EXECUTIVE SUMMARY

Exploring Opportunities Arising From Controlled Environment Agriculture

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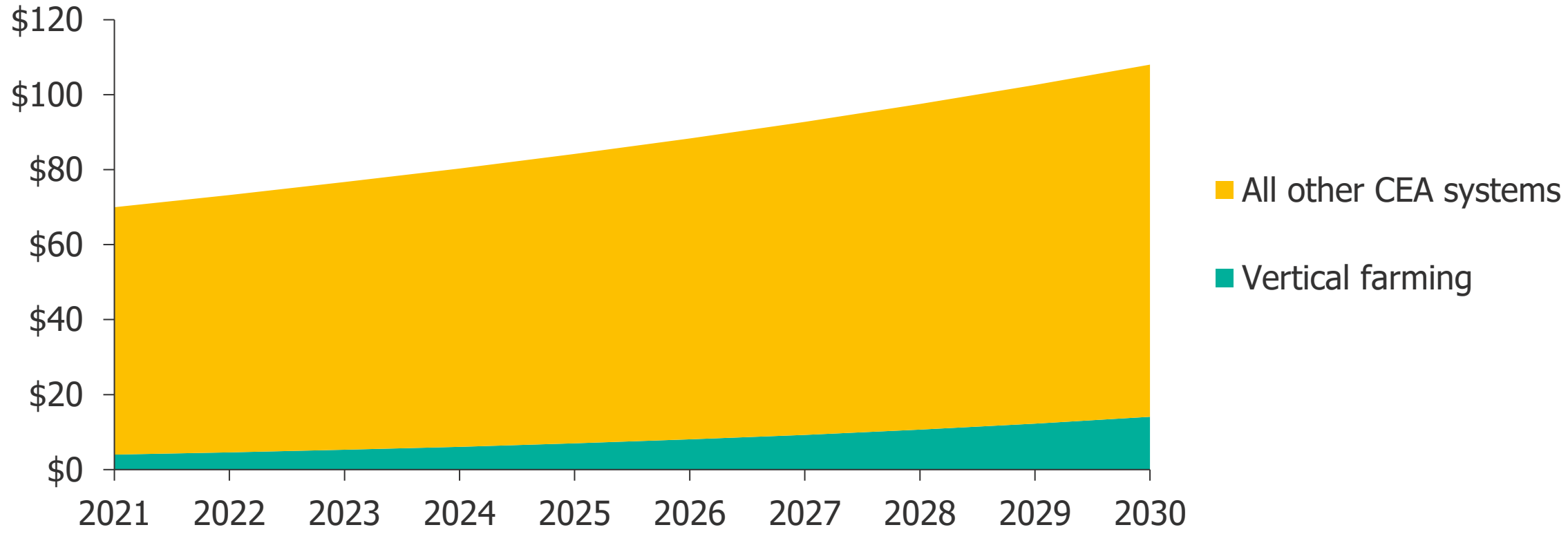
EXECUTIVE SUMMARY

Controlled environment agriculture (CEA) will be a $100 billion dollar market by 2030

GLOBAL CEA MARKET

Market size (billion dollars, USD)



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EXECUTIVE SUMMARY

CEA-enabling technologies will be a $78 billion dollar market by 2030, driven by the automation sector

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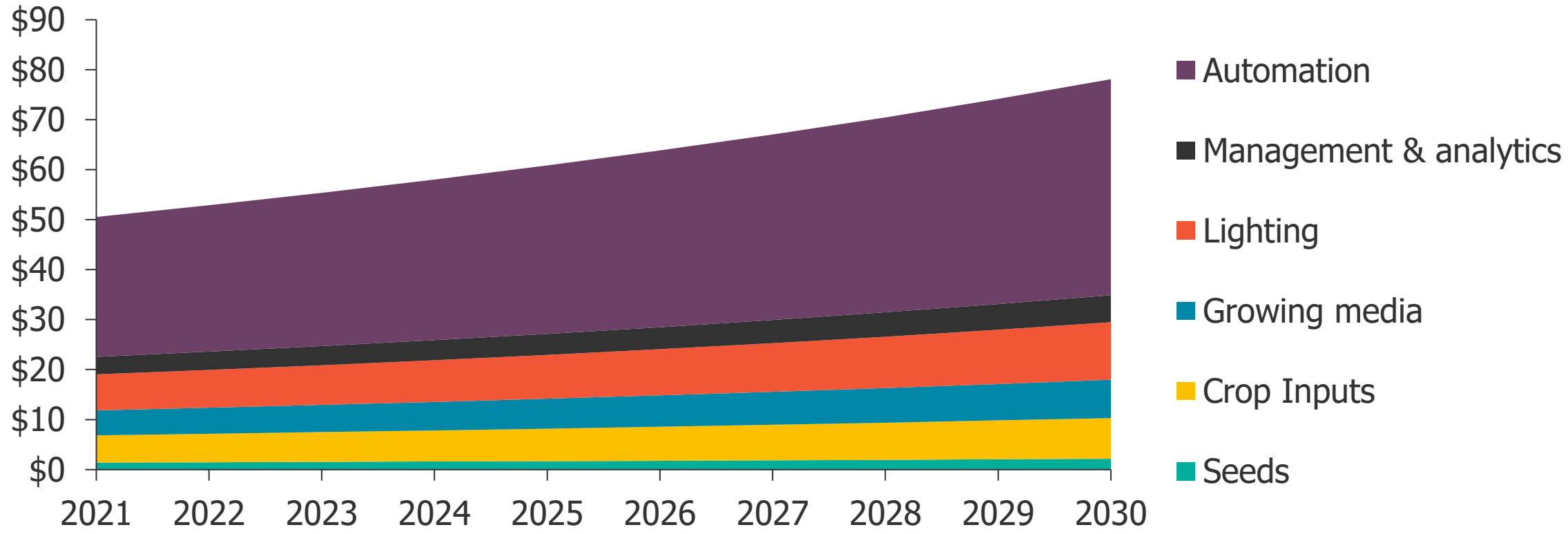

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EXECUTIVE SUMMARY

CEA-enabling technologies will be a $78 billion dollar market by 2030, driven by the automation sector

The global market size for controlled environment agriculture (CEA) is set to reach a market value of $100 billion by 2030, with six potential opportunities – automation, digital management and analytics, lighting, growing media, crop inputs, and seeds – capturing $78 billion in market share.

