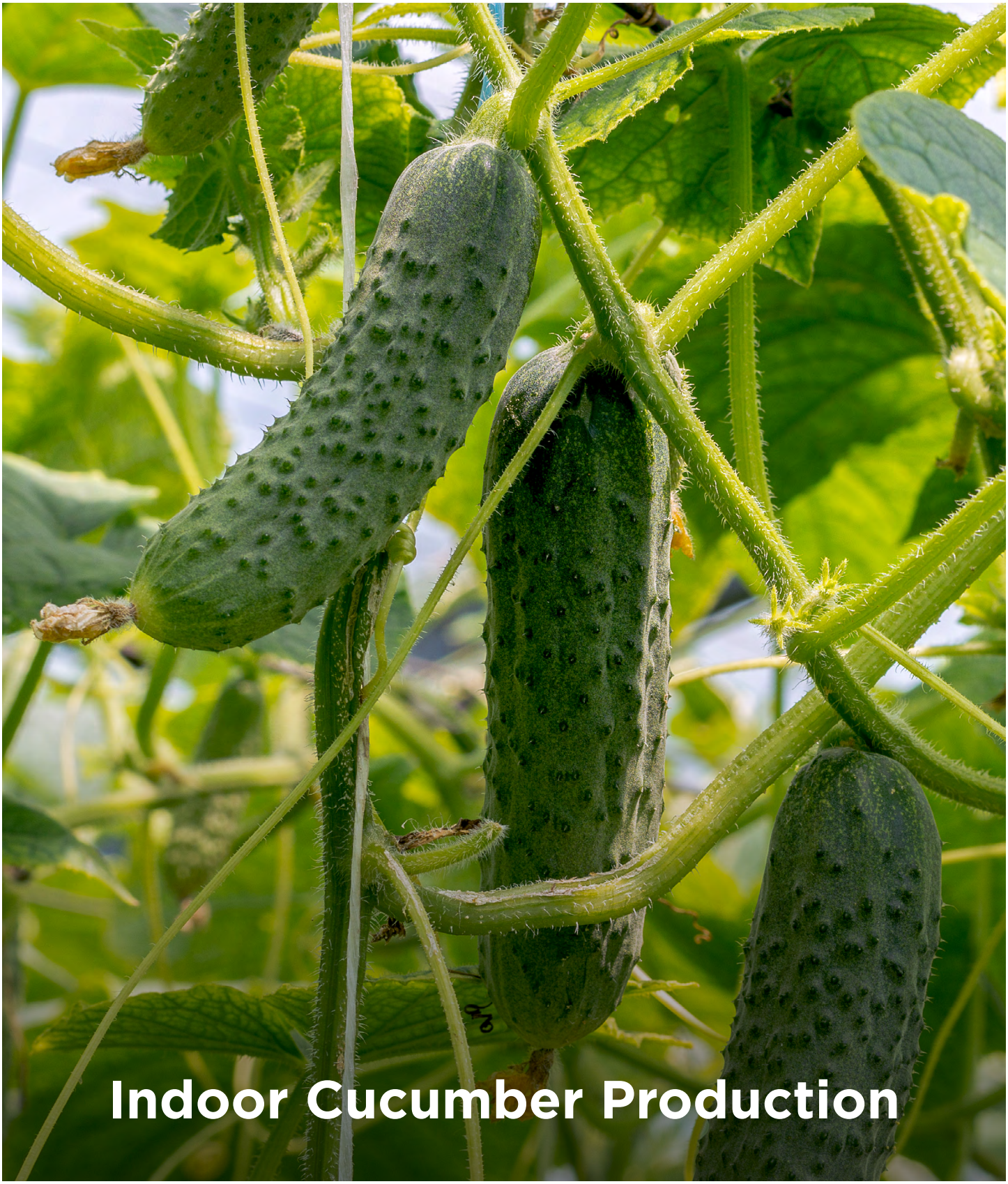

# Indoor Cucumber Production

Transfarmation

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