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This research focuses on making recommendations for the development of a Controlled Environment Agriculture (CEA) Ecosystem in Kentucky. As an approach, a desk study was conducted, a large number of experts interviewed, and a field visit to the Netherlands was made. The desk study consists of an analysis of learning experiences of the Dutch CEA ecosystem and an analysis of the Kentucky CEA Ecosystem through a cluster analysis of the horticultural complex, using the Triple Helix model and Porter's Five Forces. For this purpose, six Dutch agrocluster experts were interviewed and six stakeholders active in the Kentucky horticultural supply chain. In addition, the Knowledge System in Kentucky was examined using the Agricultural Knowledge and Innovation System approach by interviewing 29 local experts. The results were translated into 10 recommendations elaborated into more than 30 actions for the development of the CEA ecosystem in Kentucky.

Key words: Kentucky, AgTech Ecosystem, Controlled Environment Agriculture (CEA), feasibility study, Dutch agroclusters, AKIS, cluster analysis, horticulture

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Abbreviations

US abbreviations

AgTech	Agricultural Technology: any innovation used across the agricultural value chain to improve efficiency, profitability and/or sustainability. It includes hardware and software, business models, new technologies and new applications.
ARD	Agritech Research & Development Center Kentucky
ARPA	American Rescue Plan Act
BBB	Build Back Better, a strategy aimed at reducing the risk to the people of nations and communities in the wake of future disasters and shocks
CBER	Center for Biologics Evaluation and Research
CCD	Center for Crop Diversification of University of Kentucky
CEA	Controlled Environment Agriculture encompasses a variety of systems that take a technology-based approach to farming. CEA can range from simple shade structures and hoop houses through greenhouses to full indoor or vertical farms.
CFA	Community Farm Alliance
CSA	Community Supported Agriculture
EKCEP	Eastern Kentucky Concentrated Employment Program
EQIP	Environmental Quality Incentives Program; USDA-NRCS instrument
FFA	Future Farmers of America
KADB	Kentucky agriculture Development Board
KCARD	Kentucky Centre for Agriculture and Rural Development
KEA	Kentucky Education Association
KDA	Kentucky Department of Agriculture
KNLA	Kentucky Nursery Landscape Association
KY	Kentucky
NASS	National Agricultural Statistics Service; part of USDA
NRCS	National Resources Conservation Service
PA	Producers' Association
PATH	Prosperity through an AgriTech Hub
SDG	Sustainable Development Goals
SKU	Stock Keeping Units
UoK	University of Kentucky
Upike	University of Pikeville
USDA	U.S. Department of Agriculture
U.S.	United States

Dutch abbreviations

AKIS	Agriculture Knowledge and Innovation System
ATES	Aquifer Thermal Energy Storage
CMO	Common Market Organization
DPA	Dutch Produce Association
EIA	Energy Investment Tax Deduction: governmental instrument
KWIN	Quantitative Information Brochure (*Kwantitatieve Informatie*)
LNV	Dutch Ministry of Agriculture, Nature & Food Quality
MEI	Market introduction of energy innovations in greenhouse horticulture; governmental instrument
MIA	Environmental Investment Tax Deduction; governmental instrument
MJA-E	Multi-Year Agreement on Energy
MJPG	Multi-Year Plan for Crop Protection
NL	The Netherlands
OVO	Research, Extension and Education (*Onderzoek, Voorlichting en Onderwijs*)
RVO	Netherlands Enterprise Agency

SDE++	Stimulating Sustainable Energy Production and Climate Transition; governmental instrument
TKI	Top Consortia for Knowledge and Innovation
VAMIL	Random depreciation of environmental investments; governmental instrument
WUR	Wageningen University & Research

General abbreviations

BS	Bachelor of Science degree
CHP	Combined Heat and Power facilities
DC	Distribution Centres
FTE	Full-time equivalent
IT	Information Technology
MS	Master of Science degree
PPP	Private Public Partnership
R&D	Research and Development
RECs	Renewable Energy Certificates
RSG	Reusable Substrate Granulate
SMEs	Small and Medium-sized Enterprises

Preface

This study provides a number of practical recommendations to support the development of an AgTech Ecosystem, defined as Controlled Environment Agriculture (CEA) in the state of Kentucky in the United States of America. This advice is primarily aimed at the Kentucky Agricultural Development Board, and the Government of Kentucky, being the co-commissioners of this study, but also for private companies, knowledge institutions and other non-governmental organizations, such as sector organisations.

This report is a synthesis of two assignments, provided by the Kentucky Agricultural Development Board and the Dutch Ministry of Agriculture, Nature and Food Quality. The report builds on the findings of an Inception study, delivered in November 2021, commissioned by NL Works, part of the Netherlands Enterprise Agency. A joint team of researchers from the University of Kentucky, Wageningen University & Research, Vision Granted consultants conducted the study with support from the University of Pikeville.

The study describes the results of a comprehensive analysis of horticultural products produced in high-tech greenhouses in Kentucky using Porter's Five Forces, an analysis of the Agricultural Knowledge and Innovation climate, and an analysis of the learning points from the development of the Dutch CEA Ecosystem. The results are based on existing literature and several consultations with a large number of stakeholders.

The results will support the Kentucky private and public sector in making choices for establishing a successful CEA ecosystem in cooperation with the Dutch private and public sector.

We would like to express our gratitude for the support of the commissioning parties, including
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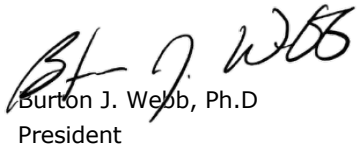

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Summary

Summary

S.1 Main research question

In Kentucky, the economic downturn in 2008 resulted in the decimation of an already struggling coal industry. In the years that followed, the low price of alternative fuels and the emergence of a global pandemic combined to eliminate over 100,000 jobs from the Commonwealth. An energy and water-rich state, Kentucky is currently struggling to redefine its economic future. In recent years, a variety of industries have emerged that offer hope to people struggling to find productive work. Among them, the Controlled Environment Agriculture (CEA) industry stands apart. Since 2018, approximately $1.6bn has been invested in CEA, resulting in the construction of dozens of acres of high-tech greenhouses and indoor farm facilities in Kentucky.

In early 2020, a group of government officials joined with academics and industry partners to study the ways in which the Netherlands has clustered and developed the CEA industry. A collaborative agreement was formed dedicated to building an CEA Ecosystem that resembles the system in the Netherlands. Twenty-six businesses, educational institutions, and government partners are now part of this collaborative effort which links the Commonwealth of Kentucky to the Netherlands. This collaboration between the Netherlands and Kentucky can be fruitful for multiple sectors than only for CEA.

The objective of this study is to expand upon the recommendations of the inception study, executed in 2021, by describing in detail the conditions needed to build an ecosystem sufficient to support the growth of CEA across the region. While the results of this study are primarily intended to direct the growth and development of the CEA many of the recommendations will also benefit other agricultural and related sectors.

The scope of this study is limited to:

1. Developments in Controlled Environmental Agriculture. CEA growing includes everything from hoop-covered rows of plants (minimal control) to greenhouses (intermediate control) to fully indoor growing systems (maximum control).
2. The development of a plan to bring together mainstream public (and private) education at all levels (from vocational schools to universities) that will support the business development of the CEA Ecosystem in the state of Kentucky.

S.2 Message

The differences that exist between the state of the CEA industry in the Netherlands and the Commonwealth are quite striking. While in Kentucky the CEA cluster is in start-up mode, the Dutch CEA cluster has existed for over 100 years. Comparing the two clusters that are in vastly different stages of development is challenging. In the Netherlands, there are approximately 25,000 acres of glasshouse greenhouses that must be carefully placed in a country that is roughly the size of Eastern Kentucky. For this reason, strict zoning requirements limit greenhouse locations in the Netherlands. While Kentucky has much more space to grow, the Commonwealth can benefit from the Dutch experience by taking advantage of regional clustering earlier in the development of CEA. The corporate cooperation required to accomplish clustering may not be as fast as an individual entrepreneur's path, but will ultimately bring cluster benefits and long-term cost reductions for energy, logistics, and labor.

One strength of the Dutch horticultural ecosystem can be found in its balanced approach to cooperation and competition. Cooperation can be seen in the way Dutch companies work together to strengthen the market power of producers, develop a skilled labor force, and in the creation of fundamental knowledge and (pre-competitive) innovation. Competition drives innovations in marketing and in technology development, ensuring a continuous focus on efficiency for all stakeholders.

Another reason for the success of the Dutch CEA is due in large part to a good knowledge system and willingness to share knowledge to ensure and maintain the knowledge and skills for CEA for new and existing employees at all levels of the supply chain. This knowledge system is characterized by intensive connections of knowledge parties (research, extension, education) that has been transformed over time into the Triple Helix approach, formalized in one of the nine existing Top sectors called 'Horticulture and Starting Materials': Triple meaning the collaboration between 1) government, 2) research & education and 3) industry. This approach to knowledge sharing is both policy and practice in the Netherlands.

By contrast, there are many attractive aspects of CEA and its potential in Kentucky agriculture is quite impressive. Kentucky has location and cost advantages for production efficiency, logistics, and market proximity. There is a good base of interest in CEA ranging from simple high tunnels to extremely sophisticated large-scale systems. Kentucky does have some locational and resource advantages compared to some other regions, especially for proximity to key markets, relatively low energy input costs, and an opportunity to enter added value products within the CEA space.

Markets for many commodity products traditionally produced in CEA systems are highly competitive. Similar to the Netherlands, the vegetable sector is highly competitive in the U.S. Spain is to the Netherlands what Mexico is to the U.S. Low-cost labor and ideal growing conditions help to keep a competitive advantage. To address this competition, Dutch horticulture has specialized in high-quality horticultural products and adding value to the product through complete assortment offerings, new varieties, high-quality packaging, and fast logistics services, all resulting in a better, tastier product in grocery markets. Likewise, Kentucky should focus on varieties that are not imported from Mexico, high-value products with short shelf life (strawberries, leafy greens, etc.), good fresh logistics, and high-end products (infant food, specialties, snack vegetables, fresh herbs, etc.), more added value (fresh washed, packed, ready-to-eat, ready-to-cook, etc.)., ingredients for the pharmaceutical or cosmetic industry (medicinal herbs, vanilla, etc.) or ornamentals (indoor and outdoor plants and flowers). Kentucky should join the Netherlands in their search for new means of mechanization and automation thereby reducing the cost of labor.

We must be aware of the push/pull relationship that exists between the investment in technology and the available markets for produce. The additional investment in CEA's technology should be recouped through increased income from higher production, new crops and improved quality. In recent years, existing regional direct markets for small-scale high tunnel growers seem to absorb this increase in production and better quality. However, when quantities rise new outlets must be found to market the product. These small-scale entrepreneurs will have to learn to take full advantage of high tunnels opportunities, establish and manage supply chains, cooperate with fellow growers to pool production, and enter into sales agreements with wholesalers or retailers. This will create a market pull for further intensification rather than via a technology push. Market pull and technology push go hand in hand.

Great care must be given to selecting the locations in which to build clusters for the CEA system. The inception study conducted by Wageningen University & Research indicated that Central Kentucky is most suitable. Because logistics are important, the intersection of the I-75 and I-64 corridors in Central Kentucky held the greatest transportation potential. Proximity to cities also increases the availability of a skilled labor force. This same location, in Central Kentucky, might be home to an innovation demonstration center that extends throughout the Commonwealth.

Perhaps the most critical investment will be in a statewide network of institutions involved in innovation, research, and education, scientifically called the Agricultural Knowledge and Innovation Systems (AKIS). CEA growers will inevitably experience real-world problems that must be solved in research and development centers spread across the Commonwealth. Sharing knowledge is powerful and necessary if the CEA industry broadly, and CEA in particular, is to thrive. Demonstration centers, educational programs, and job skill development should be done near where workers live so they can enter the labor force and quickly upskill to better-paying positions in the industry. As CEA reaches into the far corners of the state, it must also carry the message of hope that started this summary. Agriculture, in particularly CEA, is a vibrant and innovative industry, there is hope for family farms, and mid-tech high tunnels, and it can be found in high-tech sustainable CEA.

Finally, we must discuss collaboration across the Dutch Triple Helix in Kentucky. The government, the private sector, and research & educational institutions each have an important role to play in the development of CEA. At present, each works independently, doing what they can to move the CEA industry forward, but working alone is not enough. Significant partnerships must be established, funded, and maintained across the helix for Kentucky to replicate anything close to what the Netherlands has accomplished. Special attention is needed to involve more companies in developing the CEA ecosystem, creating a pull effect to establish a CEA Ecosystem. They can be parties within the horticultural value chain, such as traders, auctions, logistic service providers, or outside the horticultural value chain, such as providers of renewable energy, waste management and the food industry. Some parties are already expressed interest.

The recommendations:
Analyzing the differences between the Dutch system and the developing systems in Kentucky the following recommendations are made. Each of these recommendations comes with action items that are described in the report in more detail.

These are the recommendations:

1. **Establish a state-wide CEA industry development Taskforce.** One of the most important lessons we can learn from the Netherlands is that collaboration across the Triple Helix is essential. The CEA industry development Taskforce should be the first step toward formal collaboration between growers, educational institutions, and governmental agencies (the Triple Helix model). Representatives from across each of these sectors should be selected based on their support for the idea of developing the CEA industry. The Taskforce must be non-partisan and committed to the economic development of the entire Commonwealth.
2. **Establish a Kentucky greenhouse growers council.** In addition to the Triple Helix, a professional member organization of greenhouse growers should be formed to guide the spatial, relational, and temporal organization of greenhouses, R&D centers, and other co-clustered businesses. This growers council should review state policy and make recommendations to elected officials on behalf of the greenhouse growers across the state.
3. **Invest in and develop CEA research and development, extension, and innovation networks.** CEA businesses need continual innovation to maintain a competitive advantage. This requires educated and skilled entrepreneurs and employees at all levels. Innovation networks have the additional benefit of creating new knowledge that often leads to spin-off industries. The benefits of early and rapid investment in education and research cannot be overstated.
4. **Invest in and develop CEA educational programs.** CEA educational programs across the educational lifespan can open the doors of opportunity for students and adults who want to work in an industry that will always be needed by every person on the planet. As the CEA industry grows, there will be a significant need for well-trained managers, growers, and logisticians. Higher education must respond as well by offering programming that meets the myriad of needs generated by the CEA industry. From engineering, to robotics, to finance, the Kentucky workforce must come to understand the value of CEA.
5. **Establish a clear pathway for open field and mid-tech high tunnel growers to grow towards high-tech CEA production**. Although the family farm has been disappearing for more than a generation, by using CEA technologies, family farms can be profitable and sustainable in scale-appropriate ways, as the Netherlands has shown. This is especially true for value-added and difficult-to-grow products. The pathway exists, but it needs to be carefully marked for Kentucky farmers to find the way.
6. **Encourage market development and value chain management for Kentucky-based CEA firms through cooperation.** As Kentucky CEA firms produce more products, there will be an ongoing need to cooperate to generate new markets for their products within the state and surrounding states. Innovations that increase the size of the available market should be incentivized in a way that encourages collaboration.
7. **Develop a CEA workforce development plan in collaboration with the CEA industry development taskforce.** In the last two years, hundreds of people have been employed in CEA firms and that number is expected to double in the next two years. The Commonwealth needs a workforce development plan that will rapidly train frontline workers and enable those who chose to upskill access to the training they need. CEA firms will do some of this on their own, but a joint effort will be much more effective.

8. **Develop and pursue a CEA spatial development strategy involving state and local agency partners.** One of the first tasks of the CEA industry development taskforce should be the identification of several sites across the state that might be developed as cluster development locations, greenports, and R&D centers. Proximity to employees, water, energy, land, transportation, and markets will all be increasingly important, making Central Kentucky most suitable for the development of CEA.
9. **Devise and plan for sustainability within Kentucky's CEA ecosystem.** The goal for Kentucky CEA firms should be no net emissions. This means sustainable energy production, water use, and waste recycling. Kentucky has some systems in place to assist with this goal, such as the gasification plant in Martin County. Investments should be made in these systems and they should be located near the CEA firms' greenhouse sites wherever possible.
10. **Communicate the CEA story with society.** The story of CEA is a good one: economic development, employment, safe & healthy food production, and zero emissions. Educational and marketing campaigns can highlight the true benefits of CEA. Communication requires investment and a clear plan that includes education, but also fun events such as festivals and cooking. Tell the story, and tell it with food.

S.3 Methodology

The approach of the study consists of four parts and was carried out by a team of eight experts from three universities and one expert of a subcontracted consultancy.

The first part is an analysis of the Dutch CEA ecosystem and then focused on the greenhouse horticulture cluster. For this purpose a desk study was done and subsequently six Dutch cluster experts were interviewed. The research method from the report 'the power of the agrocluster' and the Triple Helix model were used.

The second part is an analysis of the Kentucky CEA Ecosystem. This involved a desk study using Porter's Five Forces and subsequent interviews with six stakeholders active in the Kentucky horticulture supply chain.

As the third part, the knowledge system in Kentucky was examined using the Agricultural Knowledge and Innovation System (AKIS) approach by interviewing 29 local experts.

A key component was a visit by the US research team to the Netherlands in June 2022, where the findings up to that point could be tested against the actual situation of the CEA ecosystem in the Netherlands. Unfortunately, a visit of a representative of the Dutch research team to Kentucky in March 2022 could not take place due to Covid-19 exposure.

The findings from the above four components were discussed and incorporated into ten recommendations that were developed into over thirty actions for the development of the CEA ecosystem in Kentucky.

1

Introduction

1 Introduction

1.1 Background

The state of Kentucky is known for its significant role in supplying coal to the United States (U.S.), ranking within the top five coal producing states. During the last 10 years, the sharp national decline in coal has decimated hundreds of rural underserved communities that have traditionally relied upon the mining industry for their livelihoods. From 2001 to 2021, jobs related to the Kentucky coal industry fell by 79%, total coal mines dropped by 78% and the amount of coal extracted decreased by 78%. Kentucky faces the challenge of transforming the country's most coal-dependent region into new, vital, future forward sustainable industries that create sufficient jobs and economic prospects for its residents (Richardson, 2021). Meanwhile, the Covid-19 pandemic has had a profound effect on the Kentucky economy, a state that already suffers health and wellness issues amongst its population and ranks in the bottom 10% of states in numerous health and disease categories. From March 2020 to 2021, the pandemic resulted in 107,600 lost jobs, effectuated by more than 100 trends, forces and factors affecting Kentucky's economy (Childress, Clark, & Paris, 2021).

Over the past five years, Controlled Environment Agriculture (CEA) has gained considerable attention in Kentucky and is emerging as a new industry due to significant investments in new infrastructure (greenhouses and vertical farms), technologies, and acquisition of pre-existing greenhouse facilities. Controlled Environment Agriculture is the production of horticultural (including ornamentals) crops under controlled and monitored climatic conditions such as greenhouses and indoor vertical farms. CEA growing includes everything from hoop-covered rows of plants (minimal control) to greenhouses (intermediate control) to fully indoor growing systems (maximum control). The more control over growing conditions the more technology is used. We therefore speak of low-tech, mid-tech or high-tech CEA systems, respectively simple plastic covers, high tunnels that can be ventilated with irrigation systems and glasshouse greenhouses with heating and/or cooling facilities, recycling of drainage water, CO_2 dosing systems, lighting systems. Fully indoor farming also belongs to the latter category.

These high-tech systems require an ecosystem supporting all outlets of the supply chain including companies providing goods and services, logistics, artificial intelligence, and institutions delivering education, providing technical support and training. This collection of companies and institutions is called an AgTech ecosystem, and when specially focus on CEA, a CEA ecosystem. Initiated in part by the investments of several new CEA companies the Kentucky government has set the ambition of transforming Kentucky to become a leader in CEA.

The U.S. and Dutch public and private partners have initiated a multiannual public-private collaboration program focused on this transformation. A collaboration agreement between 17 partners was signed in June 2020 and includes a shared ambition of establishing a growth model towards an CEA Ecosystem in Kentucky.[1] In 2022, another 9 partners joined this collaboration agreement. This collaboration aims at creating a sustainable and healthy food production system that can provide sustainable jobs and create locally grown, healthier food at affordable prices for consumers in the U.S., while reducing the use of land, water, and fossil fuels. The Dutch-Kentucky collaboration is now focused on CEA but offers prospects for collaboration with multiple agricultural and affiliated sectors.

CEA is developing rapidly in Kentucky. Since 2020, $484m in investment and 1,245 jobs were created in the agribusiness and AgTech sector.[2] In 2021, Food, Beverage, AgTech accounted for $1.1bn in announced investments in the state.[3] In recent years, an estimated $1.6bn has been invested in AgTech in Kentucky, and particularly in CEA.

[1] More information about this collaboration can be found on the website www.letsgrowtogether.tech
[2] Cabinet for Economic Development New & Expanding Industry Report (Data as of Feb 2022)
[3] Cabinet for Economic Development New & Expanding Industry Report (Data as of August 2022)

This research builds on previous research and closely follows the developments of the CEA Ecosystem. In 2020, a study was conducted into the market potential and investment opportunities of high-tech greenhouse vegetable production in the U.S. The potential greenhouse area that could displace imports of fresh vegetables into the U.S. is calculated at between 17,000 and 20,000 acres (7,000 and 8,000 ha). This area corresponds with a total investment of approximately $9.5-11bn (Ruijs & Benninga, 2020).

In 2021, two studies were implemented, commissioned by NL Works: 1) An inception study of the CEA ecosystem by Wageningen University & Research (Ruijs, Hennen, & Ravensbergen, 2021) and; 2) A feasibility study of a Kentucky Horti Center by Hortitech modelled on the World Horti Centre (WHC) in Naaldwijk, the Netherlands (Adrichem, 2021).

The inception study demonstrated using spatial analysis that Central Kentucky appears to be the most suitable area for the development of an CEA ecosystem and in particular for the location of greenhouses and other related activities within and outside the value chain (Ruijs & Benninga, 2020).

Other conclusions of these studies were:

- Education and training at all levels should have the highest priority. In the short term, basic education and practical training is needed for greenhouse entrepreneurs and employees to increase their knowledge and skills. In the mid and long term, education on all levels from vocational to academic degree programs is needed, covering different subjects in production and the horticultural value chain, such as crop management, climate control, waste management and logistics.
- With regard to governance, attention should be paid to new parties who can add value and /or broaden the activities of the current consortium regarding the CEA Ecosystem development. These stakeholders are very likely to increase economic significance and sustainability.
- The Kentucky government can play a greater role in supporting the establishment of greenhouses. This refers to spatial, legal and financial instruments.

This report is a continuation of the findings of the inception report and focuses mainly on improving education, research and innovation, as well as on the governance of the CEA ecosystem.

The findings of the feasibility study of a Kentucky Horti Center were used to draft a proposal called: **P**rosperity through an **A**gri**T**ech **H**ub (so-called 'PATH Kentucky') (Richardson, 2021): a fiscal year 2021 American Rescue Plan Act Build Back Better Regional Challenge, Phase 1 Concept Proposal.

Kentucky PATH's strategy is to develop a state-of-the-art AgTech research and development center focusing on CEA production in the heart of Eastern Kentucky/Appalachia with companion initiatives to spark and cultivate ancillary business and educational opportunities via partnership with an established and growing coalition of private sector, academic, public, and non-profit organizations.

The Kentucky PATH projects have the potential to transform an entire region for generations to come and are organized around three focus areas:

1. AgTech Innovation Hub:
    a. Construction of the Kentucky research and development Horti Center, a CEA research and development facility for sustainable agriculture methods.
    b. A Regional Competitiveness Officer will coordinate an AgTech research launchpad in partnership with the 26-party Ecosystem Collaborative and additional local representatives.
2. Global AgTech Start-up Challenge:
    a. Launch a Global Competition for start-ups.
    b. Create multiple financing methods to support start-ups, business expansion, and new technology adoption within the AgTech sector.
3. Talent Development and Retention:
    a. Promote Eastern Kentucky as a place to live, work and grow, including specific place-based economic development projects led by local organizations.
    b. Create responsive, inclusive education, training and workforce development systems to activate partnerships with ecosystem collaborative partners including institutes of higher education, workforce innovation boards, and local municipalities to ensure the need for a trained AgTech workforce is met.

These proposed projects will support cluster-based economic development by: 1) developing shared facilities and infrastructure; 2) matching skilled workers to attracted cluster firms, creating inclusive employment opportunities; 3) anticipating and implementing the assets for the workforce to evolve as the cluster specializes; and 4) creating an environment that facilitates knowledge exchange and innovation among partners (Richardson, 2021).

During the course of this study, the first phase of this proposal was awarded and the second phase has now been submitted (March 2022). The results are not yet known at the time of this publication.

In addition, recently, in the course of this research, UPIKE's proposal for an AgTech Innovation Center of Excellence was successfully awarded. This facility will include a greenhouse, classroom, laboratory and offices to lead high-tech agricultural research efforts that promote the continued development and long-term viability of the industry while supporting the increasing global demand for food production. Upon completion, the project will contribute to entrepreneurship and business development strategies for Eastern Kentucky and Central Appalachia, and to the education of the next generation of agricultural industry workers.

If PATH Kentucky will also be successfully funded, both ambitious projects will accelerate the development of a CEA ecosystem in Kentucky and a jumpstart can be made using the advice from this report.

In the course of this research, a new project was started, commissioned by NL Works and conducted by consultancy firm HortiTech, into the application of suitable and affordable applied technology for low- and mid-tech growers. The project will show how the development of the CEA ecosystem in the Netherlands has taken place and offers a technology entry model for companies (supported by government and knowledge institutions). The results can be used as a basis for developing education and training programs at the Agritech Research & Development Center Kentucky. Associated trainings and workshops are part of this project and some workshops will be hosted by the Kentucky Horti Council in cooperation with HortiTech.

1.2 What is an CEA AgTech Ecosystem?

An AgTech Ecosystem is composed of different sectors including producers, (technical) suppliers, logistic groups, trade and retailers, which are supported by education institutions (education and training), research and development, governmental support, finance infrastructure and other services. Collectively, activities and services determine the strength of the ecosystem (Hekkert M. , Suurs, Negro, Kuhlmann, & Smits, 2007).

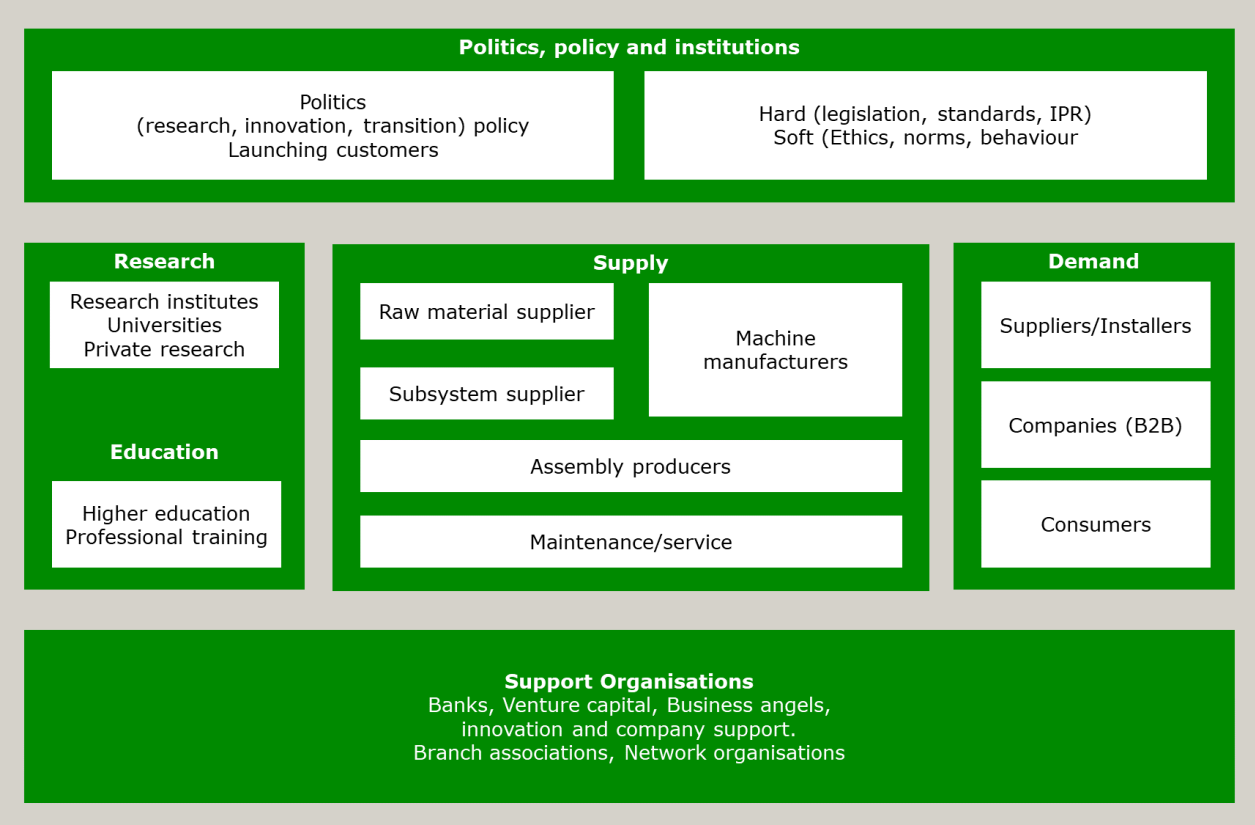

Figure 1 *Structure of an innovation/technology ecosystem (Kuhlmann & Arnold, 2001)*

The strength of the ecosystem is not determined by one party in the ecosystem but by the activities and strength of the entire cluster. For the CEA AgTech ecosystem, this means that the core is the CEA value chain, comprising not only the CEA growers, but also input suppliers (e.g. seeds and fertilizers), trading companies, logistic service providers, collection and packing companies, etc. The CEA grower has almost daily contact with most of these stakeholders concerning the management of his firm. The next circle in this network are the knowledge providers such as information officers/advisors, research centers, media, etc. Contacts with these institutions are at least monthly. Then, the next circle are the service providers such as seed/sowing companies, technical supply industry (substrates, irrigation, climate control companies, etc.), and also sector organizations, banks, insurers, accountants, tax authorities. The CEA grower contacts them at least once a year. And of course, where necessary, contact will be made with other stakeholders such as greenhouse builders, project developers, consultants, county, state government, etc. All these companies form a CEA ecosystem. The contribution to the economy (income, jobs, food security, etc.) must be seen through the entire CEA ecosystem and is not just one stakeholder group such as the CEA growers.

Scope

The scope of this study on the feasibility of an AgTech ecosystem is limited to:

1. AgTech developments in Controlled Environment Agriculture;
2. The development of a Knowledge and Innovation System in Kentucky that will support the business development of the CEA ecosystem throughout the state of Kentucky.

1.3 CEA contribution to UN Development goals

In 2015, the United Nations published a report entitled Transforming Our World: The 2030 agenda for sustainable development (U.N. Department of Economic and Social Affairs, 2015). Embedded in that report were 17 goals for a sustainable planet, so called Sustainable Development Goals (SGDs). Figure 2 gives an overview of all SGDs.

Figure 2 *United Nations Sustainable Development (United Nations, 2015)*

CEA provides of healthy, affordable, nutritious and safe food, produced sustainably and locally. In this way CEA contributes to at least 8 of the 17 SDGs (Marcelis, Zhou, & Heuvelink, 2022) compared with conventional open field production:

- 2 Zero Hunger: More yield per land use, due to longer growing and harvest season, better quality production.
- 3 Good Health and Well-being: affordable local production of healthy fruits and vegetables that encourages their consumption and contributes to a healthy society. Less emissions of nutrients and crop protection agents to air, water and soil.
- 6 Clean Water and sanitation: minimal water usage per unit of product: e.g. in high tech greenhouses in the Netherlands the water consumption for 1 pound of tomatoes is ten times less then production in the open field, due to recycling of drainage water. Also waste water is purified on-farm before discharge to open water.
- 7 Affordable and clean energy: efficient production of electricity on farms by using cogeneration (Combined Heat & Power), where the heat is used in the greenhouses and the electricity is supplied to the public grid. In the past 30 years energy use per unit of product in the Netherland has been halved.
- 8 Decent work & economic growth: CEA contributes to the economic development of a region. It creates jobs from unskilled level to highly skilled labor. Jobs are characterized by variation and vitality.
- 9 Industry, innovation and infrastructure: CEA is an very innovative and high-tech industry, e.g. automatization, robotics and data management. It requires good infrastructural facilities such as good roads, refrigerated collection centers, standardized transport carriers (e.g. pallets, barcoding), etc.
- 12 Responsible consumption and production: secure food security by producing locally, optimizing yield per land use and using sustainable production techniques with limited to no emissions.
- 15 Life on land – CEA uses sustainable local production systems producing healthy, affordable, nutritious and safe food.

Compared to conventional production CEA scores higher on these SDGs. However, improvements are required for all systems. CEA must work to reduce and replace the use of fossil energy. This is technically possible, but realization mostly depends on regulations and economic feasibility. All soil-based systems (open field, low- & mid-tech tunnels) should work toward more efficient water use with less loss of nutrients. This is often technically difficult.

1.4 Objectives

As a follow-up to the inception study the objectives of this research are:

1. To utilize the Dutch 'Triple Helix' model and Strategic Plans for Agricultural Knowledge and Innovation Systems (AKIS) in developing a plan to bring together mainstream public (and private) education at all levels (from vocational to scientific) that will support the business development of the CEA Ecosystem in the state of Kentucky.
   The results will be an overview of best practices on education, governance and technology/ innovation with clear references and advice for implementation and collaboration.
2. To provide information on regulations and instruments for developing an CEA ecosystem in Kentucky, specifically on the topics of environment, geospatial planning, infrastructure, and energy supply.
   The results will be an overview of recommendations for CEA ecosystem development for all stakeholders.

1.5 Sub-questions and main research question

The main question for this research is how the Dutch cooperation model between industry, government, and knowledge institutes, known as the golden triangle or Triple Helix approach, could be implemented in Kentucky, focusing on education, governance and innovation. This requires a long-term vision and effort, with a scope of five to seven years.

CEA Ecosystem analysis sub questions are:

Entrepreneurial ecosystem

- What is the structure of the needed ecosystem, based on the ecosystem design of the Netherlands? What is already in place and where can Dutch partners add value?
- What are the key market drivers, who are the major players, what type of companies and products are needed in both the supply chain and the logistics chain after production?
- Who are the most relevant stakeholders needed, are they currently in the collaboration, or should others be added?
- What are the potential 'spill over' effects on existing local sectors, e.g., adopting new technologies, growing businesses, and potential new business opportunities, e.g., using waste from the greenhouses, plant-based proteins, sustainable packaging, the use of new energy sources such as geothermal?
- What are the short- and long-term opportunities for Dutch companies and organizations based on expected market size, new opportunities and supply chain development?
- How can the Dutch partners best support the needed developments in Kentucky?

Knowledge development and exchange

- What type and quality of knowledge development is needed for the development of the system?
- What kind of educational and training programs in the whole Agri-food chain are already in place and what needs to be developed?
- What stakeholders in the system can play a role here? Do we have all the stakeholders needed in the consortium?
- How can Dutch knowledge partners contribute to the needed developments?
- How can the Dutch public and private partners best support the needed developments in Kentucky?
- How can the Dutch public and private partners stimulate knowledge exchange among different types of partners and across geographical borders?

Government role and vision

- What kind of design for a private public partnership (PPP) governance structure is needed and what challenges need to be addressed?
- What are the potential positive societal impacts in terms of sustainable jobs, food security, health and other Sustainable Development Goals (SDG)?
- How can the Dutch government best support the needed developments in Kentucky?

2

Methods

2 Methods

2.1 Introduction

Our approach to this project is to integrate three analysis methods to identify recommendations for developing an CEA ecosystem: 1) the Dutch 'Triple Helix' model; 2) CEA Ecosystem Analysis Model; and 3) Strategic Plans for Agricultural Knowledge and Innovation Systems (AKIS 2.0).

2.2 Triple Helix Model

The 'Triple Helix' model of the Dutch government can be used to develop and implement a similar model in Kentucky. This model is the key to innovation and business opportunities in many sectors. It is based on the concept that cooperation among the government, businesses and knowledge institutes is of the essence. One such sector is the agricultural sector. The key to the success of this approach lies in combining expertise and building links with all parties involved and listening to the ideas of those involved. (Kingdom of the Netherlands, 2019). This innovative helical framework was first introduced by Etzkowitz & Leydesdorff in the 1990s (Etzkowitz & Leydersdorff, 1995) where each sector is represented by a circle (helix), with overlapping areas showing the interactions (see Figure 3). There is a closer interaction among government, universities and industries in developed countries based on interrelated issues from research institutions (indicated as red). This kind of interaction is the basis for a sustainable strategy for technological innovation necessary for creating local jobs and maintaining international product competitiveness in markets (Kimatu, 2016).

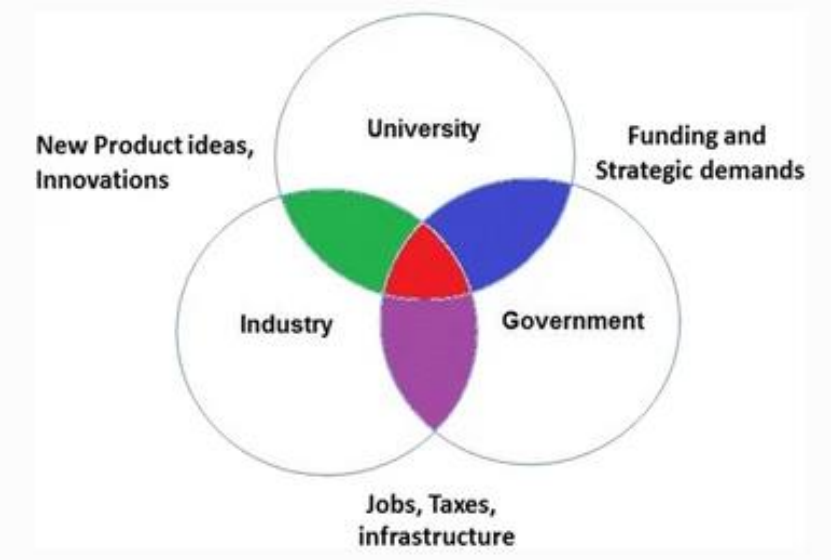

Figure 3 *The Triple Helix model (Kimatu, 2016)*

This study has no intention to impose the 'Triple Helix' model in Kentucky or systems from one country to another as a blueprint; however, using this model can assist Kentucky in determining short- and long-term successes and challenges. Moreover, strengthening linkages among the stakeholders, infrastructures, and exchanging experiences/good practices are beneficial to developing and improving knowledge flow to speed up the desired transition in agriculture. We will bring in similar examples of approaches and address challenges from the Netherlands.

2.3 AgTech Ecosystem Analysis model

To analyze and characterize the success of the Dutch horticultural ecosystem, the cluster analysis concept of Wageningen Economic Research (Berkhout, et al., 2015) is used. In the report 'The Strength of the Agrocluster' (*De Kracht van het agrocluster*) the researchers state that to analyze a cluster, one should take into account a spatial aspect (concentration of firms), a relational aspect (how and how strongly are firms connected), and a temporal aspect (the life cycles of clusters). We use these three aspects to further analyze the Dutch horticultural ecosystem.

- **Spatial aspect:**
  The spatial aspect of a cluster refers to the location (geographical boundaries), size, and spatial arrangement of the companies and institutions that belong to the cluster.
- **Relational aspect:**
  The relational aspect of a cluster describes how and how strongly the companies and institutions of a cluster are connected to each other. The interaction between clustered companies and the resulting trust form the basis for knowledge transfer and mutual learning.
  The connection can exist both horizontally (between different companies in the same or similar links of one or more chains) and vertically (companies and institutions in different links of one or more chains). There are also networks of different companies in different chains. Production companies form an essential link and together with specialized suppliers and customers, service providers, companies in related industries and interconnected institutions they form an agrocluster.
- **Temporal aspect:**
  In several respects, cluster development resembles the development of an industry with different development phases. Although the temporal aspect of clusters is somewhat underexposed in the literature, the life cycle of a cluster is an important point of reference for policy.
  There are clusters that have emerged (evolved) 'naturally' as a result of economic and natural-historical conditions. Many clusters, however, have come about through cluster-oriented policy.

