Value Chains for the Missouri Industrial Hemp Industry

Guide for entrepreneurs to understand the value chains and business opportunities in offering fiber, grain and cannabinoids

Commissioned by the Missouri Hemp Producers Association with funding from the Missouri Agricultural and Small Business Development Authority

December 2019

MISSOURI HEMP PRODUCERS
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The following report was commissioned by the Missouri Industrial Hemp Steering Committee to prepare Missouri producers for the 2020 rollout of industrial hemp in the state. Funding was provided by the Missouri Agricultural and Small Business Development Authority through its Missouri Value-Added Grant Program.

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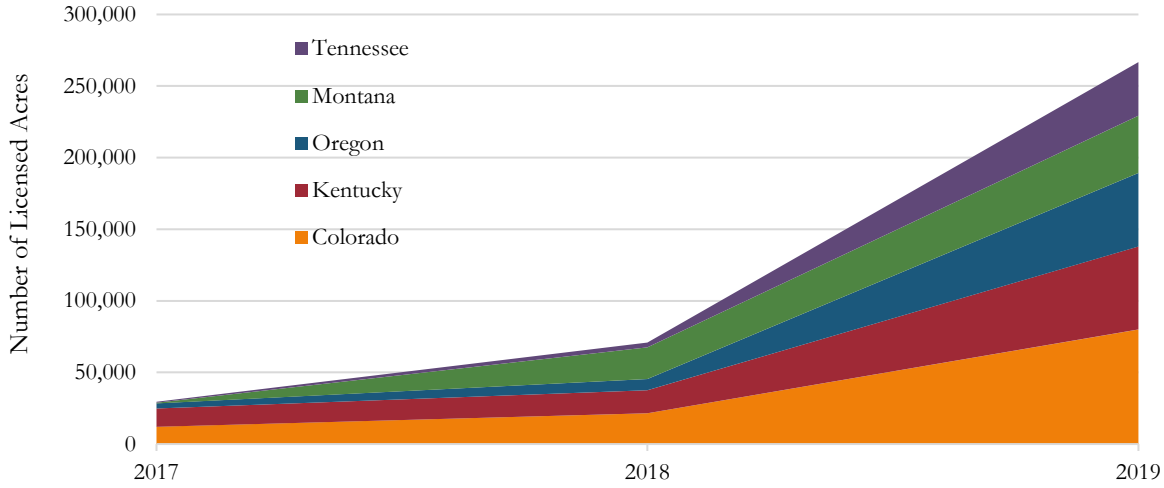
Introduction

Industrial hemp acreage has expanded rapidly in the U.S and is expected to expand further. Exhibit A1 shares the number of licensed industrial hemp acres in leading states from 2017 to 2019. Note, not all licensed acreage is planted and successfully harvested. With no official estimates available, this report's authors estimate that approximately 130,000 acres were harvested in the U.S. in 2019. A majority (more than 80 percent) of the U.S. industrial hemp acreage in 2019 was estimated to be grown for cannabidiol (CBD) extraction.

Exhibit A1 – Major U.S. Industrial Hemp States, Licensed Hemp Acreage, 2017 to 2019



Source: Sterns (2019)

Rapid acreage expansion creates a seller's market for inputs such as feminized seed, seedlings and clones. Likewise, a shortage of specialized harvesting, drying and processing equipment is creating a bottleneck in the supply chain. Harvesting and processing equipment suppliers are rapidly innovating to meet producer needs for larger scale equipment.

Processing capacity for seed, fiber and cannabinoid extracts is expanding at different rates in different geographic regions, and CBD extraction has led the growth. See Exhibit A2 for a breakdown of the number of industrial hemp processors and growers by state in 2019 based on a survey completed by Whitney Economics LLC. The survey reflects an average of one processor for every four growers or 107 licensed hemp acres across the U.S.

