State of Indoor Farming

2017

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About the Authors

Agrilyst is a management and analytics platform for indoor farms. The SaaS platform tracks and analyzes all farm data in one place, enabling growers to optimize plant performance and reduce operating expenses. Agrilyst is focused on turning data management from a burden into a grower's most useful tool.

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Acknowledgments

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Introduction

The purpose of this report is to look at the emerging trends, challenges, and benefits of farming indoors. This report not only provides an overview of the indoor farming industry, it also gives a new, updated analysis of the industry, following our 2016 report. This year, we received over 150 responses from growers around the world. We had growers participate from 8 countries, with 81% coming from the United States, 12% coming from Canada, and the remainder coming from other countries. For the most part, our analyses focused on all participating farms. Exceptions were made whenever a dataset was too small to provide anonymity.

The resulting report is both quantitative – based on data provided by survey participants – and qualitative, as it's based on farmers' opinions and perceptions.

Data from the survey was supplemented by additional research conducted by our team.

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1 The Landscape

The crops and facilities that make up the indoor farming industry.

A growing industry in a challenging scenario

During 2017, the indoor farming industry kept growing.

Plenty raised $200 million, with notable backers such as the SoftBank Vision Fund and Jeff Bezos[1];

AeroFarms raised over $80 million from two funding rounds and a $1 million grant from the Foundation for Food and Agriculture Research[2];

Bowery secured $27 million in a seed and a series A round[3].

The size of these investments and the interest of notable private and institutional backers is evidence the industry is showing signs of maturation.

This increasing interest in indoor farming comes at a critical point for our food supply chain: the world population is expected to reach 9.8 billion by 2050[4], and we're starting to investigate the effects of global warming on nutrient depletion in crops[5].

Indoor farming is proving to be an efficient way to produce more food with fewer resources than conventional farming, without being dependent on arable land availability and external climate conditions.

Types, locations, and size of indoor farms

Indoor farms can use different growing systems and structures, from urban and small-scale farming, to high-tech fully controlled and semi-automated greenhouses in rural areas, to everything in between.

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1 — SoftBank Vision Fund Leads $200 Million Bet on Indoor Farms

2 — Aerofarms | Crunchbase

3 — Bowery secures $20 million to grow indoor farming

4 — World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100

5 — Estimated Effects of Future Atmospheric CO2 Concentrations on Protein Intake and the Risk of Protein Deficiency by Country and Region

Growing Systems and Facility Types

Hydroponics
Plants are grown in water as opposed to soil.

Aeroponics
Plant roots are suspended in the air and misted with a nutrient solution.

Aquaponics
Plants are grown in water that has been used to cultivate aquatic organisms (typically, fish)

Soil-based
Plants are grown in soil.

Hybrid (Aquaponics, Hydroponics, Aeroponics)
Plants are grown in multiple systems in one facility.

Glass or poly Greenhouse
Transparent, enclosed structure made of glass or polycarbonate.

Indoor vertical farm
Fully enclosed and opaque room with a vertical growing system (hydroponic, aeroponic, and/or aquaponic). Artificial lights are used.

Low-tech plastic hoop house
Semi-circular, tunnel-shaped structure made of steel and polythene.

Container farm
Standardized, self-contained growing unit that employs vertical farming systems and artificial lighting.

Indoor DWC
Fully enclosed and opaque room with a non-vertical growing system where plants are grown in a deep-water culture system.

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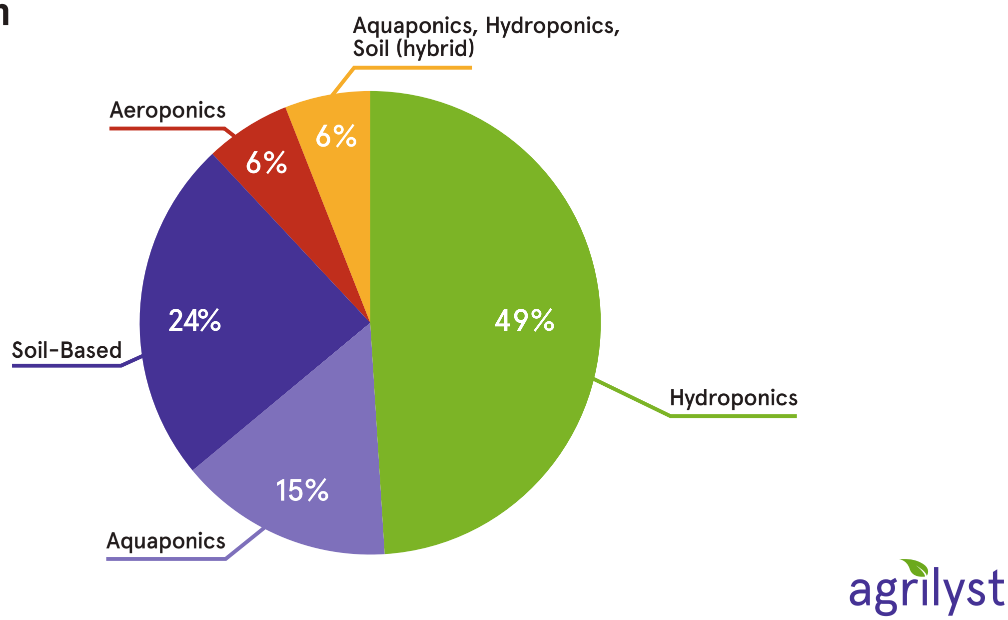
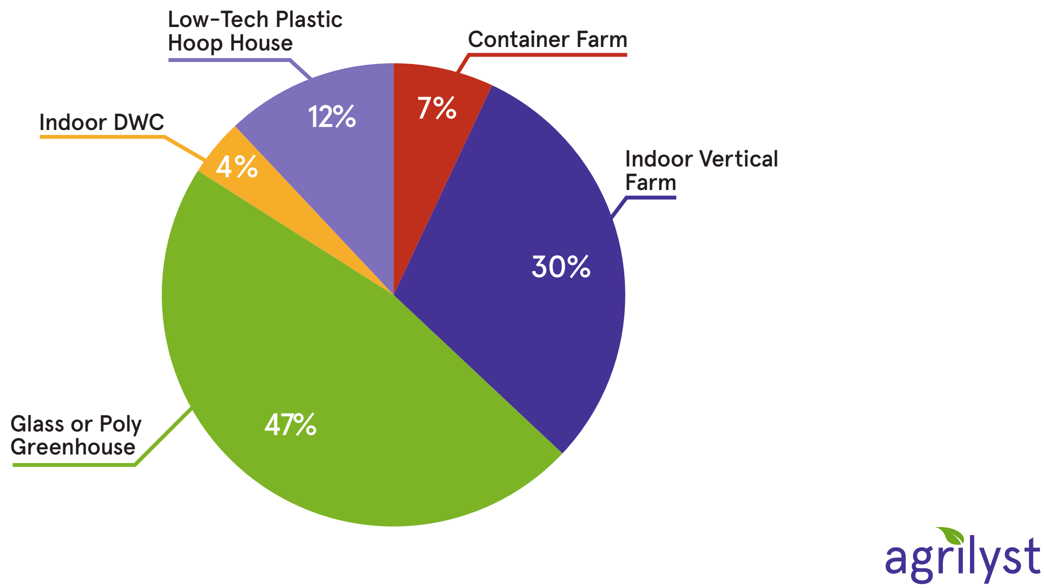
As in last year's report, respondents primarily operate greenhouses and indoor vertical farms and the majority of respondents use hydroponics as their growing system. Throughout this report, we dive into comparisons between these systems and structures.

Growing System

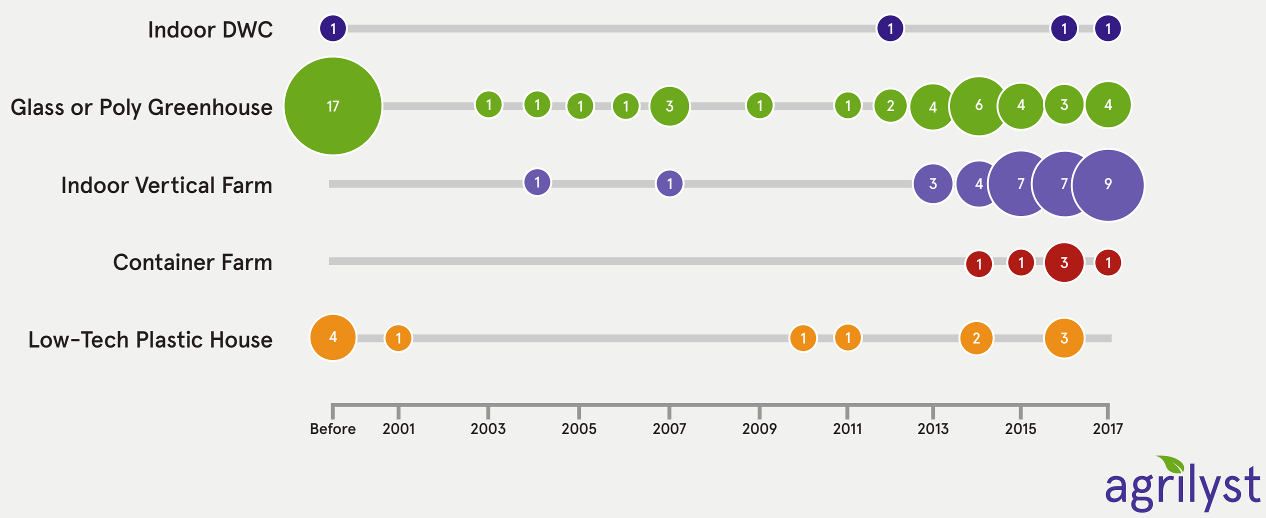


Facility Type



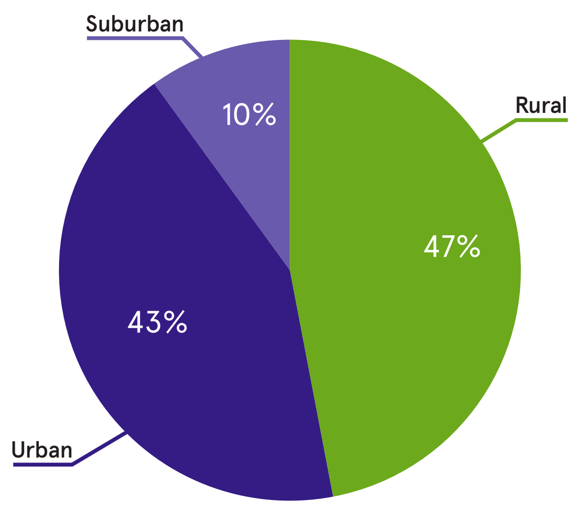
The indoor farming industry in the United States has been predominantly dominated by greenhouse crop production in the past. Tomato production is a staple greenhouse crop because growers can produce the crop more efficiently indoors. Now, due to decreases in technology costs (LEDs in particular) and an increase in local demand for food, we're seeing an increase in alternate growing systems, particularly fully enclosed vertical systems.