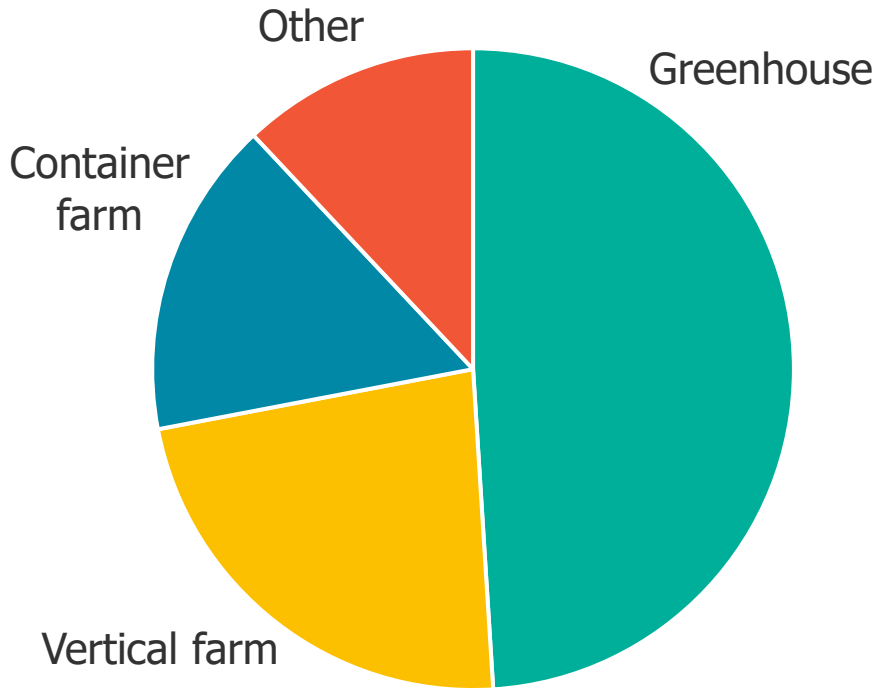
- **Automation** will become the largest sector for CEA, capturing 43% of the total market value by 2030. However, developers will need to address high costs and limited use cases per platform as major factors currently hindering adoption.
- **Lighting** and **management and analytics** are key innovation areas to improve production outcomes. However, developers that struggle to match the efficiency and cost-effectiveness of incumbent solutions fail.
- **Crop inputs** and **media** are aimed at optimizing CEA production with the highest quality standards. However, solutions may provide an "environmentally friendly" label, generating a perceived quality enhancement rather than a quantitative improvement in crop performance.
- Despite the maturity of the seed industry, the development of **seeds** for CEA environments has not been on the radar until recently. However, as the CEA industry grows and demand for seed increases, more investment in seed development will be made to drive market growth.

INTRODUCTION

What is controlled environment agriculture?

CEA, an indoor, technology-based approach to cultivating crops under optimal growing conditions, encompasses not only the vertical farming sector but also the indoor cultivation of an ever-increasing range of specialty crops for a range of applications, from food to health.

CEA facility type breakdown



Greenhouses – Protected structures with crops grown in soil; the level of control varies from low-tech to fully computerized enclosures
Estimated market share: 47% to 49%

Vertical farms – Utilize hydroponic or aeroponic systems to grow plants in a modular fashion
Estimated market share: 23% to 30%

Container farms – Self-contained growing units that use vertical farming and artificial lighting
Estimated market share: 7% to 16%

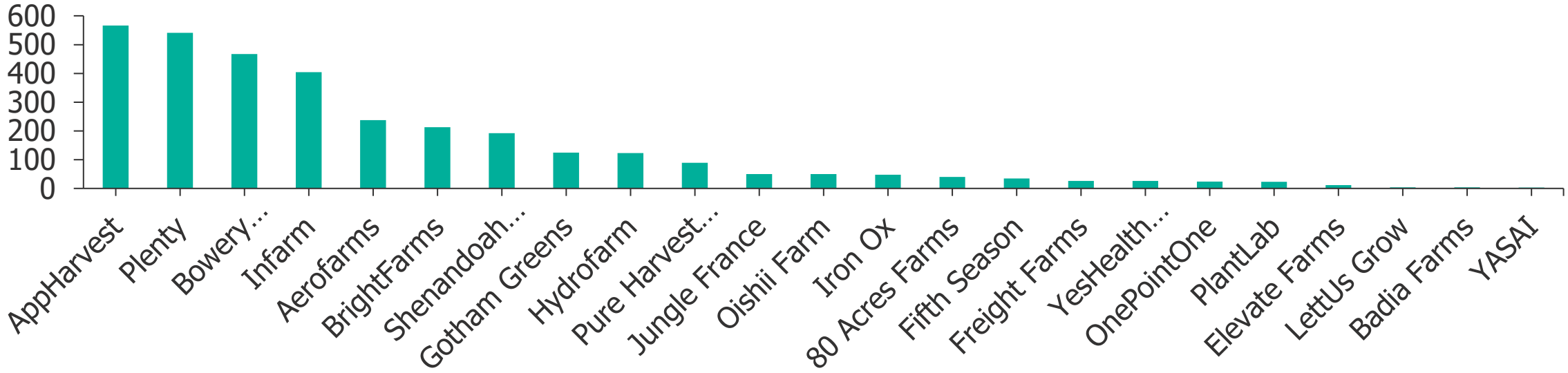
Other – Includes low-tech high tunnels and hybrid facilities, such as those that use an aquaponic system
Estimated market share: 12% to 16%

