



# Controlled Environment Agriculture

Opportunities and challenges

June 2023

## Management Summary

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### **Can Controlled Environment Agriculture (CEA) be a significant contribution to addressing sustainable food production?**

**CEA has the potential to localize food supply and ensure food security for a growing population, however reaching cost parity with outdoor farming will be key to scale.**

The global agriculture industry is facing a myriad of challenges. Technology will be key to address these growing pressures and unlock sustainable farming practices to feed a growing population. This paper focuses on one specific technological innovation being new alternative farming systems, or Controlled Environment Agriculture (CEA).

Two major growing systems dominate the CEA space, namely greenhouses and vertical farms. While greenhouses have been around for multiple decades, more high-tech greenhouses and vertical farms have emerged since the early 2000s. End-consumer, retailer and value chain dynamics are driving the uptake of high-tech controlled food production. However, high production costs, nascent technology and limitation of product varieties are hampering the scalability of CEA today. Eventually, reaching cost parity with outdoor-grown produce will be imperative for CEA to scale.

Despite challenging economics, investor enthusiasm is strong. Total investments in CEA across North America, Europe and UK have reached USD 7 bn to date, of which 65% went into vertical farms. While investments have been largely led by financial investors, interest also arises from retailers, traditional growers and food service providers. With a growing population and limited resources, uptake of CEA seems inevitable to ensure food security. However, the short-to medium term advancement of the industry will need to be perceived in light of the current challenging business conditions (such as high inflation rate, high energy cost, increasing interest rates) which has already left many CEA assets in distress.

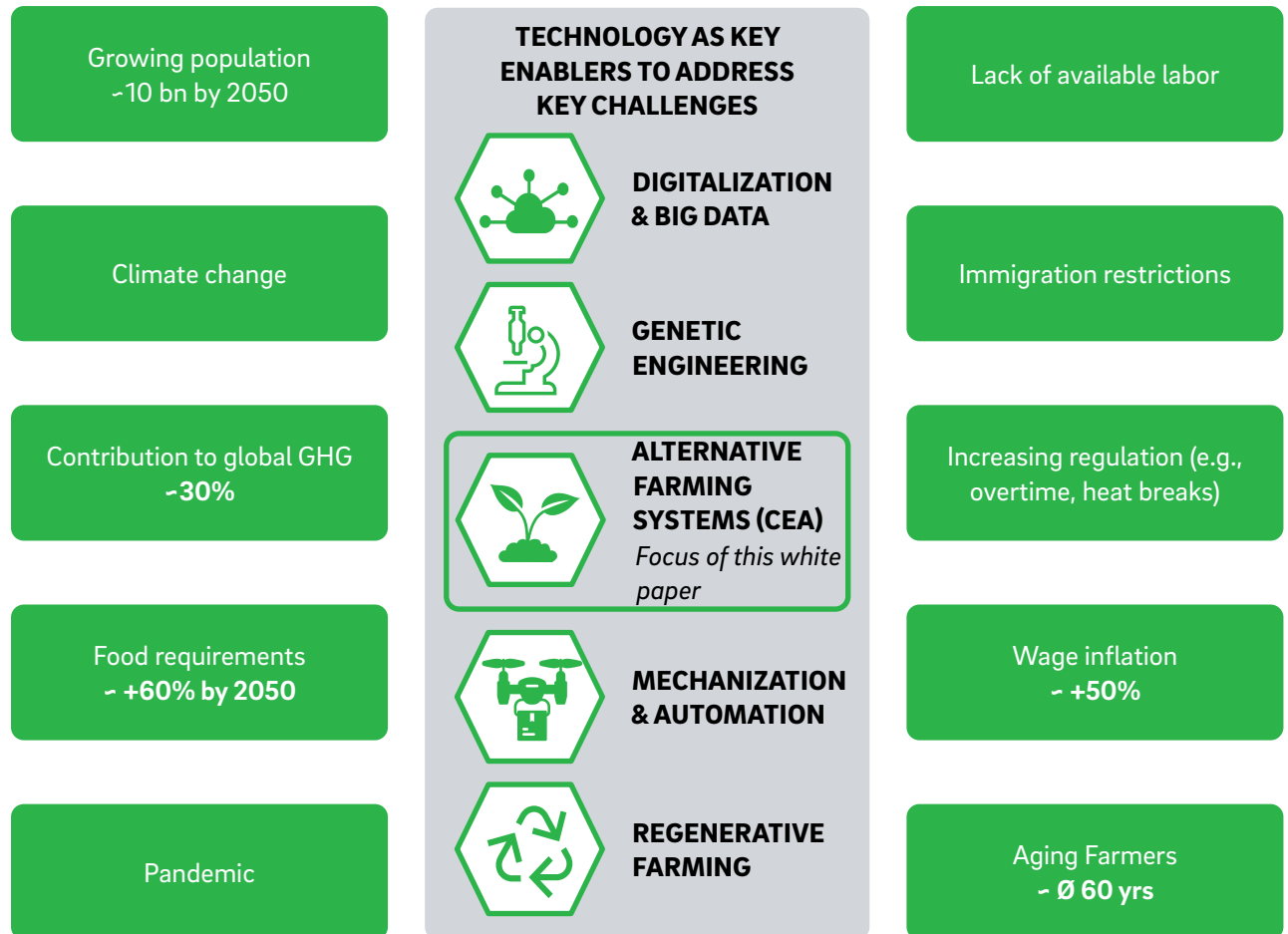
## The global agricultural industry faces a myriad of challenges – Technology, such as new farming systems, will be at the core to unlock sustainable farming practices