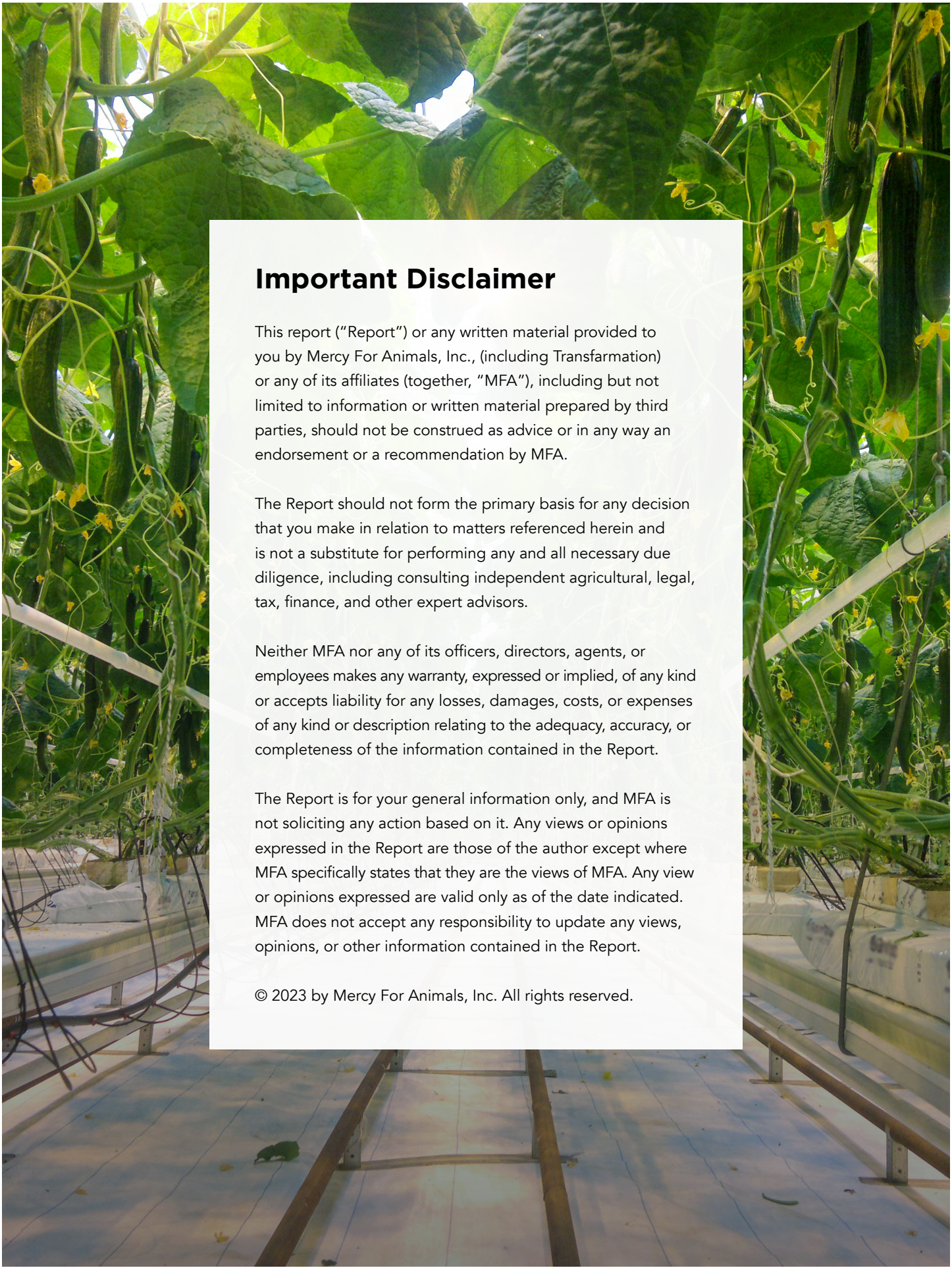

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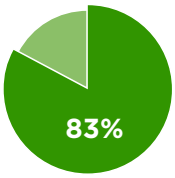
# Introduction