INTRODUCTION

Investor interest points to the leading CEA growers

Investment funding in CEA

Millions of dollars



CEA is witnessing unprecedented growth, with more than $500 million in funding going into this space just since the beginning of 2021. Notable investments include the following: Infarm raised $100 million from Hanaco Ventures and Atomico; Oishii, which produces vertically grown strawberries, received $50 million, led by SPARX Group's Mirai Creation Fund II; the latest addition to this funding landscape is Bowery's $300 million Series C – the largest private fundraise for an indoor farming company. Many CEA developers will use recent VC funding for construction of facilities and diversifying their crop portfolios.

INTRODUCTION

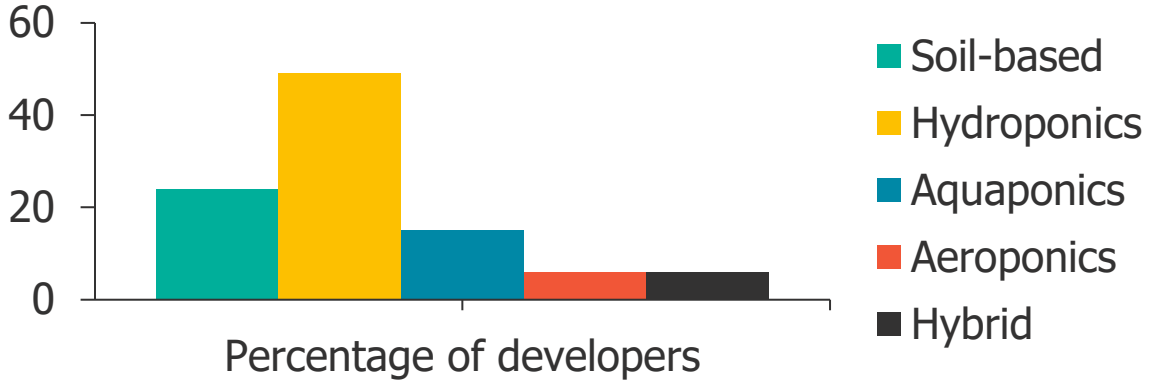
CEA technology landscape

CEA crop production uses a variety of systems, including soil, hydroponics, and aeroponics. The main differences among these systems are in irrigation, fertilization methods, and costs of production.

In-soil production is common within greenhouses, which have been around since the 1920s and are recognized as the most traditional form of horticulture. Advantages include relatively low cost of materials and equipment and a good soil buffer for pH control and nutrient availability.

Alternatively, hydroponic and aeroponic systems, most common within vertical approaches, have the strongest presence within the CEA landscape and are producing a plethora of crops. In theory, the targeted delivery of nutrients and water enables precise amounts for optimal plant growth. However, the variability in plant nutrient absorption poses challenges to the composition of the liquid medium, and the price of the recirculating equipment and monitoring required by these systems must be factored into the operational costs.

Growing system distribution



Soil-based systems use containers, such as fabric pots, or in-ground planting and cultivation in raised beds

Hydroponics uses a recirculating liquid medium to deliver water and nutrients to growing plants

Aquaponics is a hybrid approach that marries hydroponic plant production with fish production through aquaculture

Aeroponics uses a nutrient-charged hydrated aerosol to provide water and nutrients to growing plants

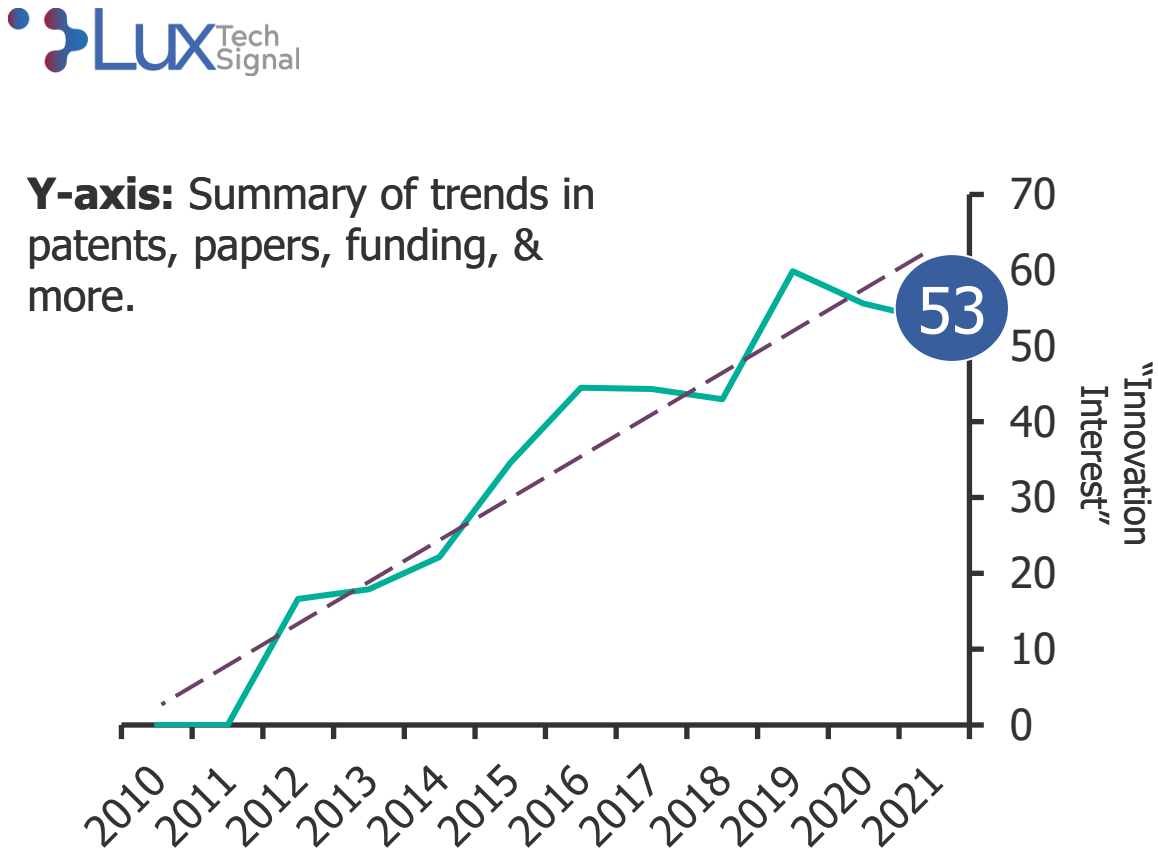
Hybrid systems include more than one type of growing system