Across the U.S. hemp value chain, processing capacity may not be sufficient to handle greater hemp production. At the same time, the primary products processed from record industrial hemp acreage face uncertain demand. For CBD extractors, the U.S. Food and Drug Administration (FDA) regulatory uncertainty regarding CBD's inclusion in foods, beverages, dietary supplements and pharmaceuticals raises ambiguity in their capital spending plans and timelines.

Exhibit A2 – Industrial Hemp Growers and Processors by State, 2019

State	Acres Licensed (at time of survey)	Number of Growers	Numbers of Processors	Growers Per Processor	Acres Per Processor
Alabama	8,000	152	59	2.58	135.59
Arizona	3,135	115	57	2.02	55.00
Arkansas	3,200	80	18	4.44	177.78
Illinois	12,949	475	100	4.75	129.49
Kansas	3,600	176	33	5.33	109.09
Kentucky	42,000	1,047	120	8.73	350.00
Michigan	25,000	331	223	1.48	112.11
Montana	40,000	277	10	27.70	4,000.00
New York	11,722	430	79	5.44	148.38
North Carolina	14,400	1,212	730	1.66	19.73
North Dakota	4,000	64	9	7.11	444.44
Tennessee	38,000	2,700	102	26.47	372.55
Utah	4,225	155	32	4.84	132.04
Vermont	7,800	820	158	5.19	49.37
Virginia	8,500	800	57	14.04	149.12
Washington	6,000	44	63	0.70	95.24
Wisconsin	38,300	1,405	692	2.03	55.35
Total	**270,831**	**10,283**	**2,542**	**4.05**	**106.54**

Source: Whitney Economics, LLC. (Allen and Whitney, 2019)

Bargaining positions of companies selling genetics and processing equipment are strong during periods of rapid production expansion. Likewise, buyers of raw farm products are in strong positions to bargain for lower prices in oversupplied markets. Given these two dynamics, industrial hemp producers buying high-priced inputs and selling raw products, either contracted or on the open market, face the prospect of declining profit margins — the situation with which many agricultural commodity producers are familiar.

The prospect of longer-term processing profits may be expected to drive capacity expansion. Acreage expansion and equipment innovation will lower the cost of production. Industrial hemp-derived products are expected to move from niche markets into more mature markets with large-scale usage. Hemp processing is in transition from its small-scale "alternative agriculture" roots to larger scale processing more common among other agricultural commodities.

As prices of hemp-derived materials begin to decline, the hemp materials may have a greater opportunity to displace competing materials in final goods. For example, hemp bast fiber competes for market share against fibers such as jute, cotton, wool and synthetic fiber. Hemp hurd competes against wood pulp and shavings for use in animal bedding and building materials.

Agricultural entrepreneurs interested in hemp's future will find potential profits along the value chain— from the farm level through retail. The U.S. industrial hemp industry will likely follow the path that unfolded in Canada, where the crop has been legal since 1998. In Canada, hemp acreage has cycled between expansion and contraction year over year as processing has developed

sporadically. Market prices have alternated between favoring producers and processors. Longer term, the trend has been toward higher acreage, lower commodity prices, expanding product development and international market development.

Hemp production for seed, fiber or cannabinoid extraction will expand at different rates dependent upon relative profitability, agronomic complexity and processing growth. With no limit on state licensed acreage, many Missouri growers are expected to explore hemp production.

Missouri producers may experiment with small acreages until they understand the agronomics well and have access to proven harvesting and storage solutions. Larger acreage for CBD production may be initiated in regions bordering existing hemp production states. Producers in these areas may enter into contracts with existing processors that have field advisers and post-harvest drying and storage solutions. Grain acreage can expand and supply nearby or distant processors as farmers incrementally learn to grow the crop. Fiber hemp acreage will expand in areas with close proximity to decorticators.

The following sections detail opportunities and challenges with Missouri's industrial hemp value chains. The discussion includes example costs of hemp processing, potential opportunities for agricultural entrepreneurs to investigate and pathways to collective entrepreneurship.

