Controlled Environment Agriculture (CEA) Policy Guide:

Benchmarking, Rate Design, Water Efficiency, and Additional Policies

POLICY BRIEF | MAY 2023

Emily Garfunkel

ACEEE
Smart Energy. Clean Planet. Better Lives.

RESOURCE INNOVATION INSTITUTE

Key Takeaways

As the Controlled Environment Agriculture (CEA) sector grows rapidly in the United States, resource efficiency has become a key consideration. Optimizing resource usage can enhance the potential of CEA to increase food system resilience and bolster economic growth in urban and rural communities.

Gathering more data and information on resource usage in CEA is necessary to advance understanding and equip stakeholders with the means to improve efficiency.

To improve efficiency in CEA, data and stakeholder engagement are important for developing future policies, such as benchmarking and disclosure policies, incentives and funding for efficiency measures, and standards for resource efficiency.

Benchmarking: Little information is currently available on the energy performance of CEA facilities. Jurisdictions, utilities, and CEA experts could provide benchmarking resources for the CEA sector to facilitate more widespread collection of information about energy and water usage, which could enable stakeholders to better understand how to improve energy and water efficiency in CEA.

Utility rate design: Few jurisdictions have CEA-specific utility rates. Utilities and regulators could design CEA rate structures—particularly for greenhouses—that consider the unique load profile of these facilities, including frequency with which a facility operates at peak demand, and allow facilities that operate infrequently at peak demand to qualify for alternate rates. This could improve energy affordability for CEA operators while encouraging energy efficiency measures to reduce energy consumption.

Water efficiency: Many water efficiency technologies for CEA, such as on-farm water recirculation, have high capital costs. To support CEA operators in adopting water efficiency measures, CEA facilities could be made eligible for state water quality loan and grant programs seeking to reduce source pollution as well as federal and state investment tax credits to offset the high capital costs of CEA water efficiency technologies.

Additional policies: Incorporating CEA into policies targeting workforce development, resilience, and economic development can benefit CEA producers, policymakers, and the public. Policies can support the expansion of CEA workforce training, resilience building, and local economic development through public funding, zoning considerations, and research on CEA.

Introduction

We are currently seeing a significant expansion of controlled environment agriculture (CEA) in the United States. With the potential to expand year-round domestic food production, CEA can bring production closer to consumers and improve food system resilience under changing climatic conditions. North America had the greatest market share of the global indoor farming market in 2021; the United States constitutes the majority of the region's market share (Mordor Intelligence 2022). CEA includes two main types of production facilities; greenhouses and indoor farms, with greenhouses being the most common facility type for CEA in the United States (Mordor Intelligence 2022). Greens are the most popular crop grown in greenhouses, followed by vine crops, herbs, and strawberries. Indoor farms primarily grow greens, herbs, fruits, and other vegetables. Areas where CEA is popular within the United States include California, the Midwest, and the Northeast (Schimelpfenig and Smith 2021).

As CEA expands, the energy required for CEA and associated costs have become key considerations for CEA producers, who use varying energy efficiency strategies. Energy use in CEA is also drawing increased attention from policymakers, utilities, and others concerned about energy use and the associated climate impacts. In this context, a variety of opportunities exist to leverage different policies and tools to improve resource efficiency in CEA and lower the costs of energy for production.

To better understand the resource challenges faced by CEA producers and to formulate policy recommendations, the American Council for an Energy-Efficient Economy (ACEEE) and the Resource Innovation Institute (RII) convened a series of workshops with CEA sector experts and subject-matter experts across the greenhouse and indoor farm sectors (see below). Over the course of six meetings, various working group members addressed interlinked areas of policy related to CEA: benchmarking and disclosure, utility regulation and rate design, water efficiency, workforce development, resilience, economic development, energy codes, and industry standards. This guide aims to offer an overview of the current policy landscape for CEA, challenges faced by the CEA sector, and policy options available for establishing resource efficiency as a priority in the growing CEA market. The guidance provided is based on the work of ACEEE and RII in the resource efficiency space and is informed by discussions held with the working groups. More information related to energy codes and industry standards for CEA can be found in our guide, *Building Energy Codes and Industry Standards to Advance Controlled Environment Agriculture (CEA) Resource Efficiency*.

POLICY WORKING GROUP MEMBERS

Evan Lee (American Hort)
Jordan Karem (AppHarvest)
Neal Benish (ARCO/Murray)
Colin O'Neil (Bowery Farming)
Thao Chau (California Energy Commission)
Jeannie Sikora (CLEAResult)
Michael Turner (Colorado Energy Office)
Craig Burg (Desert Aire)
Kyle Booth (Energy Solutions)
Kyle Clark (EnSave)
Logan Taggert (Evergreen Consulting)
Corinne Wilder (Fluence)
Madison Walker (Grodan)
Andrew Horowitz (KUBO Greenhouses)
Molly Graham (MEEA)
Diana Burk (New Buildings Institute)
Kelly Mooij (New Jersey Board of Public Utilities)
Nolan Rutschilling (Ohio Environmental Council)
Mike Roth (Pennsylvania Department of Agriculture)
Hema S. Prado (Plenty)
David Morrison (Roehm)
Bob Gunn (Seinergy)
Noah Oaks (SPEER)

*Disclaimer: The views and opinions expressed in this guide are those of ACEEE and RII and do not necessarily reflect the individual views or positions of any Policy Working Group members or ACEEE and RII members.

