



# INDOOR CROP PRODUCTION FEEDING THE FUTURE

MARCH 2015



## About the White Paper

The purpose of this paper is to consolidate knowledge on the current state of the indoor agriculture industry, demonstrate its growing importance to our food system, and present the case for its long-term economic viability. Our target audience is those that do not know the industry well; the paper is intended as an introduction to indoor agriculture. As its authors, we do not consider ourselves expert in the industry, nor are we bound by any legal or contractual relationship to one another. We came together to create this paper out of a shared belief that, by better understanding the current state and trajectory of the indoor agriculture industry, we can collectively work to expedite its growth and create new opportunities for economic gain as well as wide-scale improvement in the US food supply system.

## About the Authors

Newbean Capital is a registered investment adviser that manages early stage venture capital mandates for institutional investors. Its founder – Nicola Kerslake – has a longstanding interest in agriculture investment, having previously covered agriculture stocks as an equity analyst and managed institutional investment portfolios that covered the sector. She founded the Indoor Ag-Con event three years' ago to provide a meeting place for those who are as passionate as she is about the promise of the indoor agriculture industry.

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Local Roots is a thought leader in indoor agriculture, dedicated to solving systemic food chain inefficiencies through innovation and technology-driven solutions. Local Roots is currently pioneering modular controlled environment agriculture technologies that enable year round crop production in any climate, in any geography. Local Roots' Mission is to provide everyone access to fresh, healthy, and affordable locally-grown produce.

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## EXECUTIVE SUMMARY

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Indoor agriculture is quickly gaining momentum in the United States. Indoor farms mostly use farming techniques and technologies which allow for improved control over the variables involved in the growing of produce. We estimate that there are 15 commercial-scale vertical farms and rooftop greenhouses in North America today, and that a further 30 will be added in 2015 alone. With a total addressable market size of over \$9bn – or 17x the current US market size - indoor agriculture is poised to be the next major enhancement to the American food supply chain.

Strong growth in “local food” demand, the market for which has expanded from an estimated \$1 billion in 2005 to nearly \$7 billion last year, has meant a unique market entry point for indoor farms’ higher price-point products, whether this means leafy greens harvested that morning for lunch service or microgreens grown to order for a local supermarket. While seasonality, soil conditions, and access to land have traditionally made year-round local produce sourcing impossible, indoor agriculture is well positioned to satisfy the largely unmet need for local produce by growing year-round in any climate.

Indoor farms have historically struggled to compete on cost with outdoor counterparts but ‘field parity’ – growing at the same per plant cost as in outdoor farms - is quickly becoming a reality thanks to rapid falls in technology costs in areas as diverse as lighting, seed development and control systems. Continued advances in technology are driving the industry towards wide-scale economic viability.

Indoor crop production has secondary benefits that increase efficiency in our national food supply chain. Indoor farms can theoretically be located anywhere, including retailer parking lots, urban rooftops, vacant lots, and rural locations. Farmers can more easily grow “just in time” and can supplement outdoor growing by supplying produce “off season”. Combined, this means lower transportation costs, less spoilage and better quality produce on the supermarket shelf. It helps supermarkets cut the \$15bn they lose annually on unsold and spoiled produce. This flexibility has encouraged supermarket chains, restaurants and campuses to source produce from indoor farms.

Investors too have a newfound interest in the sector, with about 12% of global agtech investment dollars going into indoor cultivation systems last year. In the US, at least \$32 million in venture capital-like funds was invested in indoor agriculture in 2014, more than 60% of the total raised from 2011 onwards.

Like many young industries, the indoor agriculture sector looks to a variety of stakeholders to aid its expansion. Local governments have a role to play in clarifying regulation and zoning for indoor farms, while their federal counterparts can provide better data and extend existing funding programs to the indoor sector. Chefs can use their voice to incorporate indoor crops into menus, to educate consumers on its benefits and to work with farmers on innovative flavor profiles.

Indoor farming will never replace conventional outdoor farming methods. It will instead augment the food chain to create a diverse, distributed system more resilient to supply shocks and better prepared to meet the demands of a growing global population.



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**INDOOR CROP PRODUCTION**  
FEEDING THE FUTURE  
MARCH 2015

# A

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## **An Introduction to Indoor Agriculture**



## A. AN INTRODUCTION TO INDOOR AGRICULTURE

Between 1930 and 2000, United States agricultural output quadrupled while the United States Department of Agriculture's (USDA) index of aggregate inputs (land, labor, capital, and other materials) remained essentially unchanged.<sup>1</sup> The primary driver of increased productivity has been technological progress, fueled by rapid improvements in irrigation techniques, development of synthetic nitrogen fertilizers, widespread use of pesticides, advanced plant breeding, and a host of other innovations.

Indoor Agriculture, one such family of technologies, has received increasing attention over the past decade for its ability to supplement food systems in a sustainable manner. Businesses have started tackling the challenges of year-round local food production by designing and deploying systems impervious to weather and other outdoor environmental conditions.

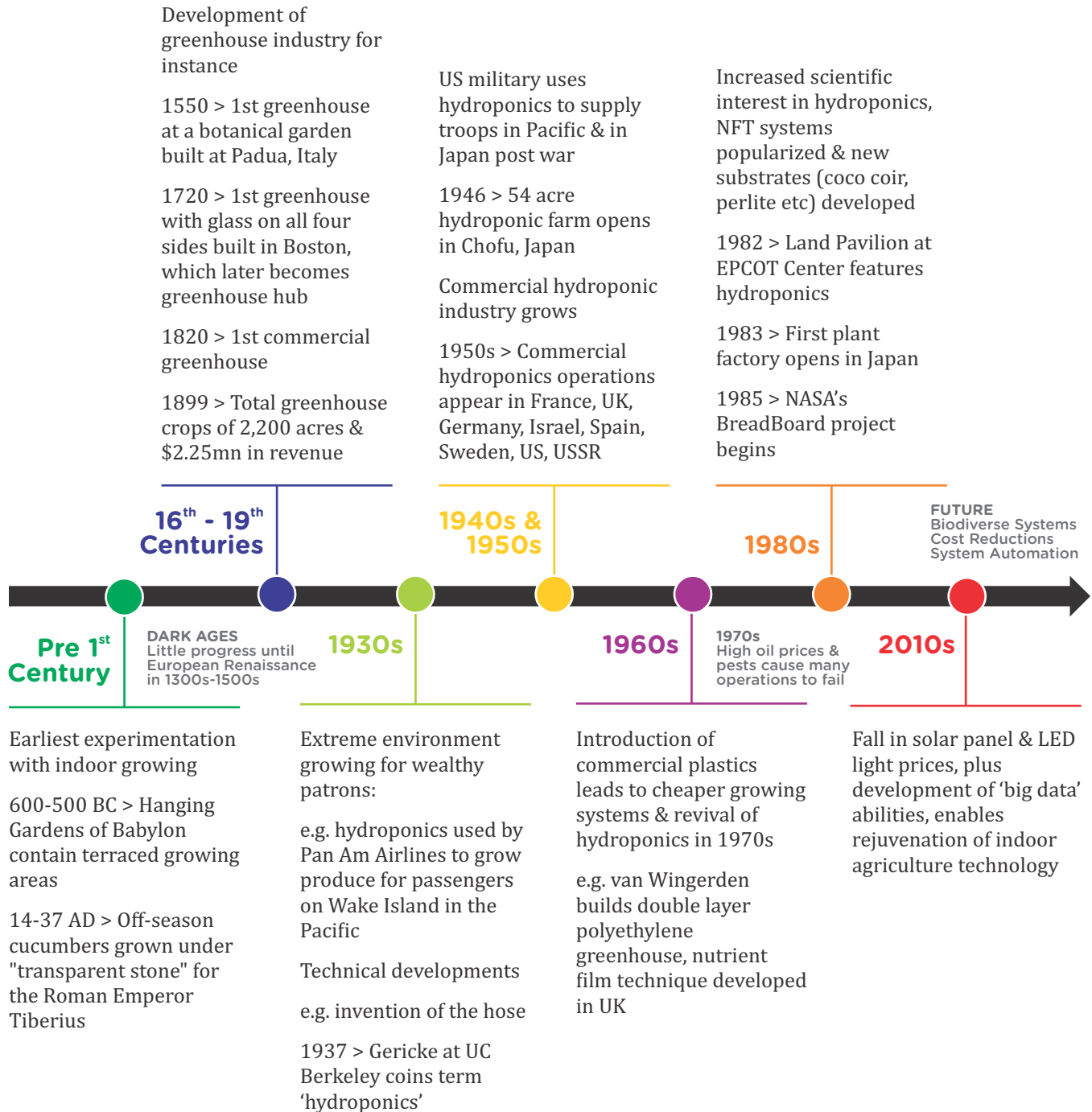
Indoor production of crops is nothing new; the foundations of modern greenhouses date back to Roman times as is shown in diagram one over page. Since the creation of key enabling technologies in the 1960s, the greenhouse industry has grown to be a significant part of the US produce supply chain and greenhouse-grown vegetables are prevalent in all national supermarket chains. Insulating themselves from the outside environment, these farms extend the growing season beyond the limits of conventional agriculture. The fresh tomato industry, for example, has experienced rapid transformation over the past twenty years as greenhouse-grown "on-vine" varieties of tomato have captured market share from traditional outdoor growers and foreign import markets during winter months.

A new wave of innovation has recently emerged that augments traditional greenhouse technologies by extending wider controls over the variables involved with the growing of plants – including light, water, carbon dioxide, air temperature, nutrients, and a variety of other factors. These systems are predominately soilless, instead using hydroponic, aquaponic and aeroponic growing techniques to facilitate plant growth. Hydroponic systems work by submerging plant roots in a closed-loop recirculating water system filled with dissolved essential minerals and nutrients. Aeroponic systems are similar in concept, delivering water and essential nutrients in a mist to increase water efficiency and expedite plant growth. Aquaponics is a coupling of hydroponic plant growing methods with conventional aquaculture.

The burgeoning industry is referred to by a number of different names: closed loop systems, Controlled Environment Agriculture (CEA), plant factories (a common term in Asia in particular), protected environment agriculture, soilless growing, urban agriculture, vertical farms. For the purposes of this paper, we use the term indoor agriculture to refer to the growing of produce using hydroponic and aeroponic technologies within greenhouses, warehouses and containers. It is an intentionally broad definition intended to encompass the full range of soilless growing techniques and environments, from the most basic greenhouse to fully automated, remotely controlled, clean room systems.