Timeline of Farm Openings by Type



This year, we asked respondents to describe their location as either urban, suburban, or rural. About half of the respondents indicated rural locations. The other half comprised of urban and suburban locations.

Farm Location



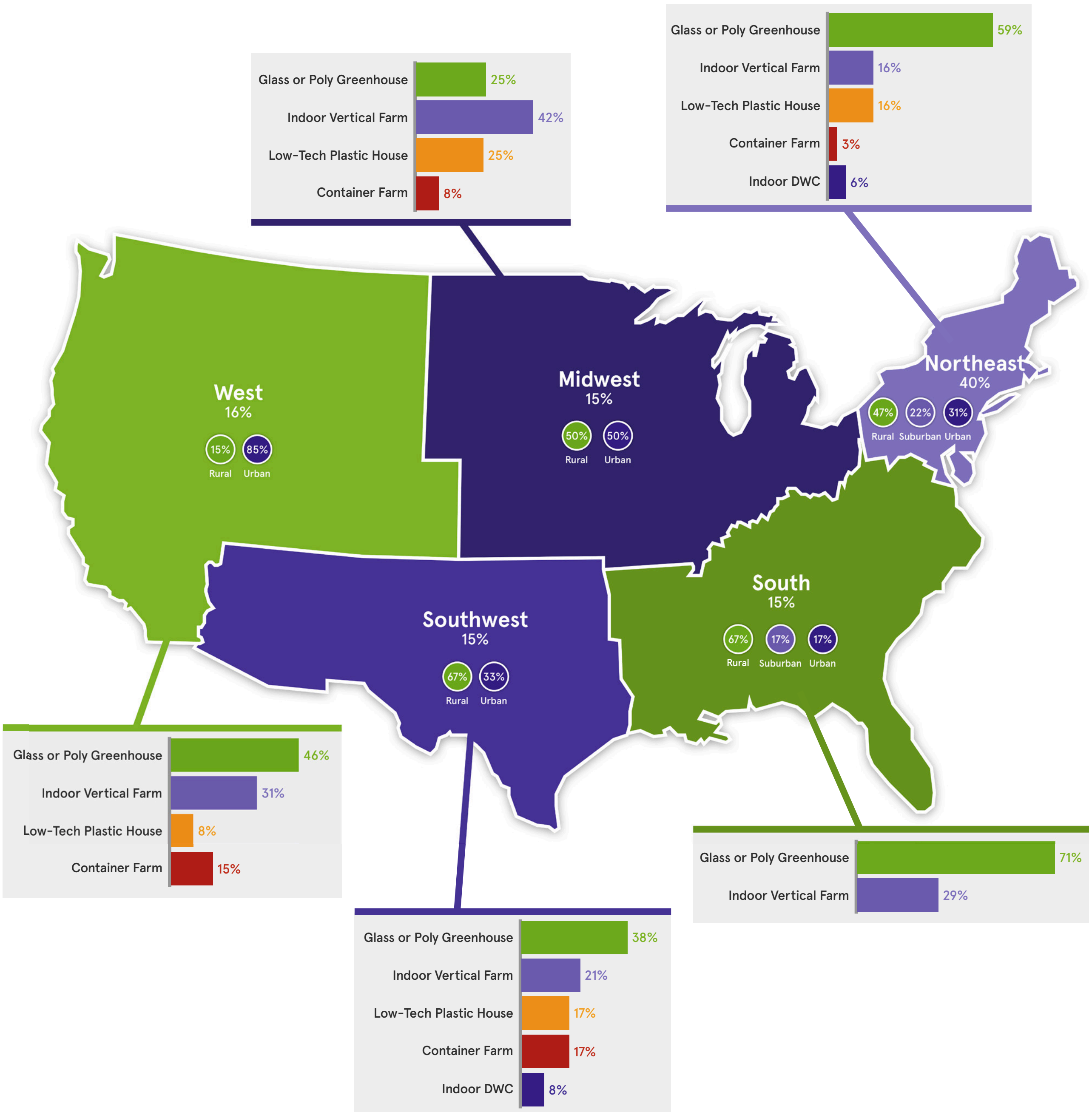
Indoor agriculture isn't equivalent to urban farming. This is a big misconception. As evidenced by the data, indoor farms typically locate close to the point of sale or where efficiency can be maximized. For a tomato grower, this may mean locating a greenhouse in a rural area where energy is cheaper and closer to a distribution center. For a container farm, this may mean placing a container at a grocery store in an urban area. This is one of the major benefits of indoor farming. Because the farmer has more control over climate, they can choose to locate a farm wherever it makes the most sense.

When we look at the physical location of farms in the United States, there is a large concentration of greenhouses in rural areas of the Northeast, South, and Southwest. In the Midwest, 42% of responding farms are indoor vertical operations and 50% of respondents are located in urban areas. The highest concentration of container farms was located in the Southwest and the largest percentage of urban farms was in the West.

Last year, farms were placed into one of two size categories: large farms (>1,500 square feet), and small farms (<=1,500 square feet) to show the differences between small non-commercial operations and larger commercial facilities. This year, we divided farms up into the same two categories: large and small farms, however we changed the threshold to 10,000 square feet. We found that 1,500 square feet did not account for the small, commercial category of farms. The 10,000 square feet threshold allowed us to separate farms that operated on a smaller square footage commercially. From an analysis perspective, we found that growers at or above 10,000 square feet had consistent per-square-foot rates for various measuring points (revenue, cost, budgets, etc.), as did farms smaller than 10,000 square feet. This should help growers using this data to create projections to categorize themselves correctly based on size. This year, 61% of respondents were small farms and 39% were large farms.

Facilities by Region

Respondents located in the continental United States



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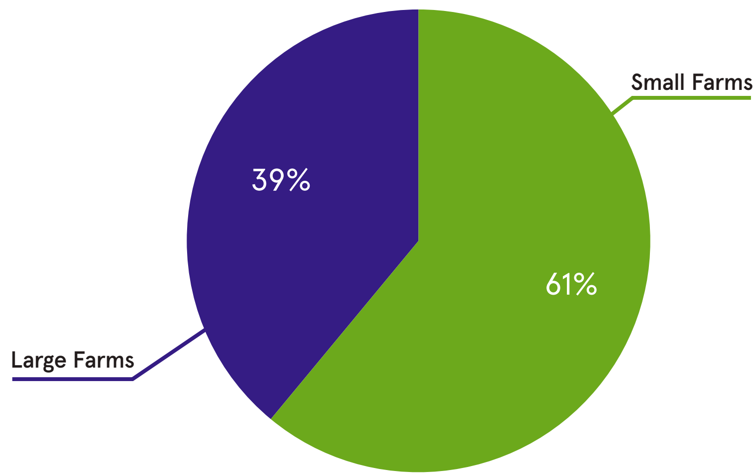
Survey Respondents by Size



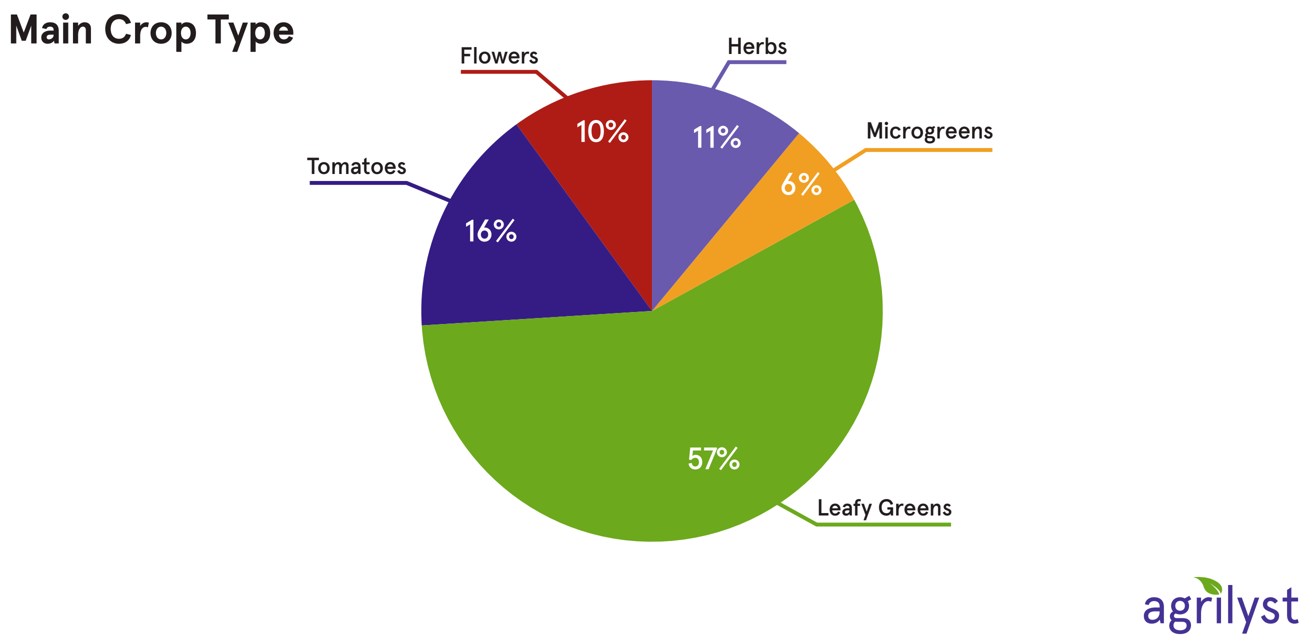
What are indoor farmers growing?

Thanks to climate control systems, indoor farms can grow a wide variety of crops.

The list of products farmers reported growing or raising includes (but is not limited to): leafy greens, tomatoes, cannabis, flowers, microgreens, strawberries, herbs, cucumbers, peppers, mushrooms, onions, leeks, hops, figs, sweet corn, eggplant, fish, insects, carrots, and shrimp.

