Controlled Environment Agriculture Strategy and Roadmap in GO Virginia Region 3

Virginia Tech Center for Economic and Community Engagement

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Executive Summary

On behalf of the Institute for Advanced Learning and Research, and with support from an Enhanced Capacity Building award from GO Virginia Region 3, the Virginia Tech Center for Economic and Community Engagement conducted a study to assess the economic growth potential for the controlled environmental agriculture (CEA) industry in Region 3, and the state of Virginia.

CEA, as a sector, is poised for additional growth. CEA refers to the utilization of technology and automation to enhance the indoor growing conditions for crops, fish, and related products. The industry is projected to grow 10.32% annually, reaching $239.8 billion by 2027. The economic potential of CEA includes the attraction, growth and retention of industry prospects; the support of start-ups and smaller-scaled CEA operations; and the potential in support and related sector firms, from lighting to sensor technologies. Jobs in CEA tend to be higher-paying, higher-skilled, and more varied than traditional agriculture and food production

Region 3, and Virginia, are well-positioned for CEA industry attraction and sector growth. Region 3 is centrally located with proximity to major urban markets across the mid-Atlantic and South. Firms in region 3 can reach up to 70% of the country's population within a two-day drive. Region 3 attracted AeroFarms, and its $42 million plus investment to build the world's largest aeroponic vertical farm. Region 3 is also home to Blue Ridge Aquaculture, Virginia's earliest CEA-related company. As a state, Virginia is newly focused on the CEA-sector. VEDP now boasts a dedicated CEA marketing effort and web-page. VDACS is one of the few state agencies in the nation with an extensive CEA focus and a specific agribusiness grant/funding program. Moreover, Virginia Tech and IALR are cited as one of the top selling points for CEA prospects and serve as resources for start-ups and existing producers as well.

Region 3 has some gaps, or needs, to better position itself for continued CEA-related growth. CEA is still poorly understood as companies vary widely in terms of scale, focus, type and needs. Region 3 has a low supply of available "prospect-ready" sites for CEA firms, with only two sites rated Tier 4. The talent pool for higher-wage CEA jobs needs to be grown (from engineers, to technologists, to plant scientists). Existing entrepreneur and start-up resources are diffuse and may lack CEA-specific understandings and focus. There is also a strong need to develop financial benchmarks and criteria for better assessing and guiding CEA operation scale-ups.

To best position Region 3, and Virginia, for continued CEA sector growth, this study identifies an inter-related set of recommendations in six strategic areas. Our top recommendation is for a CEA Hub to lead and advance these strategies in Region 3 and across the state, but there are sub-actions within each recommendation that could be pursued separately. These recommendations consider CEA broadly, as a full spectrum of activities. The six overarching strategic areas are to:

1. Develop and implement a **comprehensive CEA Hub initiative**, in conjunction with or led by IALR and the CEA Innovation Center.
2. Conduct **CEA Awareness and Informational Campaign**
3. Enhance **CEA-specific new venture and new enterprise development** assistance

4. Continue and **expand CEA Technical assistance** offerings to firms and to policy-makers and economic developers
5. **Accelerate Region 3 Site Development** with CEA targets in mind
6. **Continue and Enhance Region 3 CEA-relevant Workforce Development and Talent Attraction** Activities

CEA represents an area of tremendous economic opportunity and growth potential for Virginia. The AeroFarms and Plenty investments in the Commonwealth are evidence of this. However, some caution is in order as even these large-scale investments are accompanied by uncertainties given some notable losses or setbacks within the industry. There are also barriers to entry and growth for entrepreneurs and existing companies in the CEA space. Still, Region 3 has unique assets (such as the CEA Innovation Center at IALR and geographic centrality to markets) that create a competitive advantage. Still, *each individual CEA operation is unique and needs to be assessed on its own merits and requires specialized assistance related to its own customized approach to CEA*. Technical know-how is required on the business side as well as on the technology side. This is one role that a robust Virginia CEA Hub initiative could help play.

Introduction

The Virginia Tech Center for Economic and Community Engagement (CECE), in partnership with the Institute for Advanced Learning and Research (IALR) analyzed the potential development of the controlled environmental agriculture (CEA) industry in the state of Virginia and GO Virginia Region 3.

Overview of CEA

Controlled environmental agriculture (CEA) is a combination of engineering, plant and animal science, and computer-managed greenhouse control technologies used to optimize plant and aquatic animal growing systems, quality, and production efficiency. CEA can range from simple structures, to greenhouses, to fully automated systems with controlled lighting, water, and ventilation installed. The technology is designed to optimize growing conditions for crops and fish indoors; decrease pesticide and water use, and allows for year-round production close to consumers to minimize transportation time and carbon footprint of the products. .

There are different types of growing environments CEA can take place in:[1]

- **Indoor growing/Indoor farming:** Crop production that uses LED lighting rather than sunlight and allows growers to control the environment in a room, warehouse, container, factory, or other converted indoor spaces.

[1] Autogrow. (n.d.). What is controlled environment agriculture? Link.

- **Vertical farming:** Growing systems that stack plants horizontally or in tall towers. This type of farming is beneficial for smaller spaces, as it requires less land to cultivate produce.
- **Greenhouse:** Factors of the environment are controlled, but the system uses sunlight for crop production.

There are also different types of growing methods that can take place in these different environments:

- **Hydroponics:** Growing plants without soil while still providing water but using significantly less in the process. Crops grown using this method include microgreens, leafy greens, tomatoes, peppers, strawberries, herbs, and cannabis.
- **Aeroponics:** Growing plants without soil and using little water. The roots of plants are suspended in the air and sprayed with a water solution. Crops grown using this method are typically used in greenhouses.
- **Aquaponics:** Growing plants using a combination of aquaculture (raising fish) and hydroponics. The fish assist in delivering the nutrients to the plants. Fish used in this method include tilapia, perch, catfish, and trout.

As the impacts of climate change continue, disruptions to traditional agricultural production and supply chain systems are at an increased risk.[2] CEA has potential to provide high-quality and safe food year-round close to the consumer, using advanced technology and a highly skilled workforce.

As CEA continues to grow and demand increases for sustainable, locally grown food, Virginia can prioritize this industry and become a strategic location for CEA companies. Virginia has existing assets, such as its mid-Atlantic location near major markets, access to a skilled talent pipeline, and ability to work with partners such as the Virginia Department of Agriculture and Consumer Services (VDACS) and the CEA Innovation Center at the Institute for Advanced Learning and Research (IALR).

In the 2019 Growth and Diversification Plan update, the GO Virginia (GOVA) Region 3 Council established that it has priority to invest in projects that align with its strategies and strengths; CEA shares many similarities to advanced manufacturing and there is great potential in high-value natural resource production, entrepreneurship, and talent development, making this an attractive industry for the region to target. Additionally, with Aerofarms announcing a $42 million investment to build the world's largest aeroponic vertical farm in the region, there is an opportunity to further grow this industry in the region.

Identifying strategies and creating a roadmap to assist industry growth and workforce development in CEA can provide the necessary steps to support local businesses and determine the needs and opportunities in GOVA Region 3.

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[2] UC Davis College of Agricultural and Environmental Sciences. (2021). What is Controlled Environment Agriculture? *University of California, Davis.* Link.

CEA Industry in the U.S. and Beyond

Literature Review

In 2021, 55% of the world's population lived in urban areas, which is expected to increase to 68% by 2050.[3] For food supply to keep up with urban population growth, the agricultural industry and food systems will have to change, adapt, and grow to account for this population increase. Already, agricultural producers are locating closer to urban consumers to capitalize on the growing markets in these areas while decreasing supply chain challenges.[4] Controlled environmental agriculture (CEA) methods can help create more sustainable solutions to improve food security and locate produce farming closer to urban areas by using greenhouses and, often, vertical farming.

Current State of Industry

In 2021, the global CEA industry was estimated to be valued at $132.99 billion.[5] The industry is projected to grow 10.32% annually, reaching $239.8 billion by 2027.[6] The global hydroponic system market is valued at $12.1 billion, and the global hydroponic crop market is estimated to be valued at $37.7 billion in 2022.[7] Currently, the top market is found in Europe, accounting for 27% of the CEA industry, followed by Asia and North America.[8] The Netherlands holds the world's highest adoption rate of CEA, with over 80% of flower and vegetable production done with hydroponics.[9] Current applications of CEA are mainly focused on hydroponics, with aquaponics expected to grow by 2027.[10]

In Europe, the CEA industry has expanded over time due to a drop in prices of LED lights, a growing consumer demand of fresh, local produce with limited inputs, and higher

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[3] Financial News Media. (2021, Oct). Global Controlled Environment Agriculture Market Expected to Reach $172 Billion in 2025. *PR Newswire.* Link.

[4] Financial News Media. (2021, Oct). Global Controlled Environment Agriculture Market Expected to Reach $172 Billion in 2025. *PR Newswire.* Link.

[5] Research and Markets. (2022). Plant Factory Market Research Report by Facility Type, Technology, Crop Type, Application, Region – Global Forecast to 2027 – Cumulative Impact of COVID-19. Link.

[6] Research and Markets. (2022). Plant Factory Market Research Report by Facility Type, Technology, Crop Type, Application, Region – Global Forecast to 2027 – Cumulative Impact of COVID-19. Link.

[7] Research and Markets. (2022). *Hydroponic Market by Type, Equipment, Input, Crop Type, Farming Method, Crop Area, and Region – Global Forecast to 2027.* Link.

[8] Maximize Market Research. (2022, May). Controlled Environment Agriculture Market (2021 to 2027) – Growing Opportunities, Market Driving Factors, Trends, Barriers for the Marker, and Forecasts. Link.

[9] Research and Markets. (2022). *Hydroponic Market by Type, Equipment, Input, Crop Type, Farming Method, Crop Area, and Region – Global Forecast to 2027.* Link.

[10] Maximize Market Research. (2022, May). Controlled Environment Agriculture Market (2021 to 2027) – Growing Opportunities, Market Driving Factors, Trends, Barriers for the Marker, and Forecasts. Link.

entrepreneurship, specifically in cannabis production.[11] Particularly, the Netherlands has experienced success in CEA due to a growing need for year-round farming for a continuous supply of products, contributing to the growth of large companies such as PlantLab and GrowX. Collaborative initiatives like Urban Farming Partners and Infinite Acres work with other global companies, like 80 Acres Farms in the U.S., to provide services and expand farms.[12] Other examples of innovative approaches to vertical farming include investments made by Ikea launching their own vertical farming kit and investing into AeroFarms, and both food-service providers and retail stores growing their own herbs and microgreens in-store to shorten the supply chain.[13]

Projections and Trends

Large-scale trends, including anticipated impacts of climate change, growing consumer preference for sustainably grown produce, retailers diversifying supply to have produce sourced year-round, and the legalization of cannabis, have all contributed to the growth of the CEA industry.[14] Social forces are the strongest reasons for support of the industry, as consumers are increasingly worried about food shortages, climate change, and transparency in production practices.[15]

In the past, the focus in CEA was on testing emerging technologies; now, this focus has expanded to capital investments so that companies can strengthen their financial capabilities.[16] Large endorsements means that companies can afford better technology and labor, therefore producing more yields. For example, the Bill-Gates-backed Cascade Investment Group has invested in Soli Organics, and the Walmart corporation is supporting Plenty.[17] Large investors are changing the future of CEA.

Requirements for Industry and Site Selection

Starting a CEA farm requires three main elements: operational expertise, distribution, and capital.[18] Without these three factors, the likelihood of a CEA farm having success is

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[11] Butturini, M. & Marcelis L. (2020). Chapter 4 – Vertical Farming in Europe: Present Status and Outlook. In *Plant Factory: An Indoor Farming System for Efficient Quality Food and Production* (pp. 77-91). Wagenngen University. Link.

[12] Butturini, M. & Marcelis L. (2020). Chapter 4 – Vertical Farming in Europe: Present Status and Outlook. In *Plant Factory: An Indoor Farming System for Efficient Quality Food and Production* (pp. 77-91). Wagenngen University. Link.

[13] Butturini, M. & Marcelis L. (2020). Chapter 4 – Vertical Farming in Europe: Present Status and Outlook. In *Plant Factory: An Indoor Farming System for Efficient Quality Food and Production* (pp. 77-91). Wagenngen University. Link.

[14] Walter, P., Wilson, R., & Saavedra, S. (2020, Dec). *Controlled Environment Agriculture: A Futuristic Fix for the Food System*. LEK. Link.

[15] Janiec, C. (2022, Feb). *Controlled environment ag moves onto the next growth phase*. Agri Investor. Link.

[16] Janiec, C. (2022, Feb). *Controlled environment ag moves onto the next growth phase*. Agri Investor. Link.

[17] Janiec, C. (2022, Feb). *Controlled environment ag moves onto the next growth phase*. Agri Investor. Link.

[18] Tasgal, P. (2020, Nov). The three-legged stool: A feasibility analysis for starting a CEA farm. *AgFunder News.* Link.

significantly lower.[19] Considerations for site selection for greenhouses and vertical farms include water accessibility, level ground, reliable utilities, such as telephone services and electricity, access to major highways and transportation networks, and access to an educated local workforce.[20] Geographic location is a major consideration for building a vertical farm: the closer a farm is located to an urban center, the less transportation is required—cutting down costs.[21] In Virginia, the Danville-Pittsylvania County area is within a day's drive to 60% of the U.S. population, making this a strategic location to distribute food in a shorter time frame.[22]

The presence of supporting industries that produce CEA-related technologies can also be a factor to consider. Liquid-systems technology accounts for the largest market share in technology, with major systems adopted from the Netherlands, Spain, and France.[23] HVAC systems account for the second largest market share-- HVAC equipment is essential to maintaining the ideal conditions needed for plant growth.[24] Ensuring that supply chain needs are met so equipment can be acquired is an important part of industry growth.

Incentives can also play a role in supporting the success of CEA farms. Particularly, incentives can help existing farms to transition to CEA processes, adopting new technologies or sustainable practices.[25] For example, Chelan County in Washington offers incentives to pay up to 100% of energy-efficient upgrades for farming equipment to transition traditional farmers to CEA.[26] They advertise these incentives as not only helping the environment in the long-term but saving on costs with the newer technology that requires less maintenance over time.[27] These incentives can influence a farmer's decision to adopt more sustainable measures if the initial investment is paid for.

Climate-related tax incentives could also assist indoor farmers. Federal investments through the Inflation Reduction Act of 2022 (IRA) will fund 950 million solar panels and 2,300 grid-scale battery plants by 2030, expanding the capability of renewable energy nationally.[28] The substantial energy savings through the IRA will benefit indoor farms, making expansions more

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[19] Tasgal, P. (2020, Nov). The three-legged stool: A feasibility analysis for starting a CEA farm. *AgFunder News.* Link.

[20] University of Arizona CEA Center. (n.d.). *Chapter 11: Greenhouse Site Selection*. Link.

[21] Cowman, N., Ferrier, L., Spears, B., Drewer, J., Reay, D., & Skiba, U. (2022). CEA Systems: The Means to Achieve Future Food Security and Environmental Sustainability? *Frontiers in Sustainable Food Systems, 6,* 1-10. Link.

[22] Mamon, G. (2022). Virginia is well-suited for controlled environment agriculture, summit says. *Cardinal News*. Link.

[23] Research and Markets. (2022). *Hydroponic Market by Type, Equipment, Input, Crop Type, Farming Method, Crop Area, and Region – Global Forecast to 2027.* Link.

[24] Research and Markets. (2022). *Hydroponic Market by Type, Equipment, Input, Crop Type, Farming Method, Crop Area, and Region – Global Forecast to 2027.* Link.

[25] Piñeiro, V., Arias, J., Dürr, J. Et al. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability* 3, 809-820. Link.

[26] Chelan County PUD. (n.d.) *Energy-Efficient Controlled Environment Agriculture.* Link.

[27] Chelan County PUD. (n.d.) *Energy-Efficient Controlled Environment Agriculture.* Link.

[28] Mayer, A. (2022). New climate-related tax incentives could help indoor agriculture grow. *AgriPulse*. Link.

affordable, and drawing companies to locate in certain regions if these commitments to renewable energy or greater funding is available.[29] With Plenty's move to Virginia, for example, the state's progress to reach 100% carbon-free electricity made the state an attractive location.[30]

Workforce Requirements

Due to the technology used in CEA, the skillsets required tend to be more varied than traditional farming and typically appeal to a younger workforce.[31] Although much of CEA is automated, skilled workers are still invaluable for guiding and overseeing the equipment, plant and animal health, and other hands-on work.[32]

Issues

A significant challenge in the CEA industry is the initial investment required to start a business. Miller et al. (2017) estimated that the initial costs for a hydroponic greenhouse for lettuce was $159,756, while for tomatoes it was $121,242 due to differing equipment costs.[33] There are also more aggressive industry players who are looking to dominate the market over small, start-up companies.[34] Without sufficient investment and continuous research and development, it is difficult for smaller companies to keep up.[35]

Critics of the industry also argue that the nutritional value of hydroponic produce is not the same as soil-grown produce, and there is uncertainty about the long-term health impacts of consuming produce not grown in soil.[36] Some may argue there is also a cultural cost, as the connection to the land that many cultures value is being taken away.[37] Many organic farmers take issue with labeling hydroponics as organic, even though the USDA has stated that hydroponics, aquaponics, and aeroponics are organic.[38] But, in Europe, soil-less, hydroponic

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[29] Mayer, A. (2022). New climate-related tax incentives could help indoor agriculture grow. *AgriPulse*. Link.

[30] Mayer, A. (2022). New climate-related tax incentives could help indoor agriculture grow. *AgriPulse*. Link.

[31] Mamon, G. (2022). Virginia is well-suited for controlled environment agriculture, summit says. *Cardinal News*. Link.

[32] Mamon, G. (2022). Virginia is well-suited for controlled environment agriculture, summit says. *Cardinal News*. Link.

[33] Miller, J., Boumtje, P., & Johnson, R. (2017). Investment Analysis for Commercial Hydroponically Produced Lettuce and Tomato. *Journal of ASMIRA* 1-10. Link.

[34] Maleki, B. (2022). Analysis of Vertical Farming Business Model: Swegreen Case Study. *Swedish University of Agricultural Sciences.* Link.

[35] Maleki, B. (2022). Analysis of Vertical Farming Business Model: Swegreen Case Study. *Swedish University of Agricultural Sciences.* Link.