Where to go from here

In the past decade, CEA has garnered significant innovation interest, with technology development opportunities spanning a broad range of industries, including energy, building/real estate, water, and agriculture. However, based on currently available CEA technology, this space still has a long road ahead to matching the costs of produce grown outdoors as well as the crop diversity.

While diverse applications often require segmented experience for success, a lot remains to be decided before the work can even begin. To help discern where and how to engage within the realm of CEA, this report highlights the impacts, key drivers, and challenges of the key technology-based solutions in this space to identify the potential growth of each opportunity over the next decade.

Note: The signal measures the first half of 2021 and does not reflect the entire year.



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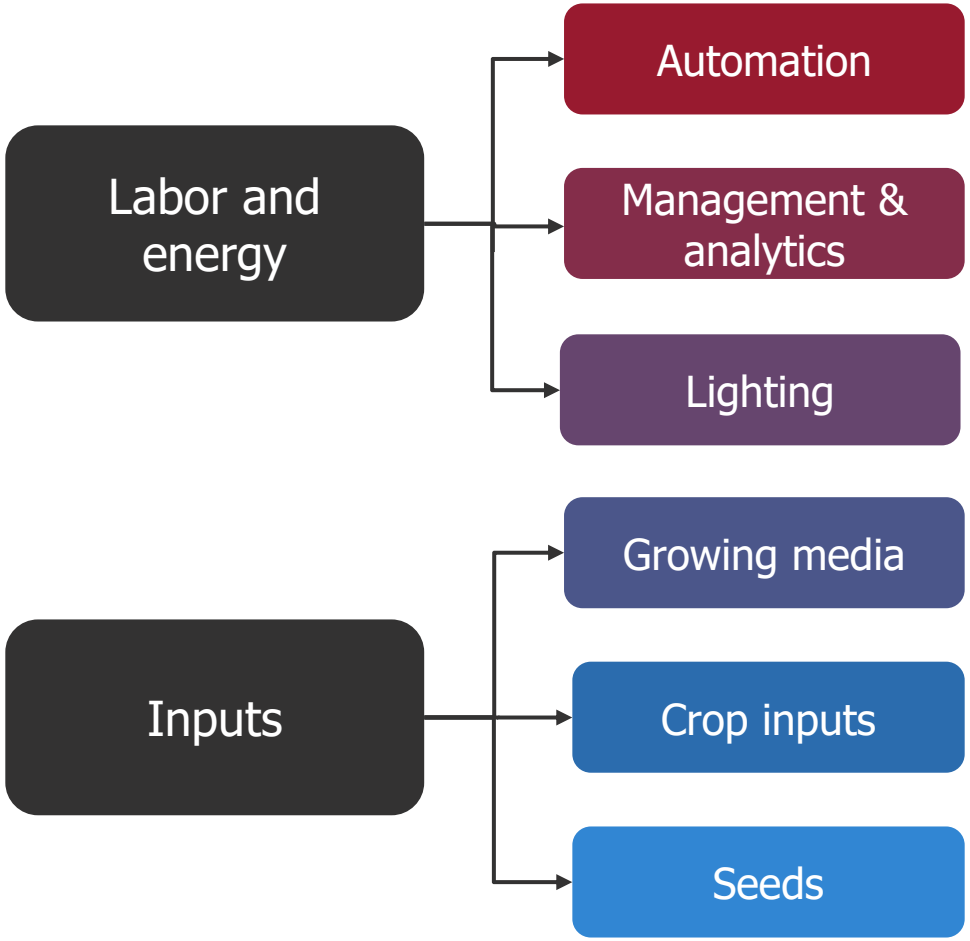
LANDSCAPE

Six key potential opportunities within CEA



Automation – Robotics and mechanized operations to decrease labor loads and/or streamline production workflows

Management & analytics – Tools for monitoring crops and/or tracking and optimizing production workflows

Lighting – Light-emitting diode (LED), high-pressure sodium (HPS), and fluorescent lighting

Growing media – Supplied nutrients for cultivating plants without soil

Crop inputs – Crop protection, fertilizers, biostimulants, micronutrients, and substrates for cultivating plants

Seeds – Germplasm development through standard plant breeding, gene editing, or the use of a computational breeding platform