For over a decade, U.S. consumer demand for year-round availability of cucumbers has increased. Domestic producers initially responded by boosting production in greenhouses and other protected-culture environments. Available data indicate that **the greenhouse area used for cucumber production in the United States rose 83 percent between 2009 and 2014**.[1] Subsequently, changes in the area devoted to protected-culture vegetable production have been mixed, and greenhouse area devoted to cucumber production in the United States has declined substantially. This is partly due to a rise in imports of greenhouse-grown produce, which has increased U.S. supplies and driven domestic prices downward, dampening incentives to expand U.S. greenhouse production.[2] This report outlines the current market conditions for cucumbers in the United States, presents information on typical production practices for greenhouse cucumbers, and demonstrates the viability of converting a poultry house into a greenhouse for cucumber production.




# Market

- Michigan is the leading state for cucumber production in the United States, followed by Florida, Georgia, North Carolina, California, and Texas.[3]

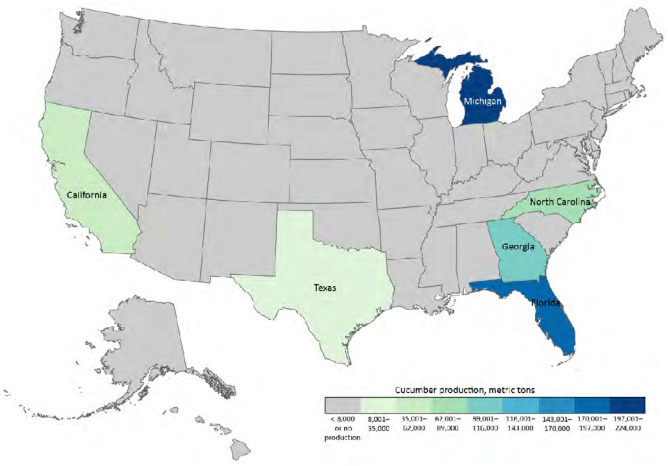



**Figure 1.** Cucumber production by state. (United States International Trade Commission.)

- Cucumber production in the United States has declined since 2014. Some of the factors driving this decline concern outdoor production only: heat, excess moisture, or drought. But effects of import competition heavily influence this trend as well.[5]
- Fresh market cucumbers can be divided into two categories: slicing cucumbers and "burpless" cucumbers. Slicing cucumbers are usually eight to nine inches long and have thick, dark-green skin and more seeds than other varieties. Burpless cucumbers are thin skinned and seedless, and they are less bitter and less likely to produce excess gas when consumed because they contain no or low levels of cucurbitacin.[6] Burpless varieties include English cucumbers and Persian cucumbers and other mini cucumbers. They are often packaged in shrink-wrap to maintain freshness and reduce water loss. These cucumbers are longer and thinner than slicing cucumbers. Burpless varieties are more delicate and are primarily grown in protected-agriculture settings (greenhouses, high tunnels).[7] This report focuses on burpless cucumbers, often referred to as seedless or "English."
- While U.S. demand for cucumbers is strong year-round, prices are inconsistent and tend to rise or fall suddenly according to changes in supply.[8] Cucumber prices can vary widely during a season and even change daily. One reason for this volatility is that cucumbers are highly perishable and cannot be held in inventory during periods of low supply.[9]
- Consumer demand for fresh market cucumbers has shifted from slicing to burpless varieties.[10] This is partly due to a snacking trend in the fresh produce segment, with consumers seeking convenient and small-sized products, such as mini cucumbers.[11] Burpless cucumbers are also becoming more common in foodservice, which generally favors slicing varieties, since they can better withstand mechanical slicing.[12]
- Imported cucumbers are priced below domestic ones at point of shipping in about half of instances. But imported cucumbers are generally priced above domestic ones in wholesale markets, where freight costs and other markups are included in the price.[13]

- The United States is a net importer of cucumbers, with seasonal patterns in imports and domestic production, and the world's largest importer of cucumbers, most of which comes from two countries: Mexico and Canada.[14] In general, Mexico ships cucumbers to the United States from November through May and is a low-cost supplier, able to produce English cucumbers in various production systems.[15] Canada supplies cucumbers for the United States from March to October and is a high-cost supplier, meaning the high-technology greenhouses there can produce more delicate, premium varieties with consistent quality and generally greater yields than most greenhouses in the United States.[16]