The five main crops grown were: leafy greens, microgreens, herbs, flowers, and tomatoes, with more than half of respondents growing leafy greens. Throughout the report, we focus predominantly on these five crops.

It's important to note why these make good crops to grow indoors. It is costly to operate an indoor facility (we'll dig into these costs in a later section). In order to operate profitably therefore, farmers have to grow crops that are high revenue generating. To do this, you can grow crops that are specialty items, like flowers, or you can target crops that have quick growth cycles, like leafy greens. If you think about a vertical growing system, you want to grow crops that are physically short (so you can get many layers), that have short growth cycles (so you can turn your facility over many times), and are highly perishable (more valuable when grown locally).



Single crop operations only account for about 20% of cases. The remaining 80% of respondents grow at least two crops. This is another benefit of growing indoors. Growers have the ability to create microclimates within the growing area and optimize for more than one type of crop.

2 Production & Operations

A snapshot of how indoor farms operate.

Yield

One of the main advantages of indoor agriculture is its higher yield compared with conventional farming. Enclosing facilities creates ideal growing environments so farmers can grow a crop from seed to harvest in less time, realize higher yields in each cycle, and repeat the harvest more times in a given year.

The average yield of conventionally grown tomatoes in 2016 was 805 cwt per acre, or 1.85 pounds per square foot, according to USDA data[1]. Greenhouse hydroponic tomato growers on the other hand, reported an average yield of 10.59 pounds per square foot.

Similarly, the average yield of conventionally grown head, leaf, and romaine lettuce is 0.69 pounds per square foot[2], compared with 8.71 pounds per square foot for leafy greens grown hydroponically in a greenhouse.

1 — Vegetables 2016 Summary, page 97
2 — Vegetables 2016 Summary, page 62,63,64

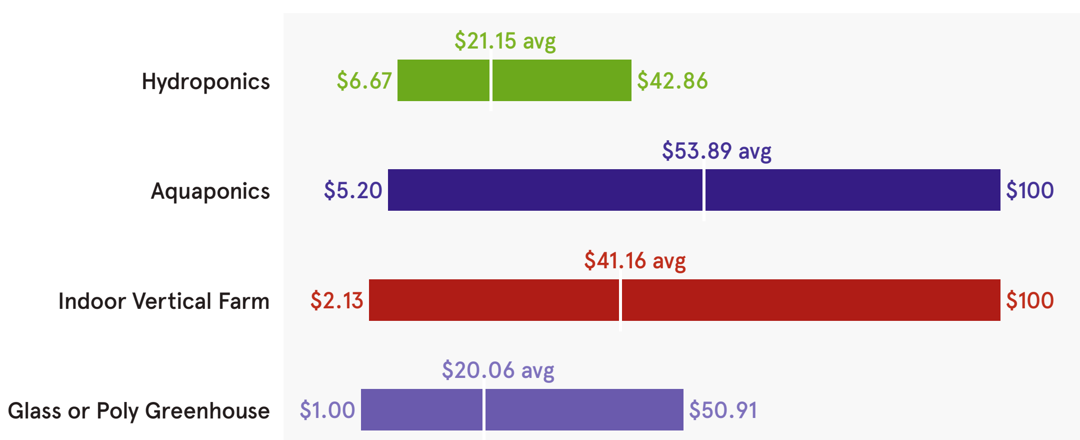
Indoor vertical growers reported yield of 5.45 pounds per square foot for leafy greens and container farms reported the lowest yields at 3.75 pounds per square foot for leafy greens. Indoor vertical farms can increase their overall yield by stacking additional layers and increasing their growing area as a percentage of available square footage.

Revenue

Looking at both profitable and unprofitable operations, we see a pretty large range of revenue data. Hydroponic operations, for example, reported a minimum of $6.67 per square foot to $42.86 per square foot, averaging at around $21.15 per square foot. Aquaponic operations, on the other hand, reported more than double the revenue per square foot. Similarly, for facility types, indoor vertical farming operations reported double that of greenhouse revenue. Because of the wide ranges in revenue, it's more important to analyze profitability than revenue alone.

Revenue — All Operations (Profitable & Not Profitable)

Revenue per sqft



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Profitability

One of the big criticisms of indoor farming is the high cost of operating facilities. This is a huge challenge for growers. In fact, only 51% of respondents reported operating profitably. The average age of profitable farms was 7 years and farms that are not yet profitable were on average 5 years old. With less conventional financial sources available to indoor farmers for both capital and operational expenses, as well as higher operational costs, it takes growers a long time to realize profits. According to Henry Gordon-Smith, Founder of Agritecture Consulting, "the three mistakes I see new growers make are: miscalculating and underestimating operational costs (labor, HVAC, and waste specifically), lack of clear understanding of the market and customer, and not understanding your production needs and whether a greenhouse or vertical operation would be best."

	% of Respondents	Average Age
Profitable Farms	51%	7 years
Unprofitable Farms	49%	5 years

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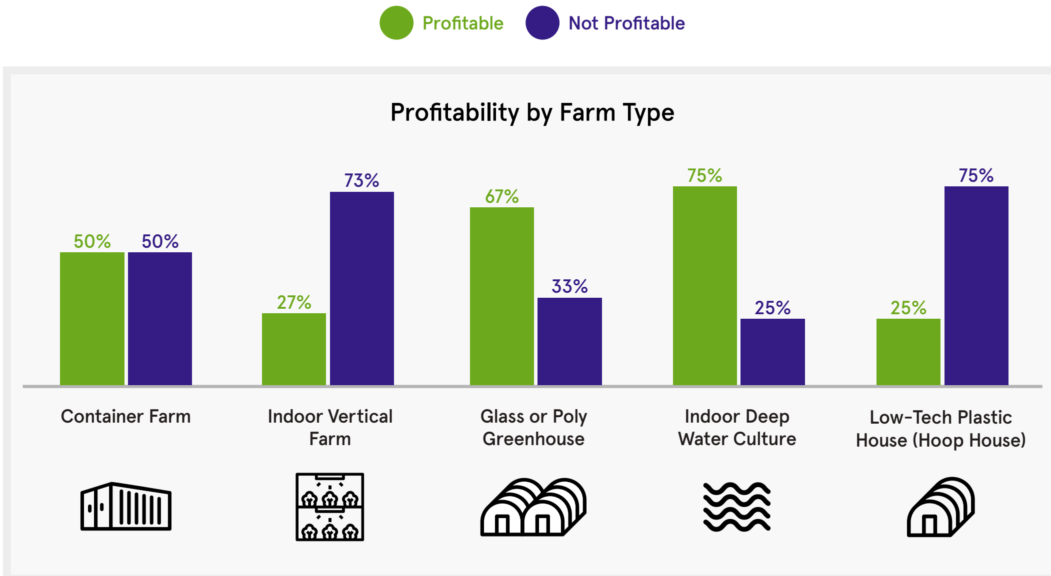
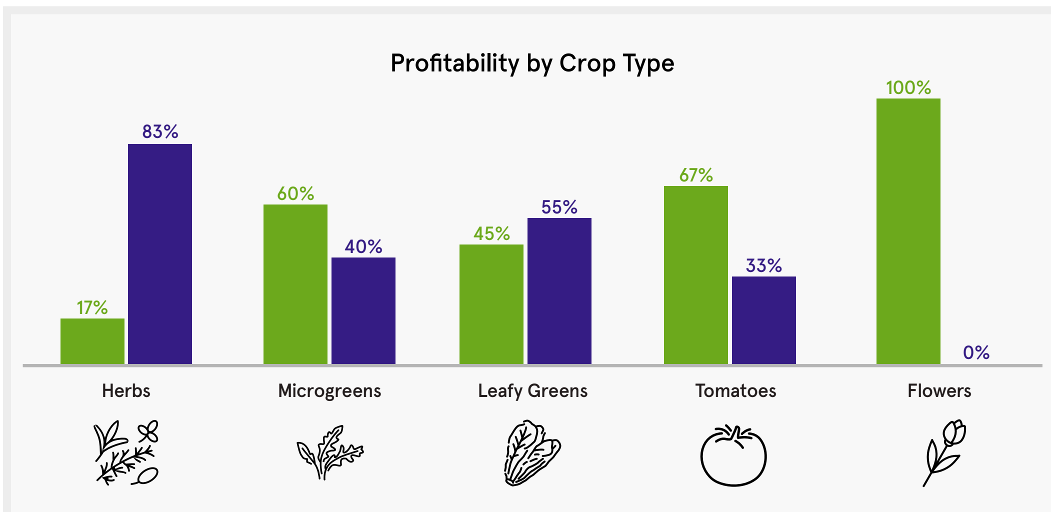
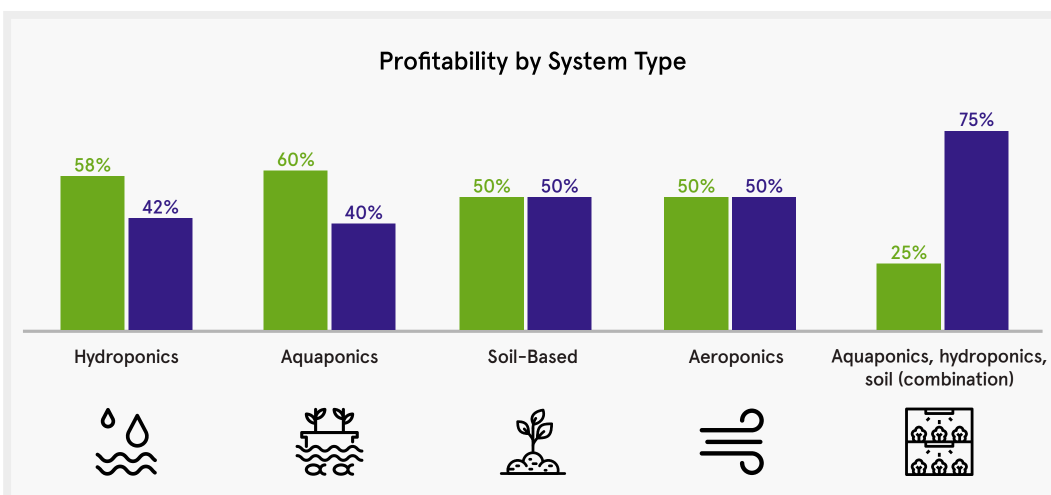
Farm Profitability







Of the facility types we surveyed, the most profitable appeared to be indoor deep water culture, followed by greenhouse operations. Of the five most commonly grown crops, 100% of flower operations reported profitability, along with 67% of tomato growers, and 60% of microgreens growers. The most profitable system types were hydroponics and aquaponics.