2.4 Agricultural Knowledge and Innovation System (AKIS)

To design a plan for a collaboration and create linkages among the stakeholders of CEA Ecosystem we will use the AKIS concept. This concept is used in this study to:

1. Identify and assess the needs, challenges and knowledge gaps of relevant stakeholders (e.g., educational institutions, governmental bodies, public/private advisory services) necessary the development of CEA Ecosystem.
2. Provide recommendations for a capacity development strategy for an CEA ecosystem to bridge government, businesses and knowledge institutes, based on the needs of relevant stakeholders.

AKIS is a useful concept to describe a system of innovation, with emphasis on the organizations and stakeholders involved, the links and interactions between them, the institutional infrastructure with its incentives and budget mechanisms (SCAR, 2012). AKIS is the combined organization and knowledge flows between persons, organizations and institutions who use and produce knowledge for agriculture and interrelated fields (Bryan, 2018) (see Figure 4).

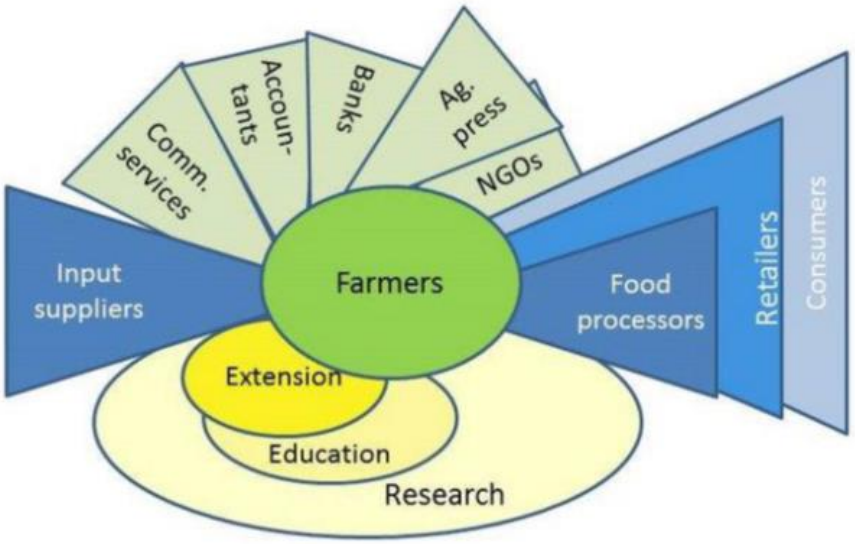

Figure 4 *Visualization of the Agricultural Knowledge and Innovation (SCAR, 2012)*

AKIS stakeholders use and produce knowledge for agriculture and interrelated fields (value chains, rural actors, consumers, etc.). Although different components of AKIS such as extension, education, and research are often stressed, it is important to realize that there are many more stakeholders in the food chain which directly influence the decision making of farmers and their innovations (see Figure 5).

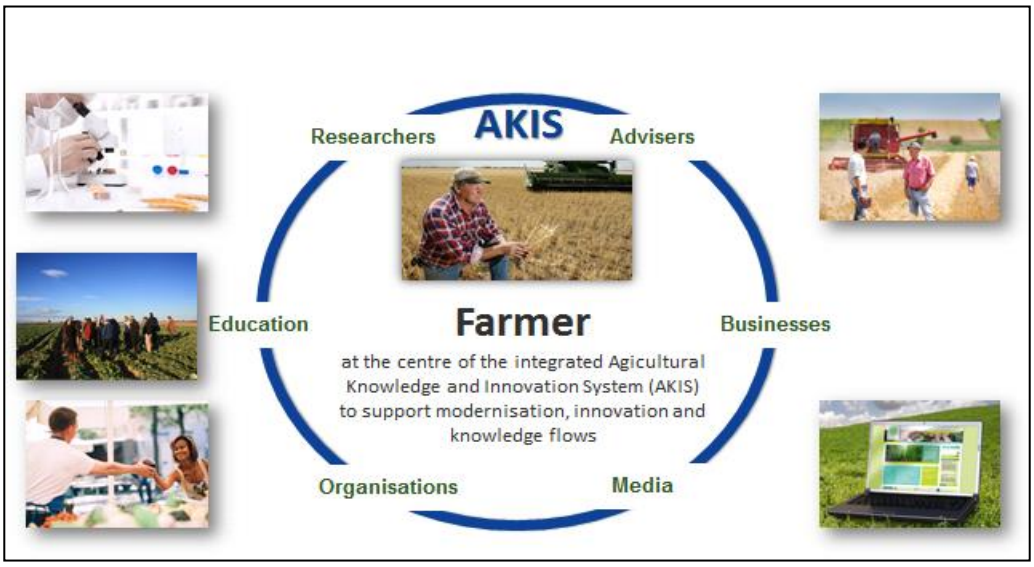

Figure 5 *Relations and interaction between AKIS (European Commission DG AGRI, 2018)*

Seven key functions for AKIS

To design the Kentucky AKIS, the first step is to provide an overview of the current state of the agricultural system in Kentucky. The previous inception study served as input information (Ruijs, Hennen, & Ravensbergen, 2021). From there, we focused on identifying the articulated demand of end-users (e.g., stakeholder groups), their needs, priorities and interests including successes, gaps and pitfalls.

The following 7 key functions are required to develop and improve the uptake of knowledge and technologies for innovation in AKIS, which form the analytical (AKIS) framework for this study (See Table 1). Since this study focuses on education and research opportunities and governance from the seven key functions of AKIS described in Table 1, the functions related to education and knowledge transfer and governance (1, 2, 3, 6

and 7 highlighted in grey) are expanded, while functions 4 and 5 are out of the scope of this study as the topics of entrepreneurship and market formation have been covered by the Inception study.

Table 1 *Seven key functions for AKIS (Andersen & Bettis, 2014), (Bergek, Hekkert, & Jacobsson, 2008), (Hekkert M. , Suurs, Negro, Kuhlmann, & Smits, 2007) , (Hekkert & Negro, 2009), (Turner, Fischer, & Luiselli, 2016), (Sixt & Poppe, 2019)*

1. Education, technical training, research and data collection	Fundamental to the transformation process and involves the learning processes related to developing and utilising new knowledge of a technology or set of practices. The development of new knowledge can occur through formal research (e.g. at universities and governmental and non-governmental research centres), the private sector (e.g. agri-business) or at the individual level (e.g. farmers).
2. Knowledge diffusion through networks	The exchange of information through networks where Research and Development (R&D) meets government and markets. Policy decisions should be guided by the latest technological research, and R&D agendas should be adapted to changing environmental, market and social conditions.
3. Development of a vision for the agricultural sector	Refers to the creation of a vision for the AKIS and mobilisation of incentive structures to promote that vision. Incentive structures may change in response to factor prices and regulatory pressures (e.g., product prices, taxes and subsidies), expectations in market growth potential, new knowledge, expression of interest by customers, cultural changes and external events.
4. Entrepreneurial activities	Turn the potential of new knowledge, networks and markets into concrete actions to develop and capitalise business opportunities.
5. Market formation	Create demand for the outputs of the development process. New technologies or practices often have difficulty competing with the status quo, so a market must be created via institutional change. Market creation can occur through changes in regulation and taxes and/or investment in infrastructure complimentary to the innovation.
6. Creation of legitimacy	It is necessary to overcome resistance to a new technology or set of practices from the existing production, trade and consumption systems. It must be considered appropriate and desirable by incumbent stakeholders for resources to be mobilised rather than blocked.
7. Resource mobilisation	Closely linked to the creation of legitimacy and concerns financing investment in innovation in the form of access to credit, seed funding, venture capital, investment in human and social capital and the development of complementary products, services, infrastructure, etc.

AKIS Study Phases

This study was conducted in cooperation with the University of Kentucky and the University of Pikeville, with researchers from Wageningen Economic Research and an expert of Vision Granted Consultants. The main activities of Wageningen Economic Research involved guiding the methodology, designing the questionnaires, and collecting the data for the resulting analysis.

The study activities were divided into 4 sequential phases depicted in Figure 6. A short description of all the phases is presented below.

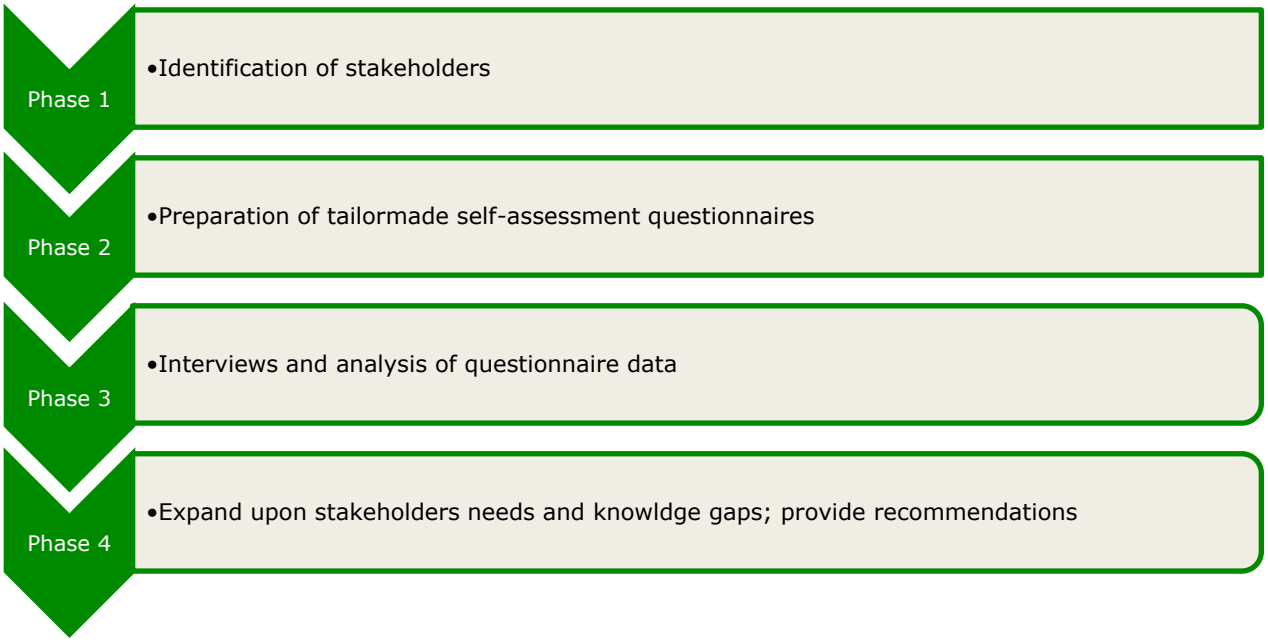

Figure 6 *Four phases of the AKIS study*

Phase 1: Identification of stakeholders
To determine the needs, knowledge gaps, and development of an CEA Ecosystem, relevant stakeholders were identified to participate in the questionnaires. The stakeholder groups were:

- Academic/Knowledge Partners - educational institutions, education training institutions and colleges in Kentucky
- Economic Development Centers - development centers operating in Kentucky such as those focused on rural development, employment programs, etc.
- Government- governmental bodies at state, regional and local levels
- State Associations/Councils/Societies/Non-Profits such as grower associations, Kentucky Horticulture Council, etc.
- Industry - Private sector representatives.

Phase 2: Preparation of tailor-made questionnaires
For each of the stakeholder groups, tailor-made questionnaires were developed. The questionnaires covered all relevant aspects for identifying needs and gaps of stakeholders, and the development of a strategic plan for an CEA ecosystem to bridge government, businesses and knowledge institutes. The questionnaire consisted of general and specific questions tailored to each stakeholder group. A semi- structured questionnaire with open ended questions was designed around the AKIS key functions studied. In total, five interview questionnaires were designed corresponding to the five stakeholder groups described in Phase 1. As an example, the questionnaire used to interview the Academic/Knowledge Partners stakeholder group can be found in Appendix 4. The four other questionnaires have been designed in a similar fashion with slight differences in some questions depending on whether a certain question was applicable and/or relevant for the specific stakeholder group.

Phase 3: Interviews and analysis of questionnaire data
The data from the questionnaires were obtained by individual and group interviews with the respondents from the stakeholder groups according to the stakeholder list (see Phase 1). The interviews were carried out by U.S. colleagues using physical face-to-face meetings and/or online tools and/or telephone calls. For the analysis, all collected data from the questionnaire were reported using a report template. For a detailed description on the number of interviews, period and the process (see Section 5.1. and 5.2).

Phase 4: Elaborate a detailed capacity development strategy including recommendations
Based on the analysis of the data and processed outcomes of the questionnaires, the stakeholders needs and knowledge gaps were elaborated and analyzed. Based on the findings, recommendations are provided (see Section 5).

3

CEA Ecosystem Analysis in The Netherlands

3 CEA Ecosystem Analysis in The Netherlands

3.1 Dutch Greenhouse Ecosystem

Companies in the Dutch CEA cluster contribute directly and indirectly $21bn to the Dutch economy. The sector is showing annual growth in production, job creation, and R&D expenditures. The CEA cluster, which consists of private and public entities in the value chain of vegetables, fruit, ornamentals, seeds and other plant propagation materials and technology, accounts for 3.4% of total national employment, providing approximately 300,000 jobs (254,000 FTE). Of the total expenditure on research and development (R&D) in the Netherlands, 4.5% is made by the CEA chain. The total contribution of the CEA chain to the Dutch economy is 2.7% of the gross domestic product, which is more than 2 times larger than Schiphol Airport (Source: Horticulture Statistics 2019, CBS and WUR 2020).[4]

A common definition of a cluster (or ecosystem) according to Porter (Porter, 1998) is: 'geographical concentrations of related companies, specialized suppliers, service providers, firms in related industries, and contiguous institutions in special fields that compete with each other but also cooperate'.

In the Netherlands, there are clusters that have arisen (evolved) 'naturally' as a result of economic and natural history, such as the glasshouse horticultural region of Westland and Aalsmeer, or the bulb-growing region of the Bollenstreek, or the fruit-growing region of the Betuwe. However, many clusters have come about through cluster-oriented policies, such as the glasshouse growing areas Agriport A7, Nextgarden, Prinsenland, etc.

The strength of the Dutch horticultural sector is strongly linked to a historically grown cluster of companies in the chain. This cluster includes players in the supply and processing of services. The horticultural cluster derives its strength from the spatial concentration of economic activities that are closely interrelated: the proximity of the companies leads to synergy and yields efficiency and innovation benefits.

A cluster or ecosystem can be further characterized by 3 aspects (Berkhout, et al., 2015):
a. Spatial aspect (concentration of companies),
b. Relational aspect (how and how strongly are companies connected),
c. Temporal aspect (the life cycles of clusters).

Spatial delineation and the way firms cooperate or compete takes many forms throughout the life cycles of clusters.

3.2 Identifying success factors for the Dutch greenhouse horticulture ecosystem

3.2.1 Spatial aspect (concentration of companies)

Climate and glasshouses
An important spatial advantage of the Netherlands has always been its climate, namely a temperate maritime climate. The Netherlands has mild winters and cool summers due to the influence of the North Sea. This relatively moderate climate is advantageous for glass greenhouses, with the aim of extending the growing season. The first greenhouses were built around 1850, intended for the cultivation of grapes. They were simple glass greenhouses, leaning against a wall on one side.

[4] https://www.cbs.nl/nl-nl/maatwerk/2020/26/tuinbouwcijfers-2019

What once started as a simple system of 'flat glass' to extend the growing season in open field cultivation has eventually been developed through a simple system of 'standing glass' into a system of heated greenhouses in which cultivation is increasingly done separately from the ground (Vijverberg, 1996). Different levels of sophistication in growing horticultural products are illustrated in Figure 7. In the Netherlands, the growing of horticultural products in plastic tunnels is small: approximately 1,235 acres (500 ha). Open-field vegetable production is done on 66,718 acres (27,000 ha) representing almost 2,900 companies.

It is expected that in the future the dependence on natural environmental conditions will decrease even further. The development towards closed greenhouses makes it possible to better regulate temperature, humidity and CO_2 in the greenhouses. In addition, in a closed greenhouse, the chance of infection from diseases and pests is also significantly reduced. This makes it easier to control harmful organisms with biological control (e.g. parasitic wasps) instead of a reliance on chemical pesticides. Finally, the further introduction of lighting reduces the dependence on day length. This high degree of control ultimately results in reduced losses of water, nutrients, CO_2 and energy, all of which lead to increased environment impacts.

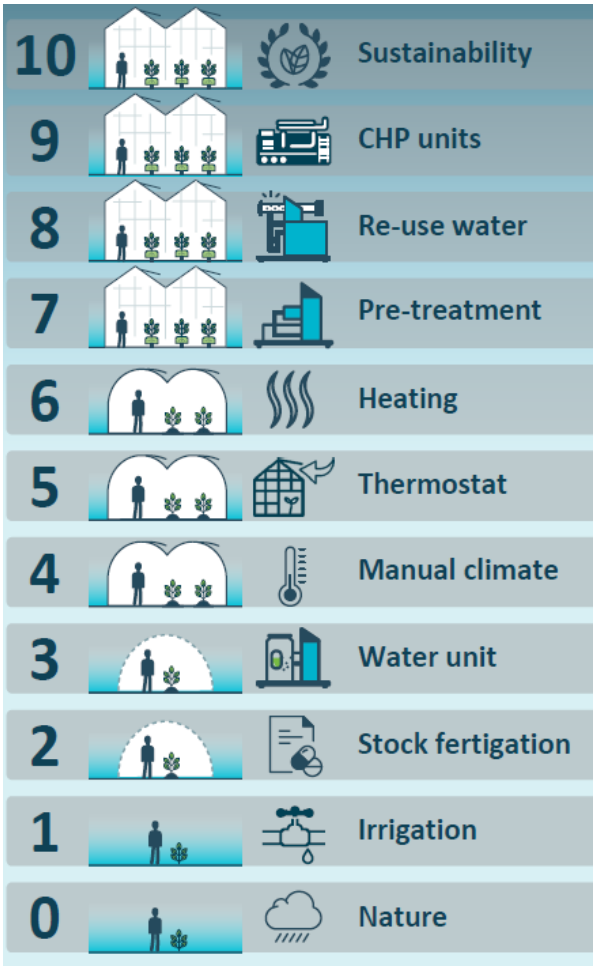

Figure 7 *Different levels of sophistication in growing horticultural products, from field production to low tech, mid-tech and ultimately high-tech (Dijk, 2012)*

Location and logistics

Another spatial advantage of the Dutch horticultural cluster is its location in the delta of Europe: the rivers Rhine, Waal, IJssel and Maas flow into the North Sea via the Netherlands. Traditionally, waterways were the first transport routes in logistics. The Netherlands recognized the importance of good logistics early on, and now has a finely-meshed logistics network by road in combination with close connections to the main ports of Rotterdam and Schiphol. This is one of the reasons why the Netherlands is the central international market place for the trade in and sale of horticultural products.

Transport distance and costs are an important location factor for all links in the chain, not only in terms of costs but also in relation to transport time, which is more or less linked to product quality. The Dutch greenhouse horticulture complex was originally developed in the vicinity (maximum 30 km) of sales markets such as the major cities of Amsterdam, Rotterdam and The Hague to have a short transport time to those markets, due to the fragile horticultural product with a short shelf life. Today, the horticultural complex has a favorable location with the most important markets within a radius of 800-1,000 km, such as Germany, France and the United Kingdom. Transport costs contribute to keeping production relatively close to sales areas. A cheaper mode of transport, such as transport by sea container, can drastically change the international production allocation. Nevertheless, transport costs remain important in international competition.

Logistics is an important part of the agrocluster and ensures that the Netherlands can be the gateway to Europe. For the Dutch agrocluster, the quality of agrologistics is essential. Logistics was previously often seen as a cost item for companies and often had a low priority for business leaders. Increasingly, logistics is seen as a value-adding process that directly supports the primary goal of the organization. Organizations can use the logistics process to be competitive by, among other things, offering high-quality customer service, being able to meet extensive service and information requirements imposed by consumers and other stakeholders in the supply chain and being able to respond flexibly to market demand (Vorst & Snels, 2014). Due to its favorable geographical location in combination with the highly developed Dutch logistics and data infrastructure, the experience with complex logistics processes and the relatively highly educated workforce, the Netherlands acts as one of the most important gateways for the European Union. The Netherlands is an important hub for goods from all corners of the world, the first point of arrival in the EU. From there, the goods continue their way to the European hinterland. The port of Rotterdam plays a major role in this; this is the largest European port for the transshipment of goods and for container transport. Rotterdam is an attractive port for transit, due to its good accessibility for large container ships and the available terminal capacity.

Agroclusters

Since the 1990s, there has been a need for large plots for the large-scale construction of new horticultural greenhouses (especially for vegetable cultivation) due to the increasing scale of expansion and a societal need to concentrate dispersed glass greenhouses on specific horticultural locations in relation to the quality of the landscape. In general, greenhouses are not really seen as a positive contribution to the quality of the landscape. The terms 'landscape pollution' and 'light pollution' have been used when greenhouses are dispersed in the landscape. The existing horticultural clusters such as the Westland and Aalsmeer, which were created over the course of time, could not provide that need for spacious plots (>50 acres or 20 ha). By creating space for the relocation of large-scale glasshouse horticulture companies, the sector is offered future opportunities for restructuring outdated glasshouse horticulture areas and sustainability goals are pursued. The aim was also to improve agrologistics by clustering businesses. From that time on, the national government and the provinces started thinking in terms of project locations and drawing up the spatial requirements for them. Within the spatial development of greenhouse horticulture, the sustainability benefits to be achieved can be realized by removing solitary glasshouses and restructuring existing areas (see Table 2).

Table 2 *Factors in the development of agroclusters (adapted from Kessel, 2005)*

Economic factors	Spatial – ecological factors	Social – societal factors
Cost advantages of collaborative measures for entrepreneurs	Energy	Creation of jobs (high skilled, low skilled)
Knowledge exchange	CO_2-reduction	Cooperation
R&D, Innovation	Water management	Social sustainability - Quality of life
Linkage between other sectors (crossovers)	Traffic and transport	Social/cultural facilities
Logistical accessibility	Waste management	Image building – reduce societal resistance
Optimal plot layout	Multi-functionality	Restructuring interest
	Spatial sustainability (location and effect on environment)	Spatial integration in landscape

Agroclusters are primarily linked to the economies of scale that arise (optimization in the production-processing-logistics chain, reduction of transport costs, efficiency of production processes). Also, agroclusters in peripheral areas are seen as important economic/social societal carriers of the countryside because they provide both high and low-skilled employment in these areas. The economies of scale also affect the social sustainability aspects of application. For example, the size of the locations makes it possible for social networks to emerge, and greenhouse horticulture in peripheral rural areas is seen by all stakeholders in these areas as an important economic carrier for the rural area and as a basis for maintaining the quality of life (stores, care facilities, welfare, education and cultural facilities) in small cores. Concentration of glasshouse horticulture will make it easier to fit glasshouses into the landscape, which may reduce social resistance to glasshouse locations (particularly in terms of integration into the landscape and light emissions). It is also important for horticulturalists to be able to operate in an area where there is a positive attitude towards glasshouse horticulture.

The subject of energy in particular has not only ecological advantages but also economic advantages in the form of cost reduction. Collective energy companies have been set up in various areas. Because of the scale of these companies, a reduction in the price of energy (by >10%) can be achieved. For water management, cost aspects (clean irrigation water) also play a role, but the role of the water authority is also important.

More background information on the roles of stakeholders and success and failure factors in the development of Dutch agroclusters can be found in Appendix 1.

Greenports Netherlands

A Greenport is a concentration of horticultural companies in a certain geographical area that are (economically) connected to each other (in analogy with seaports or airports) (Greenports Nederland, 2022) Historically, these concentration areas are close to the metropoles (due to the short shelf life of fresh produce). Ideally, a greenport is connected to main ports (like airports and sea ports) as well with other greenports. In a greenport, producers, auctions, traders, seed companies, and other supplying companies and knowledge institutions are located; this creates business and knowledge exchange.

History

Greenport was first mentioned in the Policy Paper 'Spatial Planning (*Nota Ruimte*)' in 2001, and in 2004 the national government formulated their vision on spatial development. Through this vision document, the government chose spatially clustered development of priority businesses in selected regions, aiming for synergy (in line with Porters' cluster theory). For agro-food specifically, the clustering of knowledge-intensive horticultural production and processing was recommended. Greenports are concentration areas of greenhouses and agro-trading. Originally, six greenports were designated at the start. Smaller locations were designated as satellite areas (supplying products to the logistic knots in the greenports).

A platform community ('Greenport Network'), consisting of governmental and business representatives, was set up. This platform aims at formulating research and at inspiring entrepreneurs and regional bodies to start new business initiatives related to the greenports. Furthermore, it identifies subjects of common interest (space for development, logistic infrastructures, legislation and governmental instruments) to be discussed with the government.

After the initial steps by the national government, follow-up steps were mostly done by individual stakeholders: regional governments made land destination plans in line with the Policy plan 'Spatial Planning (*Nota Ruimte*)', whereas entrepreneurs, regional development organizations and other stakeholders developed plans in line with the national vision. National governmental interference was limited to co-deciding on research priorities and small support actions to speed up regional permission procedures.

Present situation

Presently there are eight regional Greenports and horticultural regions (Greenports Nederland, 2021), (Greenports Nederland, 2020). All these regional greenports are united in one national network organisation 'Greenports Netherlands', representing the Dutch horticultural cluster.

The eight greenports are named after the regions, provinces or cities where they are located:

- Greenport West-Holland: https://greenportwestholland.nl/
- Greenport Dune and Bulb-region (*Duin- en Bollenstreek*): https://greenportdb.nl/
- Greenport Boskoop: https://greenportboskoop.nl/
- Greenport North-Holland North (*Noord-Holland Noord*): https://www.greenportnhn.nl/
- Greenport Aalsmeer: http://www.greenportaalsmeer.nl/
- Greenport Venlo: https://www.greenportvenlo.nl/
- Greenport Gelderland: https://greenportgelderland.nl/
- Greenport North (*Noord*) (added since May 11th, 2022): https://www.greenportnoord.nl/

Figure 8 *Network organization of Greenports Netherlands*

Each regional greenport has its own organization and activities. This organization includes regional governments, knowledge parties (middle and high applied agricultural schools), regional leading companies and regional representations of national partners or industry organizations. In this way, the Triple Helix approach is also given shape in the region and offers concrete results for entrepreneurs in the region.

What can we learn from this?

The spatial aspect is decisive for the success of the Dutch horticultural cluster for the following reasons:

- Since the turn of the century, there has been a policy on the location of glasshouse horticultural businesses (no dispersed greenhouse locations), which has increased the creation of clusters.
- Government, entrepreneurs and other stakeholders (such as residents) jointly develop new location choices and facilities from the outset, rather than just the government or from the drawing board.
- With entrepreneurs as a figurehead, it is ensured that an area is developed in a magnetizing way.
- The road network infrastructure is well developed in the Netherlands. Attention is being paid to multimodal transport of fresh produce.
- Businesses are relieved of the burden of energy, waste and services (truck fleet, security, etc.) at the agroparks.

3.2.2 Relational aspect (how and how strongly are companies connected)

The connection between the various cluster links in the greenhouse horticulture complex is the original and underlying force behind the added value of the cluster. There is cooperation in several areas:

1. Inputs (cooperative purchasing combinations), finances and insurance.
2. Sales: auctions in the past and now growers' associations.
3. Knowledge and innovation: from the triptych Research, Extension and Education (in Dutch: *OVO*) towards the Top Sector Horticulture & Starting Materials.

Ad 1 Inputs, finance and insurance

Greenhouse construction and associated technology
In the Netherlands, approximately 15 companies are active in the delivery of complete greenhouse complexes. There are also a few other (smaller) greenhouse builders, but these often work as subcontractors for these 15 companies. AVAG (association of the Dutch greenhouse construction *and* technology) reports that 71 members realized a combined turnover of an estimated $ 3bn in 2021 (AVAG, 2021) These Dutch companies are focusing on supplying innovative technology to further increase crop production with fewer inputs from water, crop protection products and fertilizers.

Plant breeding and seed technology
The Netherlands is an important player in the production of plant propagation material worldwide. Starting material defines any plant form that does not deliver an end product, such as seeds, tubers, cuttings and young plants. The basic material sector includes both propagation and breeding. A large part is located in four concentration areas: the Seed Valley, an area in West Friesland; the Westland, North Limburg and the area around Aalsmeer. The breeding and propagation companies vary greatly in size. In the Netherlands, there are globally operating large companies such as Bejo Zaden, Enza Zaden, and Rijk Zwaan, which breed and propagate a wide variety of vegetables. More than 350 companies in the Netherlands breed and propagate, and about 12,000 people work with seeds and young plants.

Services
Banks have always played an important role in the development of the horticultural sector in the Netherlands. At the end of the nineteenth century, Dutch farmers and horticulturalists wanted to modernize, but found it difficult to get credit. That is why they decided to set up credit cooperatives. The cooperative banks have become a great success. Even today, as financiers of the agricultural sector, banks are crucial to the transition of the sector. Agreements are made with banks about the conditions for (new) loans and the handling of old loans for investments that are not part of the transition to circular agriculture (Dutch government policy).

Hagelunie is an insurance company focusing solely on the greenhouse horticultural industry, offering insurance products to businesses operating in this sector in Europe, Australia and Canada. They insure greenhouses, commercial buildings, inventories, installations, crops grown in greenhouses and any business interruptions.

Other service providers with a special focus on the agricultural sector play an important role in the development of the agricultural sector. For instance, accessible and free cultivation advice through publicly funded services existed until the 1990s. Now there is still a lot of knowledge development and exchange on a commercial basis. These include insurance companies and accountants.

Ad 2 Sales
Supermarkets in Europe have a powerful position in the food supply chain because they are often the single most important food retail outlet. In 11 different European countries, fewer than eight retail chains control the vast majority of the nation's food retail. For example, five retailers made up 85% of the German market in 2014 and 77% of the Dutch market in 2016. The number of corporations in the food supply chain varies from country to country; yet the hourglass-shaped form of the Dutch retail market also applies to countries across Europe (see Figure 9). The model illustrates that there are just a few retailers through which food finds its way from a large number of farmers to a smaller number of suppliers and on to millions of consumers. In the case of the Netherlands, many smaller supermarkets work together in a national buying group with the result that just five companies effectively control nearly all food sold (Kate, van der Wal, & Pannenbecker, 2017)

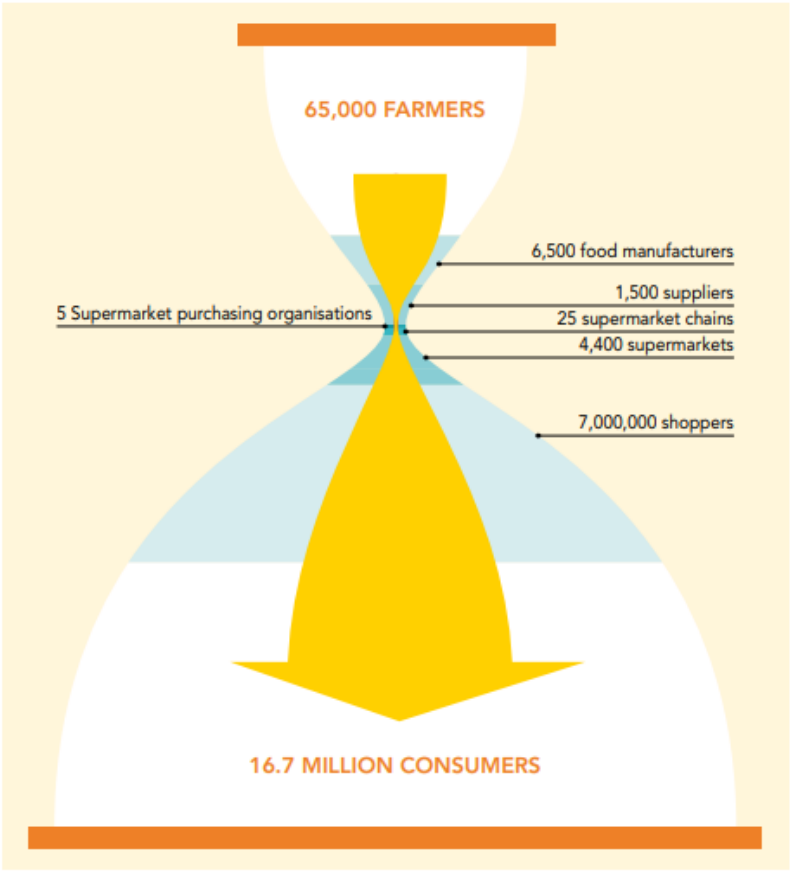

Figure 9 *Concentration of power in the Dutch food supply chain (PBL Netherlands Environmental Assessment Agency, 2022)*

To defend themselves against this powerful position of large-scale retail, horticultural entrepreneurs must work together to obtain reasonable pricing for their products. Otherwise, they will be played off against each other. Virtually all Dutch horticultural entrepreneurs are members of a cooperative marketing form in one way or another. This playing off against each other in the market is not new, but has always been played. In the past, many small growers' associations (e.g. cooperative auctions) have been established in the Dutch food crop sector. In 1935 there were 162 auctions for vegetables and fruits and 23 auctions for ornamentals in the Netherlands. In time, most of them have merged to create economies of scale in response to the economies of scale of the retailers. Nowadays only 13 producers' associations are represented by the Dutch Produce Association (DPA). A number of these associations are large sales organizations such as The Greenery, Auction ZON and Fruitmasters. These product-specific associations mainly act as representatives of interest for the producers. In addition, a new category of growers' organizations or trading houses have been set up that operate entirely independently of the large marketing organizations mentioned above. These independent associations often consist of growers who left the old auction cooperatives out of dissatisfaction. They are usually innovative entrepreneurs who feel that their products - often specialties - are not sufficiently appreciated via the traditional auctions or even via the sales organizations' agencies. Specialties often require a special marketing approach, which the large sales organizations are often unwilling to do because they offer a total package of fruit and vegetables to their customers. Establishing new, homogenous producer organizations solves some of the problems of the old auctions (such as adverse selection and difficult decision-making), but also leads to new problems (such as loss of economies of scale and market power). A frequently mentioned disadvantage for the Dutch fruit and vegetable sector as a whole is the fragmentation of investments, especially in marketing.

These Dutch fruit and vegetable producer organizations can apply for a European subsidy instrument, called Common Market Organization (CMO) subsidy (EUR-Lex, 2021). With the CMO scheme, the European Union aims to promote the sustainable, competitive production of fruit and vegetables, reduce fluctuations in producers' income during crises, increase consumption and protect the environment. Only recognized

producer organizations with a turnover of more than $ 25m and at least 10 members are eligible for this form of aid. This instrument has incentivized cooperation among producers strongly in the fruit and vegetable sector. For the ornamental sector there is not such an instrument.

Traditionally, the Netherlands has been a country that looks outwards and is in favor of free(er) trade and transparent trade relations. As a small country, the Netherlands depends on good relations with neighbors and distant friends. This also applies to the Dutch agricultural sector. As a major producer and processor of agricultural products and involvement in the trade in many agricultural raw materials, foreign trade is of great importance. The home market is limited, as it has always been, which makes the Netherlands a major exporter. The Netherlands is also a major importer, mainly due to its good logistical accessibility by sea (and air) and its favorable location in relation to Germany as a hinterland purchasing power. This makes the traders the linchpin of the Dutch trade cluster, which includes importers, exporters and specialized service providers such as packers and transporters. The Dutch trading houses have also invested in sufficient ripening facilities that are needed to ripen products such as avocadoes or bananas before they can be sold. To optimally integrate the international offers into the Dutch offers, Dutch trading houses have set up a global trade network in Africa and Latin America, among others.

Ad 3 Knowledge and Innovation
A specific strength of the Dutch horticultural cluster and an important competitive advantage compared to international competition is the knowledge intensity and knowledge integration throughout the chain. This results in a large number of innovations (product, process and system) every year. The basis for this is a solid education and knowledge system.

Triple Helix: the success of agriculture and horticulture
The Netherlands boasts an internationally valued position in the field of agricultural knowledge, with Wageningen University as the best-known showcase. The impetus for the triptych of agricultural research, extension and education (‘*OVO drieluik’* in Dutch) was given more than 125 years ago. Research institutes today still generate knowledge that is applicable in the daily practice of farmers and horticulturists.

The unsurpassed triptych (research, extension and education) may have been discontinued, but the resonance of its impact on Dutch agriculture and horticulture reverberates to this day. The Netherlands prides itself on an internationally valued position in the field of agricultural knowledge.

The former agricultural college, now Wageningen University & Research, still plays a role that should not be underestimated in the developments in Dutch agriculture, although it is mainly the adjacent research institutes that provide knowledge in the daily practice of farmers and horticulturists.

In the twentieth century – and especially after the Second World War – Dutch agriculture and horticulture experienced a stormy development in which the sector changed from producer-oriented Dutch market to an important exporter with a large contribution to the gross national product.

The dissemination of knowledge was often done through information officers, government officials who walked from farmer to farmer and from meeting to meeting to inform the primary producers about the latest developments. Information officers mainly responded to the demand of farmers, although after the war they also actively and unsolicited went to farmers to inform about new agricultural methods.

The latest data on the level of education of Dutch farmers and horticulturists show that more and more entrepreneurs have a higher academic agricultural education. Whereas in the 19th century the farmer mainly gained knowledge from the previous generation and from colleagues, the foundation is now laid at secondary or higher agricultural school.

Of the current farmers and horticulturists, about two-thirds have at least completed secondary agricultural school. An ever-smaller proportion have only had primary agricultural education, while more and more farmers and horticulturists have completed a higher agricultural education or university. The percentage of highly educated farmers and horticulturists has crept above 20% over the years.

Proximity of research institutions
The relationship between research institutions and business has two directions. It is important for companies to be close to research to be able to apply the results quickly and effectively; on the other hand, the quality of research is enhanced if there are short lines of communication. Physical proximity is convenient, but not essential. Since the early 1990s, more private research bureaus have emerged, with larger production companies increasingly carrying out their own research.

Proximity to information companies
The relationship with company information officers is of great importance to production companies. Information providers are the eyes and ears of companies behind the scenes of their own company. With the current means of communication and the expected innovations in this area, it is less necessary for extension workers to be physically located nearby, although there will always be a need for crop-related extension services on location.

Quality agricultural education
There is an interaction between agricultural schools and horticultural businesses. Students can gain practical knowledge and, vice versa, find their way to the business community. In this context, 'business' refers to all chain links. A decline in the total turnover of the horticultural complex will eventually have to lead to reduced educational capacity. Agricultural education in the Netherlands has become increasingly international-oriented over time. The proximity of agricultural education lies at the basis of sufficiently well-trained personnel and is seen as the most important factor; this applies to all links, now and in the future.

Training to increase professional competence (schooling), attention to working conditions and labor market policy for the working population employed in the Dutch CEA are looked after by an organization called Colland.[5] Colland is the partnership between (pension) funds and schemes in the agricultural and green sector. In this way, the Colland Labour Market Fund contributes to the sustainable employability of employees, stimulates compliance with the employment conditions and ensures an optimally functioning labour market. The premium for the Colland Labour Market Fund differs per sector and is paid by the employer, unless stated otherwise. The amount of the premium depends on the scope and nature of the labour market activities a sector has chosen.

Breeding ground for innovations
The Dutch agricultural complex, and greenhouse horticulture in particular, is known to be highly innovative. In the past, crises have always stimulated innovation. Banks/insurance companies have been important in this respect, both for realizing investments/innovations and for hedging against major risks. If the Dutch horticultural collective weakens, and the supplying companies in particular shift their activities abroad, the focus on innovations will shift. This need not have a negative effect on the supplying companies. It is expected that innovations will be less focused on the Dutch situation and, the reduction in the number of supplying companies based in the Netherlands will lead to a reduction in innovation capacity, in addition to a reduction in the production area.

Availability of skilled labor
The availability of labor force linked to professional competence is linked to agricultural education and of great importance to the ornamental plant sector. Changing labor regulations in the EU have made it easier to recruit labor from other countries. Over the years, the labor productivity of production companies has increased significantly, which has made them less dependent. Labor has been increasingly replaced by capital through mechanization. Growth in the size of companies can make such investments profitable.

