Building Energy Codes and Industry Standards to Advance Controlled Environment Agriculture (CEA) Resource Efficiency

POLICY BRIEF | MAY 2023

Mike Waite

ACEEE
Smart Energy. Clean Planet. Better Lives.

RESOURCE INNOVATION INSTITUTE

Key Takeaways

National model energy codes and state energy codes are beginning to include CEA-specific provisions as the sector grows rapidly, but CEA sector engagement has historically been very limited.

While industry testing and performance standards for space conditioning, water heating, and other equipment apply throughout the United States, standards specific to CEA processes and loads are emerging and being referenced in energy code provisions.

The CEA sector, policymakers, and other stakeholders have many opportunities to engage one another through consensus processes for code and standards development at the national level, as well as code development, adoption, and implementation at the state and local levels.

Increased engagement and use of real-world performance data would better focus national code and standards development processes, which can provide clarity on future policy direction and mitigate a patchwork of state and local code provisions.

Introduction

With an increased focus on local food production and sustainability, the controlled environment agriculture (CEA) sector is growing rapidly in the United States. CEA facilities can have very large energy demands, but many of the dominant energy loads are not covered by the primary building energy policy: energy codes. As the CEA sector expands, policymakers are increasingly interested in incorporating CEA-specific provisions into building energy codes, due to the energy intensity of CEA. Some such provisions have emerged in a handful of states and the model national energy codes (see table 4). However, the industry standards that typically underlie energy codes are limited for CEA-specific equipment and applications. Additionally, both energy codes and most equipment standards are developed considering human occupants of typical commercial buildings and not the systems needed for healthy plant growth in CEA facilities.

At this important moment for CEA, this guide is intended to provide common ground for the sector and policymakers to take stock of current building energy codes and industry standards, summarize emerging CEA provisions, and identify how CEA stakeholders can engage in code and standards development processes.

Key Organizations

Several organizations referred to throughout this guide are introduced here for easy reference:

Air Conditioning Contractors of America (ACCA): Trade association of professionals and companies in the heating, ventilation, air-conditioning, commercial refrigeration (HVACR) industry

Air-Conditioning, Heating, and Refrigeration Institute (AHRI): Trade association of manufacturers of heating, ventilation, air-conditioning, commercial refrigeration (HVACR), and water heating equipment

American National Standards Institute (ANSI): A private nonprofit organization that oversees the development of voluntary consensus standards in the United States

American Society of Agricultural and Biological Engineers (ASABE): An international agricultural and biological engineering professional society

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): An American professional association of building services engineers, architects, contractors, manufacturers, and building owners

ASTM International (*formerly American Society for Testing and Materials*): An international non-governmental organization that develops and publishes voluntary consensus technical standards

DesignLights Consortium (DLC): A nonprofit organization focused on energy efficiency and lighting quality in the built environment. DLC develops efficiency and performance criteria for use by utilities and other energy efficiency programs

Illuminating Engineering Society (IES): An American professional association and standard-setting body of engineers, architects, designers, educators, students, contractors, distributors, utility personnel, manufacturers, and scientists focused on the lighted environment

International Codes Council (ICC): An international association of building safety professionals that develops model codes and standards

International Organization for Standardization (ISO): An international independent, non-governmental standards development organization composed of representatives from the national standards organizations of member countries

UL Solutions (*formerly Underwriters Laboratories*): A global company focused on safety testing and standards

Industry Standards

Standards provide a common understanding across an industry by establishing test procedures and performance ratings for equipment, setting minimum performance levels, and defining acceptable practices. Standards are generally developed through a consensus process that incorporates a range of stakeholder interests and expertise. Industry standards provide a voluntary accountability mechanism for manufacturers, design professionals, contractors, and building operators. These standards become required through legislation, building codes, or other policies. Therefore, they can be a precursor to regulation, but by engaging in standards development processes, the industry can inform those regulations based on their domain expertise, practical experience, and market knowledge.

Scopes of Standards

Standards can include a range of possible scopes that can generally be categorized as follows.

Test procedures and performance rating standards define detailed procedures and methods for evaluating equipment performance and computing performance metrics based on those methods to allow for standard comparison across similar products serving a particular user need.

Performance standards generally set minimum performance requirements for a class of equipment, such as efficiency metrics determined in accordance with a standard test procedure.

Standard practices or processes are used to complete a task or assessment, often by trained professionals, sometimes requiring licensure or another credential.

Classifying Standards

It is useful to classify standards by the rigor of their development processes and the weight they carry within an industry and applicable policies.

Informal standards are generally developed by a specialized organization or consortium using non-standardized processes with the purpose of informing the broader industry of best practices. They may be an early-stage development in an emerging industry or for new technologies that could lead to future formal standards. They are voluntary without enforcement mechanisms. *Example: DLC's Technical Requirements for LED-Based Horticultural Lighting* (DLC 2021).

Formal standards are generally developed by technical organizations with participation by a representative cross section of stakeholders with relevant expertise using a standardized process that typically requires consensus. They generally apply to equipment, but can consider systems and applications, with the potential to become quite complex. They are voluntary, but become required when incorporated into codes or other regulations. *Example: ASABE S640 "Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)."*

Government standards are typically developed at the federal level for specific equipment classes. In most cases, states cannot set higher energy efficiency standards or "preempt" an applicable federal standard.[1] Government standards very often refer to or rely on formal industry standards. *Example: Federal energy conservation standards for commercial air conditioners and heat pumps and other equipment per Code of Federal Regulations (CFR) Title 10, Part 431 ("10 CFR 431") implemented by the Department of Energy (DOE).*

