may leverage additional SME as needed. - Program reactively provides basic market engagement. - Moderate exposure to realization rate impacts during program evaluation due to lack of SME and rigor.
Proactive	Large	- Recurring program investments in cost sharing opportunities that provide access to tools and resources. Resources develop cultivators, the design and construction supply chain, and emerging technology to get more projects with more measures in the pipeline. - Variety of specialized incentives offered for CEA customers via dedicated programs and existing C&I and Ag programs. - Staff have substantial experience processing structured custom CEA projects and may work with an implementer SME to provide project management services. - Program proactively provides advanced market engagement. - Lower exposure to realization rate impacts during program evaluation due to lack of SME and rigor.

Table 4: Levels of Utility Energy Efficiency Program Engagement





Strategic Networking

Once you determine what level of engagement makes sense for your team at this time, it is helpful to talk with others who have climbed the mountain before you. As utilities and efficiency program implementers become active in local CEA markets, join the growing community and contribute so it thrives. Because of your unique role in the industry, you have a great opportunity to help lead this community.

Do Your Homework - Avoid starting from scratch by building on the foundation of the programs that came before and the lessons they have learned. If you haven't already, gather a list of CEA market actors in your service territory. This list will grow with time and will allow you to effectively reach this group as program opportunities mature. Consult **Table A3** on **page 48** to learn about more mature CEA programs.

Join Industry Organizations - A very effective way for many programs to leverage this leadership position to their advantage is to become an active member of CEA industry organizations transforming the CEA industry and promoting resource efficiency, like RII. Key CEA industry organizations⁴ and their latest activities are covered

in RII's bi-annual member publication, *The Landscape*. Identify and form relationships with market actors and thought leaders in your service territory.

Join the RII Utility Working Group - You might have a steep climb to the highest summit, but can benefit from following behind experienced mountaineers. [Join RII's Utility Working Group](#) to learn from veteran program managers and network strategically with organizations across North America. RII's Utility Working Group members include municipal utilities, investor-owned utility companies, and efficiency program administrators and implementers representing dozens of efficiency programs across North America.



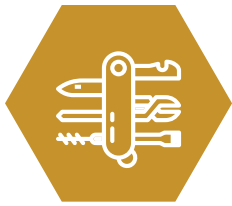
⁴ Key industry organizations affecting change in the CEA industry include Air-Conditioning, Heating, and Refrigeration Institute (AHRI), American Society of Agricultural and Biological Engineers (ASABE), American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE), ASTM International (ASTM), Controlled Environment Agriculture Design Standards (CEADS), DesignLights Consortium (DLC), Greenhouse Lighting and Systems Engineering (GLASE), Illuminating Engineering Society (IES), Optimizing Indoor Agriculture (OptimIA), and Underwriters Laboratories (UL).



Program Design for Resource Acquisition

PHOTO FROM LEFT: CEA CONSULTANCY ; GRODAN





Measure Identification

At this stage, your team should be informed of evolving CEA market characteristics, understand relevant policies affecting your CEA customers, and have considered an initial level of program engagement, all of which have filled out your map of the CEA program mountain. Your program business case is now much richer, and you can see the terrain in front of you. As you consult your map, now is the time to identify the technology that will help you up the mountain fastest and easiest, and determine your organization's perceived opportunity from the CEA market.

Choose Technologies - Several categories of CEA measures can offer cost-effective energy savings for efficiency programs, depending on the crop and cultivation approach. When evaluating this list, consider what is feasible for your organization based on your existing C&I program competencies and successful market engagement strategies.

- Greenhouse Envelope Systems
- Horticultural Lighting Systems
- HVAC Systems and Controls
- Controls Integrations

Key: Greenhouse ● Indoor ●

Vine Crops

Depending on location and cultivar, some growers supplement sunlight with electric light to meet light accumulation targets for optimal plant development. High-volume fans are used to maintain optimal airflow.

Vegetables and Herbs

Depending on location and crop being grown, some greenhouse growers supplement sunlight with electric light for optimal plant growth. When grown vertically indoors, herbs and greens need active HVAC systems to minimize microclimates and combat stack effect.

Floriculture

Most floriculture greenhouses have HVAC systems and building envelope systems for heating, cooling, and dehumidification. Some do not use supplemental lighting except for nursery crop propagation stages of plant growth. Other producers like those growing cut flowers

and potted plants may use more supplemental lighting for certain cultivars.

Mushrooms

Mushroom producers use passive and active HVAC solutions to maintain optimal environmental conditions. Some types of mushrooms during some stages of growth need light to aid fruiting.

Berries

CEA greenhouse and indoor berries require lighting and HVAC solutions for optimal plant growth.

Understand Non-Energy Benefits - As

you consider energy-saving measures, also think about the associated non-energy benefits of high-performance technologies your program may support. Document the positive effects systems can have on plant growth and development, crop quality, and shelf life. Help producers see how technology can improve safety and reduce risk for staff, extend equipment life, and save money in operations and maintenance.



PHOTO: HENRY & CO.





Estimating and Forecasting Savings Potential

Once you have determined what technology can effectively carry you up the mountain, it is time to quantify the initial benefits of the measures you have identified for both your internal stakeholders as well as efficiency program regulators and evaluators. The savings potential of facility participation in your programs depends heavily on your market characterization and chosen suite of measures to offer to CEA customers.

Consider what variety of measures work for your program this year and in the future. Your goals may vary depending on your location and market, and different years you may need to pull on different levers to diversify your portfolio.

Lighting Measures

By engaging with commercial cultivators, utilities and efficiency programs have the opportunity to claim lighting energy savings in their C&I portfolios for years into the future.

LED the Way - Many utilities in regions with CEA facilities pursue horticultural LED light fixtures as their first CEA efficiency measure given their familiarity with C&I LED lighting programs. Historically, growers have used fluorescent and high intensity discharge (HID) lighting technologies like High Pressure Sodium fixtures (HPS). Newer facilities are increasingly turning toward energy-efficient LED solutions. Of the 3,141 US utilities reviewed by Rebate Bus in January 2022, 8.7% of programs (275 programs) are currently offering dedicated horticultural lighting programs and specialized incentives. The average horticultural rebate in these states for a 600 W LED fixture replacing a 1,000 HPS fixture is approximately \$160. Programs in 35 states support efficient horticultural lighting equipment⁵.



Use the DesignLights Consortium Horticultural Lighting QPL - Several programs use the [DLC Horticultural Qualified Products Library](#) (Hort QPL) of LED lighting systems to when specifying eligible equipment for their CEA programs. In February 2022, the Hort QPL offers programs and cultivators

over 550 fixtures that meet the criteria outlined in the DLC [Horticultural Technical Requirements V2.1](#). Fixtures listed on the Hort QPL must meet equipment testing and reporting and thresholds for minimum photosynthetic photon efficacy (PPE), flux maintenance, component lifetime, and warranties. In 2021, DC-powered fixtures, externally supplied actively cooled (including liquid-cooled) horticultural fixtures, and LED replacement lamps were added to the QPL. The DLC will be issuing a draft for V3 of the Horticultural Technical Requirements in early 2022. The timeline for when V3 would come into effect is still being determined. An efficacy increase is being considered. Figure 2 below shows the current photon efficacy requirement for DLC listing and typical efficacy of several types of horticultural light fixtures.

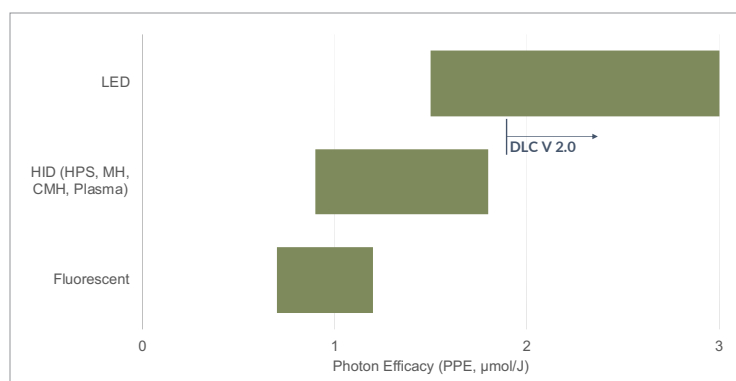


Figure 2: Photosynthetic Photon Efficacy (PPE) by Horticultural Light Fixture Type

Lighting Equipment Baselines

The recommendations in this section use several key horticultural lighting terms. Consult our [online glossary of key CEA lighting terms](#) to determine which metrics are important for your program.

⁵ [DLC Member Incentive Program Summaries \(Horticultural Lighting\)](#), 2022.



Determine Lighting Baseline - Baseline equipment for CEA lighting programs may be the minimum performance required by energy code or the minimum performance of Industry Standard Practice (ISP) equipment. However, ISP for CEA lighting equipment has not been established in many regions and facility types growing all CEA crops. Baseline lighting equipment can depend on cultivation approach and target light intensity for crops. **Table 5** below describes the intensity of horticultural lighting applications for popular CEA crops based on their required *daily light integral* (DLI)⁶ and photoperiod. When grown in greenhouses, the need for supplemental lighting may be lower than for indoor facilities, and will also vary depending on facility location.

Crop Type	Intensity of Horticultural Lighting Demand
Cucumbers	Medium-High
Tomatoes	High
Peppers	High
Greens	Medium
Fresh Herbs	Low-Medium
Strawberries	Medium
Mushrooms	Low
Nursery & Floriculture	Low-Medium

Table 5: Intensity of Horticultural Lighting Applications by Crop Type

Gather Key Lighting Inputs - *Photon efficacy* (PPE)⁷ and *light intensity* information (PPFD)⁸ for indoor farms and DLI for greenhouses) are the backbone of savings estimates for CEA lighting programs. Horticultural lighting is a process instrument, so projects can defend savings claims by comparing how baseline and high-performance lighting designs can deliver equivalent PPFD. Greenhouses have additional key inputs to gather due to the dynamic operation of supplemental lighting to achieve target DLI.

Consult **Table A1** of the Appendix on **page 45** to collect the necessary information to support lighting savings claims and document projects for evaluators.

Pick the Right Light - There are various kinds of horticultural lighting systems used by CEA producers depending on the crop and light levels required by stage of plant growth. In **Table 6** on the following page, members of RII's Lighting and Utility Working Groups recommend the following technologies as baseline fixture types for their CEA LED lighting programs. Note that LEDs with high photon efficacies (PPE) require certain spectral combinations (lots of red diodes) and operating conditions (dimmed to 50%).



⁶ The total accumulation of light across a crop canopy over single day periods from all light sources.

⁷ A light fixture's ability to convert power from electric energy.

⁸ The amount of light hitting a given area of crop canopy per second, the light intensity.



Category	Characteristic	Sprout / Seedling ⁹	Vegetative / Budding	Flowering / Fruiting
Traditional	Fixture Type	T5 HO T8 T12	HPS	HPS
	Wattage Range	60 - 435 W	400 - 1,000 W	650 - 1,000 W
	Luminaire PPE Range ¹⁰	0.7 - 1.2 µmol/J	1.0 - 1.7 µmol/J	1.0 - 1.7 µmol/J
High-Performance	Fixture Type ¹¹	LED	LED	LED
	Wattage Range ¹²	15 - 200 W	150 - 600 W	150 - 1,200 W
	Luminaire PPE Range ¹³	1.8 - 3.0 µmol/J	1.8 - 3.0 µmol/J	1.8 - 3.0 µmol/J

Table 6: Typical Lighting Equipment for Stages of CEA Plant Growth

Now and Later - Efficacy baselines are used by many programs to establish minimum equipment performance and inform savings calculations. For your program business case, establish a range of standard and high performance LEDs available today, and choose minimum PPEs based on what the supply chain can provide in your region. Looking forward, forecast where the LED market is going and how your program might evolve as the DLC's Technical Requirements are updated, the Horticultural QPL is populated with more product offerings, and PPE of the market is raised over time. Note that PPE changes depending on the wavelength of the diodes of LED light fixtures; **Table 7** on the following page summarizes academic research demonstrating the various PPE of common horticultural LED wavelengths (measured in nanometers, nm) and color temperature (measured in Kelvin, K).