AUTOMATION

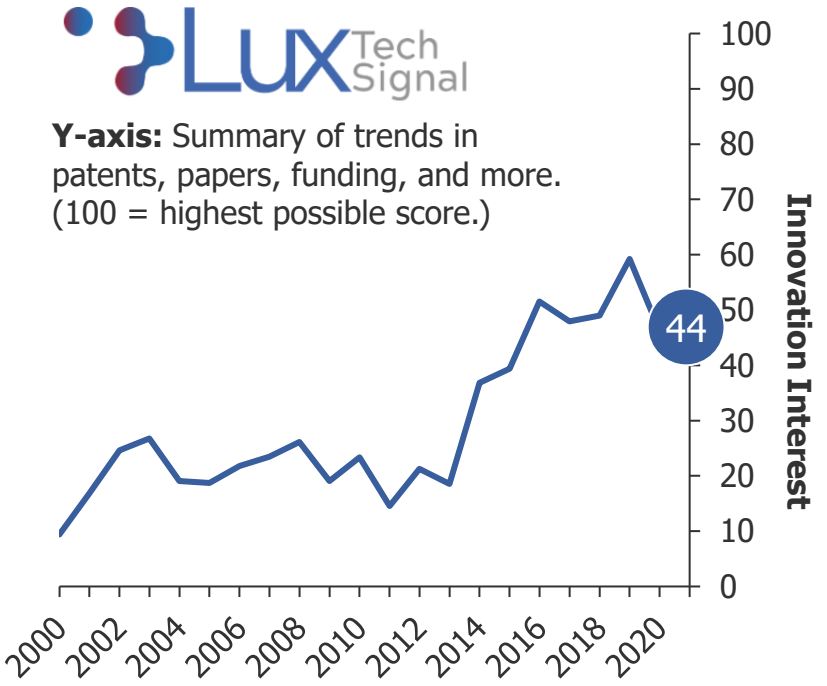
Robotics and mechanized operations to decrease labor loads and/or streamline production workflows

HOW IT IMPACTS

Manual labor in the agricultural specialty crop industry is physically demanding on workers and results in frequent injuries. Labor wages are also one of the highest costs for these operations, and technologies that reduce opex are appealing to CEA operations. Automation technologies optimize system efficiency, boosting yield and quality. Coupled with sensors for monitoring, mechanized systems help optimize moisture, salinity and pH, and fertilization and/or irrigation to improve the working hour productivity by 30% to 40%.

LUX TAKE

Automation is a must-have within CEA given the labor and energy requirements for profitable system operation. Clients can expect the development of robotic systems, particularly for crop harvesting, to continue forward at a steady pace and phase out manual labor within the CEA industry, and particularly in vertical operations.



DATA HIGHLIGHTS

26,000

Number of patent publications in the field of automation for CEA, including more than 2,000 patents already filed in 2021.

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MANAGEMENT & ANALYTICS

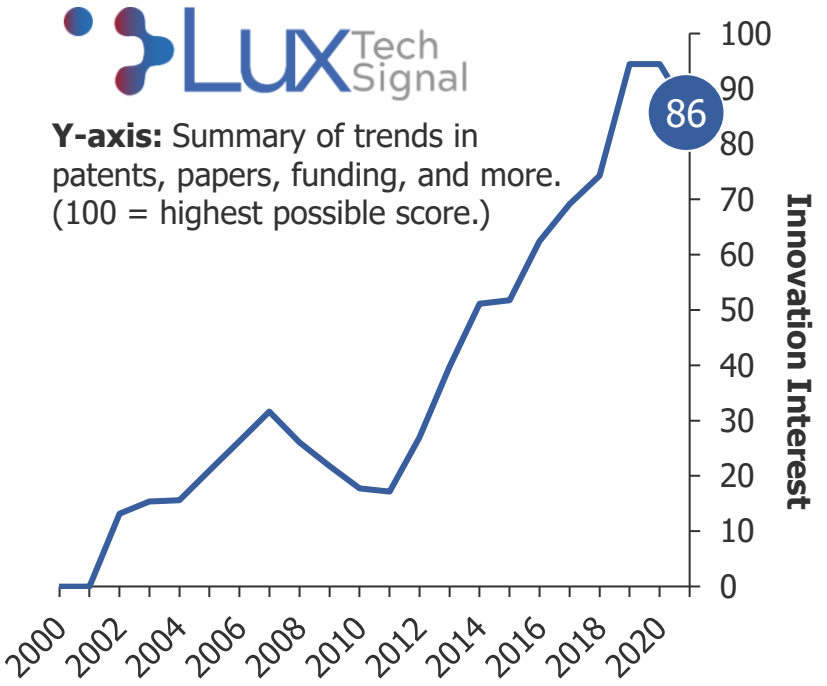
Tools for monitoring crops and/or tracking and optimizing production workflows

HOW IT IMPACTS

Real-time data acquisition and analytics visualization enables growers to make better farming decisions. These systems leverage technologies like computer vision and machine learning to fine-tune performance by monitoring plant size and health as well and macro- and microenvironments and managing crop inputs. Moreover, these software solutions identify production inefficiencies and delegate production tasks to improve labor and resource management and to potentially link to sales channels.

LUX TAKE

The digital transformation of agriculture expands to indoor farming where management and analytics are an important opportunity for high-value crop surveillance and data-driven decision-making. Clients should look for innovations that can move between sectors to improve existing technologies and add value.



DATA HIGHLIGHTS

128,319

The total number of patent applications and grants worldwide for management and analytics in the past decade.