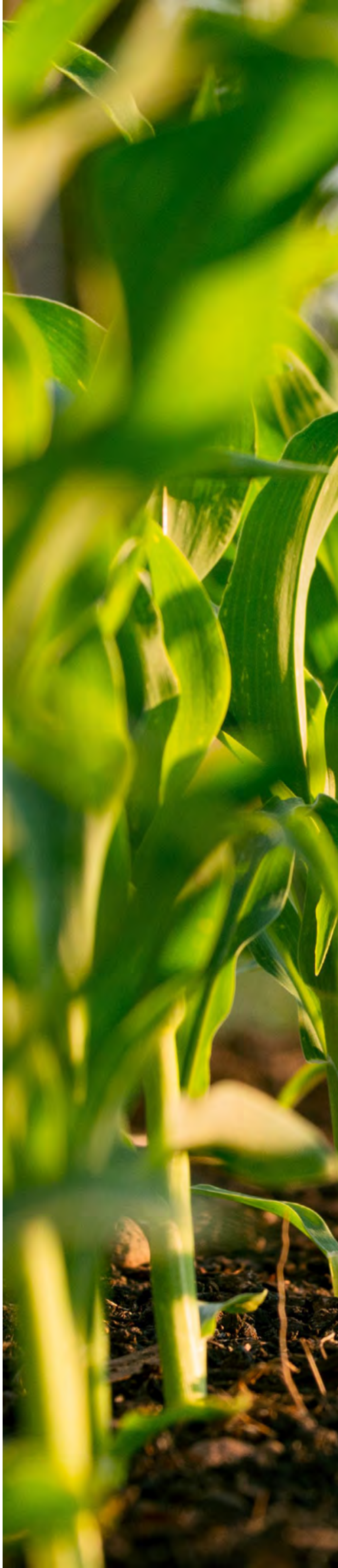
[1] More than a dozen states have adopted appliance standards for products that are not covered by federal standards, but none yet relevant to CEA.

Industry Standards Development

There are many different standards developers, including industry organizations, engineering societies, or others with technical expertise. There are also various development processes with some standardization. This guide will not be focusing on the development of informal standards as formal standards are most relevant to policy. As CEA standards continue to emerge, experts in the sector could both inform standards development and benefit from having their perspectives considered.

The American National Standards Institute (ANSI) develops a limited number of standards, but its most important role is establishing and overseeing the process for developing voluntary consensus standards. Summarizing the essential requirements for due process is useful in understanding the goals and requirements of the ANSI process (ANSI 2022):

1. **Openness** – participation by all interested parties
2. **Lack of dominance** – no over-representation of a single interest
3. **Balance** – balance among interested parties, organizations, and all involved parties
4. **Coordination and harmonization** – good faith conflict resolution
5. **Notification of standards development** – adequate public notice of standards development activity
6. **Considerations of views and objections** – established processes for public input and comment on standards development or proposed changes
7. **Consensus vote** – documenting vote results and that ANSI processes are followed
8. **Appeals** – allow for procedural appeals
9. **Written procedures** – publicly available, written standards development processes
10. **Compliance** – with normative American National Standards policies and administrative procedures



CEA Energy Efficiency

While formal standards have existed for decades and many do apply to equipment used to condition spaces in CEA facilities (lighting; heating, ventilating, and air-conditioning (HVAC); water heating), CEA-specific standards are largely new or under development. The following subsections give an overview of standards relevant to CEA energy efficiency, grouped by developing organization or topic area, as appropriate.

Standards Related to Energy Efficiency in Indoor Plant Environments

The American Society of Agricultural and Biological Engineers (ASABE) develops testing and performance standards specifically for indoor agriculture, including standards related to energy efficiency. Additional relevant lighting standards methods are developed by the Illuminating Engineering Society (IES). These standards are summarized in table 1.

Table 1. Relevant lighting standards

Standard	Description
ASABE Standards	
ANSI/ASABE S640 JUL2017 (R2022) Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms) (ASABE 2017)	ASABE S640 specifies testing procedures and units of measure to describe horticulture lighting. It defines an energy performance metric widely used in emerging CEA energy code provisions, photosynthetic photon efficacy (PPE), as photosynthetic photon flux divided by electric power in units of µmol/J.
ANSI/ASABE S642 SEP2018 Recommended Methods for Measurement and Testing of LED Products for Plant Growth and Development (ASABE 2018)	Methods for measurement and testing of LED lighting packages and arrays or modules, LED lamps, and any other LED optical radiation devices used for plant growth and development
ANSI/ASABE/ASHRAE EP653 OCT2021 Heating, Ventilating, and Air Conditioning (HVAC) for Indoor Plant Environments without Sunlight (ASABE 2021)	Air quality and thermodynamic criteria to promote cultivation; includes test standards and practices to select HVAC and dehumidification equipment
IES Standards	
ANSI/IES LM-79-19 Approved Method: Optical and Electrical Measurements of Solid-State Lighting Products (IES 2019)	Measurement procedures to determine various performance criteria for LED lighting
ANSI/IES RP-45-21 Recommended Practice: Horticultural Lighting (IES 2021)	Best practices guide for horticultural lighting design professionals

The DesignLights Consortium (DLC) sets widely referenced efficacy performance levels for horticultural LED lighting in *Technical Requirements for LED-Based Horticultural Lighting* (DLC 2021). This is not a formal standard itself, but it references ANSI/IES LM-79-19 for testing and measurement procedures and is being referenced as a benchmark for performance requirements in emerging CEA energy code provisions.

HVAC and Water Heating Equipment – Industry Standards

Heating, ventilating, and air-conditioning (HVAC) and water heating equipment standards generally apply broadly and are not industry specific. For example, standard test procedures and energy performance ratings for small commercial air conditioners apply to the equipment itself, regardless of whether it is being used to cool an office or an indoor agriculture facility. However, performance ratings generally aim for a representative performance over the full year rather than a single point of operation. Because these annual profiles are based on typical commercial buildings, they may not reflect the actual performance for CEA facilities.

Equipment energy efficiency performance levels are largely regulated at the federal level through the Department of Energy (DOE),[2] but in most cases DOE refers to industry standard test procedures and performance ratings. The biggest contributor in this area is the Air-Conditioning, Heating, and Refrigeration Institute (AHRI). Other relevant HVAC standards are developed by the International Organization for Standardization (ISO), UL Solutions, and Sheet Metal and Air Conditioning Contractors' National Association (SMACNA). Relevant industry testing and rating standards for HVAC and water heating are summarized in table 2.

[2] More information on DOE minimum efficiency standards for equipment: www.energy.gov/eere/buildings/appliance-and-equipment-standards-program.