The facility types with least profitability reported were indoor vertical farms and low-tech plastic houses. Similarly, herbs and leafy greens were the least profitable crops. The combination operations (using multiple system types) were overwhelmingly unprofitable.

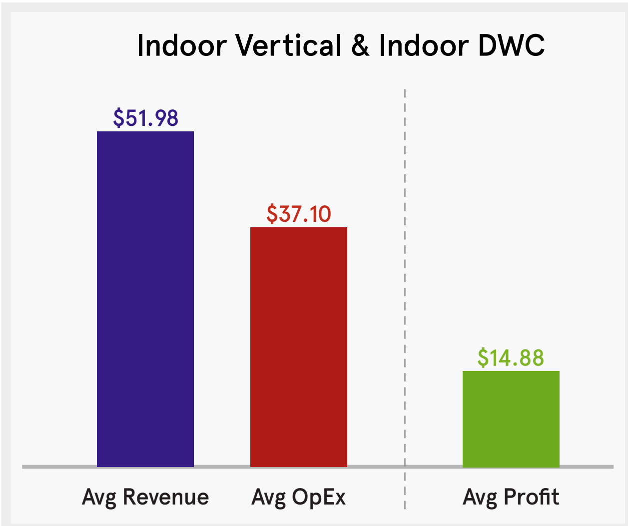
Tomatoes, microgreens, and flowers are most likely profitable because microgreens have extremely high revenue per pound, and flower and tomato producers have lower operating costs. Vertical farms reporting limited profitability is most likely because it is a new industry that is just beginning to mature.

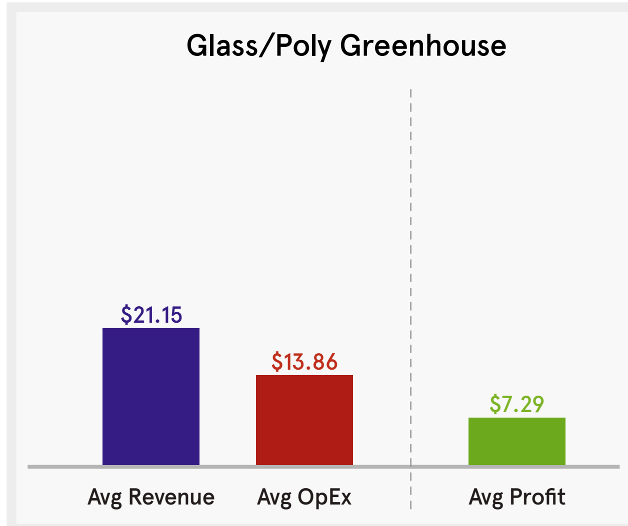
Looking at only profitable operations (for data stability), the most profitable operation is leafy greens grown hydroponically in a greenhouse at a 46% profit margin. When we analyzed revenue alone, and among both profitable and unprofitable operations, we saw that hydroponics and greenhouse operations both had average revenues of about $20 per square foot. Below we see that when farms get to profitability, the revenue per square foot increases significantly, to nearly $40 per square foot. And despite not having the highest revenue per square foot of all operations, growing leafy greens hydroponically in a greenhouse has one of the lowest operational costs per square foot, at $20 per square foot. This nets a grower $17 per square foot in profit. For an acre facility, that amounts to about $750,000 in profit.

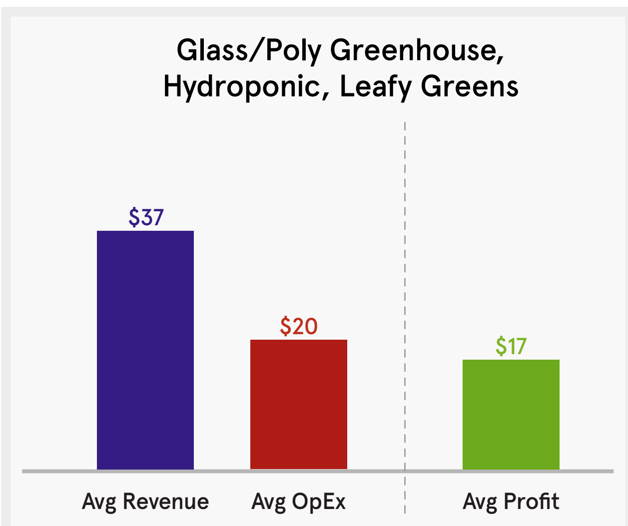
On average, leafy greens and microgreens had the highest profit margin at 40% across various facility and system types, flowers came in at 30%, and tomatoes came in at 10%.

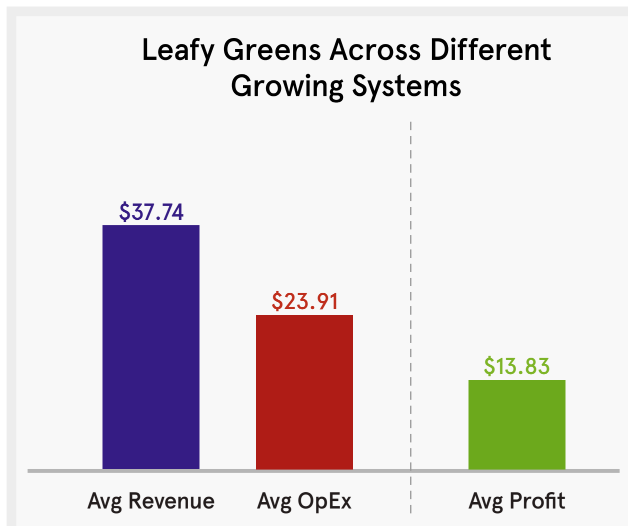
Financials — Profitable Operations

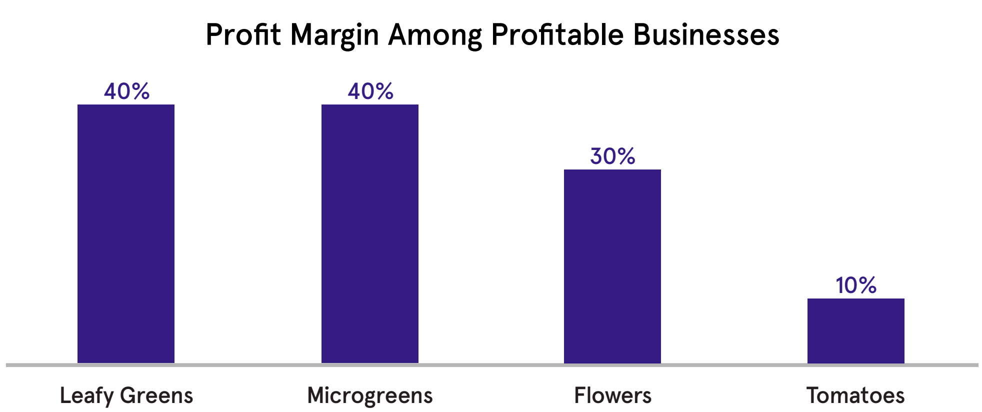
In dollars/sqft







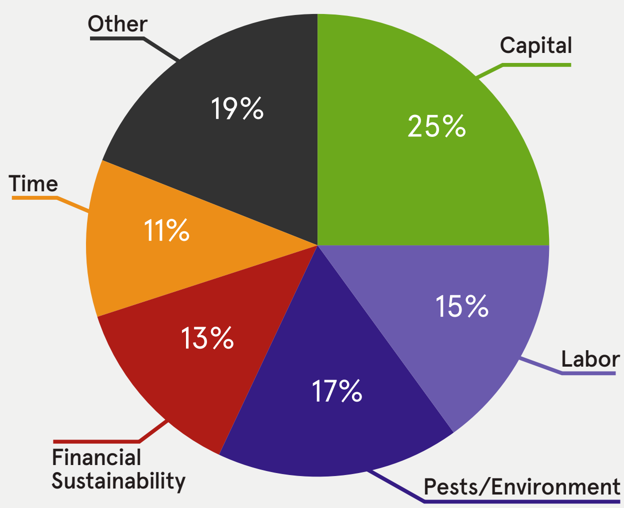




Costs

Last year, we focused exclusively on the revenue side of operations. This year, we wanted to share a complete picture of how facilities are operating. One of the biggest criticisms of indoor farming is the high operational costs. In fact, when we asked growers what their biggest challenge was, the number one challenge reported was capital related. This was an open-ended question and responses included: insufficient access to working capital, high operating costs, profitability, lack of financing for startup costs, and more.

Biggest Challenge



1. Capital

Most growers indicated challenges with access to working capital, expansion capital, or capital formation for the capex.

2. Building-related

Building-related challenges include things such as pests and managing the environment.

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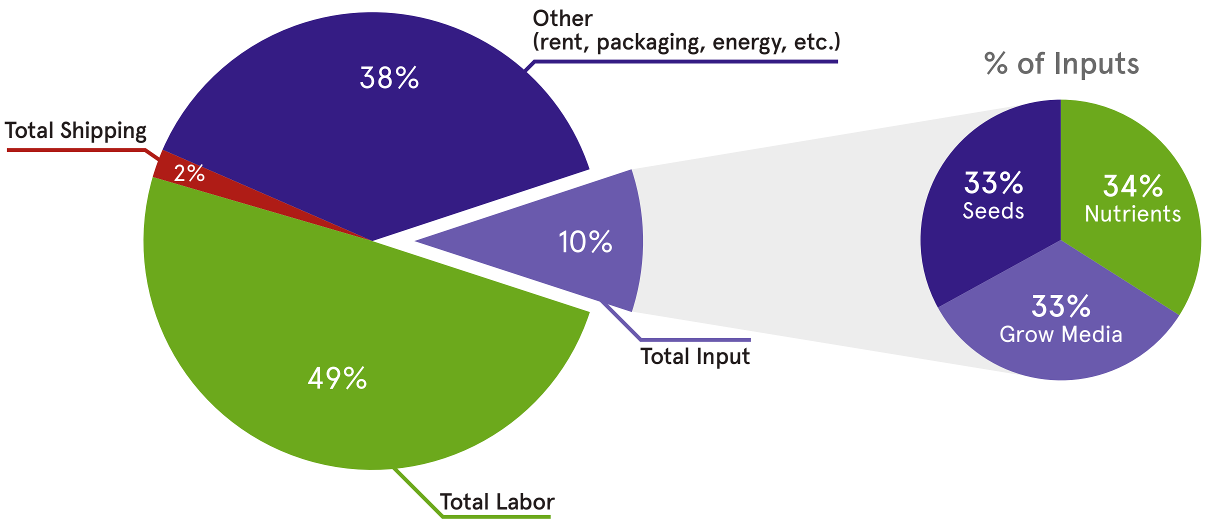
In this section, we focus on breaking down the operating costs for the most common types of operations, starting with hydroponic operations.