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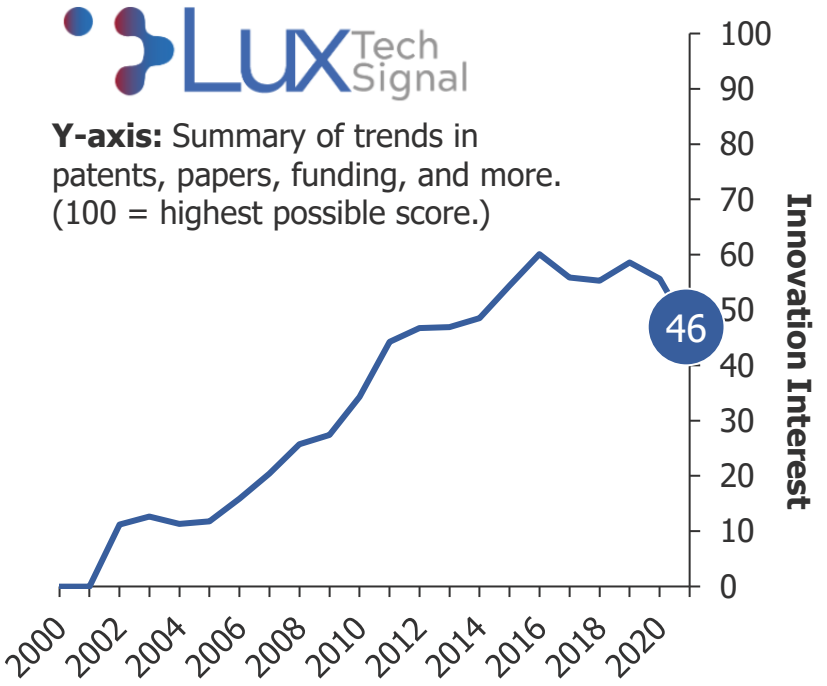
LIGHTING

Light-emitting diode (LED), high-pressure sodium (HPS), and fluorescent lighting

HOW IT IMPACTS

Lighting is a large part of the equation for increasing yields, accelerating harvest time, and controlling crop quality and consistency. While HPS lights are widely used as grow lights, the most popular CEA lighting solutions are LED, induction, and fluorescent lights. With their very targeted emission spectra, LED grow lights waste little energy and can be placed very close to plants without the risk of damage from excessive heat.



LUX TAKE

LEDs will continue to play a significant role in decreasing electricity costs in CEA. Clients should partner with companies that pair lighting with smart control systems for reduction of crop harvest time, cost, and power consumption. Further, modifiable light spectral outputs will be valuable for improving crop yield, quality, and consistency.

DATA HIGHLIGHTS

$252 million

Total amount of funding in lighting for CEA raised in 2020, with 87% of the funding received by companies post-IPO. This was a 335% increase in funding from 2019.

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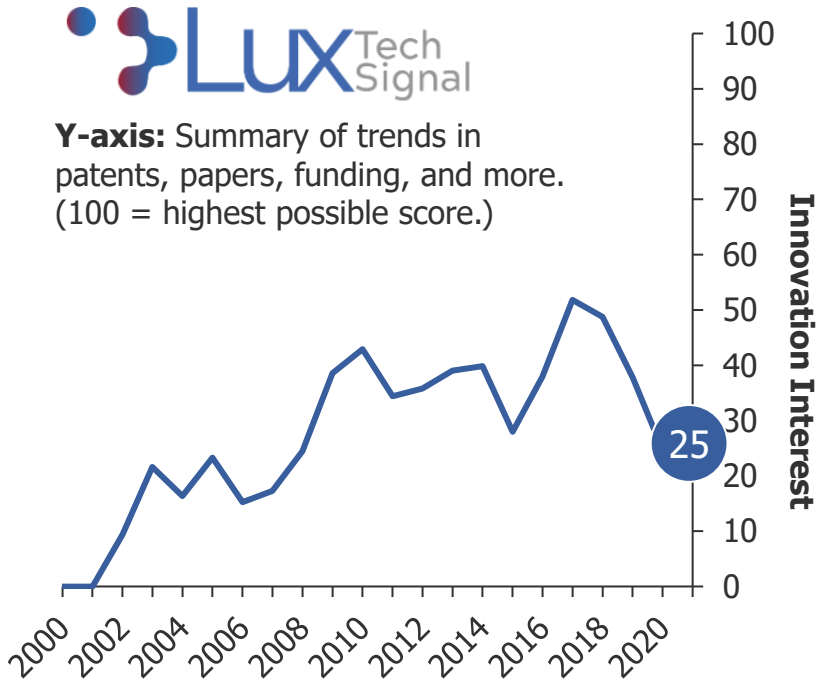
GROWING MEDIA

Supplied nutrients for cultivating plants without soil

HOW IT IMPACTS

Growing media are an important component of soilless production methods. Solutions must achieve high porosity and water retention while providing adequate aeration. The most common organic media originate from plant residues (e.g., peat moss or wood-based substrates). While not all CEA operations require a growing medium, hydroponic methods benefit from media to support roots and improve access to optimized levels of nutrients, oxygen, and moisture.



LUX TAKE

The demand for produce with low environmental impact prioritizes natural and organic substrates. Clients should expect to see reduced reliance on a single complex medium by CEA growers and a move to sourcing a variety of substrates to make their own specific formulations; engage with those demonstrating sustainable sources.

DATA HIGHLIGHTS

355

The total number of patent applications and grants worldwide for plant growth media in the past decade.