Wavelength / Color Temperature	Photon Efficacy
450 nm	2.8 µmol/J
470 nm	2.4 µmol/J
500 nm	2.0 µmol/J
530 nm	1.3 µmol/J
590 nm	1.1 µmol/J
620 nm	3.4 µmol/J
635 nm	2.5 µmol/J
660 nm	4.1 µmol/J
730 nm	3.6 µmol/J
850 nm	3.0 µmol/J
3000 K	2.8 µmol/J
6500 K	2.9 µmol/J

Table 7: Typical LED Luminaire Package Photon Efficacy by Various Wavelengths

⁹ Note that fixture wattage can be at the low end of the range for the seedling stage, and even lower in tissue culture.

¹⁰ This range reports fixture efficacy. For light fixtures that use bulbs, note that light loss factors from bulbs reduce total lighting system efficacy further.

¹¹ The type of LED fixture can influence wattage; linear LED fixtures can be at the lower end of the range.

¹² Mounting height can influence preferred fixture characteristics; vertical indoor farms may use lower-wattage LEDs when growing in narrow tiers.

¹³ Academic researchers have validated photon efficacy of LED luminaire packages in studies such as [Photon efficacy in horticulture: turning LED packages into LED luminaires](#); results from this study are reproduced in Table 6. Of the 560 tested products listed on the DesignLights Consortium Qualified Products Library as of February 2022, 95% of them have a luminaire PPE of 2.95 µmol/J or lower. Products tested for DLC listing are verified by OSHA/NVLA accredited testing laboratories.



Regulations Requiring Minimum CEA Lighting System Efficacy

The state of California has adopted updates to **Title 24, Part 6** related to CEA¹⁴, the first regulations specific to horticultural lighting for the state, which will take effect in January 2023. The draft code is triggered by new construction and major renovations and applies to greenhouses and indoor farms with more than 40 kW of total connected horticultural lighting load. The proposal requires a minimum PPE of 1.9 $\mu\text{mol}/\text{J}$ for luminaires used for indoor facilities and a minimum PPE of 1.7 $\mu\text{mol}/\text{J}$ for luminaires used in greenhouses.

Industry Organizations Establishing Minimum CEA Lighting System Efficacy

Standards organizations are similarly establishing values for minimum efficacy. ASHRAE has mirrored this proposal and has drafted additions to the **90.1-2019 Energy Standard for Buildings** which would require luminaires in greenhouses and indoor farms to meet the same minimum PPE requirements.

Plan for Controls - On top of fixture savings, programs can help producers save more energy with lighting controls. Understand how your program may evolve to claim controls savings for strategies like dimming, daylighting (DLI controls), and spectral tuning. DLC is developing technical requirements for horticultural lighting controls as they have done for commercial lighting controls systems. Learn more about effectively supporting lighting controls projects with RII's published [controls best practices guidance](#).

Flexibly Manage Demand - Some greenhouse lighting controls systems can incorporate 'day ahead market pricing' from utilities to shift lighting energy use to avoid peak loads. This strategy can be used by both indoor

facilities and greenhouses to save operating costs from peak electric demand. In greenhouse scenarios, this approach may result in more lighting hours per year than a traditional daylighting controls strategy, as the lighting system is run more often earlier in the day and may be ramped down during periods of greater solar resource.

HVAC Measures

After lighting, efficient HVAC systems and equipment present good savings opportunities, but require that program staff have subject matter expertise and can calculate accurate savings and incentives in a reasonable amount of time.

HVAC Equipment Baselines

The recommendations in this section use several key horticultural HVAC terms. Consult our [online glossary of key CEA HVAC terms](#) to determine which metrics are important for your program.

Determine HVAC Baseline - Depending on the crop being cultivated, producers may require HVAC systems to satisfy target environmental conditions such as temperature, relative humidity, and airflow. There are different kinds of HVAC systems used by different types and sizes of cultivation facilities to satisfy dynamic HVAC loads. **Table 8** on the following page describes the various kinds of approaches taken in greenhouses and indoor farms for heating, ventilation, airflow, cooling, and humidity management.



¹⁴ Final [Controlled Environment Horticulture \(CEH\) California Statewide Codes and Standards Enhancement \(CASE\) Report](#), Energy Solutions and Cultivate Energy and Optimization, 2020. Note that the proposed PPE for indoor facilities was revised from 2.1 to 1.9 $\mu\text{mol}/\text{J}$ in Appendix M in March 2021. The proposal now offers a pathway for indoor growers to use efficient double-ended HPS grow lights in addition to LEDs. The code was formally adopted by the CA Building Standards Commission in August 2021.

	Vented Greenhouse	Sealed Greenhouse	Indoor Vertical Farm
Heating	Unit heaters, hot water systems (boilers connected to radiant warm-floor slab heating or bench heating, hydronic unit heaters, root zone heating), biomass heating, furnaces	Hot water systems, geothermal heat exchange systems, air to air heat exchangers, fan coil units, electric resistance systems, latent heat converters	Electric resistance systems, heat pump systems, hot water systems, heat recovery chillers
Ventilation	Natural ventilation - ridge vents, gutter vents, side wall vents open-roof, retractable roof, powered fan systems for ventilation and exhaust	Sealed greenhouses do not bring in outside air	100% recirculating air
Airflow	Horizontal airflow fans (HAF)	Vertical air fans, destratification fans	HAFs and in-rack fan systems
Cooling	Evaporative fan-and-pad, fog (mist) cooling and humidifying, chillers ¹⁵	High-pressure fogging and integrated cooling & dehumidification	Integrated cooling & dehumidification
Humidity management	Exhaust fans, wood-fired heating, sometimes plug-in dehumidification equipment	Central dehumidification system	

Table 8: Common CEA HVAC Systems by Facility Type

Understand Energy Source - Combined heat and power (CHP) systems are used by some CEA facilities to drive facility systems, and these choices can impact the fuel that is used for HVAC processes. Some efficiency programs can incentivize cogeneration equipment, but those operating in regions with reduction goals for greenhouse gas emissions may not be able to incentivize CHP systems fueled by natural gas. For those that can support this technology, CHP systems can be a way to manage electric demand at CEA operations. For example, when there is electricity demand but heating is not needed, the CHP can run anyway and store heat in hot water buffer tanks for use later, usually at night when no electricity or CO₂ is needed for environmental enrichment. Chillers are an HVAC system that can be driven by electricity or natural gas and can also offer demand management opportunities. CEA facilities can run chillers at night when outdoor temperatures are cooler and utility rates are lower to store cold water in buffer tanks for use during the day.

¹⁵ Required for certain floriculture crops like orchids.

Gather Key HVAC Inputs - Information like system efficiency and ranges of target environmental conditions are crucial savings calculation inputs for CEA HVAC programs. Use information like cultivation approach, crop type, and system size to select high performance and baseline equipment for savings claims. **Table 9** on the following page describes typical HVAC system types by facility type, scale of cultivation space, and HVAC system size. Consult **Table A1** of the Appendix on **page 45** to collect the necessary information to support HVAC savings claims and document projects for evaluators.



Facility Cultivation Area	HVAC System Capacity	Greenhouse CEA HVAC Solutions	Indoor CEA HVAC Solutions
<10,000 sq ft	75 tons or less	Direct expansion (DX) cooling, unit heaters, passive ventilation via venting of building envelope	Direct expansion (DX) units with standalone dehumidification systems like roof-top units (RTUs) split systems, and ductless heat pumps
10,000 - 30,000 sq ft	75 - 300 tons	Evaporative cooling walls (pad & fan systems), radiant heating systems, exhaust and circulation fans	Air-cooled chillers, hot water coils, heat pump systems, electric heat
>30,000 sq ft	Greater than 200 tons	Ground-source heating systems, comprehensive ventilation systems	Water-cooled chillers, heat recovery systems, comprehensive ventilation system

Table 9: Typical CEA HVAC System Types by Facility Size and HVAC Capacity

Regulations Requiring Minimum CEA HVAC System Efficacy

In regions with energy regulations addressing CEA facilities, the baseline equipment may vary depending on required cultivation processes like dehumidification. In California's proposed **Title 24, Part 6** requirements for Controlled Environment Horticulture, indoor growing facilities needing dehumidification must use one of the following systems:

- Stand-alone dehumidifiers that meet the following minimum integrated energy factors:
 - Minimum of 1.77 L/kWh for product case volumes of 8.0 cubic feet or less
 - Minimum of 2.41 L/kWh for product case volumes greater than 8.0 cubic feet
- Integrated HVAC system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; Chilled water system with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
- Solid or liquid desiccant dehumidification system for system designs that require a 50°F (10°C) dewpoint or less.

Industry Organizations Establishing CEA HVAC Design Recommendations

Standards organizations are similarly establishing practices for effective CEA HVAC system design. ANSI, ASABE, and ASHRAE have published *Engineering Practice 653, Heating, Ventilating, and Air Conditioning (HVAC) for Indoor Plant Environments without Sunlight*, which "provides growers with the foundational information that will a) facilitate the understanding of HVAC equipment options that can be used to manage the indoor plant environment and b) allow the grower to communicate with engineers, contractors, manufacturers, investors, and other growers."

Project Baselines

Your route is mapped, your gear is packed, and now you need to build a structure for savings claims so your business case receives internal and external approvals and so your program is effectively deployed in the market and survives ex-post program evaluation intact. The next consideration for building savings claims for your chosen suite of measures is determining baseline equipment and performance. Your baselines may have to change depending on the kinds of projects your program supports.



Research Standard Practice - In emerging markets like CEA, establishing Industry Standard Practice (ISP) is not impossible, as many efficient systems and their use cases have been determined by programs in North America working with more mature markets with large numbers of commercial CEA producers. However, it is nuanced, challenging, and a topic of frequent discussion among members of RII's Utility Working Group. Prepare your program for success by documenting any information for indoor and greenhouse ISP that can be applied to your region and CEA customers. Consider how a preponderance of evidence may be demonstrated in your region.

Bring Your Baseline - North American CEA programs currently operate in a "bring your own baseline" environment as CEA standard practices are challenging to establish for both greenhouse and indoor vertical farms¹⁶. In some cases, an efficiency program may take one stance on ISP, whereas a regulatory body (e.g. CPUC) or consulting subject matter expert(s) may disagree.

Plan for Change - Emerging technologies are evolving quickly; for example, adoption of LED lighting is increasing quickly and the technology may be considered ISP in some CEA market segments in the near future. As RII transforms the CEA market towards data-driven efficiency, we will provide a clear line of sight to an ecosystem of centralized baselines for suites of efficiency measures and equipment.

Determine Indoor ISP - Many programs serving indoor cultivators have developed baselines for technology serving facilities growing some crop types, but may not understand ISP for other crop categories. Lighting baselines have been easier to determine for some programs but with less common CEA crops the baseline can be fuzzier.