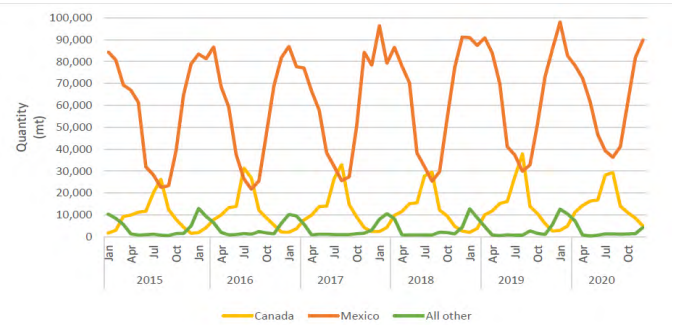



**Figure 2.** Monthly U.S. cucumber imports by quantity, 2015–2020. (United States International Trade Commission.)[17]

# Production Practices

Greenhouse cucumbers are typically produced in a soilless, or hydroponic, production system, where cucumbers are grown using substrates such as rockwool, coconut fiber, perlite, or peat and necessary fertilizers are delivered to the root system in a water solution.[18] High-tech, large-scale growers often use automatic climate controls and meters.

Production cycles in a greenhouse can vary but typically involve two or three crops a year. Annual yields across two- and three-crop systems are generally the same, but fruit quality is usually better in a three-crop system.[19] Planting typically occurs in December and June for a two-crop system and in December, May, and September for a three-crop system.[20]

Operating costs and production practices depend on the variety, type of climate control, access to light, and nutrient system. This section discusses some of the key production factors relevant to indoor cucumber production.

## Temperature

Temperatures should be kept at 75–77 degrees Fahrenheit during the day and 70 degrees Fahrenheit at night until the first picking.[21] After picking begins, night temperatures may be reduced two degrees per night down to 63 degrees temporarily (for two to three days) to stimulate growth.[22] Additionally, exceeding maximum temperatures temporarily can cause some flower abortion, which can help maintain vine balance.[23] In general, lower light intensity calls for cooler temperatures.[24]

## Carbon Dioxide

Increasing carbon dioxide in greenhouses can improve yields.[25] Normal concentration of carbon dioxide in the atmosphere is 330 parts per million, but concentrations of 1,000 to 1,500 parts per million in greenhouse atmospheres have been shown to increase yields of various vegetables 20 to 40 percent.[26] Generating and monitoring equipment are readily available but may be cost prohibitive, adding approximately $50,000 per year in operating costs. For this analysis, we recognize the yield boost this feature could provide but have not modeled the addition of carbon dioxide in a cucumber operation.

## Humidity and Air

Humidity conditions should be such that the plants do not dehydrate, which causes stress. High levels of humidity (60 to 70 percent) are best,[27] and they can be achieved with foggers, which also help cool greenhouses during high heat times. Airflow to the roots is vitally important, and some facilities use nano bubblers to increase air to the roots in hydroponic systems (not modeled in this analysis).[28]

## Growing Systems and Media

Two soilless culture systems are most often used in greenhouse cucumber production:

- Closed hydroponic systems grow plants in troughs or tubes, where plants are anchored in gravel, sand, or artificial soilless mixes or without a substrate, using a nutrient-film technique.[29] Proper application and recirculation of nutrient media is essential, and flow rates of 1.5 to two quarts per minute are most common.[30] The nutrient solution must be regularly monitored and adjusted for pH as needed. Because plants take up nutrients at different rates and roots exude certain chemicals, the nutrient solution may need to be changed frequently to avoid chemical buildup and imbalances, about every two to three weeks and as often as once a week during peak growth periods.[31]
- Bag systems use artificial media (usually rockwool) packaged in bags of three or four cubic feet. Rockwool comes in two densities: standard and low.[32] Standard-density rockwool may be sterilized and reused for up to three years, while low-density rockwool must be discarded after one.[33] Redi-Earth and Metro-Mix are two

popular manufacturers. Four-cubic-foot bags are best for cucumbers, each with two rows of plants spaced 16 inches apart.[34] Bags are typically placed in rows six feet apart. A nutrient solution is distributed through a drip-irrigation system with spaghetti drippers for each plant.[35] Excess solution—10 to 20 percent during cloudy, cool periods and 25 to 50 percent in sunny, warm conditions—is applied to provide drainage and prevent salt buildup. This excess should be collected and discarded or may be reused with certain restrictions.[36]

