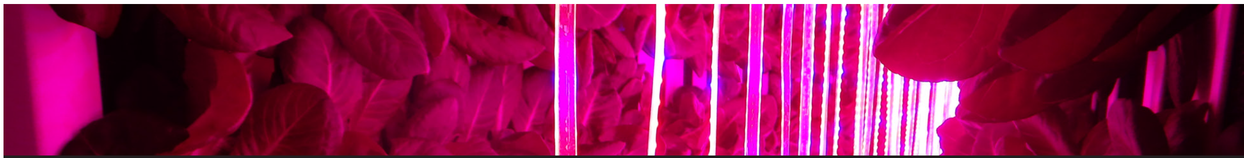
ELECTRIC POWER
RESEARCH INSTITUTE

# INDOOR AGRICULTURE

## A Utility, Water, Sustainability, Technology and Market Overview

June 2018







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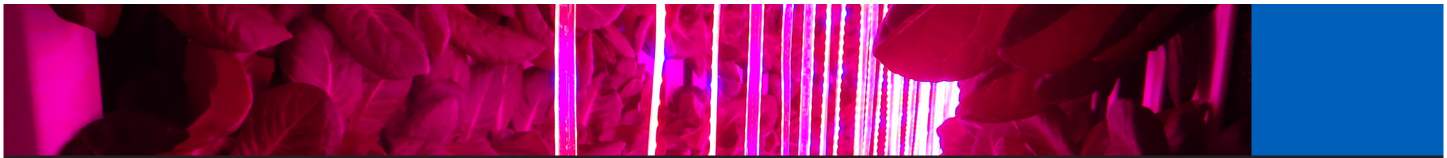



# Introduction

Currently, approximately 38% of the earth's landmass, or over 800 million hectares of land, is utilized in soil-based agriculture.[1] Additionally, over 80% of land suitable for raising crops is already in use worldwide.[2] According to the World Bank, over 44% of the land in the U.S. is used for agriculture as of 2015.[3] Today, there are ongoing conversations in many communities around the land use, future capacity, production/yield reliability, and water use of conventional agriculture.

In addition to the high percentage of the world's usable farmland already being in use, worldwide populations are expanding. The United Nations (UN) estimates that by 2050 there will be over 9 billion people on earth.[4] This is a noticeable increase from the roughly 7.45 billion people currently on Earth as of March 2018.[5] Similarly, the U.S. population is expected to increase from 327 million in early 2018[6] to 438 million in 2050.[7]

Populations of urban centers and population density are increasing as well. In 2014, Urban populations represented approximately 54% of the world's population, increasing to an estimated 66% by 2050.[8] This urban expansion may also reduce the amount of farmland near urban populations which in turn could lead to stresses on existing food production and logistics systems.

As the population of urban centers increases, surrounding farm land may decline, and the distance between the field and the consumer may increase. In many parts of the U.S. today, produce travels between 1,500 and 2,500 miles from the farm to reach the consumer. This is almost 25% farther than 20 years ago.[9] Additionally, the time spent transporting crops results in a loss in nutritional value and freshness, while also reducing the shelf life of the product.[10,11,12,13] The United States Department of Agriculture (USDA) estimates that supermarkets lose $15 billion annually in unsold produce.[14] A large percentage of this loss stems from produce damaged during transport and spoilage.[15]

Currently in the U.S., most of the fresh produce is shipped extensive distances from the field to the consumer. Billions of dollars are spent annually delivering and distributing crops from where they are grown to where they are sold, consumed or processed. Additionally, studies have shown that long-distance transport can result in fresh vegetables and fruits losing a portion of their nutrition and freshness.[16,17,18,19] Unless preservatives are used, long-distance shipment also reduces the shelf life of the produce once it reaches the warehouse or store. Reduced shelf life leads to additional spoilage and waste. It was reported in 2008 that approximately $47 billion worth of food (which includes meat, dairy, produce, and other products) did not make it into consumers' shopping carts due to waste.[20]

In addition to land, water usage is a key factor in outdoor farming. Unfortunately, fresh water is becoming a more scarce or controlled

1 http://www.verticalfarm.com/?page_id=36
2 http://reports.thomsonreuters.com/9billionbowls/
3 https://data.worldbank.org/indicator/AG.LND.AGRI.ZS?view=map
4 https://www.un.org/apps/news/story.asp?NewsID=45165#.WnD5lqinGUk
5 https://www.census.gov/popclock/
6 https://www.census.gov/popclock/
7 http://www.pewhispanic.org/2008/02/11/us-population-projections-2005-2050/
8 http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html
9 http://www.worldwatch.org/globetrotting-food-will-travel-farther-ever-thanksgiving
10 Kader, Adel A. 2002. Postharvest Technology of Horticultural Crops. University of California Publication 3311.
11 Wills, Ron and John Golding. 2016. PostHarvest: An Introduction to the Physiology and Handling of Fruit and Vegetables. 6th Edition. CABI Boston, MA.
12 Phillips, K. M., C. McAlister, R. C. McGinty, A. S. Rasor, and M. T. Tarrago-Trani. 2016. Stability of vitamin C in fruit and vegetable homogenates stored at different temperatures. Journal of Food Composition and Analysis. 45:147-162.
13 Linshan Li, R. B. Pegg, R. R. Eitenmiller, J. Y. Chun, and A. L. Kerrihard. 2017. Selected nutrient analysis of fresh, fresh-stored and frozen fruits and vegetables. Journal of Food Composition and Analysis. 59:8-17.
14 "Wasted: How America Is Losing Up to 40 percent of It's Food from Farm to Farm to Landfill", Dana Gunders, NRDC, August 2012.
15 Newbean Capital and Urban Crop Solutions, "Indoor Crop Production –Feeding the Future, 2nd Edition," 2017. [Online]. Available: indoor.ag/whitepaper. [Accessed: 22-Sept-2017].
16 Kader, Adel A. 2002. Postharvest Technology of Horticultural Crops. University of California Publication 3311.
17 Wills, Ron and John Golding. 2016. PostHarvest: An Introduction to the Physiology and Handling of Fruit and Vegetables. 6th Edition. CABI Boston, MA.
18 Phillips, K. M., C. McAlister, R. C. McGinty, A. S. Rasor, and M. T. Tarrago-Trani. 2016. Stability of vitamin C in fruit and vegetable homogenates stored at different temperatures. Journal of Food Composition and Analysis. 45:147-162.
19 Linshan Li, R. B. Pegg, R. R. Eitenmiller, J. Y. Chun, and A. L. Kerrihard. 2017. Selected nutrient analysis of fresh, fresh-stored and frozen fruits and vegetables. Journal of Food Composition and Analysis. 59:8-17.
20 https://www.usda.gov/oce/foodwaste/sources.htm

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resource in many communities. Expanding urban populations may also stress water availability, fresh water resources, water distributions systems, purification systems, and waste-water treatment facilities. This will likely lead to additional debates among farmers, government officials, and citizens over water allocations for agriculture versus urban areas. Climate variability and droughts are also putting increasing pressures on freshwater resources, as well as the recognized need for ecological allocations to meet ecosystem functions.

Indoor agriculture, also referred to as controlled environment agriculture (CEA), offers opportunities to address the challenges of space, water, resources, and logistics for the food supply chain by providing a reliable means of producing short-shelf life, high-value crops near the point of consumption, thus reducing the adverse impacts of produce delivery. In general, CEA facilities aim to reduce the logistics of produce delivery, while using less water per plant than outdoor farming.

## Controlled Environment Agriculture

Controlled Environment Agriculture (CEA) refers to augmented greenhouses or any totally enclosed structure that controls the lighting, temperature, humidity, carbon dioxide levels, and oxygen surrounding the plant. The most common type of CEA facility is an augmented greenhouse which utilizes electric lighting to augment daylight. Other types of CEA include shipping container farms/pod farms, vertical farms, aquaculture facilities and indoor fish/shrimp production facilities. A variety of crops and aquaculture can be produced indoors.

This production of food indoors is made possible due to advances in modern lighting, improved thermal and building management systems, and innovative water delivery and recovery systems. Advances in these technologies are due to forces from inside and outside of indoor agriculture, but have resulted in the ability to improve the indoor growth of a diverse range of crops.

As a result, the localized growth and distribution of a variety of pesticide-free and/or organic products is now available year-round using a range of indoor agriculture techniques. Some of these technologies and techniques also claim to increase yield per plant and additional crop cycles over the course of the year. Additionally, these industrial scale operations result in local job creation and may also provide a way to utilize empty or under-utilized buildings. It should also be noted that interest in CEA is being driven by an increased focus on sustainability, customer demand for local "farm-to-table" produce, and community interest in developing new economic opportunities.

The CEA industry is expanding globally, but faces several hurdles. The primary hurdles are cost of production (including startup costs, energy costs, labor costs, employee training, etc.), access to traditional food distribution networks, and consumer knowledge regarding indoor food production. Due to these factors the majority of CEA research and production today is focused on food crops with short shelf lives (to benefit from logistical gains), short plant heights (to increase yield per cubic foot) and high value per pound/kilogram. Food crops with long shelf lives, low value per pound/kilogram, or tall row crops are not typically grown indoors today.

### *Indoor Agriculture Growing Techniques*

A variety of factors influence which growing technique is used within an indoor agriculture facility. These factors include facility type, crop choice, and location. The four farming techniques used in indoor agriculture are aeroponics, hydroponics, aquaponics, and drip irrigation. These methods differ by the presence and type of medium used to grow plants as well as how water is delivered through the facility and to the plants.

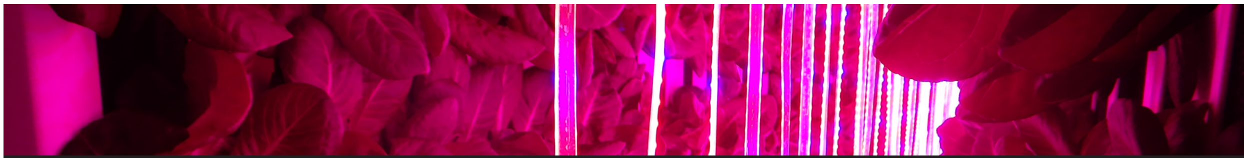
#### Aeroponics

Aeroponics is an indoor farming method where plants are grown by suspending the roots in open air. No soil and little water is used in this process as the roots are sprayed with a nutrient-dense water solution to aid the growing process. There are several benefits with this method, some of which include:

- Eliminating the need to pot and repot crops to ensure they are receiving enough nutrients,
- The ability for plants to be grown vertically and/or horizontally to use space more efficiently,
- The reduction in water use (some estimates claim that aeroponic/hydroponic systems use ~90% less water than traditional farming)
- Fast plant growth and excellent aeration allowing for plants to thrive in this environment

Some of the challenges associated with this method include:

- High initial cost
- Dependence on system design
- Root disease pathogens





### Hydroponics

Compared with aeroponics where plant roots are suspended in the air and misted with a nutrient solution, hydroponics is a method of growing where the roots are completely submerged in a nutrient solution. Hydroponic plants are nurtured indoors under grow lights, in a sterile medium that holds water and nutrients close to the plant roots, with precisely-controlled temperature and humidity.