Policy Landscape

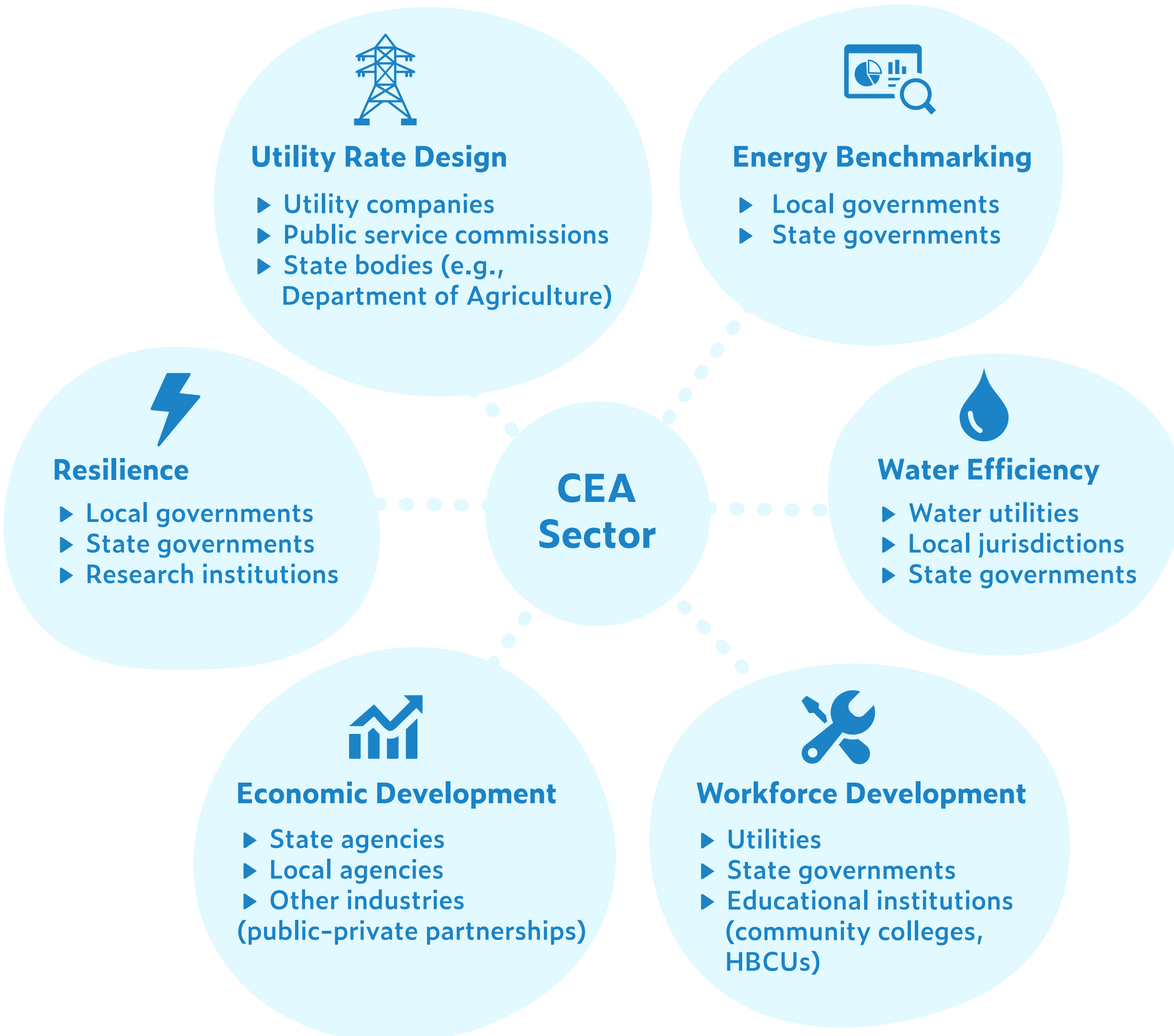
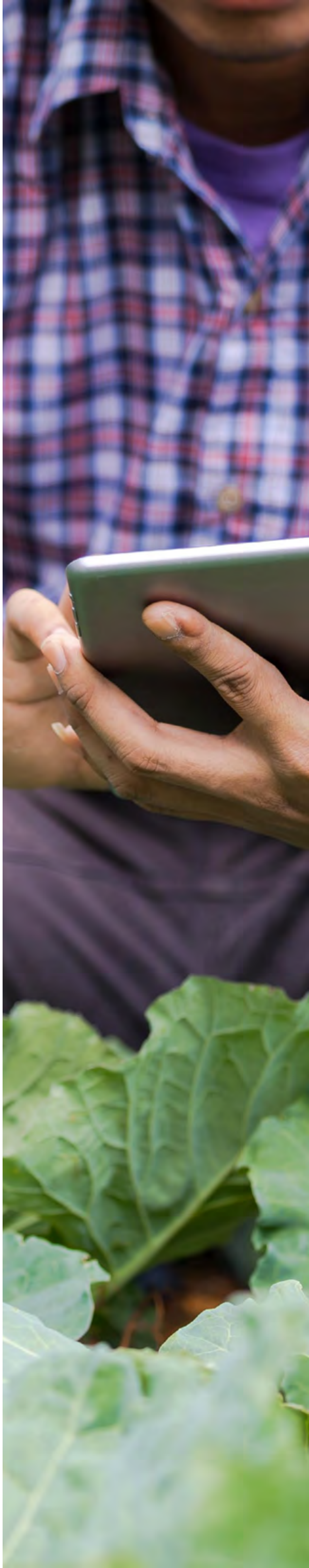


Figure 1. Policy areas and key stakeholders in the CEA policy landscape

Benchmarking and Disclosure Policies

Building owners and managers report information about how much energy their buildings consume through existing building energy benchmarking programs and policies, such as those for commercial and multifamily buildings. With tools that measure building energy performance over time in comparison to peer buildings or against a set of standards, benchmarking facilitates data collection and enables the development of energy use baselines (DOE 2012). Benchmarking and disclosure policies, which require building owners to report and assess their buildings' energy usage data, can serve as foundational policies that provide necessary data to inform building codes, utility programs, and building performance standards.

Very little information is currently available on the energy performance of CEA facilities. Benchmarking resources can enable stakeholders to better understand resource efficiency in CEA and facilitate the calculation of energy use baselines over a range of production types and crops. Stakeholder feedback will be essential in developing benchmarking tools and programs that fit the unique characteristics of the CEA sector, which can inform future policies targeting resource efficiency in CEA buildings.



