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Controlled Environment Agriculture: Farming for the Future?

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Key Points:

- Controlled environment agriculture (CEA) has expanded rapidly since the late 1990s as growers use strategically located grow houses to extend production seasons and achieve transportation efficiencies.
- A few big growers control a large share of the CEA market in the U.S. Consolidation in the retail food industry will further enhance their market influence.
- High costs of capital, labor, and knowledge are barriers to entry for new, or small, CEA operations. Many growers fail by not anticipating capital needs and not aligning scale to match sales.
- CEA growers using hydroponic technology are realizing lucrative price premiums, and are benefiting from significantly higher crop yields and an extended growing season, compared to field-grown produce.
- While risks are high for small producers, opportunities exist for those who capture price premiums in niche markets.

Introduction

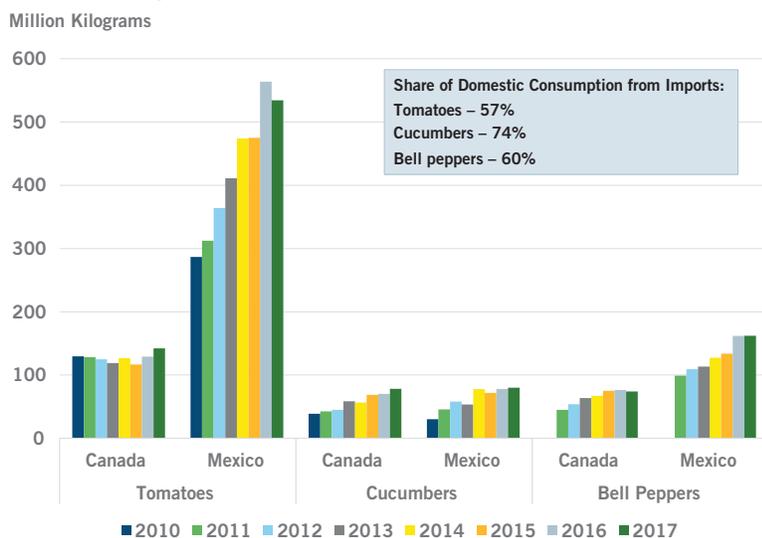
Urban vertical farms and other forms of CEA have received a lot of press lately as these crop production systems have become more prevalent. The industry has been expanding rapidly since the late 1990s, with the pace of growth picking up in recent years as technology has evolved.

By 2014, U.S. sales of food crops grown under protection totaled approximately \$797 million. CEA operations using hydroponic technology accounted for almost two-thirds of that production.¹

All this interest in CEA does seem to bode well for the future of the industry, especially considering some of the emerging trends. But, growers face many challenges. This paper aims to explore some of the opportunities and pitfalls and what it takes to succeed in this industry.

Controlled environment agriculture (CEA) is a technology-based approach toward food production. The aim of CEA is to provide protection and maintain optimal growing conditions throughout the development of the crop. Production takes place within an enclosed growing structure such as a greenhouse or building. Plants are often grown using hydroponic methods to supply the proper amounts of water and nutrients to the root zone.

EXHIBIT 1: Top U.S. Greenhouse Vegetable Imports for Consumption from Canada and Mexico



Source: U.S. Census Bureau, USDA-ERS

The power of fresh, local and sustainable

A rise in consumers' awareness about what they are eating, and a preference for top-quality produce year-round, are the main driving forces behind the sizable expansions in CEA production. And increasingly, consumers, especially those in urban areas, are seeking locally produced food.

Production increases have also been fueled by:

- Price premiums that high-quality produce carries.
- Retailers' need for a year-round supply of fresh produce.
- The consistency of indoor production.

The result is that CEA hydroponic produce – particularly tomatoes, cucumbers, and peppers – has evolved from a high-end niche category to being an important part of retailer produce programs.

The geography of production

CEA is well represented in all 50 states, but the vast majority of the larger CEA vegetable facilities in the U.S. are located in the Northeast, West, and Southwest. Growing conditions are better suited to winter and year-round production in the western regions.