Benefits associated with hydroponic growing include:

- Scalable method of farming
- Reduced water use compared to traditional farming (claimed savings are between 70% and 90% depending on crop)
- The ability to produce crops year-round with greater reliability

Challenges with hydroponic growing include:

- High initial cost and large initial water usage
- Limited crop options
- Intensive monitoring of water quality

Hydroponic farms, like all CEA facilities, can artificially control the growing environment (air temperature and lighting). This effectively frees them from the constraints of traditional growing seasons. However, a trade off presents itself in the form of an increased utility bill that is not present in traditional farming techniques.

### Aquaponics

Aquaponics can be described as a combination of aquaculture, the process of raising fish, seafood and shrimp, and hydroponics, the process of growing plants without soil. This system combines these two processes to create a symbiotic environment where both fish and plants thrive. Some of the benefits associated with aquaponics include:

- The ability to use nutrient-rich waste produced by the fish as a nutrient source for the plants
- The ability for plants to filter and clean the water for the fish to survive

Challenges with aquaponics include:

- Challenges within production stages in the process
- Mostly used on a smaller-scale and with fast growing plants

### Drip Irrigation

Drip irrigation is a method of controlled irrigation where water is slowly delivered to multiple plant root systems simultaneously by dripping water into or onto the surface of the grow medium, wicking material, or soil. Drip irrigation can be used on a variety of crops, however, the method in which the water is delivered often depends on the crop. In addition to water, liquid fertilizer and nutrients can be delivered simultaneously. The typical benefits listed for drip irrigation include:

- Increased water use efficiency,
- Reduced water evaporation, and
- Minimal to no waste water runoff compared with traditional farming methods.

Challenges with drip irrigation include:

- The "drip rate" of drip irrigation must be regulated to assure that the proper amount of water is delivered to the plant
- Risk of being over- or under- watered

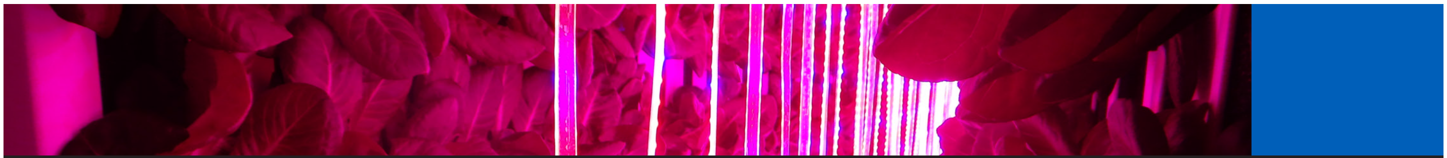
## *Types of Indoor Farms*

Though there are a variety indoor farms types, including traditional greenhouses, the majority of CEA farms today use the Vertical Farm/Warehouse Farm/Plant Farm model, the Container Farm model, or the CEA greenhouse model.

### Vertical Farm/Warehouse Farms/Plant Farms

Vertical farms—an example is shown in Figure 1 below—are designed to provide optimal conditions year-round to drive the constant and routine production of crops.

*Figure 1 – Vertical Farm/Warehouse Farm*





Vertical farms have high startup costs, however, these facilities provide great controllability which can lead to large yields. The high yield of these facilities results from the ability to regulate all the environmental conditions and vertically stack the growth beds to maximize space. They also offer the potential of becoming highly automated as picking, processing, handling and verification technologies develop.

Vertical farms have the potential to utilize brownfield sites (former industrial or commercial spaces that have been abandoned and are available for redevelopment), as well as occupy converted existing or abandoned warehouse space. Other vertical farms are located in custom-buildings; however, these types of facilities can have high capital expenditures. The electrical connection and power requirements for vertical farms vary depending on scale and design, but a 600A 120/240V service has been reported to EPRI as typical.

Vertical farms typically use aeroponics (misting), or hydroponics to deliver water and nutrients to plants. Due to the variation in water delivery systems utilized as well as in the design of the building and crop being grown, the water usage of vertical farms varies widely. Overall, water is recycled and reused to minimize water usage and water discharge.

## Container Farm

Container farms—an example is shown in Figure 2 below—are converted shipping containers (8'x 40'x 9.5' – 320 sq. ft.) with integrated thermal and lighting systems to yield plants in a controlled microclimate.

*Figure 2 – Container Farm*

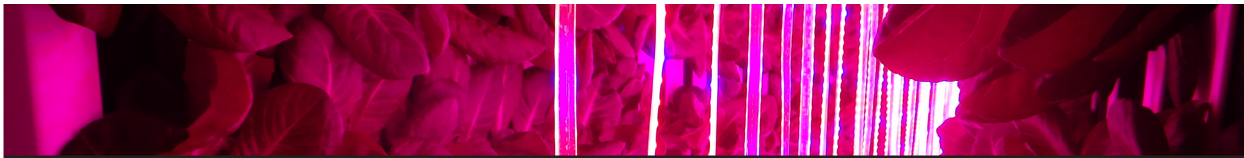
*Figure 3 – CEA Greenhouses*

As with vertical farms, container farms utilize vertical space to increase crop yield per square foot. Annual production estimates vary among container manufacturers, but most claim, when producing leafy greens, that each container produces roughly equal to 1 acre of annual outdoor production.

Container farm costs vary depending on complexity, utilized technologies, support services, targeted crop, and if the container is purchased as an integrated unit or built in a do-it-yourself (DIY) fashion. The modular nature and relatively small footprint of these farms make them easy to site, demonstrate, move and scale. Individual containers can be located on a 10' x 45' pad, but are scalable by grouping several containers side by side or vertically. Multiple container farms could be sited in empty or under-used parking lots. The electrical requirement for each container is typically a 50A or 60A service at 240V single-phase or 208V three phase.

Container farms typically have a self-regulating, closed-loop irrigation system and use drip irrigation to deliver water and nutrients. Container farm manufacturers claim their systems use about 5 gallons of water a day when producing leafy greens,[21] but other crops may require up to 20 gallons a day.[22] These claims result in 90%[23] or more, and up to 97%,[24] water savings when compared to outdoor production due to water re-use and recycling. Thus, these farms have minimal waste water.

21 https://www.freightfarms.com/product#lgm-basics
22 https://inhabitat.com/40-foot-shipping-container-farm-can-grow-5-acres-of-food-with-97-less-water/
23 https://www.freightfarms.com/product#lgm-2017
24 https://www.localrootsfarms.com/faqs-1/





### CEA Greenhouses

CEA greenhouses—an example is shown in Figure 3 below—are traditional greenhouses which add electric lighting and controls to maintain an ideal environment for crop production.

CEA greenhouses can vary from a few thousand-sq. ft. up to over one hundred acres. Crops are grown in a single layer with transparent roofs to utilize natural sunlight. Because CEA greenhouses depend largely on natural sunlight, there is limited potential for tiered farming, so many CEA greenhouses focus on vine or trellis crops.

Of the three CEA facility types covered in this report, CEA greenhouses offer the lowest per square foot start-up cost. Turn-key CEA greenhouses are offered by multiple vendors, but some of these facilities are also designed and built in a DIY fashion by their operators.

Most CEA greenhouses use hydroponic watering systems that simultaneously deliver water and nutrients to plants. Some CEA greenhouses use a controlled closed-loop irrigation system like container and vertical farms, while other CEA greenhouses collect and recycle water from ponds. Water usage varies depending on type of crop, type of watering system used, and the scale of the greenhouse.

CEA greenhouses can be found in almost any community (including rooftops in dense urban spaces), but are typically found in rural spaces with ready access to urban and suburban communities. CEA greenhouses primarily use sunlight to heat the space. Due to the nature of greenhouse design, they are prone to more thermal loss than other CEA facility types.

### Other

As mentioned previously, the primary types of CEA facilities being developed today are vertical farms, container farms, and CEA greenhouses. The majority of these CEA facilities focus on vegetable and fruit production, reduce or eliminate fertilizer, pesticide and herbicide use, require a large amount of electricity to yield crops and are typically sited to reduce the logistics between production and consumption. There are other types of CEA facilities though. These facilities focus on producing crops and products like flowers and ornamental plants (floriculture), fish and shrimp (aquaponics and aquaculture), and facilities that pair the production of fish with vegetables. Additionally, there are also some emerging CEA facilities that focus on producing insects as a source of protein.

Many of these “other” types of CEA have already established their operations (floriculture and some existing fruit and vegetable greenhouses for example) or they exist in limited numbers and display diverse production (aquaponics and aquaculture). Some of these facilities are already established in many service territories and do not represent an emerging national trend.

## *Types of Crops*

Almost any crop can be grown indoors. At Expo Milano 2015, the U.S. State Department and the James Beard Foundation demonstrated the ability to grow over 42 variety of vegetables, herbs, and grains indoors.[25] Other industry claims indicate that over 250 different types of vegetables, herbs, and fruits may be grown in vertical spaces. Though it is possible to grow many crops indoors, it is not currently cost effective or efficient to grow many of them indoors.

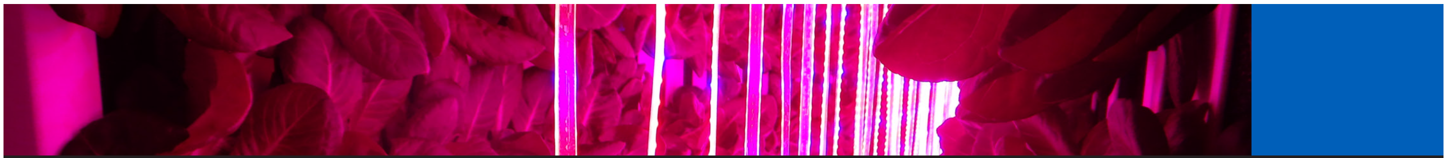
Currently, indoor agriculture is not practical or cost effective to grow crops that have a low value per kilogram (or pound), and/or a long shelf life and/or long grow cycles. Examples of these crops are grains, corn, rice, apples, grapes and oranges. As a result, many crops like corn, grain, wheat and soybeans are likely to be grown outdoors for the foreseeable future.

Today, primary CEA crops are herbs, lettuces, tomatoes, microgreens and strawberries. These crops offer high value per pound, have relatively short shelf lives, lend themselves to stacking or vertical growing configurations, and can have multiple grow cycles per year indoors. Additionally, these crops require minimal water when grown within controlled environments. Controlled environments also enable food safety controls and the ability to yield crops year-round regardless of outdoor, geographical, or environmental conditions. Additionally, apart from the crops listed above, the potential exists for the indoor cultivation of high value products like fish, insects for protein, and shrimp, which also increase food security and safety.

## *Growing Mediums*

Besides maximizing the use of available land and converting non-farming land into farmland, many CEA growing techniques eliminate or reduce the need for soil and deliver water to the plants in a number of efficient ways. In fact, some CEA farms directly expose plants to nutrients and water via water trays or misting. In most CEA facilities, moisture not absorbed by the plant is captured, returned to a reservoir, filtered, and reused for plant watering.

25 http://www.usapavilion2015.net/exhibits/vertical-farm





Some CEA facilities use manmade cellular material, shredded coconut husks, or similar materials, to hold growing plants and transfer moisture. Some CEA facilities use small grow plugs to hold seeds and retain water. Other facilities use a cloth-like material to hold moisture directly on the grow plug. There are also some CEA greenhouses that use soil or sod to grow their crops, but this soil, or sod, is reused numerous times before disposal.