Benchmarking Resources and Policies in Other Industries

COMMERCIAL AND MULTIFAMILY BUILDINGS

The ENERGY STAR® program run by the Environmental Protection Agency (EPA) provides the Portfolio Manager platform, a benchmarking tool for commercial buildings (ENERGY STAR 2023a). Through Portfolio Manager, building owners can report data on their building's energy and water consumption and measure their building's performance on efficiency metrics (Mims et al. 2017). Additionally, Portfolio Manager assesses a building's energy efficiency relative to peer buildings, producing an ENERGY STAR score (Mims et al. 2017). Portfolio Manager is currently used by 25% of commercial building space in the United States. (ENERGY STAR 2023a). Due to its widespread use and standardized data collection and analysis methods, many jurisdictions have utilized Portfolio Manager as an approved reporting tool under benchmarking and disclosure policies (Mims et al. 2017).

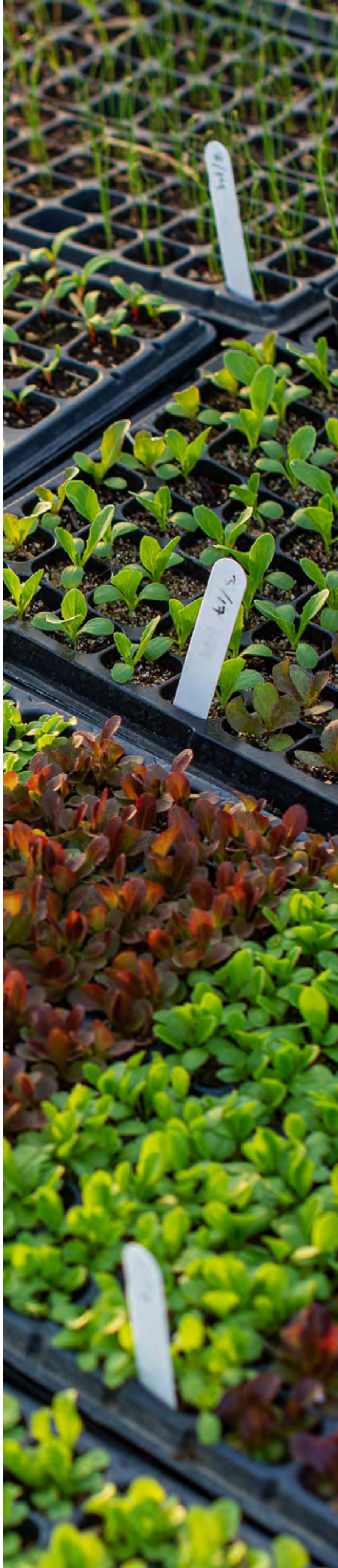
Over the last decade, benchmarking and disclosure policies have been established across the United States for large commercial and multifamily buildings. In most cases, local governments have adopted these policies; however, a few state governments have established statewide policies.[1] While the specifics of each policy may vary, most benchmarking and disclosure policies follow a consistent structure, including building and property type definitions, approved reporting tools, and key performance indicators. Since the implementation of benchmarking and disclosure policies for commercial and multifamily buildings in some jurisdictions, data have shown a reduction in energy use and greenhouse gas emissions of benchmarked buildings. Over the 10-year period since New York City's benchmarking policy was established, data show a 22.6% reduction in total emissions

[1] Source: Institute for Market Transformation (IMT); www.imt.org/resources/map-u-s-building-benchmarking-policies/. IMT provides updated information on current benchmarking and disclosure policies for commercial and multifamily buildings.

(tonnes CO_2 equivalent) and an 8.3% reduction in total energy use (kBtus) of benchmarked buildings on average (Urban Green Council 2020). Total emissions of benchmarked buildings in Chicago were reduced by 9% between 2017 and 2020, and the energy use intensity of Chicago's benchmarked buildings decreased by 7% between 2016 and 2020 (City of Chicago 2020).

INDUSTRIAL BENCHMARKING

The EPA's ENERGY STAR program provides energy benchmarking tools for a range of industrial sectors, including dairy processing, cement manufacturing, and printing. Given the unique characteristics of energy use among industrial sectors, the EPA, in consultation with industry stakeholders, has developed industry-specific Energy Performance Indicators (EPIs) for 19 types of manufacturing plants. By benchmarking a plant's energy use with the EPIs, manufacturers can compare their plant's energy efficiency to similar facilities (ENERGY STAR 2023b). Resources like industrial EPIs can assist stakeholders to better understand sector-specific energy baselines and identify opportunities to improve energy efficiency.



Considerations for Future CEA Benchmarking Programs

CURRENT CEA BENCHMARKING AND DISCLOSURE POLICIES

In the United States only a few states or cities have adopted benchmarking and disclosure policies for CEA. Most policy action has focused on cannabis, especially as more states move to legalize the crop for recreational use. Table 1 below summarizes the current benchmarking and disclosure policies for CEA.

Table 1. Current benchmarking and disclosure policies for CEA

LOCATION	POLICY DESCRIPTION
Ann Arbor, MI	Annual reporting of water usage and sanitary sewer discharge to city clerk is required.
Boulder County, CO	Energy Impact Offset Fund requires energy use reporting to the County. The County discloses anonymized electrical energy use information to the public.
Grand Rapids, MI	Use of ENERGY STAR Portfolio Manager is required for annual reporting.
Illinois	Statute requires energy use reporting.
Massachusetts	Energy and water use reporting is required as part of license renewal process. RII's PowerScore tool can be used for reporting.
Mendocino County, CA	PowerScore is an approved tool for energy and water use reporting.
Montana	Statute includes provisions for reporting on water use.
New York	Cultivators are required to report energy use annually. RII's PowerScore tool can be used for reporting.
Ventura County, CA	Cannabis businesses are required to submit an energy conservation plan in their business license application.

Experience gleaned from these nascent benchmarking policies can inform expanded benchmarking resources for a broader range of crops and CEA production facilities. Broadening the availability and use of benchmarking resources for the CEA sector can facilitate collecting information about energy performance and establishing energy use baselines. Stakeholder engagement will be essential in developing metrics and tools that provide relevant information on resource use in CEA and can be used in creating future benchmarking policies. The following sections include some critical considerations in the formulation of CEA benchmarking programs.

