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Controlled Environment Agriculture Design Standards (CEADS): Purpose, Development, and Implementation

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Abstract. Controlled Environment Agriculture (CEA) is a technology-based approach to farming to optimize environmental conditions for plant growth while minimizing the use of resources such as land, energy and water. By creating ideal conditions for production these complex growing systems enable a significant improvement in product quality and continuous, year-round production regardless of regional climate conditions. These facilities have many forms - greenhouse, vertical farm, grow room, horizontal farm and container farm - but all share unique technical advantages that have positioned CEA to dominate the future of urban agriculture, in which affordable space is often the primary limiting factor in crop production. Producers within CEA face several challenges, including high energy costs and maintaining food safety when there is a high degree of material reuse and cycling.

The Controlled Environment Agriculture Design Standards (CEADS) project was launched in 2019, when CEA professionals from the private sector, government, and academia recognized the need to define goals for the sustainable advancement of the rapidly growing CEA industry. Encompassing the management of energy, water, materials, byproducts, pests, labor, finances, and equity concerns, CEADS prioritized industry-vetted best practices into quantifiable peer-reviewed standards. CEA enterprises can utilize CEADS to guide the entire planning, design, construction, operation and expansion phases of their growing facilities, enhancing long-term business success for a more resilient and sustainable CEA industry overall. This paper discusses the sustainability challenges facing CEA, the role of standards and other approaches for improving operational performance, and how CEADS has developed documentation to address these needs.

Keywords. *Benchmarks, Circular Bioeconomy, Controlled Environment Agriculture, Design Standards, Energy Use Efficiency, Equity, Greenhouses, Light Use Efficiency, Resilience, Sustainability, Vertical Farming, Water Use Efficiency.*

Introduction

Controlled Environment Agriculture (CEA) is a technology-based approach to farming that aims to optimize environmental conditions for plant growth while minimizing the use of resources such as land and water. By creating ideal conditions, these complex growing systems allow for a significant improvement in produce quality and continuous, year-round production irrespective of regional climate differences (Gómez, 2019). CEA facilities can take on many forms - greenhouses, vertical farms, grow rooms or container farms - but all share unique technical advantages that position CEA to play a significant role in urban agriculture, in which affordable space is often the primary limiting factor in crop production and financial viability.

The CEA industry is a crop production practice that has recently expanded into urban agriculture applications to include vertical farm and container farm technologies and has vocal support and need for standardization, development, and sharing of best practices. Despite this, CEA growers face several challenges, including high energy costs and maintaining food safety when there is a high degree of material reuse and cycling (Lubna et al, 2022). Many operators fail to achieve consistent yields and profits, which can often be attributed to a lack of knowledge of the best design and management practices for their facilities (Balliu et al., 2021).

While tradeoffs are inevitable, good design, operation, and management strategies can better inform facility operators about options across a complex web of decisions (Ting et al., 2016). What is currently lacking, however, is a centralized knowledge repository for CEA enterprises that could be used by the industry to benchmark and enhance sustainability performance (ASABE, 2021a; Azzaretti and Schimelpfenig, 2022). The Controlled Environment Agriculture Design Standards (CEADS) project was launched in 2019, when CEA professionals from the private sector, government, and academia recognized the need to define goals for the sustainable advancement of the rapidly growing CEA industry.

Encompassing the management of energy, water, materials, byproducts, pests, labor, finances, and equity concerns, CEADS translates industry-vetted best practices into peer-reviewed standards for the rapidly expanding CEA industry. CEA enterprises can utilize CEADS to guide the entire planning, design, construction, and expansion phases of their growing facilities, enabling long-term business success and a more resilient and sustainable CEA industry overall. This paper discusses the sustainability challenges facing CEA, the role of standards and other approaches for improving performance, and how CEADS has developed to address these needs.

Background

The potential of controlled environment agriculture within established greenhouse industry and the emergence of the vertical farm and container farming facilities present opportunities to develop solutions that will address the grand challenges of food production facing the world with dual pressures of increasing population and reduced resources (Azzaretti and Schimelpfenig, 2022; Searchinger et al., 2018).

CEA is a well-established, profitable production practice that has developed and matured over the past century primarily in greenhouses. Now, the emergence of new lighting technologies has enabled the expansion of CEA into grow rooms, warehouses, containers, and vertical farms in urban and other areas that are not typically used for food production (Lopez and Runkle, 2017; Pattison et al., 2018; Pocock, 2016).