[36] Severson, K. (2021, July). No Soil. No Growing Seasons. Just Add Water and Technology. *The New York Times*. Link.

[37] Severson, K. (2021, July). No Soil. No Growing Seasons. Just Add Water and Technology. *The New York Times*. Link.

[38] The National Agricultural Law Center. (n.d.). *The Fight for Organic: Hydroponic Certification Under Fire*. Link.

crops cannot be certified organic.[39] Marketing as a "local, organic" company can make the product more appealing to consumers, but the discrepancies in definitions of "organic" are still highly debated.

Finding an available trained workforce to fill occupations in high technology and research is also a challenge.[40] Furthermore, as a new, emerging industry, the CEA field lacks industrial expertise and regulation, which can slow growth.[41] The industry is still defining metrics and standards of success, and the lack of information available makes entering the industry challenging.[42] There are also some environmental disadvantages due to energy-intensive lighting and temperature controls required.[43] The lack of economically viable crops is also an issue, as currently the industry is dominated by leafy greens and tilapia spp (fish).[44] Staple crops like rice, maize, and wheat are not suitable for CEA.[45] The high capital costs of establishing and running a vertical farm also makes growing low-value crops like wheat not cost-effective.[46]

Industry Trends

In the current market, there are limits to outdoor production, consumer geography, and food security. Currently, the majority of lettuce in the U.S. is grown in California and Arizona, which face climate risks and long delivery times to get the product to market: 7 to 10 days are needed for transportation, and by the time the produce reaches the retailer, 50% of its shelf life has been spent on trucks.[47] Climate change, declining fisheries, increasing urbanization, and soil depletion all threaten the future supply of arable land needed for outdoor production. Vertical farming can reduce risk and improve food security, filling a gap agriculture will soon experience as these challenges increase.[48] Productivity can be improved with year-round production,

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[39] Butturini, M. & Marcelis L. (2020). Chapter 4 – Vertical Farming in Europe: Present Status and Outlook. In *Plant Factory: An Indoor Farming System for Efficient Quality Food and Production* (pp. 77-91). Wagenngen University. Link.

[40] De Oliveira, F.J.B., Ferson, D. & Dyer, R. (2021). A Collaborative Decision Support System Framework for Vertical Farming Business Developments. *International Journal of Decision Support System Technology 13*(1) 34-66. Link.

[41] Cowman, N., Ferrier, L., Spears, B., Drewer, J., Reay, D., & Skiba, U. (2022). CEA Systems: The Means to Achieve Future Food Security and Environmental Sustainability? *Frontiers in Sustainable Food Systems, 6,* 1-10. Link.

[42] Stein, E. (2021). The Transformative Environmental Effects Large-Scale Indoor Farming May Have on Air, Water, and Soil. *Air, Soil and Water Research, 14,* 1-8. Link.

[43] Cowman, N., Ferrier, L., Spears, B., Drewer, J., Reay, D., & Skiba, U. (2022). CEA Systems: The Means to Achieve Future Food Security and Environmental Sustainability? *Frontiers in Sustainable Food Systems, 6,* 1-10. Link.

[44] Cowman, N., Ferrier, L., Spears, B., Drewer, J., Reay, D., & Skiba, U. (2022). CEA Systems: The Means to Achieve Future Food Security and Environmental Sustainability? *Frontiers in Sustainable Food Systems, 6,* 1-10. Link.

[45] Cowman, N., Ferrier, L., Spears, B., Drewer, J., Reay, D., & Skiba, U. (2022). CEA Systems: The Means to Achieve Future Food Security and Environmental Sustainability? *Frontiers in Sustainable Food Systems, 6,* 1-10. Link.

[46] Benke K. & Tomkins B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science, Practice and Policy,* 13(1) 13-26. Link.

[47] S2GVentures. (2020). *Growing Beyond the Hype: Controlled Environment Agriculture.* Link.

[48] Benke K. & Tomkins B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science, Practice and Policy,* 13(1) 13-26. Link.

transportation costs can be reduced, and vertical farming can provide new jobs in technology, food processing, maintenance, marketing, engineering, and research and development.[49] The industry also has the opportunity to address the disconnect many remote rural communities experience by reskilling workers to fulfill these roles in local farms.[50]

A main concern regarding vertical farming is the quality of the product compared to conventional farming; this presents an opportunity to educate consumers and improve marketing of vertical farming products. In a study of consumers' perceptions and willingness to pay for vertically farmed produce, it was discovered that although vertically farmed produce was highly rated in terms of safety and quality, it was considered the least natural and the least likely to be purchased by consumers.[51] A reason for this misconception is the unfamiliarity the participants had with the product. Vertically farmed produce was also assumed to be a premium product only sold in more expensive stores. Companies can develop marketing solutions to better inform their consumers of their products as compared to other available produce to reduce hesitancy of purchasing the produce.[52]

Another opportunity for CEA is providing more transparent information on successful business models. Maleki (2022) analyzed the business model of SweGreen, a Swedish company, and related the findings to smaller CEA companies, including the threats they may experience as they try to scale up. These weaknesses include unstable revenues, expensive infrastructure, and a heavy reliance on the technology rather than a strong workforce.[53] Having a successful company share their business model and provide insight into their failures helps younger, smaller companies learn. Learning from the experiences of successful CEA companies can also be done through a Design Support System Solution, which is a hub for compiling practices with an extensive economic model database to provide financial risk assessments to companies.[54] The open-source database contains crop information, environmental details, shared-user data, and a knowledge base of best practices and operational procedures to reduce risk.[55] The goal of the Design Support System Solution is to grow business plans for start-ups to reduce the learning curve, provide a risk assessment, and make suggestions for operational improvements

[49] Benke K. & Tomkins B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science, Practice and Policy,* 13(1) 13-26. Link.

[50] Benke K. & Tomkins B. (2017). Future food-production systems: vertical farming and controlled-environment agriculture. *Sustainability: Science, Practice and Policy,* 13(1) 13-26. Link.

[51] Coyle, B. & Ellison, B. (2017). Will Consumers Find Vertically Farmed Produce "Out of Reach?" *Choices, 32*(1) 1-8. Link.

[52] Coyle, B. & Ellison, B. (2017). Will Consumers Find Vertically Farmed Produce "Out of Reach?" *Choices, 32*(1) 1-8. Link.

[53] Maleki, B. (2022). Analysis of Vertical Farming Business Model: Swegreen Case Study. *Swedish University of Agricultural Sciences.* Link.

[54] De Oliveira, F.J.B., Ferson, D. & Dyer, R. (2021). A Collaborative Decision Support System Framework for Vertical Farming Business Developments. *International Journal of Decision Support System Technology 13*(1) 34-66. Link.

[55] De Oliveira, F.J.B., Ferson, D. & Dyer, R. (2021). A Collaborative Decision Support System Framework for Vertical Farming Business Developments. *International Journal of Decision Support System Technology 13*(1) 34-66. Link.

to help start-ups succeed.[56] By sharing knowledge across the sector and increased usage of shared databases, CEA companies can improve their business models and learn successes and failures when growing their companies.

CEA in Virginia

CEA Industry Cluster Analysis

Industry Overview

In recent years, the CEA industry has been a rapidly emerging focus for economic development in the state of Virginia. Over time, federal and state agencies have started prioritizing investment in CEA as well. Virginia Economic Development Partnership, for instance, identified CEA as a target industry and formed a dedicated division to pursue CEA industry opportunities for the state. [57] As of today, our team has identified a total of 18 CEA companies operating or preparing to open in Virginia, 7 of which are larger operators that have 50 or more employees. In all, we estimate approximately 35,000 existing CEA-related jobs in the state and 1,750 in GO Virginia Region 3 as of 2022.

Virginia has seen an increase in CEA companies locating in the state, with announcements of major projects like Plenty in Chesterfield County in 2022 expected to bring 300 new jobs and $300 M in investment to the area. Virginia also has a presence of existing CEA companies and indoor agriculture operations, including Blue Ridge Aquaculture, a Martinsville-based company that is the largest indoor system producer of tilapia in the world.[58] The state has a history of robust smaller-scale and start-up activity in the CEA space, with companies like Babylon MicroFarms in Richmond, founded in 2017, and Area2 Farms in Arlington.

In Region 3 and Southern Virginia, the most recent CEA announcement was Aerofarms, which first came to the Danville-Pittsylvania County area in December of 2019. Now, the company is planning to expand, with an expected 66 new jobs created in addition to 92 existing jobs, and new investment of nearly $42 M. Growing collaboration between various CEA stakeholders and policymakers is expected to continue the momentum, helping to grow the industry further. A full table of CEA company announcements in Virginia can be found in Table 1 in the Appendix**.**

Virginia boasts several advantages that have helped the CEA industry to develop in the state. Namely, the Controlled Environment Agriculture Innovation Center, a partnership between Virginia Tech and the Institute for Advanced Learning and Research (IALR) in Danville, VA, serves as a unique and crucial asset and resource for innovators, policymakers, and industry in

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[56] De Oliveira, F.J.B., Ferson, D. & Dyer, R. (2021). A Collaborative Decision Support System Framework for Vertical Farming Business Developments. *International Journal of Decision Support System Technology 13*(1) 34-66. Link.

[57] *Controlled Environment Agriculture | Virginia Economic Development Partnership*. (n.d.). Www.vedp.org. Retrieved May 15, 2023, from https://www.vedp.org/industry/controlled-environment-agriculture

[58] *Blue Ridge Aquaculture - World's Largest Producer of Tilapia Using Recirculating Aquaculture Systems.* (n.d.). Blue Ridge Aquaculture. https://www.blueridgeaquaculture.com/info/about.cfm

the CEA sector. The CEA Innovation Center features a demonstration site and agricultural technology training center, where staff, faculty, researchers, and businesses can engage in research and development and educational programming to advance CEA technologies and methods and grow the industry. Additionally, IALR and the CEAIC hosted the first ever CEA Summit East in the fall of 2022, co-hosted by Indoor Ag-Con, bringing together over 200 attendees from across the country and beyond, including growers, educators, scientists, extension specialists, suppliers, engineers, tech specialists, architect/developers and other CEA industry stakeholders. The Summit is scheduled to return September 19 – 20, 2023, with the goal of growing the success of the first summit and continuing to foster connectivity and collaboration between growers, policymakers, scientists, venture capitalists, and other CEA industry stakeholders to advance the CEA ecosystem.

The following section provides an overview of CEA industry trends and changes in employment in the state and in Region 3. It should be noted that the CEA industry is quite new and still developing, as compared to long-established industry sectors like manufacturing or healthcare. Therefore, we want to affirm that it can be challenging to find accurate, timely, and detailed data and metrics for the CEA industry. One challenge is that the industry's unique nature makes it difficult to frame industry activity and employment based on industry (NAICS) and occupation (SOC) codes. There is no existing singular NAICS or SOC code that fully captures the types of businesses and jobs in this industry. In response, we rely on professional judgement to select codes we determine to be the most relevant to the industry. Furthermore, many businesses in this industry are just starting to emerge, operating on a small scale, making them difficult to identify and track. Regardless, our efforts to analyze the industry presence in the region and the state has been guided by professional judgement and takeaways from interviews with CEA industry representatives.

The following industry codes were selected to best estimate CEA-related employment and prevent exclusion of important industries and businesses that contribute to CEA. These include: crop production; animal production & aquaculture, which captures indoor fishery and aquaponics activity; machinery manufacturing, which supports CEA with manufacturing of grow systems and more; and computer and electronic product manufacturing, such as sensor or microchip production, which is necessary to the automation and coding of environmental control processes in CEA production. The following table summarize the industries within CEA in both Virginia and GOVA Region 3:

Table 2. CEA Industry in Virginia and GOVA Region 3

Industry	VA 2022 Jobs	VA 2017-2022 % Change	VA 2022-2027 % Change	VA Avg. Earnings	GOVA 2022 Jobs	GOVA 2017-2022 % Change	GOVA 2022-2027 % Change	GOVA Avg. Earnings
Crop Production	5,727	1%	8%	$44,978	321	-6%	2%	$40,319
Animal Production & Aquaculture	3,060	-5%	-2%	$49,326	430	-13%	-10%	$52,880
Machinery Manufacturing	14,249	-1%	6%	$85,399	633	164%	27%	$71,946
Computer and Electronic Product Manufacturing	12,041	3%	6%	$138,639	364	129%	43%	$107,297
Total	35,077	0%	5%	$93,927	1,749	42%	16%	$69,233

Source: EMSI/Lightcast.

Industry growth in crop and animal production has been declining, but there is expected growth in crop production for the state and slight growth in the region in crop production over the next five years. This could present an opportunity for CEA; as labor and water becomes more expensive, traditional agriculture may continue to decline, and new ways of producing crops will be necessary. Notably, CEA-related jobs in GOVA Region 3 pay less than their counterparts throughout Virginia. However, jobs in Animal Production and Aquaculture pay higher in the region than in the overall state. Overall, most jobs pay lower, which can appeal to companies seeking affordable labor. In Region 3, machinery manufacturing and computer and electronic product manufacturing are expected to significantly grow in jobs in the next five years. The growth of these industries can contribute to the expansion of CEA in the region by providing technological support and advancement. Region 3 anticipates greater growth in CEA-related industries than the state, indicating an opportunity for the region to prioritize these industries.

Region 3's hotspots of CEA-related employment include the City of Danville, Pittsylvania County, and Mecklenburg County:

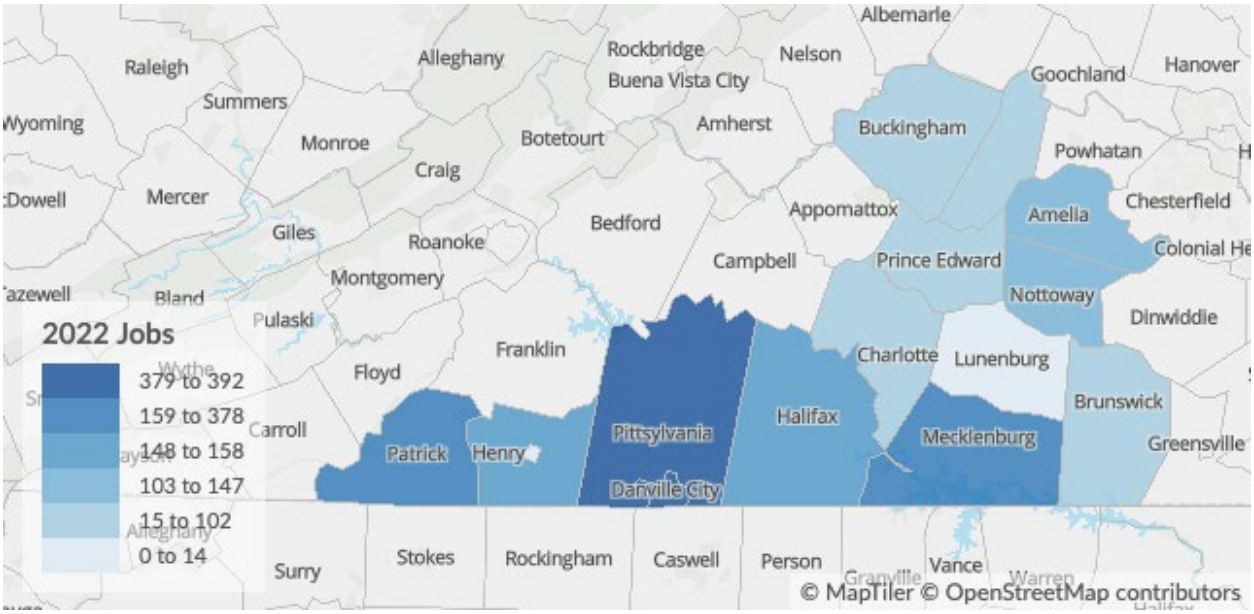


Figure 1: CEA Employment Throughout GOVA Region 3

Source: EMSI/Lightcast.

Throughout the state, CEA-related employment is somewhat dispersed. There are hotspots of employment in the northern part of the state and on the Eastern Shore, but there remains room for growth in GOVA Region 3 compared to the rest of the state.

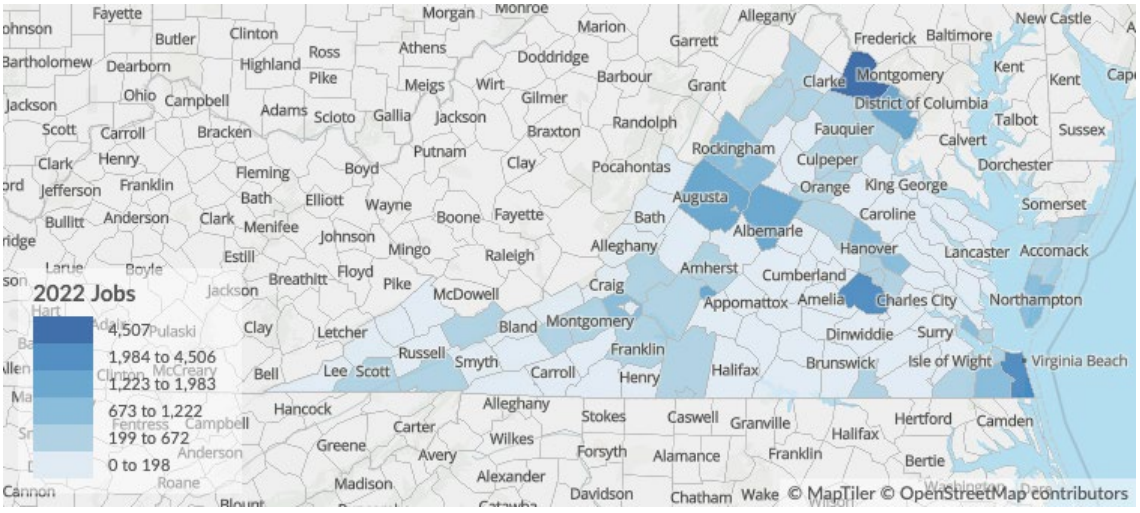


Figure 2: CEA Employment Throughout Virginia

Source: EMSI/Lightcast.

Across the continental United States, these CEA industries are concentrated heavily in California, Texas, Florida, and Washington.