**Figure 3.** Video still of cucumber plants in rockwool bags. (Hoocho, "Growing in Rockwool: Hydroponic Greenhouse Cucumbers," YouTube video, March 31, 2021.)

## Seed Selection

Typically, three-week-old plants, free of disease and insect infestations, are transplanted into the greenhouse.[37] Seedlings can be started in a separate area of the greenhouse. English cucumbers are all female (gynoecious) varieties, which do not require bees for pollination. Common varieties are Jessica, Optima, Flamingo, Corona, Sandra, Fidelio, Fertila, Factum, Femspot, Femfrance, LaReine, Pepinex 69, Pepinova, Pandorex, and Santo.[38]

## Spacing and Pruning

Six to nine square feet of space per plant are required, depending on the variety and cropping system.[39] Each plant should be trained to grow up a support string of wire or twine attached to an overhead horizontal trellis cable typically about six feet above the plant base. Because the plants need to establish a strong root system and vegetative stem before fruit is allowed to set, the following pruning practices are recommended in a greenhouse setting:[40]

- All lateral branches, flowers, and tendrils should be removed until the plant has eight to 10 leaf nodes. Twist the support string around the stem as it grows, always in the same direction.
- After the leaf nodes have developed, allow one female flower to set at each node, and remove any damaged or crooked female flowers (gynoecious varieties should have no male flowers). Remove all lateral branches, training the plant to a single stem, and remove bottom leaves as new leaves form on the upper portion of the stem, leaving 50–60 inches of healthy leaves.
- When a plant reaches the horizontal support wire, allow two lateral branches to grow along the wire about 12 inches, or two leaf nodes, toward the next plant. Allow the main, or terminal, branch and each of the lateral branches to grow another 30 inches, hanging from the wire, and then pinch them to terminate growth. When the fruit from the terminal and each of the lateral branches is harvested, remove these three hanging branches, and allow three new branches to grow from the main stem at the support wire. Repeat the process until the crop is terminated.

## Irrigation

Plants need an adequate supply of water to the roots, but excess water reduces soil aeration and can lead to productivity issues.[41] Young plants in mid-winter may need watering only once every 10 to 14 days, while in mid-summer, such plants may need water daily, requiring an estimated one-quarter to three-quarters of a gallon per plant per day, depending on size.[42] Some operations use infrared cameras to measure leaf temperature along with digital scales to measure water flow for optimal irrigation. These and other metering devices can be connected to environmental controls not only to collect data on production factors but to control such factors to optimize production.

## Sanitization and Sterilization

Many greenhouses have a sanitation process everyone must follow before entering the production area. In addition, a complete sterilization of the production area should occur between growing cycles.

## Packing and Storage

Cucumbers can be held 10 to 14 days at 50 to 55 degrees Fahrenheit with a relative humidity of 90 to 95 percent.[43] The fruit is subject to chilling injury if held longer than about two days at temperatures below 50 degrees and can ripen rapidly in temperatures above 50 degrees, turning from green to yellow.[44] Modified atmospheres, such as those with low oxygen levels, can slow yellowing. Cucumbers are very susceptible to shriveling, which is why humidity in storage should be kept high. Shrink-wrapping with polyethylene film can also delay shriveling.[45] Packing capabilities at the greenhouse should be considered unless there is a packer nearby.

# Enterprise Budget

Specific operating costs and production practices for a given operation will depend on the variety, type of climate control, access to light, and nutrient systems, among other factors. The production budget presented here identifies typical or representative assumptions to inform planning for production of conventional seedless (e.g., English) cucumbers in a greenhouse environment. The following section details the steps and expected costs and returns of cucumber production from 16,000 square feet of production space. This number is based on the size of a former poultry barn measuring 50 by 400 feet, with 4,000 square feet set aside for packing, storage, and utilities.