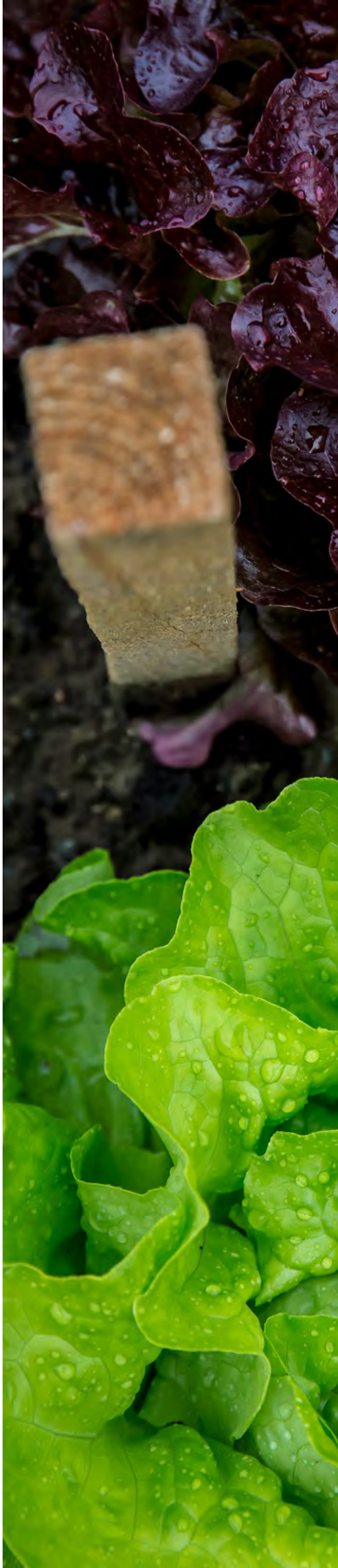
Table 2. Relevant HVAC and water heating testing and rating standards

Standard	Applicable equipment and systems
AHRI Standards	
AHRI 210/240-2023 (2020): Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment (AHRI 2020a)	Lower capacity air conditioners and heat pumps (generally less than 65 kBtu/h)
AHRI 340/360: Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment (AHRI 2022)	Mid to high capacity air conditioners and heat pumps (generally at least 65 kBtu/h)
AHRI 365 (I-P/2009): Commercial and Industrial Unitary Air-Conditioning Condensing Units (AHRI 2009)	Condensing units 135 kBtu/h
AHRI 550/590 (I-P/2020): Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle (AHRI 2020b)	Air-cooled and water-cooled chillers of all capacities (including heat recovery chillers)
AHRI 1230 I-P (2021): Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment (AHRI 2021)	VRF systems of all capacities
AHRI 560 (2000): Absorption Water Chilling and Water Heating Packages (AHRI 2000)	Absorption chillers of all types and capacities
AHRI 310/380 (2017): Packaged Terminal Air-Conditioners (PTAC) and Heat Pumps (PTHP) (AHRI 2017)	PTACs and PTHPs of all capacities
Industry Standards by Organizations Other Than AHRI	
ISO 13256: Water-Source Heat Pumps – Testing and rating for performance	Water-to-air and brine-to-air Heat Pumps (ISO 13256-1:2021) (ISO 2021a); water-to-water and brine-to-water HPs (ISO 13256-2:2021) (ISO 2021b)
UL 727 Ed. 10-2018: Standard for Oil-Fired Central Furnaces (UL 2018)	Oil-fired furnaces of all types and capacities
ANSI/SMACNA 016—2012: HVAC Air Duct Leakage Test Manual (SMACNA 2012)	Leakage criteria and expected leakage rates for ductwork constructed to the SMACNA HVAC Duct Construction Standards

HVAC and Water Heating Equipment – Government Standards

Through various statutes, the Department of Energy (DOE) implements federal rulemaking processes for test procedures and minimum efficiency standards for over 60 categories of appliances and equipment. These standards apply to consumer products and commercial and industrial equipment, are separated into specific equipment classes, and are sometimes delineated by size (e.g., heating or cooling capacity).

For test procedures, DOE will generally look to industry standards for reference and request public comments on proposed test procedures. Test procedures developed by DOE are limited to those that AHRI or other organizations discussed in the previous section do not develop, including fossil fuel furnaces and boilers, as well as all water heaters.



DOE maintains Rulemaking Dockets for each equipment class and—with some variation and occasionally shorter timelines—follows a four-phase process in setting Energy Conservation Standard minimum performance requirements.[3] These phases are summarized below, including points at which stakeholders review documents and provide public comments.

1. **Framework Phase** – DOE publishes a framework document that presents the basic analytical and procedural principles and legal authority. The framework document also typically solicits feedback from stakeholders on specific questions. At this stage, DOE might solicit public input through a Request for Information (RFI). In limited cases in the past, DOE has issued a formal Advance Notice of Proposed Rulemaking (ANOPR), particularly for a new rule or regulated technology, but this is not typical.
2. **Preliminary Analysis Phase** – DOE gathers available data and information about the product's technical, economic, and market characteristics and makes preliminary determinations concerning methods of improving efficiencies and the impacts of doing so. DOE then publishes this analysis and solicits public input. At this stage, the docket will typically include a Preliminary Technical Support Document (PTSD) with a request for public comments.
3. **Notice of Proposed Rulemaking (NOPR) Phase** – DOE considers public input from the preliminary analysis phase, revises its analysis, and proposes to the public an efficiency level that it has determined would result in the maximum improvement in energy efficiency that is both technologically feasible and economically justified. At this stage, DOE will typically release an NOPR with an updated, final, Technical Support Document (TSD) and again solicit public input.
4. **Final Rule Phase** – DOE considers public input from the NOPR phase, further revises its analysis, and issues the final rule, which establishes any mandatory minimum energy conservation standard. Typically, the rule requires that manufacturers must comply with the new standard within three to five years.

Where DOE does not currently set standards for a particular technology, they can be petitioned to do so. For example, DOE does not currently set standards for linear LEDs widely used in CEA facilities. Recent paths toward federal regulation have first seen standards produced at the state level; affected industries may then petition the DOE to set a federal standard to avoid a patchwork of state regulations.

[3] U.S. Department of Energy. "Rulemakings and Notices." www.energy.gov/eere/buildings/rulemakings-and-notices (accessed January 3, 2023).

Building Design and Process Standards

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) develops a wide range of resources related to the performance of buildings and their systems. Over the past several decades, ASHRAE has increasingly become a leader in standards for the design, construction, and operation of energy-efficient buildings. Most relevant standards produced by ASHRAE are either formal standards related to overall building performance and professional practices or guidelines that largely fit the informal standards classification described earlier in this guide. These standards apply broadly to commercial buildings but can serve as resources for improving energy-efficient design and operation of CEA facilities.

