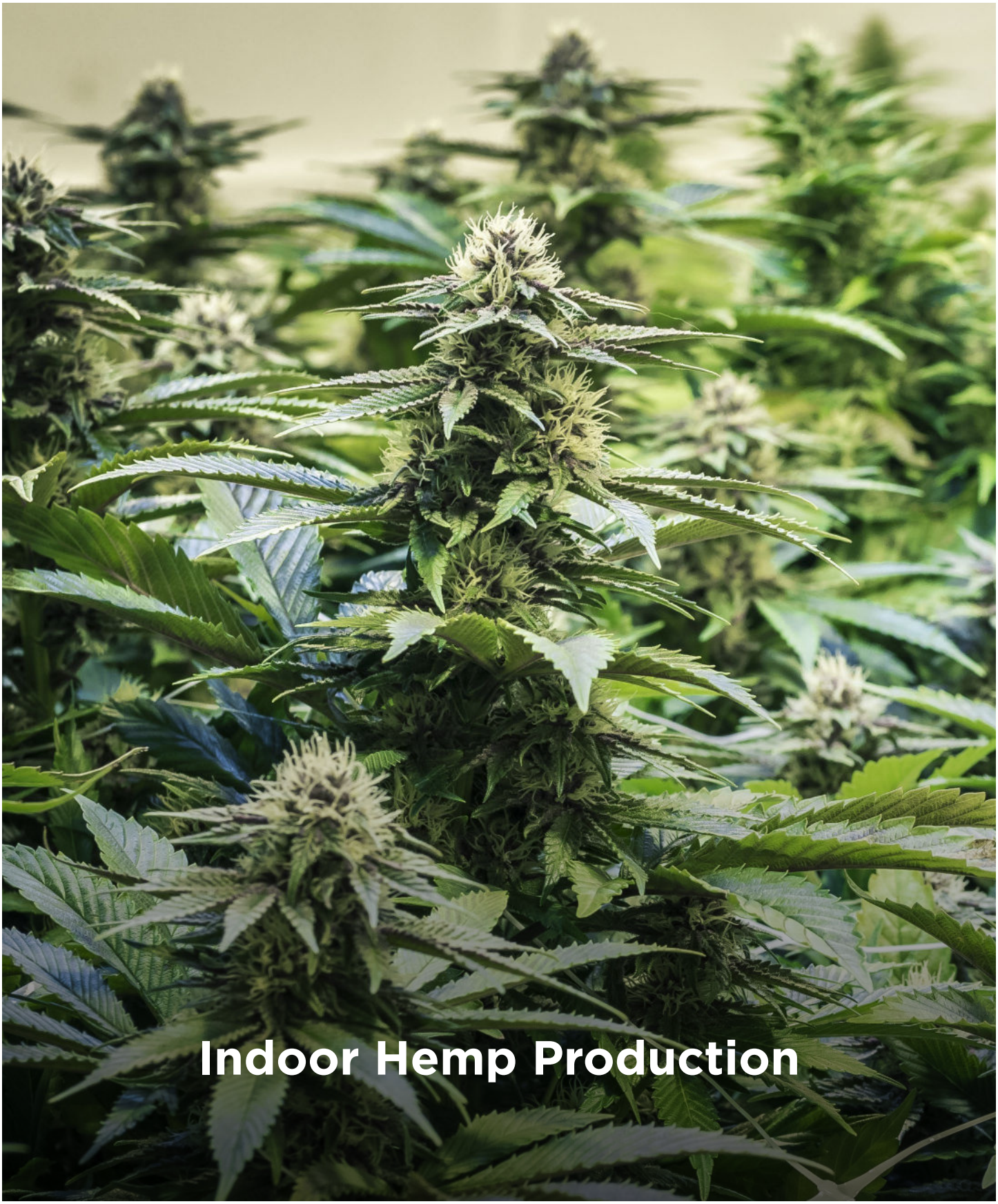

Indoor Hemp Production

Transformation

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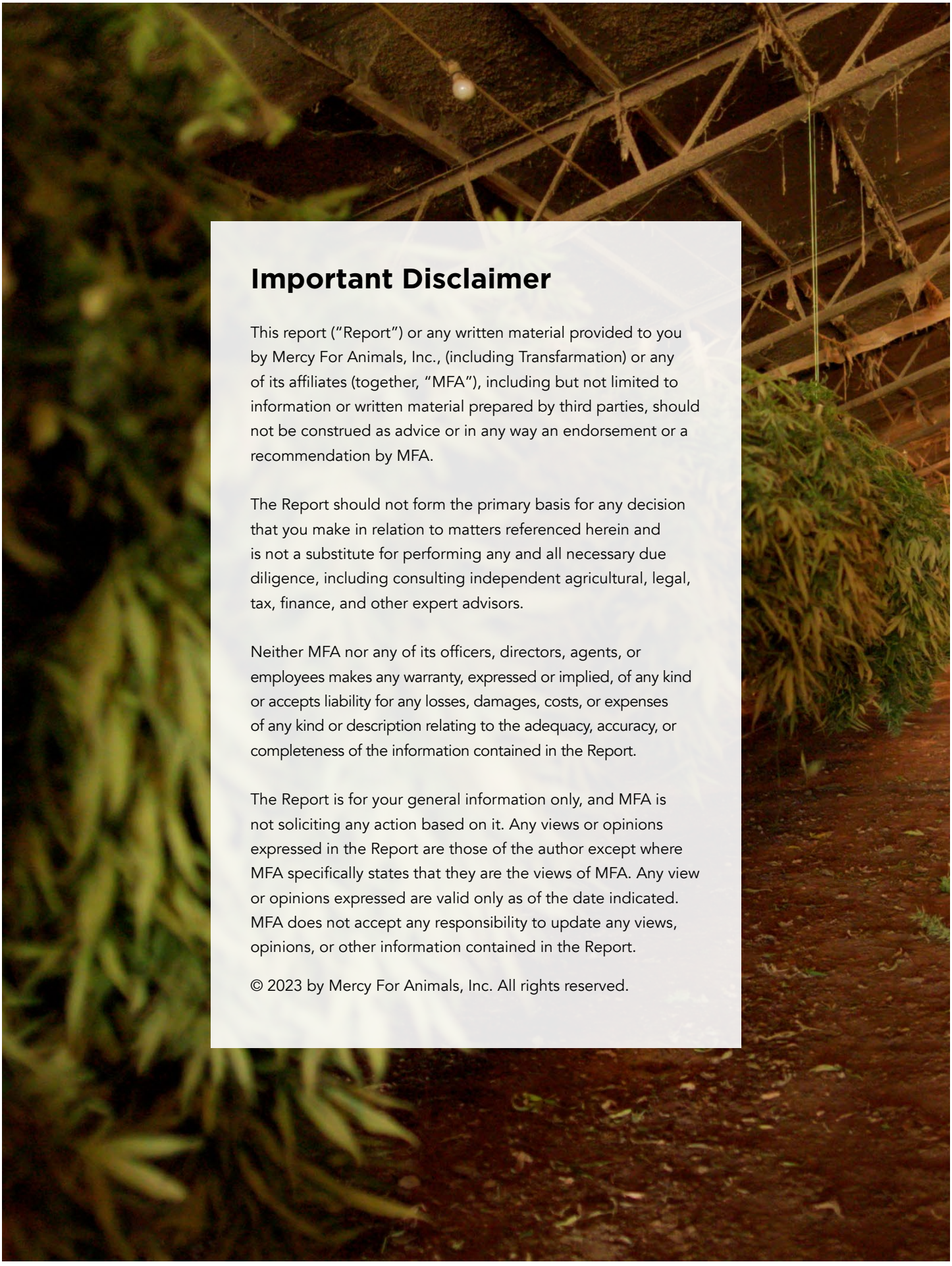

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Introduction

Indoor hemp production enables the producer to control all environmental production factors and allows for multiple harvests throughout the year. This production method is more expensive than outdoor production, however, and is viable only for a high-valued product that can be derived from hemp. High-concentration cannabidiols (CBD), generally considered the most valuable type of hemp to produce, are the most common end product for indoor hemp production. The following sections detail the nationwide market conditions for CBD hemp—riddled with regulatory uncertainty and oversupply at the moment—and provide information on typical production practices, as well as an enterprise budget, which demonstrates that intensive indoor hemp production is probably not viable at this time.