Building Definition

Given the diversity of facilities in the CEA sector, establishing clear definitions for CEA buildings and property types will be useful in benchmarking programs. Currently, CEA buildings may be labeled as commercial, industrial, refrigerated warehouse, or agricultural buildings, depending on the context. A separate definition for CEA facilities is helpful for policymaking. For example, the *California Energy Code, Title 24* defines a controlled environment horticulture (CEH) space as "a building space dedicated to plant production by manipulating indoor environmental conditions, such as through electric lighting, irrigation, mechanical heating, mechanical cooling or dehumidification" (California Energy Commission 2022). Given the distinct characteristics of greenhouses and indoor grow spaces, it could be useful for policies to distinguish them as property type classifications.

Reporting Tools

Reporting tools are important resources for data collection and benchmarking capabilities. By providing a means for reporting data and conducting analysis, reporting tools can offer stakeholders information on resource use across the CEA sector and support the development of key performance indicators (KPIs). For example, RII's PowerScore reporting tool is currently an approved platform for energy and water use reporting in Massachusetts, New York, and Mendocino County, CA (see table 1) (RII 2023). PowerScore offers a range of analytical tools and KPIs to benchmark resource efficiency in CEA and acts as a benchmarking compliance mechanism in the jurisdictions mentioned above.

Data Collection

To enable benchmarking of energy and water efficiency across CEA facilities, it will be important to consider appropriate and comparable data points for the sector. Potential data points are listed below, including some data points collected under the Massachusetts requirements for energy and water use reporting (Massachusetts CCC 2020).

- Electricity consumption
- Natural gas consumption
- Other delivered fuels
- Water consumption
- Renewable energy generation
- Building square footage
- Crop types
- Production metric
- Photosynthetic photon flux density (PPFD)

Key Performance Indicators and Metrics

Many building benchmarking policies for commercial buildings use energy use intensity (EUI), measured in energy use (kBtus) per square foot, as a metric for reporting energy performance. EUI provides a standard metric that is comparable across buildings of the same type, such as office buildings in the EPA's ENERGY STAR Portfolio Manager tool. For industrial benchmarking, ENERGY STAR's Energy Performance Indicators (EPIs) include a production metric for energy efficiency, measured in energy use per unit of product (ENERGY STAR 2023b).

As the CEA sector begins to develop benchmarking policies and other resource efficiency policies, gathering data on CEA facilities will be necessary. The selection of KPIs for CEA benchmarking policies will require consideration of metrics that are most comparable and useful for measuring the energy and water efficiency of CEA facilities.

EUI is a standard measurement of energy usage and would provide a crop-agnostic metric for energy efficiency in CEA facilities. However, it may not capture the unique characteristics of CEA facilities, which include both greenhouses and indoor farms that grow a variety of crops. The use of EUI as a KPI may therefore limit the usefulness of data gathered through benchmarking for decision making by policymakers and facility operators.

A production-based KPI for CEA facilities would be a ratio of energy usage to crop yield.

This type of KPI would reflect the unique characteristics of CEA buildings as agricultural producers. However, data for this type of KPI may be difficult to obtain, may introduce complexity, and may not account for external factors that impact yield. Further, a crop-specific productivity metric would limit the comparability of a KPI across facilities producing different crops. To address this challenge, productivity metrics could be normalized with other metrics, such as daily light integral (DLI), to create a comparable metric across crop types. As available solar radiation varies by location, this approach may require an adjustment to account for regional climate.

In addition, benchmarking tools could include KPIs that measure resource reuse and renewable energy use and generation within CEA buildings. CEA facilities often use carbon dioxide injection to support plant growth, which requires energy. By capturing carbon dioxide for reuse in plant production, CEA facilities can increase their energy efficiency. Co-location with industrial facilities to reuse excess carbon dioxide makes this option more economically feasible. KPIs related to resource reuse and renewable energy could include

- Carbon capture and reuse
- Water capture and reuse
- Heat recovery
- Renewable energy use and generation

In an upcoming RII and ACEEE report on CEA benchmarking, KPIs for energy and water use in CEA will be discussed in more detail.

Benchmarking and disclosure tools inform building owners and managers about their operations' energy efficiency and direct them to prioritize energy improvements in inefficient facilities. For CEA, this can not only help save energy but also significant amounts of water. Water and energy are connected in meaningful ways because the transportation and treatment of water and wastewater are energy-intensive processes (ACEEE 2023). Additionally, water is required for electric thermal power generation (ACEEE 2023). In CEA, the irrigation of crops requires electricity for water delivery, the collection of condensate and drainage, and water treatment, making irrigation another energy-intensive process (Sabeh et al. 2022). Due to this relationship, some water-saving irrigation measures may require additional energy, making resource efficiency in CEA a complex process.

Utility Regulation and Rate Design

An important factor in the economics of indoor agriculture is utility rate design. Utilities and regulatory bodies determine rates for various types of facilities, impacting the costs of energy borne by facility operators in those categories. Most CEA facilities are categorized as industrial or agricultural facilities, since CEA-specific rates are not available from most utility companies.

State policy influences utility decision-making regarding energy efficiency through energy savings targets, demand reduction and load management policy, and carbon reduction goals. Additionally, public utility commissions oversee the design and implementation of utility energy efficiency programs. As evidenced by ACEEE research on rate design, the structure of utility rates impacts customer behavior related to energy efficiency (Baatz 2017). State legislatures and utility regulatory agencies can better support the unique needs of CEA facilities by developing rate structures specific to CEA facilities, in turn promoting energy efficiency in CEA.

Current Utility Rate Design

CHALLENGES OF RATE DESIGN FOR CEA OPERATORS

The industrial and agricultural utility rates applied to CEA facilities often do not reflect the specific load profiles of CEA operations. The structure of utility rates is divided into fixed charges, energy demand charges (kW), and energy usage charges (kWh).[2] A significant component of industrial rate design is a demand charge based on peak facility demand. While most industrial facilities have a consistent monthly demand profile, power demand in CEA facilities can be more variable depending on production methods, facility design, and other factors. For instance, there are seasonal impacts on the heating and cooling that CEA facilities require. While indoor vertical farms may have consistent load profiles, the peak demand for a greenhouse is highly dependent on weather. For example, the peak demand experienced on a cloudy day may be significantly higher than most operational days. Under an industrial rate structure, a greenhouse operator would be charged an overall cost based primarily on its peak demand, rather than on its average usage over the period.