Today's agricultural industry is facing a **multitude of challenges**, such as a growing world population, farm labor shortages, aging farmer and farmworker populations, increasingly stringent regulations, changing consumer preferences and climate change. This puts pressure on the global agriculture industry and changes the overall market dynamics.









As in other industries, **technology is a key enabler** to address these pressing agricultural challenges. It furthermore allows the food value chain to respond to new market dynamics, such as traceability, sustainability and increased quality requirements.

While multiple technology advances are at play simultaneously, this white paper will **focus on alternative farming systems**, commonly referred to as **Controlled Environment Agriculture (CEA)**.

### KEY CHALLENGES AND DYNAMICS OF THE AGRICULTURE ECOSYSTEM



## Two major growing systems dominate the Controlled Environment Agriculture (CEA) space, namely greenhouses and vertical farms

	GREENHOUSES	VERTICAL FARMS
 <b>DESCRIPTION</b>	 <b>TRADITIONAL GREENHOUSE</b> <ul style="list-style-type: none"> <li>• Semi-permanent to permanent structures – shaded, polycarbonate or glass</li> <li>• Reliance on natural sunlight</li> <li>• Hydroponic or soil-based growing system</li> </ul>	 <b>HIGH-TECH GREENHOUSE START-UP</b> <ul style="list-style-type: none"> <li>• Permanent system – mostly glass</li> <li>• Heavier reliance on artificial light</li> <li>• Hydroponic, aeroponic, aquaponic and soil-based growing system</li> </ul>
 <b>TYPICAL CROPS</b>	<ul style="list-style-type: none"> <li>• Primarily tomatoes, cucumbers &amp; peppers</li> <li>• Berries are increasing</li> </ul>	 <b>VERTICAL FARM START-UP</b> <ul style="list-style-type: none"> <li>• Modular structures like shipping containers or permanent structures with multiple growing levels</li> <li>• Complete reliance on artificial light</li> <li>• Hydroponic, aeroponic and aquaponic, rarely soil-based</li> </ul>
 <b>TYPICAL CONSTRUCTION COSTS</b>	<ul style="list-style-type: none"> <li>• USD 0.5-1 million per acre</li> </ul>	<ul style="list-style-type: none"> <li>• Typically, greater than USD 16 million per acre<sup>1)</sup> <i>Example: USD 16 million per acre for 80 Acres Farms to USD 50 million per acre for Aerofarms</i></li> </ul>
 <b>KEY ADVANTAGES</b>	<ul style="list-style-type: none"> <li>• Established and proven growing method</li> <li>• Lowest cost structure</li> <li>• High variety of crops produced</li> </ul>	<ul style="list-style-type: none"> <li>• Year-round production irrespective of season</li> <li>• Highest yield per surface area given lowest amount of land requirements</li> </ul>
 <b>KEY DISADVANTAGES</b>	<ul style="list-style-type: none"> <li>• Seasonal production based on climate</li> <li>• Largest land requirement</li> </ul>	<ul style="list-style-type: none"> <li>• Highest cost structure due to electricity &amp; CAPEX needs</li> <li>• Limited crop catalog</li> </ul>
	<b>CEA START-UPS</b>	