Determine Greenhouse ISP - Standard practice for greenhouses is more developed than indoor farms, but is still often developed ad hoc and can be inconsistent from state to state and utility to utility, even in states like California which is a frontrunner in CEA programs. This is further complicated by the variability in greenhouse construction type, size, and crop. The greatest agreement

is on supplemental lighting, often for flowering or fruiting stages of plant growth. Standard practice for envelope and HVAC measures is less clear; for example, debate is ongoing over whether IR film is ISP and whether unit heaters or boilers are ISP.

Determine New Construction ISP - For new cultivation facilities, the baseline is likely the least first cost technically viable option, or the ISP as determined by the regulating authority. Baseline systems have to provide equivalent performance as the more efficient option that is proposed.

Determine Retrofit ISP - For existing facilities undergoing major renovations, the baseline is likely to be the existing equipment. If the equipment has failed or is at the end of life, a new construction baseline is likely to be used. If the proposed systems increase the production capacity of an existing facility, dual baselines may be required; one for the existing systems and capacity, and another baseline for the equipment serving the added production capacity. This second baseline would follow the new construction baseline path. For operations performing minor equipment replacements, the baseline is likely to be the existing equipment (unless it has failed or is at end of life, then a new construction baseline is likely to be used).

Savings Calculation Inputs

Understand how you will measure success as your customers and supply chain partners begin to participate in your program and your team ascends the CEA efficiency program mountain. Avoid painful ex-post analyses from evaluators and lost savings by requiring thoughtful pre- and post-equivalency documentation.

Choose Your Measures - Decide which measures you will support in your program. Estimate savings from different emerging technologies you will incentivize for your CEA business customers. **Table 10** on the following page describes the four major categories of CEA measures, and the types of technology hardware, software, and sequences of operation that can result in ranges of energy savings depending on the facility and project type.

¹⁶ Southern California Edison produced a [Market Characterization of Indoor Agriculture \(Non-Cannabis\)](#) in 2021 that describes some technology baselines for indoor farming facilities. There is not a comprehensive industry standard practice for greenhouses or indoor farms that is applicable to facilities in all locations in the United States growing all CEA crops.



Energy Saving CEA Measure	Energy Savings Potential
Greenhouse Envelope Systems¹⁷: • Enclosure upgrades • Shade and thermal curtains • Curtain controls	5 - 50%
Horticultural Lighting Systems¹⁸: • Air-cooled LED light fixtures • Liquid-cooled LED lighting systems • LED lamps • Lighting controls	30 - 40%
HVAC Systems¹⁹: • Heating systems • Root zone heating systems • Cooling systems • Variable frequency drives (pumps and fans) • Humidity management equipment • Environmental controls • Airflow controls	20 - 30%
Integrated Controls Systems²⁰: • Envelope, lighting and HVAC controls integrations • Water and environmental controls integrations	15 - 30%

Table 10: Energy Savings Potential of CEA Measures

Screen - For each potential measure, screening for cost-effectiveness will, as always, incorporate energy and demand impacts, but can also address total resource benefit and societal costs. Depending on the location and the energy sources for the electric grid, the financial and environmental costs of indoor cultivation can be offset by reduced land, pesticide, and fertilizer use, reduced water demand, consumption, and runoff, and shorter transport distances compared to outdoor cultivation.

Document All Key Inputs - To save time and effort, establish a list of inputs for your energy savings calculators for your suite of efficiency measures that are likely to make the most impact on energy and demand savings, and focus on gathering those with early pilot projects to check your hypothesis and adjust mandatory and optional input

fields. Learn from the experience of members of the Utility Working Group; some inputs to consider gathering for your program, especially when starting with a custom approach, are described in **Table A1** of the Appendix on **page 28**.

Describe Non-Energy Benefits - Understand the priorities of growers by crop type to share quality and business benefits of efficiency measures. One of the most popular measures for CEA facilities offers diverse non-energy benefits. LED horticultural lighting not only can reduce costs of operation, but also offer growers the opportunity to use methodologies like vertical racking and lighting controls strategies like daylighting controls and spectral tuning. LED light treatments can offer increases in biomass yield and improved quality expressions due to their photomorphogenic effects. There are diverse spectra

¹⁷ [A Guide to Energy Savings for Greenhouses](#), Efficiency Vermont, 2019.

¹⁸ Opportunities in Controlled Environment Agriculture, ERS, Resource Innovation Institute, ACEEE, and D+R, 2021. [LED Lighting Best Practices Guide](#), Resource Innovation Institute, 2019.

¹⁹ [HVAC Best Practices Guide](#), Resource Innovation Institute, 2019.

²⁰ [Controls Best Practices Guide](#), Resource Innovation Institute, 2021.



options that affect fixture efficacy and influence crops in different ways. Science is still being investigated with research studies and new findings are constantly emerging.

Claim Right - Forecast when savings potential will be realized for accurate resource planning. Account for lead times on efficient equipment, permitting, and construction schedules to accurately forecast when savings will be able to be claimed. As your programs are required to determine future load growth, while you update Integrated Resource Plans, you will want to include new economic and market barometers for the CEA industry to

predict load growth across CEA sectors.

Plan for Regulation - In future years, you must adjust your forecasted savings potential and load growth calculations based on the evolving number of regulatory requirements affecting CEA producers and their facilities. Understand how jurisdictions in regions covered by your programs are adopting industry standards like the latest version of ASHRAE 90.1 that includes an addendum for horticultural lighting efficacy. Plan for the impact of energy codes like California’s Title 24, Part 6 for Controlled Environment Horticulture.



Savings Methodologies

Choosing a savings methodology is like picking your route on your map of hiking trails up the CEA program mountain. There are also many ways to cut a path through the forest, and depending on your gear, you may chart a different course than other hikers. Programs in many states use custom approaches to work with cultivators so savings estimates can be refined using information from the project in the field. Programs in 19 states have established algorithms for certain equipment to calculate deemed savings for prescriptive CEA rebates. These approaches are described in the sections below so you can decide which course to take first, and which paths may be available to you in future years.

Custom Approaches

Program design requires working with available data and resources. Most utilities and efficiency program implementers are using **custom project approaches** to engage with CEA customers and calculate savings

estimates and incentives, which provide specificity to capture the variability in these facilities. **Table 11** below demonstrates the prevalence of savings methodologies for the four major CEA program offerings as described by RII’s Utility Working Group members representing CEA programs across the United States.

	Custom	Prescriptive	Structured Custom
Greenhouse Covering Incentives	54%	38%	8%
Lighting Incentives	40%	35%	25%
HVAC Incentives	55%	28%	17%
Controls Incentives	67%	20%	13%

Table 11: Prevalence of Savings Methodologies for CEA Program Offerings

While the traditional custom project approach offers site specific project information and may follow standard measurement and verification (M&V) protocols, it can also be costly. The primary cost can be from the skilled engineering labor providing modeling with energy savings calculators and technical design and construction support throughout the project. Some program managers

find that while custom approaches may cost more, they are best for quality control and maximizing claimed savings. Custom projects also provide the customer with an independent third party review of the cost-effectiveness of and savings associated with the project, and can give customers greater confidence in their investment.

Custom Program Approaches

Custom project approaches are designated by technical utility staff who work directly with CEA customers to review proposed design, assess cost effectiveness, measure project savings, and calculate incentives. For these projects, you must follow measurement and verification (M&V) protocols for estimating and verifying savings.

Tips for Doing Custom Projects Better

- Do not assume these are traditional agricultural customers; “know their grow” and speak their language. Plan your site visits thoughtfully, consider specialized CEA business concerns, and work with subject matter experts when appropriate.
- Use [PowerScore](#) to benchmark pre-project Performance Snapshot reports to establish facility baselines for comparison with post-project benchmarks and continuously benchmark for key KPIs year-over-year. **Figure 3** at left shows an example PowerScore Performance Snapshot for a indoor vertical farm.
- Bundle measures together to increase cost-effectiveness and improve payback periods for customers.

- Consider offering bonus payments for energy savings above certain tiers.
- Consider a strategic energy management (SEM) program structure with certain CEA customers to enable long term engagement and savings claims. Learn more about SEM programs and how they can work for CEA facilities on [page 34](#).

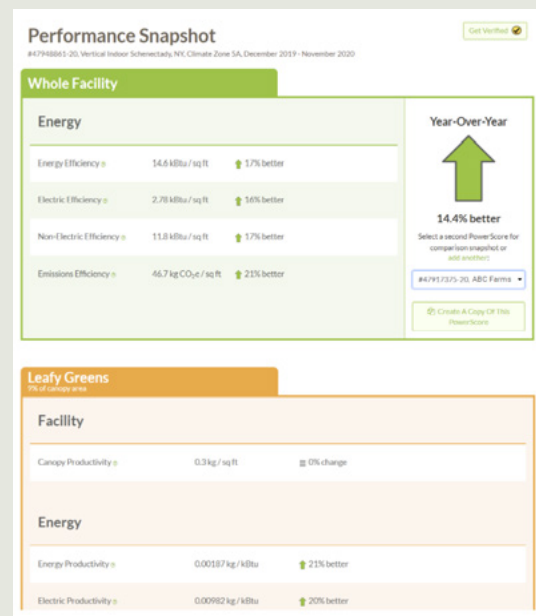


Figure 3: Example PowerScore Facility Performance Snapshot

Structured Custom Approaches

Once you have enough projects and experience under your belt, you might develop a structured custom approach. These quasi-prescriptive programs allow you to engage with CEA customers and calculate savings estimates and incentives more quickly and in a standardized manner. These programs can cost less than custom programs, and offer faster timelines for customers

to receive incentive offers, while still providing case-by-case savings calculations to be evaluated by regulators.

Programs benefit from developing technology-specific calculators for energy savings and financial incentives by using aggregated data gathered from a range of representative projects. With sufficient project data, your team has the information necessary to reduce the costs and improve the customer experience of your program.

Structured Custom Program Approaches

Structured custom project approaches leverage energy savings and incentive calculators which have been designed for specialized and unique commercial, industrial, or agricultural processes. Calculators streamline the utility engineering process, promote consistency between projects, and typically reduce the time needed for project review. Learn more about savings calculation inputs in **Table 1** in the Appendix on **page 45**.

Tips for Doing Structured Custom Projects Better

- Model pilot project energy savings and loadshapes with calculators specialized by regional climate, facility type, and crop. Modeling programs like Virtual Grower can help estimate energy savings for greenhouses and indoor farms.
- Increase customer participation by encouraging cultivators to leverage PowerScore; cultivators who use PowerScore are more likely to participate in utility energy efficiency programs.
- Use PowerScore for pre-and post-project benchmarking and compare your portfolio of projects to the Ranked Data Set. **Figure 4** at left demonstrates a portfolio of facilities in orange compared against a crop-specific Ranked Data Set in green for the Facility Electric Energy Efficiency key performance indicator.
- Use PowerScore Pro to benchmark your projects and access portfolio reports you can review to complement M&V and prepare for evaluation.
- Proactively inform evaluators of your program approach and share examples from this guide to demonstrate how others are employing similar practices.