Exhibit A3 – Industrial Hemp Value Chains and Linkages

Crop	Farmer's Critical Link	Processing	Primary Product(s)	Final Products
 CBD	*Drying *Bucking *Storage	Extraction	*CBD Crude Oil	
 Grain	*Screening *Air Flow *Storage	Oilseed Cold-press or Huller	*Hemp Hearts *Hemp Seed Oil *Hemp Protein	
 Fiber	*Baling *Storage	Decortication	*Bast Fiber *Hurd Fiber	

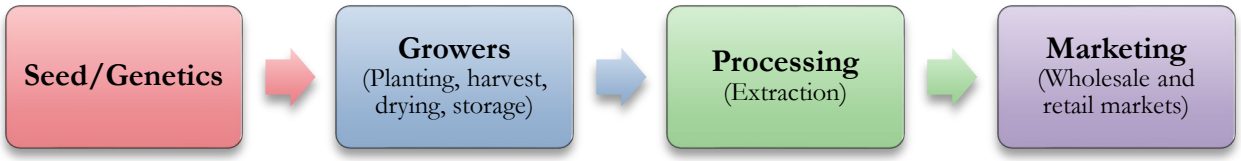
1. Value Chain for Industrial Hemp - CBD

1.1 Stages and Needs in the Industrial Hemp CBD Value Chain

CBD is leading the acreage and processing growth in the U.S industrial hemp industry. With some states beginning CBD production under state-level pilot programs in 2014, some producers and companies have profited well from early successes in CBD production and processing. Processors, wholesalers and retailers have launched a variety of CBD products in the marketplace. Consumer demand for these products has stimulated the industry.

A general framework for the CBD industrial hemp value chain is detailed in Exhibit 1.1.1. Each key component of this value chain is described in more detail below.

Exhibit 1.1.1 – Overview of Industrial Hemp CBD Value Chain



Seed and Genetics Suppliers

Industrial hemp producers must carefully select varieties that yield a high CBD concentration which maximizes the selling price. Varieties should also yield a THC level that complies with Missouri and federal regulatory provisions.

Female plants, especially the flower-bearing structures and bracts closely associated with the flowers, have the highest CBD concentration. Therefore, female plants are started in the greenhouse as clones using cuttings from a "mother" plant or from "feminized" seed from a seed supplier. Alternatively, some growers have planted seed in the greenhouse and manipulated photoperiod conditions to differentiate males from females. Then, they have destroyed the males and transplanted females to the field.

Key Need:
Quality genetics that meet three conditions: 1) conducive to Missouri's soils and climate, 2) capable of optimizing CBD production and 3) consistent in yielding THC levels that comply with state and federal regulations

Input supply companies include sellers of seed, feminized seed, clones, seed treatments, specialized fertilizers and consulting advice. With the ban on industrial hemp only recently being lifted in the U.S., genetics may come from Canada, China or Europe. Suppliers in early-adoption states such as Kentucky, Tennessee, Colorado, Oregon and California may connect with Missouri growers and agricultural service providers to offer seed, supplies and consulting packages.

Grower Operations

To produce industrial hemp for CBD, growers currently raise all female plants in wide spacings to maximize flowering. The industry standard method is to transplant female plants into the field using a vegetable or tobacco transplanter. To harvest industrial hemp for CBD, growers choose from several methods. Harvesting by hand, hanging to dry and then stripping or "bucking" the floral material is a common practice in many areas. Alternatives include mechanically chopping the top material for mechanical drying. Mechanical field-stripping of fresh floral and leaf material to be extracted or dried is another developing system. As the industry evolves, harvest and drying efficiency will be critical. Equipment manufacturers and producers continue to innovate to improve the harvest process.

Producers harvest carefully to preserve the cannabinoid-rich floral calyxes and bracts. For hemp grown for CBD and other cannabinoid extraction, quality control in harvest, drying, bucking and storage greatly affects the value and salability of the crop.

Key Needs:

- Effective equipment solutions for planting and harvest
- Good drying and storage solutions post-harvest, either on-farm or at the processor
- Crop insurance program
- Access to capital and banking

Plants are commonly dried before floral parts are harvested. This process is similar to tobacco being dried in tobacco barns. Growers experimenting with small acreages will want to develop confidence in drying capabilities before scaling acreage to meet expanded contract opportunities.