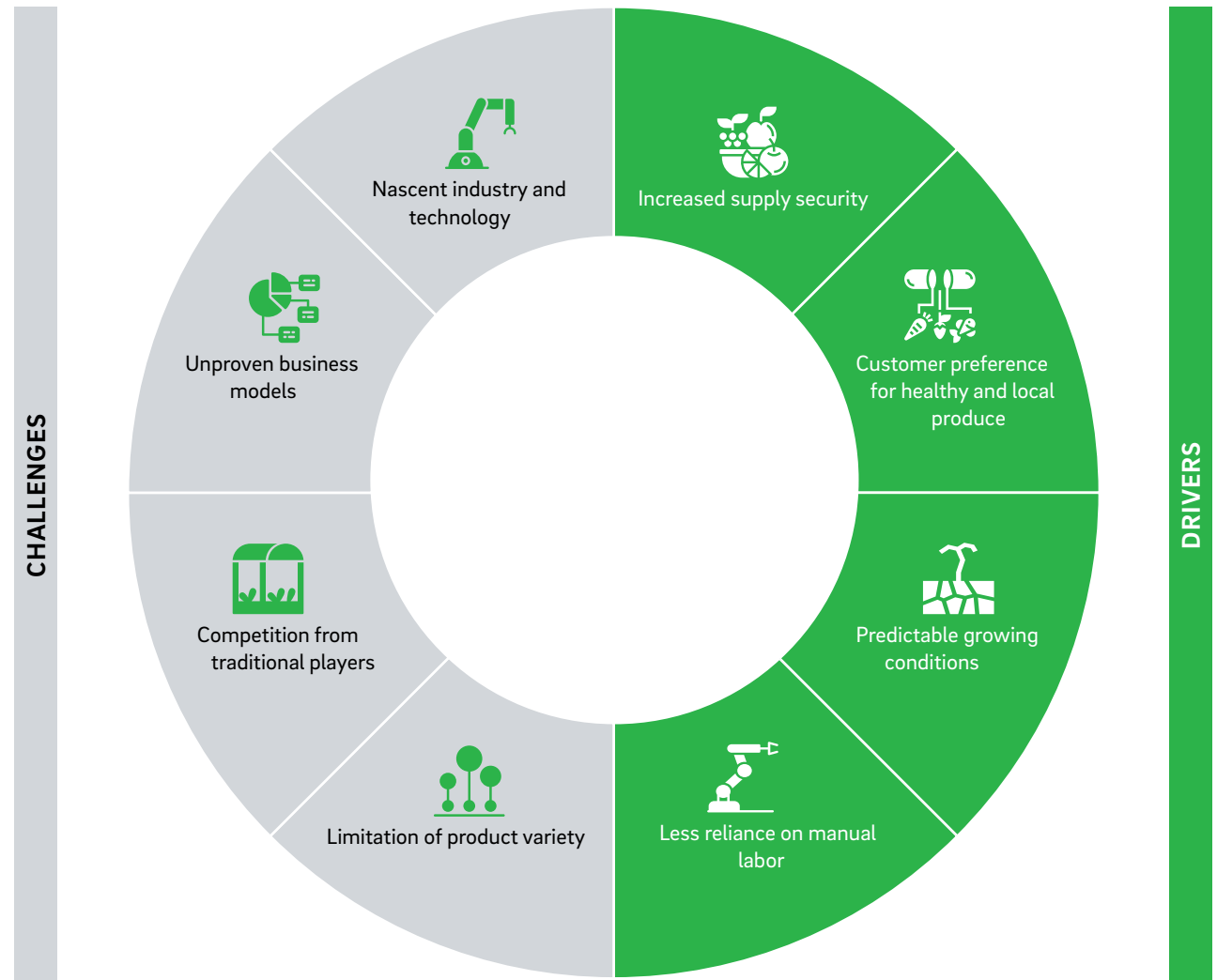
1) Acres reflecting the building footprint and not cultivation footprint (latter being higher)

## While difficult-to-overcome challenges render the scalability of the CEA market uncertain, various market drivers across the value chain are pushing its growth

To date, the overall **CEA market is still small**. As an example, in the United States, the market is estimated to account for less than 2% of the total fresh produce market. Most of the existing CEA market is supplied by traditional greenhouses that have been around for decades. As illustration, approximately 40% of the US tomato market is supplied by greenhouses.