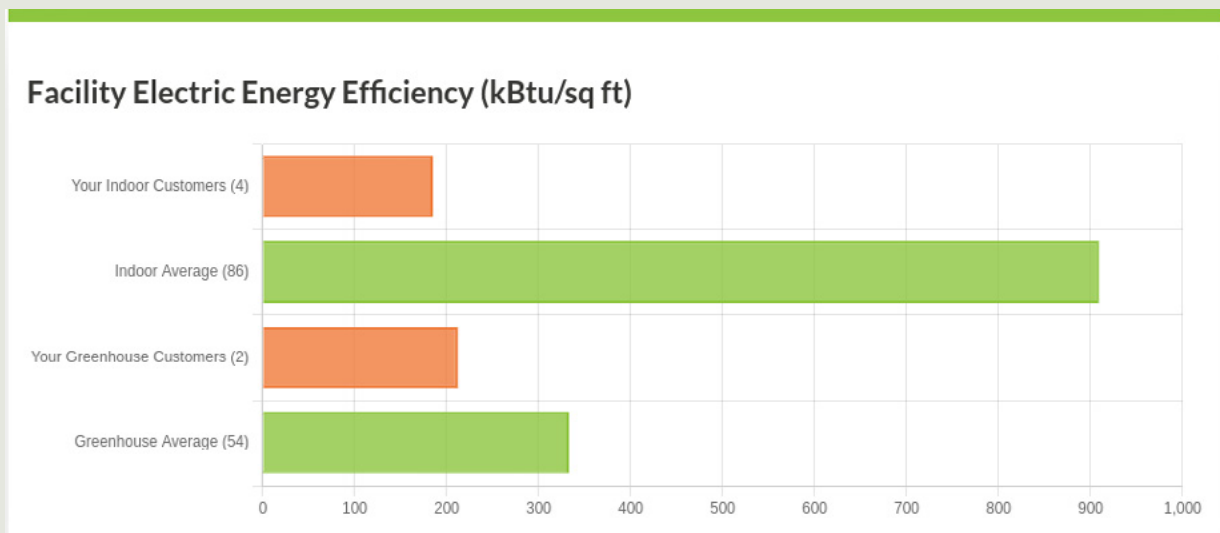


Figure 4: Example PowerScore Report Comparing CEA Program Portfolio to a Crop-Specific Ranked Data Set



Prescriptive Approaches

When programs scale up and enough historical projects have undergone evaluation, your program may be ready for a **prescriptive approach** for some technologies and measures. These programs require less direct engagement with individual customers and empower them and their supply chain partners to engage with efficiency programs. These programs can further reduce program expenses and reach broader audiences than custom programs, though claimed savings may be smaller due

to conservative assumptions made about how equipment is operated in the field. The prescriptive savings and incentive allows for streamlined participation, and offering incentives at the point of sale makes the energy efficiency decision easier for CEA producers. Instant rebates help break down financing barriers, as they reduce capital costs on day one. **Figure 5** below shows how prescriptive programs minimize both risk and cost impacts to efficiency programs.

Prescriptive Program Approaches

Several programs in North America have piloted midstream offerings to CEA customers. Prescriptive CEA offerings include lighting, dehumidification, and greenhouse technology measures and use conservative deemed savings values to manage savings risks. Deemed savings values make it easy for consumers and supply chain actors to participate, and are attractive to regulators for cost-effectiveness.

As shown in **Table 8** on **page 25**, prescriptive approaches are employed by a good portion of RII's Utility Working Group members representing CEA programs across the United States. Prescriptive programs are more popular for greenhouse coverings and lighting incentives, and are less prevalent for HVAC and controls incentives.

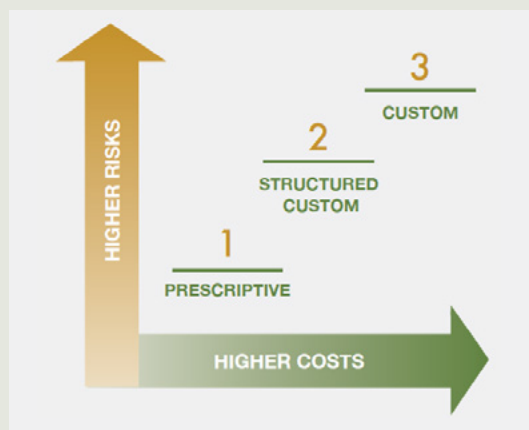


Figure 5: Risk and Cost Impacts of Different Program Approaches

Tips for Getting to Prescriptive Programs

- Migrate measures to prescriptive with confidence. Evaluate your custom CEA programs and establish parameters that affect savings the most.
- Repackage prescriptive programs with adjusted inputs to create new CEA customer savings claims. Deemed HVAC savings algorithms must have revised load profiles and operating hours, at the very least.
- Create unique deemed measures for horticultural lighting with specialized savings methodologies informed by earlier custom programs that consider fixture characteristics by facility type and crop application.
- Look at your C&I offerings and identify areas where CEA customers can cross over and participate. VFDs on pumps and fans are common ground for many prescriptive program offerings.
- Ensure you do not over- or under-claim savings by studying measures as if they were custom to calculate the impacts of CEA customers using products covered by your prescriptive programs.
- Use eligibility requirements and exclusions to protect existing prescriptive C&I programs from CEA customer participation and direct them to custom program offerings.

RII's Utility Working Group members cite fast delivery as the primary motivation for CEA prescriptive program offerings. Here are the major reasons why many efficiency program managers see prescriptive programs as a goal for their CEA offerings:

1. **Prescriptive programs are fast to deliver program incentives and savings** as qualified product libraries (QPLs) pre-verify that equipment performance satisfies minimum efficiency ratings. Familiarize yourself with testing standards to understand why a product may or may not be on a QPL. Leverage standards organizations to verify why products are not listed.
2. **Prescriptive programs are more attractive to growers** as HVAC contractors & vendors can provide rebates at point of purchase. Point-of-sale rebates reduce first costs of capital investments without requiring them to wait for a financial incentive at the end of a construction as is done in custom projects.
3. **Prescriptive programs created for HVAC and humidity control (HVAC) equipment for C&I customers can be repackaged and marketed to CEA customers** for predictable savings estimates in a specialized application.
4. **Prescriptive programs help the supply chain evolve and become more efficient** as equipment dealers receive incentives for stocking and upselling high-performance equipment and submitting program documents on behalf of customers.



Incentive Structure

After selecting your savings methodology and determining equipment baselines and crucial inputs for your program's calculators, it is time to decide how customers will be incentivized for helping you ascend the mountain.

Your map is becoming well defined and you have identified the most important tools in your pack. Now your team needs a structure for financial incentives associated with the savings from your suite of measures and associated equipment so your customers are encouraged to participate with defined benefits.

Learn from the experience of members of the Utility Working Group; incentive structure options for you to consider for your programs are described in **Table 2** of the Appendix on **page 47**.

How Much to Cover - How much of the incremental project costs (new construction) for various measures in your programs might you cover? What maximum percent of project costs or incremental costs can CEA customers receive? Incremental cost is the cost difference between the standard efficiency (baseline option) and the more efficient alternative that is proposed. Many custom C&I

programs can cover 25 - 50% of project cost for retrofits, and 60 - 90% of incremental measure cost for new construction projects, depending on program participation. Some might consider higher ends of that range for emerging technology programs.

Beyond Incentives - Financing helps producers overcome one of their biggest barriers to adopting efficient technology. Be creative with how you help CEA producers overcome barriers to efficiency projects by on-bill financing, bill credits, instant discounts at distributors. Plant the seed of efficiency by giving away free efficient products so growers can try before they buy. Many utilities offer on-bill financing to help customers overcome first cost barriers and some extend them to CEA producers. Help projects at the front end by becoming an influential member of the project team by offering technical assistance, so projects incorporate efficiency program offerings during the design phase.

Cater to Process - Consider offering different incentives for equipment used for different stages of plant growth. Some programs offer higher incentives for lighting equipment used vegetative stage of growth, given longer run hours equipment. Others offer higher HVAC incentives for facilities growing crops with intense environmental controls, if equipment might see increased usage.

Determine Metrics - For all equipment: \$/unit and \$/square foot incentives are the most easily digestible for customers. For lighting: \$/kWh incentives are very popular but require detailed savings calculations. \$/kW incentives entail simple savings formulas and tie more directly to peak demand reduction goals of some programs, especially for municipal utilities. Some programs offer

combined \$/kWh and \$/kW incentives. For HVAC: \$/ton and \$/MBH incentives are common as they have been deployed before for other C&I customers with success.

Bundle for Savings - Some programs bundle measures and offer 20% bonuses on top of measure incentives on the lowest incentive when CEA customers complete two or more projects of differing measures within a calendar year capped at some amount. Consider whether income eligible customers can qualify for additional bonus incentives. Some programs in some regions do not bundle to ensure that each incentivized measure meets the program's requirements.



Strategic Energy Management

Some customers may need a complement to measure-based incentive programs. Offering diverse structures for program participation complements the measures you strategically deploy as you ascend the CEA program mountain. Strategic Energy Management (SEM) programs can help you on your climb year after year if you pack some attractive treats in your bag.

CEA customers are focused on specialized production processes on unique schedules, and can be thought of as a very niche industrial customer. Some CEA producers are well-suited candidates for strategic energy management programs, depending on the size and type of their facilities.

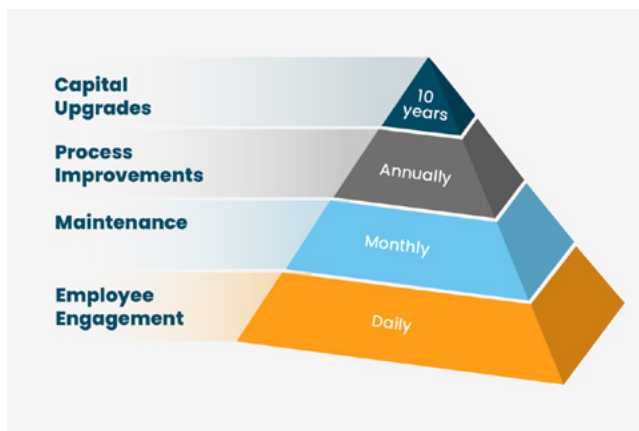


Figure 6: Strategic Energy Management Activities

Choose SEM Activities - Elements of SEM programs include coaches, organizational commitments, energy champions, benchmarking, energy modeling, peer to peer learning via cohorts, treasure hunts, workshops, and incentives. Understand how typical SEM activities like those shown at left in **Figure 6** may need to be specialized for CEA operations. Since CEA businesses do not often have energy managers on staff, participants enthusiastically value technical expertise, recommendations, and accountability for implementing energy management projects.

Create CEA SEM Programs - 38% of surveyed executives of CEA operations²¹ have heard of the term Strategic Energy Management, but performance-based incentives are offered to CEA producers by efficiency programs in only ten states. Build a pilot program to test the method and work out issues for wider adoption, cost-

²¹ Survey conducted by RII at the 2021 GROW Executive Summit.

effectiveness, and persistence²². When working with pilot producers, get buy-in not just from the top management and facility manager, but also the head grower that makes decisions impacting crop growth. Bring your experts to gain credibility and overcome grower skepticism. Engage utility partners so producers can access incentives on top of those offered by your programs.

Design Cohorts - Consider the types of cultivators you will bring together. RII Utility Working Group members have found that larger cultivators enjoy talking to smaller scale operations, offering tips for technology they have tried. When recruiting, avoid busy seasons like planting and harvest to capture attention and effectively onboard participants. Engage the business leadership team and head cultivation staff in the energy team for more traction and easier implementation. Include virtual and on-demand elements for cohort engagement in your SEM program so more cultivators can participate.

Choose Measures - CEA SEM programs can employ similar measures as conventional C&I programs: stop leaks, eliminate waste, turn things off, refine controls sequences, and calibrate sensors. Work with producers to retrocommission their controls and locate low- or no-cost energy saving opportunities in their building systems. It is useful to equip SEM program engineers and coaches with the proper tools to take on a treasure hunt like CEA-specific data collection forms and metering equipment, a general knowledge of the unique challenges of making changes in a biological system, and information about best practices like RII's published guidance and referenced resources.