Top Sector approach for innovation, R&D and knowledge dissemination
Top Sector Horticulture and Starting Materials is one of the nine top sectors that was set up by the government in 2011 as an instrument for cooperation between companies, knowledge institutions and government. Top Sectors were developed to allow public funds intended for innovation, R&D and knowledge dissemination to be implemented in public-private partnerships. This began by drawing up a joint vision and strategic agenda that was supported by all stakeholders.

[5] www.colland.nl

From 2008 to 2011, there was a global financial crisis. Confidence in the financial sector declined and the Netherlands fell into recession. As the economy worsened, the government cut spending, companies postponed investments and much innovation came to a standstill. The top sectors were established to jointly organize and help revive that innovation and investment. In 2011, therefore, a start was made to form the top sectors. The Netherlands has a strong international presence in these sectors. For example, through the knowledge we have built up within these sectors, the quality of scientific research in the Netherlands or through the development of the best products and services. In the top sectors, representatives of business, science and government work together to support innovation and share knowledge. The name top sectors refers to the international standing of Dutch knowledge and trade in the field of energy, water, food production, technology, etc. Top sectors consist of a mix of large companies, SMEs, start-ups and scale-ups. Over 90% of the top sectors are innovative entrepreneurs from small and medium-sized enterprises (SMEs). In 2019, the top sector approach is further developed into a mission-driven top sector and innovation policy. Six ministries challenge entrepreneurs and scientists to come up with groundbreaking solutions that also contribute to the competitiveness of the Netherlands. Increasing economic opportunities is still central, but by solving societal challenges and investing in key technologies. By also involving start-ups, innovative entrepreneurs and regions, the support and the chance of success are increased.

More information on Top Sector approach and governance in Dutch Horticulture can be found in Appendix 2.

What can we learn from this?
The relational aspect is decisive for the success of the Dutch horticultural cluster for the following reasons:

- The contribution of inputs, technology and service suppliers who are accessible (usually a branch in the neighborhood). Breeders who offer test opportunities with entrepreneurs, resulting in joint innovation, including feedback and the availability of capital (banks) coupled with good knowledge of the horticultural sector.
- The contribution of growers resulting in open knowledge exchange, previously through study clubs, now mainly through growers' associations. Strong mutual networks, formal and informal, regional connections.
- The contribution of fixed trading companies in cooperation with producers (and grower associations) towards customers. This was done successfully via cooperatives/auctions previously.
- Government involvement in innovations such as risk reduction and (co-)financing of research and/or market introductions.
- An intensive connection of knowledge parties (research, extension, education) which led to the Triple Helix approach. There is close cooperation between educational institutions in the green sector (Green Pact).[6] There is a close connection between education and business: trainee companies, advisory boards, etc.

3.2.3 Temporal aspect (the life cycles of clusters): Transformational developments in the Dutch CEA ecosystem over time

From economy to sustainability & economy
A strong facet of the Dutch horticultural cluster is that it is an international leader in sustainability and food safety. The sector constantly strives to reduce its dependence on fossil fuels, to increase the use of sustainable energy sources and to reduce emissions of CO_2, crop protection products and nutrients.

While the emphasis after World War II was on the economic importance of the cluster and the focus on increasing production per unit area, this changed after 1985. The negative trade-offs such as emissions of crop protection agents and nutrients into ground and surface water and CO_2 emissions, became more and more strongly felt in the 1980s and were no longer socially accepted. In the early nineties, the collective business community and the government jointly developed covenants containing agreements to reduce these emissions, such as the Multi-Year Agreement on Energy (*MJA-E*) and the Multi-Year Plan for Crop Protection (*MJPG*).

[6] www.groennpact.nl

These programs with objectives still exist today, albeit in a different guise and with stricter objectives:
1. the Climate objectives (CO_2) with the ambition of being energy-neutral in 2040;
2. Healthy plants in relation to reducing the use and emission of crop protection agents (Green Deal): resilient cultivation;
3. Waterproof: to achieve (virtually) zero emission of fertilizers and crop protection agents in 2027.

The 1990s thus marked a turning point in government policy, which until then had been based on economic progress and was then shifted towards the social importance of a healthy environment. That government policy has continued over time and is reflected in current policies with new terms such as circularity, emission-free, inclusive, socially responsible, true pricing and new business models.

From supply-driven to demand-driven

Another turning point was the change from supply-driven production to demand-driven production at the end of the eighties with the water bomb (in German: *Wasserbombe)* crisis (see Text box 1).

Text box 1 Water bomb crisis (Schouten, et al., 2019)

'Wasserbombe'

In the 1980s, a crisis arose when Dutch tomatoes were called *'Wasserbombe'* (water bombs) on German TV, because they were said to be watery and tasteless. The Germans (our most important customers) no longer wanted to eat Dutch tomatoes after that. That was disastrous for exports and Dutch production collapsed. In order to win back the consumer, the Dutch tomato sector started working on more diversity in taste, color and shape. This resulted in new genetic variations. The resilience of the sector after the *Wasserbombe* catastrophe ensured that all sorts of tomatoes, from snack tomatoes to beef tomatoes, in different sizes and colors, found their way into shops in the Netherlands and abroad. Nowadays the Dutch export value of tomatoes is the second highest in the world, after Mexico.

The formation of growers' organizations and the establishment of direct relationships with the end-consumer have helped the growers to operate in a more market-oriented way and in dialogue with the buyer. Trading parties and growers who have found each other have become increasingly larger and more important players in the market (non-cooperative partnerships). Product differentiation and internationalization of production has resulted in a wider range of products being available over a longer period of time.

Currently, Dutch traders in fruit and vegetables can offer a total package to customers, and not just products grown in the Netherlands. For example, the Netherlands imports large quantities of tomatoes in the winter months; Dutch production is then more limited. These tomatoes mainly come from Spain and are sold both in the Netherlands and exported to neighboring countries.

From energy user to energy supplier

With the liberalization of the energy market in 2005, the program 'Greenhouse as a source of energy' (in Dutch *Kas als energiebron*) was born and is still running today. Today, Combined Heat & Power plants (CHP) located on greenhouse farms supply approximately 5% of the total electricity consumption in the Netherlands.

'Greenhouse as a source of energy' is the innovative program that stimulates energy saving and the use of sustainable energy in greenhouse horticulture. The Netherlands Greenhouse Horticulture and the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) are working together on this. The program develops knowledge and (cultivation) techniques to save energy in greenhouses, and to use more sustainable energy such as bio-energy, sunlight and geothermal energy. With the input of entrepreneurs, innovations that could mean a breakthrough for the sector will be stimulated. To expand sustainable investments, knowledge exchange, subsidy schemes, and affordable techniques are provided. An example of a joint sustainable energy supply project can be found in Text box 2 (Jukema, Ramaekers, & Berkhout, 2021).

Text box 2 Joint sustainable energy supply

Within production, entrepreneurs are increasingly looking for each other. This also applies to the greenhouse horticulture companies in the Alton glass concentration area near Heerhugowaard. At the end of 2013, they saw an opportunity to work on their individual resilience and the vitality of the area by investigating the feasibility of a joint sustainable energy supply. The entrepreneurs, united in the working group Greenhouse Horticulture Alton, have tackled this together with Wageningen Economic Research. In collaboration with the waste processing company HVC from Alkmaar, a sustainable energy subsidy (*SDE+*) subsequently was applied for from the Bio Energy Powerplant (*BEC*). The subsidy was awarded and the extension of the heat network from HVC to Alton was started. The area is now on its way to becoming one of the most sustainable greenhouse horticulture areas in the Netherlands. Pepper grower NH Paprika (the largest gas consumer with 5m m^3 per year) will be the first greenhouse horticulture company to be connected to the grid and is therefore completely climate neutral. The heat from HVC comes from fired waste wood that residents and businesses deposit at waste collection stations. The heat is therefore 100% renewable.

There is a joint ambition to no longer use fossil fuels for the cultivation of crops by 2030. Greenhouse horticulture uses a lot of energy and therefore also emits a lot of CO_2. As an example, in the Alton area, more than 30% of the total energy consumption of the municipality of Heerhugowaard is from greenhouse production. By doing business sustainably, the parties involved want to reduce CO_2 emissions in the Alton area by 75% by 2030 compared to 1990. A new project by Tesselaar Freesia contributes to this. By using an Innovation Subsidy from the province of Noord-Holland, the largest solar thermal project in the Netherlands was put into use on 4 October 2019: an installation of 9,300 m^2 of solar thermal panels supplied the heat. The amount of heat is comparable to the annual consumption of approximately 300 households. Tesselaar Freesia and Mol Freesia got the knowledge from Denmark, where solar thermal energy is already being used on a larger scale. G2Energy realizes the project in the Netherlands. With the panels there is hot water all year round that is applied directly to heat the greenhouse. A surplus of heat in the summer is stored with a system for heat-cold storage (ATES) in the ground. During very hot days, cold water is pumped up to cool the crops. In winter it works the other way around: the warm water is pumped up and the cooled water goes back into the soil. This keeps the soil in balance.

From primary producer to input supplier

Within the horticultural chain, trade, logistics and horticultural technology have increasingly become the steering mechanism for developments. They are therefore decisive for the international position that the cluster occupies.

The Dutch cluster of technological companies, related industries and service providers has developed into a major manufacturing industry, with leading knowledge that can also be applied elsewhere. This has led to cooperation with world players in the fields of energy, light, climate, Information Technology (IT), water and sensing.

Text box 3 Water scarcity is by far the biggest challenge (Groenten Nieuws, 2021)

In twenty years' time, many regions on the world map will turn red as far as the availability of fresh water is concerned. This is alarming, but it also represents a great opportunity for high-tech greenhouse horticulture. Dutch input suppliers can offer many product solutions, services and knowledge for safe and sustainable food solutions worldwide. The world population is growing and there is more industry and ever greater consumption.

The challenge is enormous, but there is great opportunity. More and more countries will be introducing legislation that will demand a more efficient use of water as well as limiting the environmental impact of water consumption in agriculture and horticulture. Saving water will become an important incentive for choosing high-quality greenhouse horticulture.

Seed Valley is the worldwide center for plant breeding and seed technology, located in North Holland. Dozens of companies work daily on the development of new vegetable and flower varieties that give a higher yield, are resistant to diseases or taste better, among other things, and with as little use of space, energy and water as possible. What Silicon Valley is to IT and software, Seed Valley is to the development of new vegetable and flower varieties. In the market for horticultural seeds, 'Seeds from Holland' is an indestructible trademark. At the Seed Valley seed companies, 86% of the turnover is realized abroad. The companies not only sell their seeds abroad, but also breed and produce on site. From all continents and climate zones, they

serve the customized world market. Local specialists are assisted by Dutch colleagues who transfer their knowledge. More than 50% of vegetables have an origin in Seed Valley.

3.3 Summary of findings

The strength of the Dutch horticultural ecosystem can be summarized in two words: cooperation and competition.

Competition is mainly about the market and in technology development, ensuring a continuous focus on efficiency for all stakeholders.

Cooperation lies in strengthening the market power towards the customer and in fundamental knowledge development and (pre-competitive) innovation development.

Important success factors are:
- Availability of skilled workforce
- Quality of the workforce through good quality education
- Quality of research institutions that work closely with the private sector
- Available information in many areas for entrepreneurs, from suppliers and from specialized information companies
- Innovation climate: many innovations arise from crisis situations or societal preconditions. Short lines of communication between the supplying industry and the producers, and risk-hedging instruments by the government and banks and insurers ensure rapid innovation development
- Governments thinking along with the development of the cluster and daring to be critical with regard to meeting social preconditions
- Optimal logistical location
- Social acceptance, particularly in terms of the landscape.

4

CEA ecosystem in Kentucky

4 CEA ecosystem in Kentucky

4.1 Introduction

This chapter examines challenges and opportunities for the potential establishment of a controlled environment agriculture (CEA) industry or cluster in Kentucky. Recent significant private investment in CEA in Kentucky reflects a general growth in interest in CEA technology and its role in horticulture product supply chains. Vegetables (tomatoes, leafy greens, cucumbers, peppers), small fruit (strawberries), and a wide variety of ornamental plants and floriculture have been successfully produced in these systems in the Netherlands, Canada, and Mexico, and are now being examined for development in Kentucky.

We provide a background for the Kentucky market area, including horticulture production and related supporting institutions, with a view towards examining forces that shape competitiveness and opportunities for sustaining a viable industry in this region. There are significant challenges to building a strong industry, but there are also many opportunities for the future of horticulture production. This chapter is the result of interviews with CEA industry leaders and buyers, supported with an examination into the key forces shaping the perimeter of a competitive industry. A thriving CEA industry could be built by looking to the key success factors in other clusters, and by looking for a path that would capitalize on current production, supply chain partners, institutions, and markets.

4.2 Kentucky background

Kentucky, located in the upper South of the U.S., is a relatively rural state with a little over 4.5m residents. (America Counts Staff, 2021) (Snell, et al., 2021) Several major cities are located nearby in adjacent states, including St. Louis, Indianapolis, Cincinnati, and Nashville. Agriculture is an important part of the state's economy with over $5.5 billion in farm gate cash receipts. (Childress, Clark, & Paris, 2021).[7] Value-added food production has increased significantly in Kentucky compared to other states, up 63% since 2007 compared to the 22% average across the U.S., representing significant investments in meat processing, distilling, and other food processing. For example, the Kentucky bourbon industry represented $9bn in 2021 and generated more than 22,500 jobs with an annual payroll topping $1.23bn. The production and consumption of our spirits creates over $286m in annual tax revenue for Kentucky state and local governments. Since 2000, the growth has been 465%. About $5.2bn in capital projects will be completed or planned by 2025, including more than $100m to build or expand this signature industry. (Kentucky Distillers' Association, 2022)

Kentucky's employment history reflects that elsewhere in the U.S. during Covid-19 and experienced significant disruption. Current unemployment statewide has settled back to 5.6% compared to the national rate of 6.7%.[8] Hourly wage rates and wage growth in Kentucky have been regularly well below U.S. averages and competitor states. Job growth experienced extremely sharp disruption during Covid-19 across the U.S., with only a partial recovery observed through the end of 2020. Wage growth in the eastern part of the state has significantly lagged behind the state average.[9] Per capita personal income in Kentucky as a percentage of the U.S. average has gained some ground, but remains at around 80%, with greater income disparities in

[7] The CBER value is based on the 2019 USDA estimate of $5.5bn. Additionally, where USDA does not collect regular farm gate cash receipts, the Ag Economic Situation and Outlook for the U.S. and Kentucky (December 2021), provided by the University of Kentucky College of Agriculture, is cited. https://agecon.ca.uky.edu/sites/agecon.ca.uky.edu/files/outlook_publication_2021.pdf. This includes the 2021 estimate of $6.75 billion in KY farmgate cash receipts.

[8] CBER, reported as of November 2020.

[9] CBER estimates for E KY wage and salary growth of 8.4% between 2007-2019 compared to 40.8% statewide.

the eastern parts of the state. Labor force participation rates are also more challenging in eastern Kentucky with all 6 of the counties with the lowest participation among 25–54-year-old workers located there.[10]

Kentucky is approximately on track with the U.S. average for individuals with a high school degree or higher, but lags somewhat for those with a BS degree or higher. Kentucky reported 29% with a BS degree or higher compared to 34.8% in competitor states and 36.3 as the U.S. average, and once again with a fairly significant geographic disparity east to west.[11] Kentucky has seen a steady increase in science and engineering graduates, but is also lagging behind the rate of growth in these degrees awarded in the U.S.[12] Kentucky is classified in the lowest quintile for the Technology and Science Index for 2020 based on a compilation of measures by the Milken Institute, including human capital investments, state R&D inputs, technology and science workforce, and other factors.[13]

Energy is another important part of the Kentucky economic story. CBER notes that 'in 1988, coal accounted for about 57% of the total megawatt hours generated and natural gas accounted for just over 9%'[14] Electricity sourcing has been switching dramatically in the state with natural gas surpassing coal in 2015.[15] Kentucky's electricity costs have remained well below the national average and those of competitor states.[16]

Infrastructure in Kentucky is also a key variable framing economic opportunity. While major U.S. Interstates span the state (I-64, I-65, I-75, I-69),[17] major airports in Lexington, Northern Kentucky (Cincinnati) and Louisville are growing. Rural deployment of broadband in Kentucky exceeds the national average, although adoption lags slightly.[18]

Kentucky has steadily gained in the number of high-tech establishments in the state, although it lags nationally and competing state averages.[19]

4.3 Horticultural Sector in Kentucky

This section contains a description of the horticulture industry in Kentucky with a primary focus on vegetable production.

4.3.1 Overview of Recent Production History

Kentucky has had relatively small scale production of horticultural crops (vegetables, fruits and ornamentals) that has included a substantial emphasis on local production for local markets. While farm gate cash receipts for produce have been relatively small compared to larger production bases in the U.S., those cash receipts have been steadily growing, largely based on the growth in demand for local produce through farmers markets, on-farm retail and agritourism, and other short supply chain markets. Produce auctions and other smaller scale wholesale efforts have also expanded. Estimates drawn from NASS and grower organization estimates presented in Figure 10 place KY produce cash receipts at around $60m for 2021. This would seem to be a conservative estimate that does not include cash receipts generated from recent sales from new controlled environment systems, which potentially adds another $10m to that total in 2021.

[10] CBER also reports 'distressed' and 'medium-distressed' counties, noting the majority of eastern Kentucky counties falling into this classification. See p.75.
[11] CBER report p.124, data for 2019.
[12] CBER report p.127, 1997-2019. KY reported 15.5% per 1000 individuals 20-24 years old vs 24.3% nationally.
[13] CBER report p.198.
[14] CBER report p.132.
[15] CBER report indicates 38.4% from natural gas and 23.4% from coal in 2019.
[16] CBER report p.142 indicates average cost per kW hour in KY at 5.6 cents compared to 6.4 in competing states and 6.8 nationally.
[17] CBER report p.184 ff, KY roads above national average for repair and bridge condition.
[18] CBER report, 84% of rural KY has broadband deployed compared to 77% in the U.S.
[19] CBER report p. 206, 7.7% of total establishments in KY indicated as 'high-technology' compared to 9.9% nationally in 2018.

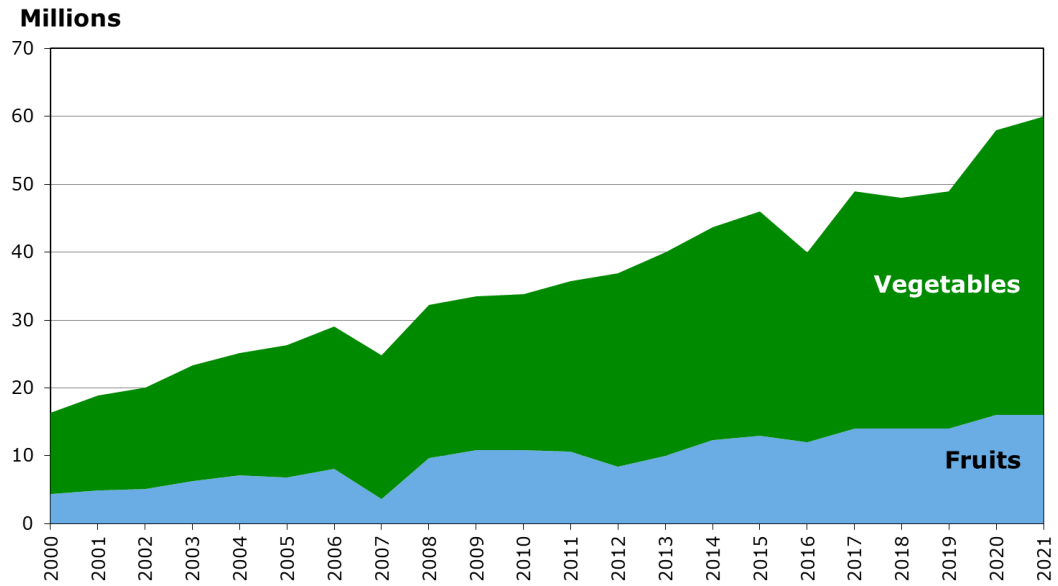

Figure 10 *Kentucky Produce Cash Receipts (Woods, Kentucky Produce Cash Receipts, 2022)*
Estimates derived by T. Woods, UK AEC, from combinations of Census of Ag, NASS, KY auction and farm market reports, presented at 2021 KY Farm Bureau Ag Outlook Conference.

Nursery production provides an important sub-sector to the horticulture industry in the state overall, including significant local and regional sales of plant material from local growers. The nursery industry supplies floriculture, starter plants, ornamental trees and shrubs, and other plant material for both wholesale and retail markets regionally. This production base has until recently included most of the controlled environment infrastructure in KY and added approximately another $118m in farm gate cash receipts, yielding the approximately $180m to a horticulture sector that has seen steady growth (see Figure 11).

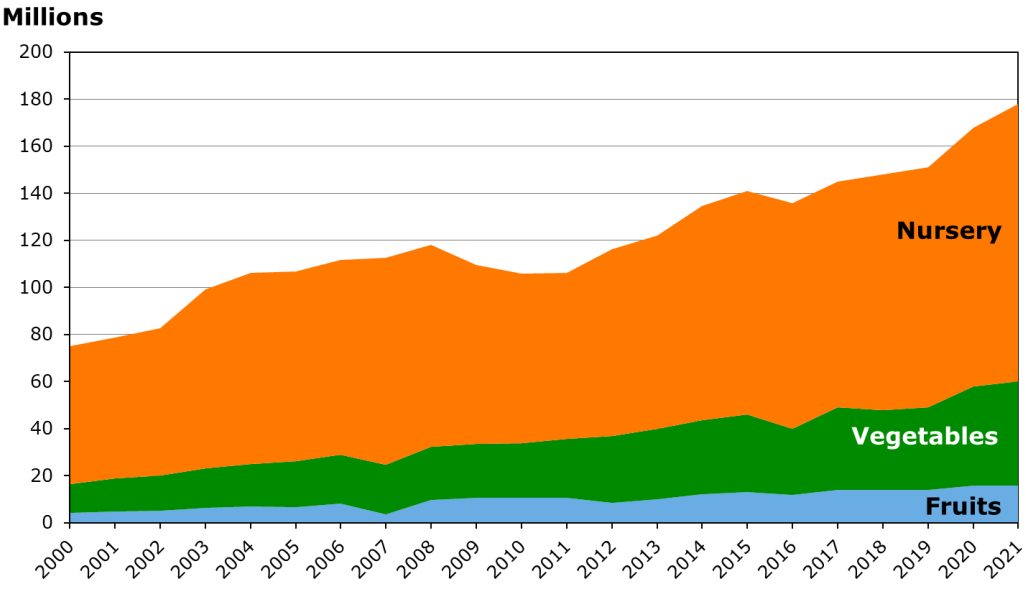

Figure 11 *Kentucky Produce & Nursery Cash Receipts (Woods, Kentucky Produce & Nursery Cash Receipts, 2022)*
Updated estimates derived by T. Woods, UK AEC, from combinations of Census of Ag, NASS, 2019 Census of Horticulture, presented at 2021 KY Farm Bureau Ag Outlook Conference.

The structure of Kentucky produce farms has historically been relatively small farms. Various levels of cooperation around the pursuit of wholesale markets ensued between 1990-2010, including formal farmer-

owned cooperatives such as the Cumberland Farm Products Cooperative in Somerset that focused on the cooperative sales of tomatoes and cabbage. Further cooperatives were pursued through the initial phases of the Tobacco Master Settlement Agreement at various locations around the state, including a further emphasis on additional annual vegetables and melons. Each of these cooperatives have since gone out of business due to facing challenging national markets for fresh produce and limitations of scale.

Produce auctions expanded into Kentucky starting in the late 1990s with the Fairview Produce Auction near Hopkinsville. These simple aggregation markets have continued to expand around the state with now five active auctions supporting roughly 700+ primarily small growers as vendors. There is no formal cooperation is being pursued by these auctions. The auctions are privately held interests that charge a 12-15% sales commission to growers and attract smaller wholesale buyers regionally (University of Kentucky, Produce Auctions, 2022). The auctions sell a range of plants, fruits, and vegetables, as well as coordinate the purchase of input supplies such as boxes. As the auctions have expanded, they have added sales space and included more order buying as a service to remote buyers. Fairview and the Lincoln County Produce Auction are the largest in Kentucky, and the auctions collectively sold roughly $10-15m in produce for 2021. These are typical of the roughly 80 produce auctions active primarily in the states along the Ohio River with origins in Pennsylvania and New York (see Figure 12). Recent market disruptions related to Covid-19 led to substantial increases in demand through the auctions with increased demand for local produce options to both supplement disrupted supplies and also meet increased interest in local produce. Much of this increase in Kentucky came through early season tomatoes and melons – products of significant focus of sales through the auctions. Increases were observed across the 2020 marketing season as Covid-19 first hit, and overall sales increased further by roughly 10% again in 2021 (see Figure 13).

- Five auctions active in KY – primarily produce and ornamentals
- 350 vendors selling in 2008, 700+ in 2022
- Fairview expansion
- Growing in KY, OH, IN, MO, PA
- Regional "wholesale" aggregation
- Buyers primarily resellers
- Attracting order buyers from larger markets – up 30-40% during Covid-19
- Strong supply, much higher gross sales following Covid-19

Figure 12 *Overview of locations of Produce Auctions in Kentucky and surrounding states*

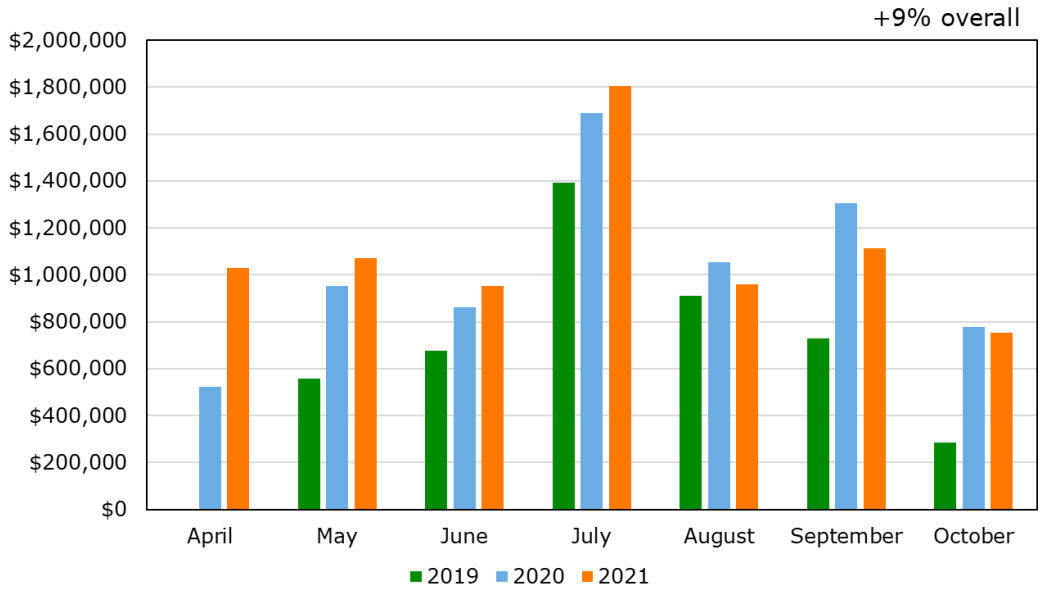

Figure 13 *Fairview Produce Auction Sales YOY (UKY Center for Crop Diversification , 2022)*

Farmers markets have grown steadily across the state and provide outlets for many small producers marketing locally (Table 3). A coordinated effort across multiple agencies has increased support for farmers markets (direct farmer to consumer) and has resulted in an increase in the number of these markets even through Covid-19. These vendors tend to be fairly small in scale, but these farm markets play an important channel option for most produce farmers in the state as strong demand for local produce is also pursued in restaurants, grocery, and other institutional markets. Significant growth in farms offering Community Supported Agriculture (CSA) subscriptions, another popular direct-to-consumer option, has been observed with 108 of these farms with primarily vegetable CSA's included in the 2022 KDA directory.[20]

Table 3 *Farmer's Market Activity in Kentucky*

Year	Community farm markets	Vendors	Reported sales (millions)
2010	145	2,549	$7.97
2011	151	2,797	$10.5
2012	147	2,490	$10.8
2013	149	2,350	$11.0
2014	151	2,450	$11.6
2015	159	2,561	$12.0
2016	160	2,729	$13.5
2017	162	2,750	$14.0
2018	162	2,760	$14.2
2019	162	2,780	$15.0
2020	163	2,500	$17.0
2021	173	2,600	$18.0

Source: Sharon Spencer, Nancy Monroe Kentucky Department of Agriculture;
Data is provided only for markets that provide reports. While this includes the major markets, a meaningful amount of sales activity is difficult to determine with precision.

Produce, Wholesalers and Retailers

Kentucky is home to several large produce wholesalers. Horton Fruit Company, located on the Louisville Produce Terminal Market, has been involved with tomato repacking and wholesaling for many years. They source from a wide geographic area and market their tomatoes under the Peak brand (Horton Fruit

[20] KY Dept of Ag CSA Directory, 2022, https://kyproud.com/csa/

Company, 2022). Horton has further packing and repacking for their brands in Arizona, Texas, and Florida. They have several networks of the Grow Farms associations of producer groups, including growers from Kentucky, Tennessee, Ohio, and Indiana (Grow Farms, 2022). Horton's vertically integrated operation allows them to grow and market tomatoes 6 months a year and then source for repacking during the periods when they are out of production. They maintain their own logistics company and, while specializing in tomatoes, also sell onions, avocados, various peppers, and organic products. Horton's has significant ripening capacity for mature greens and vine ripes, facilitating their sourcing from a wide distribution area.

Castellini Produce is one of the largest mainline produce wholesalers in the U.S., and is based in Wilder, KY (Castellini, 2022). Formerly an anchor tenant on the Cincinnati Produce Terminal Market, Castellini's moved to Kentucky about 30 years ago and remains a significant player in wholesaling to retail and foodservice buyers in the central and eastern U.S. They market their products under the Castellini brand and have a full line of conventional and organic produce that they aggregate.

Other distributors and wholesalers have direct sourcing relationships with Kentucky producers including C.H. Robinson, What Chef Wants/Creation Gardens, Piazza Produce, Paul's Fruit Market, and others.

Several large retail grocers have regional produce distribution centers (DC) in Kentucky. Cincinnati-based Kroger's has a regional distribution center in Louisville and Walmart maintains a regional DC in London, KY. Both source from a wide area and support retail stores throughout the region. Michigan-based Meijer, with multiple stores in Kentucky, maintains DCs in central Ohio and Indianapolis, has also explored sourcing options with Kentucky produce growers.

The foodservice sector is also an important market channel with the largest national distributors (Sysco, Aramark, U.S. Foods) maintaining distribution centers in major urban areas in and around Kentucky (Sysco, 2022). Other regional foodservice companies tend to work more actively with KY farms and CEA operations currently, including What Chefs Want (Creation Gardens), Piazza Produce, and others, maintaining marketing partnerships with restaurants, schools, and other intuitional buyers. The U.S. consumer food away from home spending is recovering strongly after dipping sharply early in the pandemic, continuing a trend of relatively more FAFH spending compared to at home – primarily through groceries (USDA, Food Expenditures Series, 2022). CEA vegetable production has historically targeted the higher value grocery market where premium quality products are more easily differentiated to consumers.

4.3.2 CEA Production Systems in Kentucky

The Kentucky Horticulture Council provides a useful summary of various sectors of the horticulture industry in Kentucky, drawing on various USDA sources and some of their own data. The industry in Kentucky has been characterized by small to medium sized farms with an emphasis on lower cost farm production infrastructure and heavy dependence on local and regional markets (see Figure 14). New opportunities being explored with CEA provide opportunities to expand the overall scale and market reach.

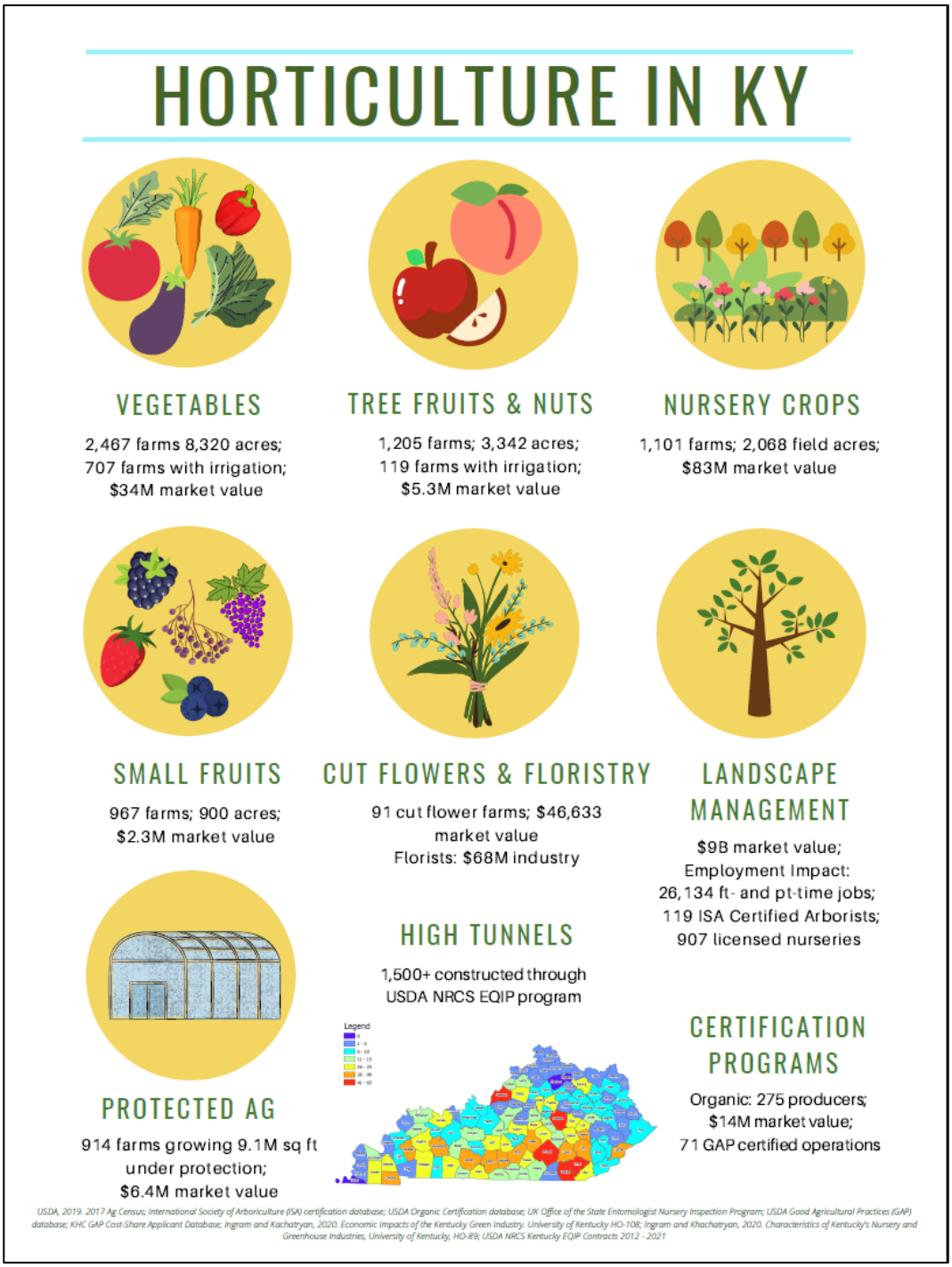

Figure 14 *Horticulture in Kentucky (USDA, Kentucky Horticulture Council, 2019)*

Most of the fruit & vegetable producing farms are geographically dispersed with concentrations in the certain areas of the state of Kentucky (see Figures 15 & 16).

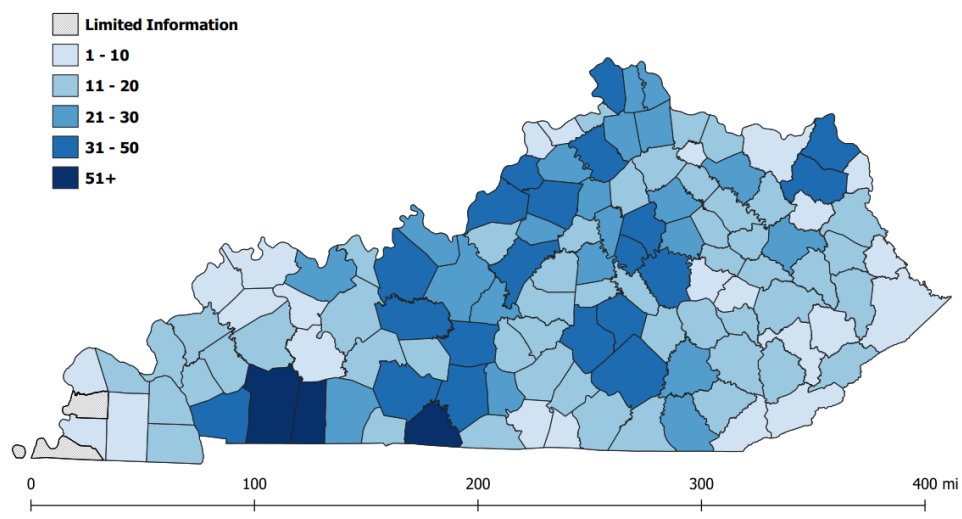

Figure 15 *Amount of farms producing vegetables, melons and sweet potatoes in the different counties in the state of Kentucky (Knight, Vegetables, melons, potatoes, and sweet potatoes Farms, 2017)*

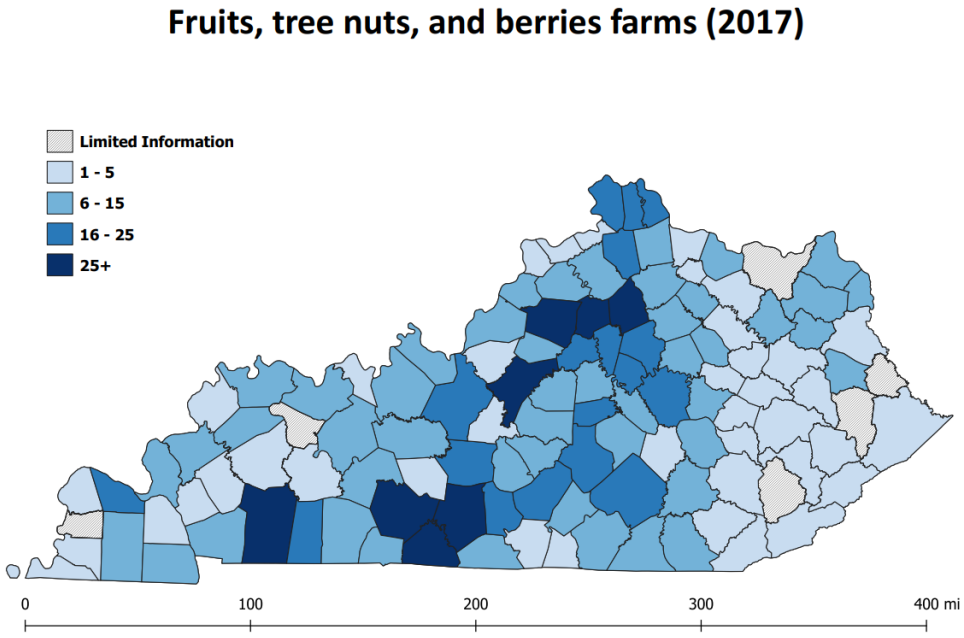

Figure 16 *Amount of farms producing fruits, tree nuts and berries in the different counties in the state of Kentucky (Knight, Fruits, tree nuts, and berries farms, 2017)*

CEA production

The introduction of some level of controlled environment agriculture production has been evident across the state, but generally on a small scale. The largest area of growth has involved high tunnel production, where Kentucky farmers have taken substantial advantage of the USDA-NRCS EQIP High Tunnel Cost Share program (Wheby, 2022). Figure 17 provides the geographic distribution of high tunnel farms, the heaviest density located in the south-central part of the state.