While agricultural rates may better fit the operational profile of CEA facilities, there is often limited availability and awareness of agricultural rates among CEA operators. Further, agricultural rates are based on outdoor agricultural operations—often focused on pumping energy for field irrigation—which differ from indoor agriculture in energy requirements and load profiles.

A challenge in determining CEA rates is a lack of load profile data for CEA facilities. Without such data available to utilities, CEA facilities are often grouped into industrial and agricultural rate categories. Greater availability of data on load shapes and energy consumption of greenhouses and indoor farms can assist the development of CEA-specific utility rates.

[2] Fixed charges are determined by rate schedules and do not vary with consumption (DOE 2023). Energy demand charges are determined by the maximum demand for electricity (kW) within a certain period (DOE 2023). Energy usage charges are determined by the consumption of electricity (kWh) within a certain period (DOE 2023).

CURRENT CEA-SPECIFIC RATES AND POLICIES

A 2019 law in Hawaii, Act 203, permitted the state's Public Utilities Commission (PUC) to set rates for protected agriculture (Heaton 2022). Protected agriculture, like CEA, includes various techniques for growing plants in modified environments, such as greenhouses or indoor agricultural facilities (Heaton 2022). While the Hawaiian law was intended to lower electricity costs for operators of indoor agriculture and greenhouses, it is facing challenges in implementation (Heaton 2022). Hawaiian Electric has proposed rate reductions of between 1.2 and 4.9 cents per kilowatt-hour (Heaton 2022). Farmer advocacy organizations in Hawaii have raised concerns that these rate reductions do not make a sufficient difference in the energy costs borne by protected agriculture operators (Heaton 2022).

Rocky Mountain Power, a subsidiary of PacificCorp operating in Utah, Wyoming, and Idaho, established a rate schedule for indoor agriculture in 2021 (Rocky Mountain Power 2021). In basing the rate qualification on lighting demand and usage as a portion of total energy demand and usage, the rate structure is designed to fit the profile of indoor agriculture operations, differentiating it from other industrial and commercial profiles (Rocky Mountain Power 2021).

These early adoption examples of CEA-specific utility rates indicate the need for adequate data on CEA load profiles and the importance of engaging CEA producers in PUC proceedings to understand and address stakeholder concerns.

Policy Guidance for CEA Utility Rate Design

CEA-Specific Rates

When designing CEA-specific utility rates, utilities could consider rate structures, with more flexible demand and usage charges representing the majority of the rate structure, as with residential rate structures. A rate structure based primarily on base load use and average, rather than peak, demand, may better reflect the load profiles of CEA facilities. To determine qualification for such a rate structure, utilities could use a threshold of the frequency with which a facility operates at peak demand, allowing facilities that operate infrequently at peak demand to qualify. An alternative rate structure would improve energy affordability for CEA operators while encouraging energy efficiency measures to reduce energy consumption.

Data and Information Availability

Enhancing communication channels among utilities, CEA customers, and other government and regulatory bodies will facilitate understanding of CEA operations and energy use. Given the lack of load shape data for CEA facilities, utilities and regulators should commission data collection studies to inform rate design. In the interim, CEA producers and their utilities can collaborate to develop representative load shapes and energy use data to inform rate design proposals for regulatory approval.

Additionally, enhanced communication (such as sharing maps of grid load availability) between utilities and CEA operators looking for locations to establish CEA facilities could facilitate better usage of existing grid infrastructure by CEA operators.

Areas for Engagement

In the CEA sector, rate design has a key role in promoting energy efficiency. This can be accomplished through collaboration and engagement between utilities, jurisdictions, and CEA owners and managers in developing appropriate rate structures for the sector. Improved communication among these parties regarding optimal locations for CEA facilities, grid availability, and rate design would address the needs of CEA producers and could support more efficient operations.

Collaboration among CEA sector stakeholders and utilities will also be important in addressing challenges related to access to renewable energy. As CEA operators in some cases have faced higher rates for renewable energy, collective action on this issue can broaden renewable energy access and increase affordability for CEA operators and other consumers.

Water Efficiency Policies

In addition to energy efficiency, water efficiency is an essential component of CEA resource efficiency. Water efficiency has a substantial impact on energy efficiency, as water and wastewater systems account for a significant portion of municipal electricity use (ACEEE 2023). There are a range of water sources for CEA, including drilled wells, surface water, drainage ponds, rainwater, and municipal water (University of Massachusetts Amherst 2023).

CHALLENGES OF WATER EFFICIENCY FOR CEA OPERATORS

The challenges some CEA operators face in implementing water efficiency measures relate to costs, incentives, and local policy.

Financing Challenges

In some cases, cost is a barrier to the adoption of water efficiency measures by CEA facilities. Many water efficiency technologies for CEA have high capital costs, such as on-farm water recirculation technology.

Incentive Challenges

Additionally, water use incentives can pose a challenge to efficiency measures. Decreasing block rate structures, wherein greater volumes of water usage are charged at lower rates than smaller volumes, are used by water utilities in some areas, creating incentives for using more water rather than less. Water utilities may also be incentivized to keep water rates low to encourage industrial consumers to operate in their jurisdictions. Overall, the low price of water creates a disincentive for consumers to save water.

In addition, the prior appropriation laws governing water rights in the western United States incentivize water rights holders to continue to use the same volume of water, with the risk of losing water rights if they do not. This presents a further challenge in incentivizing water conservation in this area of the United States. As prior appropriation laws are unlikely to change in the near future, other incentives for water efficiency should be pursued.