<sup>1</sup> "US Agriculture in the Twentieth Century", Bruce Gardner, University of Maryland, Economic History Association

DIAGRAM ONE: INDOOR AGRICULTURE INDUSTRY TIMELINE



Sources: Miscellaneous including University of Arizona's Controlled Environment Agriculture Center, Shizuoka University, Newbean Capital analysis

As can be seen from diagram two, the wide spectrum of indoor agriculture systems currently on the market can be summed up in four broad categories:

- *Hydroponic Greenhouses* – like soil-based greenhouses, these greenhouses grow crops in a single layer. Transparent roofs are employed to utilize natural sunlight, augmented with supplemental lighting during dark days and off-peak growing seasons (i.e. winter).
- *Warehouse Farms* - industrial warehouse space is built or retrofitted with hydroponic, aquaponic or aeroponic equipment and crops are grown vertically to achieve economies of scale. Artificial lighting systems are used at all times.
- *Container Farms* – standardized, self-contained growing units that employ vertical farming and artificial lighting. In contrast to custom-designed warehouses, container farms strive for standardization.
- *In Home Systems* – small standardized growing units for use by consumers in home settings. These focus more on convenience and design than on yield, and are not a focus of our paper.

As of this writing, the indoor agriculture industry is still in its infancy. Its substantial market potential has been only marginally penetrated by traditional greenhouse hydroponics, which in 2013 had total revenues of \$555mn<sup>2</sup>, with large greenhouses across North America (see diagrams three and four). Though very little industry-wide data exists on other forms of indoor crop production, we estimate that there are no more than 50 businesses in the United States focused on commercial scale vertical farming, most with single farm locations and limited investment from institutional capital. Approximately 15 are currently farming at commercial scale – that is with multiple large purchase contracts supporting a dedicated full time staff; their locations are shown in diagram five. There were none as few as four years' ago. Even the largest players are still solidifying business models and exploring strategies for rapid growth.


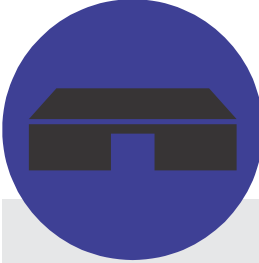


But this is quickly changing, and the potential is large. We estimate an addressable US market size of \$9bn, the calculation for which is in the appendix to this paper. The diverse group of indoor agriculture entrepreneurs is rapidly expanding, attracting those looking for new solutions, and inspired to meet the challenges of creating the food system of tomorrow.

This paper will provide an overview of technologies, opportunities and market factors driving this industry forward, and outline ways in which this growth can be bolstered and accelerated. It will focus on commercial farms using hydroponic and aeroponic growing systems in the US.



<sup>2</sup>"Hydroponic Crop Farming in the US", IBISWorld, January 2015

DIAGRAM TWO: INDOOR AGRICULTURE INDUSTRY BY STRUCTURE

				
	<b>HYDROPONIC GREENHOUSES</b>	<b>VERTICAL FARMS</b>	<b>CONTAINER FARMS</b>	<b>IN HOME SYSTEMS</b>
<b>Description</b>	Like soil-based greenhouses, these greenhouses grow crops in a single layer. Transparent roofs are employed to utilize natural sunlight, augmented with supplemental lighting during dark days and off-peak growing seasons (i.e. winter).	Industrial space is constructed or retrofitted with hydroponic, aquaponic or aeroponic equipment and crops are grown vertically to achieve economies of scale. Artificial lighting systems are used at all times.	Standardized, self-contained growing units that employ vertical farming and artificial lighting. In contrast to custom-designed warehouses, container farms strive for standardization.	Systems targeted at consumers for small scale in home growth, whether as fridges in kitchens or as standalone units elsewhere in the home.
<b>Estimated No. of Cos in US Market</b>	250 greenhouse vegetable companies, (not all hydroponic) further 20+ greenhouses under development	15 fully commercial, at least 30 more in active development	3 commercial, at least 4-5 others in process of commercializing e.g. Local Roots Farms	At least 20 offering some form of in-home solution
<b>Company Examples</b>	Houwelings, Mastronarti, Nature Sweet, Village Farms, Windset	Farmbox Greens, FarmedHere, Garfield Produce Co, Green Sense Farms, PodPonics,	Daiwa's agri-cube, Crop Box, FreightFarms, Growtainers, Pure Genius (formerly AquaHarvest)	agrilution, Grove Labs, Modern Sprout, Urban Cultivator, Windowfarms

Source: Miscellaneous public sources, greenhouse data from Cuesta Roble Consulting, Newbean Capital analysis

# Vertical Farm

3



# Hydroponic Greenhouse

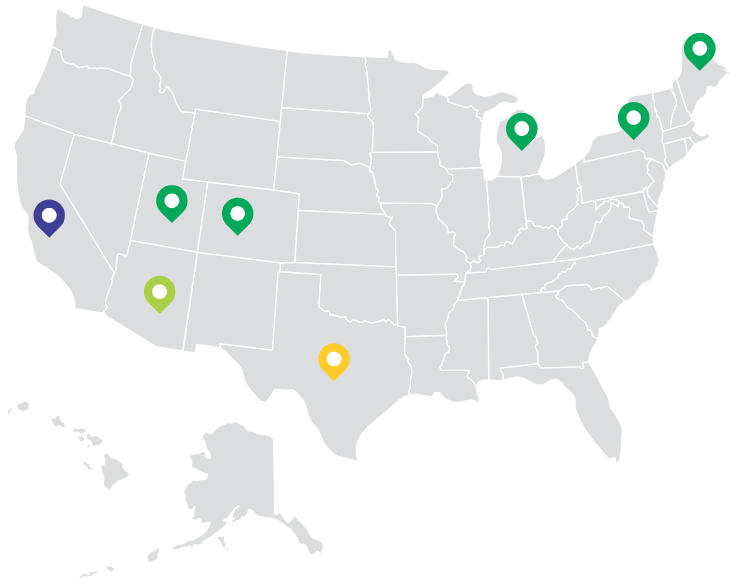
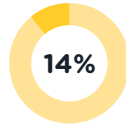
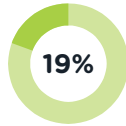
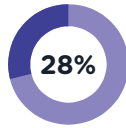
**DIAGRAM THREE: USA'S LARGE GREENHOUSE COMPANIES**

**CALIFORNIA | 28% OF CAPACITY**  
 Large Greenhouse Operators:  
 Hollandia, Houweling, Prime Time  
 International, Quail Mountain Herbs  
 SunSelect, Windset Farms

**ARIZONA | 19% OF CAPACITY**  
 Large Greenhouse Operators:  
 Nature Sweet

**TEXAS | 14% OF CAPACITY**  
 Large Greenhouse Operators:  
 Village Farms

**REST OF USA | 38% OF CAPACITY**  
 Large Greenhouse Operators:  
 Backyard Farms, Coldwater Greenhouse  
 (Mastronardi), Houweling, Intergrow,  
 Sunblest Sunsetgrown (Mastronardi)



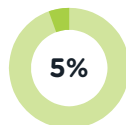
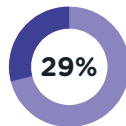
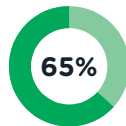
Source: Data from Cuesta Roble Consulting, analysis by Newbean Capital. Companies listed are those with greenhouses of 30 acres or more. Figures are for share of total US greenhouse acreage.

**DIAGRAM FOUR: CANADA'S LARGE GREENHOUSE COMPANIES**

**ONTARIO | 65% OF CAPACITY**  
 Large Greenhouse Operators:  
 Agriville Farms, AMCO Farms  
 Clifford Produce, DiCiocco's  
 Double Diamond Acres, Flavour Pict  
 Produce, Great Northern Hydroponics  
 Mucci Farms, Nature Fresh Farms  
 Orangeline Farms, Platinum Produce  
 Prism Farms, Red Sun Farms, Sabelli Farms,  
 Smarty Brand, St. Davids Hydroponics,  
 Sunset, Suntastic, Westmoreland Sales

**BRITISH COLUMBIA | 29% OF CAPACITY**  
 Large Greenhouse Operators:  
 Canagro, Houweling, Merom Farms  
 Millenium Pacific GHs, Randhawa  
 Farms, South Alder Greenhouses,  
 Sunselect, Vander Meulen Greenhouse,  
 Village Farms. West Coast Vegetables,  
 Windset

**QUEBEC | 5% OF CAPACITY**  
 Large Greenhouse Operators:  
 Les Serres du St Laurent



Source: Data from Cuesta Roble Consulting, analysis by Newbean Capital. Companies listed are those with greenhouses of 30 acres or more. Figures are for share of total Canadian greenhouse acreage, remaining 1% is operated by small companies

DIAGRAM FIVE: US & CANADIAN COMMERCIAL SCALE VERTICAL FARMS



Source: Industry Reports

\*Green Spirit Farms has a second location in Medina, OH

\*PodPonics is based in Atlanta GA, and also has a farm in Dubai



**GROWING CONSUMER DEMAND  
FOR LOCAL FOODS**

# B

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## Primary Factors Driving Indoor Agriculture Growth