Market

- Hemp is a non-psychoactive variety of *Cannabis sativa*. Hemp products were not differentiated from those of other cannabis plants (like marijuana) until passage of the 2018 Farm Bill (Hudak 2018).
- The 2018 Farm Bill led to a rapid production response from agricultural producers lured by the opportunity for large financial gains and a new crop in their rotations. It also piqued interest in CBD extract.
- Prior to passage of the 2018 Farm Bill, the FDA had approved a drug (called Epidiolex) with the active ingredient of CBD for treatment of seizures related to rare pediatric diseases. It is unlawful under the Federal Food, Drug and Cosmetic Act to introduce into interstate commerce a food containing the active ingredient in an approved drug (or a drug for which substantial clinical investigations have been conducted and the findings published). Thus, **selling supplements or foods that contain CBD across state borders is unlawful** (FDA 2023).
- The FDA's regulations around CBD have led to significant volatility in market demand and associated hemp prices. For example, CBD distillate prices averaged $3,500 per kilogram in 2019 (after passage of the Farm Bill but prior to the FDA's stance on regulation of CBD) but are now around $1,000 per kilogram. Similarly, prices for hemp-flower extract are currently around $160 per pound, down from a high of $250 per pound in 2019 (Deliberto 2021).
- The current supply glut in the hemp CBD market is not expected to diminish any time soon (Quinton 2021).
- The most recent USDA estimated value of hemp production indicates that CBD is still driving the market value of hemp domestically. The USDA estimated the value of hemp produced indoors at $112 million in 2021, of which $64.4 million was for "floral" purposes. One-quarter was for transplants and clones ($23.8 million), and the remaining one-quarter was for seed ($23.7 million) (USDA NASS 2022).
- The total value of all hemp in 2021 was $824 million (including open production), of which the value for floral purposes was $623 million (USDA NASS 2022).
- Yields and prices vary substantially for different hemp products and across reporting entities (the USDA and private parties, such as Kush.com). Without actual long-term observations of U.S. hemp prices and production, modeling the profitability of industrial hemp with accuracy is difficult (Deliberto 2021).

Production Practices

In 2021 15.6 million square feet of industrial hemp were produced under cover (indoor grow operations and greenhouses). The difference between an indoor grow operation and a greenhouse is access to natural light.

Our budget focuses on indoor, hydroponic hemp production with four planting cycles annually. Specific operating costs and production practices will depend on the hemp variety, type of climate control, lighting,

and nutrient systems. Below we describe the ideal conditions related to the key parameters for hemp production and follow this with an enterprise budget that models the cost of running a hemp-production operation to satisfy these key parameters.

Light
Lighting control is an important aspect of hemp production because many CBD varieties are short-day, meaning flowering does not occur until daylight is less than 12 hours per day. Some hemp varieties are auto-flowering, meaning the flowers, buds, and trichomes begin to form before the short-day period. In an indoor grow operation, light scheduling generally allows for two months of growth under 18 hours of light and one month under 12 hours of light. This allows for optimal production and up to four harvests over 12 months (Myers 2021). Recent research suggests that no other crop benefits from longer light periods the way cannabis does and that the plant has sufficient photoprotective pigments to benefit from more light relative to daylight hours, in controlled settings without UV light (Bugbee 2022).

Carbon Dioxide (CO_2)
Elevated levels of CO_2 have been shown to increase photosynthesis. A CO_2 level of around 1,200 parts per million (ppm) is considered the optimal saturation point for indoor production (Bugbee 2022). Factors all correlate, so as optimal CO_2 conditions are met, optimal fertility, lighting, humidity, etc., will be necessary to reap the marginal benefits of the investment in supplemental CO_2.

Temperature
The ideal temperature for hemp in all growth stages is the mid 70s (°F). No advantage of cooler night temperatures has been determined.

Air Flow
A full air exchange at least once a minute is recommended for hemp production. Fans that create an active air exchange in the production area are optimal for plant production. In post-harvest processing, a full air exchange of once per hour is recommended (Bhowmik et al. 2020).

Nutrients
Too much nitrogen at the growth stage can cause excessive and lengthy vegetation. The optimal phosphorus level is around 30 ppm; additional phosphorus has diminishing returns. The plant seems to actively take up calcium unlike most crops, which take it up passively. Potassium, however, is slowly absorbed by the plant. In all hydroponic substrates, such as rockwool and coconut coir, levels of silica are inadequate. Soluble silica can help build disease resistance, eliminate powdery mildew, and mitigate heavy-metal toxicity, which is important for health products created from hemp (Bugbee 2022).