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CROP INPUTS

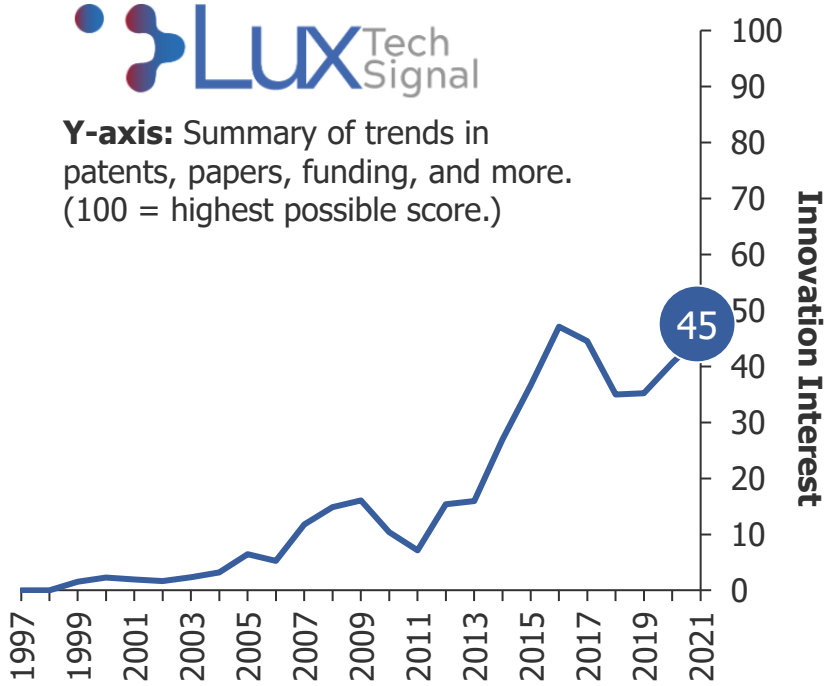
Crop nutrition, biostimulants, and alternative crop protection for CEA

HOW IT IMPACTS

CEA operations rely on high-value markets to achieve profitability. Therefore, crop inputs must enable claims of reduced environmental impact, improved quality (see Lux's report on crop quality for more information), and year-round availability. The market for alternative crop inputs available to CEA has experienced growth as a result of these requirements even though vertical agriculture operations do not often apply crop protection products, instead relying on contamination prevention strategies.

LUX TAKE

The demand for produce with organic certifications or low environmental impact places demand on natural or targeted products. Clients, expect interest in alternative crop protection and sanitation, crop nutrition, and biostimulation to grow as CEA operations expand.



DATA HIGHLIGHTS

$6 billion

Increase in fresh vegetable imports into U.S. between 2009 and 2019, establishing opportunity for CEA.

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SEEDS

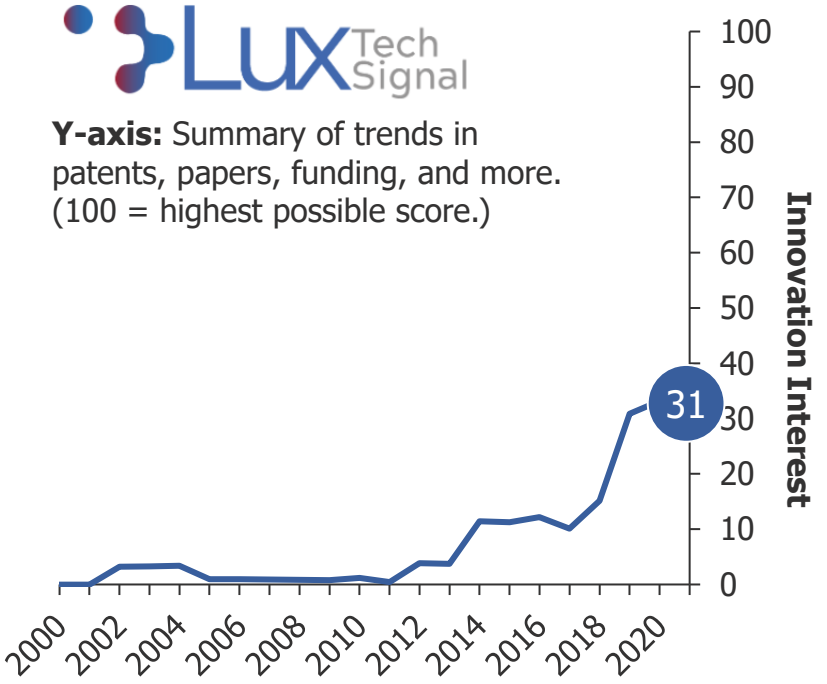
Germplasm development through standard plant breeding, gene editing, or the use of computational breeding platforms

HOW IT IMPACTS

Seed development has focused on conventional outdoor agriculture, where crops are more vulnerable to disease, pathogens, and unpredictable climate conditions. Germplasm innovation is garnering interest for enhancing scalability and quality (e.g., nutrition, processing). For now, the focus is on the scaled crops for CEA – leafy greens, microgreens, and tomatoes – which will be reinvented to accommodate indoor growing environments to optimize productivity and promote profitability.

LUX TAKE

Optimizing crop varieties specifically for production in CEA systems has become a priority as the industry has gained momentum. Future crops should be developed with technology innovations like automation in mind while balancing consumer demands for unique flavor profiles, nutritional composition, and freshness.



DATA HIGHLIGHTS

$320 million

Total amount of funding for seeds for CEA raised in 2020, with Unfold's $30 million financing being a major contribution.

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OUTLOOK & RECOMMENDATIONS

Market maturity

The three major challenges for the development of CEA systems are efficient energy management, the availability of a knowledgeable and affordable workforce, and improving the quality and quantity of fresh produce. The CEA industry must innovate to overcome this set of challenges or face slower growth rates that will fail to capture growing consumer demand.

Digital technologies currently play an important role in operational logistics; however, **achieving digital maturity to tackle energy use, workforce optimization, and increased production requires larger, more purpose-driven data sets.** For instance, lighting energy efficiency will be driven by not only materials innovation but also digital maturity.

Crop inputs must target complementarity within CEA systems to guarantee predictable quality and yield outcomes. Media sources are widely available, but sustainable alternatives are gaining some interest, though they remain a lower priority.