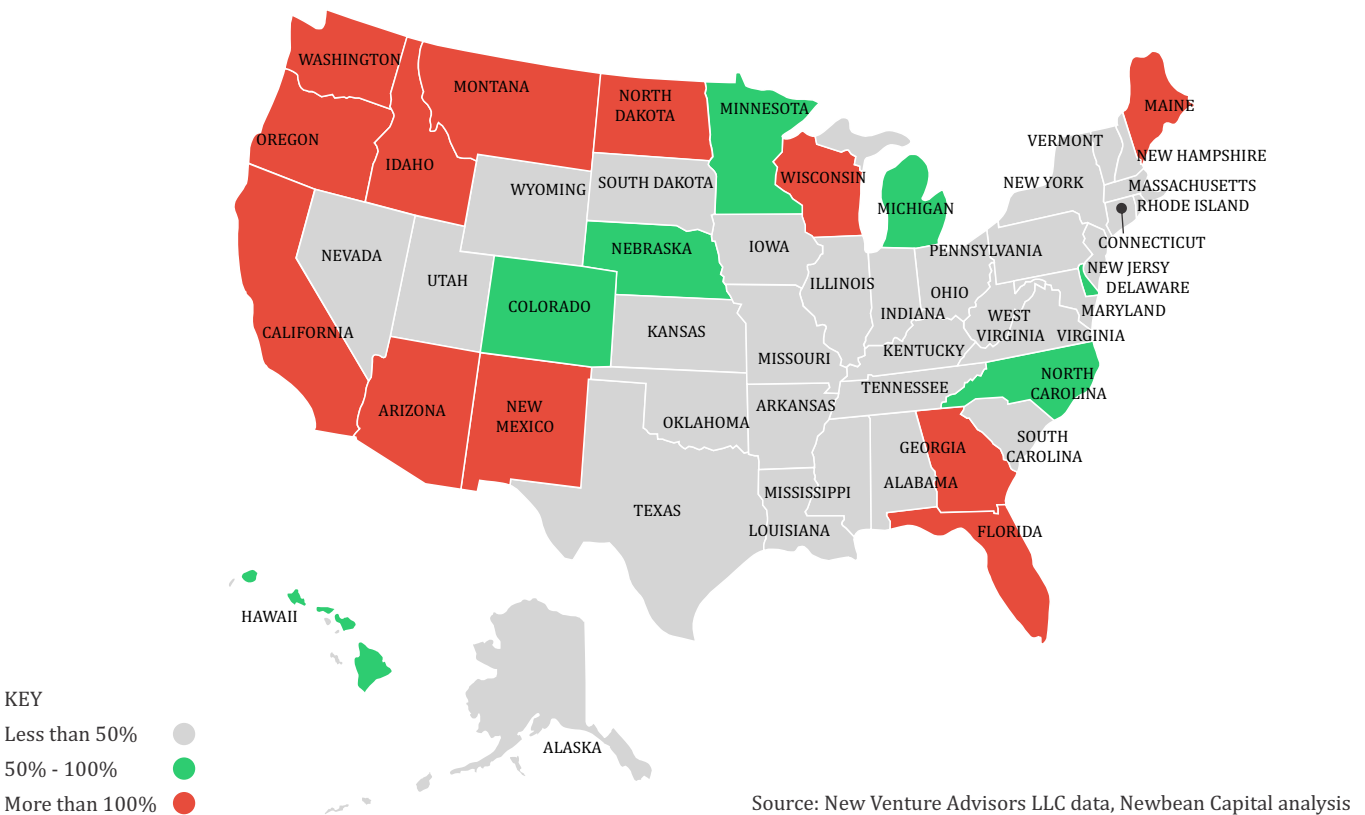
## B. PRIMARY FACTORS DRIVING INDOOR AGRICULTURE GROWTH

A primary driver of the indoor agriculture industry is its ability to satisfy the rapid growth in consumer demand for affordable, high quality, local produce. Strong growth in Natural and Organic segments over the past decade has established a precedent for premium, branded produce sold through a variety of sales channels. Distribution options have expanded for farmers as local delivery platforms have gained traction, such as New York online grocer Fresh Direct and online retailer Overstock.com’s Farmers’ Market initiative. Indoor farms have historically struggled to compete on cost with traditional outdoor farms, but the recent rapid movement towards “eating local”, along with the introduction of new distribution channels, has provided the opportunity for high-margin indoor crops to establish a foothold in the market.

### 1. GROWING CONSUMER DEMAND FOR LOCAL FOODS

As a category, “local foods” is rapidly gaining market share in the produce industry, growing from an estimated \$1 billion in 2005 to nearly \$7 billion last year with anticipated rapid category growth through 2017.<sup>3</sup> The unmet need is large: 39 states in the nation grow fewer fruits and vegetables than they consume, as can be seen from diagram six below.

**DIAGRAM SIX: STATE FRUIT & VEGGIE PRODUCTION AS SHARE OF DEMAND (%)**



<sup>3</sup> “USDA confirms farmers markets’ growth, sustainability”, AgriNews, August 25, 2013.

The desire to “eat local” is not simply the product of effective marketing tactics by corporate executives. Decentralizing the supply chain and bringing production closer to the consumer can directly result in longer shelf life and better taste. Moreover, produce traditionally bred for resilience and the ability to withstand long-distance transport can instead be cultivated for unique size and flavor profiles.

According to a 2014 study conducted by the Hartman Group; “‘local’ is emerging as a category poised to surpass both organic and natural as a symbol of transparency and trust. With its connotations of community, economy and environmental stewardship, ‘local’ offers compelling narratives that include small-scale production and closer, reciprocal relationships with food producers.”<sup>4</sup> The internet has given modern consumers information on farming practices, allowing insight into growing methods and an unprecedented opportunity to “know your farmer.” This demand for increased transparency in growing practices mirrors a broader trend of regulatory mandated traceability throughout the food chain.

Growth has been seen across direct-to-consumer channels (farmers markets, community supported agriculture) and intermediated marketing channels (grocers, restaurants, regional distributors) alike. The number of farmers markets has more than doubled over the past decade, providing increased opportunities for consumers to “buy local.”<sup>5</sup> Small farms tend to favor direct-to-consumer channels as they offer logistic simplicity and higher per-unit margins. Large farms tend towards intermediated channels, contributing towards a more permanent presence of “local food” sections in retail outlets.

## 2. BUSINESSES HAVE LACKED YEAR-ROUND SOLUTIONS

Commercial food buyers are eager to meet this increased consumer demand for local foods. For retailers, distributors, and food service professionals, the local category represents an opportunity to not only meet consumer demand, but simultaneously decrease food waste, increase unit margins and ultimately drive bottom lines.

The USDA estimates that supermarkets lose \$15bn annually in unsold fruits and vegetables.<sup>6</sup> A large portion of this loss is attributable to shrink (produce damaged during transport) and spoilage, which typically increases proportionately to food miles – the distance food travels between farm and the end customer. Local produce offers an opportunity to mitigate shrink, as food is no longer required to travel hundreds, or even thousands of miles in transport between farm and store. Shelf life is simultaneously increased as the time between harvest and customer drops. Successive studies have shown that, in common with parts of the organic category, local produce can generally demand a price premium and increase per unit margins. For example, a 2014 Cornell University study<sup>7</sup> listed a 27% premium for locally produced strawberries in Ohio, a 27.5% one for local produce in South Carolina, and premiums for both tomatoes and strawberries in a New York county.

<sup>4</sup> “Organic & Natural 2014”, Hartman Group

<sup>5</sup> “National Count of Farmers Market Directory Listing Graph: 1994-2014”, USDA Agricultural Marketing Service

<sup>6</sup> “Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill”, Dana Gunders, Natural Resources Defense Council, August 2012

<sup>7</sup> “A Case Study of Price Premiums for Local Foods in Tompkins County, New York”, Tang, Gomez & Park, Charles H. Dyson School of Applied Economics and Management, Cornell University, November 2014

As a result, many grocers have added or expanded category shelf space and are rapidly developing local-sourced initiatives. Sourcing locally enables regional grocery chains to differentiate themselves from big box competitors, and it allows larger players to meet corporate social responsibility targets. For instance, in 2010, Walmart announced its 'Heritage Agriculture' initiative whereby it aimed to double the amount of local produce that it sourced in the US.<sup>8</sup> In an article in the magazine *The Atlantic*, Walmart's Senior Director of Local and Sustainable Sourcing highlighted the change in its sourcing for jalapeno peppers, where it says that it worked with existing suppliers to expand sourcing to 20 states, so lowering costs and carbon emissions while supporting local farmers.<sup>9</sup>

In reality, most food buyers struggle to source any portion of their produce locally on a consistent basis. Seasonality makes year-round sourcing difficult, if not impossible for many parts of the country where climate conditions, soil conditions and access to land limit the growth of high-quality produce for many months of the year. Small farms frequently cannot meet delivery schedules, volume demands, regulatory requirements, or other food safety certifications imposed by large produce buyers. Instead they turn to direct-to-consumer channels where they sell at prices unattainable for much of the population.

### 3. INDOOR AGRICULTURE IS WELL PLACED TO BE A YEAR ROUND SOLUTION

By curtailing the effects of weather and seasonality and enabling year-round crop production in all parts of the country, indoor growing techniques are uniquely situated to meet this market need. Several businesses are already using indoor agriculture technologies to drive profits and grow indoor crops in a cost-competitive manner, whether it's to grow leafy greens during the winter when local produce would be otherwise unavailable, to grow a high value herb crop with particular flavor characteristics, or to substitute fresh barley for dry hay for animal fodder.

The most enduring criticism of the industry has long been that it could not compete with field grown produce, and this criticism still holds in some cases; few indoor farms can claim to produce lettuce at the same price as California's famed farming area, Salinas Valley in summer months, for instance. But 'field parity' is coming closer as the costs of indoor farm equipment falls; for example, LED light bulb prices fell by 24% between 2010 and 2012, and are forecast to halve by 2020.<sup>10</sup>

Moreover, this trend is just beginning. As is laid out below, indoor growers have an increasingly plentiful range of options when it comes to the technologies that they can employ to reach cost competitiveness.



<sup>8</sup>Walmart Unveils Global Sustainable Agriculture Goals", Press Release, October 14, 2010

<sup>9</sup>"An Insider's Account of Walmart's Local Foods Program", *The Atlantic*, November 17, 2010

<sup>10</sup> Source: Enterprise LED Market Research for historic figures, Lux Research for forecasts

## CASE STUDY: LUFU FARMS BRINGS LOCAL FOOD TO MONTREAL

Montreal-based Lufa Farms was one of the pioneers of commercial urban agriculture, opening its first hydroponic greenhouse in February 2011. Where most beginning farmers sell through local farmers' markets or small-farmer-friendly grocers, such as Whole Foods Market, Lufa Farms instead decided to sell its produce direct to consumers. The approach allows Lufa Farms to capture the full return from its produce, but also poses the challenge of building a customer base one-by-one. The company's online platform offers products from local artisans alongside its own produce; customers select a weekly basket and collect it from one of dozens of locations in the city, whether a gym, office or neighborhood coffee shop. In effect, the company has created its own distribution platform, with the added benefit of vertical integration.

In a recent interview, Lufa Farms co-founder Lauren Rathwell commented that; "we've made it to over 5,000 weekly subscribers, largely through word of mouth"<sup>11</sup>, though this downplays the role that customer service, technology and economies of scale have played in the company's success.

A strong traditional and social media presence has doubtless helped Lufa Farms reach a wider audience. It has also made ordering and collecting baskets a simple and flexible process for consumers, for instance, by allowing customers to tailor baskets to their needs that week, rather than insisting that they sign up for an entire season's worth of produce as is the case with some community supported agriculture agreements. As the company grows over 40 vegetables, there's plenty of choice and this is supplemented by other locally-sourced products, such as cuts of meat and yogurt. Customers can pick up baskets from the venues that they visit as part of their daily routines, whether that's a coffee shop or a gym.