Enterprise Budget

Industrial hemp produced indoors is a specialty horticultural crop that requires intensive management. The enterprise budget for indoor hemp production is a generalized reference and should be adapted to the specifics of any production operation. For this enterprise budget we model 16,000 square feet of production space and 4,000 square feet of space for drying and curing products. The total footprint (20,000 square feet) is equivalent to that of a poultry house that is 400 feet long and 50 feet wide.

Yields and Prices Paid

Hemp has many uses, along with cultivars that are well suited to specific uses. For this enterprise budget we focus on indoor CBD varieties. As mentioned, hemp produced indoors in the United States is sold into floral uses—smokable buds or CBD uses—transplants for outdoor CBD varieties, and varieties of CBD seed.

"Floral hemp" refers to hemp produced for CBD, which can constitute 10%–20% of the buds' weight and also exist in the biomass of the plant at lower percentages. For field-grown floral hemp, the entire plant is commonly harvested, dried, and processed for CBD. For indoor floral hemp, the harvesting focus is generally the buds, which makes indoor production more similar to marijuana production.

We estimate that four cycles of indoor production (each lasting three months) could be achieved under optimal conditions. With 16,000 square feet of production space, we estimate that each grow cycle could produce 3,200 plants, or 12,800 plants over an entire year.

Hemp-bud yields are likely to be around nine to 18 ounces per plant. As discussed below, the buds will need further drying and curing prior to sale, which would result in a saleable yield of 1.8 to 5.4 ounces per plant after accounting for a 70%–80% loss in drying and curing. We expect this product to fetch $150–$250 per

pound. Note, however, that several states have banned smokable hemp due to law enforcement's inability to distinguish hemp from marijuana (Quinton 2020).

Beyond buds, hemp yields an estimated three to four pounds of additional biomass per plant (Darby et al. 2019). Given the size of operation modeled, this means an additional 51,200 pounds of raw product, or about 11,200 pounds of dried hemp biomass for CBD distillation. We expect this biomass to fetch around $4.80 per pound (10% CBD at $0.48 per CBD percentage point). The enterprise model assumes that the plant product is optimized and both smokable buds and CBD biomass will be sold to maximize profit. Therefore we estimate just over $800,000 in annual gross returns.

Labor

Indoor hemp cultivation requires significant labor inputs. While the existing literature on hemp production details instructions for growing hemp, it lacks precise labor estimates. Further, labor-hour estimates seem to vary significantly depending on (1) **producer skill level** (novices take longer and accomplish less per plant than skillful operators); (2) **individual human traits**, which result in different levels of productivity, as with other agricultural operations; and (3) **scale**, as many steps are involved and larger production volume greatly reduces labor input per pound. We estimate that the hemp venture would require 12,000 hours annually—six full-time employees—and that labor would include the following tasks:

1. Setting up, transplanting, and operating irrigation lines: 500 hours x 4 cycles = **2,000 hours**
2. Pruning and shaping growth stage: 400 hours x 4 cycles = **1,600 hours**
3. Harvesting and post-harvest requirements: 2,000 hours x 4 cycles = **8,000 hours**
4. Other (e.g., scouting, adjusting controls): 100 hours x 4 cycles = **400 hours**

Inputs

Hemp production's main material inputs are the clones (or transplants), growing substrate and nutrients, and carbon dioxide. We estimate that the clones will cost about $2 per plant (Superior Hemp Clones, n.d.).

Growing substrates such as coconut coir, rockwool, and clay pellets could be used in a hydroponic setup. This budget assumes that one four-inch rockwool cube will be used per plant. A pack of six costs around $18. Accordingly, 12,800 plants would require 800 units of rockwool, or $14,400 annually.

Nutrients and growing solution can be mixed manually and injected into the drip system or part of an automatic dosing system. The main amendments to be purchased are a pH controller, fertility applications for the vegetative and flowering stages, and water-soluble silica. We estimate that these amendments will cost $7 per plant, or $89,600 annually, in a hydroponic system (Caulkins 2010).