Regardless of the CEA type, little to no soil is used and most water is captured for re-use within the facility. This basically eliminates soil contamination from agriculture and greatly reduces, or eliminates, the risk of water contamination from agriculture run off (sediments, pesticide, herbicides, nutrients, and dissolved solids).

### *Siting/Location*

Vertical and container farms can be located almost anywhere, whereas CEA greenhouses are typically located in rural or suburban locations but can also be sited on rooftops in dense urban locations. Regional variance in temperature and weather can also drive the type of farm most commonly found in the area. In spite of differences in weather, temperature and targeted crop, the key factors considered when siting a CEA facility are:

- Reliable and dependable utility access (electric and water) and affordable power costs
- Location—typically the goal is within 100 to 200 miles of large population centers (with 50 to 100 miles being optimal) to maximize distribution logistics via farm siting, reduce the time from field to consumer, reduce the use of fossil fuel, and improve product freshness
- Low-cost land and/or low-rental cost per square foot
- Available and reliable workforce

Labor is the highest cost for most CEA facilities. Therefore, areas where workers are available and trainable (since few people have farming experience today) are factors considered when siting. Other siting factors can also include proximity to existing utility assets, and the grid impact of these facilities.

## Market Trends and Challenges

### *Current Market Landscape*

The indoor agriculture market has seen domestic and global growth. This growth can be attributed to advancements in technology, increasing investment in the sector, and in the fluctuation of market participants.

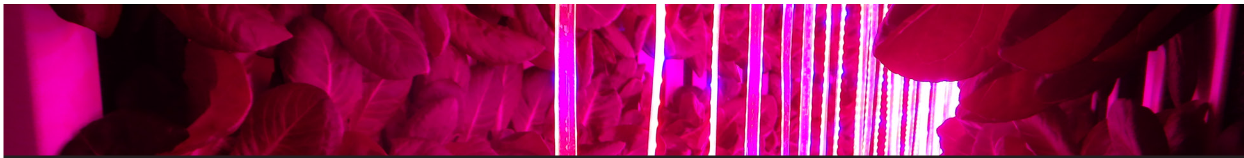
Within the U.S., the market for vegetables was estimated around $25.2 billion in 2014, with an expected growth rate of 1.2% annually through 2019.[26] One-third of this 2019 value ($9.3 billion) is estimated to potentially stem from crops grown indoors.[27] This estimate alludes to the potential growth opportunities that exist within the indoor agriculture market, which are just beginning to be realized.

According to estimates provided by the United States Department of Agriculture (USDA), the indoor agriculture vegetable market has grown to $9 billion in 2017, while the fish and seafood market using aquaponics has grown to $3 billion and the insect market to $424 million.[28] An emerging trend which could help drive this market to its estimated growth potential include pairing or building indoor agriculture facilities with grocery chains, restaurants, or entertainment facilities to directly supply vegetables.

Investment in indoor agriculture has increased dramatically since 2012. However, as a percentage of total agriculture funding, investment still remains low. According to Newbean Capital, indoor cultivation systems, including greenhouses, vertical farms, hydroponic, and aeroponic facilities accounted for 12% of global investment in agriculture technology in 2014. On a U.S. scale, 2014 venture capital investment in indoor agriculture reached $32 million, almost 60% more than the funds invested during 2011-2013.[29]

Opportunities for growth exist within the vertical farming market. According to Allied Market Research, the vertical farming market could reach $6.4 billion globally by 2023, a sixteen-fold increase from approximately $400 million in 2013.[30] Other industry estimates show a similar trend evolving as the market matures. This trend of growing market potential is evidenced by the amount of corporate and venture capital investment in vertical farming, which reached over $60 million for the first half of 2017. This is approximately 3% of total investment activity in agriculture and food recorded during the same time period.[31]

26 https://www.otcmarkets.com/ajax/showFinancialReportById.pdf?id=154731
27 Ibid.
28 Newbean Capital and Urban Crop Solutions, "Indoor Crop Production –Feeding the Future, 2ndEdition," 2017. [Online]. Available: indoor.ag/whitepaper. [Accessed: 22-Sept-2017].
29 Ibid.
30 Allied Market Research, "Vertical Farming Market: Global Opportunity Analysis and Industry Forecast, 2017-2023," Global Newswire, 2017. [Online]. Available: https://globenewswire.com/news-release/2017/05/26/999370/0/en/Vertical-Farming-Market-Expected-to-Reach-6-4-Billion-by-2023-Globally-Allied-Market-Research.html. [Accessed: Sept-22-2017].
31 I3, Investment Activity for Vertical Farming 2013-2017.





## Challenges to CEA Growth

It is important for utilities and other stakeholders to understand the emerging and evolving nature of the CEA industry, as it is very possible facilities will come and go in most utility territories. In recent years, numerous CEA facilities have launched and failed. Three notable examples of farm failures include: Chicago's vertical farm FarmedHere's, Vancouver's rooftop farm concept LocalGarden, and Atlanta's container farm manufacturer PodPonics. Although there were specific reasons contributing to each of these failures, a recent interview with these three companies revealed that a common theme that resulted in these failures was lack of focus and planning.[32] Thus, it is important to understand that management and business skills are as critical for success as technical and biological skills in this industry. Management and business faults identified that can reduce the likelihood of success in CEA facilities include:

- CEA farms try to do too many things at once
- Farms forget labor is still their biggest cost
- They fail to treat their facility like a process.

One challenge impeding CEA growth is the size of the market. Due to the economics of indoor productions, facilities focus on high cost/high value crops like leafy greens, specialty lettuces, herbs, tomatoes, etc. Those willing to pay extra money for premium produce make up a significantly smaller market than the market for lower-cost produce like iceberg lettuce and other commodity produce.

Another challenge faced by new CEA facilities is market access. The agriculture market is difficult to enter, as many food distributors have existing contracts with traditional farms. Not only do new CEA farms have difficulty competing with existing price points, but distributors are wary to engage with CEA facilities that are still working out production systems. Smaller CEA facilities often struggle with bandwidth issues and are unable to compete and gain market access. Additionally, customer perception of CEA and indoor food production continues to be a challenge. Educating consumers on the benefits and practices involved with indoor agriculture may resolve lingering issues in the future.

Today, the expansion and scale of CEA facilities poses little to no direct competition with large-scale field agriculture. However, if this industry continues to expand its yield while lowering costs, CEA facilities could challenge outdoor farming in certain crops. This paired with increasing urban populations, decreasing amounts of available farm land, fewer farmers due to age and interest, and improving technologies that increase yield (both indoors and out) could result in several future situations occurring.

32 https://www.maximumyield.com/top-3-reasons-why-vertical-farms-fail/2/3177

## Market Barriers

In summary, primary market barriers include a high risk of failure, high entry equipment costs, high rent and building costs, and competition with traditional agriculture. Additionally, CEA farms may be limited in the crops they produce, as they are designed to produce a specific range of crops and struggle to adjust their production. Other reported factors contributing to why indoor farms fail include[33,34]

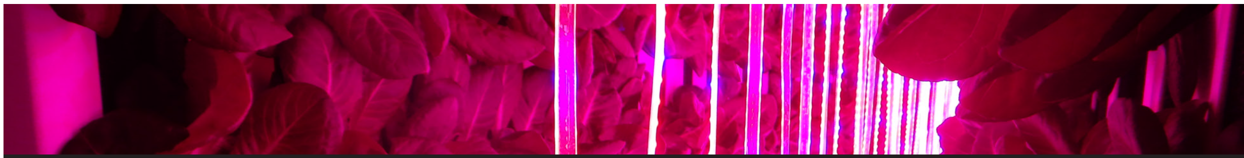
- High land costs/bad siting
- Pricing products based on value not costs.
- Inability to identify and/or hire educated farm labor/unwillingness to train.
- Inability to maximize collected farm data (energy usage, water usage, production yield, process variance, etc.)
- Reduced number of farmers and fewer people entering farming.
- Lack of understanding on the cost/value of organic certification.
- Lack of understanding the different farming techniques.

## Key Drivers of CEA

Indoor food production can be a largely electric load due to its use of lighting, HVAC, water heating, pumping, and other processing equipment. Furthermore, CEA can reduce food miles, delivering food fresher and quicker to market, while also reducing agricultural water consumption and expanding access to local food in land-constrained areas. The key drivers for the expansion of indoor agriculture are improved logistics, increased yield/additional annual crop cycles, local sourcing, water usage and developing means of addressing urban population expansion. Other market drivers include:

- Need for sustainable food sources to support growing population
- Potential health benefits of more local (due to reduced transpor-

33 Ibid.
34 https://medium.com/bright-agrotech/9-reasons-why-vertical-farms-fail-244deaecd770





tation times compared to long-distance production[35,36,37,38]) and pesticide-free or pesticide-reduced products

- Technology advances in lighting, thermal and other related technologies
- Reduction in costs and emissions associated with transportation of products as well as reduced emissions by eliminating farm equipment in the production process
- Food security and continuous year-round crop production
- Water conservation and recycling
- Less water pollution from agricultural runoff, pesticides, herbicides and sediments
- Potentially reducing food deserts and food waste

### Logistics and Location

A recent industry report stated that most states within the U.S. grow fewer fruits and vegetables than they consume.[39] The Leopold Center for sustainable agriculture reports that the average head of lettuce in Chicago travels over 2,000 miles and the average tomato in Chicago over 1,300 miles.[40] If existing production and supply chains are not able to meet demand in these states, there may be an increase in demand for locally-sourced foods.

CEA facilities can be sited in almost any community, regardless of type, due to their low water usage, their minimal environmental emissions, and flexible space requirements. In spite of these advantages, today it costs more to produce food indoors than outdoors due to high startup costs, labor costs, and ongoing energy expenses. In a 2017 survey, Agrilyst found that of 150 indoor farms surveyed, the majority of which opened since 2013, 47% were in rural areas, 43% were in urban areas, and 10% were suburban areas.[41] It should be noted that this report includes greenhouses that grow flowers in soil, so some of the indoor farms do not fall into the indoor food producers that are the focus of this report.

### Energy

Indoor food production facilities can represent anywhere from tens of kW loads up to tens of MW depending on the type of facility and the scale. If indoor food production expands noticeably, the potential exists for the energy consumption, and load profile, of fresh vegetables production in many locations to shift from distant farms to local facilities.

The typical outdoor agriculture production profile includes electric pumps, fossil fuel powered harvesting equipment, pesticides/herbicides/fertilizers, and a large amount of water to generate crops which results in substantial amounts of water run-off in most cases. Comparatively, most indoor food production facilities use a large amount of electrical energy, use minimal water, and have no run-off to produce crops (most do not have wastewater discharges and those that do typically discharge to sewer systems). The majority of CEA vertical farms and container farms do not use pesticides or herbicides, but some CEA greenhouses use pesticides to deal with spot outbreaks. The majority of emissions associated with indoor production are from electricity generation sources, which vary depending on type of generation utilized. These emissions tend to be small, and the reduced transportation also means lower amounts of emissions coming from the fossil fuel distribution equipment.