Indoor cucumber production requires significant labor and management. The representative enterprise budget in table 2 below is a generalized reference and should be adapted to the specifics of an operation.

## Yields and Prices

There is a lack of data available on prices producers command for seedless cucumbers grown in the United States, mainly due to limited production. Canadian and Mexican producers dominate this segment of the produce market (see "Market" section above). A new startup greenhouse will likely be unable to compete on price alone in this sector, as prices for greenhouse-grown seedless cucumbers are $0.50 to $0.75 per pound at terminal markets in the United States.[46] But cucumber variety and characteristics of the markets supplied, such as "local," allow for differentiation and higher prices. A horticulture report from Practical Farmers of Iowa analyzing data from three small-scale producers in Iowa with greenhouses ranging from 700 to 1,800 square feet shows that they received $1.23 to $2.50 per pound for English-

style cucumbers in 2015.[47] For purposes of this analysis, we consider a price point of $1 per pound, higher than terminal market prices but lower than those of small indoor producers. The annual yields of greenhouse-grown cucumbers in this enterprise budget (between 20 and 25 pounds per plant for each cycle) are consistent with published estimates.[48] For the 16,000-square-foot greenhouse production area modeled in this enterprise budget, we estimate a total annual yield of roughly 180,000 pounds of cucumbers from three crops.

## Labor

Indoor cultivation requires significant labor inputs, heavily concentrated in the planting and harvesting phases. Labor accounts for roughly 40 percent of total production expenses and includes seeding, transplanting, pruning, harvesting, management, maintenance, marketing, and crop delivery. In total, we estimate these tasks would require nearly 4,400 hours for one year's production in a 16,000-square-foot greenhouse. At an hourly rate of $17.58, this amounts to labor costs of $76,825 annually. Table 1 lists the major labor tasks and estimates of the hours they require.

**Table 1.** Typical operations tasks and estimated labor hours required

| Task | Time required (hours) | Description |
|---|---|---|
| Maintenance | 610 | • Installation of new plastic floor<br>• Post-harvest cleanup and sanitation |
| Harvesting | 1,500 | • Picking and packaging fruit |
| Marketing | 672 | • Marketing and delivery |
| Planting | 106 | • Placing bags of substrate and irrigation drippers<br>• Placing plants in growing medium and tying them to support string |
| Pruning and trellising | 1,482 | • Training plants to grow up support strings<br>• Pruning and managing growth |
| Total | 4,370 | |

**Sources:** Liz Kolbe, *Enterprise Budget for Cucumbers* (Ames: Practical Farmers of Iowa, 2015); Northeast Organic Farming Association of Vermont, *Cost of Production Project: Greenhouse Cucumbers* (Richmond: Northeast Organic Farming Association of Vermont, 2019).

## Inputs

Key inputs for greenhouse cucumber production are as follows:

- **Plants:** Improved varieties of cucumbers specifically recommended for greenhouse production can cost $0.50 per seed from seed suppliers. Growing three crops in a 16,000-square-foot area would require nearly 8,400 seeds per year. For purposes of this analysis, we assume cucumber seed would be started and seedlings transplanted to the large substrate cubes at around three weeks.
- **Soilless media:** This budget assumes the use of rockwool substrate bags as the soilless media.
- **Beneficial insects:** One important advantage of greenhouses is that they allow for the exclusion of insect or arthropod pests to a certain extent and containment of biological controls, such as beneficial insects, to prevent infestation.[49] We model predatory mites and parasitic wasps at costs compiled from online sources (Arbico Organics),[50] at a cost of $50 per bottle (with shipping) and an annual need for 100 bottles.
- **Nutrient solution:** Information on hydroponic nutrient solution designed specifically for cucumber production is limited, and most commercial operations maintain a custom blend they have found works best in their conditions. For this budget, we model a representative regime from The Ohio State University for hydroponic production of tomatoes.[51]
- **Miscellaneous materials:** Our budget includes sanitizer for post-harvest cleanup, packaging materials, clips, and twine.