In addition to ASHRAE, the National Institute of Building Sciences (NIBS) and ASTM International develop standards for building enclosure commissioning. ASTM is also the primary developer of test procedures for performance rating of building envelope materials and assemblies. Potentially relevant standards from ASHRAE, NIBS, and ASTM are summarized in table 3.

Table 3. Relevant building design and process standards

Standard	Summary description
ASHRAE Design Standards	
ANSI/ASHRAE 55: Environmental Conditions for Human Occupancy (ASHRAE 2017b)	Specifies conditions for acceptable thermal environments for human occupants
ANSI/ASHRAE 62.1: Ventilation for Acceptable Indoor Air Quality (IAQ) (ASHRAE 2019a)	Minimum ventilation rates and other measures to provide IAQ acceptable to and healthy for human occupants
ANSI/ASHRAE/ACCA 183: Peak Cooling and Heating Load Calcs (ASHRAE 2017a)	Information about data to be included in load calculations and acceptable methodologies to determine loads
ASHRAE Guideline 36: High-Performance Sequences of Operation for HVAC Systems (ASHRAE 2021)	Uniform sequences of operation for HVAC systems to maximize energy efficiency and performance
ASHRAE Process and Practice Standards	
ANSI/ASHRAE/ACCA 180: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems (ASHRAE 2018a)	HVAC inspection and maintenance requirements to preserve thermal comfort, energy efficiency, and indoor air quality
ANSI/ASHRAE/ACCA 211: Commercial Building Energy Audits (ASHRAE 2018b)	Practices for conducting and reporting energy audits for commercial buildings; the standard defines the procedures required to perform Energy Audit Levels 1, 2, and 3
ANSI/ASHRAE 111: HVAC Testing, Adjusting, and Balancing (ASHRAE 2017c)	Uniform procedures for measuring, testing, adjusting, balancing, evaluating, and reporting HVAC system field performance
ANSI/ASHRAE/IES Standard 202: Commissioning Process for Buildings and Systems (ASHRAE 2018c)	Describes the Commissioning Process, including individuals' roles and a framework for developing design documents, specifications, procedures, documentation, and reports
ASHRAE Guideline 0: The Commissioning Process (ASHRAE 2019b)	Best practices for applying whole-building commissioning to facilities
ASHRAE Guideline 11-2018: Field Testing of HVAC Controls (ASHRAE 2018d)	Procedures for field testing and adjusting of control components used in HVAC systems
Building Envelope Commissioning Standards	
NIBS Guideline 3-2012 Building Enclosure Commissioning Process (BECx) (NIBS 2012)	Describes a process to validate that the performance of materials, components, assemblies, systems, and design achieve the objectives and requirements of the owner
ASTM E2813-18: Standard Practice for Building Enclosure Commissioning (ASTM International 2018)	Procedures, methods, and documentation techniques that may be used in the application of the building enclosure commissioning process
ASTM E2947: Standard Guide for Building Enclosure Commissioning (ASTM International 2021)	A concise guide consistent with the more comprehensive ASTM E2813

Energy Monitoring and Management

Due to the significant resource requirements of CEA and the benefits of continuously improving operations, many CEA facilities employ some degree of energy monitoring and management. Monitoring key performance indicators can help improve facility operation and inform future facility design. There are other guides and resources to facilitate an effective energy monitoring and management plan, but relevant to this guide, the International Organization for Standardization (ISO) maintains **ISO 50001:2018: Energy management systems**, which specifies requirements for establishing, implementing, maintaining, and improving an energy management system (EnMS) and provides guidance for using such systems (ISO 2018).

Interest in distributed energy resources and grid-interactivity for CEA facilities is growing, as it is in the wider building energy landscape. Participating in demand response programs that value a facility's contribution to the utility system requires standard communication protocols. **OpenADR 2.0a and 2.0b-2019: Profile Specification Distributed Energy Resources** is a standardized demand response interface that allows utilities to send demand response signals to customers, systems, and equipment (OpenADR 2019). The International Electrotechnical Commission (IEC) maintains **IEC 62746-10-1:2018: Systems interface between customer energy management system and the power management system – Part 10-1: Open automated demand response.** IEC 62746 specifies a minimal data model and services for demand response (DR), pricing, and distributed energy resource (DER) communications (IEC 2018).

Building Energy Codes

Building energy codes set minimum efficiency requirements for building projects, particularly for new construction and major renovations. They are minimum standards intended to reduce energy usage and utility costs—and consequently, greenhouse gas emissions—for all buildings; they are not meant to represent advanced performance practices. There is ample space for improved CEA facility energy efficiency, and while leaders in the sector push the leading edge on resource efficiency, incorporating CEA-specific provisions into energy codes is emerging as a tool to realize improvements across all facilities. This section describes the overall building energy code landscape, building energy code development and implementation, how energy codes are increasingly affecting CEA facilities, and how the CEA sector can engage in energy code development at the national, state, and local levels.

Building energy codes set minimum efficiency requirements for buildings and their systems, including building envelope, HVAC, lighting, and water heating. A building looking to comply with the energy code has, broadly speaking, two paths available. A *prescriptive path* has fixed minimum requirements, such as wall insulation levels, space type–specific lighting power densities, and HVAC and water heating equipment efficiencies. A *performance path* uses computational tools to allow performance trade-offs among a building's systems to arrive at the same level of performance as that modeled for the same building meeting the specific requirements of the prescriptive path. For example, a building design might have less wall insulation than the prescriptive requirement, but more ceiling insulation and/or better windows. Another common use of the performance path is buildings with large window or glass curtain wall areas that require other measures to achieve the same level of performance as the prescriptive path (e.g., higher efficiency cooling and heating equipment, triple-paned glass, and improved air leakage performance).

Figure 1 shows an overview of the energy code development and adoption process. We will unpack this in the subsections that follow.