### Yield

CEA greenhouses depend on sunlight reaching plants to grow. Greenhouse yield per square foot varies depending on the crop being produced, crop irrigation rate, greenhouse design and the height of the building. Greenhouses with tall roofs allow for crops (like tomatoes) to develop much longer vines which increases the yield per square foot. Low roof greenhouses, or those that are not growing vine crops, may have a similar per square foot yield to field grown crops as it is yielding on a single tier. Regardless of the yield per square foot, CEA greenhouses can maintain optimal growing conditions for extended periods of time and furthermore, deliver more crops cycles per year than outdoor production.

Vertical farm and container farm yields vary noticeably depending on crop and facility design as well. For example, stacked beds growing leafy greens yield differently than indoor farms that use triangular structures that rotate the crop toward and away from light sources. Regardless of the form factor, these facilities deliver multiple crops throughout the year by maintaining optimal conditions and maximizing the annual square footage yield of available land.

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36 Wills, Ron and John Golding. 2016. PostHarvest: An Introduction to the Physiology and Handling of Fruit and Vegetables. 6th Edition. CABI Boston, MA.
37 Phillips, K. M., C. McAlister, R. C. McGinty, A. S. Rasor, and M. T. Tarrago-Trani. 2016. Stability of vitamin C in fruit and vegetable homogenates stored at different temperatures. Journal of Food Composition and Analysis. 45:147-162.
38 Linshan Li, R. B. Pegg, R. R. Eitenmiller, J. Y. Chun, and A. L. Kerrihard. 2017. Selected nutrient analysis of fresh, fresh-stored and frozen fruits and vegetables. Journal of Food Composition and Analysis. 59:8-17.
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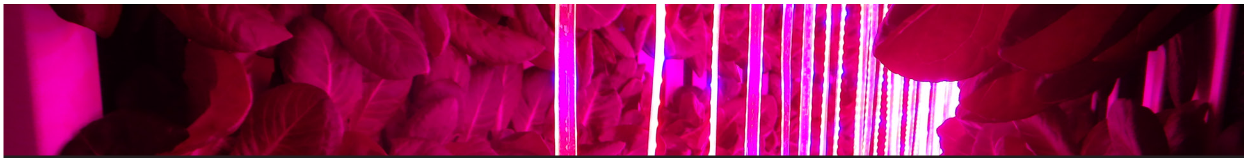
40 http://ucanr.edu/datastoreFiles/608-319.pdf
41 https://www.agrilyst.com/stateofindoorfarming2017/





## Water

Water is required for agriculture, but is also vital to urban communities. Management of the water used, reused and discharged in agriculture helps reduce the likelihood of water becoming a scarce resource. However, this can involve regulatory and logistical challenges. Indoor agriculture could help mitigate and may address a range of water management needs.

Indoor agriculture practices reduce the amount of water required to grow certain crops (i.e., lettuce, tomatoes, and other crops suitable for CEA). Depending on the crop, facility, and farming technique, EPRI has typically seen water saving claims between 70% and 90%, with some systems claiming over 95% water savings. Plants still retain basically the same amount of water whether they are grown indoors or out, therefore these claims are typically based on reducing evaporation, run-off and wastewater.

Based on information in the UN's Food and Agriculture Organization (FOA) report,[42] EPRI found that growing one tomato outdoors requires 13 liters (3.4 gallons) of water. In some cases, CEA facilities offer the opportunity to reduce the amount of water used per tomato. This practice may benefit communities with water restrictions or areas where the need for water for cities is conflicting with the need for water for agriculture.

Water runoff from traditional farms using pesticides, herbicides, and fertilizers can contribute to the complexities of water quality management due to logistical and regulatory matters. Traditional farms that use little to no pesticides, herbicides or fertilizers have minimal impact on nearby surface water. All water not absorbed by the plants in outdoor farms returns to the ground or flows to nearby surface water systems. Chemicals in pesticides, herbicides and fertilizers matriculate their way through to the wastewater run-off and can have a significant impact on local water supplies. For example, an increase in phosphorous and nitrogen in water runoff has been linked to the growth of harmful algae blooms which in turn can have a negative effect of aquatic life and even municipal drinking water.

Container farms use minimal amounts of water daily, with some claims as low as 5 gallons per day. These facilities output even less than they use, however, container farm discharge has some nutrients and potentially contains some pH balancing chemicals. Most augmented greenhouses use water recycling, but still discharge some amount of water, that contains plant nutrients and likely some pH balancing agents, depending on the scale of the greenhouse. In some cases, without adding additional fertilizers and nutrients, this water can be used at a traditional farm. Vertical farms, like container farms and greenhouses, inject nutrients into the water they deliver to plants and utilize water recycling to minimize water usage. As with greenhouses, the water discharge from vertical farms varies depending on scale. In general, CEA agriculture discharges less water than field farming and the chemical content of this discharge water contains less fertilizer/nutrients than traditional farm runoff.

42 http://www.fao.org/docrep/017/i3028e/i3028e.pdf

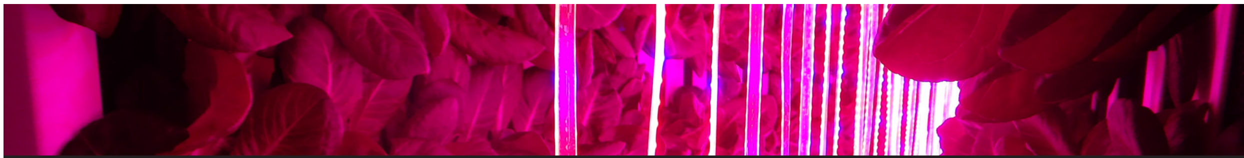
## Food-Energy-Water Nexus

Agronomic management, which focuses on crop production and soil management, is heavily intertwined with the water access, demand, and stress issues. Additionally, further opportunities to understand the connection between food production and energy resources exist. Thus, thinking about the nexus impact of Food, Energy, and Water may lead to more awareness of decisions related to planning, resource application and production.

## Opportunities for Utilities

As the CEA industry expands, utilities will likely see increased demand for electricity from agriculture since indoor agriculture is highly energy intensive compared with conventional agriculture practices. By controlling a range of agricultural factors, indoor farming should also provide opportunities to save water and minimize the added cost of treating wastewater runoff. To properly account for the total embedded energy and embedded water utilized in the CEA process, a comprehensive water and energy analysis is necessary.

CEA may be a new load trend that utilities must consider strategically as it may result in load growth through electrification of production of select crops. This load may also assist with de-carbonization measures. As a result, utilities may decide to consider market partnerships to leverage the sustainability aspects of CEA with its long-term load growth potential. CEA also offers the important potential for integrated and large-scale demand-side management, which will be increasingly important as generation is shifted more towards renewable energy. Due to the economic, social, and environmental impacts around indoor agriculture, new policy and regulatory constructs relating to safety, health and the environment may emerge in the future. While this may pose certain risks to utilities, it may also result in significant opportunities. Utilities may be able to work with indoor agriculture to establish community ties and link indoor agriculture as part of Corporate Social Responsibility (CSR) efforts.





# Technology Assessment

There are various efficiency opportunities associated with converting to newer technologies in indoor agriculture facilities. However, technology conversion has a high level of risk for many facility owners as the CEA industry is yield driven. As a result, CEA farm operators often opt to utilize proven lower-efficiency, high-yielding technologies rather than save energy by risking the adoption of higher-efficiency, higher-risk technologies.

Though they have risks, these newer technologies can provide benefits in addition to energy savings. A few examples of these non-energy benefits are micro-climate-controlled HVAC systems which can deliver and maintain specific heating, cooling and humidity levels, as well as LED lighting which can maintain specific light levels by modifying the light spectrum and illumination angles.

## *Lighting*

Both in indoor and outdoor agriculture, light and more specifically the process of photosynthesis, is essential for plant growth as it provides the plant with the chemical energy it needs to grow. In traditional outdoor agriculture, the sun is the sole source of light energy for plants, however, in CEA facilities, electric lighting acts as the sole (container or vertical farm) or the augmenting (greenhouses) light source.

### Lighting Technologies

The lighting technologies used within a CEA facility depend on the type of building and crop. CEA greenhouses typically utilize the sun as the primary source of light, but augment natural lighting at different times of the year using electric light. Vertical and container farms rely on electric lighting as the sole source of light energy as they have no access to sunlight. Various types of electric light technologies are used to grow plants indoors and include: high-pressure sodium (HPS), metal halide (MH), fluorescent, and light emitting diode (LED). Currently HPS is the most commonly used technology in most indoor plant applications, but LED technology has gained market share in recent years, especially in leafy greens. It is important to note that the lifespan and wattage of lighting is generally not as important to agriculture applications as crop yield and crop quality.

### Light Schedules

The lighting schedule for indoor crops varies based on a number of factors. CEA greenhouses are highly influenced by the location and climate of the region and may not grow year-round to avoid the hottest months and the risk of over-heating the plants. Vertical and container farms may operate year-round since sunlight is not a factor. Depending on the crop and the facility type, lighting is typically operated in cycles of 16 hours on/8 hours off, 18 hours on/6 hours off, or always on (where motorized systems are used to move the plants). For reference, a 16 hour ON/8 hour OFF schedule roughly mimics the sunlight schedule of a typical summer day.

Most plants need a nighttime phase each day. During this phase, little to no light can shine on the plant and the ambient temperature in the space needs to decline. This pattern allows the plant to undergo important growth processes. For a fully enclosed indoor farm, "nighttime" needs not match the outdoor schedule. As a result, indoor facilities may have the ability to participate in load management programs. In fact, in regions where time-of-use rates are in place for electricity, it may make sense for a CEA facility to operate their nighttime phase in such a way that it overlaps peak-pricing, thereby reducing the customer's electric bill. Since plants need a consistent schedule to thrive, it is important for utilities to understand facility growing schedules to provide grid and customer benefit.

## *Efficiency Challenges*

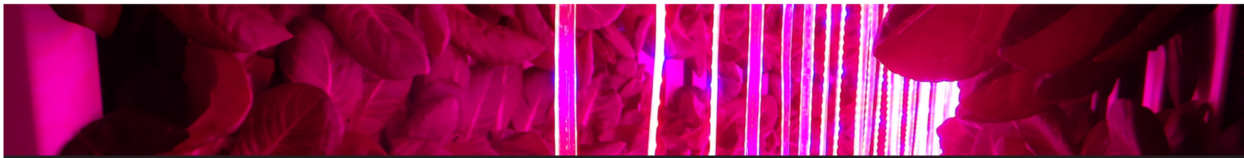
Lighting is typically the highest portion of the energy bill (labor is typically the highest farm cost) for a CEA facility. As stated before, electricity cost is typically secondary to yield in importance. An efficient operation can save on operating costs, but if plant quality diminishes or yield lessens due to the use of a more efficient lighting or other technology, the grower will install/use less efficient technologies.

## *Thermal Management*

The primary parameters for CEA heating, ventilation, and air conditioning (HVAC) consideration include temperature, humidity, airflow and $CO_2$ level. The cooling, heating, dehumidification and humidification loads that must be addressed by the HVAC system vary significantly over the course of each day, across the year as outdoor weather conditions change, and throughout the crop growth cycle (young growth versus mature plants).

### HVAC Constraints and Design Conditions

Indoor agriculture has a different set of HVAC requirements than typical applications for space conditioning. The primary focuses for





HVAC within indoor agriculture are to maintain an environment to effectively and profitability grow plants. Specific temperature set-points, humidity levels, $CO_2$ levels, night time set-backs, and varying temperatures over the growth cycle are unique to each operation and plant type. These conditions help protect crops from disease, infection, or poor growing conditions.