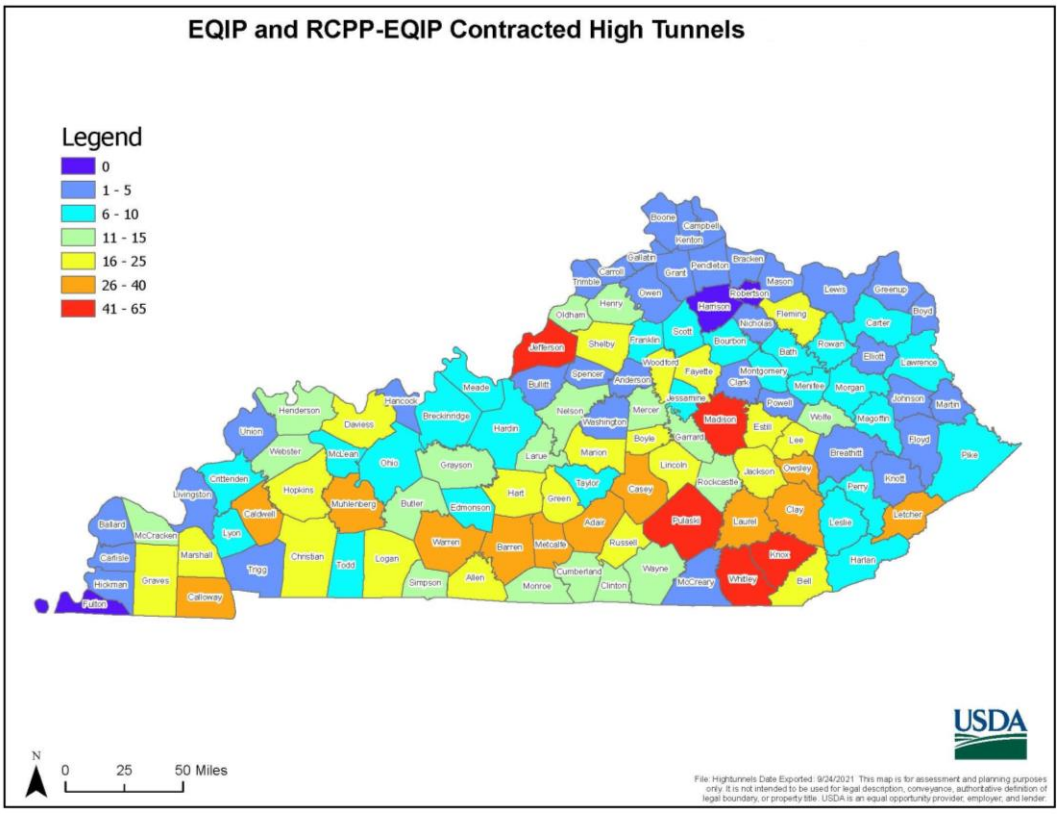

Figure 17 *Environmental Quality Incentives Program Contracted and Installed High Tunnels 2012-2021 (Kentucky NRCS State Office, 2022)*

Kentucky has the most tunnels and largest area dedicated to these systems of any state in the U.S. South: 1,215 high tunnels, representing 2.8m sq.ft. (26 ha) (Table 4). Approximately 1,500 HTs have been contracted in KY since 2012 and a new program will construct 100 more in Eastern KY in addition to the regular EQIP program. A recent University of Kentucky Center for Crop Diversification (CCD) survey summarizes participation of Kentucky producers, including an examination of their challenges and opportunities related to these systems (Ernst, Woods, Butler, Wolff, & Jacobsen, 2020).

Table 4 *Changes in the NRCS high tunnels in the US South (Kleinhenz, Woods, & Ernst, 2022)*

State	NRCS #HTs 2010	NRCS #HTs 2010-20	NRCS HT sq. ft. 2010-20
Alabama	83	519	1,063,515
Arkansas	7	395	949,113
Florida	21	260	591,359
Georgia	63	725	1,435,234
Kentucky		1,215	2,808,815
Louisiana	19	332	790,037
Mississippi	46	568	1,168,775
North Carolina	43	647	1,418,659
Oklahoma	13	320	831,300
South Carolina	18	339	857,116
Tennessee	31	583	1,293,129
Texas		362	1,883,758
Virginia	53	755	1,746,965
Total South	397	7,020	16,837,774

Source: Compiled by Matt Kleinhenz, Tim Woods and Matt Ernst, with data provided from the USDA-NRCS FAPD Implementation Branch.

High tunnel production systems in Kentucky tend to be part of smaller farm operations with a substantial emphasis on local marketing channels, as noted in Table 5 below. Note that market outlook perceptions were gathered just prior to Covid-19 which has disrupted many of these markets – positively and negatively. Season extension is a substantial advantage for these producers with 43% of the farms surveyed indicating they use their tunnels for year-round production. These low-cost systems, supported often by USDA-NRCS cost share programs, have allowed many small farmers to take greater advantage of strong local demand.

Table 5 *Use of Specific market Channels, Before and After High Tunnels (Ernst, Woods, Butler, Wolff, & Jacobsen, 2020)*

	% before installing	% after intalling high tunnel	% expecting sales to increase
CSA	25	30	86
Community Farmers Market	70	71	82
On-farm retail market	34	52	80
Wholesale to grocery	9	17	75
Wholesale to restaurants	26	34	76
Wholesale to schools or other institutions	7	17	94
Auction sales	10	15	71
Contract production to processors	1	4	100
Other (please specify)	16	7	71

Most recently, significant new CEA infrastructure and production has been introduced in and around Kentucky. This includes firms such as AppHarvest, 80 Acres/Infinite Acres, Kentucky Fresh Harvest, Bell Nursery (formerly ColorPoint Greenhouses), and others that have made substantial investments in greenhouse and vertical farming systems with considerable new infrastructure being completed or planned soon. As stated in Section 1.1. an estimated $1.6bn has been invested in AgTech, and particularly in CEA, in Kentucky in the last years. Close partnerships with Dutch technical assistance on infrastructure and large produce distributors in North America are key elements of this expansion. While facing economic and market challenges of early adoption, these and other firms are moving forward in earnest with new investment to pursue opportunities they feel exist in the region.

4.4 Location suitability potential

4.4.1 Spatial analysis

Based on the spatial analysis of the Inception Report, Central Kentucky appears to be the most suitable area for CEA Ecosystem development and in particular for future project-based locations of greenhouses and other related activities within and outside the value chain. The most relevant factor is the favorable location in relation to other parties within and outside the supply chain. Co-location with parties such as energy providers can further improve the sustainability. Nevertheless, a more detailed study is needed to identify specific areas for project-based locations with co-location of greenhouses and other supporting sectors.

When all four aspects (climate and water availability, infrastructure, land characteristics, and energy) are considered together, the following map displays suitable areas for greenhouse production (see Figure 18).

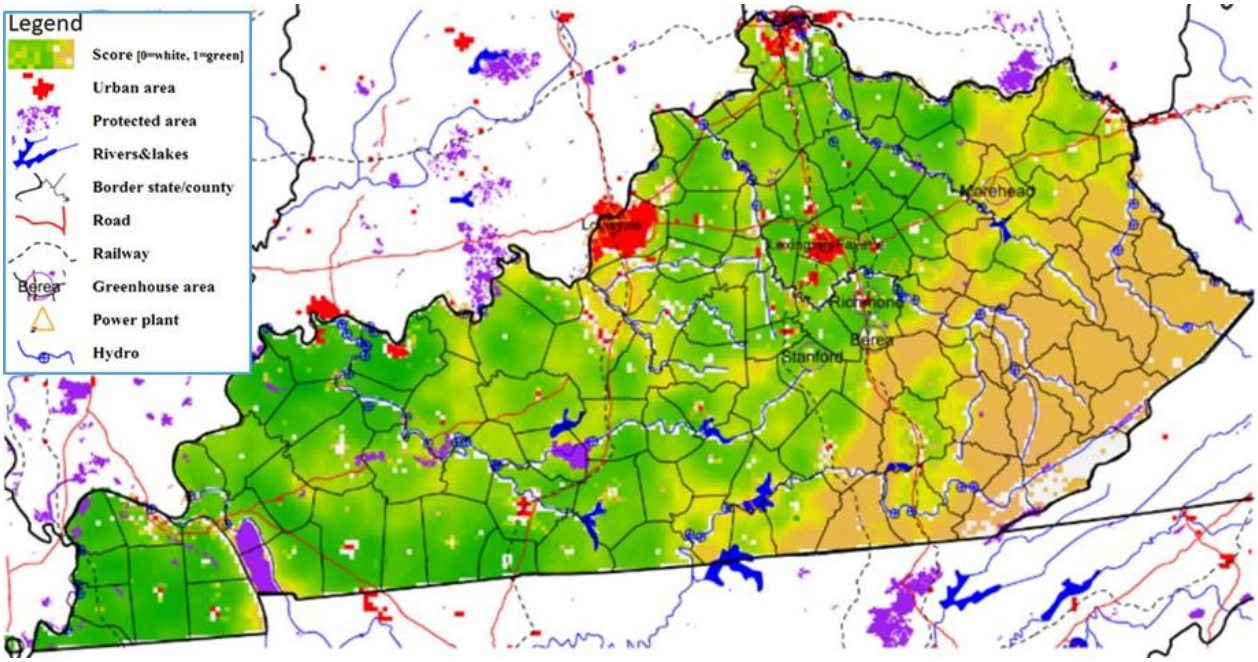

Figure 18 *Areas with high potential for greenhouse production in Kentucky (green areas have the highest potential)*

Figure 18 shows that a large part of Kentucky has favorable conditions for establishing greenhouse structures (the greener the area, the higher the potential). The eastern part of Kentucky appears to have fewer favorable conditions for the development of greenhouses.

4.4.2 Additional factors to consider in spatial analysis

Workforce

Although unemployment rates are relatively high in the Eastern part of Kentucky, we see that the conditions for the development of greenhouses are less favorable, because of mountainous terrain. Therefore, the locations for large-scale greenhouse horticulture should be more in terms of availability of workforce supply instead of unemployment rates, meaning closer to larger labor pools, such as cities like Lexington, Louisville, Cincinnati.

Most workforce in greenhouses (about 90%) is needed for crop production harvest and sorting work. The estimated labor need of a large scale high-tech year-round culture of tomato, peppers or cucumbers in the Netherlands lies between 2,500 and 3,400 hours/acre or about 1.5-2 fulltime workers/acre (6,100 and 8,500 hours/ha or about 3.5-5 fulltime workers/ha) for cultivation work and about 222 hours/acre

(550 hours/ha) for management activities (Ruijs & Benninga, Market potential and investment opportunities of high-tech greenhouse vegetable production in the USA, 2020). When starting a new large scale high-tech CEA company, these numbers are significantly higher in the first few years. However, it is expected that in time, efficiency measures will bring these values to the Dutch standards.

Energy

Considering the large energy requirements for lighting, heating, and cooling, multiple energy options should be assessed to optimize the sustainability of the CEA industry. This approach will require site-specific solutions to address individual grower needs that will vary based on scope, regionally availability and regulations, reliability, types of preferred sources, scale and load demands, and grid integration. Renewable energy should factor prominently in the development of this ecosystem to reduce costs and buffer against volatile fossil fuel-based power price fluctuations.

The utility landscape in Kentucky is complicated and diverse, with four investor-owned utilities, two generation and transmission member cooperatives, one quasi federal government power entity (Tennessee Valley Authority), and thirty municipal electric utilities. Additionally, some of these companies and cooperatives participate in two Regional Transmission Organizations that operate bulk electrical power transmission systems across much of North America. The diversity of utility providers and regulations create options that should be included in spatial assessments as the industry expands.

Several options exist or are being developed in Kentucky that create pathways to access alternative energy through onsite and offsite generation. These include:

1. Cogeneration facilities that produce electricity and others forms of thermal energy such as heat. These systems, which are common in Dutch green houses,[21] are known as Combined Heat & Power facilities (CHP) and examples exist in Kentucky. A strength of this system is that it is more efficient to produce the two forms of energy simultaneously onsite than each one individually offsite.
2. Onsite solar may be an option for some growers depending on scale. Although KY does allow net-metering, there are limitations based on the amount of energy generation that could impact the applicability of this approach in larger production facilities.
3. Onsite energy storage such as short term thermal storage in heat buffers (hot water tanks) or seasonal storage in aquifers in the ground, and electricity storage in batteries.
4. Geothermal heating and cooling systems are applicable in many parts of Kentucky.
5. Solar hot water generation.
6. Anaerobic digestion for energy generation, which provides opportunities to co-locate with dairies or large cattle operations, showing circular and symbiotic relationship with other segments of agriculture.
7. Renewable Energy Certificates (RECs) allow the environmental attribute of renewable energy generation to be utilized by a company or industry.
8. Green Tariffs allow eligible users to buy both the energy from a renewable energy project and the RECs, with the goal of providing a long-term, fixed-price structure of renewable energy.
9. Power Purchase Agreements (PPA), Virtual Power Purchase Agreements and Utility Shared Solar Options are ways for a company to potentially access renewable electricity through a utility that is generating that energy or purchasing it from another source where is it is more cost effective, such as wind turbines in the Midwest.

The CEA industry should work with the Kentucky Energy and Environmental Cabinet to identify integrated, site specific options for purchasing energy and maximizing energy efficiency. This should include a focus on utilizing alternative energy sources, onsite and offsite as appropriate.

Water

Rainwater is available in sufficient quantities in Kentucky, as well as additional sources such as surface and ground water. Thus, this factor is not the most crucial in relation to spatial analysis. Some attention should be paid to bundling the rainwater harvesting tanks for more efficient use of space and possibly connecting

[21] 11% of the national electricity consumption is produced by the CHP units in the greenhouse horticulture in the Netherlands in 2020 (Source: Energy monitor of the Dutch greenhouse horticulture 2020. P. Smit & N. van der Velden. 2021. Wageningen Economic Research. https://edepot.wur.nl/555540).

them to alternative energy generation by installing floating solar panels on the reservoir to generate green electricity.

Waste
Major waste sources in CEA are growing substrates (rockwool, coconut peat), plant residue materials and plastics.

Rockwool, formulated from melting Basalt rock and Chalk, is a widely utilized artificial horticultural growing substrate of hydroponically-grown greenhouse crops. Rockwool is used as a propagation material supporting young plants and a culture material that supports maturing and fruiting greenhouse-grown vegetables. For example, rockwool slabs used for greenhouse tomato production are wrapped in plastic thereby facilitating nutrient solution retention, aeration, and root growth. At the end of a crop production cycle, greenhouse growers must renew the rockwool slabs before planting another crop.

In the Netherlands WUR Greenhouse Horticulture[22] assumes the use of 1,429 ft^3 per acre (100 m^3 per ha) of rock wool. The weight is 4.3 lbs per ft^3 (70 kg per m^3) (this is ex-factory at the time of installation) which equals 5,666 lbs per acre (7 tons per hectare) of stone wool. Based on the figures given by experts, 450 kg per cubic meter (m^3) of waste is similar to 759 lbs per yd^3 when ingested. This includes moisture, plant residues present in the substrate, and foil. Waste substrate, if you do it very well, contains only 20% moisture. In the case of the fruit vegetable crops, substrate is replaced annually.

When the greenhouses are cleared, substrate and foil are disposed of in a single pass to a waste processor. To make the material suitable for reuse, the rockwool is shredded, sieved, and then separated into three fractions: clean rockwool, film shreds and residual waste. Only green material remains, the ideal basis for compost.

However, waste management associated with rockwool, and plastic sleeves are challenging. To address this challenge, commercial rockwool companies have established recycling manuals and facilities which demonstrates partnerships between commercial rockwool companies, growers, recyclers, and the reusable substrate granulate (RSG). The RSG is supplied to brick factories, compost, or substrate manufacturers, or other rockwool factories to be circulated back into existence as insulation.

Waste processing company Renewi (The Netherlands) reports that almost all of their waste collected is recycled through a purpose-built waste separator. Over 97% of the waste mountain gets a new destination.

To date, Grodan, a commercial rockwool company, operates five recycling facilities across the United States with one facility located in the Eastern U.S., i.e., Cleveland, OH which is about a five-hour drive from Frankfort, KY. Therefore, there is a critical need and potential to address future waste streams of rockwool by constructing a facility to recycle materials generated throughout Kentucky and the growing CEA industry of the Southeastern U.S.

While rockwool is widely utilized, coconut coir, is an alternative horticultural growing substrate of hydroponically-grown greenhouse crops. Coconut coir is an agricultural waste product derived from the husk of the coconut fruit and is marketed for hydroponic crop production. Since coconut coir is a plant-based derived product, composting facilities to manage wastes must be considered for the CEA industry in Kentucky. Likewise, facilities to compost vegetative and reproductive plant material should be considered. Such facilities would be commercial composting facilities and biodigesters.

Since 2021, there is a first bio-lng[23] plant in the Netherlands (De Ingenieur, 2021). The first tons of bio-lng have already been produced, but from the beginning of 2022 the plant in the Amsterdam port area will be running at full capacity. A milestone on the road to more sustainable road transport, say initiators Shell, Renewi and Nordsol. The new installation is located on the site of waste processor Renewi. That company collects organic waste throughout the Netherlands, such as expired supermarket products and restaurant

[22] Waste from agriculture. Bondt, N., S.R.M. Janssens and A. de Smet LEI note 10-061, 2010. https://edepot.wur.nl/140724
[23] Lng=liguid natural gas.

waste. That waste ends up in a large digester in Amsterdam-Westpoort, where it is converted into biogas; about 10.4m yd^3 (8m m^3) annually.

Current facilities in the US, such the gasification plant in Martin County (Inez Power LLC), that can convert organic waste, plastic, and rubber into combustible gas/energy, should be examined as waste disposal alternatives or model for other approaches. While these may be applicable, plastics utilized during crop production and incorporated into plant material such plant or vine clips and support twine may pose a challenge for composting. Therefore, mechanical methods to extract plastic material from horticultural crops before composting or initiatives to support purchasing of bio-degradable plant or vine clips and support twine must be considered. A facility specialized in vessel composting has been proposed in Letcher County.

Compostable plastic technology is already being developed in Kentucky in companies such as Danimer Scientific[24] in Winchester, and research projects are underway at the University of Kentucky to evaluate bioplastics made utilizing coal waste products by a company in Corbin called Arq.[25] Sustainable waste stream management will require innovation and new technologies. Companies in other states that are successfully managed agricultural waste should be evaluated such as Vanguard Renewables in MA.[26] Burning of plastics for electricity is currently being done in Indianapolis. As the industry is developed, opportunities for new or existing companies in other areas to be established in KY should be encouraged.

CEA industry should evaluate current waste management options and limitations and identify future needs. New waste management companies being developed in KY should be supported and incentivized. This effort should be coordinated with the KY Energy and Environmental Cabinet.

4.5 Market potential: Porter's Five Forces

The Porter's Five Forces model has been used to examine economic factors that can shape opportunities for sustained profitability for an industry (Besanko, Dranove, Shanley, & Schaefer, 2017). Industries can be characterized by a measure of internal rivalry and by value chain relationships (suppliers and buyers) as well as interactions with emerging complement and substitute products impacting aspects of demand for industry outputs. New entry by other firms or rival production systems are also considered as part of a comprehensive measure of the prospects for sustained profits. Economic forces are present to various degrees in each of these dimensions and the dynamics can be examined for their potential threat to sustained profits. Figure 19 shows Porter's Five Forces schematically.

[24] https://danimerscientific.com/
[25] https://arq.com
[26] https://www.vanguardrenewables.com

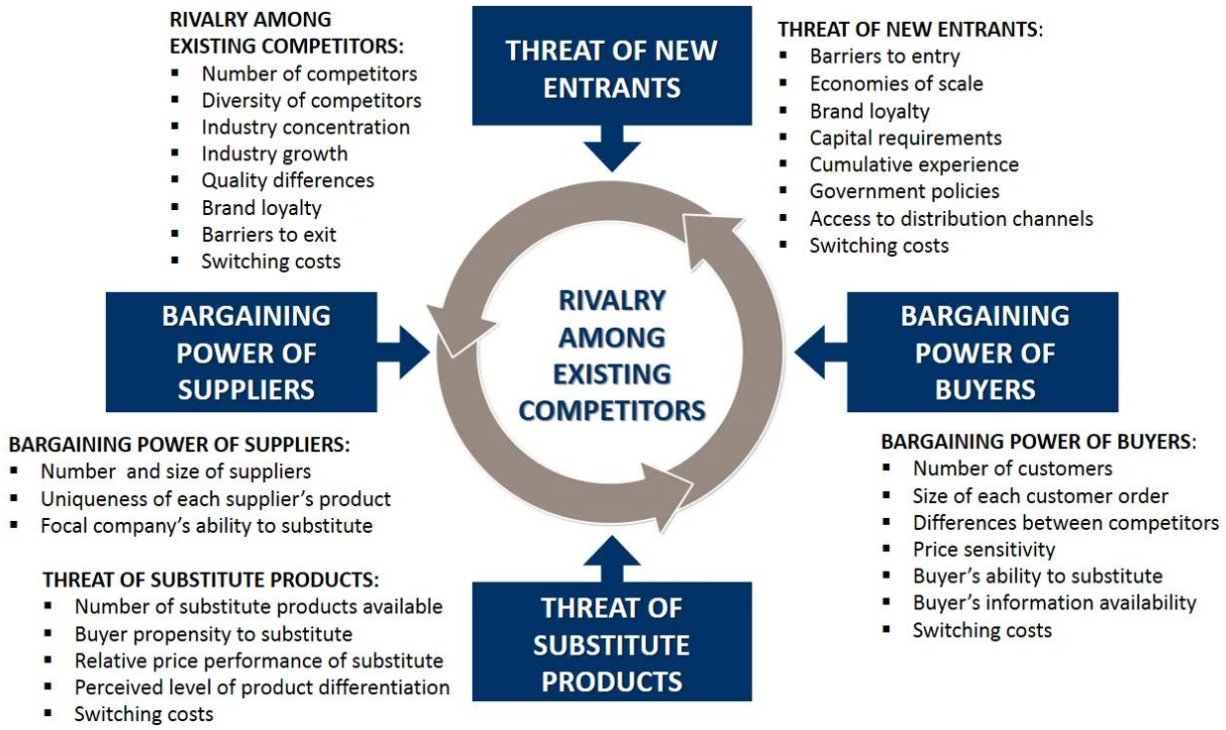

Figure 19 *Porter's Five Forces (Bruin, 2016)*

An examination of Porter's Five Forces facing the U.S. vegetable market is presented here with a special emphasis on CEA. Interest and recent investment in CEA in U.S. production areas has increased, including Kentucky and other states in the Ohio River region. While CEA has been growing in importance as a production system, especially in the dynamics of imported products from Canada and Mexico, field production and low-tech controlled environment systems also contribute a significant amount of production into this market, especially seasonally.

There are certainly many promising aspects of CEA roles in vegetable production that include efficiencies in water use, production intensity, and locational flexibility closer to urban markets. Despite the potential of CEA, considering the Porter's Five Forces for this industry summarized below, this production sector will likely face considerable challenges becoming established in the U.S. with a view towards being able to capture sustained economic profits.

4.5.1 Rivalry among competitors

U.S. Fresh Produce Markets Overview

The U.S. has transitioned into a net importer of fresh vegetables (see Figures 20 and 21). The overall supply of fresh vegetables marketed in the U.S. has been fairly stable over the past 20 years, but with a sharp increase in imports, especially from Mexico. Historical leaders of field production, California, Arizona, Florida, Texas, and Michigan have faced various pressures from population growth, water shortages, and most significantly, higher relative labor costs compared to Mexico. Overall fresh vegetable production into U.S. markets from all sources has been relatively steady for about 20 years (see Figure 20).

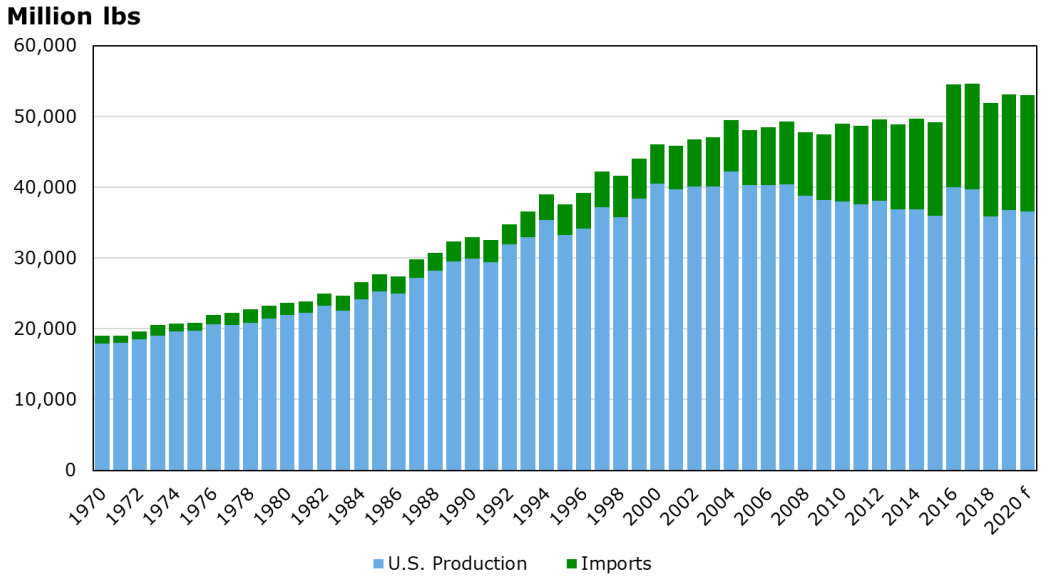

Figure 20 *U.S. and Import Fresh Vegetable Production (USDA Outlook for US, 2019)*

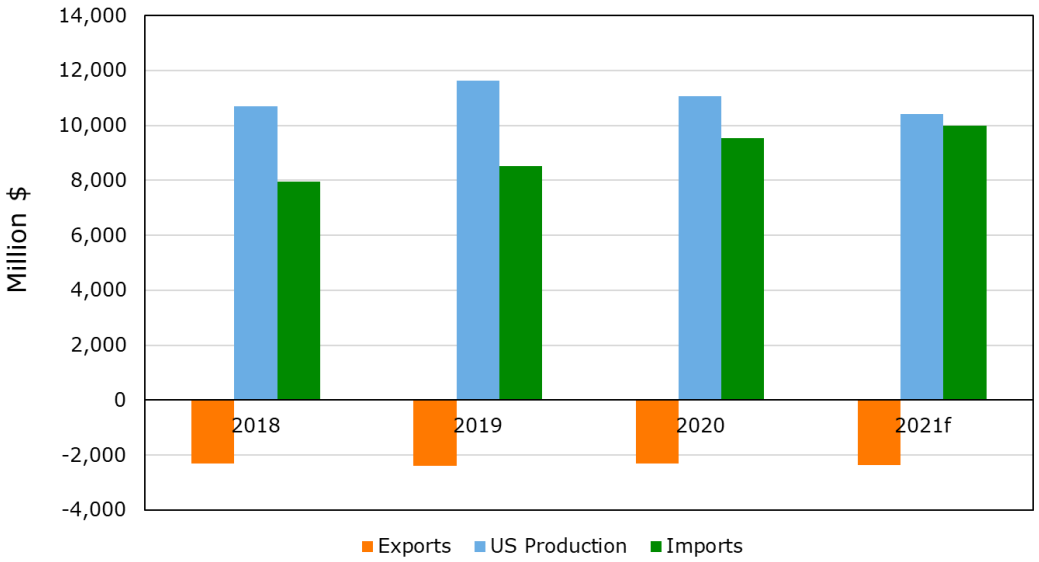

Figure 21 *Fresh Vegetable Sales and Trade (USDA V&P Outlook, 2021)*

Products that have been more widely produced in CEA systems include fresh tomatoes, lettuces and leafy greens, and strawberries. Leafy greens and romaine-type lettuces passed per capita consumption of head lettuce in 2020 and saw especially solid growth in popularity. Investments to develop these products in CEA systems have already been implemented or underway in Kentucky. These products have seen steady growth in consumption per capita in the U.S. and fit the profile of high value/unit area produced typically pursued by those developing intensive CEA systems (see Figure 22).

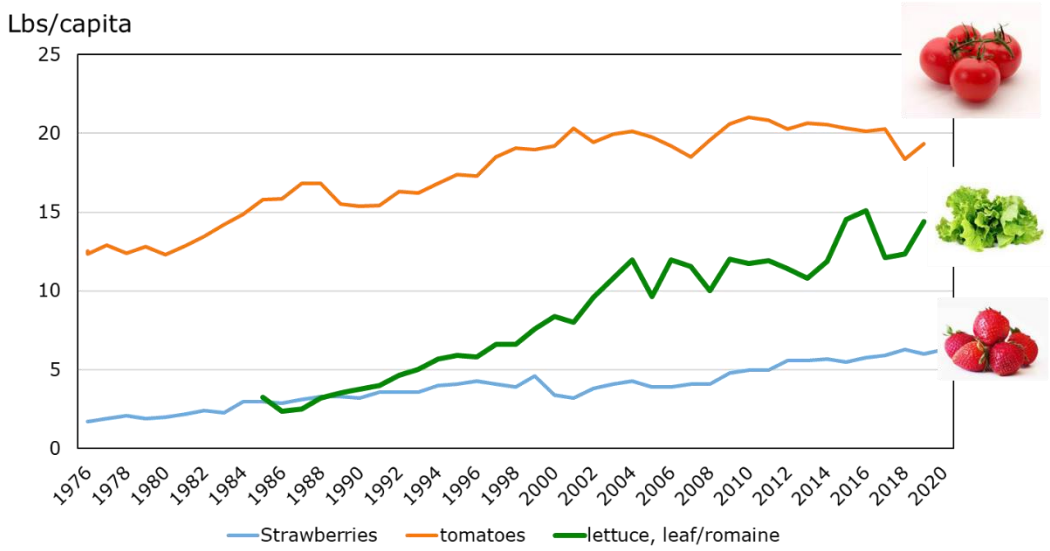

Figure 22 *Per capita consumption of fresh tomatoes, leafy greens & strawberries 1976-2020*
Source: USDA ERS Vegetable and Pulses Yearbook, 2021; Fruit and Nut Yearbook, 2021.

A significant amount of value adding for these products takes place beyond the production level. Farm share of the average retail price for fresh tomatoes and lettuce has run consistently 25-35% for the past 20 years with strawberries slightly higher at 30-40% (Stewart & Hyman, 2022). This reflects the significant amount of value-adding that takes place with these products in the distribution, marketing, and retailing beyond the farm, approximately 60-70% of the value of these products.

Rabobank provides a striking graphic showing global vegetable trade movement that emphasizes the significant increase in marketing activity and trade between Mexico and the U.S., the largest flow of vegetable trade in the world (Figure 23).

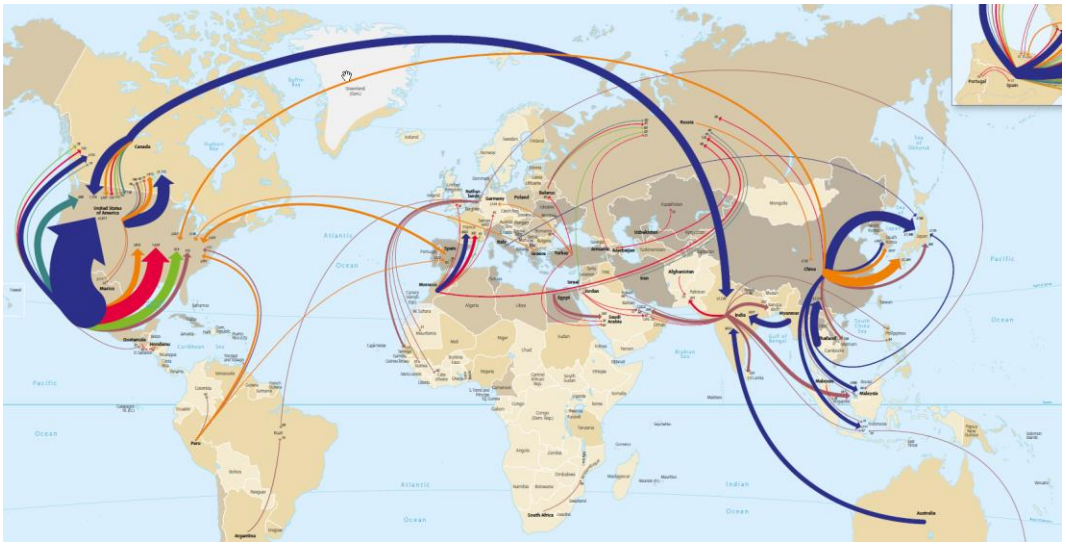

Figure 23 *Global Vegetable Trade*
Source: RaboBank, 2019.

Tomatoes
Tomatoes are increasingly produced under CEA systems and the leading commodity by volume produced by CEA firms in Kentucky. Competition from all sources of production – by production system (CEA, high tunnel, open field) and by region – is increasing in intensity. Substantially lower labor costs, increasingly flexible trade agreements, and strong demand for year-round supplies are among some of the driving factors

contributing to the growth in product sourcing from Mexico (Producepay, 2021). Mexico is the top exporter of tomatoes in the world, accounting for 23.6% of all exported tomatoes globally. Netherlands is #2, accounting for 13.8%. Mastronardi International Ltd, a major partner with CEA tomatoes throughout North America (including Kentucky), is by far the largest importing company (Table 6). Companies such as Mastronardi can readily shift production sources based on changes in regional demand and transportation costs. It is not uncommon to see their Sunset brand in Kentucky grocers with U.S. and Mexican country of origin labels. Tomatoes in Mexico are primarily produced in the open field when measured by surface area (64%), but increasing investments are being made to greenhouses and shade cloth structures to improve yield and quality. Over 60% of the total tomatoes in Mexico sent to market come from the CEA systems.

Tomatoes are an especially labor-intensive enterprise for field work, harvesting, and packing, and have seen an especially marked increase in imports from low wage areas of Mexico. Consumption of fresh tomatoes per capita in the U.S. has been steady at 19-20 pounds/capita for the last 15 years. The most recent USDA estimates indicate a $3,724,054,901 market based on 65,219,875 pounds of fresh tomatoes (2020), 62% of which is imported. U.S. production has been steadily declining for the past 20 years (Figure 24).

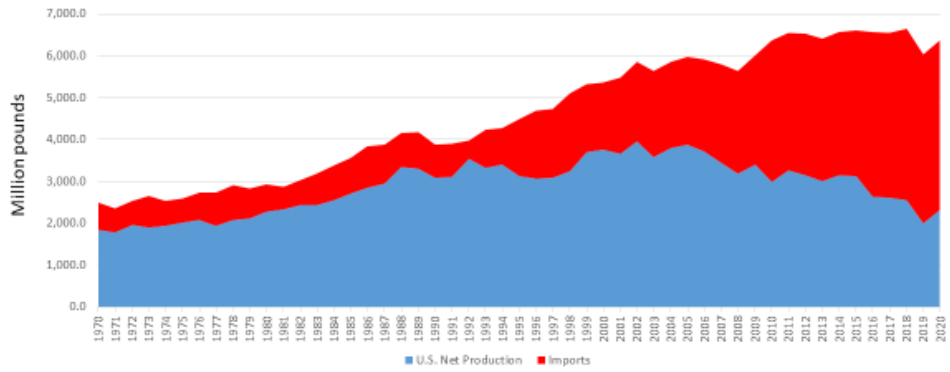

Figure 24 *Available U.S. Fresh Tomato Supply*
Source: USDA-ERS, Vegetable and Pulses Yearbook, 2021.

The Tomato Suspension Agreement was passed in 2019 that levies a tax on Mexican imports of 17.5% (PACA, 2019). Anti-dumping measures, free trade agreements such as the North American Free Trade Agreement, and other political trade measures introduces a measure of uncertainty and currently added costs for Mexico producers seeking to compete with U.S. producers. Even with a tariff, imports continue to expand. Large U.S.-based distributors increasingly look to Mexico for production, including Mastronardi, who sources greenhouse tomatoes for their Sunset brand all across North America (including AppHarvest in Kentucky) (Table 6).

Table 6 *Top importing companies of Mexican tomato in the USA (Producepay, 2021)*

	Company	Weight (kg)
1	Mastronardi International Ltd.	62,764,671
2	Ns Brands Ltd.	19,007,000
3	Masterstouch Brand LLC	12,841,990
4	Farmers Best International LLC	10,858,990
5	V and L Produce Inc.	6,751,856
6	Kaliroy Fresh LLC	5,252,690
7	Tricar Sales Inc.	5,248,904
8	Mirasoles Produce USA LLC	5,000,560
9	Jem D International	4,271,914
10	Traveler Produce LLC	3,917,967
11	Bj Brothers Produce LLC	3,816,009
12	Del Campo Supreme Inc.	3,015,010
13	Andrew & Williamson Sales Co. Inc	2,224,440
14	Divine Flavor LLC	2,120,120
15	Gr Produce Inc.	1,544,380

Source: USDA Border Crossing Data, 2021-2020.

Internal rivalry – Fierce price competition in vegetables comes from other CEA production in Mexico and Canada, as well as low-cost open field production in-season and limits any opportunity to differentiate. Fresh produce is in stable demand in the U.S. for consumption. While demand is strong for good quality produce, there is not an expectation for the core of this market to grow significantly over the next decade or so. Very high costs associated with labor relative to Mexico have accelerated a focus toward expensive robotic systems for large scale CEA enterprises (Cambon & Mena, 2022). The labor wage gap between the U.S. and Mexico has expanded significantly in the past decade. Energy (natural gas, electricity) is a significant cost component to CEA systems relative to other options and is especially critical in cooler climates with less natural light. Mexico has expanded its own greenhouse industry for vegetables, primarily with a view toward the U.S. export market. Their limiting factor is the availability of good water. There is an important trade-off between energy and water concerning CEA production in Northern or Southern hemispheres.

Internal rivalry within the U.S. CEA market for tomatoes specifically can be partly illustrated by the share of market by various products and the various countries from which they are sourced (Table 7). Mexico was by far the largest supplier overall with Canada and U.S. supplying the balance of greenhouse tomatoes shipped into U.S. markets.

Table 7 *Movement of Greenhouse tomato volumes in amount truck loads (in 40,000 pound truck loads) (USDA, Tomato Fax Report, 2022)*

Greenhouse tomato volumes	
Source	**2021**
U.S.	3,199
Canada	8,056
DR	475
Guatemala	266
Mexico	28,017

Greenhouse Cherry Type	
Source	**2021**
U.S.	100
Canada	50

Greenhouse Plum Types	
Source	**2021**
U.S.	107
Canada	317
Guatemala	50
Mexico	7,624

Greenhouse Grape Types	
Source	**2021**
U.S.	485
Mexico	749

Internal rivalry related to supply competition for the U.S. tomato market can generally be summarized with the following:

- The market is made up of several quality segments. Tomatoes are typically graded by USDA standards for U.S. #1 and U.S. #2. There are quality segments within the many stock keeping units (SKUs) that have emerged. CEA firms (in Mexico, Canada and the U.S.) have emphasized a focus on the higher quality and price segment along with year around production capability. Increasingly, these firms are focusing on scale of production to align with demands from large scale distributors, grocers and foodservice companies.
- The U.S. tomato market has historically followed a higher priced winter market (Oct-Feb) with lower prices through most of the rest of the season as more domestic field production becomes available locally. CEA production, historically mostly from Canada and now primarily from Mexico, has targeted winter and urban markets when prices are higher and domestic production is less. Mexico has provided 85.3% of CEA tomato production imports to the U.S. and Canada 13.3% over the past four years by volume.
- Mexico is the dominant fresh vegetable import supplier (79%) with Canada second at 11%. Greenhouse production has always been central to the Canadian supply and is increasingly important for Mexico.

Greenhouse and CEA production of tomatoes is becoming an increasingly important supply platform for U.S. buyers. Other field grown and minimally controlled environmental systems (high tunnels) remain important, especially during peak growing conditions.

One of the major advantages of CEA production in Kentucky is its proximity to large-scale consumer locations: large cities in Mid-West and East America. This means a short response time for delivery, which is highly appreciated by the large-scale trading companies that supply supermarkets in these cities. It also offers opportunities for products with a short shelf life, such as lettuce and soft fruits. In cooperation with the trading parties, it is also possible to anticipate which products can best be produced in Kentucky, e.g. varieties that are not imported from Mexico, high-end products (specialties, snack vegetables, etc.), more added value (fresh washed, packed, etc.).

Kentucky is not the only state in the U.S. that is committed to CEA and is in the same proximity to large-scale consumer locations. We see a growth of CEA in Pennsylvania, North Carolina, Ohio, etc. Kentucky will

have to see if and how it can compete with these new production centers. For the time being, there seems to be enough room for growth of production and the demand from the trade is positive for products originating from Kentucky. National distributors, based on interviews, value having regional CEA production sources that they can utilize to lower their sourcing and logistics costs.

