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Controlled Environment Agriculture (CEA) Production

The 2018 farm bill (Agriculture Improvement Act of 2018, P.L. 115-334) expanded support for “urban agriculture and innovative production methods like indoor and rooftop farming.” In a Joint Explanatory Statement, the farm bill conferees acknowledged the potential for urban and innovative production methods to create new market opportunities for agricultural communities, expand access to fresh food in low-income communities, improve availability of fresh products year-round, and “help build a new generation of farmers.” The 2018 farm bill also expanded some existing programs administered by the U.S. Department of Agriculture (USDA) to support innovative and emerging crop production methods. These actions have expanded USDA’s attention on a range of nonconventional farming practices including Controlled Environment Agriculture (CEA). Congress may consider amendments to these programs as it debates farm bill reauthorization.

CEA-Related Terms and Definitions

Innovative and emerging crop production encompasses a variety of cultivation techniques and alternative modes of production compared to that of more traditional outdoor open-field production in a mostly land-based rural environment. Examples of some of the types of innovative and emerging systems include indoor vertical technology operations, outdoor vertical production systems such as rooftop farms and green walls, and high-technology shade or greenhouse production. These types of operations may involve large capital-intensive production systems that grow crops throughout the year as well as smaller-scale community-based operations located in urban, suburban, and peri-urban areas or in urban clusters that grow crops for a mostly local or nearby consumer market.

Myriad definitions exist of *controlled environmental agriculture* (CEA) from various land-grant universities, system developers, and trade organizations. CEA production systems are not defined in statute or regulation. CEA generally refers to the growing of crops and plants in a protected and controlled environment, often indoors and using advanced technologies and intensive growing conditions throughout the year. Common indoor techniques may employ a vertical grow system using a soil-less system such as *hydroponic*, *aeroponic*, or *aquaponic* production systems (**text box**). CEA may also be soil-based, growing crops in greenhouses, hoop houses, growth chambers, or shade structures as well as the use of mulches, plastic film, nets or row covers to protect field-grown crops.

CEA systems are designed to create optimal growing conditions for and maximum productivity of crops and plants, usually in an intensive closed-loop system. Most systems employ artificial lighting and water and ventilation controls to allow for the stable control of environmental

factors such as temperature, light (intensity and quality), air movement, humidity, carbon dioxide levels, and damage from disease and pest infestations. Some advanced systems are fully automated and employ robotics. Some systems may integrate blockchain with system sensors, for example, to chronologically record and provide more precise crop treatments (e.g., light, fertilizers, systems controls) as well as record steps in the supply chain (e.g., harvest date, packaging, transport). Accordingly, advanced technology-based CEA systems require knowledge of engineering, chemistry, plant science and physiology, horticulture, plant pathology and entomology, and computer systems. CEA systems, however, may be scaled for smaller-sized installations at local community grow operations or schools.

Selected CEA Production Systems

- **Hydroponic systems:** Growing plants without soil using a water-based nutrient solution.
- **Aeroponic systems:** Growing of plants by suspending their roots in the air and regularly misting the roots with a water and nutrient solution.
- **Aquaponic systems:** Combines plant growing with fish or aquaculture production using wastewater from the aquatic species to fertilize a connected plant system.
- **Vertical systems:** Growing crops in vertically stacked layers on top of each other or in tall towers (rather than horizontal open-field rows). Vertical farming may use soil or soilless techniques such as hydroponics or aeroponics.

Many have documented the challenges associated with CEA systems. These include typically high initial capital investment and variable costs, high energy demand and any associated carbon emissions, water availability, plant pest and disease challenges, disposal of chemical fertilizer and nutrient waste, and the need for a technically skilled labor force. Others point to the benefits of CEA systems and its potential to supplement traditional open-field farming. Benefits include protection against weather-related grow challenges, more precise targeting of production inputs (water, land, and other natural resources), opportunities for higher yields and overall output (given the efficient use of space and tight planting densities), less weed management, decreased prevalence of some food safety concerns, reduced food loss and waste, and the ability to grow crops year-round often with multiple harvests per year (reducing seasonality and supply variability). Some further highlight possible environmental and societal benefits. These include reduced land use, ability to grow crops on nonarable land (where soil may be unsuitable), reduced use of pesticides and herbicides, less runoff and soil erosion (compared to some open field operations), reduced transportation needs

(if operations are located near consumer markets), and opportunities for local food system development.

Overview of CEA Sector

The 2018 farm bill directed USDA to conduct “data collection of urban, indoor, and emerging agricultural production (§7212). Congressional appropriators have also directed USDA to collect data on these types of operations in the periodic *Census of Agriculture* (H.Rept. 116-107). USDA does not currently maintain data and information on urban, indoor, and emerging agricultural production, including the use of CEA or vertical farming systems.