Looking ahead, **uptake of CEA is expected to increase**, driven by several factors: consumer preferences for fresher, more sustainable, and locally sourced produce; a lack of labor availability; and the desire for reduced food waste and improved supply security. This potential has led to an unprecedented level of investments over the last years.

Despite investor enthusiasm and strong market trends, **CEA start-ups still face difficulties in scaling up**. Key challenge to overcome would be the path to profitability and cost parity with outdoor-field grown produce.



## CEA enables higher annual yield and considerable reductions in water use, however the key challenge to scale will be to reach cost parity with outdoor-grown produce




To compare CEA with outdoor-grown produce on select key performance indicators, a combination of growing structures, crop types and maturity of the growing structure have been selected.

As such, following crops and growing structures have been considered:

- **Leafy greens in vertical farms:** Most widely adopted crop grown by vertical farm start-ups
- **Peppers in high-tech greenhouses:** Already grown today in traditional greenhouses and expected to be fastest-growing crops to be adopted in high-tech greenhouses
- **Strawberries in vertical farms:** Most popular crop that will be brought under the CEA format going forward, with vertical farming most likely format

While all growing structures significantly reduce water use and increase yield, **high-tech greenhouses appear closer to cost parity** with open-field growers (compared to vertical farms) which could give them a competitive edge in the near future.

### COMPARISON OF KEY PERFORMANCE INDICATORS OF CEA VS. OUTDOOR-GROWN PRODUCE, 2022

	Total landed cost [USD/lb]	Annual yield [lb/acre]	Water use [Gal/lb]	Electricity use [KWh/lb]
 <b>Leafy greens</b> (Vertical farm)	3x	35x	-90%	75X
 <b>Peppers</b> (High-tech greenhouse)	1.5x	10x	-85%	30X
 <b>Strawberries</b> (Vertical farm)	3x	7x	-50%	120X

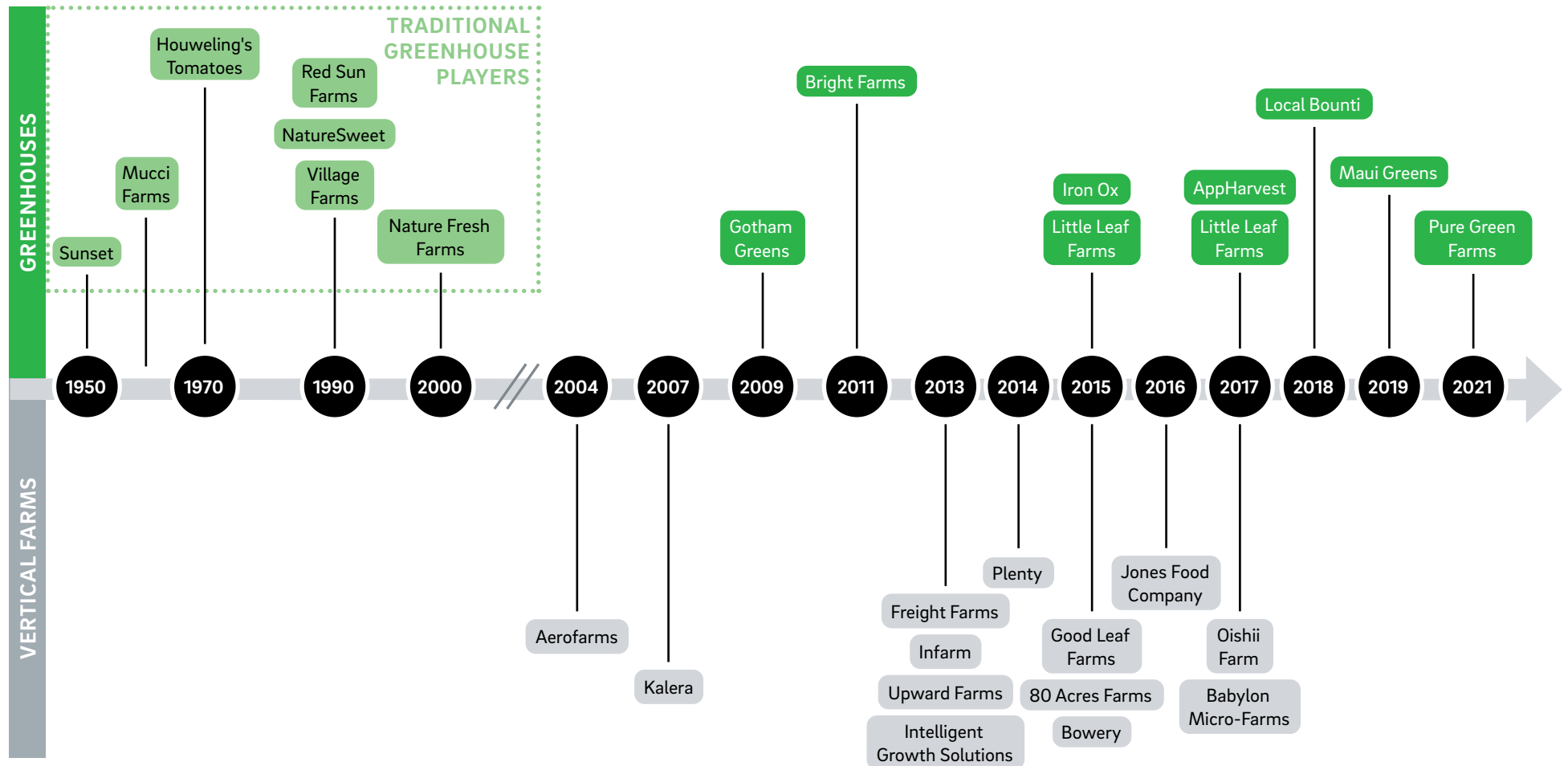
Detailed farm characteristics and assumptions are included in the 2022 specialty crop automation report, a joint Western Growers / Roland Berger report