### Indoor Temperature

The indoor air temperature of a CEA facility depends on the crop and stage of growth. For example, lettuce germinates optimally between 70–75°F, but grows best in the range of 60–65°F. Lettuce flowers and produces seed in the range of 70–80°F.[43] Other plants have different preferred temperature ranges and benefit from variation in night-time and day-time temperatures. For example, some studies have shown that higher temperatures within the appropriate range can accelerate the growth of individual fruits and reduce the total number of fruits. Localized heating or cooling can help to accurately control temperature around each individual plant. Localized air temperature control can also potentially reduce the overall space conditioning load of an indoor agricultural facility.

### Indoor Humidity

Managing the indoor air humidity of indoor agriculture facilities is also vital to plant health. High humidity can cause fungal and bacterial growth, and impacts plant transpiration because it is strongly dependent on ambient air humidity. Alternatively, low humidity in the surrounding air causes plants to lose moisture rapidly and can drastically reduce yield. In many climates, maintaining humidity may require moisture to be added during the winter (when outdoor air is dry) and active moisture removal and/or ventilation control to remove moisture in the summer.

### Other HVAC Constraints

In addition to indoor temperature and humidity, there are other HVAC factors that should be considered. This includes the following:

***Indoor Air Movement*** – Air movement facilitates gas exchange between plants and the surrounding air. This is required to maintain good crop health, allows the plant to perform essential cellular metabolism processes, and facilitates carbon dioxide delivery to the leaves which helps remove water vapor. Air movement also helps prevent mold growth and other plant health problems.

43 https://content.ces.ncsu.edu/lettuce

***Ventilation Air*** – Ventilation, or the exchange of indoor air with outdoor air, is another important consideration. System configuration determines how ventilation is handled in the facility. There are typically three ventilation categories: Open (where most of the air conditioning is done via ventilation- i.e., augmented greenhouses); Semi-Closed (outside air is used for ventilation strategically—i.e., vertical greenhouses); and Closed (no deliberate ventilation of outside air). Ventilation can also be used for temperature, humidity control, and to replenish $CO_2$. Ventilation can also have a cooling benefit and can be coupled with evaporative cooling to help control temperature and humidity in some climates.

***Indoor Air $CO_2$ Enrichment*** – In some CEA facilities, carbon dioxide is added to artificially boost plant growth. $CO_2$ enrichment is fairly common particularly in closed systems, and research has shown that $CO_2$ enrichment beyond that available from outdoor ventilation air does appear to provide increased growth, though the impact and needed $CO_2$ level varies by crop. If $CO_2$ enrichment is used, it should be balanced against ventilation to ensure that the added $CO_2$ is not directly exhausted or excessively diluted before being delivered to the plants.

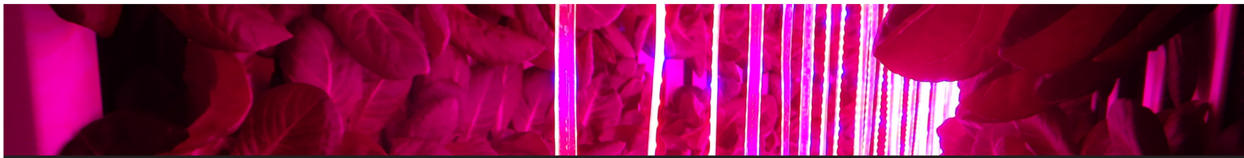
### Motors, Pumps and Fans

Though lighting and HVAC systems are the primary technologies used in CEA facilities, pumps, standalone/ceiling fans, and motors are also crucial. As a result of this, it is also crucial to consider the energy consumption, efficiency and optimization of pumps, motors and standalone fans within CEA facilities. In soilless and hydroponic farms, pumps are vital for crop health. So necessary that if a pump system fails, plant damage may result within just a few hours. Specifically, pumps are used for both water and nutrient solution circulation in CEA facilities. Fans are necessary for air circulation and ventilation. Motors are used for opening/closing vents and for operating shade curtains.

## Building Envelope

Indoor farms use a range of technologies to deal with building envelope issues and maintain proper temperature and humidity within the space. This is critical to maximize plant yield and increase the number of annual harvests.

Container farms are converted metal shipping containers which have no insulation and provide basic protection from outside conditions. Container farm manufacturers typically add insulation to the containers to reduce heating and cooling losses. However, even with





this added insulation, it can be difficult for containers to maintain proper interior conditions in some climates. Container farms typically need additional cooling solutions in hot climates. The heat generated by lighting within the container can assist with maintaining temperature within the container in cold environments, but adds to cooling load in hot conditions. Maintaining proper temperature and humidity in a container farms is also made more difficult due to plant transpiration and water evaporation.

Typically, greenhouses use metal frame structures with glass covered ceilings and walls to allow sunlight to enter the space. The glass also provides protection from rain, snow and sleet, while maintaining a minimal thermal barrier to help maintain interior temperatures. Greenhouses typically maintain a relatively high temperature regardless of outside air temperature. High efficiency greenhouses add diffuse glass to distribute sunlight within the space evenly. This prevents "hot spots" from occurring in the greenhouse. Even in hot climates most greenhouses do not have any form of refrigerant-based cooling. Greenhouse operators typically open the glass tiles or vents to allow hot air to escape. Fans can also be used to move heat through/out of the greenhouse.

Since vertical farm designs vary greatly, they also use a variety of solution to deal with building envelope issues. Each facility and operator uses different building envelope solutions to address the needs of their facility based on crop, location, and other criteria. Common technologies used to maintain interior conditions include high R-value insulation, special glass, and roof coatings. In custom built vertical farms, facility technologies are selected and tuned solely for efficiently and effectively growing plants. Some vertical farms that use converted spaces update the existing facility envelope, others leave the existing envelope untouched. Vertical farms within converted spaces may also choose to construct "a building within a building". In these situations, the existing structure only provides environmental protection while the inner structure maintains proper "farm" conditions.

## Building Design

CEA building design can be as critical to farm success as the technologies included within the facility. Proper design allows for the proper maintenance of temperature and humidity for plant growth. To do this, a CEA facility design must consider proper HVAC sizing, and select the correct lighting, water delivery, water recollection, water processing and pumping technologies. This requires combining passive technologies with integrated controllable technologies to maximize the potential success of CEA facilities. In addition to proper temperature, light and water technologies, sufficient workflow and work spaces within CEA farms are also critical. Since, CEA farms focus on yield per unit area, designs must maximize every space possible to increase yield and growth. CEA building designs can also pair technologies to deliver solutions. An example of this is the use of scissor lifts that traverse the growing rows on floor mounted water pipes.

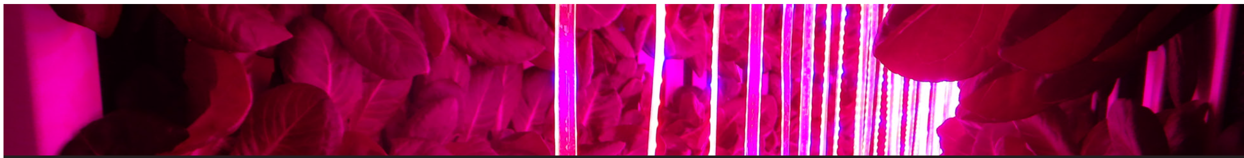
## Building Control Technologies

As with most other commercial and industrial loads, the functionality provided by connected/Internet of Things (IoT) devices are likely critical to the future success of the CEA industry. Currently, most CEA facilities utilize building control systems that integrate the control of lighting, HVAC, pumps, $CO_2$ generators, and other devices designed to maintain ideal plant growth conditions. Some of these systems can also integrate data from sensors like pyranometers to automatically adjust space conditions. These integrated building control systems allow farm operators to hone and adjust facility operations over time. Integrated systems may also provide the potential for utilities to partner with CEA farms to better understand farm loads and operations.

## Water Systems

Water systems employed in CEA operations vary widely. Some small greenhouse operations may even utilize hand watering and/or simple irrigation methods. Regardless of scale and type, greenhouse operations may also use trickle irrigation systems. Another common system is the use of overhead irrigation nozzles to deliver water directly to plant beds, or even the whole greenhouse. In larger greenhouses, vertical farms, and container farms water (and fertilizer) are often delivered to the plants via trickle or misting. Water not absorbed is captured and returned to holding tanks for later use.

Most CEA facilities use some form of water treatment, generally consisting of reverse osmosis (RO) systems and pH adjustment. Additional water quality parameters that are commonly considered include element concentration (Nitrogen, Phosphorus, etc.), total dissolved solids (TDS), conductivity, temperature, turbidity, and dissolved metals. UV treatment may also be utilized to kill pathogens, especially under conditions of effluent reuse or extreme recycling conditions. Though monitoring supply water is critical, it is also important to evaluate waste water conditions. Discharging wastewater that is high in nitrogen and phosphorus can contribute to algae blooms.





### *Other Electric Technologies*

Apart from the technologies listed above, opportunities to electrify new loads, or expand the use of electricity in existing tasks, exist within CEA facilities and outdoor farms. Two primary ones may be electric forklifts and electric delivery vehicles, but there are also future loads emerging as well.

#### Electric Forklifts

CEA facilities may already use electric fork trucks, but opportunities at some greenhouse and vertical farms to transition away from propane or Compressed Natural Gas (CNG)-powered devices may still exist. Converting to electric fork trucks further increases the sustainability of the facility by reducing local facility emissions.

#### Electric Delivery Vehicles

Expanded capacity and extended range electric transportation vehicles further expands sustainability for agriculture facilities. These vehicles can assist with product delivery as most CEA farms aim to serve locations within 100 to 150 miles of their farm. Thus, an electric delivery vehicle with a 300 to 400-mile range, capable of hauling several thousand pounds could be useful to these farms.

#### Potential Future Electric Agriculture Loads

A few examples of future electric agriculture loads are listed below.:

- Use of automated trollies to move produce from the "farm" to the processing space
- Robotic picking and sensing technologies in CEA facilities to pick, plant and package produce
- Automated tractors and harvesting equipment for outdoor farming

## Sustainability

Sustainability focuses on an organization's development of long-term business value through, and in consideration of, a commitment to environmental stewardship and corporate citizenship. As electric power companies consider a potential role in the development of the indoor agriculture companies and facilities in their service territories, several questions regarding sustainability may be explored:

- What are the sustainability issues that indoor agriculture companies need to manage?
- What metrics are appropriate to measure performance on those sustainability issues?
- How can indoor agriculture companies manage tradeoffs between sustainability issues as they seek to provide a sustainable solution to food-related needs?