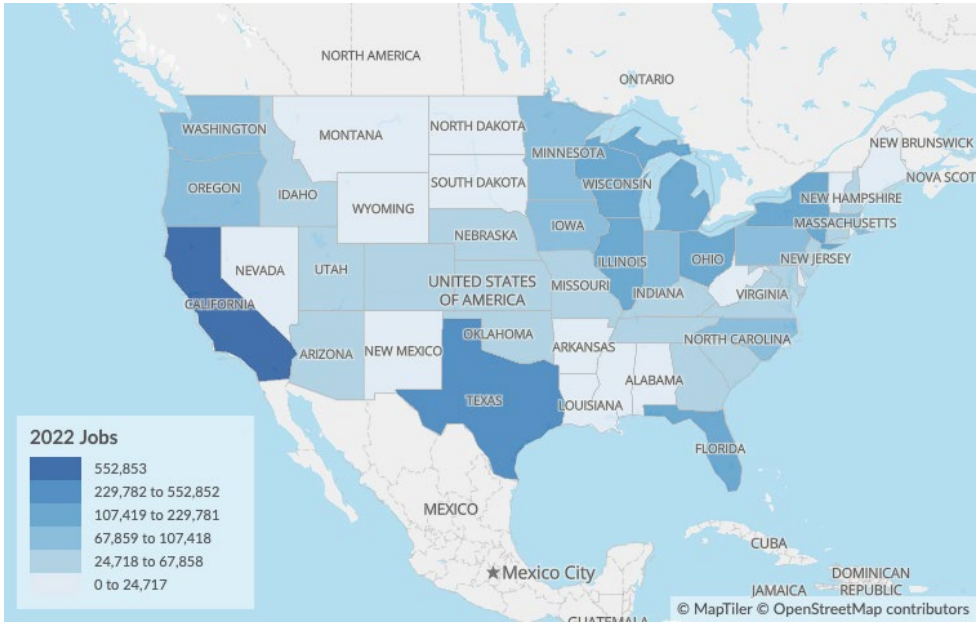


Figure 3: Animal and Crop Production Employment Throughout the U.S.

Source: EMSI/Lightcast.

Supply-Chain and Support Sector

As operators in a new and developing industry, Region 3 CEA firms may need to be flexible and creative in sourcing CEA-specific supplies. Businesses that specifically support CEA at a commercial scale are somewhat scarce in GOVA Region 3. CECE identified and categorized CEA-supporting businesses into the following categories:

- Growing Light Providers
- Hydroponics
- Aquaponics
- Microgrids and power
- Humidity Regulation
- Temperature Control
- Other Equipment

At present, there are limited firms dedicated to supplying goods and services to CEA-related industries in Region 3, showing a limited dedicated supply chain. However, suppliers that serve other or multiple industries can help meet CEA companies' needs. For instance, wholesalers or suppliers in other industries may supply lighting products, IT support, and other low-, medium-, and high-tech inputs critical to indoor and/or automated CEA-operations. When thinking of Region 3's CEA supply chain, the definition should be expanded to include firms that have the capacity to serve CEA, even if they do not presently do so.

Consideration of supply-chain is expanded to the following industries at the 3-digit NAICS code:

Table 3: Industry Growth in GOVA 3 Support Cluster

NAICS	Description	2022 Jobs	2027 Jobs	2022 – 2027 % Change	Competitive Effect	2022 Payrolled Business Locations
115	Support Activities for Agriculture and Forestry	92	112	22%	12	29
221	Utilities	473	454	-4%	-23	25
236	Construction of Buildings	1,057	1,106	5%	-12	230
311	Food Manufacturing	1,431	1,659	16%	147	17
312	Beverage and Tobacco Product Manufacturing	441	537	22%	59	10
335	Electrical Equipment, Appliance, and Component Manufacturing	535	545	2%	-30	8
336	Transportation Equipment Manufacturing	741	993	34%	220	11
423	Merchant Wholesalers, Durable Goods	1,688	1,894	12%	120	170
424	Merchant Wholesalers, Nondurable Goods	1,403	1,435	2%	-30	94
444	Building Material and Garden Equipment and Supplies Dealers	1,549	1,596	3%	-26	91
482	Rail Transportation	0	0	0%	0	0
484	Truck Transportation	1,530	1,449	-5%	-151	239
493	Warehousing and Storage	1,978	1,821	-8%	-460	22
518	Data Processing, Hosting, and Related Services	146	173	18%	3	10
541	Professional, Scientific, and Technical Services	2,984	3,620	21%	329	484
551	Management of Companies and Enterprises	813	792	-3%	-65	60
561	Administrative and Support Services	5,928	6,166	4%	-153	344
562	Waste Management and Remediation Services	140	146	4%	-6	20
Total		22,931	24,497	7%	-65	1,863

(Source: Lightcast Industry Table for relevant NAICS codes in Region 3; Q1 2023 data).

Within CEA-supporting industries, there are 22,931 jobs in GOVA region 3 (Lightcast). If Region 3 had the same cluster employment density as the rest of the United States, the number of jobs within CEA-supporting industries would be higher at approximately 31,297. However, some of the CEA-supporting industries in GOVA Region 3 have a high competitive effect, which is a metric that indicates the extent to which employment changes in a particular industry in a region can be attributed to the region's unique advantages, such as a strategic location or strong local concentration of a particular cluster. A positive competitive effect indicates that an industry is faring better at a local or regional level as compared to the rest of the nation. CEA-related industries with a high competitive effect include Professional, Scientific, and Technical Services (329), Transportation Equipment Manufacturing (220), and Food Manufacturing (147). This is beneficial for the region, as these are key supporting industries for research and development, as well as distribution and manufacturing of products. Lightcast estimates 1,863 payrolled businesses in these support industries, with the highest number being in Professional, Scientific, and Technical Services. In Region 3, most of these companies are clustered around Danville and Martinsville.

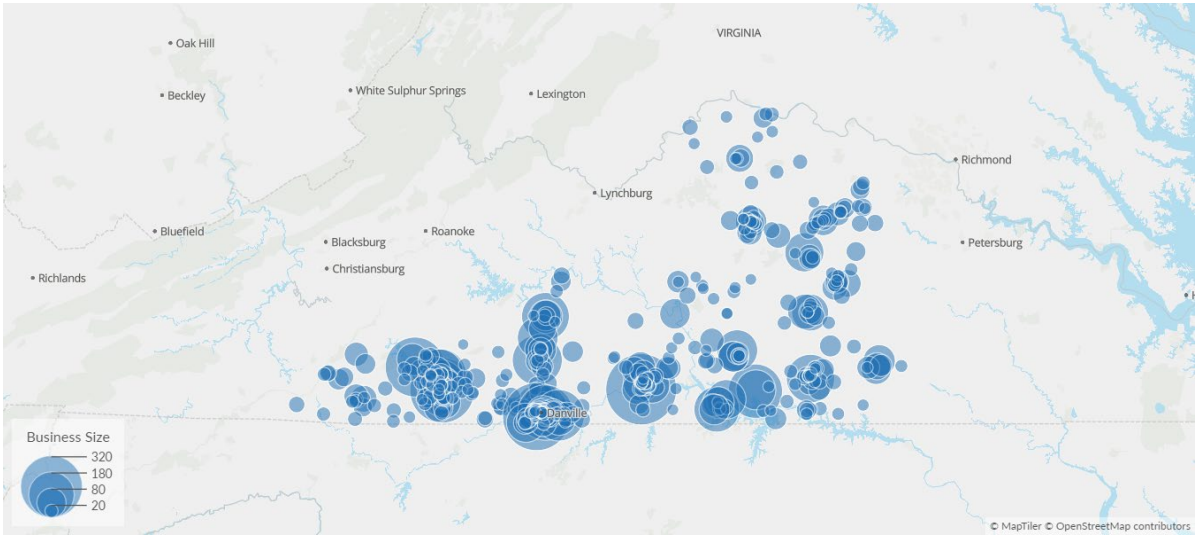


Figure 4: Business Map of Region 3's Potential CEA Supply Chain

Source: Lightcast Business Map

Jobs in CEA-related industries vary from being lower-paying and higher-paying. As shown in Table 4, jobs in the Utilities industry and Management of Companies and Enterprises are the highest paying in the support cluster. The lowest paying is Rail Transportation; this is likely due a lack of regional data, as this industry has little presence in the region. Nonetheless, this industry is important for transporting goods. Other lower-paying industries include Administrative and Support Services and Building Material and Garden Equipment Supplies Dealers.

Table 4. Low-Paying Supply Chain v. High-Paying Supply Chain Industries in GOVA Region 3

Low-Paying		
NAICS	Description	Avg. Earnings Per Job
482	Rail Transportation	$0
561	Administrative and Support Services	$36,992
444	Building Material and Garden Equipment and Supplies Dealers	$40,081
115	Support Activities for Agriculture and Forestry	$49,188
311	Food Manufacturing	$52,491
493	Warehousing and Storage	$53,675
424	Merchant Wholesalers, Nondurable Goods	$54,519
312	Beverage and Tobacco Product Manufacturing	$55,278
236	Construction of Buildings	$59,067

High-Paying		
NAICS	Description	Avg. Earnings Per Job
221	Utilities	$133,963
551	Management of Companies and Enterprises	$94,479
335	Electrical Equipment, Appliance, and Component Manufacturing	$76,570
562	Waste Management and Remediation Services	$76,424
423	Merchant Wholesalers, Durable Goods	$70,749
541	Professional, Scientific, and Technical Services	$70,513
336	Transportation Equipment Manufacturing	$69,314
518	Data Processing, Hosting, and Related Services	$69,132
484	Truck Transportation	$65,752

Source: EMSI/Lightcast.

The following CEA suppliers currently operate in Virginia. This list is not exhaustive, but highlights important existing suppliers in the state:

- ID Gardens, a small-scale operation supplier in Fairfax.
- Hyve, a hydroponic supplier in Verona.
- Bowerbird Energy, a lighting supplier in Richmond.
- Happy Trees Agricultural Supply, an indoor garden and hydroponics equipment supplier located in Richmond, Fredericksburg, and Petersburg.
- Prins-USA, greenhouse designer and manufacturer for indoor growing in Stevensburg.
- 3 Ridge Technologies, builds growing technologies and systems in Lynchburg.
- Peninsula Hydroponics, offers consulting services and hydroponic system technology in Hampton Roads.
- Falls Church Hydroponics and Garden Supply, sells hydroponic supplies including lights and pumps in Falls Church.
- Blue Ride Hydroponics, sells supplies for hydroponics in Roanoke.
- EcoSprout, sells growing systems for both hobbyists and commercial growers in Crozet.

CEA in Virginia may also be supported by general agricultural suppliers in the region. However, for CEA-specific equipment, those in the industry in Region 3 may have to turn to national suppliers. CEA firms may also consider working with niche suppliers related to hemp or cannabis production, such as Happy Trees Agricultural Supply, given the overlapping relevance of hydroponics.

For further information on firms in Virginia and the U.S., please refer to Table 1 and Table 5 in the Appendix.

Workforce

The unique nature and diverse range of CEA and CEA-related industries lends itself to a wide variety of job opportunities and skills. Jobs in the CEA space can include maintenance and repair skills, such as HVAC services to keep indoor conditions stable and favorable for crop production, to highly specialized computer science and/or electrical engineering jobs that are responsible for the automation, control, and tracking of CEA-related processes in indoor growing operations or CEA-related manufacturing. As an example, the following are some job postings that were announced by Plenty in anticipation of the completion of the company's new location in Chesterfield County, VA:[59]

- Supervisor, Production
- Supervisor, Sanitation
- Lead Farm Operations Associates
- Farm Operations Associates
- Warehouse Associates
- Health & Safety Manager
- Maintenance Technician

Particularly, larger operators or well-established CEA-related firms may have more job opportunities related to operations and logistics, as the company has a stable market presence and a need to distribute its goods to more distant markets. For instance, Blue Ridge Aquaculture, a long-time indoor tilapia producer, actively hires truck-driving jobs to fill the need to get their product to markets across the country. Other types of jobs that CEA companies look for can also include marketing and communications positions, administrative support positions, and other roles that support company operations. Therefore, we also include support occupations that are relevant but may not be isolated solely to CEA. The full table of support cluster occupations can be found in the Appendix.

The following section provides an overview of selected CEA-related occupations and trends in Region 3 and the state. The following occupations were selected as most relevant to companies directly engaged in CEA production—these occupational categories represent employees working in plant production and technology, computer systems, advanced manufacturing, and logistics. The following occupation estimates represent the supply of existing jobs in these

[59] *Virginia Future Opportunities.* (n.d.). Plenty. Retrieved May 15, 2023, from https://www.plenty.ag/jobs/6384492002/

occupational categories: jobs in these categories represent the potential labor supply for CEA companies. A full list of occupations for both Virginia and Region 3 can be found in the Appendix.

Table 6. Selected CEA-related Occupations in Virginia

Description	2017-2022 % Change	2022-2027 % Change	Avg. Hourly Earnings	Avg. Annual Earnings
Computer and Information Systems Managers	7%	10%	$82.83	$172,286.40
General and Operations Managers	56%	6%	$61.11	$127,108.80
Shipping, Receiving, and Inventory Clerks	20%	1%	$17.58	$36,566.40
Maintenance and Repair Workers	5%	5%	$21.50	$44,720.00
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	-7%	6%	$14.37	$29,889.60
Farmworkers, Farm, Ranch, and Aquacultural Animals	-6%	4%	$14.74	$30,659.20
Farmers, Ranchers, and Other Agricultural Managers	-2%	2%	$23.02	$47,881.60
Food Science Technicians	52%	9%	$25.06	$52,124.80
Soil and Plant Scientists	106%	6%	$31.97	$66,497.60
Food Scientists and Technologists	21%	5%	$41.32	$85,945.60
Total	14%	6%	$35.41	

Source: EMSI/Lightcast.

Table 7. Selected CEA-related Occupations in GOVA Region 3

Description	2017-2022 % Change	2022-2027 % Change	Avg. Hourly Earnings	Avg. Annual Earnings
Computer and Information Systems Managers	37%	22%	$60.31	$125,444.80
General and Operations Managers	55%	8%	$45.71	$95,076.80
Shipping, Receiving, and Inventory Clerks	14%	-1%	$15.98	$33,238.40
Maintenance and Repair Workers	-2%	4%	$20.16	$41,932.80
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	-16%	1%	$13.79	$28,683.20
Farmworkers, Farm, Ranch, and Aquacultural Animals	-17%	-7%	$14.89	$30,971.20
Farmers, Ranchers, and Other Agricultural Managers	-16%	-11%	$22.84	$47,507.20
Food Science Technicians	NA	NA	NA	NA
Soil and Plant Scientists	NA	NA	NA	NA
Food Scientists and Technologists	NA	NA	NA	NA
Total	12%	5%	$23.96	

Source: EMSI/Lightcast.

Average earnings in selected CEA occupations are lower in the Region 3 than the state average. However, occupations such as Computer and Information Systems Managers and General and Operations Managers are expected to grow at a faster rate in Region 3 as compared to the state. These occupations can contribute to CEA in technological and IT skills, as well as managerial positions within these companies.

Completions and Training Programs

Existing and future CEA firms often require specialized, high-skilled labor to support the precise technical work and production processes. This demand will likely continue with time, as CEA-related technologies develop and become more large-scale and complex. The high-tech nature of the industry and its operations, including use of automated and computer-controlled methods, means that future CEA firms will also likely have a great need for a skilled workforce. Findings from these trends suggest that CEA firms choosing to operate in Region 3 may have to recruit skilled talent from outside the region. The following table includes annual completions of degrees of all levels and certificates conferred in selected CEA occupations:

Table 8: Completions for CEA-related Occupations in Region 3 and in Virginia

Description	GOVA Region 3 Completions (2021)	Virginia Completions (2021)
Computer and Information Systems Managers	336	19,328
General and Operations Managers	1,595	35,191
Shipping, Receiving, and Inventory Clerks	0	0
Maintenance and Repair Workers	220	1,746
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	3	162
Farmworkers, Farm, Ranch, and Aquacultural Animals	0	87
Farmers, Ranchers, and Other Agricultural Managers	9	483
Food Science Technicians	0	25
Soil and Plant Scientists	66	4,316
Food Scientists and Technologists	10	976

Source: Lightcast. For more information on the operating definition of the word 'completion', please refer to Lightcast (Completions – Knowledge Base (emsidata.com)).

We also identify completions in the supply chain and support cluster of occupations. The top completions in supply chain industries were Electrical, Electronic, and Communications Engineering Technician, Biology/Biological Sciences, and Welding Technology. The top completions in the support cluster in GOVA Region 3 were in Project Management Specialists, Computer User Support Specialists, and General and Operations Managers. A full list of completions in the supply chain and support clusters in both GOVA Region 3 and Virginia can be found in the Appendix.

We note that certain occupations may not require postsecondary education and/or training that would typically count as a 'completion': therefore, interpretation of zero completions in certain occupations may not be cause for concern.

There are programs within the region that can prepare workers for the CEA industry. These programs range from certificates to master's degrees and, with a strong pipeline, could lead to retaining students in the region to work at a CEA company. Successful talent retention programs and connecting companies to regional institutions could help build the employment pipeline. These programs include, but are not limited to:

Table 9. CEA Degree Completions in Region 3

Program	Institutions	Degrees Offered	Total 2021 Completions
Business Administration and Management	Longwood University, Averett University	Associate's, Bachelor's, Master's	218
Industrial Electronics Technology	Danville CC, Patrick Henry CC	Less than 1 year, Associate's	102
Industrial Production Technology	Danville CC, Southside Virginia CC	Less than 1 year	91
Business/Managerial Economics	Hampden-Sydney College	Bachelor's	48
Industrial Technology/Technician	Danville CC, Patrick Henry CC, Southside Virginia CC	Associate's	46
Computer and Information Sciences	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, Associate's	43
Business Administration, Management and Operations	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, Associate's	41
Manufacturing Engineering Technology	Southside Virginia CC, Patrick Henry CC, Danville CC	Less than 1 year	40
Computer Science	Averett University, Longwood University, Hampden-Sydney College	Bachelor's	18
Environmental Science	Longwood University	Bachelor's	12
Engineering Technologies	Danville CC, Patrick Henry CC	Associate's	10
Applied Horticulture Operations	Southside Virginia CC	Less than 1 year	3

Source: EMSI/Lightcast.

There are other programs at institutions outside of Region 3 that can contribute to CEA. Pulling from graduates outside of the region may be beneficial to draw workers in with skills and degrees not offered at regional institutions. These programs include Business/Commerce, Information Technology, Finance, Engineering, and Electrical and Electronics Engineering. The full table can be found in the Appendix.