Source: 2021 Global CEA Census Report, Agritecture, Western Growers, Roland Berger

## Despite challenging economics, there is a lot of activity in the CEA market which has led to the emergence of many new high-tech players over the last decade

### OVERVIEW OF FOUNDING DATES OF MAJOR GLOBAL CEA PLAYERS

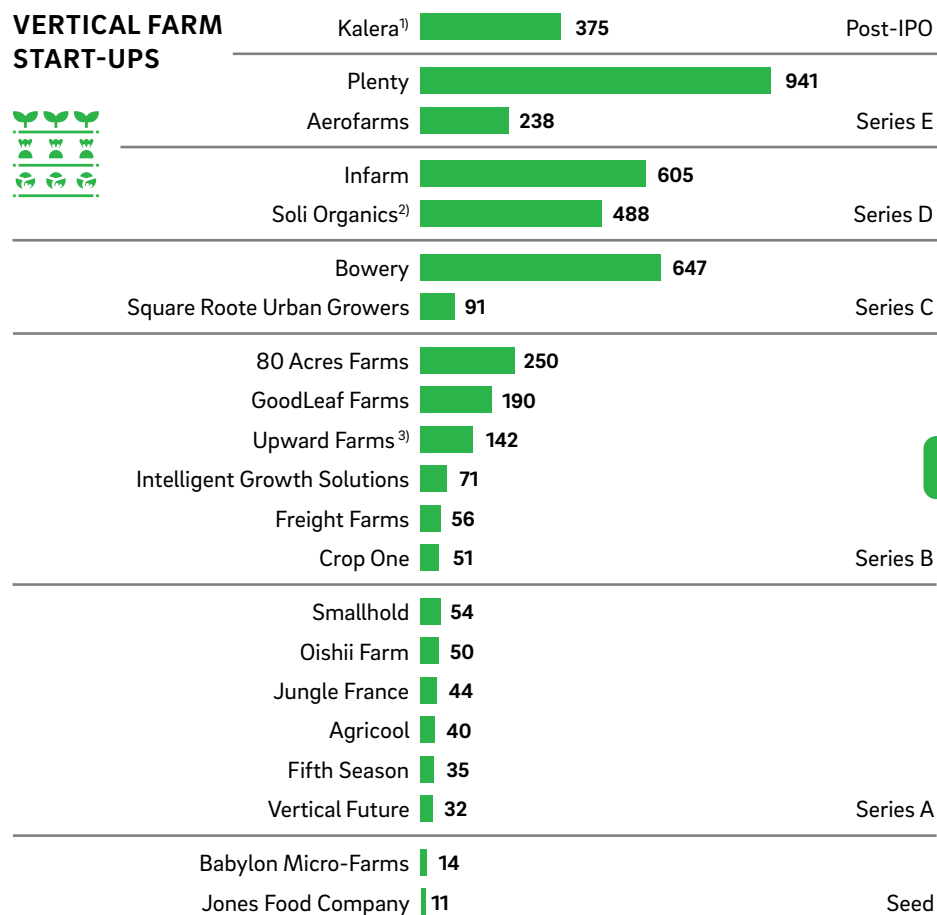
Geographical focus: United States, Canada, European Union, United Kingdom.