Operations Snapshot — Hydroponics

% of Total OpEx



	Small Farms (<10k sqft)	Large Farms (>10k sqft)
Total Input (% of total opex)	6%	13%
Total Labor (% of total opex)	57%	41%
Total Shipping (% of total opex)	0.4%	5%

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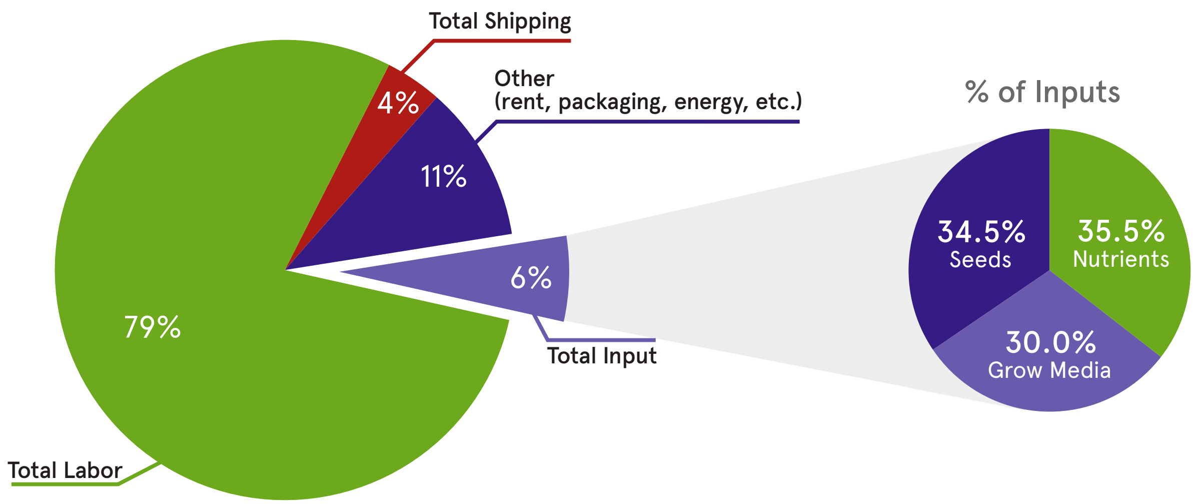
For hydroponic operations, the largest single contributor to cost is labor, averaging 49% across both small and large farms. We categorized inputs as: seeds, nutrients, and grow media. Across all operations, inputs account for 10% of hydroponic operating costs. Shipping costs accounted for 2% of the cost, and the remaining 38% of costs includes: rent, packaging, energy, and miscellaneous costs.

Operations Snapshot — Aquaponics

% of Total OpEx



	Small Farms (<10k sqft)	Large Farms (>10k sqft)
Total Input (% of total opex)	6%	5%
Total Labor (% of total opex)	71%	87%
Total Shipping (% of total opex)	5%	3%

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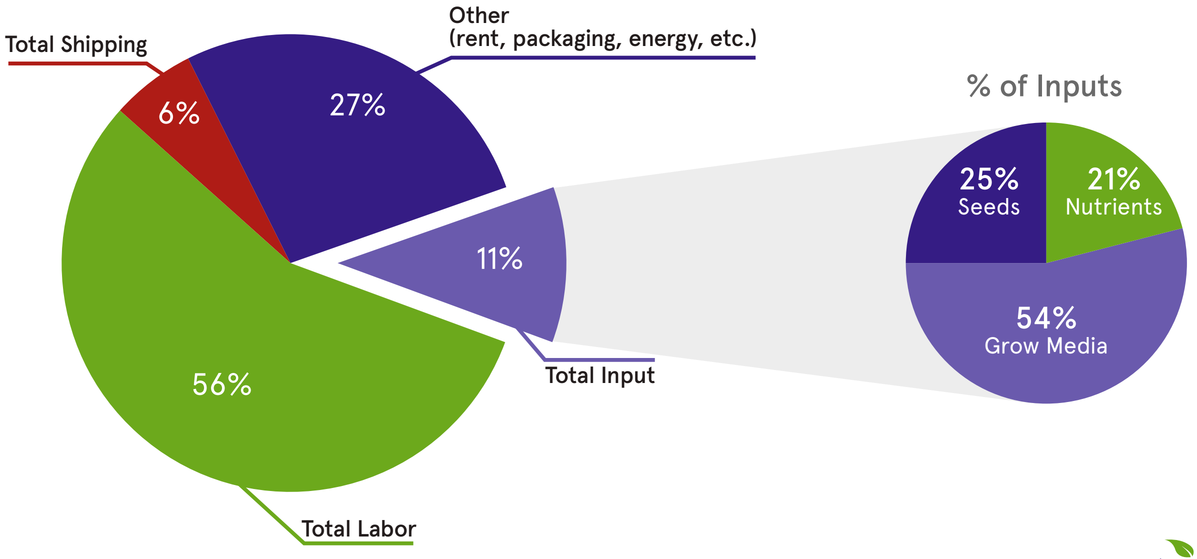
For aquaponic operations, the cost of labor increases pretty significantly to 79%. The cost of inputs reduces slightly to about 6%, shipping stays low at 4%, and the other costs decrease proportionally.

Operations Snapshot — Indoor Vertical

% of Total OpEx

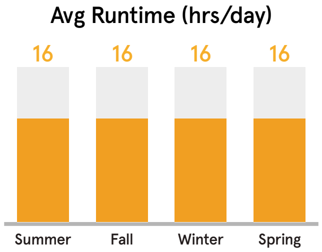


We also analyzed indoor vertical operations. Vertical farms mirror hydroponic operations from a percentage perspective. The major difference is the increased share spent on growing media, which makes sense as these facilities have stacked operations requiring more units (and producing more units) than a horizontal hydroponic operation.

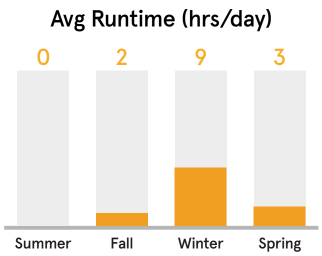
The major difference between vertical farms and greenhouses from a cost perspective is, of course, the total spend (as opposed to the breakdown). The "Financials - Profitable Operations" graph shows the operating cost of a profitable greenhouse facility (all crops, all systems) to be $13.86 per square foot. In comparison, profitable vertical farms (all crops, all systems) spent $37.10 per square foot. So at 50%, labor would cost a one-acre greenhouse grower roughly $300,000 and a vertical farmer $800,000.

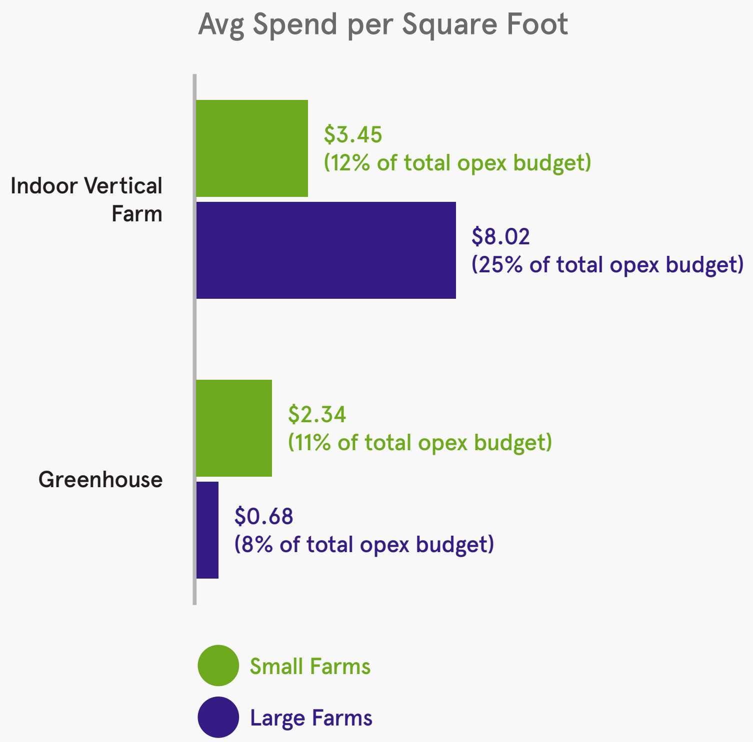
Energy

100% of **vertical indoor farms**
use supplemental lighting.



43% of **greenhouses**
use supplemental lighting.





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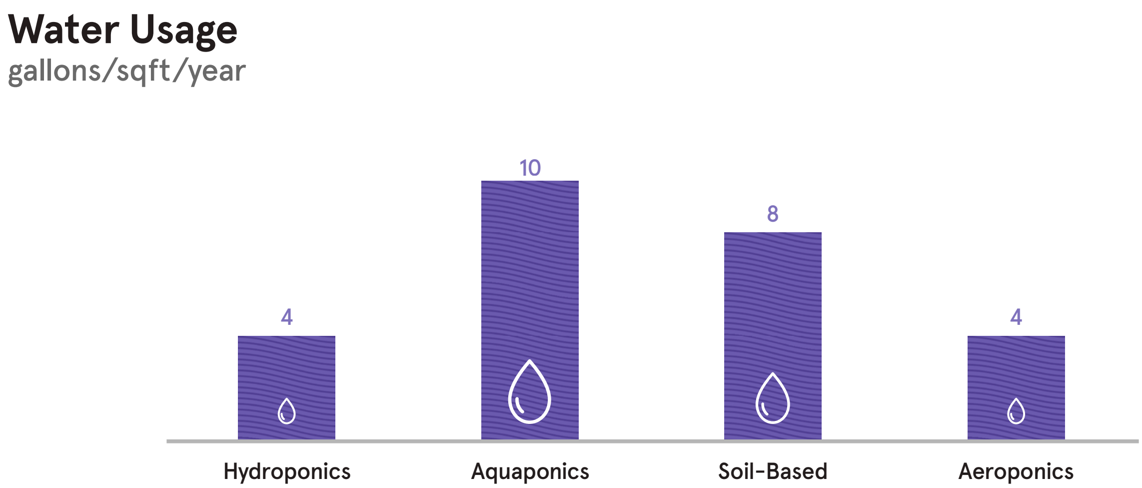
Another difference between indoor vertical operations and greenhouse operations is energy use. Supplemental, or artificial, lighting is a key component to vertical farming operations. Growers reported running their lights 16 hours per day every day all year round in vertical farming operations. On the other hand, only 43% of greenhouse growers reported using supplemental lighting at all, and of those growers the most light applied to plants was 9 hours per day in the winter.