CEA has strong potential in Region 3. Firms in this region should be able to leverage an affordable workforce alongside rich statewide networks of expertise. The main challenge firms in this industry may expect is attracting and retaining a skilled workforce. However, the labor that exists in the region is affordable, which should be attractive to firms seeking to do business. Companies may have trouble attracting talent in traditionally higher-paying support clusters but can be overcome through appropriate outreach and development efforts.

CEA Industry Interviews and Engagement Analysis

CEA Ecosystem Engagement

Throughout this study, our team engaged with numerous CEA experts, researchers, and industry stakeholders to better understand the state of the CEA industry, changing conditions, and the potential for future growth in Virginia. As part of this process, we also conducted interviews with CEA companies to understand their perspectives on the industry in Virginia, their needs and challenges, workforce and site selection decisions, and how Virginia can prioritize CEA in the future. Companies interviewed varied in their geographic markets served—companies' reach of distribution ranged from smaller markets of a ten-mile radius of the production site, to distributing across the east coast and selling products in major retail stores. Of the companies interviewed, five of the six were based in Virginia, with one in South Carolina to provide insight from outside of the state. Interviews were conducted with both younger companies, operating for one year or less, and more developed companies producing for over eight years.

Key Industry Trends

Keynote speakers at a CEA conference hosted by IALR in 2022 provided some background and context to the development of the CEA industry in Virginia. Overall, the concept of controlled environment agriculture is not brand new; rather, it has developed as a discipline and industry over the years. More recent technology advancements like biotechnology, robotic imaging, and machine learning have changed the economics of CEA as an industry. Other larger-scale factors and trends have spurred growth of the industry, such as rising climate change concerns and challenges, and food security and safety issues.

Now, industry experts, researchers, and CEA producers are working to improve process control and continue to refine the quality of production. There is an additional focus on energy conservation and sustainability in response to wider demand for greener economies. Now, CEA companies in the crop and aquaponic production space are also exploring the expansion of new niche markets and exploring production potential for new and emerging species. With the growth of this industry in the country, facilities are also expanding and getting larger in scale, likely aided by the increase in available funding for CEA-related projects and research and development.

Virginia and Site Selection

Companies chose Virginia for numerous reasons. The market that Virginia serves is widespread, making it an attractive location for produce distributors. Also, many areas in Virginia have rich agricultural history that CEA can build from; local farmers can assist with new business and a new farm can serve the existing customer base. Virginia also has many universities where companies can draw talented graduates from.

A company in Richmond stated:

> *"We chose Richmond specifically because of the urban feeling, access to lots of 20–30-year-olds, who our mission typically aligns with. It is right in the heart of the city, people driving around on scooters … this type of industry is part of the culture here."*

A Goochland-based company also stated:

> *"Goochland makes sense strategically, the idea originated in the Northern Neck area, but we found logistics didn't make sense there. Trucks weren't coming out that way. Now we are in the middle of a major interchange, you can get from all directions easily from our facility. It was also zoned agriculture, it gave us flexibility in what we built, we didn't have to jump through the traditional manufacturing setup."*

Connecting to utilities can be a challenge for companies coming to Virginia. Some participants indicated that information on natural gas connectivity is not easily accessible online prior to purchasing, leading to high costs if the pipeline is located at an inconvenient distance. Accessing sufficient power and groundwater can be a challenge as well. Ensuring sites are ready for new business with sufficient infrastructure can help facilitate the process of choosing a site.

When asked about Virginia's competitiveness, participants mentioned some reasons to locate business in different states, including greater available venture capital elsewhere. In areas such as California, more of this funding is available to businesses, making them more attractive. However, the market is more competitive in the western part of the country, making Virginia a more appropriate location due to less competition.

The South Carolina-based company stated they were potentially interested in relocating to Virginia, as the state has more of an ag-technology focus, which makes grant availability and business development easier. The support of programs at Virginia Tech and IALR are also a benefit to Virginia-based companies; not all states have similar support institutions, which can make research and finding skilled-workers a greater challenge. Companies based outside the region would consider relocating in Virginia due to these local assets.

Workforce

There is a diverse set of skills companies look for when hiring. In general, occupations in CEA are technical positions that benefit from having a horticulture or greenhouse background. Specific programs at Virginia Tech, Cornell University, and North Carolina State University were mentioned as good examples. Job applicants with a background in information technology are also preferred for working with the automation technology used in the farms and applying skills to improve the management systems used.

According to CEA and economic development experts, industry workforce needs can also vary with the scale of the company. Often, there is a spectrum of skillsets that companies need, ranging from HVAC, pest management and disease control, to high-tech computer systems engineering skills. Companies may also need personnel with management experience as well as some lower wage occupations to support operations. Across the board, personnel will likely need to be trained in specialized topics that are relevant to CEA production, including bio-security, animal and crop health, and food safety protocols.

In smaller companies, staff are required to have a wide range of knowledge and skills. Being a multi-skilled team member is important for companies of this size. With limited staff, employees may need to work outside their role to help elsewhere. There is a lot of collaboration among employees in smaller companies to ensure continuous operations and success.

One company explained their workforce, stating they had:

- 35 employees within five different departments: horticulture, software, hardware engineering, manufacturing, and customer experience.
- The average age of their workforce was 27, with many employees joining after graduating college.
- Each department has their unique role, but overall the company must work as a cohesive system to continue advancing.

Several companies mentioned they need staff to manage distribution and shipping. Finding truck drivers to distribute products and adequate warehousing staffing has been a challenge. There is an opportunity for logistics and warehousing industries to collaborate with CEA and meet this need.

Overall, interviewees stated that attitude is the most important quality they search for when hiring. Most of the companies shared that they could train anyone to do the job, but the important part is having a passion aligned with the mission of the company.

Workforce programs and training for CEA are continuing to develop in the state. Conference speakers and participants discussed opportunities for expanding existing workforce and educational programs, such as the GO TEC program in Southern Virginia, to help form a talent pipeline for CEA. IALR has also led and promoted educational programs such as teacher training to promote awareness of CEA careers among K-12 teachers, and custom workforce training programs, funded by the USDA, to provide bootcamps for basic hydroponics and CEA background, plant health and biology, and safety best practices for CEA jobs.

Future and incoming companies will continue to need a strong skilled workforce and training resources to be successful in Virginia. Continuing to develop collaborative workforce partnerships around CEA will help companies grow and individuals to take advantage of innovative CEA career opportunities.

Challenges

Navigating Growth

In all interviews, there were challenges with navigating growth. When starting a CEA company, there can be a lack of information and transparency on available resources for entrepreneurs. Some business owners miss grant opportunities because they do not know where to find grants or how to apply for them. One interviewee stated:

> *"The only time we hear about a grant is if another company has won it already. A proactive outreach to companies to inform what funds are available would be helpful."*

Companies desire an inventory of resources that lists who the contacts are for grant opportunities or service providers, especially for services such as water testing, nutritional testing, and energy resources. This can better assist future start-ups in knowing where to look for both resources and funds.

Financing for inventory and patenting were other challenges mentioned during the start-up phase. One company stated there was a lack of access to capital and that obtaining loans to spend on inventory was difficult, as many banks were unwilling to loan to small start-ups. Finding investors that understand agriculture has also been a hurdle for those patenting products. Increasing support in the early phases to gain credibility to obtain loans would assist small start-ups. This support could come from local government, the state, or USDA, so that suppliers will be more willing to lend to the smaller companies.

Other challenges include barriers to policy, zoning, and real estate. Counties across Virginia differ in how new businesses are registered, particularly agriculture-related businesses may not fit the typical outdoor farm definition. For example, an Arlington-based company stated that:

> *"Virginia is one of the most ag-friendly states, but county-by-county, the way they deal with things is different. VA has sales tax exceptions of agricultural production in the state, but Arlington has taxes on equipment and property that run counter to the state's policies. Also, when registering with the state, I called the Business License Bureau saying we have a farm, who said we didn't need a license. But in Arlington, you do require a license. These gaps in policy alignment make it difficult for small businesses to start."*

Zoning can also be difficult, as farmers struggle with determining if their operations are considered agriculture or manufacturing enterprises. It is also challenging to start a small business in the current real estate environment, especially if there are zoning limitations. Localities should carefully consider these issues when targeting the CEA industry so that business owners can avoid these barriers to starting operations.

Mid-scale and expanding companies face different sets of challenges. Some companies stated that the middle stage is the most difficult because a lack of resources can stop them from expanding to the next level. In Virginia, companies stated that when it is time to move onto the next phase of growth, there is a lack of available funds. Larger companies often have dedicated staff to acquire that funding, but those in the middle lack capacity to do so. Smaller companies may serve niche markets, while larger companies have a broader service area and big retailers; knowing the market for the middle is an important issue. The companies interviewed stated that they have goals in the future to scale up, expand the market to the Mid-Atlantic or build other facilities elsewhere, but to do so, they must push through this middle stage and have access to appropriate resources to expand.

Consumer Education

Providing consumers with information on CEA can grow support for the CEA industry and may encourage consumers to purchase more CEA produce. Many consumers may not be aware of what CEA produce is and the benefits of CEA as compared to traditionally grown produce. There needs to be greater awareness and access to data to show how CEA assists with product

consistency, food safety, and food security. Public perception can be a challenge to change, but there is an opportunity to gain greater support.

Supply Chain Disruptions

As a result of COVID-19, many companies faced supply chain issues. Particularly, delays in supply and delivery threaten new companies; one company stated that from construction to sales, supply chain delays doubled the timeline compared to what was initially proposed. Attracting not only CEA companies but also CEA suppliers can simplify this process and create a tighter network of local suppliers to growers.

Recommendations for Next Steps

- Create a network for companies to available resources. Learn from each other, encourage transparency around starting a business, and know where to access funds and assistance.
- Identify and enable mentors in the agricultural-technology industry who understand how the process works and can help new entrepreneurs interested in the industry navigate it. Interviewees stated that they felt the industry can be too siloed at times; with more collaboration between growers and sharing knowledge, there is value for everyone in that it would make the overall industry sustain in the long-term.
- Creating an ecosystem for CEA. The industry must be beyond just the growers and needs to attract supply chain businesses as well to create a vibrant local network of companies.

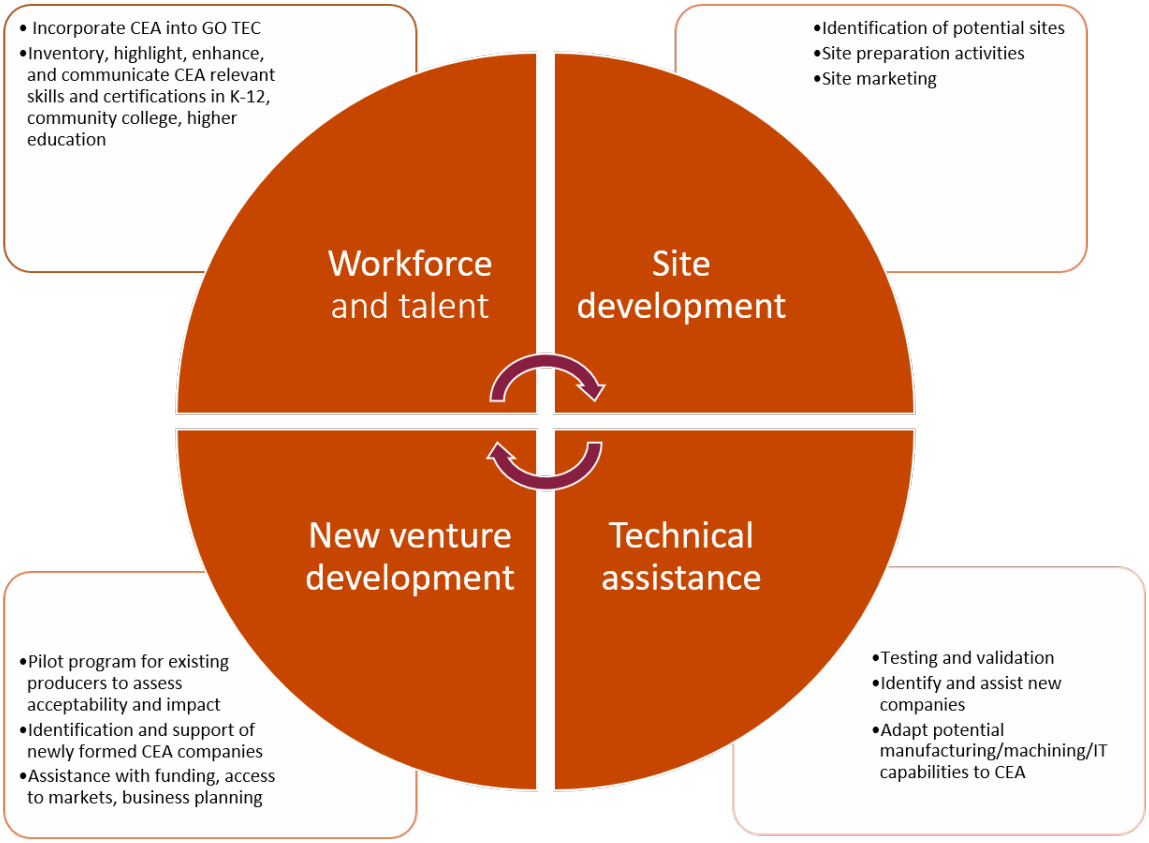
Companies stated that there is an opportunity to make Virginia a leading state in CEA, but the overall process and available resources must be clarified. Virginia has many assets, including existing companies, such as Aerofarms and Plenty, the resources at IALR, and being located on the east coast where there is a large, underserved market in CEA, but knowing how to fund and support this activity is a challenge. A clear guidebook on how to start a company in Virginia, what resources exist, and how to obtain funding can assist new start-ups and expand the ecosystem further.

CEA Strategy and Roadmap

The following section synthesizes the situation assessment for CEA via a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. The SWOT helps inform a strategy and roadmap for future CEA-related development and industry attraction. The report includes a list of priority projects for GO Virginia Region 3 to best support and grow CEA-related agribusiness investment in the region's localities and advance CEA-related workforce development programs.

The SWOT analysis is a tool that can help identify areas for strategy. Our overall framing question for the SWOT and accompanying strategy and roadmap document is:

How can Region 3 and the Controlled Environment Agriculture Innovation Center be best positioned as a research, development, and business investment catalyst for CEA-related economic development and workforce development over the next 3-5 years?



SWOT Analysis

Strengths: assets and advantages internal to Region 3

Extensive knowledge, R&D Assets, and track-record of technical assistance

- Virginia Tech and IALR are frequently cited as top crucial assets to help attract and retain larger CEA prospects, benefiting both the region and the CEA industry. The Institute provides unparalleled expertise and resources for farmers, business owners, students, and the public.
- IALR also builds strong relationships and collaborations with CEA industry. For instance, Aerofarms' CTO describes their relationship with IALR as "exciting and successful" and stated, "the extensiveness of IALR labs and capacity is impressive."
- Virginia Cooperative Extension is very active in the region and state, offering resources and assistance on small-scale and mid-size indoor and vertical farming. Extension activities, like hosting the 2019 Innovation in Greenhouse and Vertical Farming Conference, support existing producers and help landowners enter the CEA space.

Existing industry presence and agricultural heritage

- AeroFarms' engagement and $42 million plus investment in Region 3: the company is working to build the world's largest aeroponic vertical farm at Cane Creek Centre, a joint-venture business park for Pittsylvania County and the City of Danville. The company will be expanding, adding 66 new jobs on top of the 92 announced in December 2019.
- The presence of Blue Ridge Aquaculture, Virginia's earliest CEA-related company and largest indoor producer of tilapia in the world.
- The region has a concentrated agriculture industry sector, with strong cultural and historical ties to agriculture.
- The region includes several CEA-supporting industries with strong competitive advantages, including Professional, Scientific, and Technical Services (329), Transportation Equipment Manufacturing (220), and Food Manufacturing (147).
- There is a strong presence of manufacturing industries with growing sectors. These industries represent occupations with transferable competencies to CEA-related occupations, from machine and engineering technicians to marketing and managerial positions.
- The industry outlook for machinery manufacturing and computer and electronic product manufacturing is trending upwards over the next five years. The growth of these industries can contribute to the expansion of CEA in the region.

Progress in entrepreneurial, small business, and existing agricultural producer support

- The entrepreneurship environment is continuing to improve, with positive changes in year-to-year growth rate of new business formations (according to 2021 Region 3 G&D Plan). From 2019 to 2020, the growth rate of agriculture-related startups in Region 3 was 4.4%, slightly above the state growth rate.
- There are numerous entrepreneur-focused organizations, programs, and initiatives (summarized in the Region 3 REI report), including but not limited to: Dan River Business Development Center; Dan River Region Entrepreneurship Ecosystem; Longwood SBDC; The Launch Place and The Launch Place Seed Fund; Thomas P. Dalton IDEA Center; West Piedmont Business Development Center; and SCORE Martinsville Chapter.

High site availability suitable for CEA

- Region 3 has a low cost of doing business, including land prices/rates.
- According to the Region 3 Growth and Diversification plan, 91% of the region's VEDP-listed industry sites (70 out of 77) have central water and sewer service and 87% (67) of sites have natural gas service.
- 61% (47) of these existing sites have 25 or more contiguous acres, lending themselves to best uses including advanced manufacturing or high-value agriculture processing—uses that are compatible with CEA industry.
- The region has at least one mega site: Berry Hill in Pittsylvania County. The location has over 2,000 acres of contiguous developable land with a Tier 4 "Business Ready" rating and is strategically positioned for a major manufacturing facility.

- Small communities within the region have existing buildings suitable for re-development and revitalization. Many of these have the potential for small-scale urban-style CEA production and entrepreneurship.
- The region is centrally located with proximity to major urban markets and major transportation corridors across the mid-Atlantic and South, offering convenient access to consumers. CEA businesses are "capable of serving over 50 million people within a day's drive," and can access up to 70% of the nation's population within a 2-day drive.
- Some CEA operations (modern greenhouses) remain somewhat reliant on natural light—Virginia typically receives plentiful natural light year-round.