## Enthusiasm is confirmed by investors – Total investments in CEA across North America, Europe and UK has reached USD 7 bn to date, with 65% in vertical farms

### OVERVIEW OF CEA START-UPS WITH TOTAL FUNDING OF USD 10+ M, AS PER Q4 2022 [USD M]

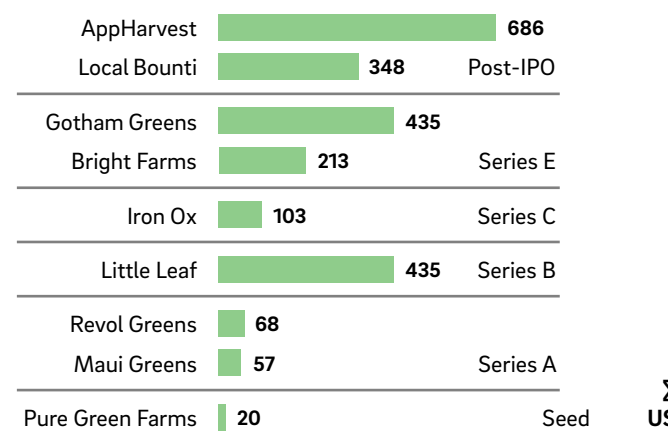
#### VERTICAL FARM START-UPS



Σ USD

4.5 bn

#### GREENHOUSE START-UPS



Σ USD

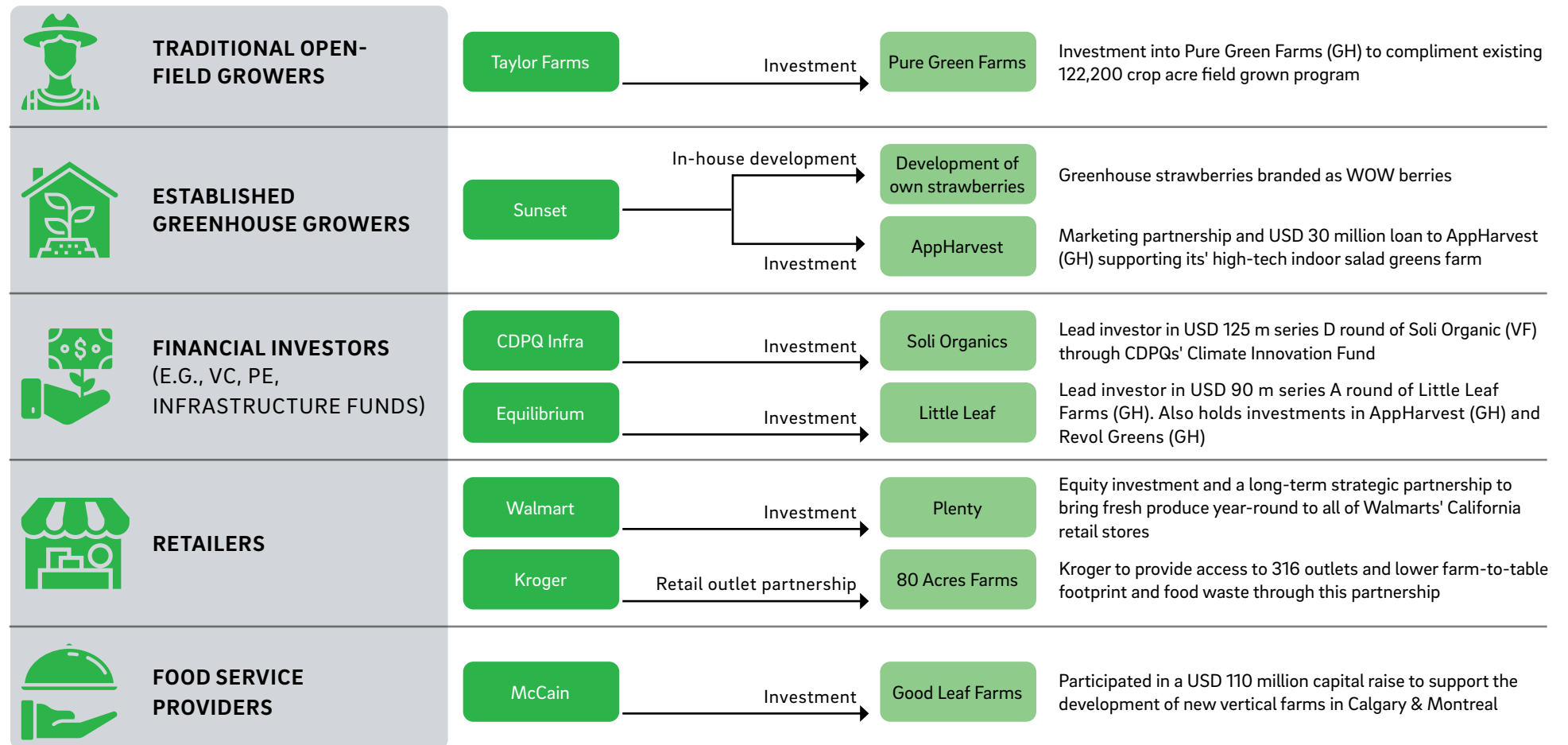
2.3 bn

While greenhouses have a proven track record and have demonstrated ability to reach profitability, funding has been more concentrated in vertical farming start-ups

1) Valuation at IPO used as proxy for total funding; 2) Shenandoah Growers; 3) Edenworks

## CEA start-ups are receiving funding from a diverse range of investors who are also seeking to leverage strategic partnerships

### ILLUSTRATIONS OF INVESTORS BUYING INTO THE CEA SPACE



## While CEA has a clear potential to localize food supply and ensure food security for a growing population, the volatile market conditions render the outlook uncertain

### KEY CONCLUSIONS AND OBSERVATIONS ON CEA MARKET OUTLOOK

#### CEA ENABLES LOCALIZED PRODUCTION AND YEAR-ROUND SUPPLY SECURITY

- With a growing population and limited resources, **uptake of CEA seems inevitable** as it solves key growing challenges, counteracts climate change and answers end-customers needs such as sustainability, traceability and increased quality requirements
- However, CEA will not displace traditional growing methods – it has the potential to **co-exist among various growing systems** to make the food value chain more resilient and more localized
- Furthermore, it can tailor to **specific use cases**, e.g.,:
  - Regions where growing conditions are inhospitable, coupled with high population density – Examples include Middle East, Singapore and Japan