Energy accounts for a large percentage of operating costs for both vertical farms and greenhouses. For large vertical farms, energy made up about 25% of total operating expenses at around $8 per square foot. For small farms, energy cost $3.45 per square foot, or about 12% of the operating expenses. This is primarily lighting costs. For greenhouses, energy makes up about 8% of total operating expenses for large farms and 11% of small farms. This is primarily heating and cooling costs.

This year, we also looked at water usage. This is one of the metrics often used in media regarding indoor agriculture. Conventional farming methods produce one pound of lettuce using 15.5 gallons of water[1]. Our respondents reported only 4 gallons per square foot per year for hydroponics and as much as 10 gallons per square foot per year for aquaponics. For hydroponic lettuce, that equates to less than 0.5 gallons per pound, or around 3% of the needs of conventional lettuce.



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Labor is the largest component of indoor farming budgets. Data held pretty steady from last year's report. Large farms employed an average of 37 full time employees and 14 part time employees per year, totaling 86,712 labor hours annually. The number of employees total is interesting, but we also have to look at the rates per square footage for different facility types. Comparing greenhouses with indoor vertical farms shows a more complete picture as operations scale, with indoor vertical farms needing many more employees than greenhouses. This makes automation technologies incredibly important as the industry matures.

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1 — http://waterfootprint.org/media/downloads/Hoekstra-2008-WaterfootprintFood.pdf

Interestingly, we found that large farms pay employees double what small farms pay per hour. Large and small farms also reported spending between 1.37% and 6.85%, respectively, collecting and analyzing data.

Labor Snapshot

	Large Farms (>10k sqft)	Small Farms (<10k sqft)
# Full Time	37	3
# Part Time	14	2
Total Cost	$1,316,537	$68,673
Annual Labor Hours	86,712	4,273
Average SF	879,194	3,336
Cost/sf	$1.50	$20.59
% Hours spent Collecting/Analyzing Data	1.37%	6.85%
$/pp	$25,923.14	$13,348.60
$/hr	$12.46	$6.42

Labor by Facility Type

	Total Employees (full + part time)	People per Sqft	People per Acre
Indoor Vertical Farm	8	0.00144	63
Glass or Poly Greenhouse	38	0.00007	3

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3 Technology

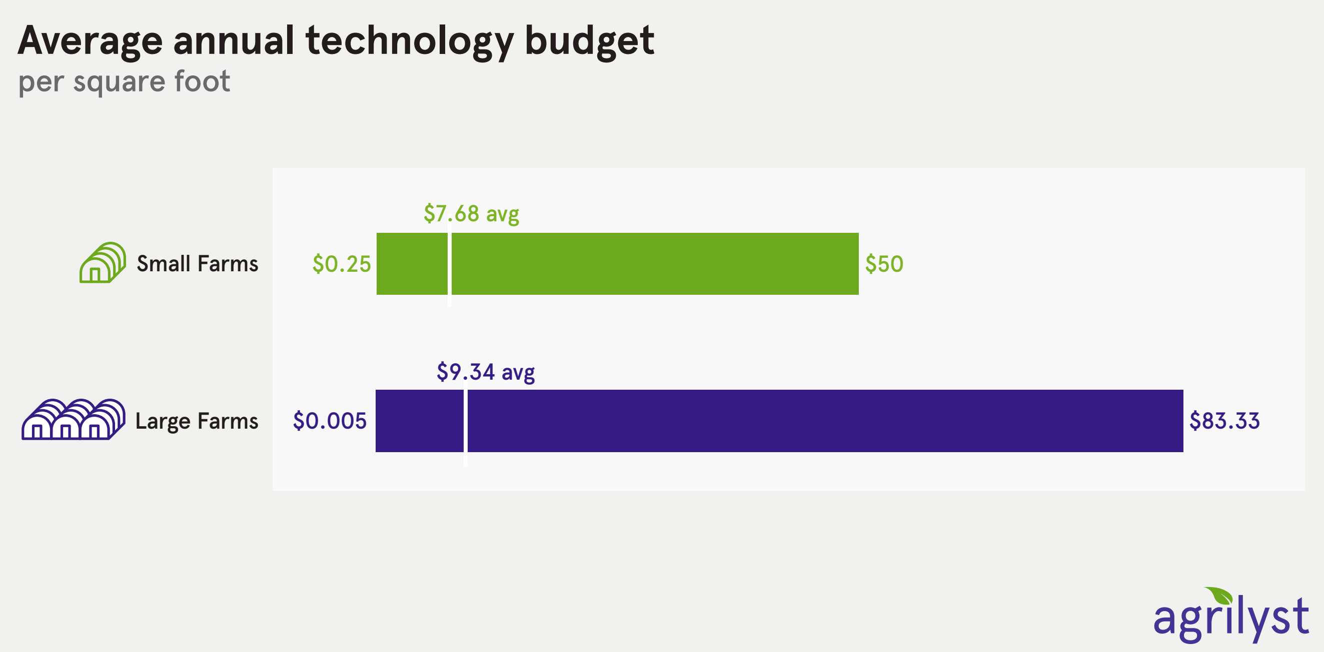
The systems that are moving indoor farming forward.

Budget for technology and goals

To produce more with less, indoor farms rely on technology: from increasing plant yields, to managing operations, to improving crop quality.

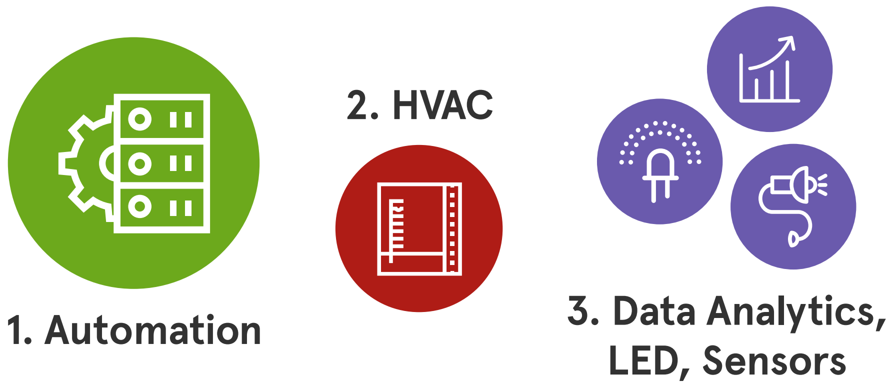
On average, small farms have an annual budget of $7.68 per square foot to invest in technology. Large farms on the other hand, spend about $9.34 per square foot.

What technologies are farmers excited about?



Automation tops the list of technologies growers are most excited about. Second to automation is HVAC (heating, venting, and air conditioning) equipment. Third was a tie between data analytics, LEDs, and sensors. Note this was an open-ended question and for sensors, most growers indicated an interest in sensors specifically for nutrient applications. Automation is not a surprising number one. With the high cost of labor, most growers are thinking strategically about investing in technology that can bring costs down.

Technology that growers are most excited about



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What technologies do farmers think are overhyped?

While LEDs are one of the things growers are most excited about, it also came in second on the list of things growers think are over-hyped. The overwhelming number one on the list of doubtful technologies was container farms.

Technology growers think is overhyped

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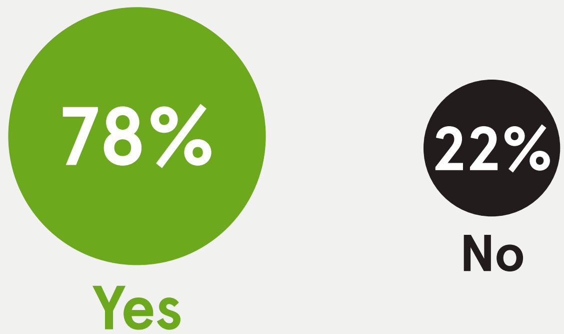
Would growers buy technology from a startup?

We asked growers if they would buy technology from a startup and 78% indicated they would. Growers are interested in innovation. However, they're hesitant to take risks and indicated they wouldn't buy unproven or untested technologies. Most growers specified they don't want to be "beta testers." Startups need to work with farmers from the onset to be successful.

Would you buy technology from a startup?



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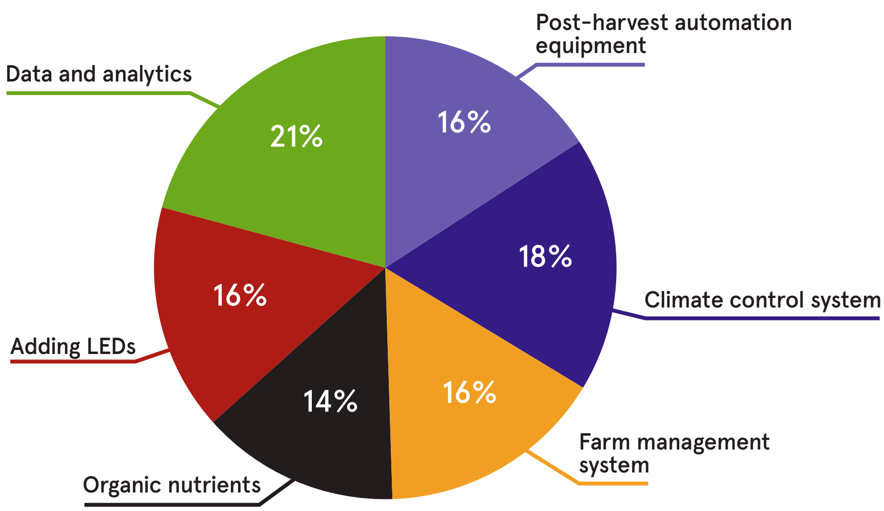
What technologies are growers buying?