The company has been at economic scale since the get-go, its inaugural Montreal greenhouse being capable of producing more than 150k lbs of produce annually. It opened a second, larger, greenhouse on the roof of a new building in October 2013 in conjunction with Dutch greenhouse manufacturer KUBO. In media reports, the company has discussed its intention to move into the US market with Boston likely to be the location of its first state-side farm.

Finally, the farms feature a good deal of technical sophistication, for example, utilizing cloud-based remote crop monitoring and disease management. It is this winning combination that has, in our opinion, allowed Lufa Farms to defy the odds in building a successful direct-to-consumer business.

<sup>11</sup> "#5 Lauren Rathwell: Co-Founder Lufa Farms", The Editorial, December 30, 2014

**INDOOR AGRICULTURE IS WELL PLACED  
TO BE A YEAR ROUND SOLUTION**



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# The Technologies Behind Indoor Crop Production



## C. THE TECHNOLOGIES BEHIND INDOOR CROP PRODUCTION

Indoor agriculture is a tech-industry at its core, driven by rapid iterations in the technologies critical to plant growth. New integrations of these systems continue to raise yields, increase growing efficiencies, and lower costs associated with indoor crop production. We anticipate that the rate of technological advancement will continue to increase as the industry proves wide-scale economic viability.

### DIAGRAM SEVEN: HYDROPONIC SYSTEM COMPONENTS

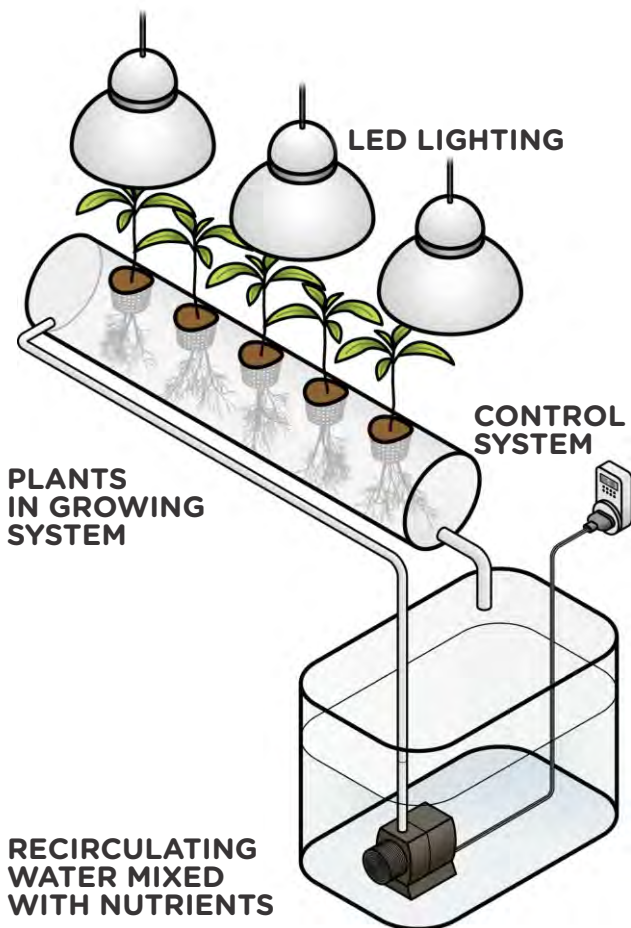


Diagram seven opposite shows the basic components of a generic hydroponic growing system, each of which are undergoing substantial technology upgrades. The most impactful areas of ongoing development are:

### FORM FACTOR AND GROWING SYSTEMS

*Current state:* As previously highlighted, indoor crop production occurs in a wide variety of configurations. Once an overall form factor is selected (greenhouse, warehouse, container, etc.), farmers can customize facilities with a variety of growing systems. These range from traditional Ebb & Flow and Nutrient Film Technique racking systems to ZipGrow vertical grow racks to even more novel concepts such as the pyramid-shaped growing system Pyramid Gardens or Volksgarden's circular Omega Gardens. Farms are most frequently custom-engineered and manufactured to meet specific geographic, and crop requirements. A farm's overall size, shape, materials used for construction, and crop spatial arrangements largely dictate upfront capital expenditures required to develop commercial-scale farms.

*What would help:* We believe that we have reached a tipping point where the focus of development should switch from creating new and novel form factors to increasing the yield and substantially lowering the manufacturing and operating costs of existing solutions, so improving payback periods of indoor growing systems. Standardization and centralized manufacturing of forms would dramatically reduce costs. Form factor research and development should continue to be directed towards increasing output and lowering costs per cubic foot, for instance, by incorporating more automation and use of sensors into systems.

## LIGHTING

*Current state:* Indoor crop production systems, particularly warehouse and modular ones, rely on highly efficient lights to augment or replace natural sunlight. Dramatic advances in LED technologies since 2010 have afforded indoor growers unprecedented flexibility to customize light spectrums as a method to expedite plant growth. Modern LEDs use primarily blue and red diodes to increase light efficiency while minimizing temperature impacts within a growth chamber. Commercially available horticulture lights now allow for analogue control over light spectrums, encouraging unprecedented work in plant spectrum response and enabling growers to optimize light delivery to achieve ideal plant characteristics.

*What would help:* Adaptive LEDs will allow light spectrums to be fully customized throughout the lifespan of a crop by adjusting, light intensity, spectrum composition (red vs. blue proportions), and light height (distance from plants) to ensure even spread across growth chambers. Upfront costs remain high, so lower prices, along with LEDs with more micromoles per joule (which translates to higher yields) would be beneficial.

## CONTROL SYSTEM HARDWARE

*Current state:* Large-scale control systems are available from industry leaders, such as Priva and Argus Control Systems. These systems are employed by many large-scale greenhouse operators, designed into farms from inception to monitor and regulate lighting, CO<sub>2</sub> levels, nutrient reservoirs, plumbing and a host of other variables. The systems are typically cost-prohibitive for small operations and beginning farmers. As a result, many practitioners are developing and leveraging proprietary control systems as a competitive advantage.

*What would help:* Small-scale control systems with robust functionality would allow businesses on a shoestring budget to better automate their systems, increasing yields while decreasing labor costs. In the long run, user-friendly human machine interfaces should allow skilled tradesmen to customize prebuilt systems and horticulturalists to more precisely control the plant environment. As sensors decrease in cost and more data is collected from tightly controlled systems, big data methods such as linear programming, non-linear optimization, machine learning, artificial neural networks, cluster analysis, and other artificial intelligence techniques should be applied to optimize plant characteristics and yields.

## WATER CONSUMPTION

*Current state:* Closed-loop indoor systems have been shown to reduce water usage by over 90% compared with traditional outdoor farms. Certain aeroponic farms and other advanced water recapture systems allow for 95% or more reduction in water usage, but can be prohibitively expensive to install and maintain. Examples of water management companies in the space include BioSafeSystems, Dosatron, and DRAMM.

*What would help:* Additional water purification, desalination, and atmospheric recapture techniques could be developed to increase potential farm site locations and ultimately drive off-grid flexibility for indoor farms.

## NUTRIENTS

*Current state:* A wide range of nutrient solutions exists for home and commercial hydroponic systems that provide a wide of macro and micro molecules essential to plant health. Most large commercial players create their own nutrient mixes.

*What would help:* Many nutrient solutions make claims regarding effects on plant formation, including increased speed of plant growth or taste, but these claims are predominately poorly documented and untested. In addition, microbiomes within soil are not well understood and future development could bring vast advantages to plant growth in hydroponic systems.

## SEEDS

*Current state:* Most indoor farms use seeds bred to grow outdoors under highly volatile environmental conditions. Select crops – particularly leafy greens, tomatoes, peppers and cucumbers – have been bred for conventional greenhouses but limited data exists on performance under more-tightly controlled environment conditions. Larger growers operate their own seed development programs.

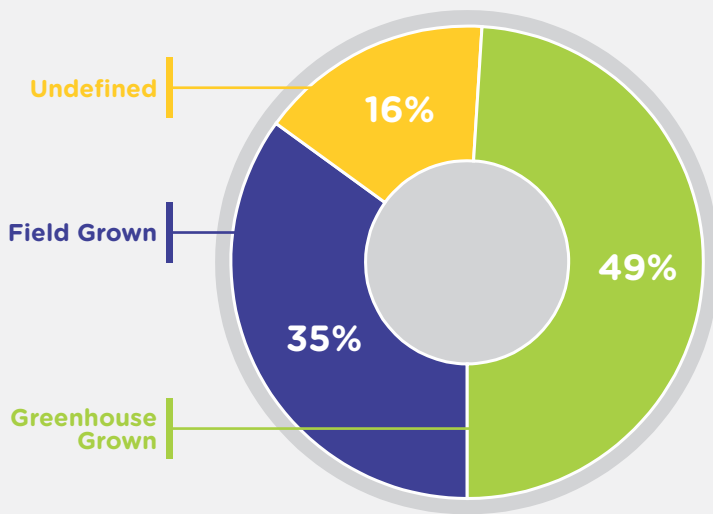
*What would help:* Seed development and testing, to optimize growing qualities for indoor systems where conditions are tightly managed and traditional outdoor concerns (pests, drought, floods, high winds, extreme temperatures, etc.) are limited, would be helpful. Such development could also be instrumental in expanding the universe of crops that can be grown commercially in indoor systems. This development is likely to be slower than that for other system components mentioned here as seed development programs are long term by nature; greenhouse seed trials have been running since the 1970s, for instance.



## CASE STUDY: THE RISE OF THE GREENHOUSE TOMATO

The second largest in the world, the US tomato market bifurcates between those that are grown for processing (most of the market) and those that are destined for the fresh produce market. Tomatoes are grown both in the field and in the greenhouse. Traditionally, Florida and California have been the largest US growers of outdoor tomatoes, with nearly two-thirds of total US fresh tomato acreage, a share that has been steady since the 1960s.<sup>12</sup>

**DIAGRAM EIGHT: RETAIL TOMATO DOLLARS**



Source: Village Farms  
 Figures exclude Costco and BJs which are 100% Greenhouse retailers

In its 2000-2001 annual report, the Florida Tomato Committee, an industry advocacy group, noted that the greenhouse tomato sector “appears to be on the rise” but that no solid numbers were available. By 2004, greenhouse tomatoes were under 10% of total US supply, but by 2011, they were 40%, with a higher share in retail channels.<sup>13</sup>

The USDA’s Economic Research Service attributes this rise to “consumer demand for year-round supply, a growing diversity of tomato types/substitutes, and developing technologies”.<sup>20</sup> The total market has also grown: US per capita fresh tomato consumption rose from under 15lb pa in 1985 to a peak of 20.6lb pa by 2010.<sup>14</sup>

Consumers have become accustomed to being able to purchase fresh produce year round, and to having abundant choices in grocery stores. The total number of all products (including packaged goods) in the average supermarket grew from an average of 8,948 in 1975 to almost 47,000 by 2008.<sup>21</sup> Greenhouse-grown tomato major Village Farms offers 10 varieties, for instance.