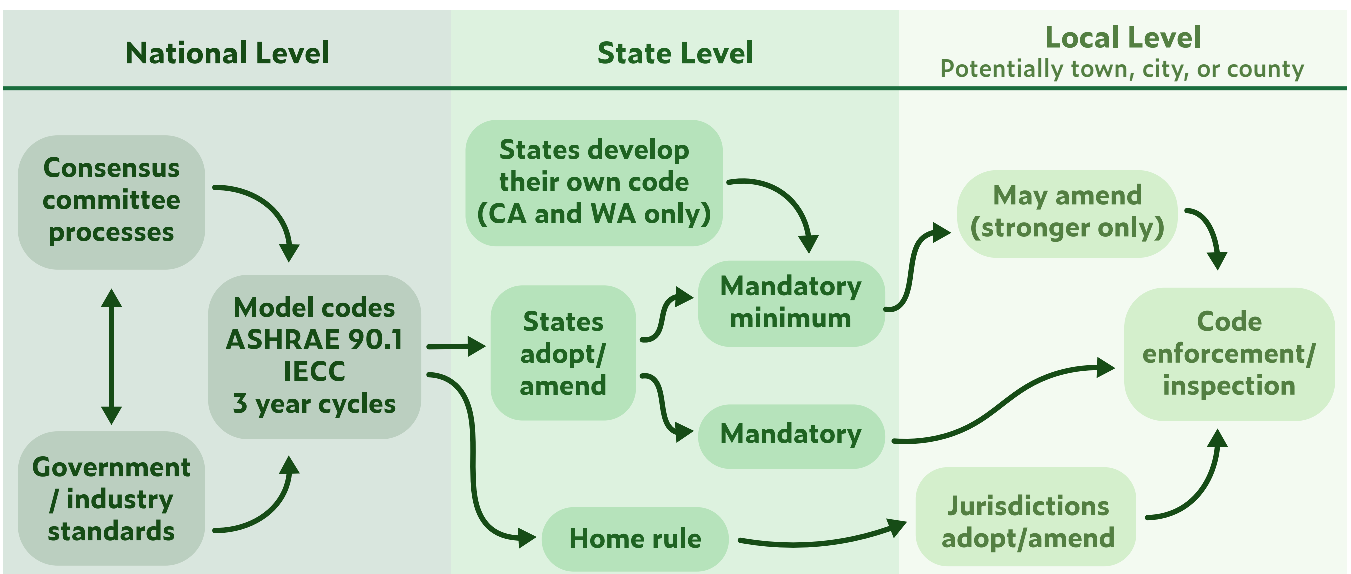


Figure 1. Overview of energy code development and adoption processes

The growth of the cannabis sector and its associated energy demands have led to building energy policies that have emerged from either agriculture-focused agencies that have not historically regulated energy usage or building energy agencies or code developers who do not have a history with the unique characteristics of CEA facilities. With increasing production of other CEA crops, it is important for the CEA sector, policymakers, and the energy codes community to work toward effective, data-informed, crop-agnostic energy codes.

Building Energy Codes – National Level

Building codes are not adopted at the national level in the United States, but national model energy codes are published by two organizations: the International Codes Council (ICC) and ASHRAE. These model codes provide a complete code so that states and local jurisdictions do not have to develop their own.

The benchmark model energy code for commercial buildings is ASHRAE 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*. The International Energy Conservation Code (IECC), which is the benchmark for residential buildings, also has a complete set of provisions for commercial buildings that is widely adopted across the United States. For commercial buildings, compliance with ASHRAE 90.1 can be used to show compliance with the IECC, but not vice versa. Both model energy codes are developed on three-year cycles, with the most recent versions being ASHRAE 90.1-2022 and the 2021 IECC (which references ASHRAE 90.1-2019). As of publication of this guide, development of the 2024 IECC is well underway, while work on the next version of ASHRAE 90.1 is just beginning.

Industry Engagement Points

As shown in figure 1, building energy codes typically reference the industry standards covered in the previous section of this guide. Model energy codes are similarly developed in accordance with the ANSI consensus process described earlier, providing ample opportunity for the CEA sector to engage in energy code development.[4] Rather than provide detailed descriptions of the unique and often complex workings of the IECC and ASHRAE 90.1 consensus committees, this guide will discuss in general terms the process and how to engage.

In the code development process, anyone can develop and submit code change proposals. CEA sector representatives can attend public IECC and ASHRAE 90.1 committee and subcommittee meetings. After the consensus committees consider and approve changes to the model energy codes, they are sent out for public comment. At this point, anyone can submit a comment in favor of the proposed change, in opposition to the change, or with recommendations for modification. This is an opportunity for the CEA sector to advocate for code changes or to contribute their expertise and experience to the process.

By engaging in model code development to ensure sound CEA provisions at the national level, stakeholders can help to avoid a patchwork of requirements in different states. In addition, it will be important for stakeholders to engage at the state level, where energy codes are adopted and administered.

[4] The current 2024 IECC development cycle is the first time an ANSI consensus process has been used for that model energy code, though ASHRAE 90.1 has long used such a process.

Current CEA Status

Within CEA facilities, HVAC, lighting, and water heating equipment are considered *process loads* that maintain plant growth environments and are thus largely exempt from code requirements that focus on energy uses for human occupancy. However, codes have specifications for greenhouse envelope requirements. Further, CEA-specific provisions are emerging in the model codes currently under development for lighting photosynthetic photon efficacy (PPE), lighting controls, and dehumidification.

Updated provisions for lighting PPE have been included in both ASHRAE 90.1-2022 and the 2021 IECC (ASHRAE 2022; ICC 2021). In ASHRAE 90.1-2022, the threshold for the lighting PPE requirements is a horticultural lighting load of 40 kW (ASHRAE 2022). In addition, new provisions on lighting controls were included in ASHRAE 90.1-2022 (ASHRAE 2022). The 2021 IECC requirement for lighting PPE applies to a minimum of 95% of plant lighting (ICC 2021). Provisions for lighting PPE will be revised in the 2024 IECC and new dehumidification provisions have been proposed for the 2024 IECC. The 2024 IECC is currently undergoing its consensus development process, including public review and comment periods.

All CEA-specific provisions are summarized in table 4.