Collaboration between growers in marketing and sales is very important in production regions such as the Netherlands, but such coordination is still in the early stages within the U.S. Opportunities to improve returns to CEA growers exists through efforts to increase production in the right quality grades, developing trade estimates of production predictions, coordinating with buyers on the right packaging, Tracking & Tracing (T&T) systems, etc. Experience and coordination within the emerging U.S.-based industry will increase the interest of wholesalers to buy. Supply chain management systems are critical for fresh produce, involving key industry partnerships with suppliers and buyers to share needed infrastructure support and plan for key inputs.

Table 8 *A comparative input and production costs between regions*

	Kentucky	**Mexico**	**Michigan**	**California**	**Ontario, CA**
Solar Radiation(kW/m2/day)	4-5[27]	6-6.5+	3.5-4	5.0-6.0	3.5-4
Labor ($/week) (U.S. Bureau of Labot Statistics, 2022)[28]	$989	$62-$169[29]	$1154	$1576	
Labor Min wage ($/hr)[30]	7.25	1.11 (Trading Economics, 2022)[31]	9.65	13	11.66 (Trading Economics, 2022)[32]
Energy (gas, electricity)	++	+	+		+
CO_2 from own heating	++	++			
Water availability	+++	+	++	+	+++
Land availability	+++	+++	+++	+	++
Existing post-harvest infrastructure	+	++	+++	+++	+++
Transport to Mid-U.S.	+++		+++	+	++
Capital	++	+	++	+++	++
Taxes	Lower property and sales taxes (Fritts, 2021)[33]	13% Tariff and exchange rate (tomatoes)	Lower property and sales taxes	High property and income taxes	Exchange rate
CEA Experience	+	+++	+	+++	+++

Note: '+' indicates a relative advantage.

Major CEA Enterprise Costs - Labour, energy and plant material are the major costs for a CEA farm. In textbox 4 the cost structure for an average greenhouse farm in the Netherlands is summarized. At the moment there is a high degree of uncertainty in the energy market, which therefore has a great impact on the costs of a CEA company, because of the use of energy, but also on the necessary inputs such as planting materials, logistics services and fertilizers.

[27] NREL indicates higher solar radiation in central and western Kentucky compared to the eastern third of the state.
[28] U.S. Bureau of Labor Statistics, Avg weekly wage by state, Sept, 2021, on-line accessed June 3, 2022, m.
[29] Ag production wages for Mexico likely much lower and closer to the minimum wage levels.
[30] Minimum wage does not necessarily reflect the cost to secure a quality workforce. Current unemployment rates for many states, including KY, are extremely low. BLS reports April 2022 unemployment rates for KY (3.9%), MI (4.3%), and CA (4.6%).
[31] Minimum wage in Mexico is 173 pesos per day which converts to $8.85/day or $1.10 for an 8 hour day.
[32] Converted to U.S. $.
[33] Sales tax in CA (8.68%), KY and MI are each 6%.

Text box 4 Average costs per farm for a horticultural farm under glass in the Netherlands

The costs for an average greenhouse farm in the Netherlands is $2.3m. The cost structure in 2021 was:

- specific costs (such as plant materials, chemicals) 31%
- net energy costs (usage minus sales) 21%
- tangible assets (such as depreciation on buildings and machinery) 16%
- paid labour 23%
- other 9%

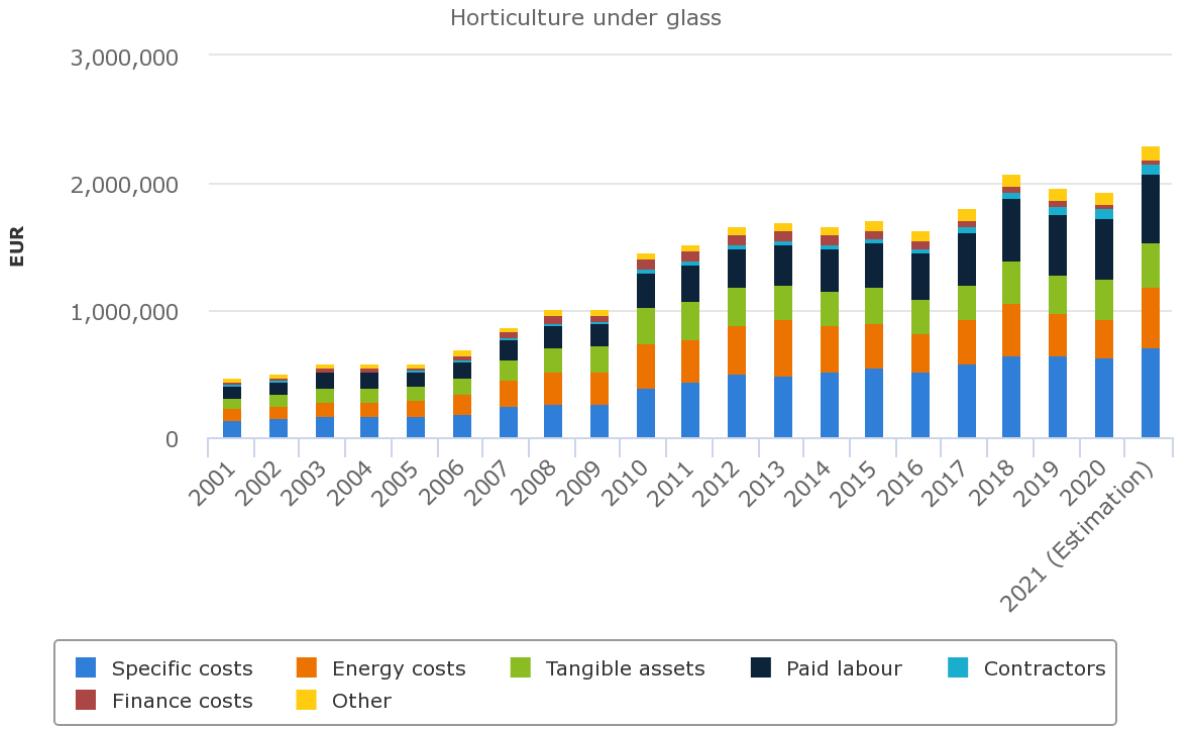

Figure 25 *Development of average total costs per farm, in EUR (Meulen, 2022)*
Source: Bedrijveninformatienet.

Figure 25 illustrates that costs have doubled in the last 10 years. Most alarming at the moment is the effect of the war in Ukraine on energy markets: currently, gas prices are more than 10 times higher than last year! Net energy costs have increased 43% in 2021 compared to 2020, but the increase in 2022 is expected to be much greater than in 2021. But it's not just energy costs that are rising. Specific costs are also increasing due to more expensive chemicals and paid labor due to strong competition in labor markets.

Alternative vegetable production systems - Another aspect of internal rivalry when considering a specific type of production system for a commodity like CEA is rivalry with alternative production systems. While CEA systems for higher value produce items continue to be developed across North America, field production and other lower-tech/smaller scale CEA systems bring significant volumes of essentially the same products to the market. Several studies have looked at the comparative economics of many of these systems and raise important questions about not just cost, but also environmental impact. Further study is needed to explore the full economic impacts by crop for these comparative systems (Delden, et al., 2021) (GreenTech, 2021) (Nicholson, Harbick, Gomez, & Mattson, 2020).

For products such as tomatoes, production has been geographically focused for greenhouses in Mexico,[34] Canada and US. Local field and high tunnel production can be found in almost every state. The smaller scale production has been more viable seasonally with local and direct-to-consumer markets.

Opportunities for product differentiation is one of the market force considerations within internal rivalry. If differentiation within an industry is possible, stronger opportunities may be presented for sustained profits. This is a challenge for commercial produce, and the prospects for sustained differentiation vary across type of production system – most notably by scale.

Differentiation opportunities can be summarized in the following way:

- **CEA/Greenhouse** – limited at the firm-level. In the Netherlands there are a few examples of branding of vegetables, e.g. Looye Honey tomatoes, Tasty Tom or Tommies snack tomatoes. Most retailers prefer their own private label store brands. The primary advantage is scale economies and lower average cost per unit as large fixed costs are spread out over large volumes of output. Year-round supply and volume important to distributors (including grocers, foodservice, consumers). Quality control easier to coordinate. More opportunities for short response time for delivery. High-end quality control for selected products (Sowder, Oishii opens NJ vertical farm, slashes price for Omakase — the 'Tesla of berries, 2019) *
- **Local field and high tunnel** – in local production regions within a specific state like Kentucky, more room for differentiation and connection through local market channels: KY Proud, Appalachian Proud, Homegrown by Heroes, and farm estate branding. Local auction markets growing with regional buyer reach and have historically been able to achieve prices above terminal markets, but less differentiation. Increasing challenges from local greenhouse with inelastic demand locally (markets easily flooded).
- **Field** – limited for large scale and wide distribution. Some minor production for local markets and farm-estate branding appealing to selected markets where identity preservation possible.

Labor quantity and efficiency is a critical input and key cost component for tomatoes and other fresh vegetables both for production and packing. Different production systems use labor differently. Most larger scale U.S. producers use H-2A temporary agricultural worker labor drawing primarily from Mexico. While many H-2A workers are experienced with produce, costs have steadily increased and the supply has real sources of uncertainty in the current economic and political environment. H-2A wage rates in Kentucky have increased 70% since 2004 (see Appendix 3, Figure 32). Wage rates in Mexico, as noted earlier, have remained far below those paid in the U.S. (see Appendix 3, Figure 33), but recent data shows that even there wage rates have been increasing (see Appendix 3, Figure 34).

- **CEA high tech production**: Labor estimates approximately **30%** of production costs, although many operations are exploring shifting some aspects of production to robotics – expensive, but slightly easier to implement in a controlled environment.
- **High tunnel production**: Relatively small scale of production, typically for local markets, auctions. Labor for all functions involves about **40-45%** of the cost of production. Often additional direct marketing expenses, although less absolute costs with a focus on smaller direct markets. (Estimated Production Costs for Tomatoes, Estimated Production Costs for Tomatoes in an Unheated High Tunnel, 2008).
- **Field production**: Labor estimates for planting, other field work, picking, packing, labeling, hauling comprises approximately **30-35%** of the cost of production for field production (Wade, Hyman, McAvoy, & VanSickle, 2018) (Center for Crop Diversification, n.d.).[35] Typically large volume, H2A worker access required.

Energy is a critical input for all production systems and especially CEA systems, contributing 20-30% or more to the overall cost of production. Various co-location or by-product schemes can be pursued to mitigate these issues, but generally, the more heating, cooling and light that needs to be provided to sustain growth year around, the more natural gas and electricity will be required.

[34] Detailed production imports by type (including hothouse) are provided by USDA-ERS Data by Commodity - Imports and Exports (usda.gov) with monthly imports (including hothouse) Data by Commodity - Imports and Exports (usda.gov). ERS notes relatively strong prices for imported whole tomatoes for early 2022.

[35] Florida: $5,500 of $16,863/acre, Wade et al., IFAS Extension, https://edis.ifas.ufl.edu/pdf/FE/FE108700.pdf; $6,000 of $15,800/acre for KY, Ernst et al., UK CCD, https://www.uky.edu/ccd/sites/www.uky.edu.ccd/files/largescaletomatobudget.pdf

Energy costs have been especially volatile in recent years through a combination of pandemic-related supply disruptions and the current war in Ukraine. Natural gas prices in the U.S. have increased by a factor of 4 to 5 during the past 3 years (see Appendix 3, Figure 35).

Electricity rates have also spiked and create a higher degree of uncertainty for higher tech CEA Kentucky has relatively low electricity rates compared to other parts of the country, but these would still be an important cost where lighting and cooling may be concerned (See Appendix 3, Figure 36). Energy policy and opportunities for energy generation and resale are discussed elsewhere in this report but remain important considerations for locational advantages for CEA and relative advantages to alternative production systems.

CEA systems that involve very high infrastructure costs are especially vulnerable to energy disruptions, especially if that is compounded by a more challenging solar radiation environment.

Summary of internal rivalry forces

Kentucky does have some locational and resource advantages compared to some other regions, especially for proximity to key markets, low energy input costs, and an opportunity to enter niche parts of production within the CEA space. Competition with Mexico and other large field production bases within the U.S. will likely keep downward pressure on sustained profits. Many uncertainties involving labor, energy, transportation, and long-term trade policies with Mexico remain that could further tip the balance of competitive advantages away from Kentucky. Kentucky should focus on varieties that are not imported from Mexico, high-value products with short shelf life (strawberries, leavy greens, etc.), high-end products (infant food, specialties, snack vegetables, fresh herbs, etc.), more added value (fresh washed, packed, ready-to-eat, ready-to-cook, etc.), good logistics, ingredients for pharmaceutical or cosmetic industry (Chinese herbs, vanilla, etc.) or ornamentals (indoor and outdoor plants and flowers). In addition, mechanization and automatization can continue to advance with further research to limit the amount of labor.

4.5.2 Threats of new entrants

New entry into production (through CEA or field production) potentially adds both the supply and increases competition for niches in the market. Easy entry by new rivals (or the credible threat of such entry) limits the opportunities of the firms within the existing industry to build and sustain their advantages, thus eroding profits. New entry into vegetable production can come from a variety of production locations and/or expanded types of production systems that can contribute to the overall supply in the market.

Capital for infrastructure, energy, labor, and knowledge of systems present the greatest barriers to larger entry of others seeking to be players within the CE production space. Normally, very high-cost CEA infrastructure and complex institutional systems would be regarded as barriers to easy entry. A Dutch high-tech greenhouse will cost about $0.8-1m per acre. Smaller CEA systems with lower technology, however, are increasingly viable. Low-cost innovations for field production and simple CE systems (high tunnels) are continuing to be developed, bringing new producers into the system. Infrastructure costs, however, are relative, and, as noted earlier, significant new entry of new CEA systems is evident in Kentucky, across the U.S., and in Mexico.

The industry itself already faces significant (internal) rivalry relating to the production of vegetables particularly: it is a primarily commodity market. New entry will mean expanded supply to the market and corresponding lower prices. While greenhouse vegetable production has been growing slightly in the U.S., and several substantial enterprises have been launched, including those located in and around Kentucky, the competition from greenhouse production coming from Canada and especially from Mexico is substantial. Greenhouse/CEA systems offer the advantages of large volume, uniform quality, short lead times to fulfil supplier orders, and year-round access for buyers that are seeking to supply their own large- scale networks – including national grocery chains and large foodservice networks. New efficiencies in production continue to be introduced, but production continues to be at a very high cost relative to field production or even simpler controlled environment systems (high tunnels). Relative higher costs in physical infrastructure, energy, and labor in consideration of U.S.-based sites are substantial compared to Mexico.

Seasonal field-based production can be supplied for most produce items at a substantially lower cost compared to CEA systems. Buyers readily switch to lower cost commodity products when quality and supply are then available and comparable. National initiatives like the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) high tunnel cost share program continue to put a large amount of very low-cost local production capacity in place. While primarily local production for local markets, these are season extension technologies that provide easier access into winter markets where CEA producers depend on generally higher commodity prices.

Limited opportunities for differentiation or branding from the production level and dependence on larger regional and national distributors and their networks contributes to longer supply chains. Scale requires wider distribution networks that are more fragile and impacted by higher fuel and transportation costs. Some opportunities are evident for specialized production with products such as specialty tomatoes.

Some distinctive sustainable advantages for CEA systems and products
There are some inherent benefits to food security with larger, controlled systems that can ensure year round supplies of quality produce that are less constrained by the limits of seasonality.

Other benefits relate to food safety: 1) the usage of pesticides per kg/produce is much lower than outdoor crops, resulting in lower residue levels of pesticides on the products. And 2) biosecurity from a human pathogen standpoint is much better in high-tech CEA, because wildlife pressures are lower and water sources are monitored and controlled more easily. This has become especially appealing for school foodservice directors that are looking for ready-to-eat products with minimal washing that are safe for children. (Interview T. Woods, name interviewee not disclosed, 2022).

Opportunities for economies of networking exist between CEA firms evident in NL, such as energy cooperation, technology sharing, shared local economies of learning, and opportunities to apply similar technology to a variety of vegetable, fruit, and ornamental products.

Potential for positive co-products (energy or by-products) exists, especially in Kentucky with potential partners in heat or energy creation where co-location (with coal-fired electricity stations or ethanol producers) could substantially lower production costs.

Summary of threat of entry forces
There is a real entry threat from new CEA systems within U.S. (or expansions across North America) (Sowder, 2022), but also the opportunity for sharing of technology and collective capacity building through national produce trade associations like the International Fresh Produce Association (formerly known as United Fresh).

There is also entry threat to CEA production systems from expanded field and/or low-tech high tunnel production that are less inhibited by expensive, extensive infrastructure and can move in with fairly low cost. In reality, interviews with most regional produce buyers in and around Kentucky called for growth of both CEA and field-based production to grow the industry.

There is disruption potential to small farms and local food systems with movement toward large, more concentrated CEA production systems. These concentrated systems have been demonstrated as fragile in other U.S. food sectors, such as meat, baby food, and dairy products during the recent pandemic. Discussions about food policy, food supply resilience, and food access are needed with a view toward orderly market development.

4.5.3 Bargaining power of buyers

Buyers include all downstream partners with whom the CEA and other producers must deal with. Fresh produce is a high velocity value chain characterized by high concentration upstream among both grocers and foodservice.

A significant threat to industry profits for the CEA producer community comes from buyers, who, while valuing volume and year around supply, can readily switch to other suppliers. Distributors working with Kentucky CEA vegetable operations regularly source from across North America to support their brands and customers, creating a wide supply network that complements their own distribution scale economies. This includes Mexico. National grocers that source high volumes are increasingly developing their own store brands for produce (i.e., Kroger Private Selection brand). Foodservice buyers in the restaurant space may place value on working with national distributors and even pursue volume supply contracts (which tend to be rare and not extensively used in produce marketing in the U.S.), but there is not much opportunity for differentiating from commodity products.

Food safety has been a driving concern for all dimensions of the food supply chain and can potentially play into an advantage for more integrated CEA systems. Produce traceability and third party farm audit quality assurance systems have become increasingly common and are easier to manage in larger, integrated systems.

Trucking sector

Trucking is a critical partnership for larger volume growers and large buyers. These firms, independent or owned by a distributor or retailer, are part of the outbound logistics critical in a fresh produce supply chain. Transportation is a critical part of the value chain, bringing products to more distant regional and national markets. High trucking costs add to the access cost for remote production regions dependent on moving large volumes greater distances.

This sector experienced significant disruptions during Covid-19 with high fuel costs and other supply chain disruption/bottlenecks (see weekly refrigerated truck rates below). Large and distant CEA production centers can be especially vulnerable when they face higher costs to access distant markets.

Trucking costs – higher fuel, wages, pandemic mitigation, strong consumer demand, low retail inventories, driver and truck shortages have contributed to rising trucking costs. At the peak of the pandemic trucking was approximately 50% of the retail cost (USDA, Vegetables and Pulses Data, 2022). Rates for trucking have substantially normalized now to about 24% of the retail cost, but future risk exposure should be a part of any business consideration.

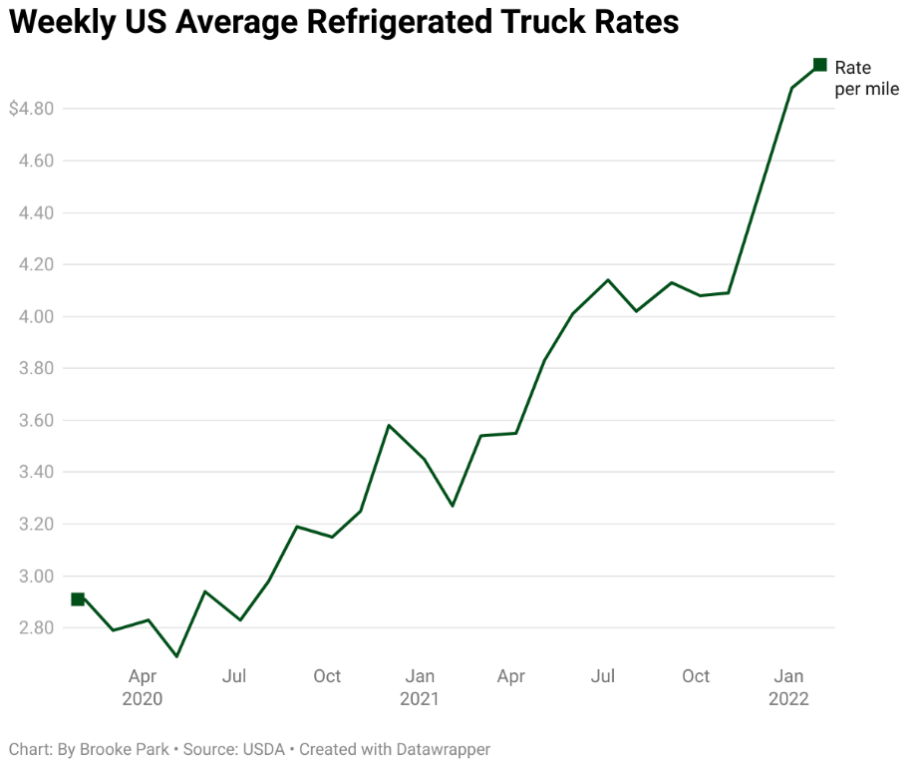

Figure 26 *Weekly US Average Refrigerated Truck Rates*

Trucking costs spiked sharply during the pandemic with expectations that they would continue rising into the future with higher fuel costs, supply shortages, and more spot market purchases (see Figure 26), (Karst, 2022). Trucking rates have come back to earth, however. Data from the USDA Specialty Crop National Truck Rate Report now shows mostly adequate supplies between most markets and generally lower/stable rates for early 2022.

Trucking costs are critical for all three systems of production (CEA, low-tech, open field). Fresh vegetables that require refrigerated trucks are among the most expensive (including tomatoes). Full loads with backhaul opportunities are critical – so volume deals are important.

- U.S. Greenhouse – volume of production requires low-cost access to wider markets within the U.S. Cost advantages over Mexico to local markets in the Mid-West/East Coast can be $0.08-$0.10 per pound cheaper.
- Field production – primarily California and Florida by volume – depends on trucking to the extent they also are trying to reach remote markets.

Produce auctions in Kentucky are impacted by trucking costs to a lesser extent, although order buying from distant markets has increased. They are much more vulnerable, however, if large CEA operations in the area have to subsequently look more to local markets and potentially challenge market share.

Trucking costs currently to urban market areas are noted in the Table 9 below.

Table 9 *Trucking Costs to various U.S. Markets from Southern U.S. and/ Mexican Production locations (USDA, AMS, Specialty Crops Market News, 2022)*

Trucking Costs			
4/27/2022			
Tomatoes			
		From	
To	**Mexico/S Texas**	**Mexico/Arizona**	**Florida**
Chicago	$ 5,050	$5,600	$2,650
	$0.13/pound	***$0.14/pound***	***$0.07/pound***
Atlanta	$4,750	$6,400	$1,600
	$0.12/pound	***$0.16/pound***	***$0.04/pound***
Philadelphia	$7,700	$7,700	$3,700
	$0.19/pound	***$0.19/pound***	***$0.09/pound***

	Total truck delivery cost
	cost per pound of tomatoes for a 40,000# haul

Grocers and foodservice distributors represent increasingly concentrated sectors that backward integrate to create their own distribution systems and position themselves to dictate many of the terms of supply. This includes issues of food safety certifications, elevated quality standards, traceability systems, store branding, distributor branding, and logistics.

Buyers – grocers and distributors – purchase in very large volumes and it is common for CEA firms that have invested significantly in infrastructure to enter sales agreements largely with a view of protecting those investments with guarantees of at least minimum prices or terms. There are relatively few options to move significant volumes of tomatoes – millions of pounds, for example, without working to a significant extent with the few very large buyers.

The Porter model raises the question about the price elasticity of demand for the industry products. In effect, what happens if CEA firms raise their prices in this market? The switching to other supplier sources is relatively easy, suggesting a fairly elastic demand typical with a commodity product.

The Porter model asks further if the product represents a significant fraction of the cost in the buyer's business. In this case, not really. Grocers, foodservice buyers, and produce distributors have lots of other products and services they are managing and are unlikely to be held hostage to the demand of a negotiation with a supplier over a single product.

Finally, pricing for the supplying industry firm depends strictly on the prevailing market rate, which is increasingly determined by imports from Mexico. CEA firms have benefitted from strong prices for produce during Covid-19, but the buyer is in an easy position to back out or limit sales. Strong demand for fresh tomatoes, leafy greens, strawberries and other products has buoyed CEA prices. However, these products are vulnerable to sharp downturns from oversupply or interruptions to logistics limiting distribution.

Summary of threat of buyer power
This is a significant threat to sustained profits for CEA firms in Kentucky and the U.S. currently. There are buyers that are highly interested in seeing CEA develop successfully in Kentucky, including all those that were interviewed in this study. The industry structure for production, puts the CEA firms themselves in a weak bargaining position, pushing them toward emphasizing cost and scale efficiencies consistent with commodity producers rather than toward marketing and differentiated products.

4.5.4 Complements and threats of substitute products

Complementary products or market trends enhance demand and opportunities for sustaining profits while substitutes can create downward pressure on prices. Opportunities for gains or threats to profits are mixed, at least with respect to vegetables. CEA is being developed for a wide range of products with high potential for positive spill over benefits. Technology, production networks, and supply chain relationships developed for one product can create opportunities for additional subsequent products using similar resources. Continued efforts to encourage Americans to eat more produce (Produce for Better Health Foundation) can potentially strengthen the fresh produce market demand along with a number of government programs to improve consumer access to better food.

Technology advances in tools such as robotics, analytics, big data/AI, and plant genetics developed in other settings can be positive for the CEA community. Technology in agriculture has been advancing generally for many kinds of applications, which can yield complementary relationships to developing scientists, technicians, managers, and marketers of science-intensive products.

There are threats for substitute systems of production. 'Climate smart' agriculture is getting substantial attention and funding from the USDA currently. Sustainability measures for agriculture are coming under greater scrutiny. While CEA firms can use much less water relative to field production systems (a key advantage in some areas such as the Southwest U.S.), they use substantially higher energy – especially during winter production for lighting and heating, depend more on trucking distribution, and would potentially be a target for some consumers or agencies focused on climate change concerns and GHG emissions specifically (Nicholson, Harbick, Gomez, & Mattson, 2020) Climate smart consumer labelling could become an important messaging point CEA firms would want to consider.

Summary of emergence of complements or threat from substitutes
There are stronger opportunities for complementary developments around science and manufacturing that could lead to positive developments for CEA. Some of this cross-sharing can be explicitly cultivated through shared research centers and initiatives. Exploration of linkages with various energy, manufacturing, and ag technology firms for possible synergy with CEA could be fruitful. Explorations for such opportunities in the Netherlands, Mexico, or Canada could point toward possible directions.

4.5.5 Bargaining power of suppliers

It can sometimes be the case that suppliers to an infant industry (such as CEA firms locating in Kentucky) have bargaining power as they may control key assets. In this case, the key suppliers would be providing the necessary seeds, plants, fertilizer, technology, and infrastructure to establish and maintain production. Generally, these resources are widely available. The current farm market, however, reflects much of the rest

of the manufacturing sector with regular supply chain interruptions. These impact the timing of key construction and coordination of joint or sequenced production activities.

Suppliers for the technology are providing specific assets and strong partnerships are critical, especially where there is a knowledge-transfer element. There could be a critical role building strategic partnerships with Dutch firms and institutions to facilitate learning and supply chain management.

Larger CEA systems face potential disruption from key inputs such as energy, labor access, steel/plastic/glass, and related infrastructure materials costs. Many of the typical inputs used by vegetable farms in the U.S. have seen sharp spikes in cost in the last year. Fertilizer, farm equipment, building materials, and labor have especially hit the vegetable sector as evidenced in the Table 10 below. While shocks in input costs are felt widely, firms either just starting or in fragile financial position can be at added risk. While these costs are certainly rising and impacting farm-level production costs, there is not strong supplier power, per se. While these costs are certainly rising and impacting farm-level production costs, there is not strong supplier power, per se.

Table 10 *Selected U.S. indices of prices paid by farmers, 2016-2022 (USDA, Vegetables and Pulses Data, 2022)*

Input	Annual average						First quarter (Jan.-Mar.)		
	2016	2017	2018	2019	2020	2021	2021	2022[f]	Change[1]
	Index, 2011 = 100								Percent
Seeds and plants	121.4	119.9	118.5	116.0	113.4	113.1	113.0	118.0	4.4
Fertilizer, nitrogen	71.6	66.5	66.5	71.4	69.2	87.4	68.8	145.0	110.8
Fertilizer, potash/phosphate	70.5	64.4	62.9	63.0	62.5	82.7	64.4	110.0	70.8
Chemicals, insecticides	107.7	103.1	100.9	99.2	93.4	96.4	92.2	106.0	15.0
Chemicals, herbicides	109.7	106.4	101.7	101.8	99.4	99.9	95.7	110.0	14.9
Chemicals, fungicides/other	98.7	95.1	95.7	99.5	98.8	98.1	94.2	112.0	18.9
Fuels, diesel	51.8	57.6	67.4	71.5	56.4	55.0	49.9	100.0	100.4
Fuels, gasoline	59.0	64.5	70.9	75.1	60.6	64.0	56.0	110.0	96.4
Farm machinery	115.4	117.7	120.0	124.1	123.1	131.8	123.8	145.0	17.1
Farm supplies	106.3	107.6	111.6	115.5	117.4	127.5	120.4	135.0	12.1
Custom services	111.6	114.3	113.3	118.4	119.6	114.7	114.7	126.0	9.9
Building materials	107.6	110.4	116.1	118.1	120.8	140.5	129.0	157.0	21.7
Cash rent	130.4	130.4	126.0	123.0	124.5	124.5	124.5	126.0	1.2
Interest	103.9	108.3	114.7	115.1	110.9	111.4	111.4	115.0	3.2
Taxes	110.7	115.5	117.1	120.4	126.8	130.0	130.0	135.0	3.8
Wage rates	115.9	119.1	126.3	133.2	138.2	146.1	144.9	162.0	4.9
Crop sector[2]	106.6	108.0	110.2	111.7	111.3	116.0	112.1	127.0	13.3
Vegetable sector[3]	106.1	107.2	109.8	113.1	113.2	118.4	114.6	132.3	15.5

Note: f = forecast

1 First quarter (January-March) change from 2021-22.

2 Input items common to crop production.

3 Input items common to vegetable production weighted by 2006 vegetable farm expenses derived from the 2006 Agricultural Resource Management Survey.

Source: USDA, National Agricultural Statistics Service except first quarter 2022 projections by USDA, Economic Research Service.

4.5.6 Summary Assessment of the Market Opportunity for CE in Kentucky

There are many attractive aspects of CEA and its place in Kentucky agriculture. There is a strong buyer interest, Kentucky has locational and cost advantages for production efficiency, logistics, and market proximity relative to many other U.S. locations, and there is a good base of interest in CEA ranging from simple high tunnels to extremely sophisticated large-scale systems. There are risks inherent in developing any new industry. There are many challenging forces that require steady attention. But there is a ready community of producers, buyers, government agencies, and emerging partners that are global leaders in supporting CEA innovation and industry development.

CEA has been successful in the Netherlands because they have found ways to build an industry cluster and ecosystem that cultivates growth, innovation, and synergies with value chain partners.

Development of CEA in Kentucky will need to be strategic, involving attention to all aspects of the supply chain and exploring opportunities for unique synergy with existing agribusiness, energy partners, and technology partners from diverse applications. Industry development will not take place overnight. Workforce development, production capacity building, on-going support from various research and governmental institutions, careful study of the markets and economics of alternatives, and strategic engagement with buyers will be among the key success factors required to create sustainable opportunities.

4.6 Summary of findings

The following is a summary of the key findings about the CEA in Kentucky:

- There are many attractive aspects of CEA and its place in Kentucky agriculture. There is strong buyer interest, Kentucky has locational and cost advantages for production efficiency, logistics, and market proximity relative to many other U.S. locations, and there is a good base of interest in CEA ranging from simple high tunnels to extremely sophisticated large-scale systems.
- Kentucky does have some locational and resource advantages compared to some other regions, especially for proximity to key markets, relatively low energy input costs, and an opportunity to enter added value parts of production within the CEA space. The vegetable sector is a highly competitive sector. Due to strong national and international competition, Kentucky should focus CEA development around on products that are not imported from Mexico, vulnerable products with short shelf life (strawberries, leafy greens, etc.), high-end products (infant food, specialties, snack vegetables, fresh herbs, etc.), more added value (fresh washed, packed, ready-to-eat, ready-to-cook, etc.), good logistics of perishables, ingredients for pharmaceutical or cosmetic industry (Chinese herbs, vanilla, etc.) or ornamentals (indoor and outdoor plants and flowers). In addition, mechanization and automation can continue to advance with further research to limit the amount of labor.
- Central Kentucky appears to be the most suitable area for future CEA ecosystem development and in particular for project-based locations of greenhouses and other related activities within and outside the value chain.
- There is disruption potential to small farms and local food systems with movement toward large, more concentrated CEA production systems. Discussions about food policy, food supply resilience, and food access are needed with a view toward orderly market development.
- There are buyers that are highly interested in seeing CEA develop successfully in Kentucky. However, a point of concern is that the industry structure for production puts the CEA firms themselves in a weak bargaining position, pushing them toward emphasizing cost and scale efficiencies consistent with commodity producers rather than toward marketing and differentiated products.
- Exploration of linkages with various energy, manufacturing, and ag technology firms for possible synergy with CEA could be fruitful.
- Development of CEA in Kentucky will need to be strategic, involving attention to all aspects of the supply chain and exploring opportunities for unique synergy with existing agribusiness, energy partners, and technology partners from diverse applications.

5

Knowledge development & Exchange

5 Knowledge development & Exchange: Analysis of the needs and gaps

5.1 Introduction & data collection

This chapter aims to provide recommendations for capacity development for a CEA Ecosystem to bridge government, businesses, and knowledge institutions, based on the needs of relevant stakeholders. To make that possible, an identification and assessment was done to the needs, challenges, and knowledge gaps of this ecosystem according to relevant stakeholders.

Data collection took place between December 2021 and March 2022. In total, 29 one-hour interviews were carried out with the representatives of the following stakeholder groups: Academic/Knowledge Partners (8), Economic development (4), Government (4), Industry (5), State Associations/Councils/Societies/Non-Profits (6), and small farmers (3). The interviews were carried out using virtual platforms (e.g., Microsoft Teams and Zoom) with individual stakeholders. In a few cases, group interviews were organized with 2-3 individuals representing the same stakeholder group.

For all interviews with the exception of one, participants were queried with open-ended questions that were group-specific and are described in Chapter 2 and Appendix 4. One interview in particular with a non-profit organization used a different questionnaire with the intent of gaining insight into their experience of coordinating similar work with stakeholder collaborations in Kentucky's Metal Manufacturing. The questionnaire was developed using the concept of AKIS and its functions (see Section 2.4)

5.2 Descriptive analysis of the interview results

The interview results demonstrate that the representees from academia and governmental organizations were more often involved in the development of the CEA Ecosystem process compared to representatives queried from other stakeholder groups. From academia, involvement in the CEA Ecosystem development was often related to grant funding. From economic development, the involvement is either via grant projects in cooperation with academia or in cooperation with industry.

Of 29 respondents, more than half are currently involved in the development of the CEA Ecosystem in Kentucky. Two respondents were not interested in participating in the queries because they did not believe that the business would be successful or have other priorities and beliefs. Most of the respondents were interested to join in the future.

The participants were asked to indicate which organizations should be involved in developing an CEA Ecosystem, and to provide what role they should play (see Figure 27). The results show that the development of an CEA Ecosystem requires a multi-stakeholder approach involving government, industry, education, farmers, advisors, and non-profit organizations. The explanation of how different stakeholders see this process is provided in the Sections 5.3.1.1-5.3.1.5.

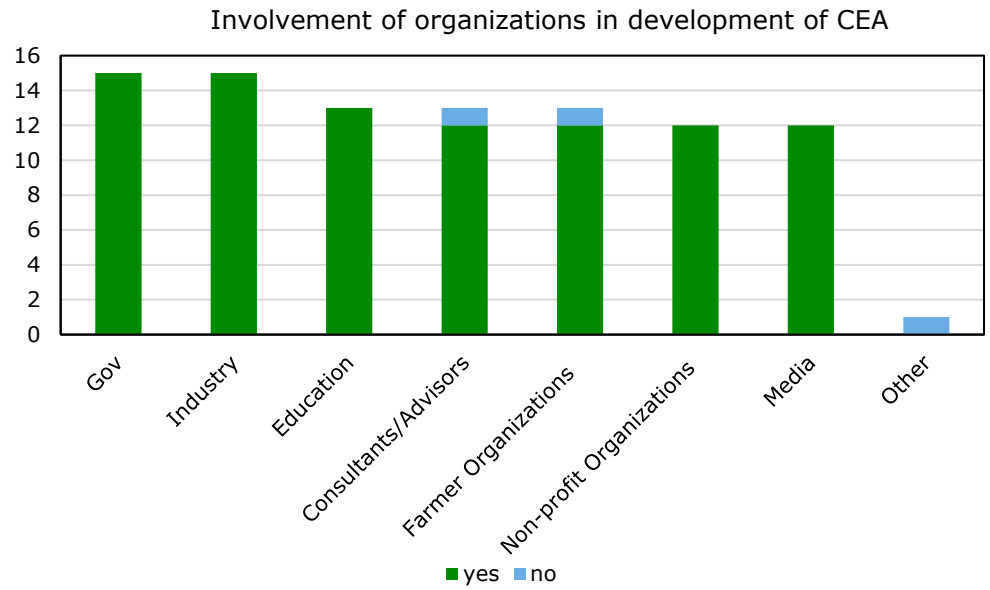

Figure 27 *Involvement of organizations in development of CEA (From 29 respondents, 14 filled out the answers)*

The participants were queried and asked to prioritize a list of actions from most to least important in developing an CEA Ecosystem (see Figure 28 below) (15 out of 29 respondents filled it out). Based on the results, **development of a new policy vision for a change** is perceived to be the most significant priority to be addressed for an CEA Ecosystem development. This was explained by the argument that government needs to make policy shifts including incentives to help facilitate growth. **Providing education/research/ training** was determined to be the second most important action by several participants, because the CEA industry is new and there is a need to develop more of an education pipeline to generate interest among youth in horticulture. **Make new resources and technologies available** together with **offering incentives for entrepreneurs** were determined as follow-up actions. In the case of making new resources available, a suggestion was made to place a container farm at a local high school and then incorporate that into the school's menu option to offset costs of what the school must purchase. This spurs entrepreneurism and the thought process of how money markets work and at the same time provides an idea of sustainability and education. With regards to offering incentives for entrepreneurs to become part of an CEA Ecosystem it was mentioned that all communities may have local and state level incentives. This could be credits or training programs to offer pathways and continuing education to encourage more people in Kentucky to invest and create opportunities. Local government should also make sites ready with infrastructure (e.g. demo center) so they can pitch to businesses.

The respondents also mentioned other actions as being important including:

- Develop a strategy;
- Communication, community building; talking to farmers and media and legislators;
- Marketing campaign;
- To carry out needs assessment (there is a need for more grower input), to find the gaps and opportunities. This would help to understand what kinds of incentives are necessary and what kinds of entrepreneurs would be attracted or needed.