As indicated, supplemental CO_2 has demonstrated yield improvements in indoor production. Increased CO_2 is achievable through piping waste CO_2 from industrial operations, such as wineries or breweries,[1] or adding environmental controls and CO_2 generators, which create propane or natural gas. This analysis models a large CO_2 tank and delivery of liquefied CO_2 from a truck as needed. We model CO_2 needs at around eight pounds per hour of the growing cycle, with CO_2 turning off a couple of hours before the light source turns off (Leidel 2019)—or 80,640 pounds per year. CO_2 prices are about $1.25 per pound (Norco Inc. representative, interview by Travis Greenwalt, April 2022). Thus, we estimate CO_2 inputs would cost around $100,800 annually.

Utilities

We expect the electricity requirements for lighting alone will be 957,600 kilowatt hours (kWh). This includes inside lighting for 18 hours per day during the growth stage (two months every cycle) and 12 hours per day during the flowering stage (one month per cycle). Heating and cooling to maintain a 70°F–75°F temperature and fans for airflow require an additional 1,600,000 kWh (Mehboob 2020). At a cost of $0.12 per kWh this constitutes a total of over $300,000 annually.[2] Utilities represent around 40% of total variable costs of the greenhouse operation.

Post-harvest

Drying is carried out in a portion of the house not used for growing. Typically, the plants are placed on racks or hung upside down in an area kept at 60°F–70°F. The ventilation requirement is one air exchange per hour.

[1] For example, The Clinic (a Denver-based dispensary) partnered with Denver Beer Company to recover leftover CO_2 from the brewing process. CO_2 gas is bottled and then released to supercharge plant growth (Brasch 2021).
[2] This estimate was derived from electric space-heating requirements as opposed to natural gas or propane.

Drying the buds and plants may take several weeks, where 70%–80% of the plant weight will be lost.[3] For the biomass to be used in CBD oil, only drying is required. Where buds are to be sold as smokable, however, the buds must undergo a curing process, which entails drying at a lower temperature and thus slower rate with the intent to reach 62% relative humidity. Curing is carried out in an area with a stable temperature of 60°F–72°F and can take several months (Bhowmik et al. 2020). We model drying and curing to occur in the additional 4,000 square feet of house available. The budget mentioned above models utilities and labor for these processes.

Other Operating Costs

Miscellaneous costs include laboratory fees, estimated at $1,500 per crop ($6,000 per year), for testing each crop to ensure the hemp THC levels fall below the 0.3% regulated level; other supplies ($2,000); and packaging, transport, and storage ($5,000). In total, this category is anticipated to represent $13,000 per year, or 2% of operating costs.

Cash Overhead

Property taxes for the grow operation will be specific to the location but are modeled at $250 per month, or $3,000 per year. Some states may impose income or other applicable taxes, but we do not model these here. This analysis does not assume any land costs, so the profit identified below should be considered a return-on-land estimate. General liability insurance is modeled at $70 per month and property insurance at $200 per month. Total insurance costs are therefore estimated at $3,240 annually.

Capital Costs and Non-cash Overhead

The capital cost of the conversion from the existing poultry house to an indoor hemp grow house is estimated at $7.50 per square foot, or $60,000 for the structure. This cost includes installation of a floor, a ventilation system, and walls to separate the growing area from post-harvest areas. No clear film or covering is required, as the light control necessary for this crop is more easily achieved in a covered area. In addition, we identify environmental controls for HVAC systems; the CO_2 tank; and distribution—along with irrigation pumps and emitters—as growing equipment in the list below, which estimates a total initial investment of $430,000 (Cannabis Business Plan, n.d.):

- Buildout Improvements: $120,000
- Growing Equipment: $150,000
- Lighting System: $120,000
- Alarm and Security: $45,000
- Licensing and Legal Fees:[4] $55,000

Thus, the total capital expenditure estimate is **$490,000**. This analysis further assumes the owner could finance the conversion through existing loan programs offered by the Small Business Administration (SBA), the United States Department of Agriculture (USDA), and possibly other lenders. Our analysis models the debt-service terms of the SBA 504 program—10% equity requirement (90% financed)—or $49,000. Further, the financial analysis below considers 10- and 20-year notes, at 6.5% and 6% interest, respectively (CDC Loans, n.d.).

Net Profit

On the basis of assumptions outlined above, including projected yield and product mix, the most likely profit potential from a 16,000-square-foot indoor hemp grow operation is negative. This aligns with reports of a supply glut of CBD hemp in the marketplace now and also projections of decreased planting of hemp. The following table presents estimates of an annual operating budget for industrial hemp grown indoors based on current conditions.