Should CEA facilities have their own energy code? If CEA sector representatives are not interested in being involved in the overall development of commercial building codes or if CEA facilities warrant unique consideration, there is precedent for a model energy code for a specific high energy intensity building type: ASHRAE 90.4 was developed to account for the specific load requirements of data centers, which differ from other commercial buildings in ways that can affect considerations for building envelopes, mechanical design, and other systems (ASHRAE 2019c). The development of an alternative model code for CEA facilities could offer the opportunity to tailor the code to the specificities of CEA facility load profiles. Such a process has not been initiated at this point, and if the CEA sector thinks this is the best route, they will most likely need to take the lead.

Building Energy Codes – State Level

In most cases, states in the United States adopt a version of the IECC and ASHRAE model codes. States can amend the codes when adopted to make them stronger or weaker in their state, but where this is done, amendments tend to reduce stringency, lowering efficiency. Due to differing state requirements for adoption of updated model codes, the timelines for state adoption of a new model code iteration vary. Energy codes at the state level are either mandated statewide or provide a mandatory minimum level of efficiency for buildings that local jurisdictions may exceed with more efficient energy codes.

Some states are *home-rule* states, meaning that energy code mandates are left to local jurisdictions; these include, but are not limited to Arizona, Colorado, and Kansas. Colorado has tried to work within this limitation through a state statute that requires local jurisdictions to update their energy code when they make any other building code update (ACEEE 2022; Colorado General Assembly 2022).

Industry Engagement Points

The processes for engaging with state-level energy code development differ by state, with various implementation agencies responsible for energy codes in different states. In general, several opportunities exist for organizations to participate in the adoption and amendment processes. Organizations can advocate for the adoption of stronger state energy codes so that all facilities must meet a reasonable level of energy efficiency performance. In most states, amendments to existing energy codes can also be proposed. California and Washington State develop their own state-specific energy codes and have associated code development processes.

Current CEA Status

CEA-specific provisions exist within the energy codes of some states, including Washington and California. Washington recently approved provisions for lighting PPE and dehumidification, which will go into effect in 2023 (Washington SBCC 2022). California has similar provisions in place in its 2022 code, including lighting PPE, lighting control, and specific requirements for dehumidification equipment in CEA facilities (California Energy Commission 2022). Washington's energy code also includes an exception to commercial building economizer requirements when high-efficiency cooling equipment is used (Washington SBCC 2020).

Other states have included amendments to the model energy codes that add provisions for CEA facilities. To date, these have been focused on cannabis facilities only (Illinois and Massachusetts), but other states are looking at broader CEA facility requirements (Illinois General Assembly 2019; Massachusetts CCC 2022). This is certainly the time for CEA stakeholders to engage in the process at the state level.

Building Energy Codes – Local Level

The majority of energy codes are implemented and enforced at the local level. Local jurisdictions for code enforcement could be cities, towns, or counties; this varies across states and sometimes within the same state. The exact relationship between code adoption and local enforcement varies by state, as outlined in figure 1. Where allowed by the state, local jurisdictions may amend the state codes. In "mandatory minimum" efficiency states, such allowances are only for amendments that are more efficient than the state code, including high-efficiency stretch codes. Stretch codes are codes with requirements and stringency that go beyond mandatory base codes. For example, the City of Santa Fe and the Town of Taos have established stretch codes that are more stringent than the 2018 New Mexico Energy Conservation Code, which is an amended version of the 2018 IECC (ACEEE 2022). New York State developed a voluntary statewide stretch code, NYStretch Energy Code-2020, with requirements for 7% greater efficiency than the mandatory 2020 New York State Energy Conservation Construction Code (ACEEE 2022). The NYStretch code has been adopted by New York City, as well as 41 other municipalities in New York, as of 2022 (ACEEE 2022). Massachusetts's stretch code, which is based on the IECC 2021 with state amendments and further stretch code amendments, is in force in jurisdictions covering 91% of the state population (Massachusetts DOER 2022; Commonwealth of Massachusetts 2023).

In states with home-rule policies, energy codes are adopted only at the local level, if at all. However, some home-rule states support the implementation of energy codes by municipalities and in some cases have established requirements for certain building sectors. For example, Arizona, Mississippi, and Missouri have state-mandated energy codes for state-owned buildings; on the other hand, some states (e.g., North Dakota) adopt a state energy code, but do not require municipalities to adopt or enforce it (ACEEE 2022).

Industry Engagement Points

Divergent and inconsistent code development among jurisdictions may create challenges for engagement. Increasing engagement at the national level and supporting effective adoption and implementation at the state level will improve this situation. In addition, as some larger cities have begun to regulate CEA resource efficiency (e.g., Denver and Seattle, as described below), there is likely to also be value in engaging with some of these jurisdictions. At the local level, municipal code officials are key stakeholders for CEA sector engagement. Offering training and education for code officials can build local capacity and promote the adoption of the national model energy codes. Further, continuing education for design professionals can be targeted at efficient design, ensuring that CEA sector best practices are disseminated to the broader architecture, engineering, and construction industry.

Current CEA Status

Some cities, including Seattle and Denver, have already included or are considering including CEA-specific provisions in their energy codes. Seattle has had minimum lighting efficacy requirements since 2015 (Seattle Department of Construction & Inspections 2015). In 2019, Denver set minimum lighting efficacy and dehumidification efficiency requirements (City and County of Denver 2019).

CEA provisions are new and emerging areas of code development, whether through adoption of model codes, state codes, or jurisdiction-specific codes. Given the nascency of CEA-specific provisions, the success of compliance has not yet been documented. Greater availability of data on compliance and efficiency results of CEA-specific provisions will promote wider adoption of these provisions in energy codes.