Indoor farms are typically located either close to markets or where efficiencies can be maximized. Demand for local produce, especially from urban consumers, is strong and growing, so metro areas are the hot spots for growth. Consequently, new CEA capacity has been added in the central and eastern parts of the U.S.

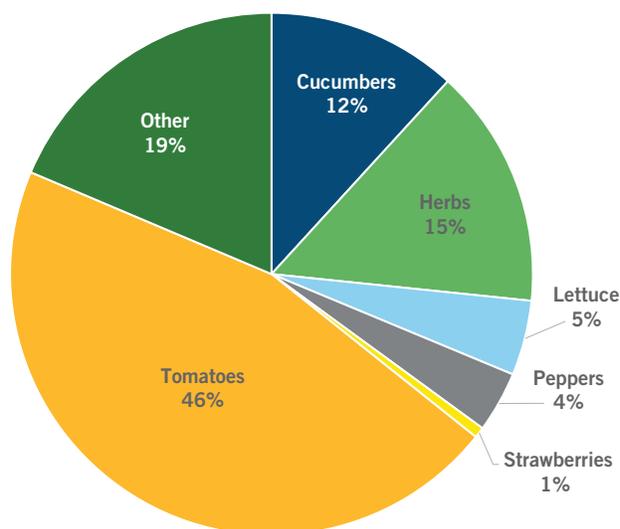
Existing large-scale growers, many who are Canadian, are increasing their operations to be closer to markets. The added benefit for these cross-border investors is that they can label their produce as U.S. grown. New entrants are also trying to capitalize on the local market movement.

The North American market for greenhouse vegetables has become more continental. It is well integrated with produce supplies flowing between Canada, the U.S., and Mexico. Despite the huge increase in CEA hydroponic vegetable production in the U.S., domestic supply is supplemented by imports from Canada and Mexico (*Exhibit 1*).

About 80 percent of Canadian production is exported to the U.S. during the Northern Hemisphere growing season (April – October). Climate and proximity to certain U.S. consumer markets are definite advantages for Canadian growers during this period. In general, the main strengths of the Canadian greenhouse vegetable industry are its expertise, high yields, and consistent quality. The lack of production during the winter is a major drawback, however.

Most Mexican-grown CEA produce flows north to Canada and the U.S. counter-seasonally, although production has been extending to benefit from higher pricing in the shoulder seasons. Despite expansions, much of the Mexican greenhouse acreage is low-tech. The Mexican industry has historically struggled with inconsistent product quality, higher distribution costs, less-experienced management, less-developed infrastructure, and high energy costs. In recent years, Mexico has made advances in growing expertise that have allowed it to extend its growing season. High capital and rising labor costs are growing challenges for the Mexican industry, though.

EXHIBIT 2: Top Crops Grown Under Protection in the U.S., 2014



Source: USDA – 2014 Census of Horticultural Specialties

Despite the increased competition from Canada and Mexico, domestic CEA hydroponic vegetable growers benefit from:

- high yields
- year-round supply
- consistent quality
- packaging innovations
- marketing expertise
- proximity to customers

Being closer to their customers contributes most to the favorable positioning of U.S. growers. This greatly reduces transportation and distribution costs and allows for enhanced product freshness and quality.

Room for expansion

The number of greenhouses, as well as the variety of covered crops, continues to increase. However, most hydroponic developments have been related to specialty tomatoes, peppers, and cucumbers; the licensing of new proprietary varieties; and, more recently, leafy greens.

Tomato crops have benefited most from the varietal improvements of the last 20-30 years. Boosts in flavor and quality have raised consumer acceptance. As a result, greenhouse tomatoes account for about half of the fresh tomatoes produced in the U.S. and for more

than half of sales and volume sold at domestic retail stores.² Almost all of these greenhouse tomatoes were grown hydroponically.