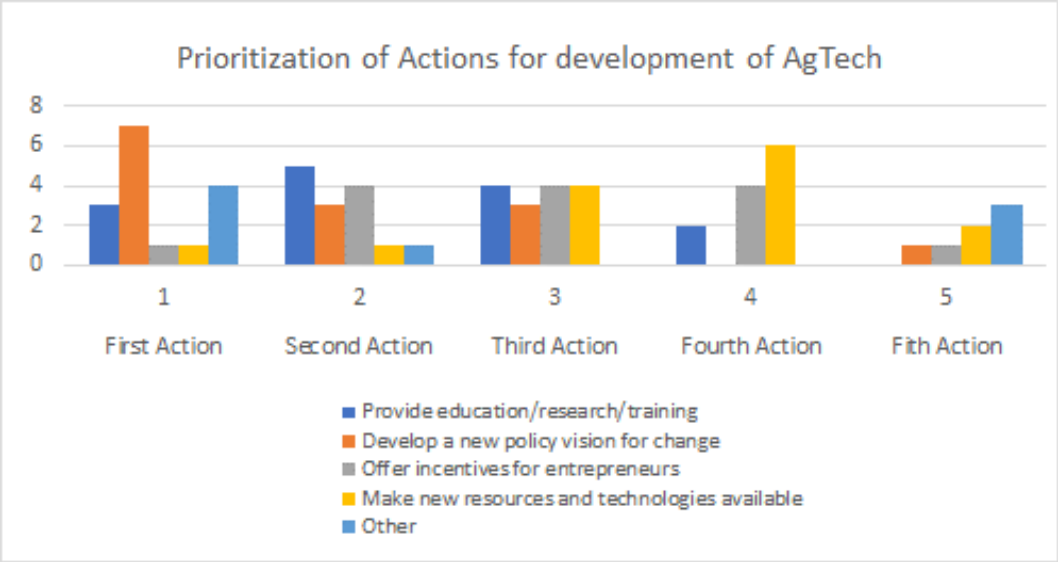

Figure 28 *Prioritization of Actions for development of CEA*

5.3 Analysis of functions of the Agricultural Knowledge and Innovation System (AKIS)

5.3.1 Education, Training, Research

This section discusses the perspectives of all interviewed stakeholders on education, training, and research and the role(s) of different organizations in developing an CEA Ecosystem. Current gaps and needs to promote education, workforce training, and research innovation for an CEA Ecosystem are analyzed and recommendations are proposed.

Education is one of the best ways to distribute information; thus, the role of education in information sharing is very important when it comes to developing an CEA Ecosystem. It is important to provide or disseminate knowledge at different educational levels including the vocational, and university level. Education of entrepreneurs is also imperative and relates to practical training or short-term trainings for those already in the workforce.

Basic education around the general concepts of CEA is imperative because most people are likely unfamiliar with CEA and controlled environment crop production. And it is important to educate citizens on sustainability, and environmental stewardship in general. The first step in addressing this challenge and educating citizens can be a 'story' of how producing vegetables in greenhouses can be done under sustainable and environmentally friendly conditions. Next to basic education, there is a need to have high-level education on CEA in order for researchers to be able to develop best cultivars and species.

Although education is perceived to be a main driver in developing an CEA Ecosystem, it appears that currently there is a very **low priority** given to general agricultural education in Kentucky (*of the 8 respondents in this category, only 4 have filled out the levels of education and all 4 have indicated that this priority is low).* Moreover, agricultural education seems to be unpopular among youth. Many Kentucky residents are located in urban and suburban areas where basic agricultural education is not seen as integral for students, and it is seen as competition to more 'significant' subject matters.

To address this challenge, educational institutions are on the forefront of communicating information about CEA, as educational institutions are a trusted resource for the general public and universities have built-in legitimacy.

5.3.1.1 Roles of different organizations in supporting education, training, and research in developing an CEA Ecosystem

This section discusses the roles of different organizations in supporting education, training, and research to establish an CEA Ecosystem.

Government

According to respondents, the government should have a facilitating role. At this moment there is very little educational material related to CEA, such as academic programs or vocational training curricula. A certificate program for business and leadership programs exists, but these need to be adjusted to extend to education related to CEA. There is a need to develop a high-quality education curriculum aligned from the first course to the capstone course, where the knowledge, skills, and abilities will be embedded and scaffolded. For this to become possible, finances are needed to invest in research and knowledge institutions to come up with new curriculums. The government can play an important role to support financial aids to educational institutions as well as to incentivize private companies to invest and innovate on short notice. There are also some thoughts about hiring staff from the Netherlands for the agricultural faculty at the University of Kentucky, or by sending key voices (e.g., educators, policymakers and businesspeople) in the agricultural world of Kentucky to the Netherlands.

One of the respondents expressed concerns that the Dutch Triple Helix model might be difficult to implement in Kentucky. The government should establish a strategy related to an CEA Ecosystem so that it can operate. For instance, from a sustainability point of view, people love the idea of becoming more sustainable; however, they do not know how to operationalize it because there is no strategy to do that. The establishment of such a strategy needs to be done with the input from many different stakeholders. The government also needs to provide incentives to create a healthier environment for encouraging business development. Furthermore, the government should provide compliance and regulation to make sure businesses are keeping their promises. The government should work closely with industry to listen to their needs and requirements, but also the other way around. The government can administer the SBIR/STTR federal innovation grants (SBIR, sd), and in Kentucky they will also provide matching funds to match those and encourage more innovation. According to farmers the education is important. However, there should be first a market for the expected growth in vegetables production by CEA. The biggest problem some stakeholders see is the investment related to the high costs of constructing CEA infrastructure and operations. According to one of the interviewed farmers, the labor shortage is the hardest issue for greenhouses right now. One respondent fears that government subsidies and regulations will determine the future of CEA, when it should be in line with market demand.

Industry

Compared to universities, industries can quickly market new ideas and innovations and more than likely take the opportunity to do so. They can therefore play a prominent role in the development of an CEA system. Also, 'they are the boots on the ground,' meaning that they can try out things that the university has done research on. The industry is the litmus test to tell what technology works, how things will affect their bottom line, etc. In doing this, they need to partner with academia and services that can be personalized for rural developments. They should do in-house trials with researchers and have opportunities for internships with students and have companies that support research by donating materials for proof of concept of small to mid-size commercial operations. When there are industry providers like AppHarvest with a high priority for training, this can create a great partnership for education as students and faculty need to know this technology.

Industry should ensure that education prepares students for the jobs of tomorrow with an emphasis on CEA. In doing so, industry needs to work with education, as industry provides the market and the jobs. They need to build the necessary infrastructure and create an environment with a competitive advantage to attract growers. Also some of the new entrepreneurs investing in Kentucky have a very positive, powerful voice and could help bring agri-food companies along. In addition, the business community can propose new projects to interest new entities in developing or expanding operations in Kentucky. By working closely with government, industry can help government identify gaps in incentive programs.

Industry should be involved and/or support educational institutions. They should work with young minds such as high school or college students throughout the state to develop pathways into the greenhouse or related CEA or CEA industries. This requires great attention to detail with strong math, chemistry and practical uses. Thus, the industry should be open to internship programs to facilitate learning. Although the classroom is much needed, the best learning is in the real world to learn directly from the businesses themselves and the experienced employees there. Learning on the job is key with CEA.

Educational institutions

With regards to education, three elements are important to consider:

1. Hardware: these are the things you see and touch like buildings, books, infrastructure, broadband, etc.;
2. Orgware: how is the supply chain organized? Who has power in supply chain? What are working business models?, etc.;
3. Software: what are the skills of people? How is the innovation climate? How knowledge is shared and transferred?

Collectively, there is a need to form a synergistic connection among all three elements. There is a need for research and development, establishing education partners, and mentorship. At the same time, growers can also teach and learn from each other. The role education should play in helping with recruiting youth to pursue agricultural education and connect youth with agricultural companies, thereby preparing our future workforce. However, this is challenging because not many young people are interested in agriculture nowadays.

Education should focus on maximizing yield in a sustainable production system with minimizing damage to the environment, production of better tasting food, increasing post-harvest shelf life, etc., all supported by science-based evidence. In education, the University of Kentucky Cooperative Extension Service (University of Kentucky, The University of Kentucky Cooperative Extension Service provides practical education to help people, businesses, and communities solve problems, develop skills, and build a better future, sd) can play an important role by connecting stakeholders and community members, and by being a trusted partner of the community. Extension can also play a key role in educating the stakeholders and the community to understand the benefits and the processes of CEA. There is a need to educate small-scale growers to be more efficient and use more technology in their present practices instead of just focusing on large-scale capital-intensive new operations. Although these examples also inspire and much can be learned from them for their own situations. Extension agents and specialists can partner with researchers to translate research-based evidence such as nutrient deficiencies, disease, etc. From the research aspect, there could be on-site research partnerships with industry. Research in disease and pest management is important, with topics including leaf mold in tomatoes in Kentucky, fungicide management, and environmental control. Educators can help to delineate the advantages of CEA from both an environmental and social impact perspective. Faculty must be trained and aware of innovative CEA technologies. By doing so, this keeps higher educational institutions on the forefront of learning. Learning outcomes at higher educational institutions should align with technical programs in high schools and the business community so that certificate programs can be offered. Education must work closely with industry for cooperatives, internships, tuition supported scholarships, and advisory councils to determine knowledge gaps and needs.

Farmers and farmers' organizations

Traditional and small-scale farmers will feel threatened by CEA, so there is a need to partner with farmers and other stakeholders from the beginning. By doing so, farmer needs, challenges, collaborations, and partnerships will be identified. These groups of stakeholders will need to be educated on new technologies and the benefits of CEA. Farmers in Kentucky need to invest in new technologies, talent, and diversify to remain competitive or to enter the CEA market. The formation of a farmer advisory group with representatives across Kentucky may be helpful to address technology and production challenges, talent acquisition, and diversification, e.g. a Kentucky Greenhouse Growers Council. Farmer organizations fit right into the community stakeholder group. There is a need to engage them at the earliest possible time to get valuable input from farmers, especially those whose land or agricultural products may be impacted by the development of an CEA ecosystem. The sooner they are engaged, the better it will help smooth things over for businesses and assuage fears farmers have about impacts to their daily lives. Farmers need to be willing and open to CEA production systems and learn how to adapt, if need be.

Non-Profit Organizations

Non-profit organizations have a limited role in the start-up phase. It is necessary to involve non-profits to give them the right information, so they will not be against the CEA ecosystem. These organizations need to be well informed so they can be supportive. In some cases, they work closely with farmers and provide education and assistance to growers and share this with the government to make sure they are on the same page to move the industry forward. Non-profits can identify the real problems that farmers face and support them by applying for grants, for example. They can help by facilitating conversations, using their political influence, and giving CEA a stronger push. This has happened in the Netherlands, for example, and now there are non-profits that work with farmers to get a license or certificate to show that they use less pesticides, produce sustainably, etc. In addition, they can also help with lobbying and have a positive role. A good example is the network organization Greenport Netherlands.

Non-profits can:

- help share and transfer information
- expose non-traditional workforce
- help small farmers become involved and work with students to get exposure
- engage farmers and demonstrate season extension
- share the vision and get more people excited.

The government supports non-profit organizations that work with a large number of farmers because the government wants to invest in organizations that can help increase the market. Therefore, the government wants to see outreach and education as part of funding given to non-profits. Non-profit organizations are a voice for farmers and often are well placed because they work directly with the farmers. For instance, Kentucky Center for Agriculture and Rural Development (KCARD) does a really good job helping farmers understand and navigate state and federal resources. Non-profits may partner with organizations such as AppHarvest, Kentucky Fresh Harvest, 80 Acres, or a similar small- to mid-size operation to help one another.

Media

There needs to be a robust marketing campaign around all aspects of CEA from education to product sales. The use of multimedia techniques is recommended in this regard: 30-second to 3-minute videos usually generated interest among the public, for instance showing unique and innovating farming techniques such as fish (Tilapia) and lettuce farms. The media should also be targeted to specific groups, since some types of media are more rapidly consumed by the younger generation. Therefore, there is a need to use new social media platforms and campaigns to reach youth. However, it is very important to make sure that the producers and educational institutions are reporting correct information. Media are needed to dispel unfounded biases. In general, big CEA industries are the ones reaching out to media. There is a gap for small-scale farmers to reach out to media. This could be part of government's role to make sure to position Kentucky as the AgTech capital of the U.S. because farmers need someone to tell their stories of success and perseverance. There is a need to have a good balance to be able to promote new technology and promote the traditional side and the small farmers. Media helps educate and inform everyone including the general public. When media takes next steps and starts pushing propaganda then that oversteps. Sharing opportunities for agricultural jobs should be on their radar. If Kentucky can be tagged as an AgTech state, then people will want to come to Kentucky to see it, as people are getting more interested in where their food originates. These things can be presented in media to promote what Kentucky has to offer.

Other

Respondents mentioned a number of other organizations that should be involved in the CEA ecosystem. These are industrial stakeholders outside of the agricultural sector, such as the logistics, energy and water sectors that are ideally situated to be involved. Partners include renewable energy source stakeholders that could valorize the waste from this ecosystem. Workforce needs to be involved to create short-term training programs for different aspects such as maintenance and operating machinery for certificate-based trainings.

5.3.1.2 Needs and Gaps

In the future, it is believed that CEA could create a mind shift in the working in agriculture with interesting high-tech & management jobs in greenhouse or vertical farms. Hereby, the factor awareness is relevant for this shift to occur:

1. Young people needs to see and understand that these types of CEA jobs are interesting and appealing, as young people are generally less or not interested in farm work. A basic understanding is important before entry into college. There is an opportunity to introduce CEA education to younger children and show them that CEA is more than plowing a field, and they can also use 'cool technology' to be a farmer. This will make the children more excited about working in this sector.
2. For an adult audience, from a workforce development perspective, education is also very important, so that people know that it can provide a viable job opportunity.

The following gaps and needs were identified:

1. Currently, interest in the agricultural sector in general is very low in Kentucky. This may be because the majority of the population lives in urban and suburban areas where basic agricultural education is not seen as integral part for students. Thus, the culture among youth is urbanized and there is little to no focus on agriculture;
2. Lack of awareness about the food supply chain from general public (e.g., where food comes from, how it is grown?). The importance of agriculture is not very well recognized among the population of Kentucky. People do not often talk about ecosystems, environment, sustainability, food, etc. as it is not the culture in Kentucky like it is in the Netherlands;
3. Young people are not interested in agricultural education - the image of working in agriculture is negative and unpopular;
4. Need for development and adjustment of curricula related to CEA for students in different levels of education: there is very little educational material related to CEA, such as academic programs or curricula;
5. Scientific research on CEA is limited. Currently, a very low priority is given to general agricultural education, which also results in limited scientific research in CEA;
6. Shortage of a workforce in agricultural sector. There is in general a shortage for a workforce in agricultural sector due to the fact that the agricultural sector is not popular;
7. There is a need for skilled workforce in agricultural sector and especially in the CEA. The workforce which is already involved lacks the required skills and knowledge related to CEA. Thus, there is a need for practical training for those already working (short term trainings);
8. There is a need for first-hand conversations and knowledge about what the businesses need, what type of technology is involved, what type of funding is needed to train the workforce;
9. Partnerships needs to be stablished between industry, academia, and education. These partnerships are needed to develop specific CEA educational curricula, set up a research agenda on CEA, create job opportunities for future students, as well as train the existing workforce;
10. Small-scale farmers might feel threatened by new developments around CEA. These farmers need to be educated about CEA, its benefits and the use of new technology.

5.3.1.3 Opportunities

Public awareness activities

To address the first two needs (#1, 2), activities for increasing awareness are the key:

- Media and organized events that accessible to the general public. The text box 5 'Welcome in the Green house' (Kom in de Kas, 2022), and Text box 6 'Better Food Festival 2022' (Albert Heijn, 2022) and the flower parades e.g. the one in the Dutch Bulb producing area (Bollenstreek, 2022) are examples from the Netherlands on how to raise awareness about CEA. In addition, vegetable & flower parades are also good activities to create a positive public opinion.
- Projects and demonstrations: seeing is believing. Producers tend to be visual and hands-on, and therefore projects and demonstrations may be more useful than a PowerPoint presentation. They want to see this in person, such as the Cattleman farm in Eaton (Kentucky Cattlemen's Association, sd) which demonstrates what can be done on a farm of any size in Kentucky. Establishing similar initiatives (e.g. demo farms) provide a promising opportunity to showcase the capabilities of CEA. Not only can the farmer become an entity that demonstrates the benefits and utility CEA, but such demo farms can also be constructed by

education centers. However, the point is to demonstrate the benefits of CEA for farmers and for the environment.
- Conferences and trade shows are important, and help building interest and knowledge in these topics and give people a chance to share what they have learned and what types of new products are being made. Such conferences already exist (e.g. the annual Fruit and Vegetable Conference, which this year had a section on greenhouses, and the Kentucky Nursery Landscape Assoc. (KNLA) Ornamental Growers Summer Meeting). By holding these conferences and placing more emphasis on CEA developments, entrepreneurs can join them and innovative technologies can be showcased. It is simple way to help entrepreneurs discover new business opportunities.

Text box 5 Welcome in the Greenhouse

Maybe you walk past it every day or have you ever heard someone talk about the work in the greenhouse. But actually you don't really know what goes on in the greenhouses! That is why during 'Come into the Greenhouse' (in Dutch: *Kom in de Kas*) you have the unique opportunity to take a look inside the greenhouses of various growers throughout the Netherlands. These greenhouse growers (growers of vegetables, flowers, plants and fruit) like to share what they are proud of: the art of growing beautiful, fresh, tasty, healthy and safe natural products that you can enjoy every day.

During this event, walk through greenhouses, admire the crops and learn all about the greenhouse by directly asking the grower your questions. It will be a day you will never forget! You will certainly be talking about it for days, weeks and even years to come…

Text box 6 Better Food Festival

This festival, organized by the Dutch retail chain Albert Heijn, is for everyone who is interested in what food can mean for yourself and the environment. On the festival site of more than 1.7 acres, you can listen to inspiring speakers, participate in interactive workshops and visitors can taste and experience the food of today and tomorrow at more than 70 different stands. One of the domains on the festival site is all about experiencing how we can feel better about ourselves, now and certainly in the future. Visitors can participate in all kinds of workshops and activities. You can discover your real age, do a health check or take a yoga class, but also learn how to easily eat more vegetables and talk to a sleep coach. Eating better is leaving the world a better place. At the festival we also see where our food comes from and visitors can come into contact with growers and farmers - with whom Albert Heijn collaborates. This way everyone can experience where Albert Heijn's fresh products come from. Farmers and growers talk about how they are working towards a sustainable future. There are interactive workshops, such as making seed packets for the wild bee or your own coffee blend for at home.

Creating interest in youth

In line with the third need (#3), the following actions may be promising, to generate youth interest in agriculture and attract more students:

- To support K-12*educators by providing access to a CEA building because it is a living learning environment that can help children learn more on a particular topic and is a great springboard at any age. Here, some industry-initiated developments are already taking place. AppHarvest, for example, provides a container farm that is a mini-version of a CEA farm (in this case: an indoor farm) and they supply it to several high schools (grades 9-12) and produce leafy vegetables. They use lighting and filtration similar to the greenhouse they have. In addition, since 2018, the AppHarvest Foundation and AppHarvest Inc. have opened number of CEA classrooms in different high schools across Kentucky (see text box 7). This sparks an interest and instils an entrepreneurism into students. This can also inspire them to pursue a 2- or 4-year degree and stimulate to go into CEA careers or start a business to support (e.g. by being a supplier or distributor). Its research side also helps generate a workforce that thinks of a sustainable food source;
- Include school subjects on healthy and sustainable food, food waste, food production and circularity. In addition, use space around schools for agricultural purposes to create interest of school children's interest in agriculture and create awareness of fresh healthy products.
- Make use of the existing Vocational Agricultural programs such as FFA (Future Farmers of America, sd), and put more emphasis on CEA studies to steer young people towards a major in agriculture, so that they start seeing it as a career choice that is lucrative.

- Promote agricultural education by making it a new lifestyle (e.g. healthy food and nutrition, vertical farming as innovative alternative to traditional farming). A good example of this is the recent development with Wageningen University in the Netherlands, where the number of students in 2022-2021 has tripled compared to 2003-2004 figures from 4,571 to 12,973 (Wageningen University & Research, 2022). This cannot be achieved without active support from the government, which should have a clear policy vision of promoting the agricultural sector and understanding that without high quality agricultural education the entire CEA ecosystem will not take off. Thus, government must be willing to provide a budget for the activities related to.

Text box 7 Appharvest Foundation Agtech program Container Farm

Since 2018, the AppHarvest Foundation and AppHarvest Inc. have opened AgTech ten classrooms in Central Kentucky at Carter G. Woodson Academy in Lexington, Madison Central High School in Richmond, Madison Southern High School in Berea.

And in Eastern Kentucky at Shelby Valley High School in Pikeville, Rowan County Senior High School in Morehead, Breathitt High School in Jackson, Elliott County High School in Sandy Hook, Floyd County School of Innovation in Prestonsburg, Johnson Central High School in Paintsville, Menifee County High School in Frenchburg.

Two more classrooms, at Fleming county High School in Femingsburg and Rockcastle County High School in Mt. Vernon, are planned to be launched by year end. For more information visit https://www.appharvestfoundation.org/

Curricula development and scientific research

To meet the needs for curricula developments and scientific research (#4, 5 and 6), the following actions are proposed:

- Curriculum design for CEA should involve a collaboration between educational institutions and industry. The curriculum should be designed to match the student's skills needed to work, and then industry experts should be brought in who can provide feedback on the curriculum from real-world experience, provide examples, give tours to student, etc. to immerse the student in the field in which they are want to start their career. If industry identifies certain courses, they can offer a certificate in those competencies in CEA.
- Align technical programs in high schools with the business community so that certificate programs and subjects are aligned.
- Finances are needed to invest in research and knowledge institutions to come up with new curricula. Here the government can play an important role by supporting financial aids to educational institutions and incentivizing private companies to invest and innovate in the short term. Scientific research on CEA can be increased by setting up a public-private partnership. In section 3.2.2 the example of the Top Sector Policy Netherlands is explained, which links the agricultural practice to the research agenda and policy.

Workforce problems

In line with needs #6, 7 and 8, the following is suggested to address workforce issues:

- A workforce development plan should be designed with the main focus of training existing staff working in CEA. This should be aligned with the existing workforce training initiatives, such as the Bluegrass State Skills Corp. Grant Reimbursement (via the Kentucky Cabinet for Economic Development), and KCTCS-TRAINS Funding (Development) as also with the services that private companies offer like PRIVA-academy (Priva, 2022) or Dutch knowledge companies like Hortitech or GreenQ.
- Specialized staffing agencies for CEA should be encouraged and the development of workforce training should be prioritized.
- Make sure that the workforce is paid decent wage.

Conversation and communication among stakeholders

To address need #9 and provide for first-hand conversations and knowledge exchange among various stakeholders we propose:

- Explore the Greenport Netherlands example and involve a non-profit organization in setting up a public private partnership. Greenport Netherlands (public-private partnership initiative in the Dutch CEA system) is a non-profit organization involved in development of a sustainable agriculture. In section 3.2.2. the

Greenport system has been explained. Thus, if it is possible to establish a non-profit NGO or foundation that focuses on network organizations for public and private partners, this can become a driving force for the CEA ecosystem development. This will also ensure the development of partnerships within the industry.

Opportunities for farmers

We propose to respond to the needs of farmers (#10):

- Farmers need to play a very direct role in developing CEA ecosystem because many farms in Kentucky are small and have different farming systems. To get small farmers on board, they will need to see the benefit to them.
- Provide demo activities for farmers, provide access to education and training so that they understand the opportunities and risks for them.
- Trainings and peer-to-peer learning. Bringing peers together to help support each other is important because most small farmers are not competing with each other, although that can be area dependent.
- Provide production education and learning constraints related to CEA. Provide trainings on how to produce, store and market the products, to understand what it takes to develop the sector and know the markets for multiple produce items, the storage constraints and logistics.
- When providing financial incentives to farmers, they should be linked to education and technical assistance. This is based on the experience with the financial incentives related to the high tunnels, which proved to be unsustainable unless they are also coupled with education and technical assistance to help the farmers become business people to know how to produce, connect with their customers, logistics, packaging, etc.
- Evaluate the Dutch Voucher Coupon (in Dutch: *Voucher*) program whether this would be implementable in Kentucky (Rijksdienst voor Ondernemend Nederland, Mkb-innovatiestimulering Regio en Topsectoren (MIT), 2022). This is a program for entrepreneurs, who can apply for a 'coupon' from the government to purchase knowledge from knowledge institutions and research companies. With this coupon the entrepreneur, together or individually, can pay a maximum of 50% of the invoice of the knowledge institution.

5.3.2 Development of a common vision on CEA Ecosystem

Development of a shared vision on CEA ecosystem is one of the most essential actions from which the other actions will follow. A shared vision on CEA is crucial for its further development as it will create a common understanding among stakeholders on what the CE Ag tech ecosystem is and will bring stakeholders in one page.

From the interviews it became obvious that the stakeholders have different visions about the feasibility of the CEA Ecosystem. Some respondents are skeptical of the idea that an CEA Ecosystem can be established with multiple collaborating stakeholders as they expect some resistance from different organizations and individuals. The skepticism has to do with the experiences in the collaboration of the different stakeholders. Other respondents believe that collaboration can be successful. In addition, the respondents pointed out that a diversity of stakeholders should be involved in the vision development, not just educational or governmental partners. The stakeholders will need a driving force and can make progress if they work together to develop a vision, mission and a policy around it. They believe that every stakeholder, from consumer to distributor, will have their own vision, but that the conversations need to start early while it is still a trend. In addition, the stakeholder model should come together to a guiding collective. There needs to be strong government leadership. There is a possibility for stakeholders to collaborate together, but it is emphasized that it needs to happen quickly. According to respondents, people in Kentucky often respond slowly and cautiously to change, which is different from the Netherlands where people react faster to change and grab the momentum. Things could move faster when people with a vision are helped and when people realize there is a private activity driving it. Respondents believe this is a possibility, although they also believe that not all stakeholders should be involved, as they have conflicting objectives, however it could be possible for collaboration to work. Moreover, there is a need for some sort of organization to lead the process. International experts can also be brought in to develop a long-term vision and ensure that the various stakeholders share common knowledge about the principles of CEA Ecosystem.

Raising awareness contributes to the development of a common vision
Information received from local media must be affordable and accessible to the public. To increase private and public awareness of the benefits of developing a CEA Ecosystem in Kentucky, demonstrations could be effective. For example, showcasing results from similar companies already established in Kentucky or other States such as AppHarvest, Kentucky Fresh Harvest, 80 Acres Farms and some companies leading in high tunnels, will be very relevant as people can see the benefits of such an Ecosystem. In addition, storytelling demonstrations, education materials and cartoons can also be used to show how advanced technology is used. It will be demonstrated in a fun way and involve the audience. Other possibilities include experiences such as tours for students or the public so that they can be interactive if it can be done in a safe way.

A communication plan should be developed. The communication plan needs be clear, well drafted and then disseminated, starting with allies and then building a small group that grows larger overtime. Also, it should be clear what the purpose and benefits are of this ecosystem and what is expected in terms of costs, quality, locally sourced products or not. As for the business parts such as marketing, PR and communications, it could be done through collaborations with local agencies and local companies. All of this needs to be captured by data to be able to measure it and back it up with data. Moreover, other companies outside Kentucky could also benefit from this and come for the good reasons to start a business in Kentucky. Non-governmental actors need to be aware of this, as it is much more powerful. Sharing results from companies that are already there, such as Fresh Harvest Kentucky, is much more appreciated and is much more powerful in raising awareness. The respondents say that language is the key to connect with the public.

The language used to connect with the people should be one that the average person can relate to and understand. The average person in Kentucky will lose interest in political or academic language such as 'Dutch consortium'. The most important message to convey to the public is to demonstrate how they will benefit and why it is important for this to happen in Kentucky. It is important for the people of Kentucky to know that their region is being improved and to know that there will be job opportunities for them not far from home.

Another way to raise awareness is to start with local leaders, because it is not possible to inform the public about all the data. There needs to be a committee of primary stakeholders forming a Kentucky Greenhouse Growers Council. This council would serve as a state-wide voice for the CEA segment focusing on public policy, legislation, and identifying and addressing issues and threat to profitability. This council should establish CEA growers networks in different regions to share technology and marketing experiences. They will come together to share their vision with secondary stakeholders such as the Chamber of Commerce, SOAR (SOAR, Shaping Our Appalachian Region 54 counties, one plan for prosperity in Eastern Kentucky, 2022) other industries inside and outside CEA and the Employment and Leadership Council.

5.3.2.1 Main takeaways and recommendations for a common vision on an CEA Ecosystem

This section summarizes the key findings from the interviews related to needs and gaps for a common vision for the development of an CEA Ecosystem in KY, and provides opportunities and recommendations to address these gaps.

Needs and Gaps:
- Lack of common understanding of what an CEA ecosystem is;
- Need to involve a broad spectrum of stakeholders in the creation of a vision;
- Need for close cooperation among stakeholders;
- Needs for a single coordinator for the vision development;
- Need for demos and awareness campaigns showcase the benefits of such systems.

Opportunities and recommendation
The development of the vision requires a clear definition of 'CEA ecosystem' to make the concept clear and understandable to all and to avoid confusion. There should be a common understanding among all stakeholders. The protection of natural resources and the environment should be considered a matter for all. The vision can be based on the principles of 'less loss of value, less damage to the environment - more value recovery':

- Collaboration and coordination: Close collaboration with all stakeholders is necessary for the development of this vision. We recommend to establish a state-wide CEA Industry Development Taskforce. Its board would include CEA producers, traders, technology suppliers, local education and research institutions, and leading government agencies. In particular, ensure representation from SME (small-medium enterprises) producers. It is worth exploring whether there is eventually a need for more regional greenports, closer to the emerging clusters and possibly representing other specializations within horticulture than CEA (e.g. fruits or field vegetables). Skilled local professionals should be invited and involved in the development of the vision in collaboration with foreign experts (e.g., from the Netherlands, Canada, Israel).
- The CEA vision should be included in the national (state) strategies so that it can stimulate CEA-based thinking. In addition, a separate Kentucky Horticultural Agenda 2023-2030 should be developed. A good inspiration for such an agenda could be the example of the Dutch National Horticultural Agenda 2019-2030 developed by Greenport (see text box 8). This effort could be a step-by-step process, starting with a statement of intent to stimulate awareness and commitment.
- Formation of a Kentucky Greenhouse Growers Council. This council would serve as a state-wide voice for the CEA segment focusing on public policy, legislation, and identifying and addressing issues and threat to profitability. This council should establish CEA growers networks in different regions to share technology and marketing experiences. The council would be eligible to join the Kentucky Horticulture Council;
- Awareness through a communication plan should be developed. The communication plan should be clear, easily understood by the general public, and should include the goals and benefits of such an ecosystem to stakeholders and society, including expectations in terms of cost, quality, locally produced products, etc.

Text box 8 National Horticulture Agenda

Greenports Netherlands is working on a Horticultural Agreement with a 10-year horizon. This is drawn up together with the regional greenports, the business community, the authorities and the education & knowledge institutions. The elaboration of this agreement results in an agenda with concrete actions, projects and agreements between the horticultural partners. The first agreement is all about 'being a frontrunner in circularity and sustainability'. We see horticulture as a frontrunner that has solutions for the challenges the world faces in terms of feeding and greening the mega cities.

More than a hundred experts, entrepreneurs, scientists, civil servants and administrators have contributed to this. In the coming period we will start working on the Horticultural Agenda. This agenda is therefore not only written for horticultural entrepreneurs, but for all those involved in horticulture.

(Greenports Nederland, Nationale Tuinbouwagenda 2019-2030, 2019)

5.3.3 Knowledge diffusion

Knowledge diffusion through networking is closely linked to the education, technical training, research and development of a vision for the CEA ecosystem. The linkages between education and training, research and extension should be primarily focused on adequately identifying workforce and technical knowledge needs at the farm level and connecting them to well-established agricultural production principles, with a solid foundation in research, to achieve a vision for the sector.

The current state of collaboration among key players of CEA Ecosystem

Collaboration is key driver of knowledge diffusion and should be central to CEA ecosystem. Currently, many activities have been already organized to stimulate this collaboration, such as the development of a core nucleus of stakeholders who can help guide this process, but there is a need to involve more stakeholders in this process. The Kentucky Department of Agriculture, City of Lexington, University of Kentucky and Alltech have developed a 'Bluegrass Ag Tech Development Corporation' and the state government has also placed substantial emphasis on CEA. Also the Kentucky Farm Bureau has developed the Kentucky Production Agri-Tech (KPAT) Initiative. Several events are already held annually to encourage collaboration in this sector. According to respondents from governmental group, the collaboration has a good representation of government, education, private, non-profits, and small farmers. Recently, during one of the annual events, companies from U.S. and the Netherlands met and had a productive conversation about the current status of KY CEA. The next step in this collaboration is to share identified challenges in the development of this ecosystem and process them together. The collaboration needs to be further improved: the established

collaborative group has 27 partners, which needs to be divided with the industry partners designing their own plans and addressing needs. The involved partners (e.g., government, Dutch partners, industry and all others) in this collaboration should bring together the strategic plan into a working plan (Agenda) using this group as a taskforce. The taskforce should decide on how the outlined strategic goals can be achieved.

Despite the numerous activities that have been organized to encourage collaboration, cooperation among the various stakeholders is not yet very strong. Some respondents seem to be more positive about the current state of cooperation, having indicated that they currently see a positive outlook and political willingness, and a sense of urgency when it comes to developing the CEA ecosystem. Others indicated that the collaboration is still in its early stages. Industry is often eager to work with universities to develop new innovations. Current collaboration involves mostly large companies, but there needs to be a way for small innovators to share more knowledge. Collaboration will take time to build the critical relationships needed to ensure long-term sustainability.

There are differences in the level of collaboration not only between different stakeholders, but also within the government as one of the stakeholders. Collaboration varies across levels of government (local, state, regional, national), especially at the level of interaction between local and national governments. At the state and federal level, there is a more consistent understanding that CEA is a priority that presents an opportunity. To further develop collaboration, there is a need for a robust R&D facility within the system that must cover the entire state to disseminate this education and R&D throughout the state. There is a need for a strong horticultural industry to enhance collaboration, as is the case with the beef cattle industry, where there is strong collaboration among various stakeholders. Another possibility is to create a 'commodity group' for the CEA ecosystem that focuses on the bigger picture of how things work in the state, similar to the KY pork producer's commodity group (Kentucky Pork Producers, 2022) that helps fund the pork producers foundation with a dedicated staff to oversee education, promotion, and policy among stakeholders.

Research and training

Research is one of the fundamental aspects of knowledge sharing. As already noted in section 5.3.1 (Education, research and training), according to respondents, the amount of scientific and applied research related to CEA ecosystems is currently low. In order for this to increase, there is a need for vision and prioritization. It could be helpful if universities would work with the K-12 system to make research and training in this area a priority. There is also a need for more financial support to make this a priority. In this regard, the government can help by providing more funding for this type of research and personnel. Furthermore, to improve the quality of scientific and applied agricultural research, there is a need for knowledge sharing and research that directly relates to end users in the field. This can be done by establishing a group of researchers with a committee of farmers who can identify key research needs and opportunities. Furthermore, the CEA knowledge and experience from the Netherlands offers a great learning opportunity, but it should be tailored to KY.

Small-scale and traditional farmers should be involved in the collaboration and research process to ensure inclusiveness and continuity among stakeholders.

Another aspect of knowledge sharing is to begin training the workforce that will support this ecosystem. There is a need for a university degree or certification in this field or in the field of CEA, and interested students need to graduate from the universities that obtain this degree. The need for workforce training has already been discussed in the Education section.

5.3.3.1 Main takeaways and recommendations for Knowledge Diffusion

This section summarizes the key findings from the interviews regarding the needs and gaps for Knowledge diffusion to support the development of a CEA Ecosystem in KY and provides opportunities and recommendations to address these gaps.

Needs and Gaps:

- The current state of multi-stakeholder collaboration is perceived differently by different groups of stakeholders: the representatives from industry as well as from economic development groups are rather positive about the level of collaboration on development of a CEA Ecosystem at this stage, while the

representatives of academia and small-scale farmers and farmer associations believe that the collaboration between different stakeholders is not very strong yet
- Need for a robust statewide R&D network
- Need to provide statewide education on CEA and R&D
- Need to develop a strong horticultural industry and/or 'horticultural commodity group' that will help to further enhance the collaboration
- Need to transfer knowledge from the Netherlands to KY and tailor it to KY
- Need to involve small-scale and traditional farmers in the knowledge-sharing process.

Needs to enhance knowledge diffusion

The following needs were identified to improve innovation and communication about a CEA Ecosystem. There is a need:
- to bring knowledgeable and experienced people in the field of CEA to KY. For example, continuing to organize tours in the Netherlands will be very useful;
- for financial support for research and workforce training;
- to adapt and adopt innovation developed in KY at all technology levels, from low to mid to high-tech.

Opportunities and recommendations
- During the term of this project the Commonwealth of Kentucky submitted recently the Agritech Research & Development (ARD) Center Kentucky ('PATH Kentucky') into the Build Back Better program. If approved, this will jumpstart the development of the CEA Research and Development;
- Agricultural colleges in Kentucky should unite in an CEA education collaboration, comparable with the Dutch Green Pact.[36] Green Pact is the innovation platform and partnership for green education. The pact acts as a driver, accelerator and connector between business, education and government within the green life-style domain and beyond. This collaboration should also take place at national level in the U.S. to create a national CEA knowledge network with the name 'CEA Brainport U.S.', in analogy with the Dutch Brainport Eindhoven (Eindhoven, 2022);
- Encourage international academic collaborations, such as the now currently being developed between University of Kentucky and Wageningen University & Research. This should be coordinated by the University of Kentucky Department of Horticulture;
- The Extension Service, in cooperation with the USDA-NASS, should create a brochure containing financial and technical economic data on the CEA and update it every 2 years. As an example, the Dutch report entitled 'Quantitative Information for Greenhouse Horticulture (KWIN) 2019: key figures for vegetable, cut flower, pot and bedding plant crops' (Eveleens, Benninga, & Raaphorst, 2019). This offers entrepreneurs a great deal of insight and an independent reference work for CEA;
- The focus should not be on a short term, but on a longer term, which is more than 10 years. It is important that stakeholders understand that this requires a long-term focus, strong perseverance and not stopping after every disappointment. Stakeholders need to go ahead and believe in the system, but not rush it. Here it is recommended to develop a roadmap for the next 5 to 10 years of agriculture.

5.3.4 Creation of legitimacy

A legal framework is important for the creation and promotion of a CEA Ecosystem. This requires changes to existing regulations and the development of new legal acts (laws) or standards.

In terms of regulations, Kentucky tends to have some of the least stringent agricultural regulations in the country. Legislative changes, modifications or improvements are needed to establish a CEA Ecosystem. The state should develop a policy plan of what it wants, how it wants it, and this plan must include regulations on environmental issues, zoning and infrastructure laws, and incentive rules. For example, waste management for large greenhouses will need to be subject to environmental regulations. These policies should cover all farm sizes, so as not to restrict the access of small to medium-sized growers. Furthermore, regulations on incentives (e.g., tax incentives to promote market access or tax incentives to build in a certain area) are important to reduce the risk to farmers. Regulations to support infrastructure such as internet, roads, etc. are also important. There is a need for changes in water pricing and infrastructure and much more. The

[36] www.groenpact.nl

overall goal of state regulation is to be inclusive. Policy objectives are driven by industry activity and input. There is some policy development at the state legislature level that affects various agencies.

Currently, there does not appear to be a consensus among stakeholders on the state's specific regulations and changes related to CEA ecosystems. While respondents from academia believe that the creation of a CEA Ecosystem requires legislative changes, amendments or enhancements, including regulations related to environmental issues, land use and infrastructure legislation, and a policy plan and vision, respondents from state organizations believe that it is too early to talk about legislative changes before the critical mass of the industry is developed. The industry suggests that there is a need to establish a working group to help inform government on what is needed for ecosystem development and success.

Following are some thoughts on possible policy changes based on the interviews:

- Sustainable agriculture is first and foremost a way of thinking. This way of thinking needs to be introduced into relevant government strategies and then implemented by other programs and projects. However, to achieve the desired results, it is advisable to develop a clear action plan with strong financial resources, and promote programs aimed at changing attitudes.
- The government should define the boundaries of the CEA Ecosystem. This should include boundaries in the following key areas: a) environmental aspects - what is allowed, b) land use planning - where greenhouses can and cannot be built, c) linkage to energy sources.