When asked to indicate one or more new technologies or improvements they're planning to make in the next 12 months, most farmers selected data analytics technology, while climate control systems ranked second.

This largely has to do with the impact growers believe data and analytics can have on their operation. Over 70% of growers believe they can increase crop yields by up to 30%, with a minimum expected growth of 14%.

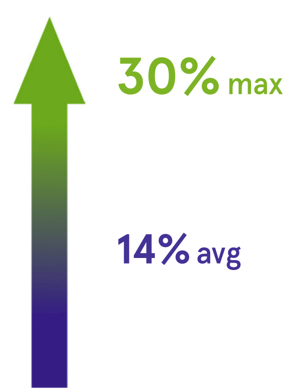
What new technologies or improvements are you looking to make in the next year?



Growers are interested in investing in technology that can improve operations. The number one thing growers are looking to do with new technology is to manage their operations more efficiently. Last year, this ranked third on the list of top priorities. This year, managing operations more efficiently was followed by lowering the cost of production and increasing yield. Last year, these ranked fourth and second respectively.

Percentage of growers who believe they can increase crop yields with data analytics

Percentage increase they believe they can achieve



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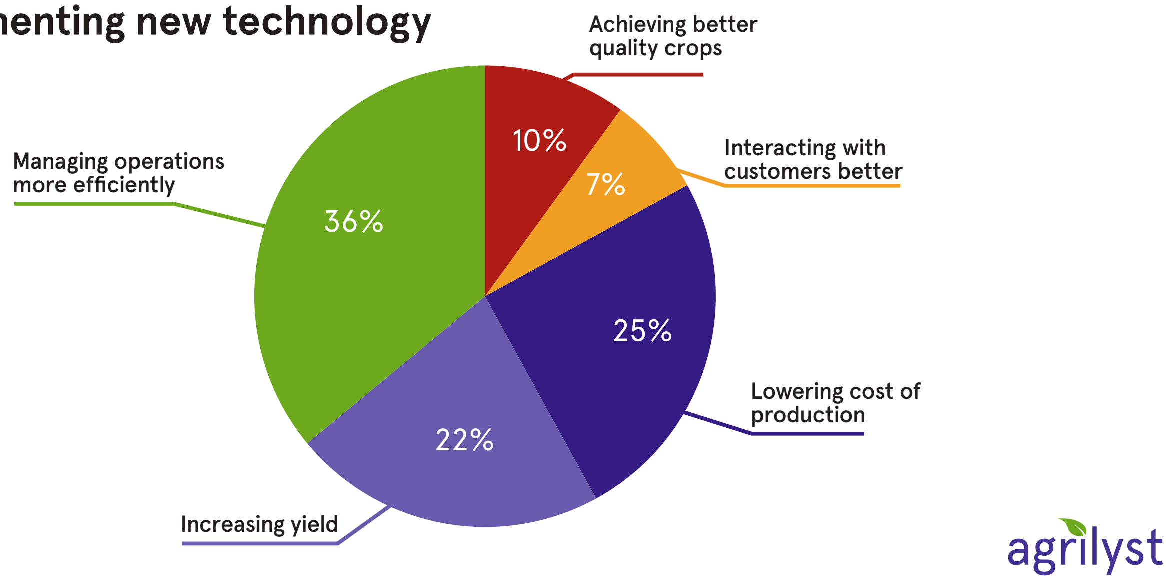
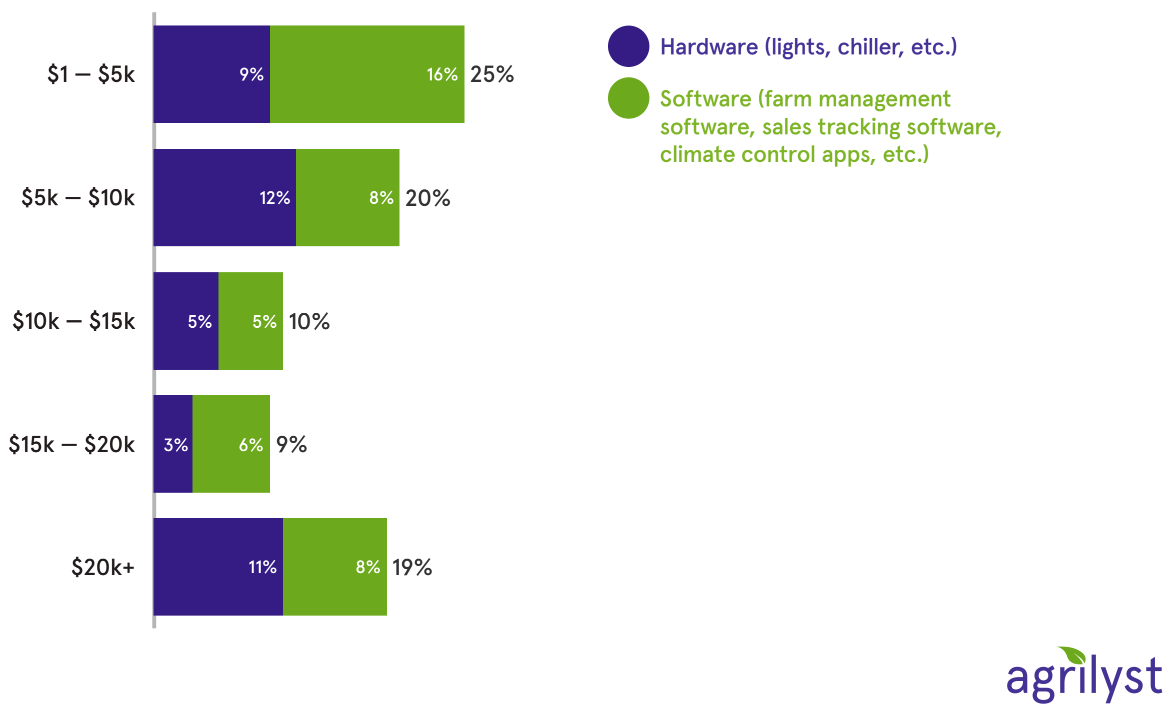
Most pressing goal for implementing new technology



Growers believe technology can not only gain additional yield and revenue, but also lower the cost of production - the second most important goal of implementing new technology. In fact, 19% of growers believe technology can save them more than $20,000 per year.

Can hardware or software save me money?



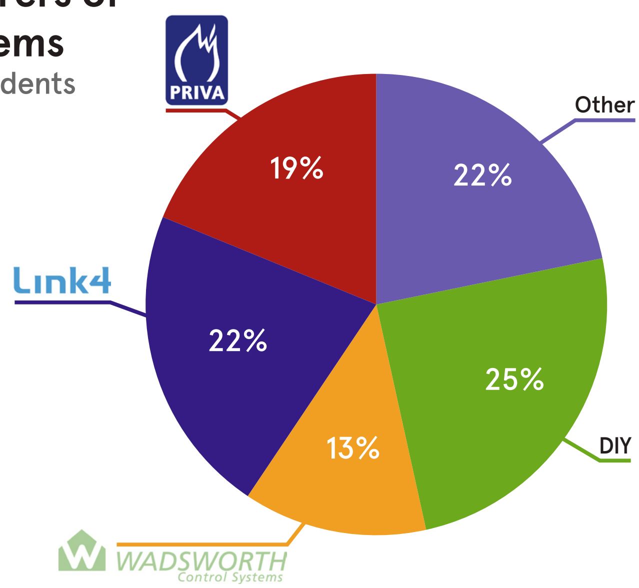
Climate control system and farm management

A climate control system is perhaps the single most important technology in an indoor farming facility, as it allows farmers to create the ideal environment for year-round production. This is why it ranked highly on growers' list of technologies they're looking to purchase this year.

Of the farmers who reported using a climate control system already, 53% indicated owning a Priva, Link4, or Wadsworth system, while the others use either less-known providers or homemade systems.

Selected manufacturers of climate control systems

Share among survey respondents

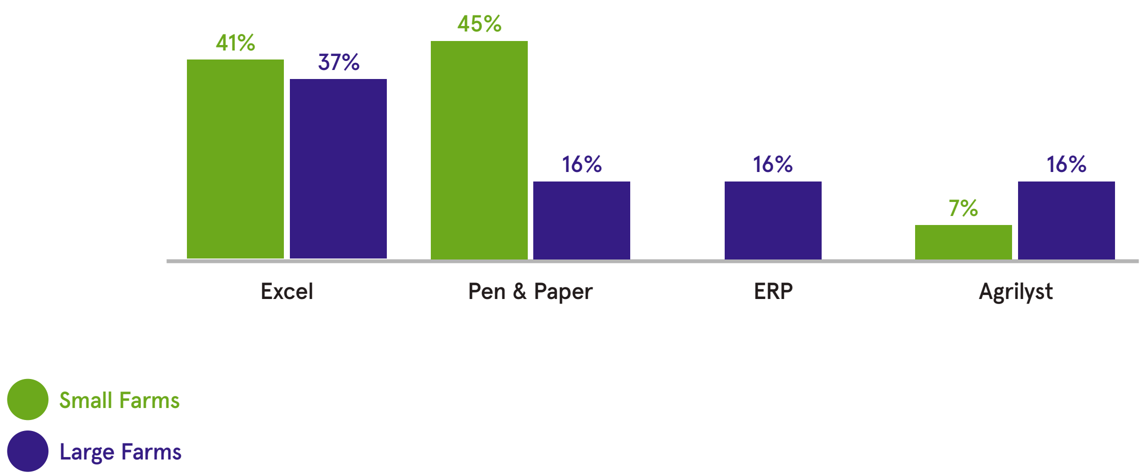


DIY includes any answer that wasn't a commercial off-the-shelf product.

Production Management Tools

While farmers are aware of the importance of data analytics and climate control systems, the use of production and inventory management software is still limited. When asked their tools of choice, most farmers - in both small and large facilities - reported using either Excel or pen and paper.