Automation and seeds show promise for overcoming workforce and production challenges but are relatively early-stage despite being advanced in other adjacent industries.

OUTLOOK & RECOMMENDATIONS

Market drivers

Crop diversity will be a key driver for CEA industry expansion, but novel crops carry novel challenges. Regional demand for more locally produced crops is growing as food security takes center stage 1.5 years into COVID-19. We observe that scaled CEA systems, which originally focused on short production cycle, low resource need crops like greens (i.e., vertical agriculture) or higher-value vegetable specialization, now aim to increase diversity to capture this momentum but require significant innovation to develop varieties that complement the systems.

The decreasing cost of sensors and increasing number of parameters monitored simultaneously enable cost-effective production and market insight. Leverage digital technologies to support decision-making but recognize that CEA systems are more diverse than you think. Tools will require facility-specific data.

Food safety, resource use, circular economy, and shorter supply chains align with core attributes of CEA, including reduced water use, reduced environmental exposure, local production, and application of alternative inputs or avoidance of conventional inputs.

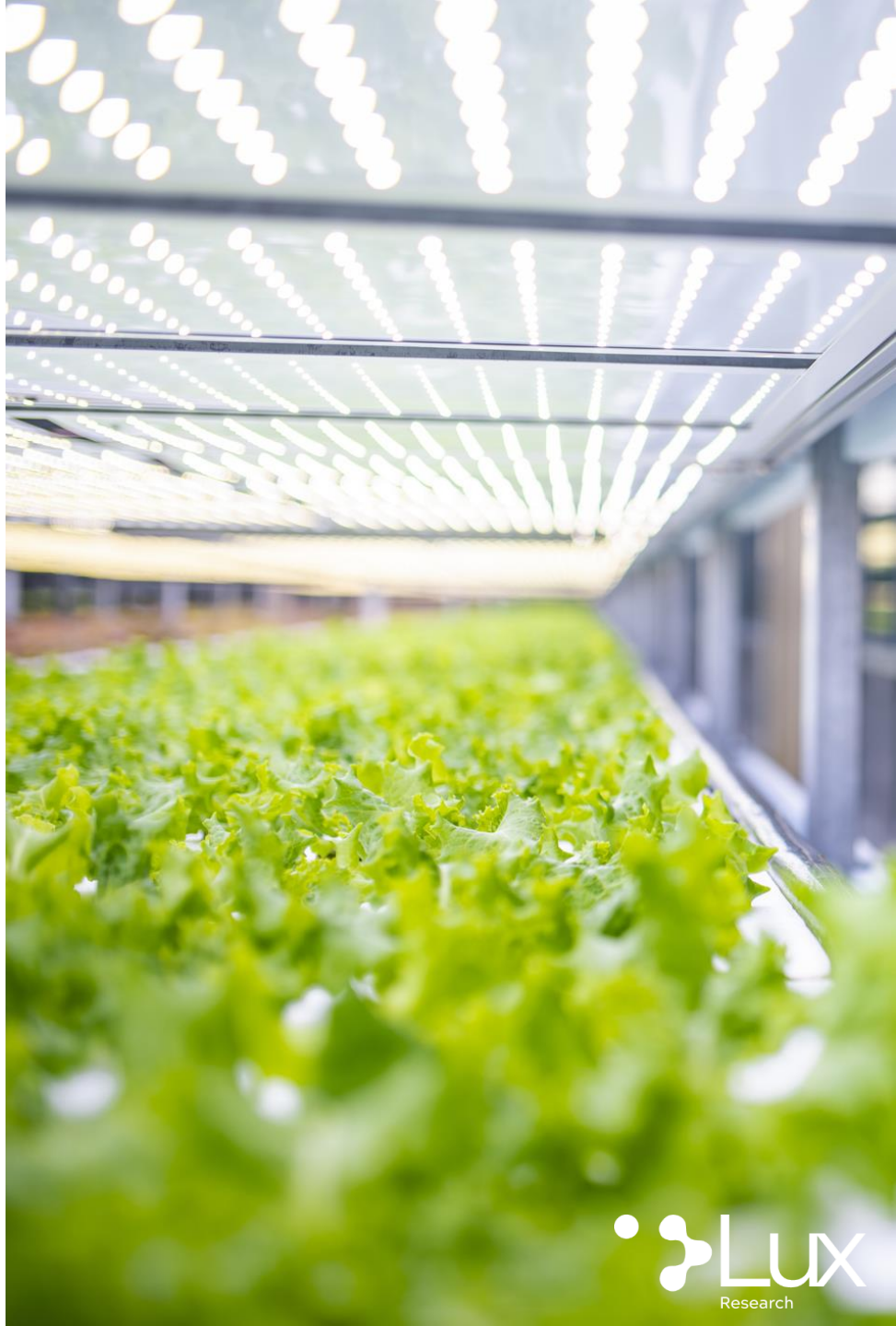
OUTLOOK & RECOMMENDATIONS

Economic feasibility

Energy and labor continue to be significant costs for CEA. The energy transition is underway, and the automation landscape is emerging, but neither is in a direct position to reduce costs. Instead, expect indirectly enabling technologies to drive profitability. Enabling technologies must provide actionable insight on real-time farm parameters to contribute to the success of CEA.

Increased economic feasibility will also come from regional demand for more diverse, locally available crops, especially in regions challenged by climate or resource constraints.

In addition, **perceived and realized quality are critical aspects to connect to market opportunities**. Avoid falling prey to greenwashing. For instance, many companies fail to mention challenges with emissions-associated energy and transportation of products from CEA but willingly tie CEA to reduced resource use. This will become more important as scaled vertical and other CEA farms move to post-SPAC or IPO scrutiny.



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