Obstacles indicated by respondents

- The image of CEA is mixed. Questions are being raised about whether Kentucky is the best place to develop such an CEA ecosystem. Finding local labor for agricultural production is not easy. There are questions about the feasibility of the scale needed for an CEA system and against the cost/investment involved. Some producers are afraid of competition and thus the future of their business. Producers need to be educated what is achievable with this CEA Ecosystem and also shown how it will affect their businesses. Also, there are consumers with resistance, as they see greenhouses as artificial and potentially unhealthy.
- Geographical challenges: The topography of Eastern Kentucky is not the most ideal for large-scale CEA complexes and there are logistical challenges that need to be addressed.
- Infrastructure: Infrastructure such as broadband, roads, distribution, etc. will be a challenge. Energy is also an issue because of the CEA's large energy needs and the potential reluctance of energy companies with limited capacity to meet those needs. Cultivation and construction materials are more difficult to obtain because of the recent Covid-19 pandemic. Also, material costs have increased due to inflation and getting supplies into Kentucky may be a challenge.
- Risks: There is a risk associated with investing in any technology, as technology can quickly become obsolete, so there should be incentives for those who want to invest in new technology. There is also a need for incentives for building renewable energy, which should be a priority for this ecosystem.

Prospects indicated by the respondents:

- Access to food and health: The CEA ecosystem offers an increase in food production and thus can provide more fresh and local produce for the community, which can lead to positive health outcomes by increasing access to fresh produce. This ecosystem also has the potential to increase food security and affordability.
- Benefits for the community: New investment opportunities for entrepreneurs will emerge as the ecosystem develops, and companies from other states will be attracted to locate in KY. In addition, Kentucky has excellent land development opportunities, which will lead to economic and educational development, and create jobs for local residents. The ecosystem could also bring additional partners for donations and sponsorships to FFA, which will increase investment for FFA and agriculture teachers in schools. It is important that companies want to come and establish themselves in Kentucky, but also that research institutes are developed. In addition, Kentucky can become a regional food hub.
- Natural resources: The availability of fresh water and natural gas in Kentucky is a great opportunity, especially during times of price instability.
- Increased number of farms and farmland, increased grower revenue

5.3.4.1 Main take aways for a Creation of Legitimacy

Needs and Gaps:
- Lack of awareness of sustainable agriculture;
- No consensus among stakeholders on urgency of legislative changes toward sustainability;
- Mixed perception of CEA ecosystem by consumers and farmers;
- Geographical, infrastructural and workforce resource challenges;
- Concerns about the feasibility of an CEA Ecosystem (e.g. scale, investments, costs).

Opportunities and recommendations
- Legislative amendments in the following areas are advisable: a) waste management and environmental issues, b) spatial design - where greenhouses can and cannot be built, c) the linkages with energy sources- encouraging the use of renewable energy sources, d) affordable water;
- Changing negative perceptions of CEA Ecosystems by consumers and farmers by raising awareness using media and organized events accessible for a large public. Examples of such activities have been already described in section 5.3.1.2.;
- Establish synergies (cross-overs) between different industries and invest in infrastructure to address geographical, infrastructural and workforce resource challenges. The development of a CEA Ecosystem brings many opportunities to other existing sectors. For example, it may provide benefits to the medical R&D. There are also opportunities for the development of ancillary industries, such as waste management through composting, or alternative uses of waste products, e.g. for animal feed. The CEA Ecosystem could also benefit the logistics sector by reducing transportation costs. This could be done through joint logistics and shared packaging activities. In addition, this ecosystem could lead to business hubs and benefit CEA companies interested in pollination, crop protection control (IPM), water technology, etc. This will create jobs and also an opportunity to educate the community and attract a skilled, reliable workforce.

5.3.5 Resource mobilization

Resource mobilization is linked to the functions of education, training, research and knowledge diffusion through networking and the development of a vision for the CEA Ecosystem. Therefore, education and training needs should also be driven by the needs of the horticulture sector and linked to research and extension. A common vision for the CEA Ecosystem for the entire horticulture sector is necessary to facilitate success.

As discussed in Section 5.3.2, there is currently no common vision among stakeholders on how the CEA Ecosystem should be developed and on its feasibility. There is also a need for industry-specific knowledge on, for example, the physical construction and spatial design of CEA systems. In addition, there is a need for extension services specifically trained in greenhouse horticulture. Interviews revealed that there are currently few educational materials related to CEA in academic programs or curricula. Resources need to be allocated to address these deficiencies. In doing so, it is important that private companies are encouraged to invest and innovate. In addition, the state should provide direct financial and policy support for development activities. Policy instruments should be created that encourage behavioral change, such as incentive mechanisms to encourage the development of the CEA ecosystem.

Role of industry
Industry involvement is required, as the creation of an CEA ecosystem requires steel and glass manufacturing and engineering services with sensors and robotics, harvesting, packaging and logistics. Industry should invest to make the system work and to produce products along the supply chain. Here it is very important that production will be done in a sustainable way and follow the sustainability rules set by the government. Investing in a CEA Ecosystem will create new jobs, spur economic growth, and increase the quality of life in KY communities.

The necessary infrastructure must be built and an environment of competitive advantage created to attract growers. According to respondents, the U.S. is currently by far the fastest growing CEA market, but little to no infrastructure is in place.

Role of Government

The following governmental actions are considered by respondents to be essential for resources mobilization:

1. Take leadership in public private partnerships and societal impacts, especially during the beginning stages;
2. Take initiative when the private sector is not able to take that initiative and encourage the development by the private sectors;
3. Provide incentives with subsidies, tax incentives, sustainable activities, which in turn will attract business partners to create jobs and become less dependent on distribution chains broken by Covid-19;
4. Streamline and support business, so that companies are not bogged down with paperwork and permits to get started;
5. Connect with industry to hear their needs, welcome them, and accommodate them. KY needs to lead by example.

Role of consultants/advisors

The role of consultants/advisors is essential in mobilizing knowledge resources for the development of CEA. Here it is important to have consultants/advisors from the places where CEA has been successfully implemented. Experienced consultants can help avoid costly mistakes. There is a particular need for regional spatial experts. For example, the construction of a CEA greenhouse in Eastern KY should be done through a regional advisor who helps guide this process. This will help avoid the stigma of large companies coming in and ignoring the community. Advice from the Netherlands is important based on Dutch knowledge and experience in this area. This will be especially important in the early stages of developing KY's CEA Ecosystem. Consultants are important for the companies and also to help the government better understand the needs of the industry.

Consulting services should be used for:

1. plan in advance what types of facilities are needed;
2. learn what types of plants to grow and what will work well;
3. understand market forces and the potential for national or regionalized production;
4. optimize facilities, market aspects, financing and legal aspects.

Role of Farmers and Farmers' Associations

To get small farmers to embrace CEA approaches, they need to see the benefit to them and see the bigger picture. When people don't have enough information, they feel a threat and the best way to prevent that threat from growing is to get them involved and make them see the value and how it would benefit the overall economy, create new jobs, increase the tax base and help everyone. The first activity for farmers should be to develop new markets for their products. Markets differ for the small and large CEA producers. Here are opportunities for local farmers to work together to create larger volumes to sell to larger customers. New markets needs to be created where small farmers can sell their produce. Creation of markets has to go hand in hand with the investment in CEA technology.

5.3.5.1 Main takeaways for Resource Mobilization

Needs and Gaps:

- There is a gap between the willingness of schools to teach horticulture and the availability of teaching materials. Young people have no or very little interest in this sector. Kentucky needs an education system where they teach horticultural processes for CEA;
- Need to create or further develop government incentives for various purposes: 1) grant funding for research, 2) funds for education to support schools to educate students on the benefits of and opportunities for employment for CEA production 3) policy instruments that can bring about behavioral changes, such as tax incentives, rewards, tax deductions (or in some cases tax credits), 4) incentives to attract workforce development.

Opportunities and recommendations:

- Incentives and policy instruments that encourage behavioral change: Policy incentives and market-based tools can be very efficient instruments to stimulate the development of a CEA ecosystem and elicit behavioral changes.

- The Kentucky Department of Agricultural should develop an comprehensive incentive and regulation program for sustainable CEA investments through governmental instruments. In the Netherlands the government support has changed its scope since the nineties of last century from economic production support towards sustainable production support. This includes subsidies and tax deduction for sustainable technologies only.[37] The Kentucky Department of Agriculture in cooperation with RVO/NLWorks should explore how these instruments could be used in Kentucky in an adjusted formulation
- An incentive may be training grants with a bluegrass skills corporation tax credit, SBIR and STTR incentives for innovative projects (see Footnote 73). Providing tax breaks for hiring certain groups of people, such as those formerly incarcerated, who may be well suited as workers for these companies is another way to encourage labor. Taxation is often a sensitive issue, so at this point a tailored solution that fits the context is important. Subsidies have proven very effective in promoting innovation and transition in agriculture. This was the case in the U.S. in encouraging the transition to organic agriculture.
- Incentives for the workforce: Workforce is a major limiting factor in agriculture. The government could invest in more workforce training programs for CEA and EKCEP[38] training programs. Another suggestion is to make use of the Build Back Better ARPA[39] funds, as this helps to support workforce development or economic development in underserved communities.
- In Kentucky, housing can be an issue. Subsidies to help companies offer affordable housing for employees are recommended.
- Funding for specific workforce training certificates and college degrees that can train people for these careers and prepare the workforce for the new businesses. In the short-term term, it is advisable to train displaced coal miners who want to move to CEA.

[37] Examples are VAMIL/MIA (Rijksdienst voor Ondernemend Nederland, MIA en Vamil voor ondernemers, 2022), Green Label Greenhouse (Rijksdienst voor Ondernemend Nederland, Groen Label Kas, 2022), energy efficiency greenhouse horticulture (Rijksdienst voor Ondernemend Nederland, Energie-efficiëntie glastuinbouw (EG), 2022), Market Introduction Energy innovations Greenhouse Horticulture (Rijksdienst voor Ondernemend Nederland, Marktintroductie energie-innovaties glastuinbouw (MEI), 2022), Energy Investment Deduction (Rijksdienst voor Ondernemend Nederland, Energie-investeringsaftrek (EIA) voor ondernemers, 2022), Stimulation Sustainable Energy production and Climate Transition (*SDE*++) (Rijksdienst voor Ondernemend Nederland, Stimulering Duurzame Energieproductie en Klimaattransitie (SDE++), 2022).

[38] https://www.ekcep.org/

[39] ARPA (American Rescue Plan Act) will deliver $120,000,000 in federal funding to the City of Lexington to aid in economic recovery to ensure growth and equitable recovery from the Covid-19 pandemic. American Rescue Plan Act (ARPA) | City of Lexington (lexingtonky.gov)

6

Discussion

6 Discussion

The state of Kentucky faces an interesting challenge with its ambition to become a leader for CEA development of CEA in the U.S., with the goal of economic advancement and creating new jobs, especially in eastern Kentucky. While CEA is not new in Kentucky, high-tech CEA is. Professor Emery Emmert of the University of Kentucky laid the groundwork for the development of CEA in plastic tunnels in Kentucky in the 1950s, and the USDA-NRCS EQIP incentive program for High tunnels has also led Kentucky to lead the U.S. in the number of plastic tunnels. These tunnels are characterized as mid-tech in the technology spectrum of CEA. With the recent arrival of several high-tech CEA companies, interest and focus on high-tech CEA in Kentucky has substantially increased. This leads the Kentucky Agriculture Development Board to ask how both a large group of mid-tech and a small group of high-tech entrepreneurs, with all other stakeholders involved, can come together to realize the ambition of positioning Kentucky as a leader in CEA production. For this ambition to be realized, the following themes and practical recommendations should be considered:

1. Market expansion: Market pull versus technology push
There is a tendency to encourage horticultural producers to intensify production methods to CEA through a technology push. However, this intensification of production methods through the use of high-tech greenhouses or mid-tech tunnels requires an additional investment, which must be recouped to remain economically viable. The question then becomes whether the increase in production due to this intensification can be absorbed by the markets and paid out sufficiently. To obtain premium prices, the first important condition is to maintain premium quality and steady supply. This is crucial for success and thus requires good crop management.

However, there is a big difference in marketing structure for high-tech greenhouses and mid-tech tunnels. This has everything to do with the specialized production in high-tech greenhouses and the large volumes produced there. Producers of high-tech greenhouses are largely dependent on large trading parties who can distribute large volumes, for example through large-scale retail customers. These trading parties buy and sell across the US as well as import products from abroad. The quantities from high-tech greenhouses in Kentucky are still limited in volume, and there seems to be plenty of room to scale up that share with premium quality through these trading parties.

Producers of high tunnels sell mostly via direct markets such as on-farm retail markets, road-side stands, farmers markets, and community supported agriculture (CSA). These direct markets may provide the greatest premiums to producers of early crops. Also, they sell to local restaurants, especially restaurants willing to pay premium prices for early and late season, locally grown crops. Early and late-season crops could also be marketed wholesale to grocery stores and through produce auctions. Here, by scaling up the intensification (from mid-tech to high-tech), the problem arises that these channels can no longer absorb the larger volume of product and new outlets must be found to market the product. This is crucial to ensure market-pull for increasing demand. To this end, these small-scale entrepreneurs will have to learn how to build and manage supply chains, contracting, and long-term sales agreements with wholesalers or retailers is a point of attention. They need to learn new skills how to assess chain partners and consider a way to cooperate. For example, they could start cooperating more through producers' associations (PAs) or through further cooperation of produce auctions. By aggregating the supply of these small producers into large blocks of volumes of the same product with the same level of quality, these parties become more interesting to regional traders who serve the institutional regional markets (e.g. supermarket chains in Kentucky, restaurant chains in the region, etc) and need more volumes of lots to do so. This creates a market-pull for further intensification rather than via a technology push. Market pull and technology push should happen hand in hand.

2. Competitiveness: is CEA in Kentucky able to compete?
The key question is how Kentucky CEA farms can be competitive, because vegetable production, particularly at the wholesale level, is a highly competitive market. For the U.S., Mexico is the largest importer of

vegetables, and the share of these imports has only grown in recent years and does not yet seem to be slowing down. Mexico exports mainly fruit vegetables tomatoes and peppers, with the share produced in CEA only increasing and with it the quality. The legitimate question is then: how can CEA in Kentucky compete with this? Is that even possible? And how can it happen ?

The challenge: labor is 10 times cheaper in Mexico than in Kentucky; energy costs are substantially higher in Kentucky compared to Mexico because of the colder winters; and investments in greenhouses and associated financial burdens are higher in Kentucky than in Mexico. Only the cost of water and transportation costs from Mexico to the US mid-west markets are higher for Mexican companies. The contribution of water costs to the total are limited. It seems that this will be a close call concerning the cost price. More insight into cost price calculation for both mid-tech and high-tech is required.

More important is the question whether the US customer is also willing to pay a higher price for a US product or local product than for an imported product. For a bulk product, that seems unlikely. For a niche product it is probably true. The question then becomes how much more the consumer will be willing to pay. More insight into this is needed.

In short, the tension is that CEA production in Kentucky can hardly compete from similar (bulk) products produced in Mexico. CEA production in Kentucky should focus on:

- vegetable varieties that are not imported from Mexico
- vulnerable products with short shelf life (strawberries, leavy greens, etc.)
- high-end products (infant food, specialty crops e.g. different colors, sizes, snack vegetables, fresh herbs, etc.)
- more added value (fresh washed, packed, ready-to-eat, ready-to-cook, etc.)
- ingredients for the pharmaceutical or cosmetic industries (medicinal herbs, vanilla, etc.)
- ornamentals (indoor and outdoor plants and flowers) that fit the regional market climate
- marginal land development: taking land into production that is normally not suited for agriculture.

3. Best locations with regard to clustering

From the location suitability potential assessment, Central Kentucky, close to highway I-75 (North-South) and highway I-64 (East-West) seems to be the most suitable area for the development of an CEA Ecosystem, and especially for future project-based locations of greenhouses and other related activities inside and outside the value chain. Some important aspects in this regard are:

- Logistics. Near to highways, maximum 1 day trip of a truck (approximately 800 km/500 miles) to distribution centres (DCs) of traders/customers;
- Sustainable energy sources, for example, a location close to industries that have residual heat, such as energy power plants or data centers. Or in areas where renewable energy (e.g. geothermal heat) is available;
- Available skilled workforce. Close to a city is better, given the availability of workforce that is well educated;
- Water availability. Although Kentucky has enough rainwater that can be collected for the water supply, the availability of additional suitable fresh water is important to supplement shortages in rainwater;
- Waste management (rockwool, plant stocks after growing season, plastics, polluted drain water, etc.) can be done cooperatively, creating more volumes of waste which might be processed in an economically viable way due to scale;
- Aesthetic landscape design. Greenhouses, especially large-scale greenhouse buildings should fit into the landscape. This does not fit everywhere and depends for example on the natural value of a landscape. In addition, possible emissions such as light pollution at night, surface water emissions, etc. must be taken into account. On the other hand, greenhouses should not be placed on an industrial estate (not being food-related) either. It requires a delicate balance in which the support of the local population is important.

4. Available labor force

As described above, high-tech greenhouse in the Netherlands requires approximately 3.5-5 fulltime workers per ha/year for cultivation work and 0.3 fulltime worker per ha/year for management. The feedback from Kentucky growers is that the need for labor is still double that of the Netherlands. If we estimate 250 acres (approximately 100 ha) existing high-tech greenhouses in Kentucky, there is a need for 750-1.000 workers

and 60 managers today. If we assume a doubling in the next 2 years, there is a need for another 1.500-2.000 workers and 120 managers. The question is are these people available? And are they skilled enough?

The amount of unemployed people in the eastern part of Kentucky could create opportunities for filling labor pool. However, the main question is if these people are willing to move to where the optimal locations for greenhouses exist (see point 3).

Current feedback suggests that hiring a local workforce is challenging and that there are still labor shortages at the most optimal locations for greenhouse horticulture. Also, the work attitude and efficiency are sometimes not enough for this type of work. This is a similar trend to what has happened in the Netherlands. Also, the influx of younger members of the workforce who want to work in CEA is still insufficient. The H2A program will therefore certainly have to be maintained, taking into account the year-round presence of foreigners in this scheme, given the year-round production in the greenhouses. It will also be necessary to attract labor especially from the cities, to meet the labor needs.

5. Invest in AKIS: Education, R&D and Innovation

This is one of the key components for the short term: investing in the CEA Knowledge & Innovation system, concerning education, R&D centers, innovation & demo-centres.

Managing high-tech CEA is top sport, similar to driving a Formula 1 race car. It requires the right competencies & skills, otherwise what's in it won't be extracted. These skills are required at all levels in CEA company (operational work force (e.g. pickers, leave cutters), middle management, high management, specialists (irrigation & nutrients, crop protection, climate, technical experts, data experts), sales department, directors, etc. And not only in production, but also at chain partners like traders, seed companies, technical suppliers, banking, insurances, etc.

Why in the short term? Because it takes several years to build a knowledge base that matches the expertise required by the CEA industry. Especially in the start-up phase of new high-tech CEA companies, their main concern is to produce volumes of sufficient quality competitively. The need is there now.

Points of discussion are:

- Is it wise to invest heavily in the AKIS already now that the CEA ecosystem is still in its infancy and has yet to prove itself? Fortunately, we see that there is still plenty of investment in CEA in Kentucky, both in high tunnels and greenhouses as well as indoor farming. There is growth of the ecosystem and hundreds more jobs will be created in this sector in the coming years. So investing in AKIS seems useful and necessary and can also give a positive contribution towards the public opinion.
- A comprehensive program most supportive to firms in a CEA industry would include agronomic production, genetics, greenhouse systems and technology, robotics, energy efficiency engineering, healthy life styles, water management, waste management together with strong linkages to the commercial produce and ornamental industry.
  In doing so, you could change gears quickly and efficiently by not reinventing the wheel but by using the CEA curricula, skills and experiences of, for example, Dutch schools (medium and high schools, such as HAS Den Bosch, InHolland, Fontys, MBO Westland, Aeres High School, CAH Dronten, WUR, etc.) and to 'adapt' them to the Kentucky situation. This can also be done by cooperating with educational institutions in the U.S. that have experience with CEA.
- Do not underestimate the learning capacity of entrepreneurs. Most producers learn by seeing what their fellow producers are doing and discussing it with each other, and by seeing what latest innovations have been demonstrated in demonstration centers. That is why knowledge exchange networks are so important, and demonstration centers. And that is why it is so important that the application for an Agritech Research & Development (ARD) Center Kentucky would be approved through the Build Back Better program. This will be a CEA research and development facility focused on sustainable agriculture methods. The Agritech Innovation Hub will develop a program to be implemented at the ARD Center. The goals of the program will be to drive innovation of current agricultural technologies such as CEA production, storage improvements, waste management, and distribution. The project will foster an AgTech launchpad for testing engineering, artificial intelligence, sensors, and robotics that will transform our nation's food supply and contribute to food resiliency (SOAR, EDA Build Back Better Regional Challenge, 2022).

The location of this ARD Center should be at a strategically suitable location for CEA. The location analysis in the Inception Phase shows that Central Kentucky seems to be suitable, especially considering the future potential of circular CEA in that area, available workforce, accessibility and proximity to sales market. Such a central location is easily accessible to both high-tech growers and the more traditional low- & mid-tech growers. It should be a place for anyone who wants to learn about the application of CEA solutions. Thus, it is a crucial component in embodying the ecosystem as the place where both public and private partners pool knowledge and skills (business/demonstration, education and training, and government participation).

- How will young people be interested to working in CEA? As in the Netherlands and in Kentucky, it is difficult to get young people interested in working in agriculture. Although CEA offers a whole spectrum of new interesting jobs, like genetics, biology, robotics, block chain, data management, healthy foods, renewable energy, etc., most people do not have an idea. This calls for an integrated approach This calls for an integrated approach to raising awareness among young people at home, at school, in places they like to go and through social media.
- How do you get research with impact for the private sector? One way of doing this is through public-private partnerships (PPP) in research projects. This means that the private parties contribute in cash & kind to the research, which drives the researchers to ensure that the outcomes are practically applicable to the participating private parties. A special budget for this CEA PPP research program could be guaranteed by the government, whereby research projects are selected annually through public-private cooperation (compare yearly PPP tender of the Top Sector Horticulture & Starting Materials in the Netherlands) (KIA *landbouw water voedsel*, Regelingen, 2022). In addition to the needs of the private sector, the government can also determine their important themes for research such as stimulating circular CEA, reducing emissions, robotization and automation, market development and business case development for financially sustainable CEA production in Kentucky, valorization of CEA waste streams, etc.

6. Sustainable CEA

Growth of the CEA ecosystem is important. But equally important is making that growth sustainable. Economic growth and sustainability hand-in-hand. CEA contributes to UN Development Goals in many ways, but there are some particular areas of concern.

Most important is attention to sustainable energy for heating, cooling and lighting to keep CO_2 emissions as low as possible. The use of energy-saving measures such as screens, LED lighting, exhaust gas condensers, etc. is important in this regard. Subsequently, sufficient knowledge among entrepreneurs of energy-efficient climate control in the greenhouse is also important. And of course other energy sources than natural gas, such as residual heat and geothermal energy are also important.

Another point is to use as few chemical crop protection agents as possible. The use of Integral Pest Management (IPM), including the use of natural enemies bumblebee pollination, microbials and biostimulants, is quite feasible in CEA and should be encouraged to the full.

Next, the emission of nutrients via drain water should be limited as much as possible by stimulating recirculation systems for irrigation in combination with drip irrigation systems and if that is not possible purifying drain water if there are problems with excess nutrients in surface water. Long term storage of rainwater on the farms themselves is crucial in this regard (in the Netherlands this is at least 6,743 ft^3/acre greenhouse or 500 m^3/ha greenhouse).

Finally, the valorization of waste streams is also important: recycling of the grow medium rockwool and gasification or composting of plant stocks after growing season, and recycling of plastics within the region of Kentucky would be nice.

7. Public opinion

Communication with society is seen as very important from the AKIS interviewees' responses because CEA is a relatively unknown concept in Kentucky. And unknown makes unsupported.

- Provide a good narrative that is easily digestible; not a story that explains the technical method of production, but more the importance of a healthy, fresh and safe product that is made possible precisely through CEA. Explain clearly what the Triple Helix and a greenport model is. Make it clear with examples and preferably examples that relate to them like horses and the bourbon industry.

- The proposed newly built Kentucky Horti Centre (PATH BBB) can also play an important role in this as a visible demo center for the public. All kinds of activities can also be initiated here, such as open days, food festivals, vegetable & flower parades, etc.
- Last but not least the public support for the siting policy for CEA with regard to landscaping is important.

8. Cultivating a CEA Triple Helix for Kentucky

A good cooperation of government, industry and knowledge institutions is the basis for a well-functioning CEA Ecosystem. This cooperation is called the Triple Helix. Institutions representing each of the three arenas bring unique perspectives and capabilities to build and cultivate an economic environment in which CEA can be successful. Government (policy, economic development, public service), industry (CEA growers, value chain partners) and knowledge institutions (research, skill development, Extension and industry support) all have valuable perspectives to contribute to long term CEA industry development. A point of attention is the involvement of more companies in developing the CEA ecosystem. This is very important and can create a pull effect. These new actors will most likely increase the economic significance and sustainability. They can be parties within the horticultural value chain, such as traders, auctions, logistic service providers, or outside the horticultural value chain, such as providers of renewable energy, waste management and the food industry.

A strong and engaged planning base can be developed with intentionality that can together develop strategies for cluster development, workforce development, supply chain coordination, market development, energy utilization, and the creation of thoughtful policies leading a healthy, high performing industry in Kentucky.

The Dutch Greenport model discussed earlier could eventually be a model for establishing this kind of governance and cross-agency engagement. These Dutch Greenports allow for the development highly localized clusters – a potential model for a large and geographically diverse state like Kentucky.

This three-way coordinated industry development strategy spans the broader recommendations outlined in the next section. These agencies will need to work together within Kentucky to maximize knowledge sharing, innovation, CEA resource and workforce development, and markets, and in a way that will be sustainable.

7

Recommendations

7 Recommendations

1. Establish a state-wide CEA Industry Development Taskforce
The most important recommendation is to establish a state-wide CEA Industry Development Taskforce. Its board would include CEA producers, traders, technology suppliers, local education and research institutions, and leading government agencies. In particular, ensure representation from SMEs (small-medium enterprises) in the CEA value chain. It is worth exploring whether there is eventually a need for more regional greenports, closer to the emerging clusters and possibly representing other specializations within horticulture than CEA (e.g. fruits or field vegetables).

One of the first tasks of this Taskforce is to create a shared vision, strategy and agenda for a Kentucky CEA Industry Development Strategy 2022-2030 (comparable to the Dutch Horticultural Agenda 2020-2030) (Greenports Nederland, Samenwerken is Groeien samen aan de slag, 2022). This will ensure that there is an action plan in which each party takes responsibility in the collaboration and plans are developed that are inclusive and implementable. Working groups appointed by the Taskforce can be assigned to develop in more detail specific and on-going recommendations around CEA issues such as workforce development, market development, R&D, knowledge sharing, energy, CEA social acceptance messaging, and other issues identified within this report. All of the recommendations in this report can be an important input to the shared vision, strategy and agenda designed by the Taskforce.

The Taskforce should report regularly to all industry stakeholders and agency leaders, with updated analyses of issues and recommendations for industry progress. One example would be to hold an annual CEA conference for all CEA involved companies and institutions across the state, where key relevant issues would be presented and progress on the agenda would be discussed with participants.

Action:
1.1 The Kentucky Department of Agriculture should take the initiative to create this CEA Industry Development Taskforce, including balanced organization representation. A non-partisan chair should be appointed to lead the Taskforce. Funding to set up the CEA Taskforce initially could come from the KADB and those counties where significant new CEA facilities have been and will be located. Longer-term costs for the Taskforce can be covered by in-kind contributions from the farmer and industry partners, representative knowledge institutions, and appropriate government agencies. Longer-term support for the Taskforce could also be considered in tandem with wider Kentucky horticulture industry development initiatives proposed by the Kentucky Horticulture Council.

2. Establishing a Kentucky Greenhouse Growers Council
To represent existing and new greenhouse enterprises throughout Kentucky, a strong, cohesive professional member organisation of growers, suppliers, and academic specialists is needed. The organization would serve as a state-wide voice for the CEA segment focusing on public policy, legislation, and identifying and addressing issues and threat to profitability. To date, Michigan has two strong regional grower organizations and a state-wide council that accomplishes the aforementioned services. Other U.S. states where greenhouse horticulture is of economic significance, i.e., North Carolina, New York, and Virginia, and states where greenhouse horticulture is of lesser economic significance, Indiana and Connecticut, all have state-wide greenhouse grower organizations that support growers through research, education, and service.

Action:
2.1 The University of Kentucky Department of Horticulture and the Kentucky Horticulture Council should take the initiative to create this Kentucky Greenhouse Growers Council. This council should establish CEA growers networks in different regions to share technology and marketing experiences. The council would be eligible to be part of the Kentucky Horticulture Council. In addition this council should explore opportunities for CEA network economies that have been developed in places mentioned above, but also in other countries such as the Netherlands and Canada.

3. Invest and develop CEA Research & Development, Extension, and Innovation networks

This is one of the most important recommendations for the short term: investing and developing the CEA Knowledge & Innovation system, concerning R&D centers, innovation & demo-centers. The following actions are defined below:

Action:

3.1 If the Agritech Research & Development (ARD) Center Kentucky ('PATH Kentucky') will be approved by the Build Back Better program, this will mean a jumpstart for the development of the CEA Research and Development. Just recently, the proposal for an UPIKE AgTech Innovation Center of Excellence, has been approved already. Both CEA research and development facilities, focusing on sustainable agriculture methods, will be the centers for knowledge development, demonstrations and business development. The location of the Agritech Research & Development (ARD) Center should be at a strategically suitable location, considering the future potential of circular CEA in that area, available workforce and market potential. The UPIKE AgTech Innovation Center is planned to be located in Pikeville in the Eastern part of the state.

3.2 The KDA and the CEA Industry Development Taskforce should develop a comprehensive research program most supportive to firms in a CEA industry in Kentucky. This research program should focus on the sustainable production and trade of vegetables and ornamentals, and the relevant knowledge questions that exist in these chains. Research projects are selected annually through public-private cooperation in which the private sector is contributing in cash and kind to the research projects (compare yearly PPP tender of the Top Sector Horticulture & Starting Materials in the Netherlands) (KIA landbouw water voedsel, Kennis- En Innovatieagenda Landbouw, Water, Voedsel 2020-2023, 2022).

3.3 The KADB should evaluate the Dutch Coupon (in Dutch: *Voucher*) program whether this would be implementable in Kentucky (Rijksdienst voor Ondernemend Nederland, MIT: Kennisvouchers, 2022). This is a program for entrepreneurs, who can apply for a 'coupon' from the government to purchase knowledge from knowledge institutions and research companies. With this coupon the entrepreneur, together or individually, can pay a maximum of 50% of the invoice of the knowledge institution.

3.4 There should be investment in CEA specialization skills for the extension workers, as well as investment in staffing levels. Most extension workers are broadly trained, and are not enough specialist in the field of CEA. This is mainly due to a lack of knowledge and skills. As a result, they cannot properly advise growers on how to make the best use of the high tunnels or greenhouses, leaving much potential untapped. There is still a lot of potential for improvement here.

3.5 The Extension Service should organize a knowledge enhancement program for CEA farmers or farmers interested in CEA, consisting of demonstrations at existing experienced CEA farms in coordination and cooperation with the planned Agritech Research & Development (ARD) Center Kentucky (PATH-Kentucky) and planned UPIKE AgTech Innovation Center of Excellence.

3.6 The Extension Service, in cooperation with the USDA-NASS, should create a brochure containing financial and technical economic data on the CEA and update it every 2 years. As an example, the Dutch report entitled 'Quantitative Information for Greenhouse Horticulture (KWIN) 2019: key figures for vegetable, cut flower, pot and bedding plant crops. This offers entrepreneurs a great deal of insight and an independent reference work for CEA.

3.7 The University of Kentucky together with other academic partners in the state and in the US should set up a CEA knowledge network in the U.S. with the name 'CEA Brainport U.S.', in analogy with the Dutch Brainport Eindhoven (Brainport Eindhoven, 2022)

3.8 Encourage international academic collaborations, such as the now currently being developed between University of Kentucky and Wageningen University & Research. This should be coordinated by the University of Kentucky Department of Horticulture

4. Invest and develop CEA Educational programs

For the development of the CEA industry, it is important that new young people are properly trained that matches the requirements and needs of the private companies. It appears that CEA education throughout the learning chain (from elementary school to University) still has a big development step to make. This requires the highest priority in the short term.

Action:

4.1 Academic institutions with agriculture and horticulture programs in Kentucky could unite in an CEA education & innovation platform, in analogy with Dutch Green Pact (Groenpact, 2022): by acting as a booster, accelerator and connector between business, education and government within the green lifestyle domain, the impact of educational institutions will be enhanced. The Kentucky Department of Education should evaluate this Green Pact approach, whether this would be interesting for Kentucky.

4.2 Establish student exchange programs between Kentucky Academic Institutions and those in the Netherlands. This is being led by the Council on Post-secondary Education (CPE).

4.3 Develop a coordinated CEA curriculum across the whole learning chain (from elementary school to University). The CPE and Kentucky Education Association (KEA) association should coordinate this.

4.4 Procurement of knowledge and teaching materials by the agricultural colleges associated with CEA in Kentucky from the applied agricultural Dutch schools.

4.5 Framing and promoting CEA education as a *green lifestyle* education instead of an agricultural education.

4.6 Demonstrations of CEA in schools such as the ongoing program AgTech classroom program of Appharvest which is already at more than a dozen schools.

5. Establish a clear pathway for open field and low- and mid-tech high tunnel growers to grow towards high-tech CEA production

The vast majority of CEA producers in Kentucky produce in high plastic tunnels, which can be classified as low- & mid-tech. Thus, to build a CEA cluster in Kentucky, it is important to identify and support this group to the next step in moving toward a sustainable high-tech CEA industry. This requires additional mid-tech (towards high-tech) technology and knowledge that matches the development stage and financial capabilities of these entrepreneurs.

Action:

5.1 The CEA Industry Development Taskforce should evaluate and demonstrate new and applicable technologies by CEA technology supplying companies (f.e. in the U.S., Canada, France, Israel, and the Netherlands) for potential use in Kentucky. The results of the ongoing NLWorks project into the application of suitable and affordable applied technology for low- and mid-tech growers can be used here.

5.2 The Taskforce should investigate the affordable availability of capital and insurance options for CEA development for companies developing from mid-tech to high-tech, as well as for high-tech companies.

6. Encourage Market Development and Value Chain Management for Kentucky-based CEA Firms Through Cooperation

With the expected growth of CEA in Kentucky, additional volumes of vegetables will be produced and new markets will need to be opened up in Kentucky and surrounding states. This will require further cooperation between entrepreneurs and marketing organizations to bundle volumes of the same quality to open up new markets that are now less accessible to small entrepreneurs.

Action:

6.1 The Taskforce should increase marketing opportunities for small-scale growers to open up new direct markets and institutional markets in Kentucky and surrounding states, through a coordinated marketing approach to further cooperation among growers, auctions and traders in Kentucky.

6.2 The Taskforce and KDA should invest in a chain management knowledge building program for growers and other stakeholders in the CEA value chain. Experiences from the Dutch Agricultural Chain Knowledge Program40 (1994-2008) could be useful in this regard.

6.3 The Kentucky Department of Agriculture could examine how the European Common Market Organization instrument (EUR-Lex, 2021) could be utilized in Kentucky in an adjusted formulation. In Europe registered producers' organizations (such as auctions) for the sale of fruit and vegetables can receive 50% subsidy for market and technological innovations.

[40] https://www.akk.nl/

7. Develop a CEA workforce development plan in collaboration with the CEA Industry Development Taskforce

In the past two years, hundreds of people have been employed in the CEA industry. These numbers are expected to double in the next two years. Many of these people have had no training in CEA. Thus, they will all need to be retrained and up-skilled. This will require a lot of effort from the private sector in cooperation with the public sector in the coming years.

Action:

7.1 CEA Industry Development Taskforce should design a workforce development plan with the main focus of training existing staff working in CEA. This should be aligned with the existing workforce training initiatives, such as the Bluegrass State Skills Corp. Grant Reimbursement (via the Kentucky Cabinet for Economic Development), and KCTCS-TRAINS Funding (Team Kentucky Cabinet for Economic Development) as also with the services that private companies offer such as PRIVA-academy (Priva, 2022) or Dutch knowledge companies such as Hortitech or GreenQ.

7.2 Specialized staffing agencies for CEA should be encouraged and the development of workforce training should be prioritized.

8. Develop and Pursue a CEA Spatial Development Strategy Involving State and Local Agency Partners

Currently, the location of new CEA buildings to be built is not regulated in Kentucky. In the Netherlands, greenhouses may only be built in specifically designated locations because the limited availability of land and because of the cluster advantages in terms of energy, water, logistics and limiting the hindrance aspects such as light pollution, cluttering of the landscape, unwanted emissions to the environment. Although the area of agricultural land is large enough in Kentucky and the proportion of plastic tunnels and greenhouses is still relatively small compared with the available agricultural land, thinking strategically about settlement locations is important because of the benefits of clustering and mitigation of the disadvantages of CEA.

Action:

8.1 Develop and pursue a CEA spatial development strategy, taking into account that Central Kentucky is most suitable for CEA development. An in-depth analysis for optimal location assessment is needed, taking into account logistics, distance to DCs, sustainable energy possibilities, distance to cities, workforce availability, water availability, land use priorities, and esthetics. Included in this strategy is an evaluation of the potential of CEA clustering on specific physical locations of 250-1,000 acres (100-400 ha). Also the optimal location of the Agritech Research & Development (ARD) Center Kentucky (PATH project in Build Back Better program) should be at a strategically suitable location for CEA in Central Kentucky.

8.2 CEA industry should work with the Kentucky Energy and Environmental Cabinet to identify integrated, site specific options for purchasing energy and maximizing energy efficiency. This should include a focus on utilizing alternative energy sources, onsite and offsite as appropriate (link with action 9.1 and 9.2).

8.3 Additional research is needed into if and how CEA can be legally qualified as an agricultural activity in spatial designing.

9. Devise and plan for sustainability within Kentucky's CEA ecosystem

Emission free and circular CEA are the mayor challenges for a CEA sustainability plan: this means no emissions of CO_2, (chemical) nutrients and crop protections means into the environment and valorization of side and waste streams like plant and growing materials.

Action:

9.1 Study for the usage of sustainable energy in CEA: how the Kentucky CEA industry can become less dependent on fossil fuels: what are the opportunities for geothermal heat, hydro-, sun- and wind-energy. Where are opportunities for collaboration with industry with waste heat, like powerplants, data centers, etc.?

9.2 Study how cogeneration (Combined Heat & Power (CHP)) in CEA can be used in cooperation with the state energy supply industry.

9.3 The CEA industry, through the Growers Council and University partners should evaluate current waste management options and limitations and identify future needs. New waste management companies being developed in KY should be supported and incentivized. This effort should be coordinated with the Kentucky Energy and Environmental Cabinet.

9.4 The Kentucky Department of Agriculture should develop an comprehensive incentive and regulation program for sustainable CEA investments through governmental instruments. In the Netherlands the government support has changed its scope since the nineties of last century from economic production support towards sustainable production support. This includes subsidies and tax deduction for sustainable technologies only. The Kentucky Department of Agriculture in cooperation with RVO/NLWorks should explore how these instruments could be utilized in Kentucky in an adjusted formulation.

10. CEA communication with society

Communication with society is seen as very important for societal support in the further development of CEA industry in Kentucky.

Action:

10.1 The Taskforce should provide a good narrative that is easily digestible in which CEA provides healthy, fresh and safe products and new interesting jobs. Explain clearly what the Triple Helix and a Greenport model is. Make it clear with examples and preferably examples that relate to them like horses and the bourbon industry.

10.2 The Taskforce should organize an annual open day for general public to show how the products are grown in analogy with the Dutch 'Welcome in the Greenhouse' (Kom in de kas) (Kom in de Kas, 2022).

10.3 The Taskforce should organize an annual Food Festival in the state of Kentucky with the goal of informing and inspiring consumers about healthy food and sustainable production systems like CEA.

10.4 The Taskforce should organize recreational activities such as flower parades or vegetable and fruit parades, like there are in the Netherlands (Bollenstreek, 2022).

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Appendices

Appendix 1 Roles of stakeholders and success and failure factors in the development of Dutch agroclusters

Roles

The development of an agrocluster is in almost all cases taken in hand by a large number of parties, with mostly the municipality taking the lead in the cooperation structures that are formed. This is also logical from a financial perspective because the municipalities often receive some kind of subsidiary from the national government. Parties involved are: municipality, province, entrepreneurs, banks, project developers and many others such as water authorities, energy companies, sector organizations, regional associations of municipalities, ministries, private consultancies, brokers, but also societal organizations such as nature and environmental organizations.