Table 4. Emerging lighting efficacy and lighting power density requirements for CEA facilities

Code	Adopted	Requirement	Threshold
90.1-2022 (ASHRAE 2022)	2023	1.7 µmol/J (greenhouse) 1.9 µmol/J (other) Daylight/schedule controls	40 kW horticultural lighting load
2021 IECC (ICC 2021)	Misc. states, cities	1.6 µmol/J	95% plant lighting
2024 IECC	In development	*Draft requirements same as ASHRAE 90.1-2022*	
California (California Energy Commission 2022)	2022	1.7 µmol/J (greenhouse) 1.9 µmol/J (other) Daylight/schedule controls	40 kW horticultural lighting load
Washington (Washington SBCC 2022)	2023	1.7 µmol/J (greenhouse) 1.9 µmol/J (other)	10 kW
Seattle (Seattle Department of Construction & Inspections 2015)	2015	1.2 µmol/J	
Denver (City and County of Denver 2019)	2019 (same provisions in 2022)	1.6 µmol/J (luminaires) 1.9 µmol/J (lamps)	80% plant lighting
Illinois* (Illinois General Assembly 2019)	2019	2.2 µmol/J *or* 36 W/sf growing canopy	
Massachusetts* (Massachusetts CCC 2022)	2019 (most recent)	2.2 µmol/J *or* 36/50 W/sf canopy	+/– 5,000 sf

*Cannabis facilities only

Conclusion

The existing equipment standards and energy codes for commercial buildings are largely related to commercial uses that do not consider the unique energy usage profiles and process loads of CEA facilities, given the lighting needed for plant growth, dehumidification requirements, and the internal loads' effect on cooling and heating. However, CEA-specific provisions within energy codes are emerging at the national, state, and local levels. At this early stage, energy code provisions for CEA are a patchwork across the United States that depend very much on a project's locale. Even where there are similar provisions, there can be differences in lighting efficacy levels, compliance thresholds for total facility lighting power and percentage of fixtures that must comply, and specific HVAC requirements.

Within this period of nascency for CEA-specific codes and standards, there are important opportunities for the CEA sector to have input in the development of codes and standards. Industry standards are emerging and being incorporated into energy codes. As such standards are informed by the expertise and experience of those in the industry, potential new standards provide an opportunity to ensure future energy code provisions are rooted in industry practices and processes. This guide not only details the current state of affairs but also highlights how quickly the landscape is changing. Now is the time for the CEA sector, policymakers, and other stakeholders to engage one another and work together to reduce energy usage and costs in all CEA facilities.

Acknowledgments

This report was made possible through the generous support of the United States Department of Agriculture (USDA) 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 (in alphabetical order by last name) Kyle Booth from Energy Solutions, Chris Burgess from the Midwest Energy Efficiency Alliance (MEEA), Bob Gunn from Seinergy, Alison Lindburg from MEEA, 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, Mariel Wolfson, and Amber Wood; internal reviewers from RII included Carmen Azzaretti, Rob Eddy, and Derek Smith. 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). 2022. "Commercial Code." database.aceee.org/state/commercial-code.

AHRI (Air-Conditioning, Heating, and Refrigeration Institute). 2000. *AHRI 560 (2000): Absorption Water Chilling and Water Heating Packages*. Arlington, VA: AHRI. www.ahrinet.org/search-standards/ahri-560-absorption-water-chilling-and-water-heating-packages.

—. 2009. *AHRI 365 (I-P/2009): Commercial and Industrial Unitary Air-Conditioning Condensing Units*. Arlington, VA: AHRI. www.ahrinet.org/sites/default/files/2022-10/ANSI.AHRI-365%20%28I-P%29-2009%20-%20ANS%20expired.pdf.

—. 2017. *AHRI 310/380 (2017): Packaged Terminal Air-Conditioners and Heat Pumps (CSA-C744-17)*. Arlington, VA: AHRI. www.ahrinet.org/sites/default/files/2022-06/AHRI_Standard_310-380_2017_CSA_C744_17.pdf.

—. 2020a. *AHRI 210/240-2023 (2020): Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment*. Arlington, VA: AHRI. www.ahrinet.org/sites/default/files/2022-06/AHRI%20Standard%20210.240-2023%20%282020%29.pdf.

—. 2020b. *AHRI 550/590 (I-P/2020): Performance Rating of Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle*. Arlington, VA: AHRI. www.ahrinet.org/search-standards/ahri-550590-i-p-and-551591-si-performance-rating-water-chilling-and-heat-pump-water-heating-packages.

—. 2021. *AHRI 1230 (I-P/2021): Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment*. Arlington, VA: AHRI. www.ahrinet.org/sites/default/files/2022-06/AHRI_Standard_1230-2021.pdf.

—. 2022. *AHRI 340/360 (I-P/2022): Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment*. Arlington, VA: AHRI. www.ahrinet.org/sites/default/files/2022-06/AHRI%20Standard%20340-360-2022%20%28I-P%29.pdf.

American National Standards Institute (ANSI). 2022. ANSI Essential Requirements 2022. www.ansi.org/american-national-standards/ans-introduction/essential-requirements.

ASABE (American Society of Agricultural and Biological Engineers). 2017. *ANSI/ASABE S640: Quantities and Units of Electromagnetic Radiation for Plants (Photosynthetic Organisms)*. St. Joseph, MI: ASABE. elibrary.asabe.org/abstract.asp?aid=48303.

—. 2018. *ANSI/ASABE S642: Recommended Methods for Measurement and Testing of LED Products for Plant Growth and Development*. St. Joseph, MI: ASABE. webstore.ansi.org/standards/asabe/ansiasabes642sep2018.

—. 2021. *ANSI/ASABE/ASHRAE EP653: Heating, Ventilating, and Air Conditioning (HVAC) for Indoor Plant Environments without Sunlight.* St. Joseph, MI: ASABE. webstore.ansi.org/standards/asabe/ansiasabeashraeep653oct2021.

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). 2017a. *ANSI/ASHRAE/ACCA 183-2007 (RA 2017): Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings*. Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2017b. *ANSI/ASHRAE 55-2017: Thermal Environmental Conditions for Human Occupancy*. Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2017c. *ANSI/ASHRAE 111-2008 (RA 2017): Testing, Adjusting, and Balancing of Building HVAC Systems*. Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2018a. *ANSI/ASHRAE/ACCA 180-2018: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems*. Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2018b. *ANSI/ASHRAE/ACCA 211-2018: Standard for Commercial Building Energy Audits*. Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2018c. *ANSI/ASHRAE/IES Standard 202: Commissioning Process for Buildings and Systems*. Atlanta: ASHRAE. www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/202_2013_b_20180308.pdf.

—. 2018d. *ASHRAE Guideline 11-2018: Field Testing of HVAC Control Components.* Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2019a. *ANSI/ASHRAE 62.1-2019: Ventilation for Acceptable Indoor Air Quality.* Atlanta: ASHRAE. www.ashrae.org/technical-resources/ashrae-standards-and-guidelines.

—. 2019b. *ASHRAE Guideline 0: The Commissioning Process*. Atlanta: ASHRAE. www.scribd.com/document/491021774/ASHRAE-Guideline-0-2019-The-Commissioning-Process-pdf.