CEA production facilities are promising solutions to achieving a consistent and sustainable supply of nutritious and healthy food and because they are protected from the variability of the natural environment, the indoor plant growing conditions can be optimized for maximum production and quality, and where critical resources such as water and nutrients can be recycled and reused (Costa et al., 2022; Cuce et al., 2016).

Fully enclosed CEA facilities can be constructed anywhere in the world with water and energy resources and produce food and other plant bioproducts. By limiting transportation costs, minimizing water consumption, and optimizing nutrient use, CEA can be a major contributor to mitigating environmental and social issues associated with the water-food-energy nexus (Sabeh et al., 2022).

Achieving these benefits can be costly with high technology CEA facilities requiring significant capital investment, large energy inputs to provide lighting and environmental control, and a skilled labor force to achieve yield and profit potential (Lubna et al., 2022).

The growth of the CEA industry is driven by the promise of consistent, year-round production of high-quality products anywhere in the world. This promise has prompted claims of environmental sustainability, economic growth, and social stability. However, understanding complex environmental, social, and economic tradeoffs required to achieve sustainability in CEA requires a level of transparency and a multidisciplinary approach analysis that has previously not been developed (ASABE, 2021a).

With this context, the U.S. Department of Agriculture's National Institute of Food and Agriculture (USDA NIFA) sponsored a two-day CEA conference that was hosted by the University of Arizona Controlled Environment Agriculture Center (UA CEAC) at Biosphere 2 in Tucson, Arizona, 9-11 September 2019. This conference brought together stakeholders from industry, academia, and government sectors to discuss the critical issues facing vertical farms and indoor food production systems and revolved around seven major themes: Economics, Production Systems, Engineering, Plant Breeding, Nutrition and Safety, Industrial Ecology, and Pest and Disease Management.

Participants from across industry, government, and academia agreed that an opportune moment was at hand to define sustainability and develop a set of standards to guide the sustainability of the industry. Thus, a working group was established at the conclusion of the 2019 USDA NIFA AZ-CEA Conference.

The CEADS working group developed the CEADS website (https://ceads.ag) and the CEADS Version 1.0 (v1.0) Scorecard which encompassed the management of energy, water, materials, byproducts, pests, and safety, as well as broader financial implications and concerns around social equity and engagement in local communities. CEADS, Inc., was incorporated as a 501(c)(3) nonprofit in February 2021 and publicly released the first CEADS Scorecard (v1.0) in October 2021.

This publication an overview of the process for developing the sustainability criteria, creating the CEADS v1.0 Scorecard, and discussing the tradeoffs involved in defining "Sustainability in CEA."

Development of the CEADS Scorecard

CEADS provides a central repository of recommended industry curated practices and benchmarks that can be used in the design of sustainable CEA operations. The CEADS Scorecard is designed as a guide for CEA enterprises from the initial design phase to long-term operation to maximize performance and profitability aligned with economic, environmental, and social considerations.

The goal of CEADS is to provide a structure for assessing and continuously improving the sustainability and resilience of CEA facilities, using seven categories of operations/impacts for all CEA settings (from greenhouses to vertical farms) and products (food and other plant products) and providing a level of certification that standard practices are generally included and maintained.

The CEADS certification approach represents industry-vetted, peer-reviewed performance standards for the CEA industry. Achievement of CEADS certification is expected to give enterprises market validation and positioning as sustainably run CEA enterprises, which will improve a company's profile and reputation with customers, financiers, government authorities, and other stakeholders.

Concept Development

During the USDA NIFA/ University of Arizona-sponsored CEA meeting, the lack of quantifiable metrics for sustainability in CEA was identified as a critical need. A request for individuals who were interested in developing the concept was made, and an initial teleconference was held 9 October 2019 with participants from academia, industry and government, and represented the range of CEA from greenhouses to vertical farms and was international in scope.

A series of mind mapping sessions were held to identify objectives, priority areas and primary customers of CEADS. These included two key questions: 1) who are the customers and beneficiaries, and 2) what is the value proposition? The mind map guided the development of the CEADS domains and operational model for implementation.

A series of subcommittees were formed to draft an initial set of recommended practices for the domains (i.e., themes) of sustainability that were identified during these mind-mapping sessions. These even domains were 1. Crop Quality, 2. Integrated Pest Management, 3. Utilities, 4. Material and Waste, 5. Automation and Labor, 6. Equity and Localness, and 7. Profitability.