In the US, California is the dominant field-grown tomato supplier in the summer, and Florida in the winter, with Mexican and Canadian imports fulfilling surplus demand in the winter in particular. This deficit allowed greenhouse growers to gain a foothold in the market by, for instance, introducing tomatoes on the vine, which are now the most popular variety among consumers.

At the same time, a 2013 University of Florida paper concluded that the improved yields in greenhouse production outweighed substantially higher costs, in turn rendering greenhouse based growing more profitable than field based production in some environments.<sup>15</sup>

With continued improvements in greenhouse technology and falling US farmland acreage, the market expectation is that the greenhouse grown share of the market will continue to rise.

<sup>12</sup> USDA Economic Research Service data

<sup>13</sup> “Protected-Culture Technology Transforms the Fresh-Tomato Market”, USDA ERS, September 2013

<sup>14</sup> Food Marketing Institute figures

<sup>15</sup> “The Potential for Greenhouse Tomato Production Expansion in Florida”, VanSickle, Cantliffe & Ascì, Southern Agricultural Economics Association (SAEA) Annual Meeting, 3-5 February 2013



**INDOOR CROP PRODUCTION ENABLES YEAR-ROUND  
GROWING BY MITIGATING THE EFFECTS OF WEATHER.**

**D**

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**Secondary Benefits of  
Indoor Crop Production**

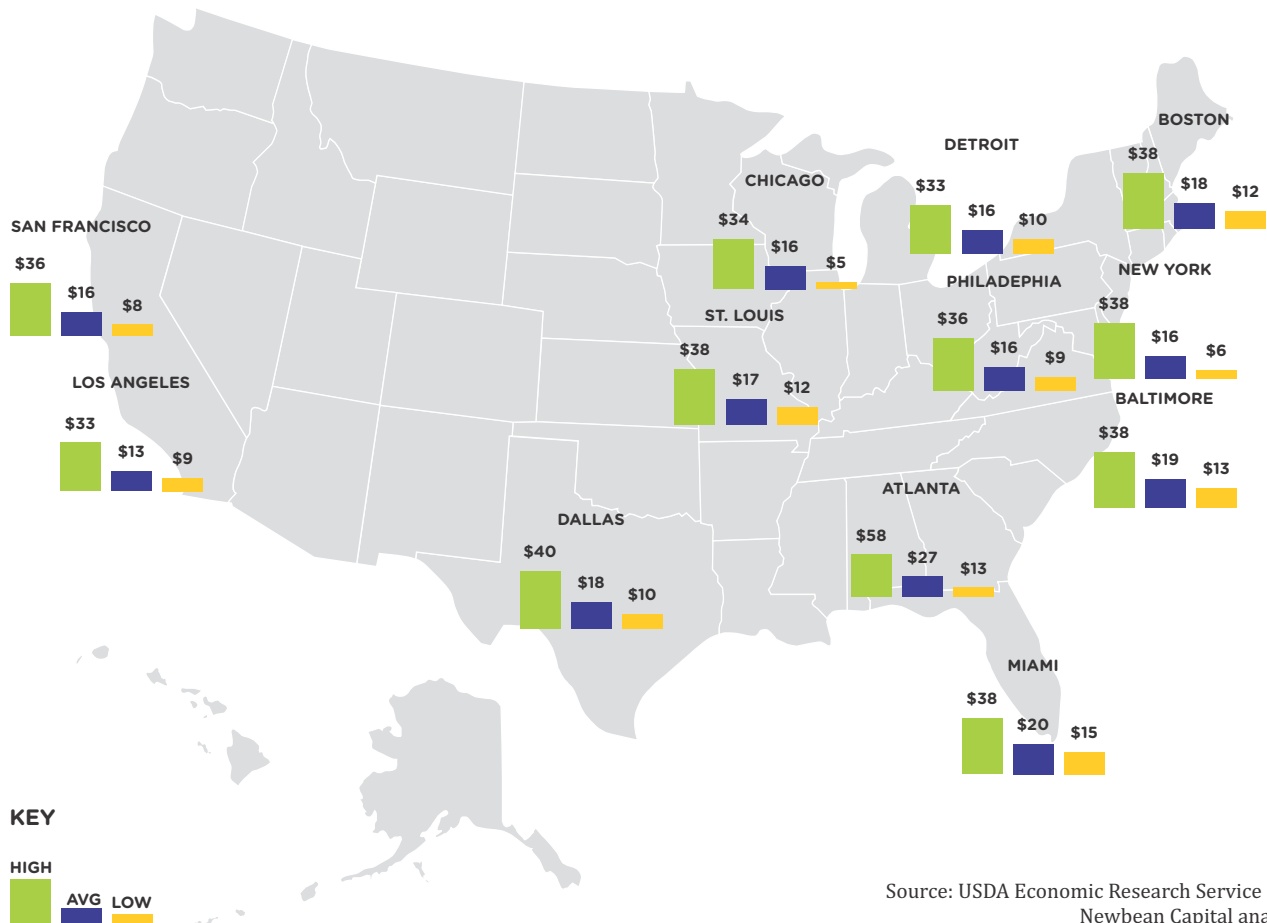
## D. SECONDARY BENEFITS OF INDOOR CROP PRODUCTION

It is clear that consumer demand, business demand, and technologies are converging to create an opportunity for rapid expansion of indoor crop production. To expedite this growth and win broader public opinion, the indoor agriculture industry should communicate its secondary benefits as well.

### *Year Round Growing*

Indoor crop production enables year-round growing by mitigating the effects of weather. This control over crop timing allows indoor farms to increase margins by growing “off-market” and selling against outdoor seasonality. In other words, indoor farms are uniquely capable of growing traditional summer crops during the winter and winter crops during the summer. Further, indoor farming techniques greatly reduce production variability at the farm level and enable unprecedented accuracy in cost forecasting. For consumers, this allows consistent availability and quality of produce throughout the year in all parts of the country, and for produce buyers accustomed to inconsistent supplies and volatile market prices,

**DIAGRAM NINE: NON-ORGANIC GREEN LEAF LETUCE PRICES BY HUB, \$/CARTON 24S, NOV 2012-NOV 2014**



Source: USDA Economic Research Service data, Newbean Capital analysis

it represents a potential paradigm shift as the practice becomes more common. Suddenly produce buyers do not need to aggregate from multiple farms on an ongoing basis to hedge against volatility; as is shown in diagram nine below, prices vary by as much as 300% across a year for a crop as commonplace as lettuce. Instead, longer-term contracts with fixed pricing and volumes can be instigated. In this scenario both sides benefit. Farms receive guarantees that their product will be sold and have greater insight into revenue metrics for strategic planning purposes. Produce buyers can accurately forecast costs, while saving time and energy by avoiding the spot markets. Certain produce buyers who have traditionally relied upon distributors to smooth supply may have greater flexibility to deal direct with farmers, increasing profit margins on both sides.

### *Flexibility of Farm Locations*

Indoor systems can, in theory, be located anywhere – including retailer parking lots, urban rooftops, vacant lots, and rural locations. For businesses seeking to fit into existing transportation infrastructure, farms can be located adjacent to cold-storage warehouses or end points of consumption. Co-location with customers reduces transportation costs, minimizes spoilage and mitigates quality degradation while extending product shelf life for consumers.

### *Potential Health Benefits*

USDA's Economic Research Service estimates that 23.5mn Americans live in food deserts, of which 13.5mn are low income.<sup>16</sup> These individuals lack both regular access to nutritious foods and the ability to afford fresh produce. Enabling mass crop production in urban environments allows for unique approaches to solving food access issues because it changes the unfavorable economics of last-mile distribution logistics. By placing indoor farms inside of food deserts, the cost of shipping produce is greatly reduced or eliminated entirely. These savings can be passed on to customers, ultimately lowering produce prices to levels affordable even in low-income communities. The Farmery, for example, is a prototype facility that acts simultaneously as a farm and a retail outlet in downtown Durham, NC. Other creative solutions, such as the Arcadia Center for Sustainable Food & Agriculture's Mobile Markets, a 28' farm stand on wheels, provide relevant partnership opportunities and areas for blue ocean market expansion.