Policy Challenges

Additional water efficiency challenges for CEA are related to local policy. In some jurisdictions, local building and public health codes restrict water recycling and reuse due to contamination concerns and wastewater treatment challenges. While water recycling is a crucial strategy for CEA water efficiency, operators have faced challenges in finding measures to recycle water that comply with codes in some jurisdictions, such as Los Angeles County.

Policy Guidance for CEA Water Efficiency

To increase the adoption of water efficiency measures among CEA operators, policy can reduce cost and implementation barriers, guide economic incentives to align with water efficiency, and establish regulations for uniform water efficiency measures.

Water Quality and Quantity Data

Currently, limited data are available on water usage within the CEA sector. To inform policy decisions regarding CEA water efficiency, greater reporting on useful metrics is needed to improve the availability and actionability of data. Such metrics and data should represent both water quality and quantity of usage within CEA operations.

As CEA facilities can be considered point sources of pollution, there is an opportunity to measure CEA facility discharge and create benchmarks for discharge quality. A possible avenue is to expand existing state loan and grant programs focused on water quality improvements for point source pollution to include CEA facilities.

Like energy efficiency, water efficiency in buildings is often measured in water use intensity (gallons of water per square foot). Additionally, water footprints can be measured at a crop or aggregate productivity level (gallons per pound). As with energy efficiency metrics for CEA, utilizing a water use intensity metric may pose limitations for representing water efficiency in CEA, while a productivity metric may require standardization over various types of crops and CEA facilities. Collaboration with CEA sector stakeholders will provide vital feedback in determining the most accurate and representative metrics for measuring water efficiency. Further, a baseline study of CEA water efficiency at the national level could be an important first step in improving the availability of data on CEA.

Incentive-Based Approaches

Incentive-based approaches to water efficiency policies can be taken by water utilities and by jurisdictions. With greater availability of data on CEA water usage, water utilities and providers can design incentive programs that support CEA operators in implementing water efficiency measures. As the cost of water and the cost of efficient technologies have a significant impact on water efficiency in CEA, water utilities can incentivize water efficiency through targeted incentive and rebate programs.

Local, state, and federal policy updates can also reduce the economic barriers to water efficiency measures. Programs such as investment tax credits could offset the high capital costs of CEA water efficiency technologies, and other financing measures and technical assistance provisions could support CEA operators with economic and capacity challenges.

If jurisdictions aim to implement water usage and quality reporting and targets in the future, it may be helpful first to establish voluntary targets and allow for a longer compliance horizon that would provide incentives for the gradual adoption of water efficiency measures by CEA operators.

An additional incentive-based approach to improving water quality is the creation of a market for saleable credits for CEA effluent. As CEA facilities are permitted as industrial facilities, more mechanisms are in place for controlling discharge than for conventional agriculture. Given this, there may be an opportunity to create saleable effluent credits for CEA to further improve discharge quality.

Regulation

Within a gradual approach from incentive-based programs to regulation, voluntary reporting and benchmarking on water usage and discharge of CEA facilities can establish baselines and offer opportunities for stakeholder engagement in creating policies. Robust data and tools from voluntary programs can support the development of mandatory disclosure policies and performance standards. To complement these policies, utilities and government agencies can ensure financing and incentives are available for CEA facilities.

Additional CEA-Related Policies

Local policymakers are pursuing resource-efficient CEA as a source of opportunities for advancing workforce, economic development, and climate resiliency goals. Given the intersection of CEA and many other policy priorities, incorporating CEA into workforce development, resilience, and economic development policy stands to benefit CEA producers, policymakers, and the public.

Workforce Development

With the rapid expansion of the CEA sector, job opportunities will grow, and fostering workforce development, including education and training programs, will become increasingly important. Energy efficiency workforce development programs can serve as a model for CEA workforce development programs. In the energy efficiency job market, state and local workforce training programs as well as utility training programs have proven successful. States including New York, Pennsylvania, Massachusetts, and Michigan have established programs targeting energy efficiency workforce development.

In creating workforce development programs, measures to ensure an inclusive workforce are important equity considerations. CEA companies throughout the United States have been prioritizing equity and inclusion in their hiring practices and workforce development and training programs. Three examples of such companies are featured in this guide.

In the design of training and education programs, it is beneficial to identify the skill sets needed for specific applications, such as those needed to develop high-performance buildings in the field of energy efficiency. A clear understanding of the skills needed in the CEA sector can help job seekers identify knowledge and expertise that may translate to the CEA sector and into opportunities for specific CEA jobs. Professionals within the CEA sector utilize expertise in a variety of fields, including design, construction, and engineering. CEA workforce development programs can offer targeted an enhanced training in energy- and water-efficient design, technology, and engineering.

Having identified a market need for training and education in the CEA sector, RII is developing a training and credentialing program. The program will include curriculum for various levels of experience and provide credentialing for CEA producers, facility designers, and related trades. To embed equity into the program's design, RII plans to offer asynchronous courses, subtitled presentations, Spanish language translations, and English as a second language (ESL) provisions. To prioritize equitable outcomes in program recruitment, RII's training and credentialing program is establishing relationships with community organizations, community colleges, and historically black colleges and universities (HBCUs).

To support the scaling of CEA workforce training, states can establish policies that provide funding for workforce development and guidance to agencies. With resources made available, community organizations, community colleges, and vocational schools can embed CEA training programs into existing workforce training programs. New programs can draw best practices from existing workforce development efforts, training, and credentialing programs in the CEA sector.

Case Studies

PLENTY

Plenty, an indoor vertical farming company, has farms under way in Compton, California, and near Richmond, Virginia, as well as a plant science research center in Laramie, Wyoming. The company's mission is to make fresh food accessible to everyone. As Plenty expands its farms to new geographic regions, it is investing in communities and creating year-round, full-time local employment opportunities.

Plenty utilizes place-based approaches to recruitment, embedding strategies for community engagement and hiring that address the unique challenges and skill gaps in diverse communities. The company has engaged a wide range of strategic partners through hiring events, information sessions, and job preparedness training. Plenty's employee programs prioritize equity and inclusion and are created to support the whole person, with a focus on employees' mental, physical, financial, and career well-being.