A 2021 USDA-commissioned report found that nearly 3,000 fruit and vegetable operations grow crops under CEA-type protection, accounting for 2-3% of the value of U.S. crops. This estimate excludes mushroom and indoor cannabis production or aquaculture. Leading CEA-grown crops are typically higher-value crops such as leafy greens, herbs, microgreens, berries, vine vegetables (cucumbers, tomatoes, peppers), mushrooms, flowers and nursery crops. Some industry estimates suggest there may be more than 2,000 vertical farming operations in the United States.

CEA operations represent a diverse range of systems and practices, spanning large capital-intensive operations and smaller-scale community-based operations. Larger-scale operations tend to be commercial grow operations and/or proprietary technology and growing platform developers. Some are publicly-traded companies. Hybrid operations that both grow crops and are engaged in research and development (R&D) as technology developers might grow crops mainly for demonstration or investment purposes (i.e., not directly engaged in commercial farming). Some companies operate plant science research facilities.

In the past year, the CEA sector has been marked by high-profile operation closures, layoffs, and bankruptcies both in the United States and globally. Among the cited reasons for these current challenges is a perception that the sector may have been built out too quickly given the initial sizable influx of venture capital and private investment funds in recent years. This has caused some companies to become financially overleveraged. Some identify exaggerated expectations for growth in the marketplace. Others cite a perceived tendency to prioritize R&D and emphasize the construction of ever-larger grow facilities without a focus on business fundamentals, market testing and viability, and efforts to reduce high start-up and variable costs in the sector. While some claim recent bankruptcies, layoffs, and closures represent an inevitable market correction, this has raised questions about the near-term viability of the sector.

Provisions in Farm Bill Legislation

Congress expanded support for innovative and emerging agriculture in the 2018 farm bill. It created the Urban Agriculture and Innovative Production (UAIP) to encourage and promote urban, indoor, and emerging farming practices, and also authorized UAIP project grants (§12302; 7 U.S.C. §6923). It further authorized competitive grants supporting research, education, and extension activities for the sector (§7212; 7 U.S.C. §5925g). Congress also established a micro-grants program to support locally-grown food,

including the use of CEA practices as part of a small-scale production in food insecure areas (§4206; 7 U.S.C. §7518).

Other existing USDA programs may support CEA systems, even if not explicitly so. In general, CEA operators may access USDA grants and loans broadly available to U.S. farmers; however, most federal grants and loans tend to target smaller-sized businesses and may be insufficient to meet the needs of larger CEA growers/developers. For example, grants under the Local Agricultural Marketing Program (LAMP) mostly target locally-based operations and Small Business Administration loans target small business. CEA developers might also not be eligible for USDA farm loans that target family-sized farms and ranches. Support for high-tunnels and energy efficiency practices may be eligible under USDA conservation programs. Educational and technical support also is available through USDA’s Urban Agriculture Office or county cooperative extension offices. For background on USDA and other federal programs, see CRS Report R46538, *Local and Urban Food Systems: Selected Farm Bill and Other Federal Programs*, and CRS Report R47387, *Federal Economic Development Resources for Food Businesses and Systems: In Brief*.

USDA has continued to commission research supporting CEA growers. Leading research areas cover hydroponic and vertical farming growing applications; LED light spectrum impact analysis on plant growth; use of renewable energy; nutrient optimization; plant pathology; plant breeding and selection; pollinator experiments; and automation processes. USDA is also supporting projects to improve CEA efficiencies, lower the carbon intensity of resource inputs, educate consumers and producers to CEA products and practices, and develop CEA “best practices” guides.

Considerations for Congress

At a March 2022 House Committee on Agriculture hearing, a CEA representative stated there are opportunities to support CEA “in nearly every title” of the farm bill. Recommendations focused the Horticulture and the Research titles, but noted opportunities in the Nutrition, Credit, Rural Development, and Energy titles. Two recommendations were (1) expand LAMP to explicitly cover CEA and indoor vertical farming; and (2) increase funding for USDA’s research and extension support for urban, indoor and emerging agriculture. Others note opportunities for CEA in programs such as the Small Business Innovation Research program and initiatives that leverage public and private research partnerships. Other legislative priorities have been put forward by the trade association, CEA Alliance. Its legislative priorities include ensuring CEA producers are specifically eligible for USDA loans and grants, ensuring CEA’s eligibility under USDA’s rural development and conservation programs, and expanding USDA’s Specialty Crop Research Initiative to prioritize innovation and technology and increase research and extension services for CEA systems. CEA Alliance also recommends codifying USDA’s Food Supply Chain Guaranteed Loan program that was part of the Biden Administration’s Build Back Better Plan. Congress may consider these and other options as it debates the farm bill.

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