*Sustainable development* was defined by the Bruntland Commission in 1987 as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[44] Over time, the definition of sustainability has evolved. Today, the general focus is on balancing economic, environmental and social considerations. This is often referred to as the triple bottom line or people, planet, profit.[45]

### *Why Sustainability in Indoor Agriculture may be Important for Electric Power Companies*

There are several reasons why an electric power company may want to engage with and understand the sustainability of indoor agriculture facilities, including:

1. Electric Power Companies as Part of Indoor Agriculture Sustainability
2. Driving Progress on Electric Power Company Priority Sustainability Issues
3. The Business Case for Sustainability
4. Developing Business-to-business (B2B) Social Collaboration

### *Electric Power Companies as Part of Indoor Agriculture Sustainability*

The efficient use of electricity can reduce the environmental impact (e.g., Scope 3 carbon emissions) associated with the generation source of the electric power consumed by a CEA facility. Efficiency may also help positively influence CEA farm profitability by reducing operating costs. For an indoor agriculture facility considering a sustainability-related certification as a market differentiator, factors like reduced electricity consumption and use of renewable energy can be a part of such an evaluation, and they will turn to their electric power providers to help understand their efficiency and renewable generation options.

### *Driving Progress on Electric Power Company Priority Sustainability Issues*

In 2017, EPRI refreshed its priority sustainability issue research, identifying 20 issues critical to the long-term success of electric

44 http://www.iisd.org/topic/sustainable-development
45 Elkington, 2009.

power companies and/or their stakeholders (Figure 4). As electric power companies consider the most efficient and effective ways to drive change on these issues, they may find that activities within their value chain provide opportunities beyond what they may be able to accomplish on their own. For example, supporting the development of downstream customers such as an indoor agriculture facility, which may lead to reduced freshwater consumption (as explored in the water section of this report), may be a way of addressing potential water issues beyond their own direct company activities. It is this type of value chain related action that can help support the development of a sustainable economy.

### The Business Case for Sustainability

A literature review performed by EPRI in 2015 identified several studies which have found a correlation between financial and sustainability performance.[46] With this in mind, as electric power companies consider the long-term viability of its customers, an understanding of their sustainability may be an indicator of their financial health.

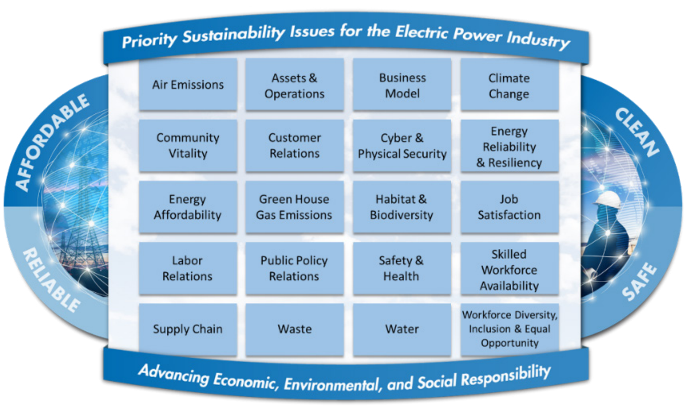



*Figure 4 – Priority Sustainability Issues for the Electric Power Industry*

### Developing Business-to-business (B2B) Social Collaboration

The "social pillar" of sustainability may also be improved by encouraging collaboration between electric power companies and indoor agriculture facilities. This supports the concept of shared value which describes a management approach of solving social problems through the development of business models.[47] Indoor agriculture may create shared value by developing a business around the production of produce locally while reducing environmental impact. Since electricity is a critical component to all segments of the indoor agriculture supply chain, an electric power company has the unique opportunity to be a beneficial partner to this emerging industry. This can be achieved by identifying mutually beneficial ways to engage with the CEA industry, the electric power companies that serve them, and the communities they both support.

46 https://www.epri.com/#/pages/product/000000003002005759/
47 https://www.sharedvalue.org/about-shared-value

### Sustainable Agriculture

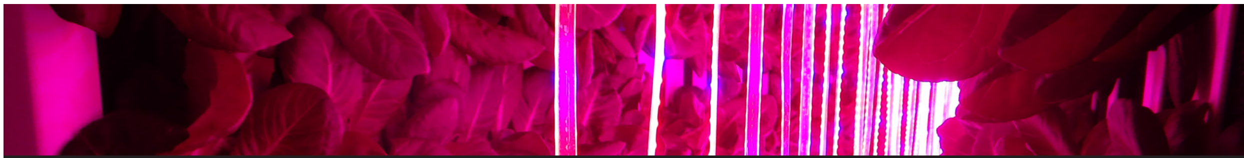
The United Nations (UN) Sustainable Development Goals (SDGs) have underscored the importance of sustainable agriculture using resilient agricultural practices to end hunger, achieve food security, and improve diet.

According to Sustainable Agriculture Research and Education (SARE) program, "sustainable agriculture does not refer to a prescribed set of practices. Instead, it challenges producers to think about the long-term implications of practices and the broad interactions and dynamics of agricultural systems."[48] Indoor agriculture may be a means by which sustainable agriculture can be achieved, addressing the challenges associated with the future food supply chain, urbanization, climate change and resource imbalance. Additional benefits acknowledged during EPRI Indoor Agriculture research have been extending the seasonal availability of fresh local produce, expanding local food production in densely populated areas, reducing food transportation miles, relieving pressure on water availability and addressing fresh water needs.

Several sustainability issues that need to be managed related to food production have been identified through certification programs and research organizations including, but not limited to, Sustainability Assessment of Food and Agriculture Systems (SAFA),[49] Global G.A.P.[50], and Columbia University[51] and cover wide variety of topics such as governance; environmental impacts; economic viability; and well-being of employees, customers, and communities.

For an electric power company with an indoor agriculture facility in its service territory, a commitment to sustainability can also mean a commitment to supporting the development of their customer's sustainability efforts in the pursuit of a sustainable economy.

48 https://www.nal.usda.gov/afsic/sustainable-agriculture-definitions-and-terms
49 http://www.fao.org/fileadmin/templates/nr/sustainability_pathways/docs/SAFA_History10.9.14.pdf
50 https://www.globalgap.org/uk_en/for-producers/globalg.a.p./integrated-farm-assurance-ifa/crops/
51 http://sustainability.ei.columbia.edu/files/2016/01/Sustainability-Certification-for-Indoor-Urban-and-Vertical-Farms.pdf





## Economic, Customer, and Employment Issues

### *Affordability*

Considering affordability factors is critical to the bottom line profitability for a CEA operator and impacts the sale price of the product to the communities served. Efficient management of resources and inputs could help to manage affordability and product competitiveness with traditional agriculture produce. Future economic research to understand, reduce, and manage the cost premium of indoor agriculture (from initial investment and ongoing expenses) could give insights into opportunities for future economic tools (e.g., subsidies) that might support cost competitiveness and affordability.

Another influencing factor on affordability is a CEA facility's revenues and payback of initial capital investment. One report shows that the average age for a CEA farm to become profitable is 7 years.[52] This suggests that farmers and investors need to understand that it may take longer than typical business models to become profitable. As CEA operators consider the consumer affordability of their products, investment questions, including the length of the payback period for initial investment, need to be addressed. Consideration of these factors could lead to potential partnership opportunities in which new sources of capital, or regulatory/legislative incentives that can address financial challenges, are identified.

### *Customer Relations*

Many evaluations of indoor agriculture consider sustainability, water use/discharge, energy use, utilized technologies, crop yield, production costs, labor costs, and a range of other factors. Unfortunately, consideration of the opinions and loyalty of consumers are not routinely evaluated in these evaluations. Thus, understanding relationships with customers may be an area of consideration for the indoor agriculture sector, particularly due to the benefits of turning customers into brand ambassadors.[53]

### *Jobs*

Since indoor agriculture facilities can be sited in a variety of locations, an opportunity is created for cities and towns to establish new, local jobs. Further research is needed to better understand how the creation of indoor agriculture jobs may or may not impact jobs in traditional farming. With local job creation being an important topic in many communities, a deeper exploration of this issue may be important to both rural farming communities and urban cities considering the development of indoor agriculture facilities.

The presence of indoor agriculture facilities can lead to the creation of local jobs. The scale and type of farm clearly impacts the number of local jobs created. Average wages were also found to be dependent on facility size, scale, and geographic location. Facilities visited by EPRI reported having between 45–100 employees and offered wages in-line with that warehouse employment locally. Regardless of pay, CEA facilities can struggle with hiring and retaining 3rd shift workers.

## Energy Impact Analysis

To fully understand the opportunities and challenges of indoor agriculture, further research comparing CEA to outdoor farming should be performed. Metrics that should be analyzed include type of crop, crop value per pound, shelf life and others to fully understand the impact and potential of CEA.

### *Load growth or load shifting/Total Energy Usage*

Questions raised about CEA from a utility perspective, which are addressed below, include:

- Is indoor farming load growth and/or load shifting?
- Does indoor agriculture use more total energy than outdoor farming?

#### Is indoor farming load growth and/or load shifting?

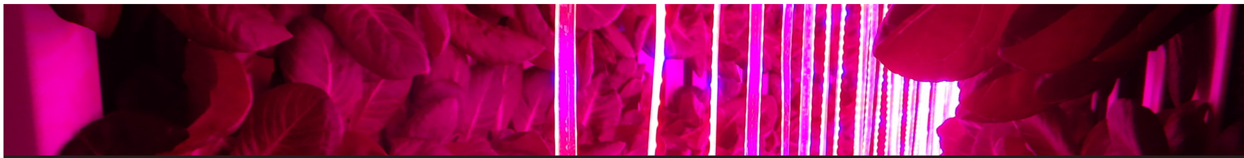
Most indoor agriculture facilities are multiple MWs in load, and use far more electricity in crop production than outdoor farming. Currently, most CEA facilities will consume more electricity in producing crops than would *likely* be consumed in harvesting, packaging, storing, transporting, warehousing and distributing an outdoor crop. CEA facilities can participate in demand response (DR) events and peak shifting programs by dimming or turning off lights during peak periods and by shifting farm operations to evenings and mornings to help with load stabilization.

#### Which strategy uses more total energy?

Indoor agriculture typically uses more electricity than outdoor farming. Indoor farming is highly dependent on electric loads to generate crops, where electric usage related to outdoor farming typically revolves around packaging, transit, refrigeration and logistics. Indoor agriculture eliminates the use of diesel powered farm vehicles

52 MISSING FOOTNOTE?

53 Fuggetta, R. (2012). Tracking in Brand Advocates: Turning Enthusiastic Customers into a Powerful Marketing Force. Hoboken, N.J.: Wiley.





and typically reduces the amount of water used per plant. So, the question becomes whether the non-electricity energy usage of outdoor farming (fossil fuel consumption, water usage, etc.) meets or exceeds the additional electricity usage of indoor agriculture in total energy usage. This is one of the key research questions EPRI is attempting to address as there is no clear answer to this question today due to the variance in scale, climate, crop, logistics, and CEA facility type which all impact these calculations. Additional factors to consider are type of supplies, cost of supplies, and utility rates.

## Typical CEA consumption today

Depending on type and scale of the facility, a typical vertical farm can consume between 1 and 8 MWh per hour and roughly 8,700 MWh to 70,000 MWh per year. These are wide variances because the type of farm and the crops produced can greatly impact the consistency and size of the facility load. Greenhouses vary widely as well depending on season, crop and climate and can range from kWh to MWh loads depending on season, daily light, and climate. Container farms are a bit more stable. A single container farm, averaging 125kWh a day, would consume about 45.6 MWh a year. Based on EIA values for an average U.S. home,[54] that would mean each container farm is equivalent to adding about four average residential homes to the grid.