## Packaging

Retail English cucumbers are typically shrink-wrapped and marketed in 12-pound cases.

## Utilities

The utility requirements of a greenhouse include fuel for heating, electricity for fans, water, sewerage, and communication. In this budget, we assume the natural gas requirements of heating will require 2,180,000 cubic feet at a cost of $9.52 per 1,000 cubic feet. In addition, we expect the electricity requirements will be 25,000 kilowatt hours of energy per year and estimate a cost of $0.12 per kilowatt hour.[52] Telephone (cell) and internet costs for the business are modeled at $1,440 per year. Utilities represent around 18 percent of the total variable costs of the greenhouse operation.

## Other Operating Costs

Miscellaneous costs include laboratory fees (such as for analysis of leachate, tissue, and nutrient solution), estimated at $1,440 per year; office supplies ($600); postage; and marketing materials ($600). In total, we expect such costs to be $2,640 per year.

## Cash Overhead

Property taxes for the operation will vary by location but are modeled here at $250 per month, or $3,000 per year. Some states require payment of income or other applicable taxes on top of property tax, but these are not modeled here.
No land costs are assumed in this analysis; thus, the profit identified below can be considered a return-on-land estimate. Insurance for general liability is modeled at $70 per month, and property insurance is estimated at $200 per month. In total, we estimate annual insurance costs at $3,240.

## Capital Costs and Noncash Overhead

The capital cost of converting a poultry house into a greenhouse is estimated at $5.47 per square foot, or $87,520 for the structure (16,000 square feet of production area).[53] We estimate the cost of the hydroponic system to be used in production at $35,760 according to a quote from Carolina Greenhouses for a Dutch Bucket system.[54] In addition, we estimate a cost of $25,450 for environmental controls and other necessary equipment, identified from a list of requirements developed by The Ohio State University Extension, with cost factors indexed to 2022 dollar values:

- Backup generator: $5,200
- Cooling system: $2,400
- Fan jets (two): $2,600 ($1,290 each)
- Computer for environmental controls: $3,300
- Heating system: $2,600
- Miscellaneous building supplies: $2,000
- Sprayer: $100
- CO2 generator: $500
- Cooler: $2,000
- Fertilizer mixing pump: $50
- Feeding system: $3,200
- Meters, monitors, sensors, and scale: $1,000
- Shrink-wrap system: $500

Thus, the total capital expenditure of converting a poultry house into a functioning greenhouse for hydroponic production is estimated at **$148,730**. This analysis further assumes the owner could finance the conversion through existing programs offered by the Small Business Administration (SBA), the United States Department of Agriculture, and possibly other lenders. For purposes of this analysis, we model the debt-service terms of the SBA 504 program: 10 percent equity requirement (90 percent financed), or $14,873. Further, 10- and 20-year notes, at 6.5 and 6 percent interest, respectively, are considered in the financial analysis below.[55]

## Net Profit

According to the assumptions outlined above, including projected yield, the break-even price of cucumbers from a 16,000-square-foot greenhouse is around $0.85 per pound. Thus, net operating profit from the operation is expected to be $29,046 annually, or a profit margin of 14 percent, as shown in table 2. This profit margin is consistent with reported profit margins for specialty-crop and greenhouse or nursery producers in midwestern states.[56]