The interests of the above parties partly run parallel but there are also some differences. The interests of each party with respect to the development of a greenhouse horticultural area are discussed below:

- National government: preservation of an economically powerful, sustainably developing and spatially well-suited greenhouse horticulture sector.
- Provinces: stimulator behind the cluster development, with the main interests of promoting the provincial economy and employment and stimulating capital-intensive agriculture, partly as an alternative to the redevelopment of other agricultural functions.
- Municipalities: initiator and (co-)implementer and co-financier with the main interest of promoting the local economy and employment.
- Water authorities: importance of good integration in water systems and responsible water drainage and storage.
- Sector organisations: to obtain sufficient space for the development of the sector including the necessary restructuring, preferably in connection with agrologistics centers.
- Project development companies: to develop a greenhouse location in a profitable way.
- Banks and other financial institutions: helping to finance the development of glasshouse locations for profit.
- Nature and environmental organisations and the public: fitting glasshouse locations into the environment in spatial terms and developing them sustainably, assuming that such locations are developed.

Public acceptance

Crucial to the development of an agrocluster is the role of the municipality or municipalities where the agrocluster is to be developed. Administrative support within the municipality and the ambition, often as an economic pull factor and as an opportunity for employment, to develop glass and to co-invest in this, turn out to be a very important factor for the development of the agrocluster (making it ready for distribution and recruiting companies). It appears that the administrative support is higher in municipalities that have a strong interest in greenhouse horticulture than in municipalities where this is not the case. Public acceptance for greenhouse horticulture plays a crucial role in gaining support for the development of new or expansion of existing greenhouse horticulture areas. The general rule is that in areas where glasshouse horticulture is a significant socio-economic factor, public support is often greater than in areas where this is not the case.

Success and failure factors in the development of a location (planning process)

Administrative support in the region is crucial to the development of an agrocluster. Administrative support within the municipality and the ambition to develop glass, often as an economic pull factor and as an opportunity for employment, and also to co-invest in this, turns out to be a very important factor for the development of the agrocluster (making it ready for distribution and recruiting companies). Setting up and implementing a good process is at least as important for the successful development of the agrocluster as the physical measures (space and availability of infrastructure).

In addition to the pull factors or the location factors that were already assumed to be important at the time the agrocluster was designated, the following location factors also emerge:

- integral vision on the development of the area
- sustainability as a selling point
- favorable location in relation to agrologistics facilities and/or existing glasshouse centers
- profiling of the municipality as a greenhouse horticulture municipality
- presence of a social network and horticultural culture
- attractive price-quality ratio and/or low land price.

Factors that stagnate the development of an agrocluster after completion of planning procedures are:

- degree to which land acquisition is successful
- the importance of the first entrepreneur setting up at a location and getting others to follow (the first sheep to cross the dam)
- limitation of investment risk by the project developer and/or municipality
- the market for project development of the agrocluster is structurally unattractive
- insufficient knowledge of the sector
- too limited cooperation with existing greenhouse horticulture centers and knowledge institutes
- moderate to poor market conditions (lower growth) due to economic development
- image of an area
- attractive residential environment
- investment density per m^2 is high, so that the land price need not be a decisive factor.

Appendix 2 Governance of the Dutch horticultural cluster

In this section we will consider the governance of horticulture and in particular of the horticultural cluster. Although there is much to be said about it, especially given the changes in the last 20 years, we would like to highlight the following main points:

1. Trade associations
2. Product Board for Horticulture
3. Greenports Netherlands
4. Top Sector Horticulture & Starting Materials

A key message of this section is that for good governance, it is important that all parties involved in horticulture, whether or not organized in trade and industry associations, government agencies (at all levels) and knowledge institutions work together to build the horticultural cluster. Each with its own contribution, task and responsibility. This requires mutual trust and a willingness to make concessions.

Re 1) Sector organizations

Horticulture is traditionally characterized by a large number of small businesses. To still have an impact in all kinds of areas, the sector has organized itself into sector organizations. Despite the fact that the number of companies has fallen sharply and the size of the companies has increased significantly, trade organizations still play a strong role in the themes of labor, sustainability, market access, market information, standardization and IT. They are an important interlocutor for the government.

Although horticulture comes across as a single cluster, it is characterized by many subsectors such as fruit & vegetables, ornamental horticulture, trees, bulbs, open field vegetables, mushrooms. Many of these producers are represented by several branch organizations. In addition, the chain links such as traders are also represented in their own branch organizations for each subsector. Finally, there are also sector organizations for the supply industry and for plant reproduction materials. Together, this forms a small dozen of sectoral organization players, who sometimes act individually or want to act jointly, sometimes tackle a particular issue together and sometimes even oppose each other in terms of their importance in certain dossiers. That makes it a dynamic whole. In the past the cooperation was formally laid down in the Horticultural Product Board. More about that later. Today, cooperation takes place via the Greenports Netherlands. And in certain areas trade associations are working together, for example in the new organization called PlantNed International,[41] which is aimed at intensifying cooperation in the international trade sector.

Re 2) Product Board for Horticulture

An important administrative institute which has played a role in the development of the horticultural cluster is the Product Board for Horticulture. It was established on 1 January 1997 from the Joint Secretariat of the Product Board for Ornamental Crops and the Product Board for Fruit and Vegetables, both of which were founded in 1956. The Horticulture Product Board was dissolved in 2015.

A product board was a Dutch public-law organization of the companies in a so-called 'production column': breeders, propagators, plant breeders, growers, auctions, traders, manufacturers, green space/gardeners, retailers and their employees.

A product board had public law status and thus usually also the power to levy taxes and establish certain rules, but at the same time it also functioned as an interest organization for companies in the industry and as an advisory body for the government.

[41] www.plantnet.international/nl/#

Broadly speaking, the product board had three functions:[42]
1. it was the consultation platform of horticulture
2. it was a hub of knowledge
3. it was the (private) government of the horticultural sector.

With these functions the product board served the interests of the horticulture and green space sector and a social interest. It did this in cooperation with the branch organizations and trade unions. It pleads with the government for favourable conditions for running a business. For example, multi-year agreements have been made with the government to reduce the usage of crop protection products, energy and packaging. It tries to adjust the regulations so that the companies can implement them practically. (Source: Wikipedia)

Financial means
The product board also had financial means for numerous activities for growers and traders: for example promotion, inspections, information, labour market research and research at test stations and institutes. With these activities the PT wants to secure and strengthen the international market and competitive position of the Dutch sector.

All growers and traders pay a certain percentage of their turnover to the product board. Sometimes this is done through the auction, in other cases directly. When selling, for example, products through the auction, the grower pays 0.625% over the turnover and the buyer at the auction is charged 0.485%. Growers who do not do business through the auction but directly with the trade pay 1.11%. A discount rule applies to the cultivation of young plants (starting material). Growing and trading companies with an annual turnover of more than €11m can also qualify for a lower levy percentage.[43]

In 2014 the revenue from the levy was about €95m. Of this, about 40% is spent on promotion and marketing, some 34% is spent on research.[44]

As of January 1, 2014, the public tasks of the PT were transferred to several ministries.

After the disappearance of the product board, several branch organizations took the initiative to set up collective budgets for research, for example Foundation 'Knowledge in your greenhouse'[45] (*Stichting 'Kennis in je kas*') of sector organisation Protected Horticulture Netherlands (*Glastuinbouw Nederland*)). Each greenhouse horticultural entrepreneur pays €350 per hectare per year in contribution to this Foundation.

Ad 3) Greenports Netherlands[46]
A Greenport is a concentration of horticultural companies in a certain geographical area that are (economically) connected to each other (in analogy with seaports or airports) and is already explained in Section 3.2.1.

National Horticultural Agenda[47]
In 2018, Greenports Netherlands took the initiative to create a Horticultural Agenda with a 10-year horizon. This was drawn up together with the regional greenports, the business community, the authorities and the education & knowledge institutions. More than one hundred experts, entrepreneurs, scientists, civil servants and administrators participated. The first agreement is all about 'being a leader in circularity and sustainability'. Greenports Netherlands sees horticulture as a front runner that has solutions for the challenges the world is facing in terms of feeding and greening the mega cities.

The elaboration of this agreement resulted in an agenda with concrete actions, projects and agreements between the horticultural partners, entitled National Horticultural Agenda 2019-2030. In 2019, eight so-called transition tables started deepening and implementing the program lines with a time horizon of

[42] Horticulture product board carries out what you want. https://edepot.wur.nl/172976
[43] What does the Product Board for Horticulture do? https://edepot.wur.nl/116670
[44] https://www.productschaptuinbouw.nl/artikel/heffingen, https://edepot.wur.nl/172976
[45] https://www.kennisinjekas.nl/
[46] Greenport Nederland, www.greenportsnederland.nl
[47] Horticultural Agenda 2019-2030. https://lumencms.blob.core.windows.net/media/67/Greenports%20Nederland_DEF5_colofon2_juni2019_spread.pdf)

10 years. This ambition has been developed into concrete annual plans for each theme. The focus is to work with the regional greenports, industry associations and knowledge institutes through a Triple Helix approach to achieve the right acceleration. In 2021, all the themes will be further deepened and expanded. Below is an overview of the theme tables:

1. energy
2. healthy people
3. healthy plants
4. spatial planning
5. labour market and education
6. innovation
7. fresh logistics
8. internationalization

The strength of Greenports Netherlands was confirmed once again in March 2020, at the start of the Corona crisis. When demand dropped drastically and a mild panic broke out in the horticultural cluster, Greenports was quick to set up a crisis team with the sector organizations that, together with entrepreneurs, could enter into talks with the government to take the right measures, including setting up a Corona crisis fund.

Ad 4) Top Sector Horticulture and Starting Materials

Top Sector Horticulture and Starting Materials is one of the nine top sectors, set up by the government since 2010, as an instrument for cooperation between companies, knowledge institutions and government. Top Sectors were developed to allow public funds intended for innovation, R&D and knowledge dissemination to be implemented in public-private partnerships. This starts by drawing up a joint vision and strategic agenda supported by all stakeholders.

Background[48, 49, 50]

Three basic documents underpin the objectives of the top sectors:

1. the Knowledge and Innovation Covenant (KIC): in this covenant the three parties (private sector, knowledge institutions and government) ratify their effort for the coming years on important innovation themes.
2. Mission-driven Top sector and Innovation Policy (also called 'Missions').[51] Inspired by leading missions of the past, such as the Dutch Delta Works and the U.S. Apollo Space Program, the government launched a new approach to innovation policy in 2018, so-called Mission-driven innovation, with the aim of further strengthening the collaboration of scientists with governments and societal stakeholders.
3. the Knowledge and Innovation Agenda (KIA): in this agenda it is described which knowledge and innovation are to be developed to realize the mission. Sometimes several top sectors develop a joint a KIA. An example is the top sector Horticulture & Starting Materials, Water and Agri-Food. In Figure 29 a schematic overview is given of how a top sector is organized, where the Missions, the KIC and the KIA are starting points.

[48] Adviesraad voor wetenschap, technologie en innovatie (AWTI), 2014. Balans van de Top sectoren 2014. Den Haag.

[49] Janssen, M., den Hertog, P., Korlaar, L., Groot-Beumer, T., Steur, J., Rienstra, Y., de Boer, P.J., Erven, B., (2017). Evaluatie Top sectorenaanpak, Deel 1 – Hoofdrapport. Dialogic.

[50] Janssen, M., den Hertog, P., Korlaar, L., Groot-Beumer, T., Steur, J., Rienstra, Y., de Boer, P.J., Erven, B., (2017). Evaluatie Top sectorenaanpak, Deel 2 – Achtergrondstudie per Top sector. Dialogic.

[51] https://hollandhightech.nl/_asset/_public/Documenten/English-version-Kamerbrief-Mission-Driven-Top-Sector-and-Innovation-Policy-2.pdf

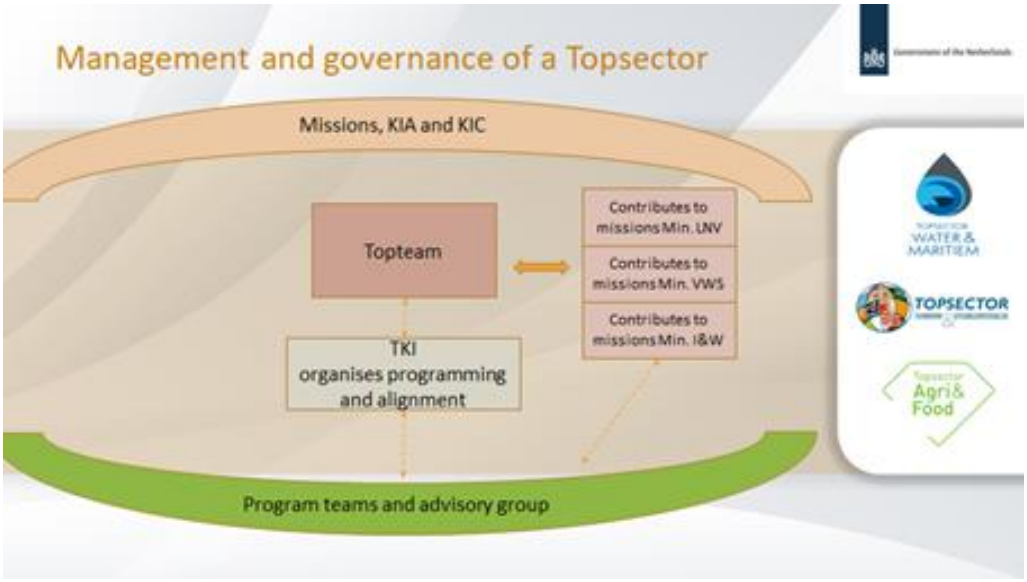

Figure 29 *Management and governance of a top sector (Source: Website TKI Agri-Food (adapted) (Topsector Agrifood, 2022)*

Organization (Top sectoren, 2022)
Each top sector has a **Top team** that consists of an elected chairman (captain of industry), a scientist, a representative of the government and an innovative SME entrepreneur. The members of the top team are elected/nominated by the Ministry for a period of 4 years. After that period the members can be re-elected. The chairman and SME entrepreneur receive remuneration, respectively for a working time factor of 0.3 (3 half-days in the week) for the figurehead and 0.222 for the SME entrepreneur. The other board members receive only an allowance for costs made.[52]

In addition to the top team, each top sector has one or more offices called the **Top Consortia for Knowledge and Innovation (TKIs)**. These TKIs are responsible for the implementation of the activities within the context of the Knowledge and Innovation Agenda. Top sector Horticulture & Starting Materials has its own TKI office.

Each TKI is represented by a board with members from the 3 parties (private sector, government, knowledge institutes). The members of the TKI board are appointed by the top team. The TKI board Horticulture & Starting Materials has six members: one chairman, three members from the business community, one from the knowledge institutes and one from the government (Ministry of Economic Affairs). The government representatives in the TKI formally have the status of observer. The board members receive only an allowance for costs made.

Organization finances
The budget for the TKI office Horticulture & Starting Materials ca. €600,000 per year. The cost for the TKI consist of two key elements: personnel (€400,000) and office costs (€200,000)[53].

The resources of the TKI-office consist of 1) a Public Private Partnership (PPP surcharge), 2) RVO subsidy instrument called Programme Support Activities and 3) SME Innovation Stimulation instrument for Top sectors (*MIT*) to be used to appoint 'innovation brokers'. The basic principle of the PPP surcharge is: for every €1.00 of private cash R&D contribution from a company to a research organization, the Ministry of Economic Affairs and Climate adds €0.30 as the PPP surcharge. This PPP surcharge must be used again for R&D. Private-public partnerships and Top Consortia for Knowledge and Innovation (TKIs) can apply for a PPS surcharge.

[52] Institutional Decree on the Top teams Mission-driven Sectors and Innovation Policy, 2019.
[53] Top sector Horticulture & Starting Materials, www.topsectortu.nl/en/

Instruments[54]

TKIs, as the operational bodies of the top sectors, use different instruments. We can distinguish at least four TKI instruments: 1) Fundamental Research, 2) Applied Research in the form of Public Private Partnership, 3) Seed Money Proposal and 4) Knowledge Valorization. The two most important are mentioned below.

The first TKI instrument is Fundamental Research in collaboration with the Dutch National Research Council. Together with TKI Horticulture & Starting Materials and TKI Agri & Food, the Dutch National Research Council (NWO) develops programs with sufficient breadth, resulting in applications and stronger competition. Also, there are crossover programs with initiatives that transcend the top sector. The top sectors support such programs as well as co-finance fundamental research projects that are approved in the European R&D programs. The available budget for the three sectors Agri-Food, Horticulture & Starting Materials and Water & Maritime is approximately €11m per year. Additional required private co-financing is 10-30%. Allocation of the budget remains a responsibility of NWO both in terms of frameworks (amount of money per top sector) and procedure.

The second TKI instrument is Applied Research through Public Private Partnerships (PPP) on Research and Innovations. Every year, these top sectors organize a call for research proposals. For the three joint top sectors Horticulture & Starting Materials, Agri-Food and Water & Maritime, the available governmental budget is approximately €50m per year. Together with recognized applied research organizations (such as Wageningen Research, Deltares and TNO), private parties in a consortium with companies are requested to submit proposals to carry out research. The Ministry of Agriculture, Nature & Food Quality and the Ministry of Economic Affairs contribute 50% of the costs by financing part of the project costs of the knowledge institutions. The other 50% has to be contributed by the private sector, of which half has to be in cash and half in kind (number of hours, materials etc.). This is according to the European Framework for State Aid regulations for Research and development and innovations (2014/C 198/01). This resulted in 100-120 projects/year for the KIA Mission Agriculture, Water & Food.

PPP proposals are selected in two phases to ensure selection of those linking strongest to top sector agendas: 1) submission of a concise project proposal (pre-registration) and 2) submission of a complete project proposal for public-private partnerships. The pre-registration enables the TKI to staff the assessment committees in a targeted manner and, upon request, to identify any links with other top sectors. The applicant can also receive (non-binding) advice (e.g. on the suitability within the Missions of the KIA, the content and the consortium, etc.). PPPs should be pre-competitive (which justified investment from public authorities), should ideally link to a larger integrated program and clearly indicate how the developed knowledge and innovations are disseminated to relevant sectors and other parties.

The ministry allocates budgets to the research institute for the approved PPP proposals. After approval, all private parties have to sign a PPP consortium agreement with the applied research institute for each project. Based on these agreements the TKI informs the Ministry to allocate the budget to the research institute. Besides, the research institute will invoice all private stakeholders once a year for their committed contribution in cash. For the contribution in kind, all private stakeholders have to keep accounts. Once a year with the invoice, the research institute will request these accounts of the private sector.

Impact

An impact analysis of the subsector Starting Materials of the top sector Horticulture & Starting Materials for the period 2013-2018 showed significant results in terms of investments, scientific output and follow up projects (Stolk, 2019)

1. 80 PPP research projects: 49 were finished by the end of 2018.
2. Total budget €25m of which 50% contributed by the government and 50% private sector.
3. 17 scientific promotions, >100 scientific publications.
4. 2 patents filed and another 2-3 expected to be filed.
5. Of the researchers at PhD level already 8 persons are working within a breeding company.
6. 46 follow-up projects.
7. One start-up company in process.

[54] Ravensbergen P., Rijn, F. van, Vazquez, O. Martinez, A., Hetterscheid B., Montsma, M., 2021. Plataforma Agrologística 2030; A diagnosis of the potential for public-private partnerships in the Mexican agrologistics sector following the Dutch top sector model. Wageningen, Wageningen Economic Research, Report 2021-065.

Appendix 3 CEA Agriculture in Kentucky

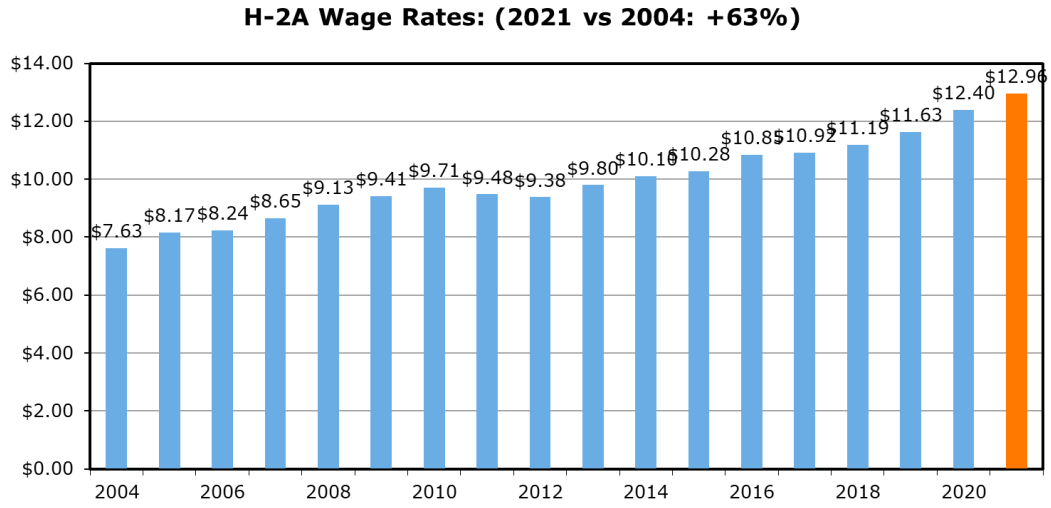

Figure 30 *Kentucky H-2A Wage Rates ($/hr)*
Source: NASS/USDA.

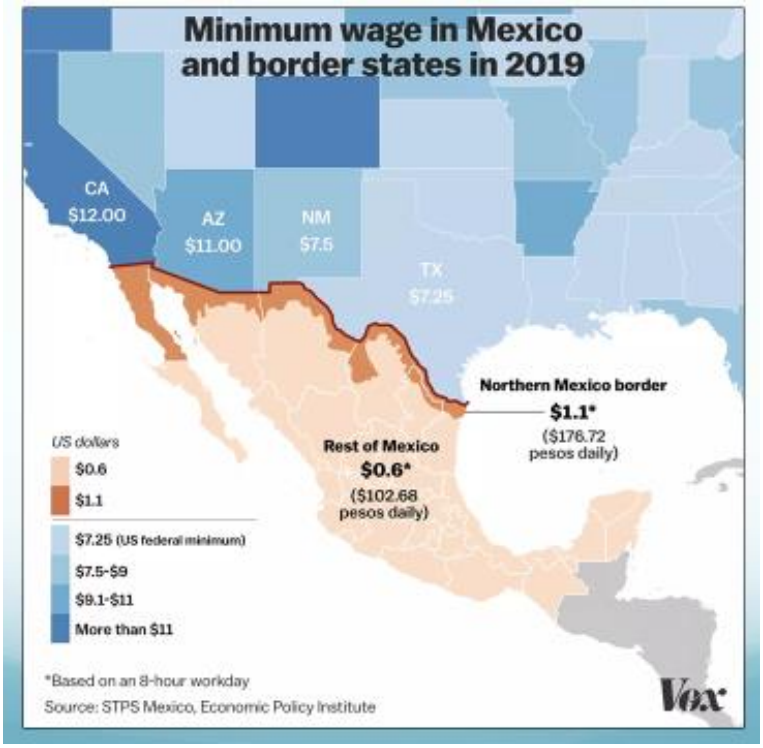

Figure 31 *Minimum wage in Mexico and border states in 2019*

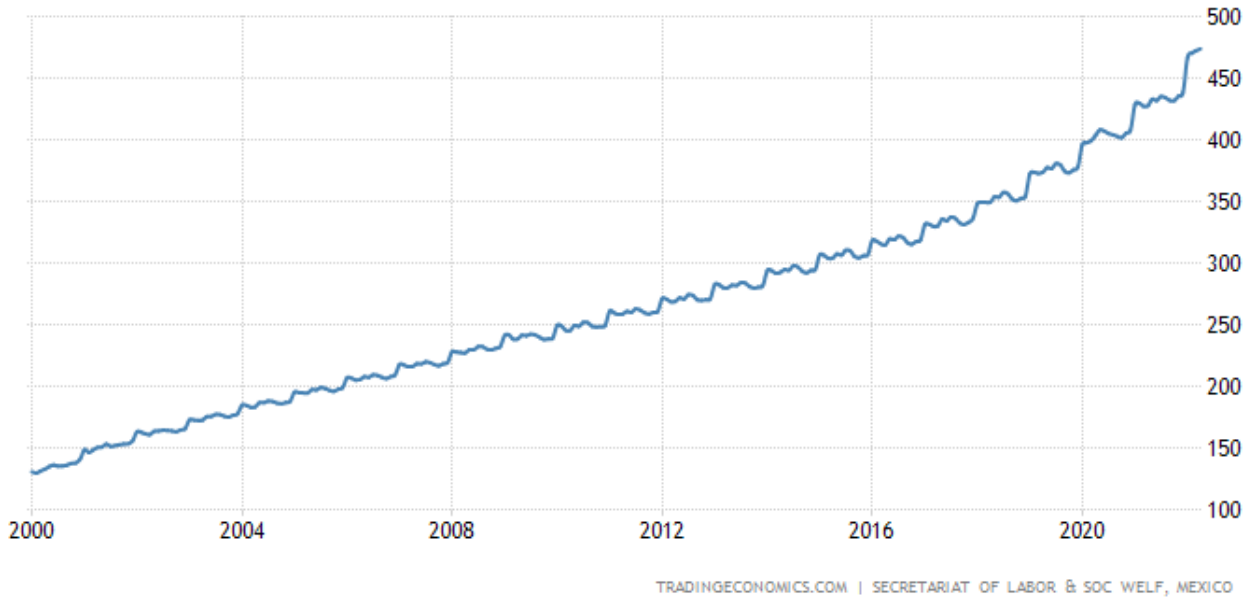

Figure 32 *Average Daily Wage Rates for Mexico 2000-2022 (Mexico Secretariat of Labor & Social Welfare, 2022)*

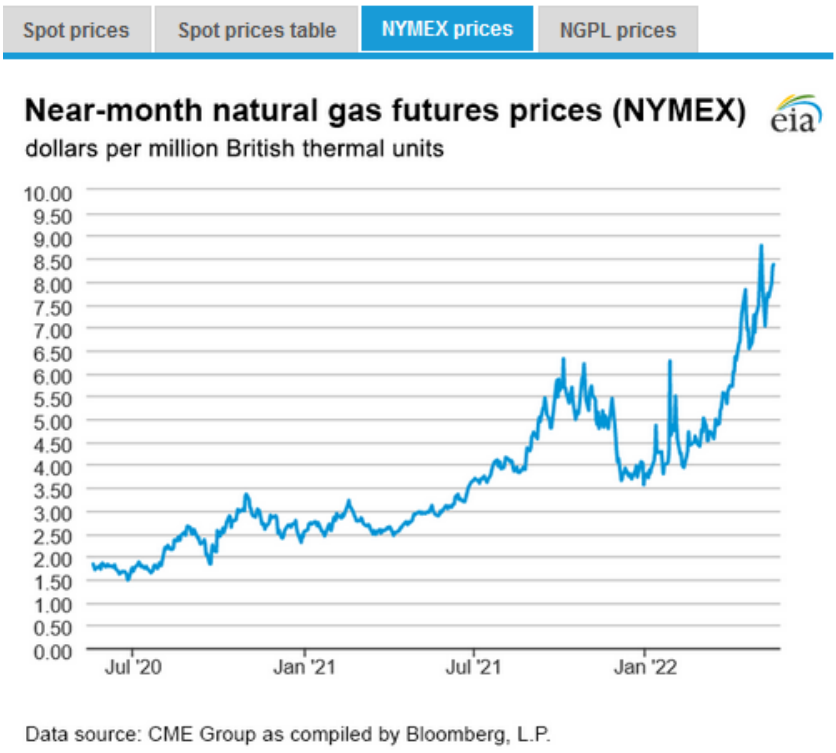

Figure 33 *Near-month natural gas futures prices (NYMEX) (CME Group as compiled by Bloomberg, 2022)* *https://www.eia.gov/naturalgas/weekly/archivenew_ngwu/2022/05_19/#tabs-prices-3*

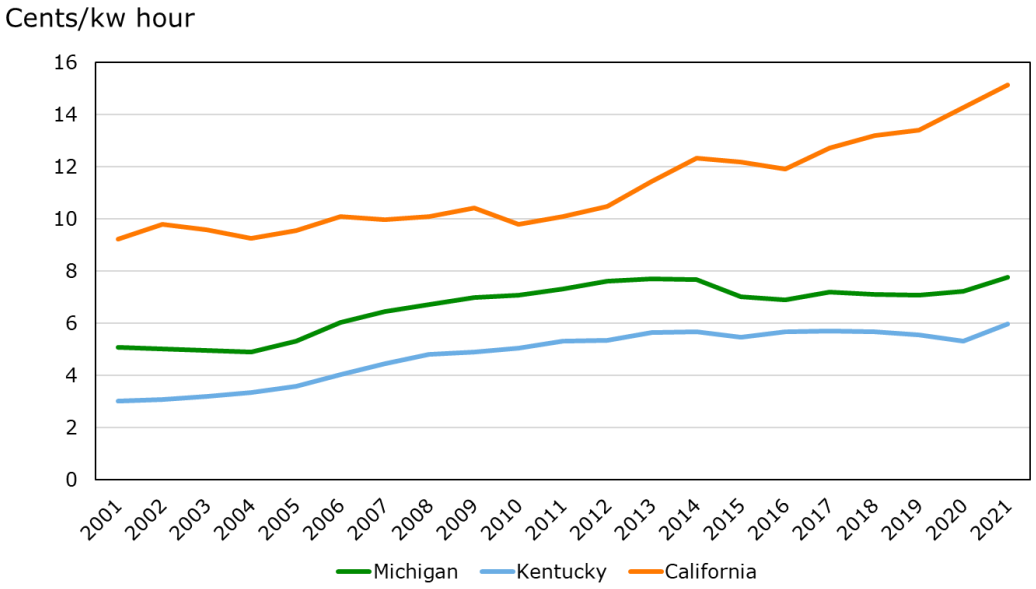

Figure 34 *Electricity rates in Kentucky, Michigan and California: 2001-2021 (U.S. Energy Information Administration, 2022)*
Source: U.S. Energy Information Administration.

Appendix 4 Example questionnaire: Academic/Knowledge Partners as stakeholder group

Key function 1
Education, technical training, research, and farm advice

Info: Fundamental to the transformation process and involves the learning processes related to developing and utilizing new knowledge of a technology or set of practices. The development of new knowledge can occur through formal research (e.g. at universities and governmental and non-governmental research centers), the private sector (e.g. agri-business) or at the individual level (e.g. farmers).

1. Roles: Are you or your organization currently involved in the CE Ag Tech ecosystem development process?

- If yes:
  - How? *Answer:*
  - Are there other ways you'd like to be involved? *Answer:*
- If no:
  - Why not? *Answer:*
  - Would you like to be involved in the future, and how? *Answer:*
  - What, if anything, would need to change within your organization in order to be a part of a CEA Tech Ecosystem? *Answer:*
- What is the role of education in information sharing related to the development of a Controlled Environment Agriculture (CEA) Tech Ecosystem? *Answer:*
- How can educational institutions contribute to communicating information about CEA Tech? *Answer:*
- Below is a list of different types of organizations. Which of these organizations do you think should be involved in developing and establishing a CEA Tech Ecosystem? And, if so, tell me the role you think they should play.

Y/N	Organization Type	Role this organization should play in developing a CEA Ecosystem
	Government (local, state, regional, etc.)	
	Industry (producers, controlled environment businesses, entrepreneurs, etc.)	
	Education (research, innovation, technology transfer, cooperative extension, etc.)	
	Consultants/Advisors	
	Farmers/Farmer Organizations	
	Non-profit Organizations (including state societies and ag associations, etc.)	
	Media	
	Other (please explain)	

2. Priorities:

- In your opinion, which of the following actions have priority in establishing a CEA Tech Ecosystem? Please rate in order of importance/priority, with 1 being most important and 5 the least important. Please, elaborate your choice.

Priority (1-5) and WHY? 1=Most Important 5=Least Important	Actions
	Education/research/training
	A new policy (public/private) vision for change
	Incentivizing entrepreneurs to become part of a CEA Tech Ecosystem
	Availability of new resources and technologies
	Other (please list)

- On a scale of 1-3 how much priority is given to agricultural education in Kentucky?
  Low - 1 Average - 2 High – 3

3. Education:

➢ Below are different types of research, innovation, and educational initiatives. Which types should be included as part of a CEA Tech Ecosystem? Then, mark the ones that are most urgent.

Mark initiatives to include (Y/N)	Research, innovation, and educational initiatives	Urgency (mark most urgent)
	Projects and demonstrations	
	Trainings and peer-to-peer learning	
	Conferences and trade shows	
	Advising and mentoring sessions	
	Other (please list)	

- How popular is agricultural education among students? *Answer:*
- Are students interested in programs or curricula on CEA Tech? *Answer:*

Key function 2
Knowledge diffusion through networks

Info: The exchange of information through networks, where research and development (R&D) meets government and markets. Policy decisions should be guided by the latest technological research, and R&D agendas should be adapted to changing environmental, market and social conditions.

4. Current State: Consider the current state of the CEA Tech Ecosystem and all the key players, including: research, education, extension, the private agricultural/ horticultural sector, government, and non-profits.

Collaboration:

i. What does the current state of collaboration look like? *Answer:*
ii. Does current collaboration support the development of a CEA Ecosystem? *Answer:*
iii. How could current collaboration be improved? *Answer:*
iv. Could public-private partnerships help? *Answer:*
v. How would you describe the interactions between research, education, and government in Kentucky agriculture?

Very weak – 1 Weak – 2 Average – 3 Strong – 4 Very Strong – 5

Please elaborate the answer:

i. What is needed to improve these interactions? *Answer:*
ii. Does your organization have any collaborations with private sector and/or governmental organizations related to a CEA Tech Ecosystem? *Answer:*
iii. Are you interested in collaborating within a CEA Tech Ecosystem?

(1) If yes, what type of collaboration? *Answer:*
(2) If no, why not? *Answer:*

Regulation:

i. Are there currently clear policy goals regarding this technological field? *Answer:*
ii. Are you aware of any government programs or policies that could contribute to the development of a CEA Ecosystem? *Answer:*
iii. Do you think there is a need for legislative amendments, changes, or improvements in order to establish a CEA Tech Ecosystem? Please explain. *Answer:*

Research:

i. How would you evaluate the quality of scientific and applied agriculture research in Kentucky?

Low - 1 Average - 2 High - 3

ii. What is needed to improve the quality of scientific and applied agriculture research? *Answer:*
iii. How are results from this research being implemented in Kentucky? *Answer:*
iv. Are research results used to improve and/or innovate education (including new curricula and new educational materials)? *Answer:*

Needs:

i. Through education and workforce training, what do you think is needed to enhance innovation and communication about a CEA Tech Ecosystem? *Answer:*
ii. What else is needed for Educational organizations to improve awareness about CEA Tech? *Answer:*

Questions- Key function 3
Development of an AKIS vision

Info: Refers to the creation of a vision for the AKIS and mobilization of incentive structures to promote that vision. Incentive structures may change in response to factor prices and regulatory pressures (e.g. product prices, taxes and subsidies), expectations in market growth potential, new knowledge, expression of interest by customers, cultural changes and external events.

5. Future State:

- **Vision:** Do you think a collective vision of a CEA Tech Ecosystem with multiple stakeholders collaborating could be established?
    i. If yes, how should a clear vision of the industry and market be developed in terms of growth and technological design? *Answer:*
    ii. If no, why not? *Answer:*
- **Promoting Awareness:**
    i. What do you think could be done to increase public and private awareness of the benefits of developing a CEA Tech Ecosystem in Kentucky? *Answer:*
    ii. Is there a need for a database or website to collect and share related information, research, data, and publications? *Answer:*

Questions -Key function 6
Creation of legitimacy

Info: It is necessary to overcome resistance to a new technology or set of practices from the existing production, trade and consumption systems. It must be considered appropriate and desirable by incumbent actors for resources to be mobilized rather than blocked.

6. Creating Catalysts:

i. What are some incentives or disincentives that could aid in the development of a CEA Tech Ecosystem? (i.e., market incentives, regulations, financial incentives, investment/transfer initiatives) *Answer:*
ii. Are there any arrangements within the private sector that would support the development of a CEA Tech Ecosystem? *Answer:*
iii. How can the State work with public and private partners to best support the needed developments in Kentucky? *Answer:*
iv. Aside from traditional incentives, are there any policies that could be changed to spur the development of the ecosystem? *Answer:*

7. Unexpected Effects:

i. How can the development of a CEA Tech Ecosystem benefit other existing sectors (i.e., grain crops, cattle, dairy, poultry, etc.) either through technological innovations in these sectors or through the creation of new markets for these sectors? *Answer:*
ii. What are potential 'spill over' effects on existing local sectors (e.g., adopting new technologies, or growing new business opportunities such as greenhouse waste, plant-based proteins, sustainable packaging, and the use of new energy sources)? *Answer:*

8. Opportunities:

i. What do you think are the most prominent opportunities for developing a CEA Tech Ecosystem in Kentucky? *Answer:*
ii. What are the benefits of developing a CEA Tech Ecosystem?
    a. for your organization? *Answer:*
    b. for society? *Answer:*
iii. In terms of research and education, what are some of your expectations from a CEA Tech Ecosystem? *Answer:*
iv. Of all the opportunities, which are the most urgent in the short or long term? *Answer:*

9. Obstacles:

i. What are the most prominent constraints and obstacles to developing a CEA Tech Ecosystem in Kentucky? *Answer:*
ii. Is there resistance from traditional growers, suppliers, consumers towards this production approach? *Answer:*
iii. Are there geographical or site-related challenges in the different regions of the state? *Answer:*
iv. What are the risks of developing a CEA Tech Ecosystem?
    1. for your organization? *Answer:*
    2. for society? *Answer:*
v. Are there physical resource constraints that may limit the adoption of CEA technologies? *Answer:*
vi. How can the obstacles you listed be overcome? *Answer:*
vii. Of all the obstacles, what are the most urgent to address in the short or long term? *Answer:*

Questions- Key function 7
Resource mobilization

Info: Is closely linked to the creation of legitimacy and concerns financing investment in innovation in the form of access to credit, seed funding, venture capital, investment in human and social capital and the development of complementary products, services, infrastructure, etc.

10. Potential Actions: In the table below, there are several actions that might enhance the development of a CEA Ecosystem. Which of these actions do you consider to be relevant? Why?

Actions	Explanation	Relevant (Y/N)	Why?
Subsidies/innovation funds (particularly for producers)	Governmental support in form of subsidies/funds to establish a CEA Tech ecosystem		
Public market enablers	Public market enablers are policy instruments that encourage behavioural change through market signals by providing economic incentives rather than through traditional regulations. These are trading schemes, subsidies and grants, accreditation systems, taxes, and tax concessions.		
Enforcement of laws	Law enforcement such as governmental regulations and legislation (amendments, changes, improvements).		
Demo/pilot projects	Implementation of small-scale pilot or demonstration projects as an initial step to prove the viability of a project idea.		
Other			

11. Potential Resources:

i. What CEA resources can be locally sourced? *Answer:*
ii. What are the other needed resources and their potential availability in terms of infrastructure, knowledgebase, skilled workforce, investment, legal framework? *Answer:*
iii. What financial resources are available, and where would they come from ? *Answer:*
iv. At your institution, on a scale of 1-5, what is the level of available human resource capacity (lecturers, researchers, etc.) related to new technology and practices (e.g. knowledge capital)?

Very weak – 1 Weak – 2 Average – 3 Strong – 4 Very Strong – 5

v. What is needed to further develop human resource capacity? *Answer:*
vi. Does your organization possess educational material related to CEA, such as academic programs or curricula?
    1. If yes, how well is it developed? *Answer:*
    2. If no, how can the current educational material be enhanced? *Answer:*
vii. Does your organization need support from government and/or the private sector in order to be involved in a CEA Tech Ecosystem? Please explain. *Answer:*
viii. What short-term and long-term action(s) is/are most urgent for developing CEA Tech Ecosystem?
    1. In the short term? *Answer:*
    2. In the long term? *Answer:*

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The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,200 employees (6,400 fte) and 13,200 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.