## Grid Impact and Grid Dependence

Since CEA facilities use a large amount of electricity, utilities should consider the impact a facility would have in their service territory regarding distribution networks, sub-stations, and homes and businesses located near the facilities. Consultations between CEA operators and the utility can be essential for vetting/siting a facility and evaluating the potential impacts of its load.

### Interconnection and Power Quality

Based on a high-level review by EPRI grid connectivity experts, CEA loads do not appear to offer any unique interconnection issues. Therefore, a standard analysis used for commercial/industrial facilities can be utilized, as well as the use of standard interconnection procedures for commercial or industrial loads. Additionally, CEA facilities use the same equipment found in large warehouse and manufacturing facilities, and therefore should not bring about additional challenges from a grid harmonics and/or power quality (PQ) perspective. If PQ issues do arise, it is likely that the filters used in other commercial and industrial facilities would resolve the issue.

Although there are similarities to commercial/industrial facilities, a survey of the CEA facilities load and operational nature should still be considered.

### Infrastructure build out

Most CEA facilities aim for locations with low rent per square foot, available warehouse space, abandoned or undeveloped tracts, and suburban to rural locations that can provide a delivery radius of 100 to 200 miles for their produce. However, these locations may not have the existing infrastructure to support these facilities which may require utilities to build or expand infrastructure.

Many CEA facilities do not initially operate at full capacity. Some CEA facilities have a multi-year plan to build out, or even sub-let, facility space. Such plans may allow the utility to expand their grid infrastructure at a more gradual rate. So, utilities may benefit by considering the initial estimate of consumption for the facility as well as future potential consumption.

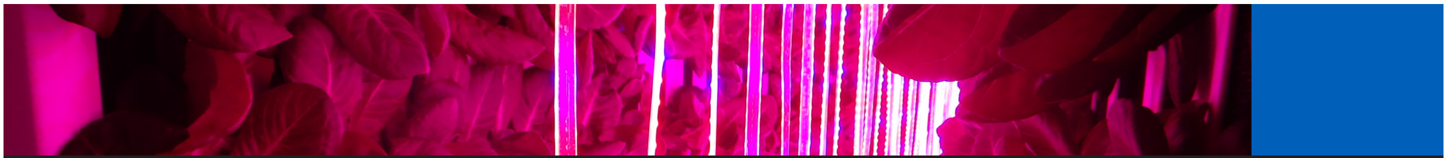
These factors, combined with the risk of a CEA facility failure, mean a partnership between the facility and utility could help this process. Utilities may also want to consider splitting the cost for infrastructure improvements with facilities to reduce the risk of stranding under-utilized assets in remote areas.

### Critical Loads and Reliable Power

The most critical load of any soilless CEA facility, as well as CEA greenhouses using drip irrigation into a natural grow medium, is pumping and irrigation. Irrigation systems must be maintained to assure that the plants are properly watered, otherwise crop yields are impacted. Regardless of CEA type and crops, utilities should understand that facilities cannot respond quickly to events or emergencies as their operation is based on consistent and repeatable daily operation. As a result, CEA farms are very dependent on the reliable and dependable delivery of power to maintain operation. This dependence on the grid should be considered when siting a CEA facility, and when designing or sizing any systems that power the facility. This should also be considered in utility maintenance or upgrades near the CEA facility that may result in the disruption of power.

Backup generators used for critical loads during grid interruptions may only provide support to a CEA facility for a few hours. As a result, utilities may want to consider offering to help size these generators and discuss various outage solutions with the farms.

54 https://www.eia.gov/tools/faqs/faq.php?id=97&t=3





## Load Profile and Peak Shifting

Vertical farms and container farms have fairly consistent load profiles, with variation typically only stemming from HVAC loads that respond to external temperatures and weather. Since electric lighting is used in these facilities to simulate optimal sun conditions, lighting is typically operated on 16 or 18 hours ON, and 8 or 6 hours OFF per day cycles. Variation in lighting schedules do occur, with some facilities operating 12, 22, or 24 hours ON. Note, each facility's schedule will vary depending on crop, farm type, and phase of growth. Regardless of their chosen lighting cycle, once established, it should be regular and routine. Due to their self-contained design and set operational nature, vertical farms and container farms may have the potential to participate in demand-side management and peak shifting programs.

CEA greenhouses have varying load profiles since electric lighting is used to augment natural light. Natural light varies noticeably depending on season and weather. As a result, these operations may not be able to quickly shift loads. They may be able to participate in load management programs via scheduled peak shifting though when they can plan to operate their lights during off peak times.

Other opportunities exist for utilities to work with CEA facilities in the areas of operational cycle and efficiency improvement including heating and cooling solutions which must be operated year-round and maintain a set temperature.

## Co-Location

Co-location opportunities vary depending on service territory, type of farm, farm scale, adjacent industries, and the generation asset type being operated.

Some vertical farms and greenhouses burn natural gas to create $CO_2$ for their facilities while others purchase "bottled" $CO_2$. The amount of $CO_2$ required varies by the size of the facility, the stage of growth, and the amount of natural $CO_2$ already in the air.

Large scale greenhouses and vertical farm operations may offer the potential to utilize $CO_2$ captured from power plants or other industrial processes that generate large amounts of $CO_2$. The scale and scope of this is dependent on the size of the vertical farm and large-scale greenhouse though. This opportunity may help reduce the operating costs of indoor farms by eliminating the cost of generating, capturing, or purchasing $CO_2$. Even though CEA does not rely on fertilizer for yield, a large amount of $CO_2$ is created from fertilizer producers and therefore may be a good industry for partnerships.

Similarly, cement, iron and steel, and chemical production may offer the potential to provide $CO_2$ to CEA facilities. CEA facilities may also benefit from sited where they can utilize excess generation from renewables.

A single container farm uses approximately one 20-pound propane canister a month for $CO_2$ production. This is offers no potential for co-location. However, if several container farms are going to be grouped there may be an opportunity to discuss co-location for $CO_2$ use.

### Steam

Most CEA facilities attempt to maintain a warm environment with moderate humidity. So, the injection of steam can be problematic. As a result, a CEA farm must be able to properly deal with controlling the impact of injected steam.

As with $CO_2$, large vertical farms and CEA greenhouses may offer the potential to use waste steam from utility generation and other industrial processes like commercial laundries, refineries, chemical, steel and metal production. Food production and processing, which may also offer partnership benefits, are also good steam co-location opportunities. Beyond ensuring that the economics work, some limitations include:

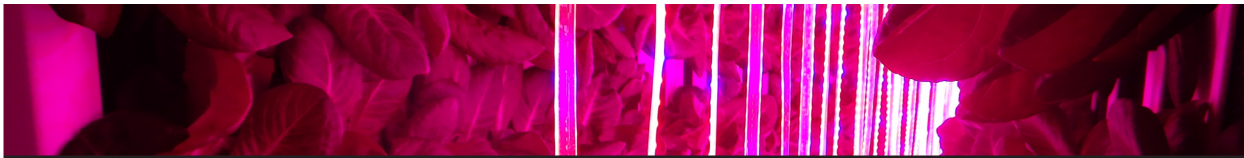
- Medium to large CEA facilities typically have a boiler. Therefore, the scale, location, sale and/or distribution of steam must align well.
- Small vertical farms, small CEA greenhouses, and container farms do not appear to offer the potential for steam sales or distribution. In fact, container farms require reduced humidity, so steam injection would be problematic for them.

### Solar/Wind

Vertical farms may be able to utilize customer-owned solar to offset some of their power needs, however, limitations to this exist, including:

- A vertical farm's roof footprint is typically not large enough to fully power the facility
- Viability depends on solar forecasts and commercial/industrial power rates
- Economics benefits are highly variable, and depend on location

At this point, calculations show that a 320 sq. ft. container farm with rooftop solar will not yield enough energy to fully power itself.





When paired with battery storage, the container farm owner will be able to reduce their energy bill, which may be particularly valuable in avoiding peak power prices and may also allow them to participate in DR events in return for beneficial power rates. There may be a potential to fully power these facilities economically in the future with improved PV efficiency and lower battery costs. CEA greenhouse operations offer minimal opportunity to take excess solar power since peak solar generation typically coincides when they are using the least power.

As with solar, some vertical farms and container farms may benefit by shifting operations to coincide with dependable peak excess generation from wind. CEA greenhouses may be able to use wind energy to offset or power night lighting, but this is dependent on the location and prevailing power rates. But remember CEA facilities cannot quickly shift their power usage, and require dependable energy sources for scheduling their operations.

#### Batteries

As the cost of storage declines, CEA facilities may be able to better utilize excess solar and wind energy. Currently, the cost of storage makes the economics difficult. In the future, the potential for using renewables paired with storage in CEA facilities will increase as storage costs decline.

#### Rebates, rate structures, and discounted rates

Opportunities or positions which utilities can take to expand indoor agriculture within their service territory include:

- Offering financial incentives for indoor agriculture technologies.
- Offering discounted energy rates and alternative rate structures (time-of-use).
- Developing DSM programs tailored to the CEA needs.
- Allowing this industry to locate in, or expand, within their service territory organically without incentives.

Factors to consider related to discounts and rebates for the CEA industry include:

- Due to regulatory factors, the utility may first determine if the offered incentives benefit all ratepayers.
- The utility must decide what type of incentives to pursue. The four primary types are #1) economic development, #2) rate discounts, #3) line extension waivers, and #4) property subsidies.
- Whether the load shape produced by this industry allows for cost recovery of incentives
- Whether incentives will likely result in CEA farms locating in their territory instead of another
  - If this is verifiable, and it should be verified, collaborations with local or state economic development agencies may assist in this process.
- Whether the number of created local jobs offset incentive costs

#### Incentives/Rebates

Based on the type of farm and the type of technology the farm utilizes or plans to use, utilities should consider a range of options. This include using their existing rebate/incentive programs to partner with CEA facilities. Additionally, utilities may want to consider creating programs and solutions that address the unique technologies used in CEA facilities that do not fit into traditional programs.

Many of the core technologies utilized within CEA facilities are already included in many utilities' rebate and incentive programs. Examples include LED lighting, high SEER HVAC units, ASD based pumps, electric fork trucks, and high efficiency water heating units. As a result, many utilities may already be able to support the use of CEA technologies that maximize efficient energy usage and production. Utilities would still need to verify that the utilized, or considered, products meet the requirements and goals of the local utility or municipality though.

Some technologies and products specifically focused on CEA production may not fit into existing rebating programs. Therefore, utility programs may have to be modified to include products based on specific characteristics. An example would be including LED products based on PAR values instead of efficiency values.

Utilities looking to rebate CEA technologies may also need to address products that are not compatible even modified efficiency programs. Two examples of this are HID or fluorescent lighting which CEA farmers use due to their ability to yield crops. Rebating or incentivizing these technologies do not align with the energy efficiency plans of most utilities or their regulators. However, in these cases, utilities will likely have to take the role of letting the CEA farm utilize the technology they feel will yield their crops effectively. The efficiency of horticulture lights is not measured with visible light and therefore, current energy efficiency lighting metrics do not apply to these measures.

When less efficient technologies are used, utilities may need to consider special or discount energy rate structures. These situations may provide an opportunity for the utility to engage the farmer in discussions around emerging technologies. To gain adoption, any replacement or new technology must deliver equal or improved crop yields.