Coordinated workforce and talent programs and relevant credentialing

- K-12 programs in the region offer horticulture programs for students, which can create a pipeline to industry, as well as CTE high school programs in agriculture and ag technology. Programs such as the GO TEC Initiative focus on building the pipeline starting in middle school, with CEA-focused training and career awareness.
- Post-secondary educational institutions that award credentials in fields relevant for CEA industry occupations include community colleges (Danville, Southside and Patrick and Henry); four-year colleges and universities (Averett, Longwood, and Hampden-Sydney); and three higher education centers. In 2022, at least 672 individuals earned CEA-relevant credentials from these institutions in areas such as applied horticulture operations, manufacturing engineering technology, and industrial electronics.

Strong coordinated statewide support

- Virginia is very supportive of CEA industry. One CEA company described Virginia as "one of the most ag-friendly states."
- VEDP prioritizes CEA as a target industry sector, with a dedicated marketing and development division and webpage.
- VDACS is one of the few state agencies in the nation with an extensive CEA focus and a specific agribusiness grant/funding program.

Weaknesses: gaps or areas of weakness related to CEA within region 3

Limited awareness, knowledge and understanding of CEA

Currently, there is still much confusion around what CEA looks like. There is a need for greater understanding of the variety of CEA companies in terms of scale, focus, type and needs. Some have more in common with technology firms or "internet of things" companies; some are more like larger advanced manufacturers; and some are large-scale greenhouse operations. Growing mediums and products can also differ widely and are often highly specialized.

Some gaps in entrepreneurial support

The Region 3 Regional Entrepreneurship Strategies Report found a number of gaps in the regional entrepreneurial ecosystem, including lack of connectivity among resource providers; in some cases, resistance to collaboration; limited awareness of entrepreneurship resources among providers and

potential resource users; lack of pride in entrepreneurship (i.e. some business owners do not self-identify as entrepreneurs); lack of a robust training pipeline for aspiring entrepreneurs; lack of youth entrepreneurship training; lack of risk capital, including an angel network; and limited broadband access for online training, remote work and business opportunities.

Limited prepared sites

- The region's available industry sites and major prospect activity are unevenly geographically distributed. The Region 3 GO Virginia Growth and Diversification Plan noted most developed sites and prospect activity clustered in 5 localities along the NC/VA border and identified a need to enhance site assets and activities across the greater region.
- Of the 33 sites that are currently available with VEDP "Business Ready" ratings, 76% (25 sites) are rated as Tier 2. Only 2 sites are rated Tier 4 and another 2 sites rated Tier 3. Significant investment is needed to boost site Tier ratings.
- There are currently no existing shell-buildings for CEA, and the lack of utility connections means potentially higher construction costs and challenges that limit a prospect's time to market.
- Access to renewable energy and low-cost energy is a priority for CEA firms; there is unequal access and adoption rates of renewable energy sources across the region.

Workforce and talent attraction limitations

- Existing Region 3 jobs in areas such as Animal Production, Aquaculture, and crop farming tend to be lower paying compared to other sectors, though some of these are entry-level CEA-related positions.
- The number of existing employees with CEA-relevant skillsets is smaller compared to similarly sized regions, which could impact companies looking to hire immediately.
- Beyond Aerofarms and Blue Ridge Aquaculture, the number of existing CEA-specific employers (and jobs) is limited.
- Housing quality and affordability in the region, as well as uneven broadband and cellular access makes attracting and retaining workers a challenge.

Opportunities: trends and market factors beyond Region 3

Positive growth trajectory due to demand

- Nationally, and globally, CEA industry is still on a growth trajectory – with continued growth projected over the next decade plus. Improvements in technology (lighting system efficiency, etc.) can accelerate and extend this growth.
- As changes in technology and process improvements drive CEA industry growth, the economic and production feasibility of some species (such as berries) could improve in the near term. Larger CEA companies and new or smaller CEA operations could benefit from the increased economies of scale.
- R&D is critical in CEA industry, and companies seek out R&D partnerships and collaborations for intellectual property and new product development (the technology is also a "product" of CEA).
- Increasing consumer preferences for sustainably-grown, fresh, high-quality produce.

- Large-scale CEA operations and prospects are actively exploring Virginia sites—the state fields frequent inquiries. In addition to AeroFarms, the state announced Plenty, the world's largest investment in indoor vertical farming in Chesterfield County, outside of Richmond, in 2022. The California-based company plans to invest $300 million, creating more than 300 full-time jobs.
- CEA companies and technologies can attract and have attracted large-scale private capital investments, representing new money into the region.

Industry sustainability and resilience due to predictability and reliability

- As climate issues affect the dependability and quality of traditional agriculture, CEA offers more dependable, reliable, and consistent product year-round.
- CEA can help shore up food supply chains and improve supply consistency for buyers and customers. Predictability and reliability has economic value—CEA can be a "value-add" over some other forms of traditional agriculture.
- CEA operations, in general, utilize less resources (water, etc.) than traditional agriculture.
- Food safety is increasingly important. Recalls are very costly. CEA can help ensure standardized processes to enhance food safety and minimize recalls.

Positive for promoting resilient food systems for local communities

- Smaller-scale CEA can help enhance regional food system resilience. For instance, localized CEA facilities could supplement traditional agriculture in the off-season to extend local food supply and help to serve local farm-to-school programs, prisons, and/or hospitals.
- Standardization of specific successful enterprise models can allow existing farmers or landowners to adopt CEA practices for particular crops. For instance, a facility producing a certain crop with a set of inputs at a specific price point can be adopted in another part of the country (Walker Brothers in NJ offers an example of this by sharing a model for others to enter indoor farming.)

Alignment with entrepreneurship and potential for new allied support industries

- CEA includes "allied support companies," like lighting companies, sensor manufacturers, system engineers, farming wholesalers (such as trays or seedlings), and more. Entrepreneurs and start-ups, and existing companies, have the opportunity to diversify their markets by serving CEA producers.
- Attracting or growing supply chain or "allied support" companies will help other types of companies coming to the region. A strong supply chain can assist existing companies and enhance the overall CEA ecosystem.
- Legalization of cannabis may provide additional market opportunities for hydroponics/CEA and supporting companies.
- Controlled environments present potential for growing for additional medicinal uses, such as components for the biomedical and pharmaceutical industries

Good jobs for workforce and talent

- Jobs in CEA tend to be higher-paying, higher-skilled, and more diverse than traditional agriculture and food production. CEA firms hire for a variety of occupations, such as harvesters, front-line

supervisors, engineers, plant scientists, HVAC specialists, marketing personnel, and more. There is a stratification of job types, from lower- to higher-skill.
- De-urbanization trends and quality of life preferences for smaller metros, towns, and rural places could be leveraged to attract human capital and CEA-skilled workers.

Threats: potential areas of concern external to Region 3

Nascent industry status

- Some feel that CEA remains a nascent industry, undergoing rapid growth and change, creating a dynamic and sometimes uncertain environment for companies.
- The largest CEA companies are dominating the market and attracting the largest share of venture capital (11 companies represent over 75% of the total private sector investment in CEA, according to Agritecture analysis).
- Some CEA companies see other states as more competitive due to availability of venture capital funding. Venture capital funding for CEA could tighten in the future.
- Prominent, publicized CEA company failures in the last 1-2 years have generated concern. One news article claimed, "The vertical farming bubble is finally popping," citing company closures and reduced earnings projections from several CEA firms such as AppHarvest and AeroFarms.[1]

Limited economies of scale at present

- Some species are not economically feasible for CEA production due to input and specialized technology costs.
- The costs of CEA production remain high overall. A 2020 study from Cornell University estimated that lettuce from indoor farms in Chicago or New York was more than twice as expensive to produce as lettuce grown and delivered from the West Coast.
- CEA start-up costs such as system set-up and capital remain high. Miller et al. (2017) estimated that the initial costs for a hydroponic greenhouse for lettuce was $159,756, while for tomatoes it was $121,242 due to differing equipment costs.

Lack of public awareness and understanding

- The variety of CEA business models and technologies mean that each operation has to be looked at on its own merits and assessed for economic viability and ROI.
- Unknown designation of CEA businesses makes managing a regulatory environment challenging. Local regulatory policies such as land use and zoning and how CEA would be classified for taxation purposes may require a better understanding of the industry and how to manage it. This includes county-by-county differences in agricultural permitting, taxing, etc.
- There is a need to improve public understanding of the CEA industry to decrease opposition encourage CEA growth.
- There is a need to improve the perception of CEA jobs as being primarily low-skill and low-wage, by raising awareness of CEA career opportunities, especially among middle and high school students.
- Studies and conclusions on the environmental impacts of CEA are mixed. Some studies find that the energy required for indoor farming resulted in an overall higher climate impact than traditional farming methods. Meanwhile, hydroponics and aeroponic farming use less water but would need to source more energy from renewable sources like solar or wind to see positive climate impacts.

Strategy and Road Map:

Based on the data collected in this study, and the SWOT analysis above, the study team has identified an inter-related set of recommendations in six strategic areas. Our top recommendation is for a CEA Hub to lead and advance these strategies in Region 3 and across the state, but there are sub-actions within each recommendation that could be pursued separately. It should be noted that to maximize the potential for CEA to advance economic growth more widely in Region 3, that these recommendations focus on an expansive definition for CEA. CEA includes a spectrum of activities that include some level of technology designed to enhance growing conditions for crops indoor and allow for year-round or extended season growing. This may range from simple structures, to greenhouses, to fully automated systems with controlled lighting, water, and ventilation installed.

We offer an important caveat or caution as well. CEA represents an area of tremendous economic opportunity and growth potential for Virginia. We need look no farther than the AeroFarms and Plenty investments in the Commonwealth to support that claim. However, even these large-scale investments are accompanied by uncertainty given the current market conditions, closures, and notable losses or setbacks within the industry. In addition, there are some significant barriers to entry and growth for entrepreneurs and new and existing companies in the CEA space (tightening venture capital environment, high costs of technology adoption and energy use, and specialized business models and variations in technology and product type that make revenues and success less predictable.)

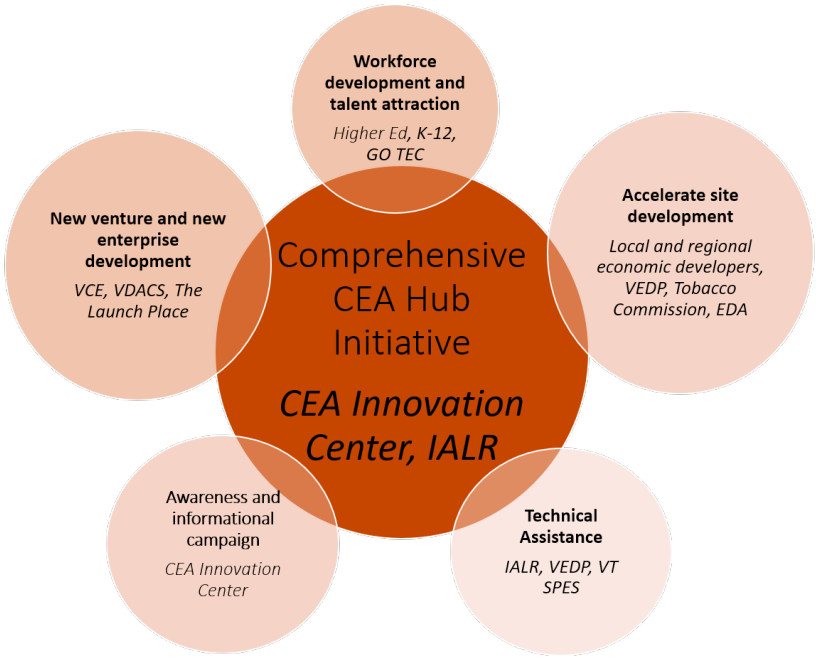
Despite these uncertainties and barriers to entry and growth, the CEA sector, as a whole, represents a tremendous opportunity for growth. CEA company needs align well with regional and state strengths. We have unique assets (such as the CEA Innovation Center at IALR and geographic centrality to markets) that create a competitive advantage for our state. The caution here is that while the CEA sector, as a whole, represents tremendous potential and should be focused on as a high-priority target sector in region 3 and beyond, *each individual CEA operation is unique and needs to be assessed on its own merits and requires specialized assistance related to its own customized approach to CEA*. Technical know-how is required on the business side as well as on the technology side. This is a role that our chief recommendation here for a robust Virginia CEA Hub initiative could help play.

The six overarching strategic areas are:

1. Develop and implement a **comprehensive CEA Hub initiative**, in conjunction with or led by IALR and the CEA Innovation Center.
2. Conduct **CEA Awareness and Informational Campaign**
3. Enhance **CEA-specific new venture and new enterprise development** assistance
4. Continue and **expand CEA Technical assistance** offerings to firms and to policy-makers and economic developers
5. **Accelerate Region 3 Site Development** with CEA targets in mind
6. **Continue and Enhance Region 3 CEA-relevant Workforce Development and Talent Attraction Activities**

1. Develop and implement a comprehensive Virginia CEA Hub initiative, in conjunction with, or led by, IALR and the CEA Innovation Center

Our primary recommendation focuses on a Virginia-wide CEA Hub initiative, concentrated in Region 3, but advancing CEA activity state-wide. Such a project would represent a multifaceted approach with strong multiregional collaboration to catalyze further growth of the CEA sector across Region 3, and the Commonwealth.



The CEA Innovation Center at IALR would be a natural leader and focal point for a Virginia CEA Hub Initiative with engagement with VDACS, VEDP, industry leaders, Virginia Tech, Virginia Cooperative Extension, and other key partners. The Hub would represent a formal collaboration of companies, resources, universities, and others engaged or contributing to CEA industry growth. The Virginia CEA Hub might:

- Serve existing CEA firms and operations in region 3 and Virginia, through connectivity to resources, networking, and technical assistance provision. This might include state-wide and region-focused networking or educational events, on-going information sharing, and related activities to connect and share. Tactic may also include a regional and a state-wide, online centralized, externally searchable, resource directory for users to locate industry specific assets. The CEA Hub may also create and update an online, regional and statewide events calendar of industry-relevant specific activities.
- Educate and inform policy-makers, partners, local officials, economic developers, workforce and education partners, as well as the general public, about CEA in Virginia and beyond. A key focus of this work is to highlight the CEA industry and its nature; to share the breadth of CEA operations and firms; and to raise awareness as to the range of CEA occupations and career pathways. (see recommendation area #2).

- Support new entrepreneurs, existing producers, and others interested in entering the CEA space, from the commercialization and spin-off of CEA-related technologies in high growth ventures, to the small-scale utilization of low-cost CEA greenhouse or indoor growing technologies by farmers or start-ups in Region 3, and beyond. (see recommendation area #3)
- Provide specialized and accessible technical assistance for CEA firms, as well as for local government, policymakers, and economic developers in working with CEA firms, entrepreneurs, and prospects (see recommendation area #4)
- Support the acceleration of site development in Region 3, and be a state-wide resource for site-related CEA prospect needs (see recommendation area #5).
- Closing the talent gap and meeting future workforce needs for CEA sector (including allied support companies) through career awareness, workforce preparation, job connections, internships, and network opportunities (See recommendation area #6).

CEA Hub Initiative Road Map and Action Steps	
Who	• IALR with GOVA Region 3 to develop concept. • Identify a core leadership team or director (s). This might include IALR, GOVA Region 3, Virginia Tech, with input from VEDP, VDACS. • Assemble an Advisory board or committee for the Hub initiative. This should include a mix of industry, workforce, resource partners, and state officials. The Advisory group will help to grow the larger network, and provide input on strategic decision-making and growth. • The Hub would be a larger collaboration, so there is a need to engage the larger collaborative group and identify a wider network to be affiliated with the Hub. This may include industry partners, resource providers, workforce partners, and others.
What	• Develop concept for Virginia CEA Hub Initiative (core leadership team or directors) • Formalize leadership team/directors. • Formalize advisory group • Identify larger collaboration and network members. • Develop short-term operational plan for Hub (3 year timeframe with goals). • Pursue seed or startup funding or commitments to establish the Hub Initiative.
Where	Led by and focused largely on Region 3, but the collaborative group, focus, and activities could be state-wide
How	• The Virginia CEA Hub Initiative might be conceived and grown in a manner somewhat analogous to the Virginia BioHub Initiative (statewide focus with regional nodes, focused around the needs of a specific sector, including a mix of networking, entrepreneurship and workforce/talent activities). • The CEA Hub would include technical assistance and serve as a backbone organization based in Region 3 but potentially serving a statewide footprint. The collective impact/backbone organization model is one to consider. • Another approach might be a Design Support System Solution, which is a hub for compiling practices with an extensive economic model database to provide financial risk assessments to companies[2].

Funding	• GO Virginia Region 3 per capita (implementation) grant; possibly followed in 1-2 years by a statewide competitive grant. • Parts of model could be funded by USDA, EDA, VDACS, and others.

2. Conduct CEA Awareness and Informational Campaign

The Virginia CEA Hub Initiative could plan and implement activities to increase awareness and share information about CEA. One aim is to better educate and inform policy-makers, partners, local officials, economic developers, workforce and education partners, as well as the general public, about CEA in Virginia and beyond. A primary focus is to highlight the CEA industry and its nature; to share the breadth of CEA operations and firms; and to raise awareness as to the range of CEA occupations and career pathways.

CEA Awareness Campaign Roadmap and Action Steps	
Who	Virginia CEA Hub Initiative (led by IALR with GOVA Region 3)
What	• Develop CEA Hub website including an accessible online resource page. • Develop a media and communications strategy, to include network-building and social media (using social media tools and groups) • Prepare and deliver a CEA presentation focused on economic opportunity and industry awareness for a primary audience of local government and economic development community. Presentation can be delivered in counties, at association meetings such as VACO, VML, or VEDA, and available on-line or on request along with an accompanying handout or 1-2 page informational sheet. • Hold a monthly in-person Hub networking event (rotating each month to a different locality or different region of state) to bring together industry partners, Hub network members, and interested others for information sharing and professional networking. • Prepare and deliver a CEA presentation focused on career awareness and opportunities for primarily an audience of education, workforce, students, or general public. Presentation can be delivered in schools, at meetings, and available on-line or on request along with an accompanying handout or 1-2 page informational sheet. • Consider an annual or biennial (every 2 years) conference or “flagship” event for information sharing, network building, and education around CEA. Consider differing “tracks” or foci for small-scale CEA, large-scale industry, new entrants, existing ag producers, policy-makers and economic developers, workforce and education partners, and entrepreneurs. • Explore hands-on tours or experiential opportunities for students and the public to learn about CEA: company visits, IALR labs, "open house” type events. A “mobile” open-house could also be developed to bring the technology to students and to be on hand at public events, farmers markets, and elsewhere. **Crosscutting strategies** o Expand and continue partnership with GoTec to include CEA-focused career awareness and skill development. o Partner with VCE (Virginia Cooperative Extension), VDACS, or others to prepare and deliver CEA-focused programming and workshops for existing, small, and

	new producers with a focus on lower cost, lower barriers to entry CEA as an entrepreneurial or revenue diversification opportunity. o Develop programming and resources for entrepreneur resource providers, partners, and potential entrepreneurs regarding case studies (examples); and opportunities for CEA-related entrepreneurship, as well as the need for CEA-related ventures. o Develop a "working with CEA entrepreneurs, companies and prospects" 101 guide or workshop for local economic developers, regional entrepreneurial providers, and investors or local funders to better help them identify and assess high-potential CEA opportunities and to know which resources to call upon.
Where	• On-line resources and webinars. • In-person networking events and information sessions • In-person presentations, workshops, across region and state.
How	• CEA Hub 3-year operational plan should include a staff person or network member team dedicated to network-building, awareness, and education.
Funding	• GO Virginia Region 3 per capita (implementation) grant; possibly followed in 1-2 years by a statewide competitive grant.