The subcommittees drafted a set of recommended practices that identified the key concepts, intentions and implementation strategies for each criterion. For each action, there were up to three levels of implementation categorized as "Good", "Better", or "Best". These criteria and implementation levels were then shared with the entire group for review and comment and discussed during a series of one-half day virtual retreats in October 2020.

The CEADS leadership team also began outreach efforts to other organizations in the US and Europe that were developing regulatory guidelines and benchmarks for operation of CEA facilities. Where regulatory guidelines had been established, those criteria were used as benchmarks in the assessment of sustainability. Where regulatory guidance was not available the adoption of best practice criteria across various disciplines was reviewed and incorporated where quantifiable and verifiable documentation of adoption could be achieved.

The sustainability criteria were further refined, and the individual sections were sent out for external review and comment to experts in industry and academia. Each expert was given a section of the criteria and invited to comment. Each of those comments was recorded and addressed by the committees prior to finalizing in the initial version.

A public announcement of the CEADS v1.0 Scorecard was made on 4 October 2021 in Orlando, Florida at Indoor AgCon.

The Seven CEADS Domains of Sustainability

Defining criteria

Each CEADS subcommittee was tasked with developing an introduction to the domain, establishing and rationalizing the categories, and either scoring criteria based on existing standards/certifications or identifying knowledge of the state of the art. The template is shown in Table 1.

Table 1: Domain Template for Establishing Certification Criteria

Category	Concept	Action	Intention	Implementation
Type of CEA system – operation, facility, project, business, or other – for which this information is relevant (i.e., Indoor Farm Operations, Greenhouse Construction, Labor Management, Food Distribution, etc.)	Issue relevant to domain that applies to specified CEA system	Desired action on part of the CEA system. Think of this as a LEED "credit."	Justification for that desired action. Include other domain names here if relevant	One or more recommendations for how that action could be achieved by CEA system (with references, links, etc. if needed)

Domain 1: Crop Quality

The Crop Quality domain lists and describes the Category and Concept of the desirable characteristics of products grown in CEA facilities and the strategies needed to obtain these characteristics within CEA environments. It includes strategies that enhance the quality and nutritional/medicinal/other attributes of CEA crops (Gould et al., 2022). The high-level categories are Safety, Quality, and Traceability. Product Quality was further categorized into Nutritional quality of food crops, physicochemical quality of non-food crops, genetic material, growth conditions, health management, and post-harvest handling (Table 2).

Table 2: Top Level Categories and Concepts for Domain 1: Crop Quality

Category	Concept
Safety	Food Safety
Quality	Nutritional Quality of Food Crops
	Phytochemical Quality of Non-Food Crops
	Genetic Material
	Growth Conditions
	Plant Health
	Post-Harvest Quality
Traceability	Tracking of Crop Conditions

Domain 2: Integrated Pest Management

The integrated pest management domain incorporates prevention and mitigation measures with workers, system, and environmental safety standards to control disease, pests and contamination in CEA facilities (Baudoin et al., 2013). IPM ideology features biological, cultural, mechanical/physical, and chemical pillars, which together aim to manage pests while fostering system and environmental stewardship and sustainability. Table 3 provides the categories and concepts for Integrated Pest Management Domain.

Table 3: Top Level Categories and Concepts for Domain 2: Integrated Pest Management

Category	Concept
Pest Avoidance	Pest Identification
	Outbreak Prevention
Pest Mitigation	Threshold establishment
Pest Management	Outbreak Mitigation measures
	Data recording and sharing
	Protection of employees and facility

Domain 3: Resource Utilization

The Resource Utilization domain focuses on the effective and efficient use of electrical, water, and heating fuel resources to minimize inputs and maximize efficiency and profitability in a sustainable manner. This domain guides the selection of sole and supplemental lighting fixtures (Nelson and Bugbee, 2014); water and nutrient infrastructure (Sabeh et al., 2022); generation and distribution of carbon dioxide (Ahmed et al., 2022); and the minimization of volatile contaminants affecting plants and humans (ASABE, 2021b). Table 4 shows the top-level categories and concepts for the Resource Utilization domain.