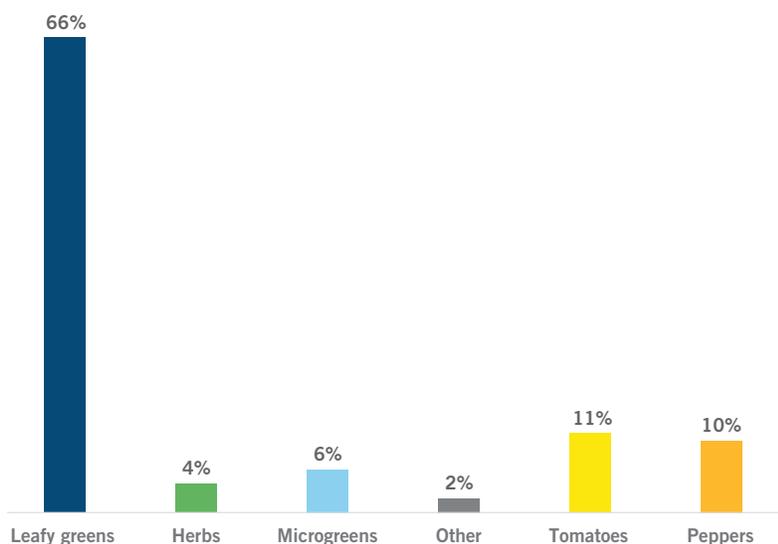
The hydroponic tomato market is maturing as it replaces field-grown tomatoes in response to better prices and the ongoing development of new varieties. A few large companies dominate this very competitive high-volume, low-margin market. Although the exact current hydroponic tomato acreage is unknown, it is estimated that the five largest growers hold about two-thirds of U.S. tomato acres.³ These large growers have profited from maximizing scale efficiencies and focusing on differentiation strategies. They have created a niche in the market with proprietary varieties and packaging, specialty tomatoes, and year-round contract pricing.

The expansion in hydroponic tomato production has also spurred the emergence of many smaller urban and local players. In fact, the majority of domestic greenhouse growers farm on less than an acre. These operators survive and thrive by targeting and serving the premium markets, which allows them to offset their higher costs and lower production volumes.

While the retail market is well supplied by hydroponically grown tomatoes, the foodservice market represents a major opportunity for hydroponic tomato growers. This market accounts for about half the fresh domestic tomato volume, yet it remains largely untapped by the hydroponic industry. Among the factors that will combine to unlock more demand for this market segment: 1) the development of new tomato varieties with better firmness and slicing attributes, and 2) commitments by institutional foodservice users such as schools and colleges to source more food locally.

Beyond tomatoes, the share of other CEA crops in the U.S. pales by comparison. This offers opportunities for expansion, especially given the volume of produce that is imported (*Exhibit 2*). Leafy greens, microgreens, herbs, and novelties like turmeric and ginger are up-and-coming crops. The potential for higher margins and smaller area requirements associated with these crops are appealing to growers.

EXHIBIT 3: Future Expansion Plans by Crop, in Percentage of Total Square Feet by Crop



Source: Agrilyst

Positive market signals are prompting most CEA growers to plan facility expansions over the next five years. Production of leafy greens, tomatoes, and peppers is likely to increase the most in the next few years (*Exhibit 3*). Roughly 90 percent of the leafy greens consumed in the U.S. is produced in California and Arizona because of climate advantages. However, there are other benefits to developing more widespread and localized production: transportation cost savings and improved product quality resulting from reduced time between harvest and consumer purchase.

The increasing interest in organic produce presents further opportunities for growth. Organic fresh produce sales totaled almost \$5 billion in 2017, and continued growth is expected. Few pesticides, herbicides, and fungicides are typically used in CEA. Therefore, the National Organic Standards Board announcement in late 2017, which declared that hydroponic operations can still be certified organic under USDA regulations, should support CEA hydroponic production expansions.⁴ In contrast to organic field-grown produce, hydroponic systems do not require a three-year transition period – a huge benefit and cost savings for growers.