3. New venture development: tech entrepreneurs and existing producers

This recommendation encompasses support for start-ups, entrepreneurs, existing producers, and others interested in entering the CEA space. This includes a wide range of entrepreneur types, from the high growth ventures associated with commercialization and spin-off of CEA-related technologies to the (relatively) smaller-scale utilization of low-cost CEA greenhouse or indoor growing technologies by farmers or start-ups in Region 3, and beyond.

It is important to recognize that greenhouse-style CEA represents tremendous opportunity. It is familiar to existing producers and in some forms may be less cost and resource intensive than higher volume vertical farming while still employing some of the technologies of CEA (lighting controls, automation, etc). Existing Virginia businesses such as Greenswell Growers in Chesterfield County and Schuyler Greens in Goochland County illustrate the vast growth potential here.

Additionally, Virginia has a number of smaller more technology-focused CEA companies that have demonstrated start-up and expansion success, such as Babylon MicroFarms in Richmond or Area 2 Farms in Arlington.

Also included in this recommendation area is the technology and innovation from CEA operations. For instance, AeroFarms in Danville cited the extensive company involvement in technology commercialization and intellectual property as the company was involved with over 345 total invention disclosures; 95 active inventions in process; 54 trade secrets; 32 patent protections; and more. There is tremendous opportunity for technology, automation, software, and a range of agriculture-tech products and systems.

This recommendation area refers to enhanced and focused support for this entire spectrum of entrepreneurship and venture development.

New Venture Development Road Map and Action Steps	
Who	Virginia CEA Hub Initiative (led by IALR with GOVA Region 3)
What	• Create an entrepreneur assistance program as one part of the CEA Hub. With a full-time staff position focused on encouraging and assisting new ventures and small-scale CEA operations and small-scale CEA adoption by existing producers. This would be similar to an SBDC/entrepreneur assistance role but focused on CEA and ag-tech across state but housed in Region 3 at IALR. • Organize and host an annual CEA and ag technology-themed entrepreneur pitch competition. The competition might employ a comprehensive approach that includes mentoring and focused assistance for participants using a model similar to the Gauntlet program. • There are many ways to structure such a program. For instance, winners of the pitch session could have a 6 month virtual "residency" with the Hub and could be identified as a cohort group who would each gain access to seed funding, connections to capital investors, and focused mentorship. • Assess what training, resources, and activities already exist in VA related to small-scale CEA (example, VCE workshops or assistance on high tunnels, etc.) • Aggregate existing information and resources on the CEA Hub resource page and consider a site or page dedicated to small-scale CEA, perhaps jointly owned/hosted by VCE and IALR • Conduct an annual workshop on CEA enterprise development as part of an existing farm or as a standalone venture: for producers, farmers, land-owners, or new entrepreneurs with agriculture interest. Perhaps led by VCE/IALR related to small-scale CEA production – strategies, best practices, resources, technical assistance. • Create and implement a pilot program of 5-10 farmers interested in participating in CEA: • Provide equipment and training • Conduct ride-along mixed-methods research to understand the experience of farmers, identify concerns, risks, scale-up potential and limitations, and impact on income • Coordinate with NSF/VT-CAIA precision agriculture program to address technology adoption • Collect "success stories" of CEA start-ups and enterprises in Virginia to share. • Engage new CEA start-ups, producers, and those exploring CEA ventures in the CEA Hub network activities. • Host regional CEA start-up days around the state once per year in conjunction with other resource providers.
Where	• Staff and programming housed in Region 3, perhaps at IALR. • Programming and outreach offered around Region 3 and state. • Webinar and virtual opportunities.
How	CEA Hub 3 year operational plan should include a full-time staff person dedicated to entrepreneur assistance, ideally with personal experience with new company formation and industry knowledge of CEA.
Funding	• GO Virginia Region 3 per capita (implementation) grant; possibly followed in 1-2 years by a statewide competitive grant. • Explore other funding sources such as USDA, SBA, DHCD.

4. Provide specialized and accessible technical assistance for CEA firms, and conduct CEA industry engagement

This recommendation relates to the provision of specialized and accessible technical assistance for CEA firms, as well as for local government, policymakers, and economic developers in working with CEA firms, entrepreneurs, and prospects.

This strategy is closely linked and integrated with recommendation areas 2 (awareness) and 3 (entrepreneurship assistance). Beyond entrepreneur support, this recommendation encompasses coordinating and enhancing direct work with CEA firms.

Industry Technical Assistance and Engagement Roadmap and Action Steps	
Who	Virginia CEA Hub Initiative (led by IALR with GOVA Region 3) and related entities such as GenEdge, Virginia Tech, VDACS, and VEDP
What	• Designate a point person to serve as lead contact to work with existing and larger CEA firms and prospects. This would be a resource for local economic developers as well as for companies/prospects – helping link firms to research, suppliers, support entities and more. This would be a part of the Hub initiative and be a resource for VEDP and local economic developers and REDOs when engaging with companies and prospects. • Work with manufacturers and other support companies to identify opportunities for adapting their existing products/systems to CEA applications, creating new supply-chain companies. Also work to adapt or package their products or systems as applicable to CEA. • Provide accessible and affordable resources and consulting on process and lean manufacturing, systems improvements, marketing, human resources, and other assistance to CEA companies in Virginia. • Develop an inventory of resources, links, and expertise contacts to be able to share with companies, developers, and others. • Meet with economic developers, universities, and others regularly to learn about offerings and to share knowledge of CEA industry needs. • Represent the CEA Hub across Virginia and beyond and keep abreast of CEA industry trends and developments. • Develop close relationships with CEA firms in Virginia and substantively engage companies in CEA Hub network activities, advisory groups, conferences, and other activities
Where	• Staff and programming housed in Region 3, perhaps at IALR. • Programming and outreach offered around Region 3 and state. • Webinar and virtual opportunities.
How	CEA Hub 3-year operational plan should include a full-time staff person dedicated to industry engagement and technical assistance. This may be a shared position with an entity such as GenEdge, but it will be important for services and offerings to be associated under the Hub, for coordination and identity purposes.
Funding	GO Virginia Region 3 per capita (implementation) grant; possibly followed in 1-2 years by a statewide competitive grant. Explore other funding sources such as USDA, SBA, DHCD.

5. Accelerate Region 3 site development and readiness for CEA industry

The CEA Hub Initiative can be an advocate and source of information for site readiness, participating in meetings with economic developers and local officials to offer CEA industry knowledge and to champion the site needs of industry firms. CEA Hub should actively participate in Region 3 EDOs and in any future site assessment and planning activities in the region.

Site Development Roadmap and Action Items	
Who	Virginia CEA Hub Initiative (with regional EDOs and localities)
What	• Inventory, assess, and prioritize sites and site development needs in Region 3, related to CEA prospects and CEA company expansions. • Engage CEA companies and prospects to identify site needs and communicate needs with CEA Hub network, and with Region 3 EDOs and localities. • In conjunction with regional EDOs, visit and meet with each locality and ED in region 3 to share information on CEA industry prospects and company needs and discuss county-related opportunities and tactics.
Where	Region 3 primarily (could consider teaming up with additional GOVA regions with CEA presence)
How/Funding	EDA; VEDP; GO Virginia Region 3 per capita (implementation) grant; possibly followed in 1-2 years by a statewide competitive grant.

6. Closing the talent gap and meeting future workforce needs for CEA sector, including allied support companies.

While listed last here, this is among the most pressing and important strategic areas for near-term AND long-term growth of the CEA sector in Region 3, and state-wide. Closing any existing talent gaps and meeting future workforce needs for the CEA sector (including allied support companies) is critical. This encompasses career awareness, workforce preparation, job connections, internships, and networking.

Workforce and Talent Roadmap and Action Items	
Who	Virginia CEA Hub Initiative (with regional WDBs, EDOs, VEDP, educational entities, K-12, and others).
What	• Improve understanding of the talent pipeline and occupation and competencies needs for CEA companies. • Develop, recruit and retain specialized talent to grow a skilled CEA workforce pipeline to meet existing and future industry demand with high quality candidates through a focused internship program. • Region 3, and Virginia, interns could be placed with existing CEA firms as well as CEA smaller firms and start-ups. • Grow the GoTech program and enhance the components associated with CEA. • Develop CEA career awareness offerings in K-12 through a variety of means and formats (video, on-line, career events, field trips, company visits, etc.).
Where	Region 3 primarily
How/Funding	GO Virginia Region 3 per capita (implementation) grant; possibly followed in 1-2 years by a statewide competitive grant. Explore other funding sources such as DOL and DOE.

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Appendix

Company Inventories

Table 1. Virginia CEA Company List in VA

Company Name	Location	Website
Area 2 Farms	Arlington	https://www.area2farms.com/
Fresh Impact Farms	Arlington	https://www.freshimpactfarms.com/
WeGrow Company	Alexandria	https://www.wegrowcompany.com/
Babylon Micro-Farms	Richmond	https://babylonmicrofarms.com/
Magic Sun Farms	Richmond	https://magicsunfarms.com/
Greenswell Growers	Goochland County	https://greenswellgrowers.com/
FreshH20 Growers	Stevensburg	https://www.fresh2ogrowers.com/
Schuyler Greens	Schuyler	https://schuylergreens.com/
Beanstalk	Herndon	https://beanstalk.farm/
True Farms	Prince William County	https://www.truefarms.com/
Fox Urban Farms	Winchester	https://www.foxurbanfarms.com/
Four Oaks Farms	Wirtz	https://www.4oaksfarms.com/
Aerofarms	Danville	https://www.aerofarms.com/
Soli Organic	Harrisonburg	https://www.soliorganic.com/
Bright Farms	Culpeper County	https://www.brightfarms.com/how-we-grow/
Red Sun Farms	Dublin	https://www.redsunfarms.com/
Sunny Farms	Virginia Beach	NA
Blue Ridge Aquaculture	Martinsville	http://www.blueridgeaquaculture.com/
Plenty	Chesterfield County	https://www.plenty.ag/

Table 2. CEA Industry in Virginia and GOVA Region 3

Industry	VA 2022 Jobs	VA 2017-2022 % Change	VA 2022-2027 % Change	VA Avg. Earnings	GOVA 2022 Jobs	GOVA 2017-2022 % Change	GOVA 2022-2027 % Change	GOVA Avg. Earnings
Crop Production	5,727	1%	8%	$44,978	321	-6%	2%	$40,319
Animal Production & Aquaculture	3,060	-5%	-2%	$49,326	430	-13%	-10%	$52,880
Machinery Manufacturing	14,249	-1%	6%	$85,399	633	164%	27%	$71,946

Computer and Electronic Product Manufacturing	12,041	3%	6%	$138,639	364	129%	43%	$107,297
Total	35,077	0%	5%	$93,927	1,749	42%	16%	$69,233

Source: EMSI/Lightcast.

Table 10: VEDP Announcements of Agriculture-Related Fields as of January 24, 2023

Company Name	Locality	Business Description	Month Announced	New / Expansion	New Jobs	Investment ($M)
Plenty Inc	Chesterfield	Indoor vertical farming	Sep 2022	N	300	300
AeroFarms	Pittsylvania	Production of micro-greens	Jul 2022	E	66	0
Beanstalk	Fairfax	Indoor vertical farming	May 2021	E	17	6.5
Sunny Farms, LLC	Virginia Beach	Hydroponic greenhouse	Apr 2021	N	155	59.6
Babylon Micro-Farms	Richmond City	Develops and produces remotely controlled, indoor hydroponic systems	Feb 2021	E	24	0.14
The Plant Company of Virginia LLC	Augusta	Greenhouse operations	Sep 2020	N	22	10.55
Greenswell Growers	Goochland	Commercial hydroponic greenhouse	Aug2020	N	27	17.416772
AeroFarms	Pittsylvania	Vertical grow house; Distributes leafy greens	Dec 2019	N	92	41.836
BrightFarms	Culpeper	Greenhouse for lettuce, tomatoes, and other vegetables.	Oct 2015	N	24	7.35
Red Sun Farms	Pulaski	Greenhouse tomato production; hydroponic vegetables	Mar 2013	N	205	30
Shenandoah Growers, Inc.	Rockingham	HQ; Herb growing and herb brokerage	Jan 2011	E	31	3
Shenandoah Growers, Inc.	Rockingham	HQ; Herb growing and herb brokerage	Jun 2007	E	20	3.2

Source: VEDP Announcements, Virginia, Agriculture, Forestry, Fishing, and Hunting (*https://announcements.vedp.org/Announcements/*).

Table 5. National CEA Company List (non-exhaustive)

Company Name	State	City	Website
PodFarms	South Carolina	Greenville	https://www.podfarms.com/
MicroLab Farms	California	Needles	https://microlabfarms.com/
Ouroboros Farm	California	Half Moon Bay	https://www.ouroborosfarms.com/
Infinite Harvest	Colorado	Lakewood	https://infinite-harvest.com/about/
Altius	Colorado	Denver	https://altiusfarms.com/
Buttercrunch Farms	Colorado	Eagle	http://www.buttercrunchfarm.com/
GroFresh Farms	Colorado	Grand Junction	http://www.grofresh365.com/
Grand Valley Greens	Colorado	Loma	https://www.grandvalleygreens.com/
Metropolitan Farms/Urban Transformation Network	Illinois	Chicago	http://metro-farms.com/
MightyVine	Illinois	Chicago	https://mightyvine.com/
Green Sense Farms	Indiana	Portage	https://www.greensensefarms.com/
Bella Vita Farm	Maryland	Brookevale	https://bellavitafarm.com/
Garden Fresh Farms	Minnesota	Maplewood	https://gardenfreshfarms.com/
Bushel Boy	Minnesota	Owatonna	https://www.bushelboy.com/
Element Farms	New Jersey	Florence	https://www.element-farms.com/
Farm.One	New York	NYC	https://farm.one/
Upward Farms	New York	Brooklyn	Products • Upward Farms
Dream Harvest	Texas	Houston	http://dreamharvestfarms.com/
Forest County Potawatomi	Wisconsin	Laona	https://farm.fcpotawatomi.com/
Vertical Harvest	Wyoming	Jackson	https://verticalharvestfarms.com/
Copperstate Farms	Arizona	Snowflake	https://www.copperstatefarms.com/
Plenty (Bright Farms)	California	South San Francisco	https://www.plenty.ag/
Glass House Farms	California	Carpinteria	https://glasshousefarms.org/
Harborside	California	Oakland	https://stage.shopharborside.com/
Iron Ox	California	San Carlos	https://ironox.com/
Houweling's	California Canada	Camarillo British Columbia	http://www.houwelings.com/
Village Farms	Canada Texas	British Columbia	https://villagefarms.com/
Kalera	Florida	Orlando	https://kalera.com/
Cresco Labs	Illinois	Chicago	https://www.crescolabs.com/

AppHarvest	Kentucky	Morehead	https://www.appharvest.com/
Little Leaf Farms	Massachusetts	Devens	https://www.littleleaffarms.com/
Planted Detroit	Minnesota	Detroit	https://planteddetroit.com/
Revol Greens	Minnesota	Medford	https://www.revolgreens.com/
Local Bounti / Pete's	Montana (HQ) Georgia California	Hamilton Byron	https://localbounti.com/
OISHI	New Jersey	Jersey City	https://oishii.com/shop
Bowery	New York	NYC	https://bowery.co/
Gotham Greens	New York Illinois Rhode Island Maryland Colorado California Georgia Texas	NYC Chicago Providence Baltimore Denver Davis Atlanta Dallas	https://www.gothamgreens.com/
Square Roots	New York Michigan Wisconsin	Brooklyn Grand Rapids Kenosha	https://squarerootsgrow.com/
Smallhold	New York Texas California	Brooklyn (HQ) Austin Los Angeles	https://www.smallhold.com/
Mucci	Ohio	Huron	https://www.muccifarms.com/our-farms/about-our-farms/
80 Acres Farms	Ohio	Hamilton	https://www.80acresfarms.com/
Fifth Season	Pennsylvania	Pittsburgh	https://www.fifthseasonfresh.com/our-story
Vertical Roots	South Carolina	Charleston	https://www.verticalroots.com/

Table 11. Virginia Supply Chain Company List (non-exhaustive)

Company Name	Location/County	Website	Notes
Bowerbird Energy	Richmond, VA	https://bowerbirdenergy.com/solutions/energy/controlled-environment/	LED lighting
Happy Trees Agricultural Supply	Richmond, Fredericksburg, Petersburg, VA	https://www.happytreesag.com/	Retail store that specializes in hydroponics and indoor gardening supplies.
Hyve	Verona, VA	https://growhyve.com/home	Hydroponic supplies.