Table 4: Top Level Categories and Concepts for Domain 3: Resource Utilization

Category	Concept
Energy	Energy Sources
	Energy Storage and Recovery
Water	Water Sources
	Water System
	Water Quality
Lighting	Electrical light energy to support plant growth
CO_2	CO2 sources
	Carbon Footprint
HVAC	HVAC system design
	HVAC system operation

Domain 4: Materials and Waste

The Materials and Waste domain focuses on the reduction, reusage, and recycling of resources used in CEA operations to maximize output per input. These criteria pertain to construction materials, growing methods, consumables, and packaging (van Tuyll et al., 2022). The top-level categories and concepts are shown in Figure 5.

Table 5: Top Level Categories and Concepts for Domain 4: Materials and Waste

Category	Concept

Materials	Infrastructural materials
	Growing operation materials
	Produce packaging and transport materials
Waste	Post-harvest
	Drain water and run-off management
	Organic byproduct management
	Infrastructure maintenance and renovation

Domain 5: Automation and Labor

The Automation and Labor domain includes the strategies that balance effective use of automation with human labor in CEA facilities are included here (Afzali et al., 2021; Chen et al., 2022). Automation, including mechanization, is used by CEA growers for precision growing and enables growers to increase resource use efficiency, reduce waste, and steer crops using continuously available data-driven decisions (Neo et al., 2022). The top-level categories and concepts for the Automation and Labor Domain are shown in Table 6.

Table 6: Top Level Categories and Concepts for Domain 5: Automation and Labor

Category	**Concept**
Conditions for Growth	Root Zone Environment
	Aerial Environment
Production Processes	Growing System Operation
	Transplanting
	Harvest and Post Harvest Handling
Maintenance	Canopy Management
	Facility maintenance and storage
Worker safety, health and awareness	Equipment and Machinery Operation
	Fires hazards
	Air Quality
	Security
	Work task ergonomics

Domain 6: Equity and Localness

The Equity & Localness domain promotes mutualistic relationships between a CEA facility, other businesses, and the communities in which the facility operates (Sonnitno, 2010). These criteria include listing the location of the facility decisions, stakeholder engagement, employment, and economic development. It is particularly relevant to locations where large segments of residents are physically, politically and/or economically disenfranchised. The top-level categories and concepts for Equity and Localness are shown in Table 7.

Table 7 : Top Level Categories and Concepts for Domain 6: Equity and Localness

Category	**Concept**
Economic mobility	Siting
	Ownership and Governance
Employment	Targeted hiring
	Career development; continuing education
	Fair wages
Community relationships	Community Involvement
	Community outreach
Collaborative business relationships	Connection to other businesses
	Information sharing

Domain 7: Profitability

Profitability is an essential component of sustainable agricultural production systems. This domain addresses profitability by providing a hierarchy of factors to consider from the initial development to the establishment of an economically sustainable CEA enterprise. As the ultimate success of a CEA production facility hinges on demand preferences and capacity, top level categories of the profitability domain include the selection of a geographic area to operate, types of crops to produce, including quality determinants, size of markets and prices, and how to better use local supply chains and structure product distribution. Furthermore, appropriate definition of a business model and careful selection of sources of capital must secure the financial health of the enterprise. Finally, the economic sustainability in the medium to long-term depends on well-established distribution systems, access to labor resources, and continuous monitoring of operational costs and potential trade-offs between operational costs and capital investments. Ultimately, the achievement of profitability will enable long term success and sustainability of a CEA enterprise. The top-level categories and concepts for profitability are shown in Table 8.

Table 8: Top Level Categories and Concepts for Domain 7: Profitability

Category	**Concept**
Site Selection	Legal Requirements
	Electricity Costs
	Distribution system location
Production	Crop choice
	Growing systems
Distribution	Distribution system process
Labor	Local labor resources
	Training
Capital	Sources of Capital
	Forms of Capital

Markets	Supply Chain
	Choice of Markets
Business Model	Business goals
	Business partnerships
	Business size, structure and products
	Corporate/business relationships
Trade-offs	Operational vs Capital Costs
	Labor vs Technology investments

CEADS v1.0 Scorecard

The CEADS v1.0 Scorecard is the initial iteration of an ongoing process for providing objective and quantifiable metrics of sustainability for the complex production system. The overriding assumption is that sustainability is not achieved with any single action, but through the totality of the decisions and actions taken during the design, construction and operation of a CEA facility.

It is also recognized that each CEA is unique to its crop, location, operator experience and market. For example, the options available for lighting are different for an indoor cannabis facility versus those for a hydroponic greenhouse lettuce producer (Graamans et al., 2018) and the optimal HVAC solutions are different in the hot dry climate of the desert (Sabeh et al., 2007) versus those in a hot humid environment (Wei and Chen, 2022).