Producers under contract to deliver dried biomass material or those who sell on the open market will need to invest in a drying solution. Drying solutions can be as simple as hanging whole or partial plants in a barn that supports air movement. Equipment for drying may be as advanced as gas dryers, modular tobacco dryers or hops dryers. Technology is developing fast in the industry. If the demand for CBD grows with FDA approval for food additive or medicinal uses, larger volume drying solutions may be expected.

Storage is another important consideration. General recommendations provided by processors should be followed by growers to prevent product degradation and mold issues (Sandy, 2019).

- Quarantine and test biomass samples before putting in climate-controlled storage.
- Maintain consistent 10 percent moisture for long-term storage.
- Maintain temperatures between 68 degrees Fahrenheit and 78 degrees Fahrenheit.
- Monitor daily.

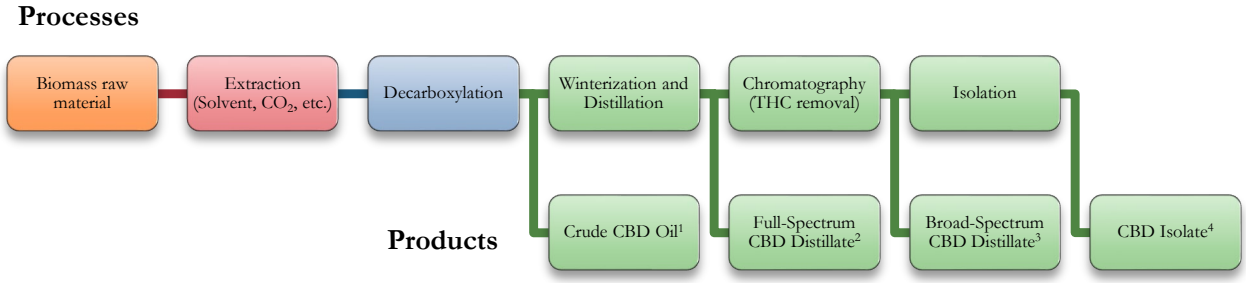
Larger scale drying and storage facilities will develop as producers connect with experienced companies offering more capital-intensive drying solutions. Some producers may skip the assembly and storage function entirely if they contract fresh biomass directly to processors, as some currently do in major production areas such as Kentucky.

Processing and Extraction

Hemp floral and leaf biomass processing for cannabinoid extraction was typically done first on a small scale by vertically integrated medicinal herb companies that sold their own branded products. More extractors have entered the industry, and the shelf space devoted to branded CBD products has become crowded. Larger extraction companies employing multiple extraction units are

becoming common. Extraction companies may buy hemp biomass from producers under contracts or through bids or online marketplaces. As a service offered to hemp producers, many extractors toll process floral biomass into crude hemp oil; refined hemp oil (full-spectrum or broad-spectrum); CBD isolate; or white label products. White label products are sold by retailers with their own branding but the products are manufactured by a third party. In addition, some extractors process producers' material for a share of the crude oil or final product, with share splits depending on product delivered.

Exhibit 1.1.2 – Overview of Industrial Hemp for CBD Processing and Products



[1] Crude CBD oil contains all waxes, fats, chlorophyll, etc. after extraction.

[2] Full-Spectrum CBD Distillate is generally between 70% and 80% CBD and contains other cannabinoids and terpenes including THC.

[3] Broad-Spectrum CBD Distillate is generally between 80% and 90% CBD and contains other cannabinoids and terpenes but does not contain any THC.

[4] CBD isolate is the purest form of CBD and is around 99% CBD.