Peninsula Hydroponics	Hampton Roads, VA	https://www.peninsulahydroponics.com/services	Commercial systems, plant delivery in Hampton, consulting services and school hydroponic systems
Falls Church Hydroponics and Garden Supplies	Falls Church, VA	https://fallschurchhydro.com/	Sells hydroponic supplies, lighting, pumps, to hobbyists, commercial food producers, and large-scale cultivators
Blue Ridge Hydroponics	Roanoke, VA	https://blueridgehydro.wordpress.com/	Hydroponic supplies
ID Gardens	Fairfax, VA	https://www.idgardens.com/	Sells indoor garden racks for people's homes
Prins-USA	Stevensburg, Va	https://prinsusa.com/	Works with clients to build greenhouses for indoor growing and also has heating systems, irrigation, and lighting
EcoSprout	Crozet, VA	https://www.ecosprout.biz/	Products specifically for small-medium size growers

Table 12. National Supply Chain Company List (non-exhaustive)

Company Name	Location/County	Website	Notes
California Light Works	Canoga Park, CA	https://californialightworks.com/commercial/?msclkid=a3ba5c1c8f1b1f751d003eb692e21bc4	Cannabis lighting
ChilLED Tech	United States	https://chilledgrowlights.com/commercial-grower-led-grow-lights-trial-program	Custom solutions for commercial growers and DIY folks
1000 Bulbs	Mesquite, TX	https://www.1000bulbs.com/fil/categories/hydroponic-supplies	Growing lights and hydroponic supplies
Fresh Water Systems	Greenville, SC	https://www.freshwatersystems.com/	Hydroponic supplies
CropKing	Lodi, OH	https://cropking.com/	One of the largest hydroponics suppliers, serves over 700 operations in the US. Works specifically with Greenswell Growers in VA.
Nelson Pade	Montello, WI	https://aquaponics.com/	Aquaponics supplies and planning services
The Aquaponic Source	Wheat Ridge, CO	https://www.theaquaponicsource.com/our-services/	Home, farm, school system supplier

PentAir Aquatic Eco-Systems	Apopka, Florida	https://pentairaes.com/	Supplier of aeration, pumps, etc.
Green Life Aquaponics	Spring, Texas	https://greenlifeaquaponics.com/	Specializes in aquaponics, though they delve into other related sustainable farming practices
Endless Food Systems	Forestburg, TX	https://www.facebook.com/EndlessFoodSystems	Small-scale assistance
Symbiotic Aquaponic LLC	Talihina, Oklahoma	https://www.symbioticaquaponic.com/	Offer supplies and education
Scale Microgrid Solutions	Ridgewood, NJ	https://www.scalemicrogrids.com/	Clean energy consulting and solutions
Automation Direct	Cumming, Georgia	https://www.automationdirect.com/adc/home/home	Sells various electronic components, etc. for automation
Cold Shot Chillers	Houston, TX	https://waterchillers.com/	Industrial chiller sales
North Slope Chillers	Salt Lake City, UT	https://northslopechillers.com/	Can serve cannabis, fermentation, chemical processing, hydroponics; offer rental
Stuppy Greenhouse	North Kansas City, MO	https://www.stuppy.com/	Supplier of greenhouse structures, systems, and equipment
Indoor Growers World	Nashville, TN	https://indoorgrowersworld.com/about-us/	CEA design and construction

Occupation and Industry Information

Table 3: Industry Growth in GOVA 3 Support Cluster

NAICS	Description	2022 Jobs	2027 Jobs	2022 – 2027 % Change	Competitive Effect	2022 Payrolled Business Locations
115	Support Activities for Agriculture and Forestry	92	112	22%	12	29
221	Utilities	473	454	-4%	-23	25
236	Construction of Buildings	1,057	1,106	5%	-12	230
311	Food Manufacturing	1,431	1,659	16%	147	17
312	Beverage and Tobacco Product Manufacturing	441	537	22%	59	10

335	Electrical Equipment, Appliance, and Component Manufacturing	535	545	2%	-30	8
336	Transportation Equipment Manufacturing	741	993	34%	220	11
423	Merchant Wholesalers, Durable Goods	1,688	1,894	12%	120	170
424	Merchant Wholesalers, Nondurable Goods	1,403	1,435	2%	-30	94
444	Building Material and Garden Equipment and Supplies Dealers	1,549	1,596	3%	-26	91
482	Rail Transportation	0	0	0%	0	0
484	Truck Transportation	1,530	1,449	-5%	-151	239
493	Warehousing and Storage	1,978	1,821	-8%	-460	22
518	Data Processing, Hosting, and Related Services	146	173	18%	3	10
541	Professional, Scientific, and Technical Services	2,984	3,620	21%	329	484
551	Management of Companies and Enterprises	813	792	-3%	-65	60
561	Administrative and Support Services	5,928	6,166	4%	-153	344
562	Waste Management and Remediation Services	140	146	4%	-6	20
Total		22,931	24,497	7%	-65	1,863

(Source: Lightcast Industry Table for relevant NAICS codes in Region 3; Q1 2023 data).

Table 4. Low-Paying Supply Chain v. High-Paying Supply Chain Industries in GOVA Region 3

Low-Paying		
NAICS	Description	Avg. Earnings Per Job
482	Rail Transportation	$0
561	Administrative and Support Services	$36,992
444	Building Material and Garden Equipment and Supplies Dealers	$40,081

High-Paying		
NAICS	Description	Avg. Earnings Per Job
221	Utilities	$133,963
551	Management of Companies and Enterprises	$94,479
335	Electrical Equipment, Appliance, and Component Manufacturing	$76,570

115	Support Activities for Agriculture and Forestry	$49,188
311	Food Manufacturing	$52,491
493	Warehousing and Storage	$53,675
424	Merchant Wholesalers, Nondurable Goods	$54,519
312	Beverage and Tobacco Product Manufacturing	$55,278
236	Construction of Buildings	$59,067

562	Waste Management and Remediation Services	$76,424
423	Merchant Wholesalers, Durable Goods	$70,749
541	Professional, Scientific, and Technical Services	$70,513
336	Transportation Equipment Manufacturing	$69,314
518	Data Processing, Hosting, and Related Services	$69,132
484	Truck Transportation	$65,752

Source: EMSI/Lightcast.

Table 6. Selected CEA-related Occupations in Virginia

Description	2017-2022 % Change	2022-2027 % Change	Avg. Hourly Earnings	Avg. Annual Earnings
Computer and Information Systems Managers	7%	10%	$82.83	$172,286.40
General and Operations Managers	56%	6%	$61.11	$127,108.80
Shipping, Receiving, and Inventory Clerks	20%	1%	$17.58	$36,566.40
Maintenance and Repair Workers	5%	5%	$21.50	$44,720.00
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	-7%	6%	$14.37	$29,889.60
Farmworkers, Farm, Ranch, and Aquacultural Animals	-6%	4%	$14.74	$30,659.20
Farmers, Ranchers, and Other Agricultural Managers	-2%	2%	$23.02	$47,881.60
Food Science Technicians	52%	9%	$25.06	$52,124.80
Soil and Plant Scientists	106%	6%	$31.97	$66,497.60
Food Scientists and Technologists	21%	5%	$41.32	$85,945.60
Total	14%	6%	$35.41	

Source: EMSI/Lightcast.

Table 7. Selected CEA-related Occupations in GOVA Region 3

Description	2017-2022 % Change	2022-2027 % Change	Avg. Hourly Earnings	Avg. Annual Earnings

Computer and Information Systems Managers	37%	22%	$60.31	$125,444.80
General and Operations Managers	55%	8%	$45.71	$95,076.80
Shipping, Receiving, and Inventory Clerks	14%	-1%	$15.98	$33,238.40
Maintenance and Repair Workers	-2%	4%	$20.16	$41,932.80
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	-16%	1%	$13.79	$28,683.20
Farmworkers, Farm, Ranch, and Aquacultural Animals	-17%	-7%	$14.89	$30,971.20
Farmers, Ranchers, and Other Agricultural Managers	-16%	-11%	$22.84	$47,507.20
Food Science Technicians	NA	NA	NA	NA
Soil and Plant Scientists	NA	NA	NA	NA
Food Scientists and Technologists	NA	NA	NA	NA
Total	12%	5%	$23.96	

Source: EMSI/Lightcast.

Table 13: CEA Support Cluster, Virginia

SOC	Description	2022 Jobs	2027 Jobs	2022 - 2027 Change	2022 - 2027 % Change	Avg. Hourly Earnings	Avg. Annual Earnings
11-1021	General and Operations Managers	84,603	90,000	5,396	6%	$61.24	$127,379.20
11-2021	Marketing Managers	4,853	5,390	537	11%	$81.73	$169,998.40
11-2022	Sales Managers	6,704	7,407	703	10%	$77.88	$161,990.40
11-3013	Facilities Managers	1,808	1,952	145	8%	$48.87	$101,649.60
11-3021	Computer and Information Systems Managers	14,025	15,566	1,542	11%	$82.95	$172,536.00
11-3051	Industrial Production Managers	2,390	2,669	279	12%	$60.03	$124,862.40
11-3071	Transportation, Storage, and Distribution Managers	2,740	2,969	229	8%	$51.12	$106,329.60
11-9041	Architectural and Engineering Managers	3,697	3,881	184	5%	$73.29	$152,443.20

13-1028	Buyers and Purchasing Agents	21,728	21,417	(311)	(1%)	$37.80	$78,624.00
13-1071	Human Resources Specialists	28,330	30,389	2,058	7%	$37.44	$77,875.20
13-1074	Farm Labor Contractors	0	0	0	0%	$0.00	Insf. Data
13-1075	Labor Relations Specialists	1,067	1,053	(15)	(1%)	$28.66	$59,612.80
13-1082	Project Management Specialists	29,345	30,905	1,560	5%	$52.88	$109,990.40
13-1151	Training and Development Specialists	13,497	14,260	764	6%	$33.63	$69,950.40
15-1231	Computer Network Support Specialists	6,918	7,236	319	5%	$36.60	$76,128.00
15-1232	Computer User Support Specialists	22,108	23,539	1,431	6%	$28.35	$58,968.00
15-1244	Network and Computer Systems Administrators	15,272	15,672	400	3%	$47.50	$98,800.00
15-2051	Data Scientists	3,878	4,621	742	19%	$55.59	$115,627.20
17-2021	Agricultural Engineers	28	29	1	2%	$43.70	$90,890.73
17-2031	Bioengineers and Biomedical Engineers	560	600	41	7%	$45.16	$93,932.80
17-2051	Civil Engineers	10,511	10,896	385	4%	$45.76	$95,180.80
17-2061	Computer Hardware Engineers	3,616	3,725	109	3%	$66.91	$139,172.80
17-2071	Electrical Engineers	4,971	5,120	149	3%	$52.85	$109,928.00
17-2072	Electronics Engineers, Except Computer	3,616	3,726	110	3%	$58.58	$121,846.40
17-2081	Environmental Engineers	945	993	48	5%	$48.19	$100,235.20
17-2112	Industrial Engineers	5,391	5,922	531	10%	$47.41	$98,612.80
17-2131	Materials Engineers	471	501	31	6%	$51.22	$106,537.60
17-2141	Mechanical Engineers	7,277	7,565	288	4%	$49.34	$102,627.20
17-3022	Civil Engineering Technologists and Technicians	1,459	1,477	19	1%	$27.44	$57,075.20

17-3023	Electrical and Electronic Engineering Technologists and Technicians	4,057	4,141	84	2%	$37.99	$79,019.20
17-3025	Environmental Engineering Technologists and Technicians	404	414	11	3%	$24.34	$50,627.20
17-3026	Industrial Engineering Technologists and Technicians	1,130	1,214	83	7%	$30.28	$62,982.40
17-3027	Mechanical Engineering Technologists and Technicians	825	853	28	3%	$31.01	$64,500.80
19-1021	Biochemists and Biophysicists	707	797	90	13%	$63.06	$131,164.80
19-1022	Microbiologists	215	243	28	13%	$37.38	$77,750.40
19-2031	Chemists	1,526	1,637	111	7%	$47.40	$98,592.00
19-4021	Biological Technicians	1,731	1,864	132	8%	$25.43	$52,894.40
19-4031	Chemical Technicians	805	884	80	10%	$24.45	$50,856.00
29-1131	Veterinarians	2,669	2,969	299	11%	$52.27	$108,721.60
29-2056	Veterinary Technologists and Technicians	2,444	2,805	361	15%	$20.12	$41,849.60
43-5061	Production, Planning, and Expediting Clerks	7,459	8,017	558	7%	$25.33	$52,686.40
43-5071	Shipping, Receiving, and Inventory Clerks	18,475	18,690	215	1%	$17.57	$36,545.60
43-6011	Executive Secretaries and Executive Administrative Assistants	10,502	9,876	(626)	(6%)	$33.49	$69,659.20
45-2011	Agricultural Inspectors	433	463	30	7%	$21.46	$44,634.12
45-2021	Animal Breeders	0	<10	Insf. Data	Insf. Data	$0.00	Insf. Data
45-2041	Graders and Sorters, Agricultural Products	514	521	6	1%	$14.24	$29,616.70
45-2091	Agricultural Equipment Operators	686	763	76	11%	$16.96	$35,283.27

45-2099	Agricultural Workers, All Other	707	763	56	8%	$18.03	$37,494.26
49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	1,533	1,609	76	5%	$31.87	$66,289.60
51-2041	Structural Metal Fabricators and Fitters	2,057	1,983	(73)	(4%)	$23.74	$49,379.20
51-3011	Bakers	2,788	3,100	312	11%	$16.32	$33,945.60
51-3021	Butchers and Meat Cutters	2,849	2,938	89	3%	$17.09	$35,547.20
51-3022	Meat, Poultry, and Fish Cutters and Trimmers	3,106	3,077	(29)	(1%)	$14.13	$29,390.40
51-3023	Slaughterers and Meat Packers	1,116	1,211	95	9%	$14.85	$30,888.00
51-3091	Food and Tobacco Roasting, Baking, and Drying Machine Operators and Tenders	777	768	(9)	(1%)	$15.01	$31,220.80
51-3092	Food Batchmakers	2,639	2,933	295	11%	$18.36	$38,188.80
51-3093	Food Cooking Machine Operators and Tenders	773	784	11	1%	$16.33	$33,966.40
51-3099	Food Processing Workers, All Other	1,085	1,124	39	4%	$15.91	$33,092.80
53-3031	Driver/Sales Workers	10,727	11,735	1,007	9%	$15.63	$32,510.40
53-3032	Heavy and Tractor-Trailer Truck Drivers	47,710	50,338	2,627	6%	$22.65	$47,112.00
53-3033	Light Truck Drivers	23,910	26,854	2,944	12%	$19.47	$40,497.60
53-7041	Hoist and Winch Operators	28	29	1	2%	$17.25	$35,877.70
53-7051	Industrial Truck and Tractor Operators	16,542	17,792	1,249	8%	$19.72	$41,017.60
53-7061	Cleaners of Vehicles and Equipment	8,002	8,482	481	6%	$14.22	$29,577.60
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	50,027	54,548	4,521	9%	$16.58	$34,486.40

53-7064	Packers and Packagers, Hand	6,675	7,329	654	10%	$14.62	$30,409.60
53-7065	Stockers and Order Fillers	71,777	75,559	3,782	5%	$15.45	$32,136.00
		611,216	648,584	37,367	6%	$35.41	

Source: Emsi/Lightcast

Table 14: CEA Support Cluster, GOVA Region 3

SOC	Description	2022 Jobs	2027 Jobs	2022 - 2027 Change	2022 - 2027 % Change	Avg. Hourly Earnings	Avg. Annual Earnings
11-1021	General and Operations Managers	1,953	2,101	148	8%	$45.71	$95,073.83
11-2021	Marketing Managers	131	147	16	12%	$71.46	$148,643.09
11-2022	Sales Managers	127	147	21	16%	$54.94	$114,279.85
11-3013	Facilities Managers	47	49	2	4%	$39.55	$82,272.86
11-3021	Computer and Information Systems Managers	118	144	26	22%	$60.12	$125,051.38
11-3051	Industrial Production Managers	147	167	21	14%	$54.97	$114,339.96
11-3071	Transportation, Storage, and Distribution Managers	52	54	2	5%	$46.42	$96,554.94
11-9041	Architectural and Engineering Managers	49	56	7	14%	$70.47	$146,574.58
13-1028	Buyers and Purchasing Agents	311	308	(3)	(1%)	$28.35	$58,972.72
13-1071	Human Resources Specialists	408	446	39	10%	$27.22	$56,616.96
13-1074	Farm Labor Contractors	0	0	0	0%	$0.00	Insf. Data
13-1075	Labor Relations Specialists	81	74	(8)	(9%)	$27.81	$57,841.24
13-1082	Project Management Specialists	275	311	37	13%	$38.60	$80,291.46
13-1151	Training and Development Specialists	206	220	13	6%	$29.51	$61,386.79
15-1231	Computer Network Support Specialists	51	55	5	9%	$28.82	$59,943.43
15-1232	Computer User Support Specialists	269	295	25	9%	$22.68	$47,164.07
15-1244	Network and Computer Systems Administrators	156	160	3	2%	$34.58	$71,929.08

15-2051	Data Scientists	25	31	6	24%	$50.02	$104,048.46
17-2021	Agricultural Engineers	0	0	0	0%	$0.00	$0.00
17-2031	Bioengineers and Biomedical Engineers	<10	<10	Insf. Data	Insf. Data	Insf. Data	Insf. Data
17-2051	Civil Engineers	115	119	4	3%	$41.94	$87,237.41
17-2061	Computer Hardware Engineers	26	30	4	15%	$77.50	$161,196.65
17-2071	Electrical Engineers	67	78	11	16%	$47.76	$99,332.16
17-2072	Electronics Engineers, Except Computer	39	44	5	13%	$51.19	$106,469.74
17-2081	Environmental Engineers	28	29	1	4%	$40.68	$84,609.10
17-2112	Industrial Engineers	178	205	28	15%	$40.18	$83,564.73
17-2131	Materials Engineers	<10	<10	Insf. Data	Insf. Data	Insf. Data	Insf. Data
17-2141	Mechanical Engineers	128	146	18	14%	$43.65	$90,799.99
17-3022	Civil Engineering Technologists and Technicians	25	22	(3)	(13%)	$22.76	$47,338.87
17-3023	Electrical and Electronic Engineering Technologists and Technicians	44	50	6	13%	$35.93	$74,726.67
17-3025	Environmental Engineering Technologists and Technicians	<10	<10	Insf. Data	Insf. Data	Insf. Data	Insf. Data
17-3026	Industrial Engineering Technologists and Technicians	50	54	5	9%	$25.42	$52,883.24
17-3027	Mechanical Engineering Technologists and Technicians	<10	<10	Insf. Data	Insf. Data	Insf. Data	Insf. Data
19-1021	Biochemists and Biophysicists	11	11	0	4%	$56.83	$118,213.01
19-1022	Microbiologists	<10	<10	Insf. Data	Insf. Data	Insf. Data	Insf. Data
19-2031	Chemists	46	45	(2)	(3%)	$38.72	$80,529.88
19-4021	Biological Technicians	24	23	(0)	(1%)	$23.80	$49,509.45
19-4031	Chemical Technicians	27	29	1	5%	$22.51	$46,817.53
29-1131	Veterinarians	70	90	20	28%	$46.16	$96,017.94
29-2056	Veterinary Technologists and Technicians	57	78	22	39%	$16.80	$34,942.95