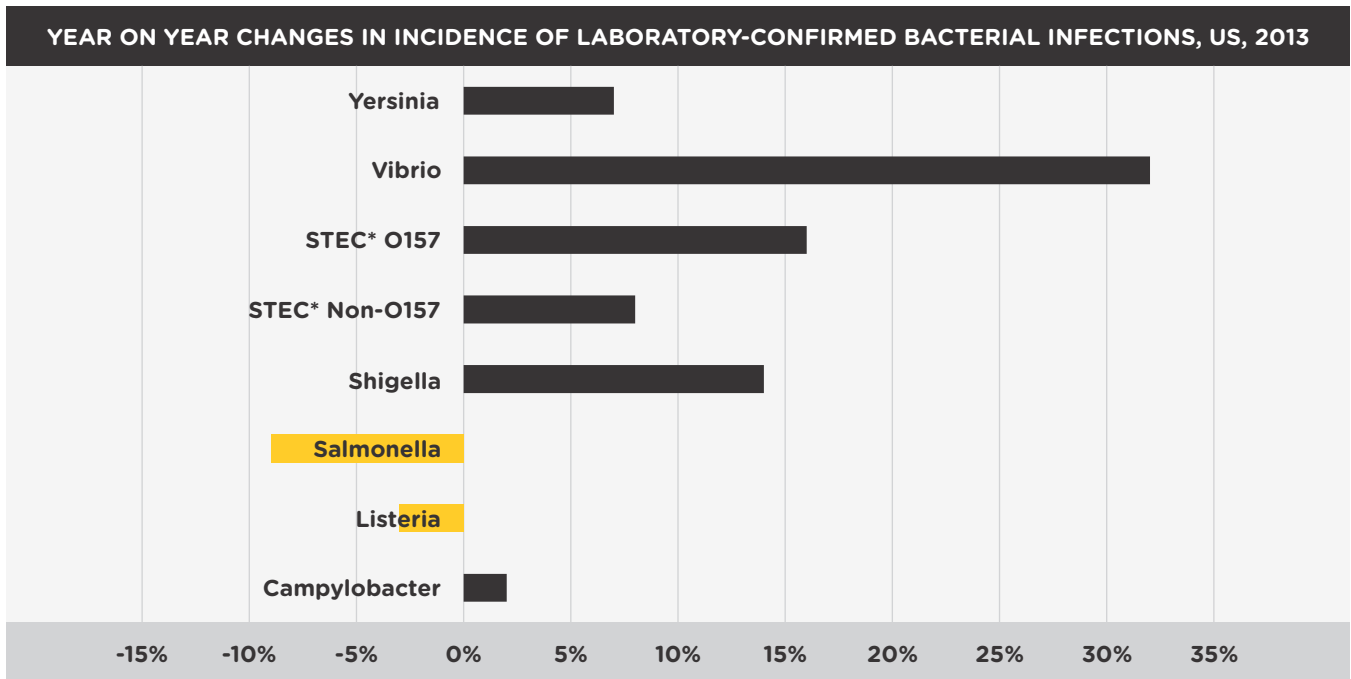
### *Water Efficiency Is Important*

Record drought conditions are currently occurring in key agricultural regions, specifically the largest in the U.S., California. If drought conditions persist as is as is predicted due to the changing climate, there will be continuing pressure to reduce agricultural production and fallow some land. Indoor agriculture can take up some or all of this slack in production, in regions like California, using only a fraction of the water, and continuing to operate even under severe drought conditions.

<sup>16</sup> "Food Deserts", USDA Economic Research Service



**DIAGRAM TEN: YEAR ON YEAR CHANGES IN INCIDENCE OF LABORATORY-CONFIRMED BACTERIAL INFECTIONS, US, 2013**



Source: United States Centers for Disease Control and Prevention, data is most recent available  
 \* Shiga toxin-producing Escherichia coli

*Increased Food Safety and Traceability*

Growing indoors in soilless systems inherently limits exposure to many soil-borne pathogens that may have caused E. Coli, salmonella, and in turn produce recalls in recent years. This is of particular benefit during a time when the incidence and awareness of food borne illnesses are rising. Some indoor farms are creating “clean-room” environments where workers wear special gloves, hats, and uniforms to prevent outside pathogens from infecting crops. Pests are much easier to keep out, and manure use is all-but eliminated.

Should a recall prove necessary, indoor systems are often able to track individual plant variables throughout the growth cycle, allowing farmers to quickly identify the source of contamination and isolate any affected products. The overall result is cleaner and safer produce for the end-consumer.

## CASE STUDY: FEEDING A GRASS-FED HERD IN A TIME OF DROUGHT

TomKat Ranch is an eighteen hundred acre cattle ranch in Pescadero, CA which acts as a “learning laboratory for animal agriculture focused on climate stability, nature’s benefits, healthy food, biodiversity, and vibrant community”. It houses several businesses, including LeftCoast GrassFed, a grass-fed beef company that sells at local farmers’ market in order to educate consumers about the benefits of grass-fed meat.

As for any cattle operation, feed is a large component of LeftCoast GrassFed’s costs, and became a particular concern when hay fodder was in short supply this past summer. Owing to California’s drought and lower surface water allocations to farmers, hay prices rose 35% year on year by May 2014 to \$320 per ton.<sup>17</sup> Naturally, both pasture and hay crops require sufficient water for optimal growth. Worse, hay was coming to TomKat from ever further afield: “we were paying \$100 per ton just for transportation in some cases” comments Wendy Millet, TomKat’s ranch director. LeftCoast GrassFed holds Animal Welfare Approved and American GrassFed Association certifications, so traceability is extremely important to the venture, and its values lead it to seek locally sourced fodder wherever possible.

The answer came in the form of a self-made fodder machine from Symbi Biological, which raises insect protein for an aquaponics operation on TomKat Ranch. The system consists of three racks of growing trays, in which the ranch grows fresh barley. “The cattle really liked it once they figured out what it was” Wendy adds “and it ended up being cheaper than importing hay”.

There are also ready-made solutions on the market, such as that from Fodder Solutions, an Australian technology company that distributes its hydroponic fodder system globally and is used by a ranch neighboring TomKat. The product consists of a truck containing up to 108 hydroponic growing trays in six layers, which rotate as the crop grows such that a portion of the fodder can be harvested and planted daily. The unit can be driven to the cattle feed stations, and barley takes only six days to grow from seedling to feed in the climate-controlled growroom. The seeds grow on mats that are edible by cattle, so there’s no waste from the system. It allows the ranch to precisely control inputs into the feed, and the largest unit uses under 300 gallons a day of water. For a ranch that is careful to track such metrics, it also reduces feed miles and waste, for instance, hay stored outside can develop mold and lose protein quality in times of heavy rain as was seen in Montana in September 2014 for example.

Traditional fodder growers have often been dismissive of hydroponically grown fodder, citing the higher moisture content contained in young hydroponically grown barley and lower ‘dry matter’ (the part of feed that contains the nutrients that animals need) content in hydroponically grown fodder. They argue that this renders hydroponic fodder extremely expensive on a like-for-like basis, but their analysis has been challenged by some ranchers, for instance, a 2005 paper by Australian rancher Joseph Mooney<sup>18</sup> argued that the cost to fatten a beast on hydroponic fodder over a 90-120 day period is around a sixth of the cost of fattening the beast on grain.

We anticipate that fodder systems will become more efficient and economic as LED lighting and other technologies develop, and as hay prices remain at risk from drought (NOAA<sup>19</sup> forecasts continued drought for California in 2015), it seems likely that ranches such as TomKat Ranch will continue to find a place for hydroponic fodder as a supplement to traditional animal feeds.

<sup>17</sup> USDA Hay Report, comparing May 24, 2013 and May 23, 2014 prices for Sacramento Valley FOB Supreme Alfalfa

<sup>18</sup> “Growing Cattle Feed Hydroponically”, Joseph Mooney, July 2005, Australian Nuffield Farming Scholarship Association

<sup>19</sup> National Oceanic and Atmospheric Administration, December 2014 forecast

**GROWING INDOORS INHERENTLY LIMITS EXPOSURE  
TO MANY SOIL-BORNE PATHOGENS**

**E**

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**The Indoor Agriculture  
Investment Landscape**

## E. THE INDOOR AGRICULTURE INVESTMENT LANDSCAPE

For investors, the indoor agriculture industry has much in common with the solar one of a decade ago; detractors criticize both for being more expensive than alternatives (traditional energy and field farming respectively) and decry the “backyard” nature of many of the solutions. In both cases, they miss the rapid fall in technology costs and the swift adoption among those for whom the industry fixes a real problem of meeting year-round consumer demand for local produce.

Investment in indoor agriculture remains a fraction of that in agtech as a whole, where the hip sectors of biologicals, precision agriculture and distribution platforms (such as, Sequoia Capital-backed Good Eggs) have attracted the greatest attention. Global agtech venture capital investments in 2014 alone were \$1.1bn, up 34% year on year, according to industry consultant, the Cleantech Group. In the US, we estimate that there’s been a total of \$52mn invested since 2011 by venture capitalists in indoor agriculture, with over 60% of this being in 2014 alone:

**TABLE ELEVEN: VENTURE CAPITAL INVESTMENT IN NORTH AMERICAN INDOOR AGRICULTURE**

Company	Funders	Description	Amount (\$mn)	Yr Funded
Aerofarms	Quercus, 21Ventures	Vertical System	\$1.70	2009
BrightFarms	Emil Capital, NGEN	Greenhouse	\$4.30	2011
BrightFarms	WP Global, NGEN, Emil Partners	Greenhouse	\$4.90	2014
BrightFarms	WP Global, NGEN, Emil Partners	Greenhouse	\$2.40	2014
FarmedHere	Private Investors	Vertical System	\$6.00	2014
Freight Farms	WeFunder, LaunchCapital, Morningside Group, Rothenberg Ventures	Container Farm	\$1.20	2013
Freight Farms	Spark Capital et al	Container Farm	\$3.70	2014
Gotham Greens	NYSERDA, Private Investors	Greenhouse	\$2.00	2011
Gotham Greens	Private Investors	Greenhouse	\$8.00	2014
Green Sense Farms	Private Investors	Vertical System	\$0.65	2014
Green Spirit Farms	Private Investors	Vertical System	\$0.30	2013
Grove Labs	Upfront, Vayner et al	Consumer	\$2.22	2014
Indoor Harvest Corp	Private Investors	Vertical System	\$0.06	2013
Indoor Harvest Corp	Private Investors	Vertical System	\$0.46	2014
Indoor Harvest Corp	Private Investors	Vertical System	\$0.02	2015
Lufa Farms	Cycle Capital Management, Kubo Greenhouse, Andrew Ferrier	Greenhouse	\$4.50	2012
PodPonics	NA	Container Farm	\$0.73	2011
PodPonics	NA	Container Farm	\$1.25	2013
PodPonics	NA	Container Farm	\$2.00	2013
PodPonics	New Ground Ventures	Container Farm	\$3.40	2014
TruLeaf	InnovaCorp	Vertical System	\$0.80	2012
TruLeaf	InnovaCorp	Vertical System	\$0.25	2013
Urban Barns	Dundee Corp, Private	Vertical System	\$0.50	2014
Windowfarms	Kickstarter, Private Investors	Consumer	\$0.26	2011
<b>TOTAL</b>			<b>\$51.59</b>	

Sources: Crunchbase, media reports, company press releases, SEC filings

Our figures exclude LED lighting companies (such as, Illumitex which has raised \$64mn<sup>20</sup> in venture funding), and overseas investments (for example, the 2014 IPO of Swedish LED lighting firm Heliospectra). They include only rounds where investment amounts have been publicly announced, and we believe that they consequently underestimate total investment in the sector by a significant margin.

These investments run the gamut from early stage tech to growth capital for farming operations. Hydroponic greenhouse operator BrightFarms – whose investors include NGEN Partners and Emil Capital – has raised over \$9mn for its strategy of building greenhouses proximate to grocery chain customers on long term agreements. On the other end of the scale, Grove Labs – created in an MIT dorm room – has raised \$2mn from Upfront Ventures, among others, to develop aquaponic fridges designed for use in residential kitchens. The units are in beta at the moment. Elsewhere, TechStars graduate Freight Farms sells fully equipped container farms that can be sited anywhere that power and water are available. Each supplies enough lettuce to meet the consumption of more than 3,400 Americans, and the Company has around 20 units deployed so far.