—. 2019c. "ASHRAE's Data Centers Standard Updated to Align with Industry's Evolving Technologies." www.ashrae.org/news/hvacrindustry/2019-update-to-standard-90-4.

—. 2021. *ASHRAE Guideline 36-2021: High-Performance Sequences of Operation for HVAC Systems*. Peachtree Corners, GA: ASHRAE. webstore.ansi.org/standards/ashrae/ashraeguideline362021?gclid=Cj0KCQjwz6ShBhCMARIsAH9A0qWD-9LLDdAAuOa8Xzerf1P-Xt2VB4VkmGEQ4MygBo6YEk3Bu1rbWYIaAuSoEALw_wcB.

—. 2022. *Standard 90.1-2022—Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings*. Peachtree Corners, GA: ASHRAE. webstore.ansi.org/standards/ashrae/ansiashraeies902022?source=blog&_ga=2.2974128.1644245969.1677642982-1255971265.1677642982&gclid=Cj0KCQjwz6ShBhCMARIsAH9A0qWq6TbBo6yU3pnPh7o6HgYdml3_UtOjV3FG1n3kG6_XhJCkfvQ1-GEaAnDEEALw_wcB.

ASTM International. 2018. *ASTM E2813-18: Standard Practice for Building Enclosure Commissioning*. West Conshohocken, PA: ASTM International. www.astm.org/e2813-18.html.

—. 2021. *ASTM E2947-21a: Standard Guide for Building Enclosure Commissioning*. West Conshohocken, PA: ASTM International. www.astm.org/e2947-21a.html.

California Energy Commission. *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 and County of Denver. 2019. *2019 Denver Energy Code.* Denver: City and County of Denver.

Colorado General Assembly. 2022. "HB22-1362 Building Greenhouse Gas Emissions." leg.colorado.gov/bills/hb22-1362.

Commonwealth of Massachusetts. 2023. "Building Energy Code." www.mass.gov/info-details/building-energy-code.

DLC (DesignLights Consortium). 2021. *Technical Requirements for Horticultural Lighting V2.1.* Medford, MA: DLC. www.designlights.org/our-work/horticultural-lighting/technical-requirements/hort-v2-1.

ICC (International Code Council). 2021. *2021 International Energy Conservation Code (IECC)*. Washington, DC: ICC. codes.iccsafe.org/content/IECC2021P1.

IEC (International Electrotechnical Commission). 2018. *IEC 62746-10-1:2018: Systems Interface between Customer Energy Management System and the Power Management System – Part 10-1: Open Automated Demand Response*. Geneva: IEC. webstore.iec.ch/publication/26267.

IES (Illuminating Engineering Society). 2019. *ANSI/IES LM-79-19: Approved Method: Optical and Electrical Measurements of Solid State Lighting Products*. New York: IES. webstore.ansi.org/standards/iesna/ansiieslm7919.

—. 2021. *ANSI/IES RP-45-21: Recommended Practice: Horticultural Lighting*. New York: IES. webstore.ansi.org/standards/iesna/ansiiesrp4521.

Illinois General Assembly. 2019. *Cannabis Regulation and Tax Act, Public Act 101-0027*. Springfield: Illinois General Assembly. www.ilga.gov/legislation/publicacts/101/PDF/101-0027.pdf.

ISO (International Organization for Standardization). 2018. *ISO 50001:2018: Energy Management Systems—Requirements with Guidance for Use*. Geneva: ISO. www.iso.org/obp/ui/#iso:std:iso:50001:ed-2:v1:en.

—. 2021a. *ISO 13256-1:2021: Water-Source Heat Pumps—Testing and Rating for Performance—Part 1: Water-to-Air and Brine-to-Air Heat Pumps.* Geneva: ISO. www.iso.org/obp/ui/#iso:std:iso:13256:-1:ed-2:v1:en.

—. 2021b. *ISO 13256-2:2021: Water-Source Heat Pumps—Testing and Rating for Performance—Part 2: Water-to-Water and Brine-to-Water Heat Pumps.* Geneva, Switzerland: ISO. www.iso.org/obp/ui/#iso:std:iso:13256:-2:ed-2:v1:en.

Massachusetts CCC (Cannabis Control Commission). 2022. "935 CMR 500.00: Adult Use of Marijuana." www.mass.gov/regulations/935-CMR-50000-adult-use-of-marijuana.

Massachusetts DOER (Department of Energy Resources). 2022. *Community Adoption of the Stretch Energy Code; "Appendix 115 AA" of the MA State Building Code (780 CMR).* Boston: Massachusetts DOER. www.mass.gov/doc/stretch-code-adoption-by-community-map/download.

NIBS (National Institute of Building Sciences). 2012. *NIBS Guideline 3-2012 Building Enclosure Commissioning Process BECx*. Washington, DC: NIBS. www.wbdg.org/FFC/NIBS/nibs_gl3.pdf.

OpenADR (OpenADR Alliance). 2019. *OpenADR 2.0 Specifications*. San Ramon, CA: OpenADR. www.openadr.org/specification.

Seattle Department of Construction & Inspections. 2015. *2015 Seattle Energy Code*. Seattle: Seattle Department of Construction & Inspections. www.seattle.gov/sdci/codes/codes-we-enforce-(a-z)/energy-code#2015seattleenergycode.

SMACNA (Sheet Metal and Air Conditioning Contractors' National Association). 2012. *ANSI/SMACNA 016-2012: HVAC Air Duct Leakage Test Manual Second Edition*. Chantilly, VA: SMACNA. webstore.ansi.org/standards/ansi/smacna0162012.

UL (Underwriters Laboratories). 2018. *UL 727: Standard for Oil-Fired Central Furnaces*. Northbrook, IL: UL. global.ihs.com/doc_detail.cfm?document_name=UL%20727&item_s_key=00097210.

Washington SBCC (State Building Code Council). 2020. *Washington State Energy Code—Commercial: 2018 Edition*. Olympia: Washington SBCC. www.sbcc.wa.gov/sites/default/files/2020-04/2018 WSEC_C 2nd print.pdf.

—. 2022. *Washington State Energy Code—Commercial: 2021 Edition*. Olympia: Washington SBCC. app.leg.wa.gov/wac/default.aspx?cite=51-11C.