43-5061	Production, Planning, and Expediting Clerks	213	237	23	11%	$21.97	$45,693.68
43-5071	Shipping, Receiving, and Inventory Clerks	625	619	(7)	(1%)	$15.97	$33,216.16
43-6011	Executive Secretaries and Executive Administrative Assistants	168	147	(21)	(12%)	$27.39	$56,973.64
45-2011	Agricultural Inspectors	21	21	(0)	(2%)	$24.28	$50,506.09
45-2021	Animal Breeders	0	0	0	0%	$0.00	Insf. Data
45-2041	Graders and Sorters, Agricultural Products	14	15	1	5%	$14.15	$29,425.75
45-2091	Agricultural Equipment Operators	57	59	1	3%	$16.23	$33,763.82
45-2099	Agricultural Workers, All Other	55	55	(0)	(0%)	$17.24	$35,851.37
49-2094	Electrical and Electronics Repairers, Commercial and Industrial Equipment	36	41	5	12%	$28.10	$58,441.39
51-2041	Structural Metal Fabricators and Fitters	149	153	4	3%	$21.18	$44,064.49
51-3011	Bakers	78	96	18	23%	$14.37	$29,899.98
51-3021	Butchers and Meat Cutters	88	89	1	1%	$14.77	$30,716.42
51-3022	Meat, Poultry, and Fish Cutters and Trimmers	123	150	27	22%	$14.18	$29,497.05
51-3023	Slaughterers and Meat Packers	48	61	13	28%	$13.99	$29,104.13
51-3091	Food and Tobacco Roasting, Baking, and Drying Machine Operators and Tenders	36	37	1	3%	$14.57	$30,296.76
51-3092	Food Batchmakers	144	165	20	14%	$15.33	$31,893.66
51-3093	Food Cooking Machine Operators and Tenders	18	20	3	14%	$17.03	$35,428.31
51-3099	Food Processing Workers, All Other	42	46	3	8%	$14.65	$30,470.61
53-3031	Driver/Sales Workers	359	373	14	4%	$16.54	$34,399.06
53-3032	Heavy and Tractor-Trailer Truck Drivers	2,204	2,231	27	1%	$21.28	$44,252.91
53-3033	Light Truck Drivers	926	993	67	7%	$16.35	$33,998.20
53-7041	Hoist and Winch Operators	<10	<10	Insf. Data	Insf. Data	Insf. Data	Insf. Data

53-7051	Industrial Truck and Tractor Operators	1,110	1,119	9	1%	$19.00	$39,526.68
53-7061	Cleaners of Vehicles and Equipment	209	241	32	15%	$13.55	$28,190.24
53-7062	Laborers and Freight, Stock, and Material Movers, Hand	1,981	2,081	100	5%	$14.41	$29,972.57
53-7064	Packers and Packagers, Hand	355	369	14	4%	$12.48	$25,957.64
53-7065	Stockers and Order Fillers	3,070	3,121	52	2%	$13.56	$28,201.70
		17,496	18,382	887	5%	$23.96	

Source: Emsi/Lightcast

Completions Lists

Table 8: Completions for CEA-related Occupations in Region 3 and in Virginia

Description	GOVA Region 3 Completions (2021)	Virginia Completions (2021)
Computer and Information Systems Managers	336	19,328
General and Operations Managers	1,595	35,191
Shipping, Receiving, and Inventory Clerks	0	0
Maintenance and Repair Workers	220	1,746
Farmworkers and Laborers, Crop, Nursery, and Greenhouse	3	162
Farmworkers, Farm, Ranch, and Aquacultural Animals	0	87
Farmers, Ranchers, and Other Agricultural Managers	9	483
Food Science Technicians	0	25
Soil and Plant Scientists	66	4,316
Food Scientists and Technologists	10	976

Source: Lightcast. For more information on the operating definition of the word 'completion', please refer to Lightcast (Completions – Knowledge Base (emsidata.com)).

Table 9. CEA Degree Completions in Region 3

Program	Institutions	Degrees Offered	Total 2021 Completions
Business Administration and Management	Longwood University, Averett University	Associate's, Bachelor's, Master's	218
Industrial Electronics Technology	Danville CC, Patrick Henry CC	Less than 1 year, Associate's	102
Industrial Production Technology	Danville CC, Southside Virginia CC	Less than 1 year	91

Business/Managerial Economics	Hampden-Sydney College	Bachelor's	48
Industrial Technology/Technician	Danville CC, Patrick Henry CC, Southside Virginia CC	Associate's	46
Computer and Information Sciences	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, Associate's	43
Business Administration, Management and Operations	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, Associate's	41
Manufacturing Engineering Technology	Southside Virginia CC, Patrick Henry CC, Danville CC	Less than 1 year	40
Computer Science	Averett University, Longwood University, Hampden-Sydney College	Bachelor's	18
Environmental Science	Longwood University	Bachelor's	12
Engineering Technologies	Danville CC, Patrick Henry CC	Associate's	10
Applied Horticulture Operations	Southside Virginia CC	Less than 1 year	3

Source: EMSI/Lightcast.

Table 15. Supply Chain Degree Completions Region 3

Program	Institutions	Degrees Offered	Total 2021 Completions
Electrical, Electronic, and Communications Engineering Technician	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, 1-2 years	119
Biology/Biological Sciences	Averett University, Longwood University, Hampden-Sydney College	Bachelor's	56
Welding Technology	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, 1-2 years	55
Business Operations Support and Secretarial Services	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, 1-2 years, Associate's	42
Electrician	Danville CC, Southside Virginia CC	Less than 1 year, 1-2 years	40
Economics	Longwood University, Hampden-Sydney College	Bachelor's	35
HVAC Technology/Technician	Danville CC, Patrick Henry CC, Southside Virginia CC	Less than 1 year, 1-2 years	23

Chemistry	Averett University, Longwood University, Hampden-Sydney College	Bachelor's	10
Accounting	Averett University	Bachelor's, Master's	8
Management Science	Averett University	Bachelor's	8
Marketing Management	Averett University	Bachelor's	8

Source: EMSI/Lightcast.

Table 16: Completions in Support Cluster

Description	GOVA Region 3 Completions (2021)	Virginia Completions (2021)
Project Management Specialists	1,707	33,741
Computer User Support Specialists	1,634	34,285
General and Operations Managers	1,595	35,191
Sales Managers	1,595	32,726
Marketing Managers	1,552	31,552
Executive Secretaries and Executive Administrative Assistants	1,314	15,445
Human Resources Specialists	1,053	21,587
Computer and Information Systems Managers	336	19,328
Electrical and Electronic Engineering Technologists and Technicians	271	1,424
Industrial Engineering Technologists and Technicians	249	1,044
Electrical and Electronics Repairers, Commercial and Industrial Equipment	244	1,600
Labor Relations Specialists	136	3,787
Network and Computer Systems Administrators	112	7,368
Biochemists and Biophysicists	110	6,019
Computer Network Support Specialists	77	6,771
Microbiologists	56	3,813
Biological Technicians	56	5,002
Architectural and Engineering Managers	46	6,108
Industrial Engineers	42	1,130
Mechanical Engineers	42	2,004
Industrial Production Managers	40	3,483
Computer Hardware Engineers	20	1,841

Environmental Engineers	15	2,124
Data Scientists	14	1,097
Transportation, Storage, and Distribution Managers	11	3,137
Bakers	11	218
Butchers and Meat Cutters	11	166
Civil Engineering Technologists and Technicians	10	471
Mechanical Engineering Technologists and Technicians	10	479
Chemists	10	1,084
Chemical Technicians	10	846
Animal Breeders	7	284
Facilities Managers	3	1,995
Agricultural Engineers	2	744
Bioengineers and Biomedical Engineers	2	1,371
Civil Engineers	2	1,335
Electrical Engineers	2	1,733
Electronics Engineers, Except Computer	2	1,578
Materials Engineers	2	990
Buyers and Purchasing Agents	0	218
Farm Labor Contractors	0	75
Training and Development Specialists	0	169
Environmental Engineering Technologists and Technicians	0	0
Veterinarians	0	160
Veterinary Technologists and Technicians	0	164
Production, Planning, and Expediting Clerks	0	0
Shipping, Receiving, and Inventory Clerks	0	0
Agricultural Inspectors	0	100
Graders and Sorters, Agricultural Products	0	75
Agricultural Equipment Operators	0	75
Agricultural Workers, All Other	0	0
Structural Metal Fabricators and Fitters	0	0
Meat, Poultry, and Fish Cutters and Trimmers	0	0
Slaughterers and Meat Packers	0	0
Food and Tobacco Roasting, Baking, and Drying Machine Operators and Tenders	0	0

Food Batchmakers	0	0
Food Cooking Machine Operators and Tenders	0	0
Food Processing Workers, All Other	0	0
Driver/Sales Workers	0	33
Heavy and Tractor-Trailer Truck Drivers	0	153
Light Truck Drivers	0	27
Hoist and Winch Operators	0	0
Industrial Truck and Tractor Operators	0	126
Cleaners of Vehicles and Equipment	0	0
Laborers and Freight, Stock, and Material Movers, Hand	0	27
Packers and Packagers, Hand	0	0
Stockers and Order Fillers	0	9

Source: EMSI/Lightcast.

Table 17. Other Degree Completions Outside of Region 3 (Top Three Completions)

Program	Institutions	Degrees Offered	Total 2021 Completions
Business/Commerce	Strayer University, Virginia Commonwealth University, Liberty University	Bachelor's	1,459
Information Technology	George Mason University, Northern Virginia CC, Liberty University	Associate's, Bachelor's, Master's	1,414
Finance	Virginia Tech, George Mason University, James Madison University	Bachelor's	895
Engineering	Virginia Tech, University of Virginia, Old Dominion University	Bachelor's, Master's, Doctor's	649
Electrical and Electronics Engineering	Virginia Tech, University of Virginia, Old Dominion University	Bachelor's, Master's, Doctor's	602
Computer Engineering	Virginia Tech, University of Virginia, George Mason University	Bachelor's, Master's, Doctor's	482
Foods, Nutrition, and Wellness Studies	Virginia Tech, James Madison University, Radford University	Bachelor's, Master's, Doctor's	312
Industrial Engineering	Virginia Tech, George Mason University, Liberty University	Bachelor's, Master's, Doctor's	265
Environmental Studies	Virginia Commonwealth University, University of Virginia, Virginia Tech	Bachelor's, Master's	231

HR Management	ECPI University, University of Richmond, Strayer University	Associate's, Bachelor's, Master's	169
Veterinary Health Technician	Blue Ridge CC, Northern Virginia CC, Tidewater CC	Less than 1 year, Associate's	133
Agricultural Engineering	Virginia Tech	Bachelor's, Master's, Doctor's	95
Computer Software Engineering	George Mason University, Stratford University, The University of Virginia's College at Wise	Bachelor's, Master's	51
Web Page, Digital and Information Resources Design	Northern Virginia Community College, The Art Institute of Virginia Beach, Thomas Nelson CC	Less than 1 year	46
Horticultural Science	Virginia Tech	Bachelor's, Master's, Doctor's	32
Agronomy and Crop Science	Virginia Tech	Bachelor's, Master's, Doctor's	28
Entrepreneurship Studies	Strayer University	Bachelor's	27
Environment Control Technologies	Mountain Empire CC, New River CC, Virginia Highlands CC	Less than 1 year, 1-2 years, Associate's	24
Logistics, Materials, and Supply Chain Management	Virginia Commonwealth University, Old Dominion University	Master's	22
Fishing and Fisheries Science	Virginia Tech	Master's, Doctor's	12

Source: EMSI/Lightcast.

Figures

Figure 1: CEA Employment Throughout GOVA Region 3

Source: EMSI/Lightcast.

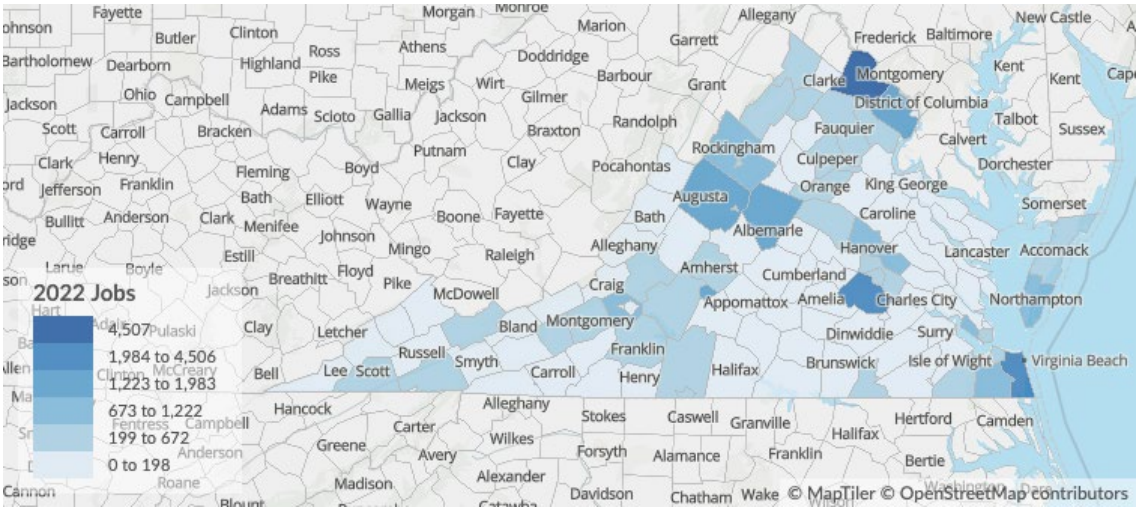

Figure 2: CEA Employment Throughout Virginia

Source: EMSI/Lightcast.

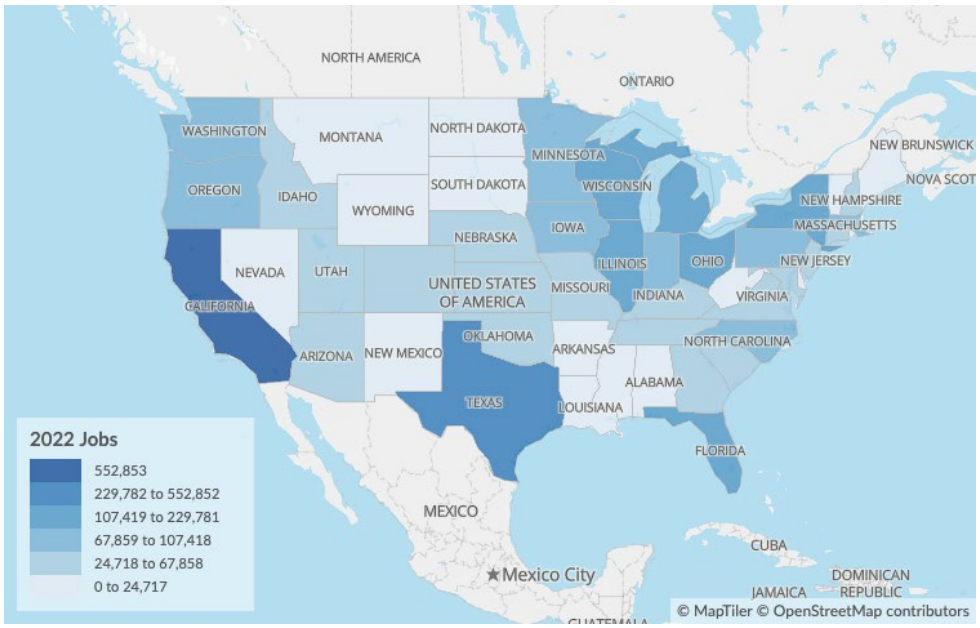

Figure 3: Animal and Crop Production Employment Throughout the U.S.

Source: EMSI/Lightcast.

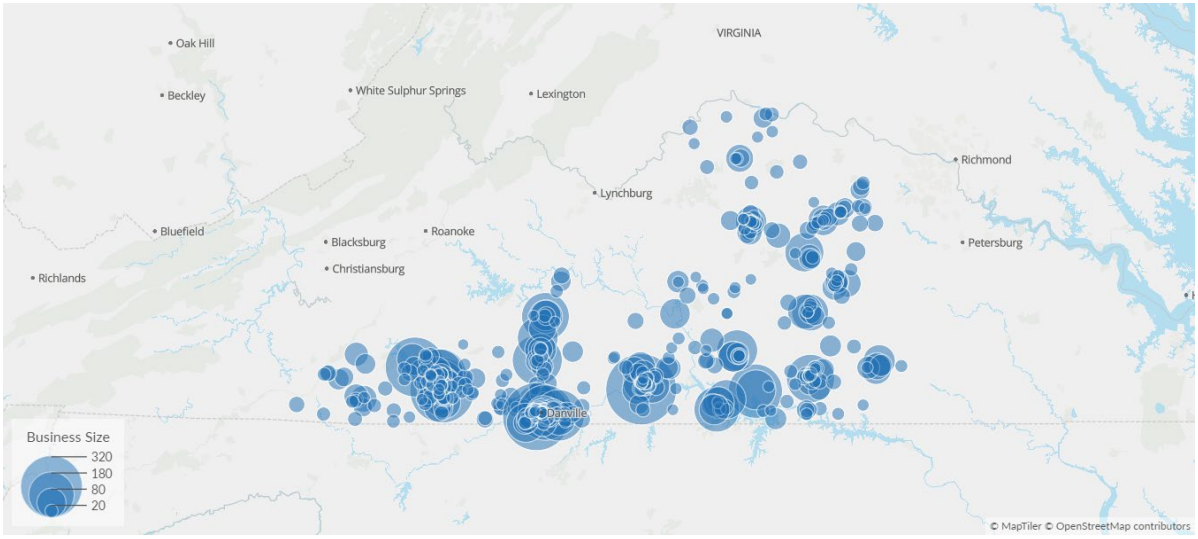

Figure 4: Business Map of Region 3's Potential CEA Supply Chain

Source: Lightcast Business Map