Investors have been attracted by rapid technical change, by innovative business models and by a large and growing market:

#### *Very Large and Growing Market*

The 2014 domestic market for fresh vegetables is estimated at \$25.2bn<sup>21</sup>, with forecast annual growth rate of 1.2% to 2019.<sup>22</sup> We estimate that more than a third of this value is in crops that could be grown indoors (see appendix for rationale). Within this, greenhouse and vertical farm sectors are experiencing faster growth; greenhouse growing is expected to grow by 10% per annum through 2016.<sup>23</sup> Further, a well-placed industry consultant estimates that a further 30 vertical farms are under construction in the US alone, double the number presently operating. In some cases, these farms are substituting for imports. Elsewhere, their products are creating new markets, such as from the popularization of microgreens.

#### *Innovative Business Models*

On the farming side of the industry, entrepreneurs are introducing long term produce purchase agreements and seeking niche crops as business model innovations. Long-term produce purchase agreements, such as those procured by multi-site greenhouse firm BrightFarms, have gained popularity in recent years amongst large buyers looking to lock in good rates for high-quality, local produce. These agreements have an additional advantage as they can be used to secure alternative financing to help offset upfront capital expenditures. Examples of niche crops include high-value herbs, microgreens and tree saplings.

<sup>20</sup> Crunchbase figure

<sup>21</sup> These market estimates represent only a fraction of the total lettuce value chain, as they are derived from terminal wholesale market prices and do not reflect additional value created at retail, foodservice, value-add processing, and other market segments prior to end-consumption

<sup>22</sup> "Vegetable Farming in the US", IBISWorld, July 2014

<sup>23</sup> "Global Greenhouse Horticulture Market 2012-2016", TechNavio, March 2013

On the technology side of the industry, a nascent business model is software as a service (SAAS), as data capture and remote farm monitoring becomes a more prevalent offering in an industry that has previously eschewed such arrangements.

### *Technology Development*

The bulk of venture capital investment has, of course, gone to startups focused on developing new form factors or growing systems to date, these being the area best suited to returning the 35%+ on capital commonly expected by venture capitalists. We anticipate that this will change as the industry matures and focus shifts away from the basics of growing and towards improving yields and returns in the industry.

Broadly, there are three types of investment opportunity within the sector:

### *Farming*

Produce farming has traditionally been funded by family investments and bank debt. Outside of the large row-crop focused farmland funds – managed by the likes of GMO, John Hancock, Macquarie Bank and UBS – there are few institutional investors in the farmland space and the investment size and return potential offered by indoor farms means that this is unlikely to change in the short run. Though some indoor farmers expect to return 40%+ to investors, most are looking to raise funding at an 8-12% return rate, well below those presently seen in less risky investment categories, such as real estate.

### *Technology Investment*

As was outlined above, there remain a number of high-potential avenues for technology development within indoor agriculture, whether in biologic, big data or environmental sensing arenas. It is logical that these would accrue venture-capital like returns, and general venture capitalists – whose usual stomping grounds are software and healthcare – have begun to take an interest in the sector as a consequence.

### *Financing or Leasing*

Indoor farms have comparatively high startup costs, and raising sufficient capital to cover these or to retrofit new technology into an existing farm, is one of the greater challenges faced by indoor farmers. Consequently, an obvious ‘next step’ for the industry is the development of additional leasing and financing structures that allow farmers to fund capital costs through the farm’s revenue streams.

As was the case for the solar industry, there are plentiful opportunities for innovative entrepreneurs to create technology solutions for the indoor agriculture industry, for everything from tracking plant behavior to creating organic nutrient mixes to planning new farms. What we’ve seen so far is just the tip of the iceberg.

**F**

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**Expediting Industry  
Growth**



## F. EXPEDITING INDUSTRY GROWTH

Increasing the size of the indoor agriculture industry ultimately requires a multitude of solutions involving advances in technology, changes in supply chain operations, and increasing industry awareness amongst produce buyers and end-consumers. As has already been seen from the success of the renewable energy industry, several tactics from both public and private sectors are critical to expediting industry growth.

### 1. HOW LOCAL GOVERNMENTS CAN SUPPORT INDOOR CROP PRODUCTION

*Clarify Regulation and Zoning on Indoor Agriculture.* Removing ambiguity in regulations pertaining to urban farming and vertical farming at county and municipal levels can eliminate large barriers to entry for entrepreneurs seeking to start indoor crop production in urban or suburban areas. Cities such as Chicago, IL, Cleveland, OH and Seattle, WA have provided blueprints for the introduction of urban agriculture ordinances.

*Extend Tax Abatements or Rebates to Indoor Crop Production.* As is already the case for traditional farming, incentives should be put in place to attract indoor crop production. Many cities have vacant lots, abandoned buildings, or other underutilized space that could be offered at discounted rates to indoor farmers. New York, for instance, has 10,000 acres of usable land and rooftop space.<sup>24</sup> Indoor crop producers could hire local workers and develop innovative ways to supply fresh produce into food deserts.

*Facilitate Farm Relationships with Potential Customers and Local Utility Providers.* Government officials could connect farmers with potential customers other resources necessary to mitigate customer acquisition risk prior to farm deployment. In cases where municipal leaders have direct influence on utility providers, steps could be taken to negotiate long-term electric rates and allow easier market entry for new indoor crop providers.

### 2. HOW FEDERAL GOVERNMENT CAN SUPPORT INDOOR CROP PRODUCTION

*Track data on indoor crops.* USDA data is a 'go to' source for any industry observer looking to understand agriculture trends or for beginning farmers looking for a benchmark on product prices. We used the USDA's wholesale market prices to calculate national lettuce price variance in chart nine, for instance. Usable strong data sets for the industry – including production, pricing and volume data - would all be welcome.

*Extend federal funding programs to indoor farming.* As is shown in the table over page, we estimate that indoor farmers are eligible for three USDA funding programs whose funding \$192mn.<sup>25</sup> Some government-backed lenders, such as 1st Farm Credit Services, work with indoor farmers. Yet, the sector is currently

<sup>24</sup> "The Potential for Urban Agriculture in New York City", Columbia University's Urban Design Lab, 2012

<sup>25</sup> For 2014-15, REAP total allocation is \$101.35mn per Environmental Policy & Law Center, \$66mn for specialty crop block grant for 2014 per USDA, \$25mn in value added producer grants in 2014 per USDA

excluded from other federal funding programs, such as the \$3.5bn<sup>26</sup> new market tax credit program, which provides forgivable debt mostly to infrastructure projects. The program specifically excludes farming activities at present, though we understand that some equipment purchases may qualify for the program. As many indoor farms are in urban, industrial or suburban areas, they do not qualify for rural-focused USDA grants. Moreover, the indoor agriculture industry lacks the specific programs that have fueled other new agricultural industry sectors. For example, in January 2013, the USDA's Farm Service Agency introduced a popular microloan program to aid beginning farmers. A funding program which extended low cost loans or other forms of capital to indoor farmers would be helpful.

*Create clear standards.* One barrier to entry for indoor farmers is the lack of clarity around food safety and organic standards. Given this, we encourage safety auditors to incorporate indoor agriculture guidelines for GAP, HACCP, GFSI, and other food safety standards, and to formally delineate standards for the sector's produce to qualify for organic certification.

### 3. HOW UNIVERSITIES CAN SUPPORT INDOOR CROP PRODUCTION

*Continue groundbreaking research.* Academia has undoubtedly been the driving force behind many technical advances in the indoor agriculture field. Of particular note in the US is the pioneering work of Drs. Gene Giacomelli, Merle Jensen and Cheiri Kubota at the University of Arizona's Controlled Environment Agriculture Center. Examples include the development of a lunar greenhouse. Elsewhere, Professor Toyoki Kozai at Chiba University has done much to champion the development of plant factories. For example, one of his recent papers compared the resource utilization of greenhouse and plant factories, and concluded that the latter was a more efficient use of resources such as water, carbon dioxide and energy. More recently, the initiatives of Dr. Caleb Harper at MIT's CityFARM project on open data and Dr. Jan Janse of the Dutch Wageningen University on the nutritional benefits of indoor crops have extended discussions of indoor agriculture to new audiences.

*Expand collaboration with industry.* While preparing this paper, a number of industry stakeholders commented to us that they felt the industry would benefit from a center of excellence established along the lines of the Fraunhofer Institute, a German organization that offers "demand driven, applied research combined with scientific excellence"<sup>27</sup> in the service of industry and in close collaboration with academics. It derives about 70% of its revenues from specific industry contracts. The model has been successfully replicated across 67 disciplines, would allow for greater collaboration between academia and industry, and would be especially helpful to smaller industry players that lack their own research and development capabilities.

<sup>26</sup> 2014 allocation per Community Development Financial Institutions Fund

<sup>27</sup> Fraunhofer Institute quote

## AN OVERVIEW OF GRANT FUNDING FOR INDOOR FARMS

For-profit indoor farmers are eligible for grant funding and incentives under a number of different government and utility programs. Chicago-area vertical grower FarmedHere has put together the following list of programs that may be available to indoor farmers. Please check with the individual funding agency to determine whether your project is eligible.

- Under USDA's Rural Energy for America Program (REAP), indoor farms may be eligible for funding to purchase, install, and construct renewable energy systems and energy efficiency improvements. Renewable energy projects may include anaerobic digesters, solar panels, and geothermal systems. Energy efficiency projects may include improvements to HVAC systems, switching from fluorescent to LED lights, and replacement of energy-inefficient equipment.
- Under USDA's Specialty Crop Grant Program, indoor farms in participating states may be eligible for funding related to specialty crop research, so long as the farm partners with a research organization or cooperative extension to publicize the results of the research.
- USDA Value-Added Producer Grant Program. Indoor farmers are eligible for this to promote, market, and distribute value-added products, such as FarmedHere's basil salad dressing. The funds must be used for marketing and promotion costs, which include packaging, labels, delivery, etc.
- Many local utilities provide incentives for making energy efficiency improvements. FarmedHere, for example has received incentives that tie directly to the amount of energy saved by choosing LEDs instead of fluorescent lights, under the ComEd Smart Ideas for Your Business<sup>®</sup> program. In addition, FarmedHere has been accepted into the ComEd and Nicor Gas New Construction Service program, pursuant to which it may receive incentives for increasing the energy efficiency of its farm.
- Certain states make grant funding available for technological advances in farming that create jobs. For example, in 2014, FarmedHere received a substantial grant from the Illinois Department of Commerce and Economic Opportunity, Emerging Technological Enterprises Program, for use in purchasing LED lights. FarmedHere became eligible for the grant by demonstrating that the installation of LED lights would increase its plant yields, and increased plant yields would create new jobs related to harvesting and packing.