[3] Curing the buds requires a slower drying process than that of drying the biomass for CBD oil.

[4] This is probably an overestimate of licensing and legal fees, as it is specific to medical marijuana, not industrial hemp.

Table 1: Representative indoor industrial hemp budget

	Unit	Quantity	Price	Value
Gross returns				**$805,760**
Smokable buds	lb	3,760	$200	$752,000
CBD biomass	lb	11,280	$4.80[5]	$53,760
Variable costs:				
Cloning and transplants	Plants	6,400	$2	$25,600
Rockwool cubes, four-inch	Units	400	$18	$14,400
Grow solution and nutrients	Harvests	4	$11,200	$89,600
Carbon dioxide	Pounds	40,320	$1.25	$100,800
Labor	Hours	6,000	$17.58	$210,960
Lighting / electricity	kWh	478,800	$0.12	$114,912
HVAC energy	kWh	800,000	$0.12	$192,000
Other supplies	House	1	$2,000	$2,000
Lab testing	Each	4	$1,500	$6,000
Packaging and transport	House	1	$5,000	$5,000
Property tax				$3,000
Insurance				$3,240
Total operating cost				**$767,512**
Operating income				**$38,248**
			Debt obligation (20-year, 6.5% interest)	$38,450
			Debt-service coverage	**0.99**
			Debt obligation (10-year, 6% interest)	$61,345
			Debt-service coverage	**0.62**

The expected operating profit of $38,248 from the converted poultry house represents a profit of $2.40 per square foot of production area. 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 1.00 indicates potential solvency problems, while a DSCR of at least 2.00 is generally considered very strong. As the table above indicates, the DSCR is less than 1.00; thus, we expect that the operation would struggle to generate enough cash flow to pay back the debt required for this type of venture.

Sensitivity

We undertook a sensitivity analysis to evaluate the impact of key assumptions on the profit estimate for the enterprise modeled. These key assumptions are as follows:

- Yield of hemp buds (0.75–1.5 pounds annually)
- Price paid of smokable (cured) hemp buds ($150–$250 per pound)
- Yield of other dried hemp biomass for CBD (3–4 pounds per plant)
- Price paid of dried hemp biomass ($0.3–$0.55 per percentage point CBD)
- Percentage CBD of dried biomass (8%–12%)
- Electricity costs ($0.1–$0.14 per kWh)
- Labor hours (8,000–16,000)

[5] This is probably an overestimate of licensing and legal fees, as it is specific to medical marijuana, not industrial hemp.

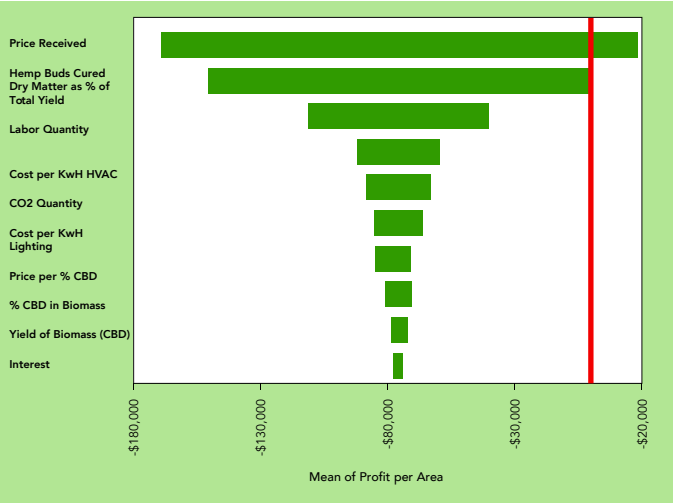

Figure 1. Sensitivity analysis results.

Price paid for cured hemp buds is the most sensitive variable of those considered in this model. The red line indicates the profit level at which the DSCR would be more than 1.00. The uncertainty of price points makes this a risky venture to consider at the present time. One caveat to the findings of this analysis is that this enterprise budget models high-intensity hemp production in a controlled setting. Less expensive methods could be employed to produce hemp, such as in a greenhouse without supplemental CO_2, but the yield potential, number of harvests, and percentage of CBD would decrease relative to the figures presented here.

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