A considerable effort was made to make the CEADS v1.0 Scorecard crop and location agnostic. CEADS was designed to guide the decision making of a hydroponic crop grower dependent on sunlight (Robson et al., 2022) as well as a highly automated indoor vertical farm depending on sole source LED lighting (Mitchell and Stutte, 2015).

Each of the actions in the CEADS v1.0 Scorecard domains was based on the intention of the action and mechanism of implementation to achieve implementation. It was recognized that multiple levels of implementation are available for each criterion, and they were categorized as “Good”, “Better”, and “Best”.

- “Good” is determined to be the minimum requirement to be considered a viable practice.
- “Better” is implemented at level indicating recognition and implementation of technology and best practices,
- “Best” is determined to be best-in-class.

Where possible, these criteria are anchored against existing certification or regulatory criteria such as construction materials, water use efficiency, and electrical efficiency. Documentation requirements for each of those Actions are also provided within the domain.

Example of Use of CEADS v1.0 Scorecard

The CEADS v1.0 Scorecard is a set of best practices intended for use in evaluating the sustainability performance of CEA facility designs.

The CEADS v1.0 Scorecard includes action items pertaining to an enterprise's considerations of and commitment to people, planet, and profit.

The action items include up to three performance levels (Good, Better, and Best), and the overall performance is calculated based on applicable actions.

Upon review of the completed Scorecard by CEADS, facilities will be offered the opportunity to obtain CEADS Certification at the qualifying level.

A set of instructions (Figure 1) is provided within the Scorecard to guide the user in the self-assessment of their facility.

How to Use the CEADS v1.0 Scorecard:

1. For each line, determine if action item applies to facility.
- If not, select "0" in Column B drop-down menu for that action.
- If so, leave default selection as "1" to include item in evaluation calculation.

2. For each applicable action, determine facility's level of implementation.
- Select level of implementation (1, 2, or 3) in Column A drop-down menu.
- Prepare supporting documentation if applicable for each action item.

3. Review facility's evaluation score calculated at the end of the Scorecard.

Figure 1: Instructions on how to use the CEADS v1.0 Scorecard to Assess Sustainability

The CEADS v1.0 Scorecard is facility agnostic, as it enables the user to determine whether a set of scoring criteria are applicable to their case or not. The first action required by a user to determine whether a particular criterion is applicable to their facility or not with 1=yes/0=no, followed by an assessment of the facility's level of implementation.

An example taken directly from the CEADS v1.0 Scorecard for the lighting system is described below and shown in Table 9.

Lighting falls under the Category of Domain 3: Resource Utilization (RU-3)
The first concept of lighting is "Electrical light energy to support plant growth" (RU-3.1), which has three criteria for assessing the sustainability of the system: "Choose energy efficient light sources" (RU 3.1.1), "Minimize energy use for lighting for target application" (RU 3.1.2) and "Optimize facility lighting efficiency (FLE)" (RU 3.1.3).
These criteria are applicable to a vertical farm using LED lighting, an indoor cannabis facility implementing double ended HPS lights, and a greenhouse using supplemental lighting to achieve desired light quantities, but not to a greenhouse that is solely dependent on sunlight.

Table 9: Example of CEADS v1.0 Scorecard for the assessment of sustainability of the lighting regime in Domain 3 (Resource Utilization)

YES	ACTION IS APPLICABLE? (1 = YES, 0 = NO)	NOTES	CATEGORY	CONCEPT	ACTION	INTENTION	IMPLEMENTATION	LEVELS OF IMPLEMENTATION	SUBMITTAL DOCUMENTATION		
	1		**RU-3**: Lighting	**RU-3.1**: Electrical light energy to support plant growth	**RU-3.1.1**: Choose energy efficient light sources	Encourage CEA operations to select energy efficient lighting systems	Select lighting fixtures with high photosynthetic efficiency (PPE)	**GOOD**: PPE is equal to or greater than 1.7 µmol/J.	List of lighting fixtures and relevant technical information (PPE rating) from manufacturer	1	3
								BETTER: PPE is 25% higher than DLC singular standard for PPE (currently 2.4 µmol/J).		2	
								BEST: PPE is 50% higher than DLC singular standard for PPE (currently 2.9 µmol/J).		3	
	1				**RU-3.1.2**: Minimize energy use for lighting for target application	Design efficient use of lighting in crop production systems	Optimize lighting power density (LPD) with proper light fixture placement. Lighting power density is W/ft^2 of canopy.	**GOOD**: LPD is between 51 and 60 W/ft^2.	Description of design strategies used to optimize LPD; documentation of LPD analysis	1	3
								BETTER: LPD is between 36 and 50 W/ft^2.		2	
								BEST: LPD is less than 36 W/ft^2.		3	