Source: FarmedHere

## CASE STUDY: HOW AN URBAN ORDINANCE FUELED CHICAGO'S INDOOR AGRICULTURE INDUSTRY

The Chicago area is home to the largest cluster of indoor farms in the country, with three existing farms (FarmedHere, Garfield Produce Co, The Plant) shortly to be joined by a fourth from New York rooftop farmer Gotham Greens in conjunction with consumer goods company Method. Four years' ago, there were none.

One of the enabling factors for this development is an Urban Farm Ordinance introduced in September 2011, through which the City of Chicago provides clear guidelines – for rooftop, indoor and outdoor farms – to urban farmers. According to the City of Chicago, it “clearly defines community garden and urban farm uses, identifies where each use is permitted and establishes regulations designed to minimize potential impacts on surrounding property and help maintain the character of Chicago's neighborhoods.” Previously, Chicago's urban farmers had operated in a gray area, where the legality of their farms was unknowable. The ordinance was developed and enacted over a summer, led by two Chicago non-profits –the Chicago Food Policy Advisory Council and Advocates for Urban Agriculture – along with the City of Chicago.

Megan Klein, a lawyer who worked on the initiative with the Chicago Food Policy Advisory Council, makes three recommendations when it comes to enacting such ordinances:

1. Find an influential figure to spearhead the initiative. “Once we had Mayor Emmanuel on board, and he allocated a policy director to the project, things really started to move” comments Klein.
2. Involve stakeholders in the drafting process. Sharing early drafts of the ordinance with farmers and other stakeholders meant that unworkable suggestions, such as long setbacks from residences in densely populated urban areas, were nixed early. In Chicago, a couple of public meetings allowed stakeholders to learn about the ordinance and add their opinions and suggestions.
3. Develop an implementation plan. Once the ordinance is in place, city departments (especially building and licensing departments) and farmers need information on how the initiative works in practice. For instance, the City of Chicago devoted a section of its website to outlining its ordinance.

Klein – now Chief Legal Counsel at Chicago-area vertical farmer FarmedHere – sees two benefits from such ordinances; better public awareness of urban farming and more urban farms in the local area. For instance, local non-profit Advocates for Urban Agriculture lists 49 farms and community gardens in the area.

#### 4. HOW THE PRIVATE SECTOR CAN SUPPORT INDOOR CROP PRODUCTION

*Incorporating indoor crops into menus.* Chefs have led the charge when it comes to organic, sustainable local food, and partnering with indoor farmers to include new flavor profiles in menus would be a further enhancement to this movement. Examples include Chef Darren Brown, who incorporated Village Farm's greenhouse grown produce into Fairmont Hotel menus during his tenure with the company.

*Collaborating on product development.* As a relatively small industry, indoor agriculture does not always get the 'share of voice' that larger ones command with industry suppliers and this can deter the development of products beneficial to all industry players. A solution is for companies to band together to request, for example, the development of seeds with specific traits.

*Gathering data on nutritional content of produce.* Currently there is no conclusive evidence that indoor produce is, on average, healthier or denser in nutrients than traditionally grown produce, though the Dutch Wageningen University has released two studies that show improved Vitamin C content in strawberries<sup>28</sup> and tomatoes<sup>29</sup> grown in controlled environment systems. Growers could regularly conduct tissue sample analyses, aggregate the data, and work together to communicate findings if there is significant evidence to suggest indoor produce is healthier.

*Improving access to capital.* As was outlined above, there are plentiful opportunities for deployment of capital into the industry. We encourage banks and other funders to establish financing models that support indoor farms and technologies that enable them.

#### 5. HOW NON-PROFITS CAN SUPPORT INDOOR CROP PRODUCTION

*Advocating for the industry.* It is important that indoor growers themselves work together as an industry, potentially through early formation of a centralized body advocating for beneficial policies at state and federal levels. Such a body would advocate on behalf of industry for regulation and zoning changes that enable urban farms at the gubernatorial level, and for a share of existing funding programs and clearer organic standards at a national level.

*Gathering data.* Any young industry is hampered by a lack of data, and indoor agriculture would benefit from data on everything from its impact on local food systems, to comparative growing and capital costs. One model that could be used for such an initiative is the Kauffman Institute, which focuses on providing data and thought leadership around entrepreneurship.

*Educating consumers on the benefits of indoor farming.* Non-profits have a lengthy history of educating and influencing consumers when it comes to food and agriculture matters. Examples include raising awareness of genetically modified foods, of childhood obesity, and of animal welfare issues. Nutrition-focused non-

<sup>28</sup> "Tasty strawberries with LEDs", Wageningen UR Greenhouse Horticulture, December 2014

<sup>29</sup> "Tomatoes with extra vitamin C via LED lamps", Wageningen UR Greenhouse Horticulture, May 2013

profits had revenues in excess of \$300mn last year, more than double that of one of the industry's larger farmers, Village Farms.<sup>30</sup> Non-profits have a unique opportunity to leverage indoor crop production to further missions pertaining to food access, nutrition, or promotion of local economies. We propose that they incorporate indoor agriculture into their advocacy where relevant. General nutrition campaigns don't educate the uninitiated about the benefits of indoor crops, so ones focused on the benefits of indoor agriculture to the environment, to farm laborers and to local food systems work best.

*Providing philanthropy.* Indoor agriculture has the disadvantage of requiring a relatively high upfront investment in equipment, and this can be tough for beginning farmers. Consequently, philanthropic financing, whether in the form of grants or low interest loans, would be beneficial. There are templates for this in the form of programs such as the Maine Organic Farmers and Gardeners Association's Organic Farmer Loan Fund which makes loans of up to \$20,000 to local organic farmers working to build a credit history for their farms.

## **6. HOW CONSUMERS CAN SUPPORT INDOOR CROP PRODUCTION**

*Support local indoor farms.* By seeking out hydroponically-grown producer at farmers' markets and grocery stores, and purchasing directly from local indoor farms, many of which offer either online sales or community supported agriculture (CSA) subscriptions, consumers can bolster year-round local food supplies.

*Request local food at restaurants and grocery stores.* As in most industries, the consumer voice is extremely important to the food and beverage industry, so we encourage consumers to ask questions at the restaurant and grocery store; "where does your produce come from?", "how do you source fresh produce in the winter?", "do you work with local farms?"

<sup>30</sup> Annual revenue for K40 Nutrition 501c3 NTEE category of \$304mn per National Center for Charitable Statistics as at December 2014. Annual revenue for year to September 2014 for Village Farms of \$134mn per Yahoo! Finance.



**INDOOR FARMING TECHNIQUES GREATLY REDUCE PRODUCTION VARIABILITY AT THE FARM LEVEL AND ENABLE UNPRECEDENTED ACCURACY IN COST FORECASTING.**

# G

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**The Future of Indoor  
Crop Production**



## G. THE FUTURE OF INDOOR CROP PRODUCTION

In order to secure broad market penetration and scale beyond a niche industry, indoor crop production must become cost competitive with outdoor crops. Price parity has already been reached for some high-value crops and in certain markets during winter, suggesting that the true tipping point for rapid industry expansion has already transpired. As technologies continue to advance, the primary cost drivers of the industry – capital equipment, and labor, electricity, and nutrients per harvested plant – will continue to decrease. Simply put, economic momentum is on the side of indoor growers, and we envisage the industry playing a greater part in the nation's food supply chain as existing farmers supplement production, and grocers, restaurateurs and state entities begin to grow their own produce.

Beyond this, we expect the indoor agriculture industry to play a part in the ongoing reintegration of farms into urban and suburban life. We envision a future where office atriums provide food for in-building cafeterias and local restaurants. Green buildings such as Urbanarbolismo's vertical garden complex in Spain continue to grow in popularity, complete with green walls, balcony gardens and rooftop farm. In-home appliances automatically growing vegetable and herb gardens will provide families supplemental fresh produce grown right in their kitchens. And countless other applications we can't now foresee will continue to inspire entrepreneurs for generations to come.

Indoor farming will never replace conventional outdoor farming methods. It will instead augment the food chain to create a diverse, distributed system more resilient to supply shocks and better prepared to meet the demands of a growing global population.



## APPENDIX: CALCULATING THE ADDRESSABLE MARKET FOR INDOOR CROPS

To calculate an addressable market size for the US indoor crop industry, we begin by taking a list of crops that can be commercially grown in such systems from a University of Florida paper.<sup>31</sup> Next, we match these crops to USDA's National Agricultural Statistics Service (NASS) production statistics for 2013, the most recently available set of data, to reach the following potential market value:

**TABLE TWELVE: PRODUCTION VALUE BY CROP (\$1,000)**

Crop	Value (\$1,000)	Notes
Baby Squash	248,725	All squash, not just baby
Bell Peppers	627,540	
Cantaloupe	325,337	
Chile Peppers	175,145	
European Cucumbers	420,807	Fresh & for Processing
Head Lettuce	805,658	
Leaf Lettuce	444,082	
Romaine Lettuce	621,771	
Spinach	240,677	Fresh & for Processing
Tomatoes	1,874,527	Fresh & for Processing
<b>TOTAL COMMERCIAL VEGETABLES</b>	<b>12,067,897</b>	

Source: "2013 Agricultural Statistics Annual", USDA's National Agricultural Statistics Service

The NASS statistics account for strawberries (\$2.4bn) and mushrooms (\$1.1bn) separately in the fruits, tree nuts, and horticultural specialties section, so we add these estimates to our vegetable total of \$5.8bn. Combined this yields a total addressable market of \$9.3bn, or nearly 17 times the current \$555mn<sup>2</sup> revenue estimate.

We note that this figure excludes the following crops for which data was not available: Arugula, Basil, Chervil, Dill, Edible Flowers, Eggplant, Italian Parsley, Kale, Microgreens, Mini Cucumbers, Musk Melon, Mustard, Other Herbs, Swiss Chard. Further, they do not account for market growth between 2013 and 2015.

<sup>31</sup> "Alternative Greenhouse Crops - Florida Greenhouse Vegetable Production Handbook, Vol 3", R. Hochmuth and D. Cantliffe, University of Florida IFAS Extension



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