Hunt Treasure - If producers are willing, bring cohorts of facility operators on treasure hunts so together they can learn from each other as they 'show and tell' about their experience with emerging and high-performance technologies, which provides a stronger recommendation for efficiency than any program can achieve. Note that some growers often cite proprietary growing processes and may not be open to site visits from perceived competitors.

Estimate Potential Savings - Savings results for CEA SEM programs stack up against conventional SEM participants according to Utility Working Group members²³. Program implementers find that annual savings vary by crop category and facility type. SEM approaches may help cut flower greenhouses save 12% electricity annually and nurseries might achieve annual natural gas savings of 3 - 4%. Indoor mushroom facilities can use SEM strategies to save 3 - 7% electricity annually. Operations growing crops with higher resource needs have validated 11% annual electricity savings.

Model Accurately - Like modeling for individual efficiency measures, modeling for SEM can be challenging due to seasonality of production, varying environmental conditions, and dynamic climate and weather conditions. Bottoms-up engineering calculations may be required according to members of RII's Utility Working Group. Consider pandemic impacts that continue to affect savings calculations.



Use Federal Tools - The U.S. Department of Energy developed the 50001 Ready program to help organizations implement comprehensive energy management systems that align to the ISO 50001 standard, the global framework for implementing energy management systems. 50001 Ready is a free self-paced program that can complement efficiency program activities and arm producers with steps to adopt best practices. Learn more in the Resources section on **page 42**.

²² [Strategic Energy Management Program Persistence and Cost Effectiveness](#), ACEEE, 2021.

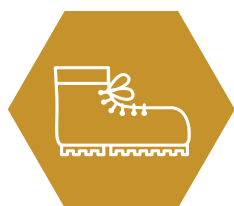
²³ According to the 22 members in attendance at the January 28, 2022 Utility Working Group meeting.



Program Implementation for Market Transformation

PHOTO: TIMA MIROSHNICHENKO





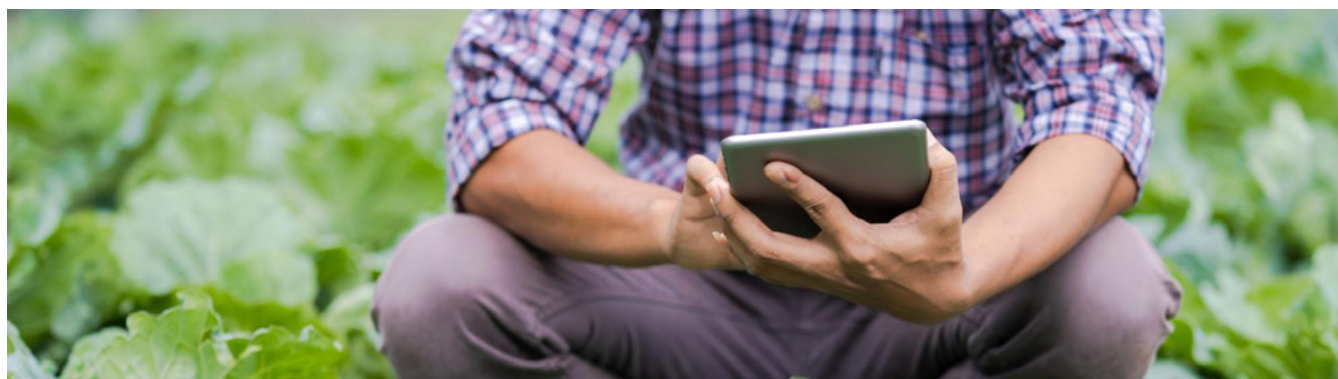
Best Leverage Points for Market Interventions

Your team should now be looking at a well-defined map with effective routes for your journey up the CEA program mountain and have identified the gear most suitable for your hike. It is unwise to go into the field without the proper kit, and implementing a CEA program is no different. Much like a camper has to pack both gear and provisions, the intrepid efficiency program manager must account for both the products and services that will be necessary to ensure success.

Utilities are key market actors who can influence the choices CEA producers make when purchasing equipment and help overcome the highest-ranked challenge facing CEA producers: operating costs. **Table 12** below describes other primary challenges, some of which can also be addressed by efficiency programs.

Challenge	Degree of Challenge (1 = very challenging to 5 = not challenging)
Keeping operating costs down	1
Predictability/stability of operating costs	3
Sales	4
Predictability of plant performance	4
Managing farm labor	4
Food safety or regulatory compliance	5

Table 12: Operational Challenge Rankings for CEA Producers



²⁴ Survey conducted by RII at the 2021 GROW Executive Summit.

²⁵ *DSM Resource Acquisition and Market Transformation: Two Inconsistent Policy Objectives?*, Pahl, Schlegel, 1994.

Increase Incentive Participation - There are still many CEA producers who do not take advantage of efficiency program offerings like financial incentives. 59% of surveyed executives of cultivation operations²⁴ report receiving energy efficiency incentives from their utility. 61% of those who have received incentives report using them for lighting systems, 11% for HVAC, and 6% for controls projects.

Transform the Market - Compared to resource acquisition²⁵, *market transformation* may: (1) yield greater savings, demand different performance incentive schemes for program implementers, require an increased emphasis on education and the generation of structural changes in the marketplace, call for changes in the types of technologies and market actors that are emphasized in program marketing, and require changes in evaluation and resource planning practices.



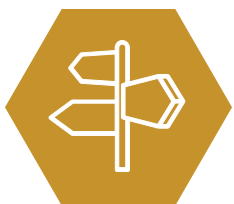


Use Your Tool Kit

As you set out on your hike, you will begin to use your CEA program map and need to be ready to deploy your provisions swiftly and effectively. Program products and services can be generally defined as products and services. Table 13 below describes the differences between products and services and their associated costs and values for CEA programs.

Products	Services
Information sharing and technical tools directly used by program staff and/or customers	Involve a subject matter expert performing services on behalf of the efficiency program
Lower cost investment	Higher cost investment
Passive or reactive levels of engagement	Proactive engagement to develop and serve the utility market
Dependent on program staff and customers to leverage them	External service providers generate positive demand cycle for program offerings
CEA program websites	Educational curriculum
Savings calculators	Virtual classrooms
Resource benchmarking platforms	Live workshops

Table 13: CEA Program Offerings



Program Content Planning

At the center of all utility market engagement is the content. Developing and deploying strategic communication with your CEA customers helps the market with finding their way to your program offerings. Content consists of all the specific language, key technical terms, the market-facing guidance, and other customer communications. Consider how you plan to develop and present content to reflect emerging standard practice among utilities.

Talk How They Talk - Craft market-facing content written from the utility perspective and addressing professionals in the CEA market. Utility program language should be precise and use technical terms consistent with industry standard practices.

Know How They Grow - Show literacy in CEA crops, cultivation processes, and final products. Leverage content created by the supply chain and market leaders to provide horticultural education to your customers.

Be Accessible - Some of the tools in your backpack are

helpful to post online so your CEA customers can get the most out of your program and find their way to your offerings.

Bring Out the Welcome Wagon - Offer a dedicated landing page for controlled environment agriculture cultivator customers with CEA resources like RII Best Practices Guides, savings calculators, case studies, and links to educational workshops and curriculum. Include program offerings with eligibility and technical performance requirements, blogs written from utility perspective toward producer audience, FAQs, and a CEA newsletter.



Resource Benchmarking with PowerScore



Customers who understand their energy use are far more likely to do something about it. Resource benchmarking is used commonly in commercial and industrial buildings; industrial buildings require specialized benchmarking metrics to accurately measure their production efficiency in units produced per unit of energy.

Create Performance Snapshots - [RII's PowerScore](#) platform provides crucial benchmarking services for CEA businesses to access key performance indicators to understand their opportunities to increase resource efficiency and become more productive.

Validate Savings - Cultivators who use the PowerScore platform are more likely to participate in energy efficiency programs. Information from pre- and post-project benchmarks can be used for savings calculation estimates and to validate claims.



Market Engagement Services

Gather your CEA customers around the fire so they can share stories and develop their network. Many efficiency programs in North America are realizing the complex and rapidly evolving nature of the CEA market and are investing in educational programming, staff development, benchmarking products, and services.

Technical Assistance

Programs reaching CEA customers need to support producers with access to horticultural subject matter expertise (SME). Whether a utility contracts program implementation to a consulting company or manages it internally, use SME to elevate your program and provide technical assistance to your customers with the latest research and recommendations.

Support Projects - Experts are most often in need at the project level to provide technical support. Utility and efficiency program administrators are at the table with customers to guide them as they navigate decisions. Ensure these staff are ready to answer questions about how to achieve the best outcomes for plants with efficient technologies incentivized by your programs so your programs can maximize savings claims and your customers can get the greatest financial support for purchasing choices.

Engage the Supply Chain - Even if your program is downstream, trade ally networks add value to the program and increase participation when local dealers are engaged

and aware of incentives. Programs can provide services such as upselling trainings using operating cost analysis.

Train Up - It is important to educate your own staff to hone internal SME. Develop internal resources through programming like RII's [Harvesting Savings curriculum](#) to help programs retain CEA program savings, build project pipelines, launch new incentive offerings, and enhance technical assistance with PowerScore benchmarking services. Table 14 below describes subject matter beneficial for both CEA producers and CEA program staff to understand.



PHOTO: THISISENGINEERING



Technical Support Areas	Cultivator Benefits	Program Benefits
Selecting facility sites	Flag electric and gas service increases	Expose customers to program offerings early
Estimating energy consumption and demand	Forecast monthly and annual energy bills	Educate customers so they can succeed
Understanding program eligibility requirements	Assess facility for projects and incentives	Streamline program implementation
Understanding product eligibility requirements	Understand available efficient equipment	Devote time to eligible customers
Designing profitable facilities	Identify efficiency opportunities	Increase participation in programs
Determining feasibility & cost effectiveness	Make decisions about efficiency projects	Increase number of customers program can serve
Estimating energy savings and potential incentives	Maximize return on investment	Produce valid savings claims at attractive yield rates

Table 14: Common Areas Covered by CEA Subject Matter Experts

Educational Curriculum and Training

Offer educational programming for CEA customers outside of your program's online content like workshops for cultivators to learn about efficiency and connect with supply chain professionals who can implement projects in their facilities.

Raise Awareness - Help CEA customers overcome three of the barriers to efficiency: lack of knowledge of efficient technologies, skepticism and lack of trust in product

performance, and not enough cultivator training on how to effectively use new technologies. Develop the knowledge and skill sets of cultivators, the CEA supply chain, and utility program staff with a diverse training program that conveys the benefits of efficiency in compelling ways. Educate your customers with training like RII's [Efficient Yields curriculum](#) that can be customized for any program serving any kind of cultivator and facility type. **Figure 7** below illustrates how virtual workshops can engage CEA producers in compelling ways by offering training live and streaming on-demand.