### Rate Structures

Rate structure categorization is another challenge for CEA rebating and incentivizing. While some utilities have created rate structures specifically for indoor agriculture, others have included CEA in industrial and agriculture rate structures. Each of these pathways has benefits and challenges.

Including CEA in existing rate structures (e.g. Industrial and agriculture) can allow utilities to efficiently deal with CEA facilities by applying the same rules, regulations and program offerings which may lead to growth of that rate program. However, it can also pose challenges, since CEA may not align with the typical load or usage profile (e.g., agriculture) or may not offer the consistent and controllable load profile (e.g., industrial) as other participants in the rate structure.

Creating a new rate structure for CEA can help accommodate the needs and load profiles of CEA facilities. However, it may create challenges around what power rates are correct due to the broad variances in total energy usage (container farms vs. vertical farms) and the daily variance (CEA greenhouses vs. vertical/container farms) that occur between CEA facility types.

In making this decision, utilities should consider their current and projected energy costs, their current rate plans, the potential scale (short and long term) of CEA within their territories, the difficulty of justifying or creating new rate structures, and any potential conflicts and concerns that other customers and consumers may have with CEA facilities. This in-depth analysis should allow utilities to determine the best decision for their individual utility.

### Process Efficiency and Discounted Rates

Utilities encounter several challenges and options regarding the reduced power and/or water rates. Before considering special pricing or discounted rates, utilities should look to help improve the operation of the facility by honing processes, reducing costs, and improving technologies to increase crop yields. Specifically, this can be done by:

- Engaging with and deepening relationships with CEA facilities in the pre-construction and planning phase as to suggest technology, operations, and design ideas.
- Conducting site audits to identify areas where existing facility operations can be maximized.
- Assisting with the development or improvement of CEA specific technologies. This may take the form of participation in standards development, partnerships with technology manufacturers to enhance and develop products and solutions, and the encouragement of CEA facilities to develop best practices.

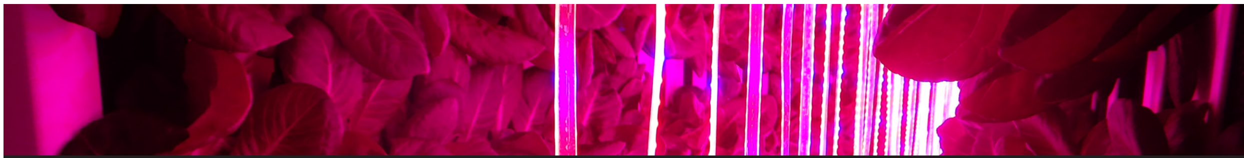
When deciding whether to create a special rate or price for CEA facilities, a utility must understand the benefit of an indoor agriculture facility to the service territory. Factors to consider when understanding this benefit include:

- Grid and transmission impacts
- Siting issues
- Load profiles
- Actual energy use
- Water use and reuse
- Discharge and emissions
- Community impact
- Impact on existing local agriculture
- Other factors

Utilities must also consider the cost of supporting/encouraging these facilities when compared to the cost of any new or updated infrastructure they will require, facilities failure risk, and the potential of stranded assets.

After sufficient vetting occurs, if a utility decides to create special rate structures for CEA farms, several factors need to be considered, including:

- Whether these rate structures will be applied to all CEA facilities or if they will be scaled depending on type or energy usage.
- How regulators will address this request and what information the utility will need to request, justify, and defend the new rate structure.





- If CEA rates are lower than prevailing rates, the reaction and backlash of other customers and existing businesses; especially those that employ a large number of local residents, have the ability to participate in peak shifting/DR events, and have higher energy consumption levels.
- Verification that CEA facilities have realistically estimated their energy use and can respond to the requirements of the contract.

In general, the utility needs to be able to justify and explain the reasons behind offering an emerging industry, and one that typically does not have a large number of employees when compared to large manufacturing or industrial processes, preferential rates.

## Additional Non-Energy Factors

### *Indoor Food Safety*

CEA farms must meet the same food safety requirements as outdoor agriculture. That said, many CEA farms integrate additional safe guards and steps into their operation and building designs in an attempt to exceed these requirements. Examples include requiring employees and visitors to wear hairnets and sanitary smocks in processing areas, as well as shoe covers to prevent dirt and debris from entering. The controlled nature of indoor farming also results in a reduction in, or elimination of, pesticides and herbicide use which may also increase food safety. Many CEA facilities closely monitor plant status, interior conditions, and limit access to plants in attempt to reduce the likelihood of outside events, pests, and disease impacting their plants. As with outdoor farms, CEA farms must be diligent to maintain safety. The controlled nature of indoor food production may offer some food safety benefits not possible with field-based agriculture due to its controlled and integrated nature.

It should be noted that outdoor agriculture also takes steps to reduce risks, including requirements to provide restroom facilities and other safeguards in the field to reduce the risk of disease transmission.

### *Food Security*

Although sometimes overlooked, indoor agriculture can help address the issue of food security by assuring that a population has access to a reliable source of safe food. This is especially pertinent for areas of the world struggling with crop production, whether it is due to water constraints, land constraints, or supply chain issues. Since CEA facilities can yield crops reliably regardless of exterior conditions (temperature extremes, drought, etc.), crop failures, famines, pests/disease, politics, and disasters (natural or man-made), it is viewed by some as a way to address food security issues. CEA may also be used to address issues that arise between nations related to trade and military conflicts.

### *Investment in data analytics*

Lack of data analysis has been identified as a key factor for farm failures. An Agrilyst survey[55] of 150 small and large indoor farms also found that the vast majority of surveyed facilities operate and collect data by manually entering it into computer spreadsheets or with pen and paper. The majority of the facilities found that production would increase as a result of using a data analytics system. The average anticipated production increase from facilities switching to data analytics platforms was 14%. Data from this report also showed that 21% of surveyed farmers were planning to invest in data and analytic processing systems, and 16% were planning to invest in a farm management system.[56] This interest in data analytics indicates an opportunity for further research and engagement.

### *Codes and Standards*

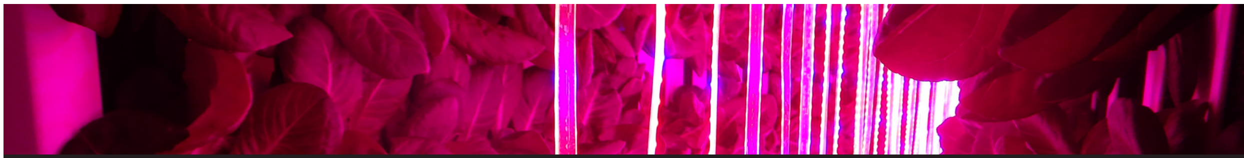
There are many organizations working on codes and standards, and while some are for technologies that are used in indoor agriculture, none were found in this research that focused on CEA.

The Illuminating Engineering Society (IES) is the primary developer of performance standards for lighting components, lighting sources, lighting fixtures, and lamps including those found in indoor agriculture like fluorescent, HID and LED. Currently, there are no IES standards specifically focused on agricultural lighting or for the maintenance of agricultural light spectrums.

Although it has not been pursued, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has discussed creating the ASHRAE 90.5 Energy Standard for Indoor Agriculture focused on baseline values for envelope, lighting, HVAC, water delivery and pumping.

There are currently no UL, NEMA and/or ANSI standards specifically focused on agriculture technologies or applications. Products and devices used in CEA facilities must still pass UL standards, or NEMA/ANSI requirements applicable to commercial devices or application-specific conditions.

55 https://www.agrilyst.com/stateofindoorfarming2017/
56 https://www.agrilyst.com/stateofindoorfarming2017/





The American Society of Agricultural and Biological Engineers (ASABE)[57] is working on standards for the indoor agriculture industry. In 2014, ASABE published their guidelines on using multi-wavelength LEDs capable of control via Ethernet in greenhouses.[58] ASABE is developing a standard outlining recommended practices for HVAC products used for indoor plant growth. ASABE has a range of other standards related to indoor agriculture and is developing testing practices for agricultural lighting.

CEA standards, guidelines, and best practices are still being developed, which presents an opportunity for EPRI and utilities to partner with the CEA industry to advance these efforts. Participation will also provide additional insight into areas where utilities can partner with equipment manufacturers to advance CEA technologies.

EPRI is not aware of any federal programs or guidelines specifically focused on CEA facilities. As stated previously, all CEA farms must meet the same standards for food handling, food safety, packaging and transit as traditional farms. Establishing even local standards and/or guidelines will drive effective and sustainable resource management for all stakeholders.

## Conclusion

Outdoor field-based, traditional agriculture has provided produce to populations for generations and is typically associated with transporting products a long distance from field to consumption. Regardless of the expansion of indoor agriculture, field agriculture will continue to deliver the majority of grain, rice, corn, and soybeans for the foreseeable future since these crops have long shelf lives and are low cost per pound. Even with higher yield per plant and additional annual harvests, the economics do not make CEA a viable solution for *most* crops today. Near term, indoor agriculture will remain focused on the production of high value and short shelf life produce that offer economic opportunities by being grown, distributed, and consumed locally or regionally. Despite its limited short-term applications, CEA will likely continue to expand nationally and internationally due to drivers like food safety, food security, consumer demand for fresh and local produce, interest in water savings, and local sourcing.

Today, there is an interest in indoor agriculture from a range of market participants, including utilities, municipalities, technology manufacturers, food distribution companies, urban planners, and water providers. It is likely that interest in this industry will grow due to market expansion, as well as interest in the various technologies and concepts that are part of indoor agriculture. Growing urban populations, issues related to food safety and security, interest in sustainable industries, water management issues—including water usage and discharge—will likely further encourage participation and interest.

Utilities would benefit from collaborating with existing and future/in-process CEA facilities within their service territories. Establishing a relationship can help maintain the viability of a facility by helping to improve processes and lower energy bill costs. This can be achieved in many ways including introducing facilities to more efficient technologies as well as making operators aware of load shifting and demand response programs they can participate in. Engaging in these activities can help maintain the viability of a facility can in turn benefit the utility by establishing as a consistent source of electricity consumption. Such partnerships between CEA operators and the utility are essential for vetting/siting a facility.

Furthermore, opening communication between engaged parties can help utilities understand the load profile and energy consumption of a facility. This can help with program rate design and incentive program planning as well as understanding the impact a facility on distribution networks, sub-stations, and ratepayers located near the facilities. This is especially true when looking at the infrastructure required to support the new load and can even result in opportunities for gradual infrastructure build outs and cost sharing plans.

Indoor production of crops is energy intensive and involves the use of a range of electric technologies, as well as the proper use and reuse of water, to maintain proper climate, moisture, and lighting conditions. The result of these efforts is the development of a local industry that provides jobs, potentially reuses empty structures, delivers crops reliably and sustainability and does so while using less water per plant. This combination of issues related to utility impact, grid stability, energy usage, water impact, sustainability, community opportunities and the like means that EPRI will continue to research indoor agriculture in the coming years.

57 https://www.asabe.org/

58 https://elibrary.asabe.org/abstract.asp?search=1&JID=5&AID=44955&CID=mon2014&T=1&urlRedirect=[anywhere=on&keyword=&abstract=&title=&author=&references=&docnumber=&journals=All&searchstring=&pg=&allwords=lighting&exactphrase=&OneWord=&Action=Go&Post=Y&qu=]&redirType=newresults.asp

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