	1				**RU-3.1.3**: Optimize facility lighting efficiency (FLE)	Encourage energy efficiency with optimized operation of lighting system	Describe how facility lighting system operation optimizes energy efficiency, and provide estimates on FLE	**GOOD**: Power monitoring system for lighting is installed.	Description of operational strategies used to optimize FLE; documentation of FLE analysis (kg/kWatt/ft^2)	1	3
								BETTER: Active control of power to lighting system is installed.		2	
								BEST: Lighting power management is integrated with facility power management.		3	

The scorecard automatically adds and subtracts points from the total available in each category, and as such does not penalize a facility based on its operating model.

Each of the Actions has a score of 1 for "Good", 2 for "Better", and 3 for "Best". The total score is automatically scored, and the percentage of points for the criteria applicable to the facility are summarized, and the certifications awarded in Table 10.

Table 10: CEADS certification level thresholds.

CEADS Certification Levels	Required Achievement (Percentage of Total Applicable Points, %)
CERTIFIED	50-59
SEEDED	60-69
ROOTED	70-79
CULTIVATED	80 or higher

The points are broken out into categories and the owner/operator can identify areas of strengths and weaknesses. Assuming that all the criteria are applicable, the following number of points and relative percentages are applied (Table 11).

Table 11: Total points and the overall percentage of points for each of the CEADS v.1.0 Scorecard domains.

Domain	Possible Points	Percentage of Total Possible Points
Crop Quality	50	11.2
Integrated Pest Management	45	10.1
Resource Utilization	54	12.1
Materials and Waste	57	12.7
Automation and Labor	117	26.3
Equity and Localness	48	10.8
Profitability	75	16.8
All Domains	446	100

The relative value of each of the seven domains will be dependent on the applicability of the criteria to the individual CEA facility.

CEADS and the Circular Bioeconomy

The selection and the weighting of the seven domains place the emphasis of sustainability squarely on the totality of the facility, and not on the selection of a single component, process or piece of equipment.

The utilization of efficient lighting systems, properly sized HVAC systems, and re-utilization and recovery of water resources are highly desirable, and indeed encouraged and rewarded with the CEADS v1.0 Scorecard. However, these innovations are not the sole focus of the CEADS scoring system.

The CEADS v1.0 Scorecard attempted to establish quantifiable metrics and reward a CEA facility's effort at integrating into a local community through co-utilization of resources, upcycling and recycling byproducts, appropriate balancing of automation and local labor, and decision making that promotes long term success and sustainability. When making decisions that are appropriate for location, utilize local resources, and strive to achieve equity across all domains, then the ultimate potential for CEA to provide year-round healthy food and medicine for a growing population, even in locations with less favorable climates, can be achieved.

Summary

CEA is a technology-based approach to crop production within farming techniques that has the potential to optimize environmental conditions for plant growth while minimizing the use of resources such as land, energy and water. The creation of conditions results in complex growing systems allowing for a significant improvement in produce quality and continuous, year-round production anywhere on Earth.

Although CEA facilities can take on many forms, they all share unique technical advantages that have positioned CEA to transform agriculture in urban environments, achieve sustainable food supplies, and create circular bioeconomies.

A sustainability strategy cannot be copied across the types of CEA systems in different climates. Locale climate, water, energy and social conditions must be the guide in the design and operation of CEA facilities.

CEADS v1.0 Scorecard codifies seven domains of sustainability of energy, water, materials, byproducts, pests, labor, finances, and equity concerns, translating industry-vetted best practices into quantifiable peer-reviewed benchmarks that can be documented and certified.

CEA enterprises can utilize CEADS to guide the entire planning, design, construction, and expansion phases of their growing facilities, enabling long-term business success and a more resilient and sustainable CEA industry overall.

CEADS v1.0 Scorecard provides the CEA industry with the framework to benchmark their sustainability goals, a roadmap to advance research, and a certification program to validate those efforts to investors and consumers.

Additional information on CEADS and the v1.0 Scorecard can be accessed at https://ceads.ag.

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