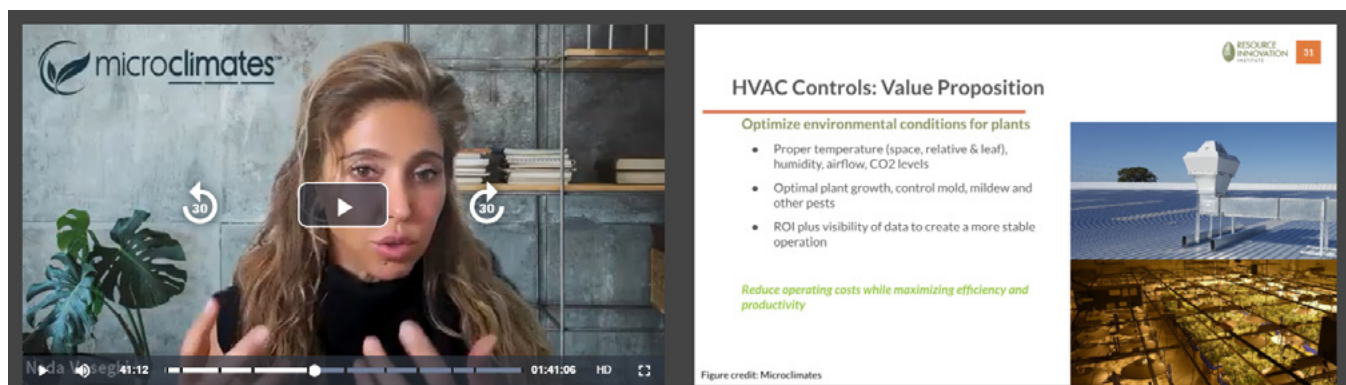


Figure 7: Example Training with CEA Subject Matter Experts

Highlight Research - Connect your customers to the experts in the field producing research that demonstrates the benefits of efficient technologies and cultivation strategies. Present information in workshops and in program literature leveraging CEA SME in partnership with energy service professionals. **Figure 7** on the previous page demonstrates how online workshops and on-demand streaming can reach cultivators with valuable expert guidance in ways that are compelling and flexible.

Build the Pipeline - Use curriculum and training to provide a platform for sponsoring utilities to highlight available programs and resources. Share stories from customer facilities with details like annual energy savings, incentive amount, payback period, and return on investment. Include information about non-energy benefits to build executive support for trying something new.

Provide Options - Cultivators are notoriously busy and need a variety of ways to access and digest curriculum. Hold training events virtually and in person. Offer digestible educational content like shorter videos conveying quick tips. Offer on-demand learning resources which complement and further sustain the conversations started at the event. Offer a structured and comprehensive platform cultivators can access frequently, as opposed to ad hoc workshops once or twice a year. Consider organizing workshops into a series for an effective outreach strategy, as cultivators will be more likely to attend one or more workshops out of a list of topics relevant to them. **Figure 8** below shows example images for promoting workshop series and live training.

Figure 8: Example CEA Training Marketing Materials



CEA Continuing Education & Credentialing Programs

Build up the supply chain so customers can be served by a qualified network of professionals as they install efficient equipment and deploy energy management strategies. Recognize excellence in the workforce by recommending customers work with credentialed professionals.

Develop the Workforce - Hone the skills of design and construction professionals serving CEA businesses in your region by working with subject matter experts and industry organizations providing educational curriculum and training for CEA professionals. Ensure persistent energy savings and satisfied customers by improving the quality of the CEA design and construction market in your program region.

Work with the Best - As credentialing programs emerge for the CEA industry, recommend customers work with partners listed in trade ally networks. Understand the continuing education opportunities for CEA professionals and consider requiring credential maintenance as part of trade ally network participation. Later in 2022, RII will be launching a USDA-funded credentialing program for CEA supply chain actors like architects, engineers, construction managers, contractors, and consultants.

Resources

Organization	Resource	Description	Link
Resource Innovation Institute	Utility Working Group	Landing page for RII Utility Working Group information and resources.	https://resourceinnovation.org/utility
	Catalog of Resources	Catalog of RII's published curriculum and training.	https://catalog.resourceinnovation.org
	Workshops and Webinars	Library of RII's live and recorded Efficient Yields educational workshops for CEA producers.	https://catalog.resourceinnovation.org/category/efficient-yields-workshops
	Best Practices Guides	Library of RII's peer-reviewed and brand-agnostic best practices guidance on efficient technology and approaches.	https://catalog.resourceinnovation.org/category/best-practices-guide
	PowerScore	RII's specialized resource benchmarking platform for controlled environment agriculture production facilities. PowerScore generates KPIs for resource efficiency and productivity of energy, water, emissions, and waste.	https://resourceinnovation.org/powerscore https://powerscore.resourceinnovation.org/go-cea
DesignLights Consortium	Horticultural Technical Requirements	Database of third-party certified LED light fixtures suitable for horticultural applications.	https://www.designlights.org/horticultural-lighting/search/
	Horticultural Qualified Products Library	Database of third-party certified LED light fixtures suitable for horticultural applications.	https://www.designlights.org/horticultural-lighting/search/
	Member Incentive Program Summaries	A comparison of horticultural lighting program offerings and incentive levels across DLC Member territories.	https://www.designlights.org/resources/reports/dlc-member-program-summaries-horticultural-lighting/
Greenhouse Lighting & Systems Engineering	GLASE Lighting Short Courses	Plant Lighting Short Course in partnership with Greenhouse Lighting & Systems Engineering (GLASE), OptimIA , and Lighting Approaches to Maximize Profits (LAMP)	https://glase.org/plant-lighting-short-course/
University of Arizona	University of Arizona CEA Short Courses	Greenhouse Production & Engineering Design Short Course presented by the University of Arizona Biosystems Engineering Controlled Environment Agriculture Center	https://ceac.arizona.edu/events/cea-short-course
University of Arizona, Ohio State University, Michigan State University, Purdue University	OptimIA Indoor Ag Science Cafe	Supported by USDA and NIFA	https://scri-optimia.org/cafe.php



RESOURCES

Organization	Resource	Description	Link
U.S. Department of Agriculture NRCS	Urban Agriculture Resources	NRCS conservation assistance is growing along with it. NRCS provides technical and financial assistance for assistance for urban growers in areas such as: soil health, irrigation and water conservation, weeds and pests, and high tunnels.	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/urbanagriculture/
U.S. Department of Agriculture NIFA	Urban, Indoor, and Emerging Agriculture	NIFA supports research, education, and extension activities for facilitating the development of urban, indoor, and other emerging agricultural production, harvesting, transportation, aggregation, packaging, distribution, and markets.	https://nifa.usda.gov/program/uie-ag
U.S. Department of Agriculture ARS	Virtual Grower	Virtual Grower can help identify energy savings through different greenhouse and indoor farm designs, predict crop growth, assist in scheduling, make real-time predictions of energy use, and see the impact of lighting on plant growth and development.	https://www.ars.usda.gov/midwest-area/wooster-oh/application-technology-research/docs/virtual-grower/
U.S. Department of Energy	50001 Ready for Utilities, Implementers, and Energy Service Providers	50001 Ready recognizes facilities that implement an ISO 50001-based energy management system – a self-paced, no-cost way to build a culture of continual energy improvement. DOE partners with utilities and other organizations to support the program's implementation, often as part of an SEM offering.	https://betterbuildingssolutioncenter.energy.gov/iso-50001/50001-Ready/50001-ready-program-utilities-admin-implementers https://betterbuildingssolutioncenter.energy.gov/sites/default/files/DOE_50001-Ready_Cohort.pdf



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Appendix

Table A1: Key Savings Calculator Inputs for Lighting and HVAC Measures

System	Calculation Input	Savings Implications
Facility	Facility floor area, cultivation space area, and canopy area by crop	Draw the project boundaries. Some measures are dependent on the area of plant production, while some measures apply to the entire cultivation space or at the facility level.
	Cultivation space program: crops at what stages of growth, served by which HVAC and lighting system	Establish the production goals for each growing area helps tie savings to the correct processes, systems, and target environmental conditions.
Lighting	Baseline light fixture PPE and PPF	Quantify baseline efficiency of standard horticultural lighting systems at converting electrical energy into photons of usable light for plant photosynthesis.
	Proposed light fixture PPE and PPF	Verify light fixtures qualify for the program and meet eligibility requirements so savings can be claimed.
	Proposed light fixture DLC listing	Verify third-party certification of lighting equipment.
	Greenhouses: Target DLI by crop / month of year	Determine crop needs based on crop type.
	Greenhouses: Solar resource	Determine facility needs based on facility location. Inform amount of supplemental lighting needed to reach target DLI throughout the year.
	Greenhouses: Light transmission	Understand how glazing material visible transmittance (VT) affects greenhouse supplemental lighting needs.
	Greenhouses: Lighting schedule	Document monthly or weekly schedule for supplemental lighting operation based on available solar resource, greenhouse covering VT, maximum usable light intensity in the greenhouse, and target DLI for crops by stage of growth.
	Indoor retrofits: Pre- and post-project light intensity (Photosynthetic Photon Flux Density, PPFD)	Establish pre-project PPFD to create a baseline for comparison for retrofits. For both new construction and retrofit programs, calculate post-project PPFD for crucial measurement and verification.
	Indoor retrofits: Quantities of existing light fixtures, wattages, actual PPFD in existing system	Establish industry standard practice to inform program development and calibrate custom savings calculations formulas to get to rules of thumb for existing operations using legacy lighting systems.
	Indoor farms: Proposed target light intensity (PPFD)	Establish desired operating conditions of the system which informs efficient equipment.
	Proposed equipment specs and lighting layout including quantity, spacing, and mounting height of LED grow lights	Establish lighting power and expected PPFD of proposed efficient equipment. Determines industry standard practice for operation of LED lighting for cultivation.
	Proposed PPFD map demonstrating target PPFD	Validate target PPFD can be achieved and allows for calculation of horticultural LPD.



Table A1: Key Savings Calculator Inputs for Lighting and HVAC Measures

System	Calculation Input	Savings Implications
Lighting	Indoor farms:	Time of day is important for demand savings and on/off peak costs.
	Lighting schedule	Members of the UWG shared common hours of use for estimating energy savings from efficient horticultural lighting: • Flowering & Fruiting: 4,380 hours annually (12 hours per day) • Vegetative & Budding: 6,570 hours annually (18 hours per day) Note that crops grown for seed production may have longer daily lighting hours, up to 24 hours per day.
	Lighting controls characteristics	Dimming sequences of operation are important for accurate savings estimates.
HVAC	Greenhouse: Covering type	Understand how greenhouse coverings affect heat loads. U-factors are associated with material and thickness. Plastic films can have greater U-factor if an air gap is actively maintained with fans.
	HVAC system type and efficiency characteristics	Determine interactive effects from HVAC equipment.
	Dehumidification approach	Greenhouses may use passive strategies, venting, and fans to reduce condensation. Indoor farms may use more mechanical solutions.
	Watering rate	Determine interactive effects from HVAC equipment. For indoor operations, all water provided to the plants is transpired and removed by HVAC system equipment.
	Transpiration rates	Understand dehumidification loads using transpiration rate.
	Method of maintaining airflow	Determine equipment used to move air and how equipment is controlled.
	Target environmental conditions (temperature, relative humidity, dew point, VPD)	Determine sensible and latent loads and operational efficiency of both baseline and proposed equipment.
	Lights on/lights off conditions	Establish variable load conditions of both baseline and proposed equipment.
	Varieties of plant stage of growth in the same cultivation space	Understand the sizes of plants and associated loads happening at the same time in areas served by the same HVAC equipment.
	Standard operating procedures for different plant growth stages	Determines industry standard practice for operation of HVAC equipment for cultivation.