Exhibit 1.1.2 depicts a general overview of the processes and products generated from industrial hemp grown for CBD processing. The first step is preparing the raw material. The dried floral parts are ground to prepare for extraction. Next, hemp oil is extracted. Most common extraction technologies in the market today are carbon dioxide, water and solvent extraction. Carbon dioxide extraction is a process that applies pressurized carbon dioxide to remove oils. In solvent extraction, the floral parts are mixed with a solvent such as alcohol or ethanol to draw out the oils. A water or steam extraction process uses water or vapor to extract oils. Extraction technologies are evolving. Equipment suppliers are manufacturing to optimize throughput and capital and operating costs and meet customer desires for finished products.

Key Needs:
- Toll-processing capacity for extraction
- Financial incentives to attract processor prospects or stimulate business development
- Access to capital and banking

Decarboxylation refers to heating the solution to release a carboxyl group from the compounds inside the extract, activating the cannabinoid and creating crude CBD oil. Crude oil contains fats, waxes, chlorophyll, cannabinoids, terpenes and other plant compounds. An oil's CBD content can vary depending on extraction method and the plant's CBD content, given that the oil has not been distilled of other compounds.

To further refine the oil, winterization removes some of the terpenes, lipids, waxes and chlorophyll. The raw extract is mixed with alcohol or ethanol. Then, it's frozen to separate the cannabinoids from other compounds in the extract. This solution can then go through distillation. The remaining

oil is full-spectrum CBD distillate, which contains 70 percent to 80 percent CBD and levels of THC. Chromatography separates THC from the CBD and other cannabinoids. Broad- spectrum CBD distillated via chromatography will have 80 percent to 90 percent CBD content and no THC. Further processing can refine and purify CBD into an isolate (99% CBD).

Retail and Wholesale

The retail landscape for hemp extract products has developed rapidly online and at small shops in strip malls across the U.S. These retail outlets typically sell CBD tinctures, oils, edibles, salves, vaping cartridges and smokables. They may also market other hemp products to hemp enthusiasts. Retail shops may be franchises linked to a large processor or distributor. See Exhibit 1.1.3 for examples of CBD products marketed online.

Key Needs:

- Entry of new extraction businesses to process in Missouri
- New product development with CBD or other cannabinoids
- Promotion of Missouri-based retail businesses selling local CBD

Exhibit 1.1.3 – Current Examples of CBD Products Sold Online

Full-Spectrum Hemp Extract Drops
Source: Pluscbdoil.com

CBD Topical
Source: Bluebirdbotanicals.com

Full-Spectrum Hemp Extract Soft Gels
Source: Broadwayhemp.com

1.2 Situational Analysis for Missouri Stakeholders

A strengths (S), weaknesses, (W), opportunities (O) and threats (T) analysis — or SWOT analysis — is used to summarize the development of a hemp CBD value chain in Missouri. External factors include opportunities available in the marketplace and threats that pose challenges to Missouri having a place in the industrial hemp for CBD industry. Internal factors include understanding the strengths that Missouri stakeholders could leverage as they pursue industrial hemp opportunities and the weaknesses that may create barriers.

Exhibit 1.2.1 – SWOT Analysis for Missouri Industrial Hemp for CBD Industry

Strengths	**Weaknesses**
• Farms may have profit potential if using family labor on limited acreage to produce CBD hemp • Missouri has the second largest number of farms in the U.S. behind Texas • Some growers have close proximity to experienced processors in Kentucky and Tennessee with first-mover advantages • Missouri does not require processors to be licensed or pay a fee; this may attract new firms	• Missouri's entering into the CBD industry after prices have dropped and early profits are gone • Growers face production issues in overcoming weed pressure, dicamba drift, diseases and pests • Drying and storage capacity represent needs • Current production has been built on labor-intensive practices, which limit scale • The CBD production system is much different from traditional row-crop systems and more like horticultural or tobacco operations
Opportunities	**Threats**
• Projected market growth for hemp-derived CBD used in food, cosmetics and supplements represents potential • Major companies, brands and processors will likely enter the industry if FDA regulation removes uncertainty • Niche markets exist for locally sourced CBD hemp and related products	• Other states have had rapid growth in producing and processing industrial hemp for CBD • Independent CBD products and brands have inched toward market saturation • Pending FDA regulation of CBD and its impact on the market may create a barrier to entry • Lack of CBD health research and knowledge gap within the medical community and among consumers represent a challenge