  - CEA as complimentary solution to the traditional growers – Example includes cost optimization by focusing CEA on nursery crops as input for outdoor growing

#### REACHING COST PARITY WITH OUTDOOR GROWING WILL BE KEY TO SCALE

- To reach sizeable market shares, CEA produce will need to **reach cost parity** with field-grown organic produce – especially given current market with high inflation where consumers are more cost-conscious
- **Enablers** to increase viability include
  - Smart energy set-up (e.g., in-house generation, off-peak consumption, energy storage)
  - Increased levels of automation
  - Precision farming using big data analytics
- To date, **greenhouses are closer to cost parity** than vertical farms and have the advantage of familiarity
- Furthermore, more expensive CEA produce could tailor to **niche, premium segments** in the market that are willing to pay a premium (e.g., food service, local restaurants)

#### TOUGH MARKET CONDITIONS RENDER SCALABILITY AND OUTLOOK OF CEA UNCERTAIN

- **Energy crisis, high inflation and rising interest** rates pressure the business and operating model of CEA
- Various **CEA players are already in distress**, e.g.,:
  - **Infarm** (DE) announced in Nov 2022 to lay off 50% of staff and refocus its growth strategy, due to escalating energy prices and tough financial markets
  - **AppHarvest** (US) discloses substantial doubt about future outlook, resulting in deep stock price drops (USD 30 in Feb 2021 to USD 1.20 in Nov 2022)
  - **Kalera** (US) getting de-listed from NASDAQ in Nov 2022, following IPO early 2022
- **Looming consolidation wave** expected due to distressed nature of CEA assets and search to reach profitability through economies of scale

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