Table A2: Incentive Structures and Savings Metrics

Savings Metric	Incentive Range	Incentive Structure Notes
\$/kWh	\$0.009/kWh (net lifetime) to \$0.45/kWh (custom) Average \$0.14/kWh	Low end: dehumidifiers High end: LED horticultural fixtures
\$/kW	\$68 - 500/kW Average \$237/kW	Offers load shifting and time of use benefits
\$/Watt	\$0.09/Watt - \$1/Watt Average \$0.47/Watt	Prescriptive or structured custom programs for LED horticultural fixtures and daylighting controls
\$/unit	\$50 - 250 / fixture for LED light fixtures	Prescriptive or structured custom programs for LED horticultural fixtures
\$/hp	\$20 - 200 / hp	Prescriptive or structured custom programs for process VFDs
\$/sq ft	\$0.02 - 0.50 / sq ft Average \$0.18 / sq ft	Infrared (IR) polyethylene greenhouse coverings
\$/sq ft	\$0.03 / sq ft - \$0.25 / sq ft Average \$0.11/sq ft	Greenhouse controllers
\$/sq ft	\$0..5 / sq ft - \$1.17 / sq ft Average \$0.45 / sq ft	Greenhouse thermal curtains
\$/sq ft	\$2.19/ sq ft of canopy	Under-bench (root zone) heating
\$/therm	\$0.09 - \$3.00/therm Average \$1.22/therm	Greenhouse reglazing and efficient condensing boilers
\$/ton	\$20 - \$100/ton	For efficient chillers and split AC systems and RTUs
\$/MBH	\$1 - 20 / MBH	Radiant heating systems and condensing unit heaters Condensing water boilers
\$/MMBTU	\$3-27/MMBTU	Radiant heating systems and condensing unit heaters Condensing water boilers
\$/kBtu	\$5.00 - \$10.00 / kBtu	Radiant heating systems and condensing unit heaters



Table A3: North American Energy Efficiency Programs for CEA Producers

State	Programs	Incentive Structure Notes	Website
Arkansas	Entergy Arkansas	Entergy: Custom \$0.17/kWh Up to 75% of the product cost	https://www.energy-arkansas.com/your-business/save_money/ee/agricultural/
Arizona	Salt River Project (SRP)	SRP: Custom \$0.08 / kWh + \$300 peak kW Up to 75% of the incremental cost Capped at \$300,000 per year per customer	https://savewithsrpbiz.com/rebates/customrebate.aspx
California	Willdan Bonneville Power Administration (BPA) Pacific Gas & Electric (PG&E) San Diego Gas & Electric (SDGE)	Willdan: Statewide Custom Energy Design Assistance (CEDA) serving PG&E, SDGE, SCE, SoCal Gas New Construction and Major Renovations projects: \$0.009-\$0.051 / discounted net lifetime kWh \$68 - \$298 / on-peak kW \$0.09 - \$0.51 / discounted net lifetime therm Cannot reduce payback below 2 years Capped at the lesser of 100% of incremental measure costs or 50% of full measure costs Capped for buildings with onsite generation exceeding usage Custom Whole Building Energy Analysis Go Green Financing BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp PG&E: Custom On Bill financing SDGE: Custom \$0.12 - 0.25/kWh \$150/kW \$1.25/therm Comprehensive Audit Program On Bill Financing	CaliforniaEDA.com https://gogreenfinancing.com/smallbusiness https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx https://agenenergysavings.com/ https://www.sdge.com/businesses/savings-center/facility-improvements/comprehensive-audit-program http://streamlinedag.com/

Table A3: North American Energy Efficiency Programs for CEA Producers

State	Programs	Incentive Structure Notes	Website
California	SoCal Edison (SCE)	SCE: New construction: CEDA Retrofits: Commercial Energy Efficiency Program (CEEP)	https://pages.willdan.com/sc-commercial
	SoCalGas	SoCal Gas: Custom \$2.50 - \$3.00 /therm saved in first year Prescriptive Thermal curtains & energy screens \$0.35 - \$0.50/sq ft Infrared (IR) film \$0.045 - \$0.10/sq ft Condensing boilers \$6.00 - \$10.00/MBH capacity Pipe insulation \$2.50 - \$4.00/ft Boilers 90%+ CE \$2.5-10/MBtuh	https://caenergyprograms.com/sites/default/files/28492_SoCalGas_AgEE_2021_Overview_v18.pdf https://caenergyprograms.com/AgEE
Colorado	Efficiency Works	Efficiency Works: Free energy advising and assessments	https://efficiencyworks.org/business/advising-and-assessments/
	Xcel Energy	Xcel: Custom Up to \$500/kW peak demand \$100/kW non peak in excess of peak savings Up to \$4/Dth natural gas Up to 60% of project cost	https://www.xcelenergy.com/programs_and_rebates/business_programs_and_rebates/equipment_rebates/custom_efficiency https://www.xcelenergy.com/programs_and_rebates/business_programs_and_rebates/new_construction_and_whole_building/business_new_construction https://co.my.xcelenergy.com/s/business/cost-savings/custom-efficiency



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State	Programs	Incentive Structure Notes	Website
Connecticut	Eversource	Eversource: Custom Virtual Net Metering Bill Credits	https://www.eversource.com/content/general/about/about-us/doing-business-with-us/builders-contractors/interconnections/connecticut-net-metering
	Energize CT	Energize CT: Smaller farms: Custom Up to 65% of project cost Interest free financing Free energy audits	https://energizect.com/events-resources/energy-articles/Agriculture https://energizect.com/your-business/solutions-list/Small-Business-Energy-Advantage/
Delaware	Energize Delaware	Energize Delaware: Custom Up to 30% \$0.15-.25/kWh \$9-27/MMBTU	https://www.energizedelaware.org/nonresidential/business/energy-efficiency-investment-fund/
Georgia	Georgia Power	Georgia Power: Custom \$0.10/kWh	https://www.georgiapower.com/business/products-programs/efficiency-maintenance/custom-ee-programs.html
Hawaii	Hawaii Department of Agriculture	Hawaii DOA: Custom Cap of \$1,500,000 Up to 85% project costs Agricultural Loans	https://hdoa.hawaii.gov/agl/alternative-energy-loan-program/
	Hawaii Energy	Hawaii Energy: Custom lighting \$0.08/kWh <5yr project life \$0.12/kWh >5yr project life	https://hawaiienergy.com/for-
Idaho	Bonneville Power Administration (BPA)	BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp	https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx
	Idaho Power	Idaho Power: Custom \$0.18/kWh per year Up to 70% project costs	https://www.idahopower.com/energy-environment/ways-to-save/savings-for-your-business/custom-projects/



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State	Programs	Incentive Structure Notes	Website
Illinois	Ameren	Ameren: Custom \$0.20 - \$0.45/Watt reduced with LED \$0.40 - \$0.75/Watt controlled DLC listed lighting products	https://amerenillinoisavings.com/business/industry-solutions/agriculture/
	Commonwealth Edison (ComEd)	ComEd: Custom \$1.00/Watt reduced with DLC listed LED \$0.07/kWh for custom lighting projects \$0.12/kWh for custom non-lighting projects	https://www.comed.com/WaysToSave/ForYourBusiness/Pages/Agriculture.aspx
Indiana	Duke Energy	Duke Energy: Custom \$0.065/kWh \$150/kW	https://www.duke-energy.com/business/products/smartsaver/custom-incentives
Iowa	MidAmerican Energy Company	MidAmerican Energy Company \$0.10/kWh	https://www.midamericanenergy.com/IA-Bus-Lighting
	Interstate Power & Light Company (Alliant Energy)	Alliant Energy Custom lighting \$0.06/kWh Prescriptive \$50 - \$120/LED fixture Greenhouse Climate Controls \$0.03/sq ft VFD \$30-\$75/hp Heating \$1.00 - 4.00/MBH	https://www.alliantenergy.com/waystosave/energyassessments/farmenergyassessment
	Black Hills / Iowa Gas Utility Company (Black Hills Energy)	Black Hills Energy: Custom Rebates	https://www.blackhillsenergy.com/efficiency-and-savings/commercial-rebates/iowa-gas-commercial-rebates
Kentucky	Duke Energy	Duke Energy: Custom \$0.065/kWh + \$150/kW	https://www.duke-energy.com/business/products/smartsaver/custom-incentives



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State	Programs	Incentive Structure Notes	Website
Maine	Efficiency Maine	Efficiency Maine: Custom \$0.28/kWh Up to 50% of project cost Up to 75% of incremental cost Up to \$25/MMBTU Prescriptive \$75 - \$300/unit for HVAC	https://www.efficiencymaine.com/at-work/commercial-industrial-custom-program/ https://www.efficiencymaine.com/docs/All-Programs-Brochure.pdf
Maryland	Baltimore Gas & Electric Southern Maryland Electric Cooperative (SMECO) Potomac Edison	Baltimore Gas & Electric: Custom Up to \$0.28/kWh Up to 50% project costs Up to 75% incremental cost SMECO: Custom Potomac Edison: Custom \$0.28/kWh Up to 50% total project cost	https://bgesmartenergy.com/business/business-programs/energy-solutions-business https://www.smeco.coop/save-energy-and-money/business-solutions/custom https://energysavemd-bizsolutions.com/
Massachusetts	Mass Save program administrators	Mass Save: \$0.18/kWh \$1.50/therm 40 - 50% of project cost for custom lighting projects 50 - 75% of project cost for non-lighting projects	https://www.masssave.com/saving https://www.masssaveapplicationportal.com/mapstart https://www.masssaveapplicationportal.com/resource/1642551439000/BusinessIncentives



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State	Programs	Incentive Structure Notes	Website
Michigan	Consumers Energy	Consumers Energy: Prescriptive \$0.70 - \$1.00/W reduced for horticultural lighting \$0.09/W controlled on daylight sensor controls \$1.20 - 20/MBH \$20 -200/hp VFDs \$30 - 40/ton AC systems \$50/unit ductless or heat pump \$0.10/kWh custom offering for standalone dehumidifiers \$0.25/sq ft for thermal curtains \$0.15/sq ft for IR films \$0.25/sq ft for greenhouse environmental controls \$0.25 - 0.50/sq ft for in-floor heating systems	www.ConsumersEnergy.com/startsaving https://www.consumersenergy.com/business/energy-efficiency/special-programs/agriculture
	DTE	DTE: New Construction \$0.20 - 0.30/W installed LED horticultural lighting \$0.055/W reduced for HVAC \$1.00/pint/day for dehumidifiers >150 pints/day \$0.05/sq ft for thermal curtains & IR films \$50/1000 sq ft for greenhouse controls \$0.08-0.14/sq ft for hydronic under floor/bench heaters \$3.50/MCF	https://www.dtebizrebates.com/
	Efficiency United and SEMCO	Retrofits \$0.22 - \$0.33/W reduced by horticultural lighting Efficiency United & SEMCO: Prescriptive \$0.05/sq ft thermal curtains \$0.04 -0.09/sq ft IR film \$0.07- 0.12/sq ft hydronic heating \$0.07/sq ft greenhouse environmental controls \$0.53 - 2.60/MBH	https://www.efficiencyunited.com/commercial/solutions https://www.semcoenergygas.com/commercial-industrial-savings/
	Great Lakes Energy	Great Lakes Energy: Custom \$0.06/kWh Up to 75% of project cost Prescriptive \$0.35-\$0.50/W reduced with LED lighting	https://www.michigan-energy.org/aboutfarm/GreatLakes