High risk, high reward

Establishing a CEA hydroponic vegetable operation requires considerable capital investment. Depending on the size of the operation and the level of technology involved, the capex can run into the tens of millions of dollars. In addition, these types of systems usually have high operating costs. This is a huge challenge for growers and has implications for the length of time it takes for them to realize a profit.

Knowledge is a further barrier to entry. The success of a CEA hydroponic venture requires skilled labor and a range of horticultural, engineering, and business skills.

Hydroponics can be very profitable, but the stakes are high given the required level of investment and know-how. Because of this – if and when businesses fail – the losses can be significant.

Ensuring profitability

Returns and costs vary greatly by size of CEA operation, the type of crop, region, production system, and the production period (seasonal versus year-round).

Amongst profitable operations, leafy greens that are grown hydroponically are the most profitable crop. They yield an average 46 percent profit margin and have one of the lowest operational costs at \$20/sq. ft. (*Exhibit 4*).

Across all indoor farming systems and facility types, leafy and micro greens have the highest profit margins (40 percent) because of extremely high revenues per pound. Despite lower operational costs, the average profit margin for tomatoes is much lower (10 percent).⁵

Profit margins and crop biological/productive characteristics can be a determinant of the size of operations as scale efficiencies can help to improve lower profit margins. However, establishing who the customer is should be the starting point for determining the size of an operation.



A 2017 survey found that the average revenues of profitable hydroponic and greenhouse operations is about \$40/sq. ft.⁶ Pricing is one of the main determinants of profitability and is key to counterbalancing the higher costs associated with CEA production.

It is critical to understand the impact of pricing on the bottom line. While prices fluctuate according to available supplies (seasonality) and consumer demand, greenhouse vegetables typically fetch higher prices than their field-grown counterparts because of their year-round availability and consistent quality. Greenhouse growers usually see higher prices in the Northern Hemisphere during the winter months, but more retailers are starting to implement contract pricing for six, nine or 12 months to reduce some of the higher seasonal pricing. However, the contracts benefit growers by locking in long-term sales.

Yields are another important driver of profitability. Even though CEA does generate higher yields than conventional farming, research has found that there are optimum CEA yields that growers should strive towards to maximize revenues and profitability (*Exhibit 5*).

Recipe for success

CEA farming can be a very profitable business, but it is also very risky with a steep learning curve. While the failure rate is high, there are many successful growers.

So, what does it take to succeed in this industry?

Growers come in many shapes and sizes, and there is a lot of variation in the how, what, and where of production. But no matter the size of the operation or the crops produced, the following fundamentals are foundational to grower success:

EXHIBIT 4: Average Profit Margin of Hydroponic Leafy Greens vs. All Other Greenhouse Grown Crops

	Hydroponic, Leafy Greens \$/sq ft	Greenhouse, Avg All Crops \$/sq ft
Average revenue	37	21
Average Opex	20	14
Average profit	17	7

Source: Agrilyst

EXHIBIT 5: Optimum Yields in CEA*

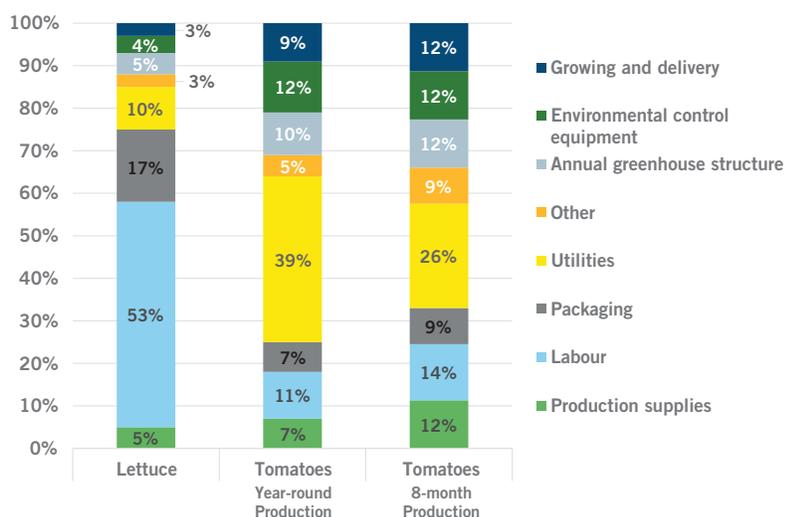
Crop	lbs/sq ft/year	lbs/acre/year
Lettuce	23	1,000,000
Cucumber	16	697,000
Tomato	12	523,000
Sweet pepper	6	261,000