SQUARE ROOTS

Square Roots established its first farm in Brooklyn, New York, in 2016, and has since expanded across the Midwest, with farms in Grand Rapids, Michigan; Springfield, Ohio; Kenosha, Wisconsin; and Shepherdsville, Kentucky. The majority of employees in each location are local, and the company has created location-specific KPIs for inclusion of underrepresented populations in its hiring process. The company is committed to providing a living wage to its employees based on the cost of living in the locations where it operates, and it provides full benefits to both hourly and salaried employees.

Training is a priority at Square Roots, where new farm employees participate in the company's proprietary Farmer Training Program. Both onsite and remote training are offered to employees, as are opportunities for professional development and management training. In addition, Square Roots has collaborated with educational institutions, including Cornell University's College of Agriculture and Life Sciences and McHenry County College's Horticulture Program in Illinois, to provide input on curriculum development for horticulture, agriculture, and CEA programs.

Photo courtesy of Square Roots

Photo courtesy of Vertical Harvest

VERTICAL HARVEST

Vertical Harvest is a CEA company with two hydroponic vertical greenhouses: its flagship farm in Jackson Hole, Wyoming, founded in 2016; and its farm in Westbrook, Maine, currently under development. Vertical Harvest was founded with an inclusive employment model, seeking to provide quality jobs for underserved populations. Currently, 50% of employees in the Jackson Hole farm have physical and/or intellectual disabilities.

A core element of Vertical Harvest's inclusive employment model is the training programs provided for prospective and existing employees. Vertical Harvest has a three-month pre-applicant training program targeted toward individuals with disabilities, with the goal of increasing equity in the company's hiring process. Additionally, the company has a three-month job experience program, with many participants from transitional high school programs and vocational rehabilitation programs. Existing employees are given opportunities for ongoing job training and internal promotions. In offering competitive wages and equity in employment, Vertical Harvest aims to address social inequities in the communities it serves.

Resilience

Changing temperatures and weather patterns due to climate change may increasingly impact crop growth, and supply chain disruptions due to events like the COVID-19 pandemic may challenge the transportation of fresh food. Given the threat of food system challenges, CEA can potentially increase food system resilience by improving the availability and proximity of fresh food production for consumers. Therefore, policymakers have an opportunity to incorporate CEA into climate resilience policy and plans.

Policy Objectives

CEA can play an essential role in achieving various policy objectives on resilience. To combat the growing problem of food deserts, CEA can bring the production of fresh produce closer to consumers in areas where access is currently limited. In doing so, CEA can also support efforts to address the public health priority of nutrition.

Additionally, the proximity of food production and consumption through CEA can build resilience against supply chain and climate disruptions. The COVID-19 pandemic showed that supply chain challenges due to global events can have dire impacts. CEA can aid efforts to reinforce the resiliency of food systems to extreme events by simplifying and localizing food supply chains.

As explored in previous sections, CEA can be a method to facilitate the circularity of water and energy systems. With water recycling and energy-efficient technology, CEA can serve as a model for achieving sustainability objectives for local economies.

Furthermore, CEA has implications for emissions reduction and resource conservation beyond the CEA facilities themselves. Food production through CEA results in conservation of land, reduction of freight emissions for food transportation, reduction of refrigeration energy use, and reduction of plastic waste. As such, CEA can play a part in achieving a myriad of resiliency and sustainability objectives.

Policy Options

A key role for policy in supporting resilience goals and resource efficiency in CEA is through funding for CEA research. Such research could cover an assessment of local market characteristics and a needs-and-opportunities assessment to examine how CEA can build resiliency in local communities. In particular, programs can support research to evaluate the opportunities for CEA in rural farming areas, as well as research and development of seed breeds suitable for indoor growth.

Although zoning restrictions may challenge CEA development in certain regions, policymakers can consider how zoning conditions can be used to support CEA in a way that advances resilience and boosts local economies.

Lastly, a resilience fund can be a mechanism for supporting CEA development. For example, the City of Denver has established the Climate Protection Fund, which supports the municipality in resilience-related activities (City of Denver 2023). With this model, CEA could be financially supported as a method of resilience building.

Economic Development

In addition to aligning with workforce development and resilience goals, resource-efficient CEA presents opportunities for economic growth. Resource efficiency in CEA can increase the availability of sustainable local jobs and sustainable community development.

Policy Objectives

CEA complements existing policy objectives for economic development, both on a local level and more broadly. As a source of business and job creation, CEA can bring economic activity and employment opportunities to local communities. As a source of local produce, CEA is a key catalyst for "buy local" initiatives.

As CEA is location agnostic, it can be developed in urban and rural areas, offering equitable expansion of economic opportunities. Economic development policy at a state level can support the growth of CEA across various contexts. Further, CEA presents a chance to advance equitable economic development by bringing job opportunities to underserved communities. CEA can be incorporated into policies targeted toward increasing economic opportunities for marginalized groups.

In areas where industry has declined or been phased out, former industrial and brownfield sites can be remediated and converted into CEA facilities. Redeveloping industrial and brownfield sites can advance local economic development objectives, offering opportunities for revitalization and creating jobs for communities experiencing losses of other industries.

Policy Options

Existing state and local economic development funds can provide a mechanism for supporting the growth of CEA by offsetting the high start-up costs associated with CEA. Additionally, state and local governments could offer tax incentives to CEA businesses to locate in their jurisdictions. In providing financial support to CEA developers, state and local governments can encourage economic growth of sustainable, resource-efficient industry in their jurisdictions. Public service announcements and other marketing campaigns can promote CEA to the public, demonstrating CEA's contributions to resilience, jobs, and local economic activity.

As discussed previously, workforce development as a core economic development strategy is vital in supporting CEA sector growth. Workforce development programs can be aligned with other economic development policies to grow an employment base for local CEA operations. In aligning these policies, equity must be a central consideration.

In addition, state and local funds directed toward redeveloping industrial sites can support CEA development in those locations. Through public-private partnership models, opportunities exist to support both the CEA sector and other industries. CEA facilities can be co-located with other commercial facilities, creating opportunities for resource circularity, such as waste heat and water reuse. Through resource efficiency, CEA can benefit food systems, local communities, other industries, and climate resiliency.