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State	Programs	Incentive Structure Notes	Website
Michigan	Lansing Board of Water and Light (LBWL)	LBWL: Custom \$0.07/kWh Prescriptive \$0.25/W reduced for lighting systems with >4000 annual hours of operation \$0.40/W reduced for lighting systems with >6000 annual hours of operation	https://www.lbwl.com/customers/save-money-energy/commercial-industrial-incentives https://www.lbwl.com/customers/save-money-energy/indoor-agriculture-program https://www.lbwl.com/sites/default/files/inline-files/bwl-indoor-agriculture-app.pdf
Minnesota	Southern Minnesota Municipal Power Agency (SMPMA) Xcel	SMPMA: Custom \$0.045/kWh Xcel: Custom Up to \$450/kW peak demand \$200/kW non peak in excess of peak savings Up to \$5/Dth natural gas	https://smpma.com/members/lake-city https://www.xcelenergy.com/programs_and_rebates/business_programs_and_rebates/equipment_rebates/custom_efficiency https://mn.my.xcelenergy.com/s/business/cost-savings/custom-efficiency
Mississippi	Entergy Mississippi	Entergy: Custom \$0.17/kWh Up to 75% of project cost	https://www.energy-mississippi.com/your-business/save_money/ee/agriculture/
Montana	Bonneville Power Administration (BPA) NorthWestern Energy	BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp NorthWestern: Custom	https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx http://www.northwesternenergy.com/save-energy-money/business-services/business-services-montana/rebates-incentives/e-commercial-lighting-rebates



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State	Programs	Incentive Structure Notes	Website
New Hampshire	NH Saves & Eversource	Eversource: Custom	https://new-hampshire.libertyutilities.com/acworth/commercial/smart-energy-use/electric/large-business-programs.html https://www.nhec.com/equipment-retrofit/
	Liberty Utilities	Liberty Utilities: Custom Up to 35% project cost	
	New Hampshire Electric Co-Op	On Bill Financing NH Electric Co-op: Custom	
New Jersey	Atlantic City Electric	Atlantic City Electric: Custom \$0.16/kWh or up to 50% project cost Prescriptive \$50 - \$250 / LED fixture	https://commercialeee.atlanticcityelectric.com/Home/Incentives https://njcleanenergy.com/commercial-indusCommercial, Industrial and Local Government Programs NJ OCE Web Site/retail/home/home
	NJ Clean Energy	NJ Clean Energy: \$50 - \$200/LED light fixture Pay for Performance	
New Mexico	Public Service Company of New Mexico (PNM)	PNM: Prescriptive \$0.30 - \$0.60/Watt reduced by DLC-listed horticultural lighting \$0.80 - \$2.00/pint/day for Energy Star-listed dehumidification units \$20 - 100/ton plus \$15 - 25 efficiency bonuses for air conditioning and heat pump systems Custom \$0.08/kWh	https://www.pnmenergyefficiency.com/retrofit-rebate/ https://www.pnmenergyefficiency.com/new-construction/ https://nm.my.xcelenergy.com/s/business/cost-savings/custom-efficiency
	Xcel	Xcel: Custom Up to \$400/kW	



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State	Programs	Incentive Structure Notes	Website
New York	NYSERDA	NYSERDA Statewide NYSERDA Agriculture Energy Audit Program Free energy audits and benchmarking to CEA facilities statewide (excluding Long Island)	https://www.nyserdera.ny.gov/All-Programs/Agriculture-Energy-Audit
	Central Hudson Gas & Electric	Central Hudson Gas & Electric: Custom \$0.123/kWh \$1.35/therm	https://www.cenhud.com/en/my-energy/save-energy-money/business-incentives/
	ConEdison	ConEdison: Custom \$0.45/kWh	https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-commercial-industrial-buildings-customers/save-with-energy-efficiency-upgrades
	National Grid	National Grid: Custom Electric Projects \$0.197/kWh Up to 50% project cost Gas Projects \$1.00/therm Up to 70% of project cost	https://www.nationalgridus.com/Upstate-NY-Business/Energy-Saving-Programs/Agri-business-program
	New York State Electric and Gas Corporation (NYSEG)	NYSEG: Custom \$0.13/kWh for lighting Up to 50% of project cost	https://www.nyseg.com/wps/portal/nyseg/saveenergy/businesssolutions/commercialandindustrialrebates/
	Orange & Rockland (ORU)	Orange & Rockland: Custom \$0.20/kWh \$1.50/therm \$0.08/kWh for LED lighting Up to 25% of project cost	https://www.oru.com/en/save-money/rebates-incentives-credits/new-york-customers/incentives-for-business-customers-ny
	Rochester Gas and Electric Corporation (RG&E)	RG&E: Custom \$0.13/kWh \$1.50/therm	https://www.rge.com/wps/portal/rge/saveenergy/businesssolutions/commercialandindustrial
North Carolina	Duke Energy	Duke Energy: Custom \$0.065/kWh \$150/kW	https://www.duke-energy.com/business/products/smartsaver/custom-incentives
	Electricities of North Carolina	Electricities of North Carolina: Custom	https://www.electricities.com/services/commercial-industrial-services/



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State	Programs	Incentive Structure Notes	Website
Oklahoma	Oklahoma Gas & Electric (OG&E)	OG&E: Custom 20 - 40% of project cost	https://www.oge.com/wps/portal/oge/save-energy/business/commercial-industrial-efficiency/
	Public Service Company of Oklahoma (PSO)	PSO: Custom	https://powerforwardwithpsocom/my-business/rebates/
Oregon	Bonneville Power Administration (BPA)	BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp	https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx
	Eugene Water & Electric Board (EWEB)	EWEB: Custom \$0.13/kWh	https://www.eweb.org/business-customers/rebates-loans-and-conservation/new-construction-and-custom-projects
	The Energy Trust of Oregon (ETO)	ETO: Custom \$0.15/kWh Up to 30% of measure cost Prescriptive \$0.30 sq ft thermal curtains \$0.02/sq ft IR films \$0.10/sq ft greenhouse controls \$1.00 - \$8.00/sq ft greenhouse heating systems	https://www.energytrust.org/incentives/agriculture-greenhouse-upgrades/ https://www.energytrust.org/incentives/horticultural-lighting/
Pennsylvania	Philadelphia Electric Company (PECO)	PECO: Custom \$0.05/kWh	https://www.peco.com/WaysToSave/ForYourBusiness/Pages/Custom.aspx
	PPL Electric Utilities	PPL: Custom \$0.075 / kWh + \$250/kW	https://www.pplelectricbusinesssavings.com/ppl-business/incentives/overview/



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State	Programs	Incentive Structure Notes	Website
Rhode Island	National Grid	National Grid: Custom \$0.35/kWh \$1.50/therm 10 - 50% of project cost	https://www.ridap.nationalgridus.com/RIDAP_Start
	Narragansett Electric (PPL)	PPL: To be determined after March 2022	
South Carolina	Duke Energy	Duke Energy: Custom \$0.065/kWh \$150/kW	https://www.duke-energy.com/business/products/smartsaver/custom-incentives
Utah	Bonneville Power Administration (BPA)	BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp	https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx https://www.rockymountainpower.net/savings-energy-choices/business/wattsmart-efficiency-incentives-utah.html https://www.rockymountainpower.net/content/dam/pcorp/documents/en/rockymountainpower/savings-energy-choices/wattsmart-business/utah/UT_wattsmart_Business_Lighting_Interior_Retrofits_Incentives.pdf
	Rocky Mountain Power	Rocky Mountain Power: Custom \$0.15/kWh annual savings Up to 70% of incremental measure cost or a one-year simple payback Prescriptive New construction & retrofit \$0.03/kWh for replacement lamps \$0.05/kWh for light fixtures Up to 70% of purchase cost	



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State	Programs	Incentive Structure Notes	Website
Vermont	Efficiency Vermont	Efficiency Vermont: Custom \$0.05 - \$0.25/kWh Up to 30% of measure cost for commercial customers Prescriptive \$0.20 - 0.30/therm for greenhouse insulation and air sealing measures \$0.50/sq ft for greenhouse thermal curtains Up to \$0.10/sq ft for HVAC and lighting controls \$2-3/MMBTU saved Agricultural Financing	https://www.efficiencyvermont.com/products-technologies/agricultural-equipment/greenhouse-equipment https://www.efficiencyvermont.com/rebates/list/greenhouse-equipment
	Burlington Electric Department (BED)	Efficiency Vermont & BED: Prescriptive \$100 online rebate for DLC-listed LED grow lights for residential and commercial customers BED: Custom \$0.05 - \$0.25/kWh Up to 50% of measure cost for commercial customers Prescriptive \$150 rebate for DLC-listed LED grow lights	https://www.efficiencyvermont.com/rebates/list/led-indoor-growing https://www.burlingtonelectric.com/indoor-grow

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State	Programs	Incentive Structure Notes	Website
Washington	AVISTA Utilities	AVISTA: Custom \$0.23/kWh \$5.00 - 11.00/MBH	https://www.myavista.com/energy-savings/tools-for-your-business/rebates-washington
	Bonneville Power Administration (BPA)	BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp	https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx
	Clark Public Utilities	Clark Public Utilities: Custom \$0.20 - 0.27/kWh Annual energy consumption must be reduced by at least 25%	https://www.lcpud.org/save-energy/commercial-industrial/lighting/
	Cowlitz County Public Utility	Cowlitz County: Custom \$0.20/kWh Up to 70% of project cost \$0.13/kWh for new construction lighting	https://www.cowlitzpud.org/efficiency/commercial-efficiency-programs/
	Energy Trust of Oregon (ETO)	ETO: \$1.17/sq ft thermal curtains \$0.10/sq ft IR film and greenhouse controls \$2.19/sq ft under bench heating \$5.00/MBH input condensing unit heater	https://www.energytrust.org/incentives/greenhouses-washington/#tab-two
	Puget Sound Energy (PSE)	PSE: \$0.25/kWh lighting \$0.10/kWh controls Lighting must be 10% more efficient than the current WSEC	https://www.pse.com/business-incentives/commercial-new-construction-programs/commercial-new-construction-grants
	Seattle City Light	Seattle City Light: Retrofit lighting \$0.10-\$0.15/kWh DLC listed \$50-\$75/fixture QPL network controls	https://energysolutions.seattle.gov/wp-content/uploads/Commercial-Industrial-Retrofit-Program-Requirements.pdf
	Tacoma Power	Tacoma Power: Custom \$0.23/kWh saved in first year Up to 70%	https://www.mytpu.org/ways-to-save/business-rebates/custom-projects/



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State	Programs	Incentive Structure Notes	Website
Washington, D.C.	DC Sustainable Energy Utility	DCSEU: Custom Financing Benchmarking	https://www.dcseu.com/commercial-and-multifamily/start-a-project
Wisconsin	Focus on Energy	Focus on Energy \$0.06/kWh lighting \$50 - 120/ LED fixture Custom lighting \$0.06/kWh Prescriptive \$50 - \$120/LED fixture Greenhouse Climate Controls \$0.03/sq ft VFD \$30-\$75/hp Heating \$1.00 - 4.00/MBH	https://www.focusonenergy.com/horticulture https://focusonenergy.com/business/agribusiness https://focusonenergy.com/sites/default/files/inline-files/2020_Agribusiness_Top_5_Ways_to_Save_Energy-Greenhouse_Handout.pdf
Wyoming	Bonneville Power Administration (BPA)	BPA: Custom Up to 70% project costs Retrofit \$0.03 - 0.25/kWh New Construction \$0.03-0.35/kWh Prescriptive VFD pumps \$50-80/hp	https://www.bpa.gov/EE/Sectors/agriculture/Pages/default.aspx





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