Source: Cornell University

*Although these yields are representative of New York greenhouse operations, they provide a framework for assessing cost structures and operational efficiencies.

- **Operational cost.** The newer production systems are much more capital intensive with high startup and working capital needs. Growers often run into cash flow problems early on because they don't realize just how high these costs are.
- **Assessment of the market.** It is imperative that growers target and serve a sustainable market. They need to practically assess demand and determine whether profitable margins are possible given their level of output and the market price. Producers should think carefully before scaling an operation to meet customer demand and follow a market-driven approach when making planting decisions.
- **Assessment of competition.** Differentiation from the commodity market and other competitors is key to having a profitable and thriving business. Successful growers have managed to create a better value proposition by producing a quality (branded) product that demands a price premium.

EXHIBIT 6: Comparison of Production Costs of Lettuce vs Tomatoes*



Source: Cornell University

*Although these costs are representative of New York greenhouse operations, they provide a framework for assessing cost structures and operational efficiencies.

Aside from the preceding fundamentals, there are several common misconceptions about CEA farming that can trip up prospective growers. These include, but are not limited to:

- Assuming full production from the start when it usually takes a year or two to get to full production.
- Miscalculating and misunderstanding operational costs, especially labor and energy costs. Costs can vary by crop type and production period (*Exhibit 6*).
- These types of production systems cut out pest and disease problems.
- Misunderstanding the importance and cost of providing adequate light.
- All product that is grown will be sold.
- Customers will remain loyal.
- Underestimating the importance, affordability, and availability of highly skilled labor and greenhouse managers. The value of having a reliable, capable workforce can't be stressed enough.
- Thinking that the crop will grow itself. It may not be conventional agriculture, but CEA is still commercial crop farming.

As markets mature and become more crowded, margins typically get squeezed. Many growers have developed winning strategies by establishing a brand, maintaining consistent product quality, and securing supply contracts. The development of strong sales relationships will be particularly important amidst the ongoing wave of retail consolidation that is leading to fewer, larger buyers.

Conclusion

CEA production is an efficient way to produce more food (locally) using fewer resources than conventional farming while protecting crops from weather risks. It enables the production of high-quality crops in areas not necessarily suitable for traditional agricultural production. CEA production systems also provide growers

with tools to help them deal with such challenges as labor and food safety.

There is growing interest in this industry – as evidenced by the number of new operations, both large and small. CEA is a way for producers to diversify their operations and income. Meanwhile, the larger operations are leveraging their access to capital, economies of scale and scope, and expertise to take advantage of the growth opportunities.

While opportunities abound and the rewards are attractive, the learning curve for CEA production systems is steep and the risks are high. Many new ventures fail because this industry has its challenges despite the myriad technological benefits and advances. Nevertheless, despite being capital and knowledge intensive, CEA crop production is likely to continue to grow due to the advantages it offers. CEA will not take the place of conventional agriculture in the future, but all indications point to it being an important tool for meeting the world's food needs. ■

References

¹ 2014 USDA Census of Horticultural Specialties

² 2014 USDA Census of Horticultural Specialties

³ CoBank ACB based off of tomato acreage estimates
by Roberta Cook

⁴ For hydroponic crops to be labelled as organic, the operation will still have to be certified organic by a USDA accredited certifying agent and remain compliant with USDA organic regulations.

⁵ Agrilyst, State of Indoor Farming Report 2017

⁶ Agrilyst, State of Indoor Farming Report 2017

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