Acknowledgments

This report was made possible through the generous support of the United States Department of Agriculture (USDA) and developed in partnership with the Resource Innovation Institute (RII). The authors gratefully acknowledge external reviewers, internal reviewers, colleagues, and sponsors who supported this report. External expert reviewers included Kyle Booth from Energy Solutions, Chris Burgess and Molly Graham from the Midwest Energy Efficiency Alliance (MEEA), Colin O'Neil from Bowery, Hema S. Prado from Plenty, Ashley Rafalow from Square Roots, Jeannie Leggett Sikora from CLEAResult, and Henry Gordon Smith from Agritecture. External review and support do not imply affiliation or endorsement. Internal reviewers from ACEEE included Jennifer Amann, Camron Assadi, Mark Kresowik, Steve Nadel, Mike Waite, Mariel Wolfson, and Amber Wood; internal reviewers from RII included Carmen Azzaretti, Rob Eddy, and Derek Smith. The authors also gratefully acknowledge the assistance of Hannah Bouline from Vertical Harvest, Robert Chase IV from Plenty, and Ashley Rafalow from Square Roots in offering information for case studies. Last, we would like to thank Mariel Wolfson for developmental editing, Ethan Taylor and Mary Robert Carter for managing the editing process, Phoebe Spanier for copy editing, Roxanna Usher for proofreading, Kate Doughty for graphics design, and Mark Rodeffer for his help in launching this report.

References

ACEEE (American Council for an Energy-Efficient Economy). 2023. "Water-Energy Nexus." Accessed January 2023. www.aceee.org/topic/water-energy-nexus.

Baatz, B. 2017. "Why Rate Design Matters for Energy Efficiency." ACEEE, March 22. www.aceee.org/blog/2017/03/why-rate-design-matters-energy.

California Energy Commission. 2022. 2022 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. Sacramento: CEC. www.energy.ca.gov/sites/default/files/2022-12/CEC-400-2022-010_CMF.pdf.

City of Chicago. 2020. "2020 Chicago Energy Benchmarking Report." Accessed January 2023. www.chicago.gov/content/dam/city/progs/env/EnergyBenchmark/2020_Chicago_Energy_Benchmarking_Report.pdf.

City of Denver. 2023. "Climate Resiliency and Adaptation." Accessed January 2023. www.denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Climate-Action-Sustainability-Resiliency/Climate-Action/Climate-Resiliency#:~:text=Increased%20drought%20and%20water%20scarcity%20Climate%20resiliency%20is,by%20investing%20in%20Denver%E2%80%99s%20climate-vulnerable%20neighborhoods%20and%20communities.

DOE (Department of Energy). 2012. "Energy Benchmarking, Rating and Disclosure for Local Governments." Accessed January 2023. www.energy.gov/sites/default/files/2021-07/commercialbuildings_factsheet_benchmarking_localgovt.pdf.

———. 2023. "Evaluating Your Utility Rate Options." Accessed January 26. www.energy.gov/eere/femp/evaluating-your-utility-rate-options.

ENERGY STAR. 2023a. "Benchmark Your Building Using ENERGY STAR® Portfolio Manager®." Accessed March 2023. www.energystar.gov/buildings/benchmark?s=mega.

———. 2023b. "Industrial Energy Management." Accessed March 2023. www.energystar.gov/industrial_plants.

Heaton, T. 2022. "How Much Should Hawaii Discount Electric Rates for High-Tech Farmers?" Civil Beat, July 20. www.civilbeat.org/2022/07/how-much-should-hawaii-discount-electric-rates-for-high-tech-farmers/.

Massachusetts CCC (Cannabis Control Commission). 2020. Energy and Environment Compiled Guidance. Massachusetts CCC. masscannabiscontrol.com/wp-content/uploads/2020/02/Energy_and_Environment_Compiled_Guidance_01.2020.pdf.

Mims, N., S. R. Schiller, E. Stuart, L. Schwartz, C. Kramer, and R. Faesy. 2017. Evaluation of U.S. Building Energy Benchmarking and Transparency Programs: Attributes, Impacts, and Best Practices. Lawrence Berkeley National Laboratory. eta-publications.lbl.gov/sites/default/files/lbnl_benchmarking_final_050417_0.pdf.

Mordor Intelligence. 2022. "Indoor Farming Market—Growth, Trends, and Forecasts (2023–2028)." Accessed January 2023. www.mordorintelligence.com/industry-reports/indoor-farming-market.

RII (Resource Innovation Institute). 2023. "Massachusetts Energy & Water Reporting and Resource Tracking." Accessed January 2023. cannabispowerscore.org/ma/.

Rocky Mountain Power. 2021. "Electric Service Schedule No. 22." Accessed January 2023. www.rockymountainpower.net/content/dam/pcorp/documents/en/rockymountainpower/rates-regulation/utah/rates/022_Indoor_Agricultural_Lighting_Service_1000_kW_and_Over.pdf.

Sabeh, N., D. Ross, L. Miner, and S. Everett. 2022. Literature Review of Energy and Water Use in Controlled Environment Horticulture and Potential Efficiency Opportunities. Pacific Gas and Electric Company. www.etcc-ca.com/reports/literature-review-energy-and-water-use-controlled-environment-horticulture-and-potential.

Schimelpfenig, G., and D. Smith. 2021. Controlled Environment Agriculture Market Characterization Report: Supply Chains, Energy Sources and Uses, and Barriers to Efficiency. Portland, OR: Resource Innovation Institute. catalog.resourceinnovation.org/.

University of Massachusetts Amherst. 2023. "Water: Supply and Sources." Center for Agriculture, Food, and the Environment. Accessed February 2023. ag.umass.edu/greenhouse-floriculture/greenhouse-best-management-practices-bmp-manual/water-supply-sources.

Urban Green Council. 2020. "New York City's Energy and Water Use Report." Accessed January 2023. www.urbangreencouncil.org/sites/default/files/2020_nyc_benchmarking_report.pdf.