Tools used for production and inventory management



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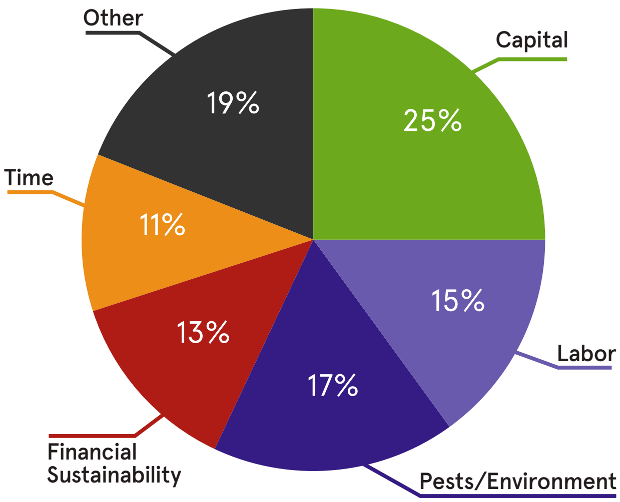
4 Market & Future

A look at the benefits from and challenges with rapid market expansion over the next five years.

Despite its explosive growth, the indoor farming industry is not without its challenges. When asked what their number one challenge is, 25% of growers responded with an answer related to capital - from access to working and expansion capital to cost of production. The second challenge was building-related, including things like pests or challenges managing the environment.

Biggest Challenge



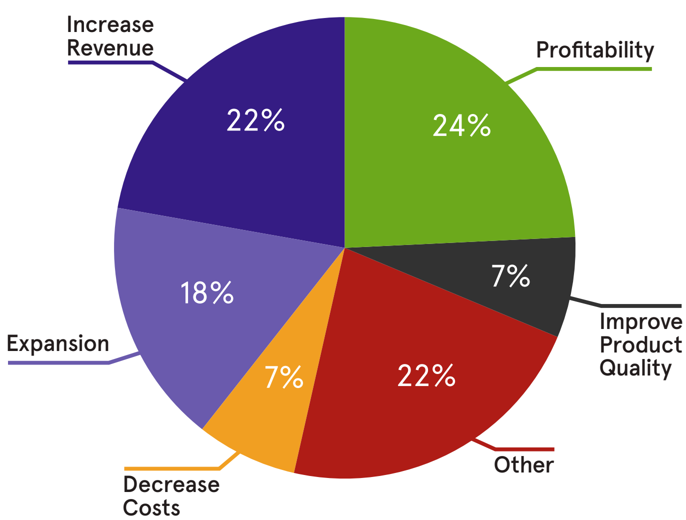
1. Capital

Most growers indicated challenges with access to working capital, expansion capital, or capital formation for the capex.

2. Building-related

Building-related challenges include things such as pests and managing the environment.

Primary goal for 2018



1. Profitability

2. Increase Revenue

3. Expansion

When asked about their number one goal for 2018, 46% of farmers indicated either increasing profitability or revenue. For an additional 7%, the primary goal is decreasing costs, which takes financial-related goals to 53%.

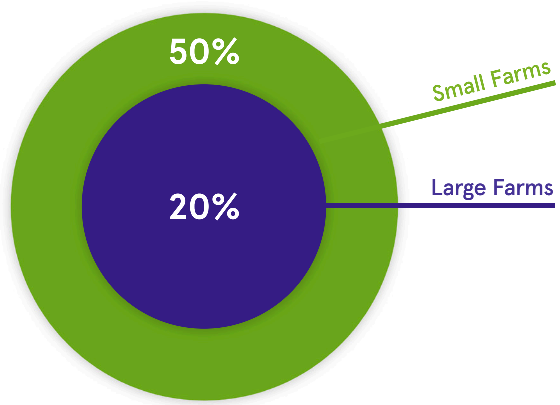
2017 Expansion

If the industry can figure out these challenges and help growers become profitable faster, the industry will continue to see additional growth. Of the survey respondents, 30% expanded in the past year, adding over 450,000 square feet in new production area. On top of that, 16% of respondents were new farms created in 2017. Small farms added 50% more area in 2017 and large farms added 20%.

Past 12 Months

- **30%** Respondents who expanded in the last year
- **~450k** Square footage added
- **21%** Increase from existing square footage in the last year
- **16%** Respondents that were newly-created farms in 2017

Percent of Area Increase in the Last Year



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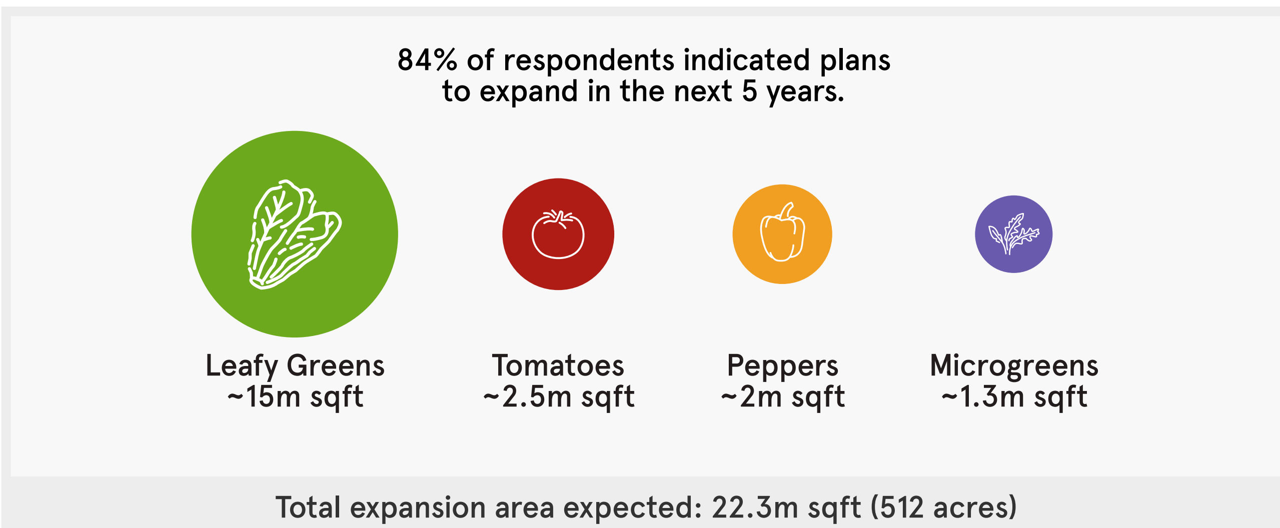
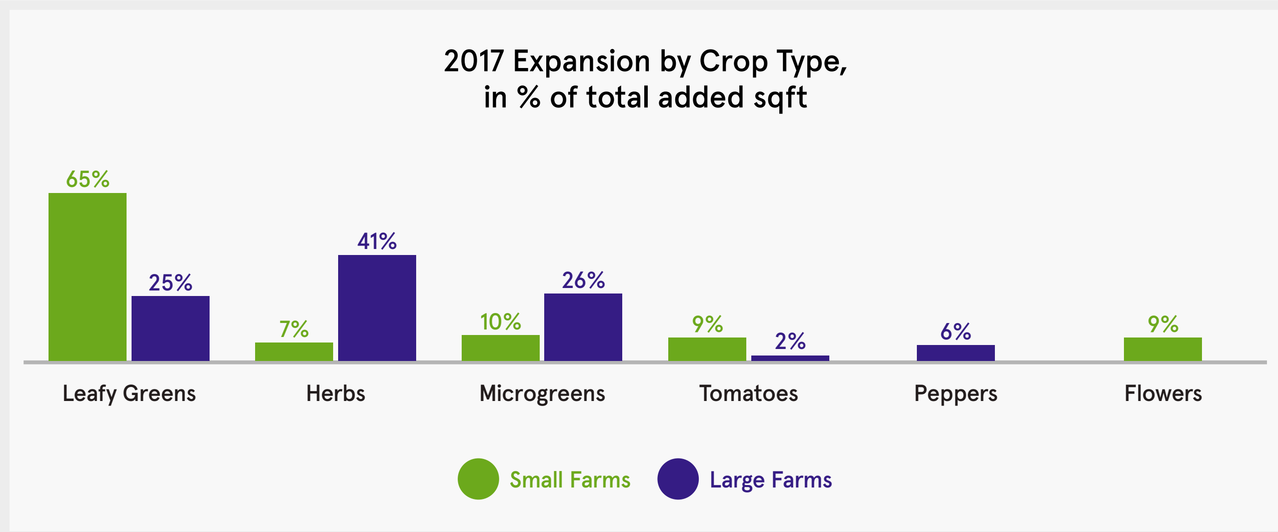
The Future

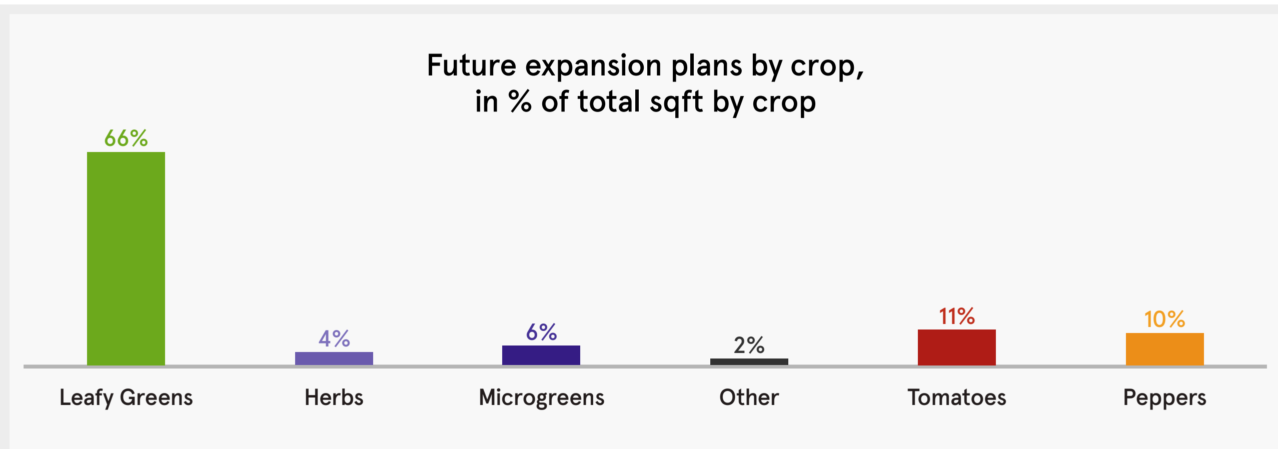
The vast majority of growers, 84% of survey respondents, are planning to expand their facilities in the next five years and they're planning on growing significantly, with plans to add 22.3 million square feet of growing area. This expansion primarily comes from leafy greens growers, with expectations of adding 15 million square feet in new growing area.

Expansion by Crop Type



Expansion by Crop Type





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