**Table 2.** Representative greenhouse cucumber enterprise budget

| Description | Unit | Quantity | Price | Value |
|---|---|---|---|---|
| **Gross returns** | **Pound** | **180,000** | **$1.00** | **$180,000** |
| **Variable cost:** | | | | |
| Beneficial insects | Package | 100 | $50.00 | $5,000 |
| Fertilizer mix | Pound | 3,000 | $2.50 | $7,500 |
| Fungicide or pesticide | Gallon | 18 | $20.00 | $360 |
| Sanitizer | Gallon | 14 | $24.00 | $336 |
| Rockwool slabs | Bag | 168 | $85.00 | $14,280 |
| Seeds | Seed | 8,400 | $0.50 | $4,200 |
| Hooks, twine, and clips | | | | $1,000 |
| Labor | Hours | 4,370 | $17.58 | $76,825 |
| Packaging | | 180,000 | $0.025 | $4,500 |
| Labels | Roll | 96 | $30.00 | $2,880 |
| Natural gas | 1,000 ft.$^3$ | 2,180 | $9.52 | $20,754 |
| Electricity | kWh | 50,000 | $0.12 | $6,000 |
| Telephone and internet | | | | $1,440 |
| Miscellaneous | | | | $2,640 |
| Property tax | | | | $3,000 |
| Insurance | | | | $3,240 |
| **Total operating costs** | | | | **$153,954** |
| | | | | |
| **Operating profit** | | | | **$26,046** |
| | | | | |
| *Debt obligation (20 years, 6% interest)* | | | | $11,670 |
| ***Debt-service coverage ratio*** | | | | **2.23** |
| | | | | |
| *Debt obligation (10 years, 6.5% interest)* | | | | $18,620 |
| ***Debt-service coverage ratio*** | | | | **1.39** |

The expected profit of $26,046 from the converted poultry house represents a profit of $0.14 per pound of cucumbers yielded from greenhouse production. As mentioned, cucumber price points are highly variable by season and largely influenced by imports. Production contracts can help alleviate some of the market price risk in this sector. Debt-service coverage ratio (DSCR) is a measurement of a firm's available cash flow to pay current debt obligations, calculated as the net operating income divided by debt obligations (principal and interest payments). A DSCR less than 1.0 would indicate potential solvency problems, while a ratio of at least 2.0 is generally considered very strong. The DSCR for this enterprise is positive (solvent) to very strong, depending on the terms of the loan undertaken.

## Sensitivity

A sensitivity analysis was conducted to evaluate the impact of key assumptions on the operating profit estimate for the enterprise in question. The key assumptions in the sensitivity analysis include the following:

- Yield (20 to 25 pounds per plant)
- Price received ($1.25 to $1.75 per pound)
- Labor rate ($15 to $20 per hour)
- Natural gas usage (1,800,000 to 2,200,000 cubic feet)

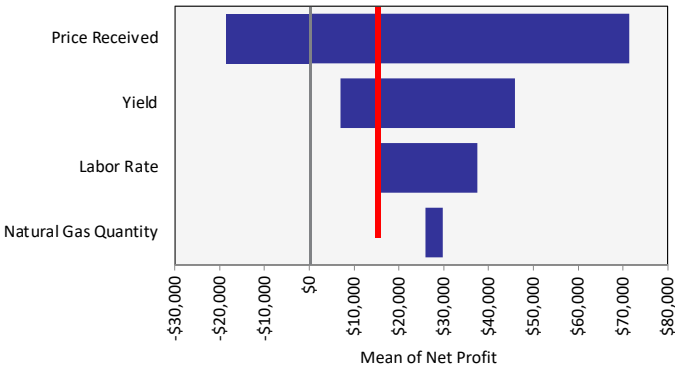



**Figure 4.** Sensitivity analysis results.

Price is the most sensitive variable considered in this model. As mentioned, at the scale modeled here, a new startup in the United States growing conventional greenhouse cucumbers is unlikely to generate a profit at published terminal-market prices. While the price-point model here can be achieved, it would likely be with a niche cucumber product, entry into the value chain at the wholesale level, or a distinguishing certification (e.g., organic). The red line in figure 4 indicates the level at which the DSCR would fall below 1.0, which occurs only in the low end of the price and yield range considered in the analysis.

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53. Quotes from Carolina Greenhouses for converting a chicken house into a greenhouse for crop production ranged from $3 to $8 per square foot, depending on the type of material used in covering the structure. The midpoint between estimates for double-layer film ($4.23) and corrugated polycarbonate ($6.23) is $5.47. This includes the costs of fans, groundcover, ventilation control, shade cloth, and labor.
54. The quote was $11,175 for 100 feet of greenhouse space, and our budget assumes 320 feet of greenhouse space for crop production for a total of $35,760.
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