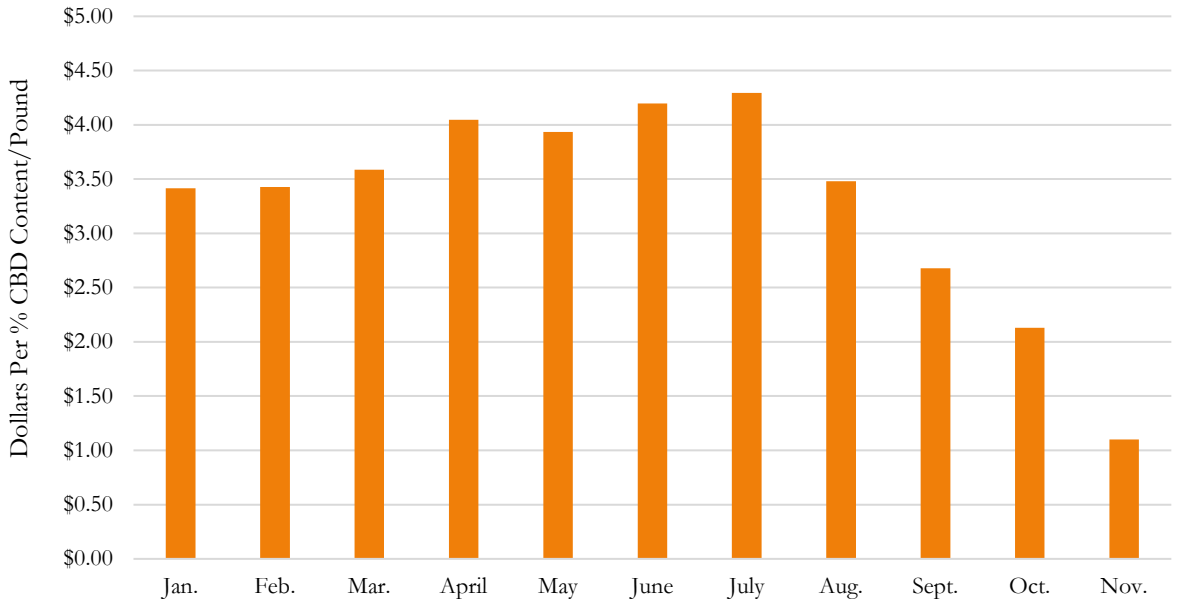
1.3 Industry Value Proposition

The industrial hemp industry is in its early stages in the U.S., and market pricing will evolve over time. In their farmer production contracts, many buyers and processors will list specifications about delivery point, form, acceptability, final pricing mechanics and deductions that will apply to crops.

There has been some movement to add price transparency to the CBD marketplace. Hemp Benchmarks® (hempbenchmarks.com) provides a monthly market price and intelligence report. PanXchange (panxchange.com) started reporting data in 2019. It posts monthly reports on biomass spot prices for Colorado, Kentucky and Oregon and refined hemp products for Colorado.

Exhibit 1.3.1 details midpoint hemp biomass spot prices (average of Colorado, Kentucky and Oregon) by month in 2019. Since July, industrial hemp biomass prices have decreased significantly. In November 2019, prices in Kentucky ranged from $0.80 to $1.25 per percentage point CBD content per pound (PanXchange Inc., 2019).

Exhibit 1.3.1 – Biomass Spot Pricing, 2019 Midpoint Prices Per Percentage Point CBD Content Per Pound



Source: PanXchange, Inc. (2019)

With a glut of biomass material in the market, prices have experienced downward pressure. In 2019, a majority of CBD growers did not contract with a buyer before harvest. See Exhibit 1.3.2 for data from growers in 18 U.S. states that indicated whether they did or didn't have a contract at the time of the survey (July and August). Approximately 65 percent of the industrial hemp biomass did not have a buyer before harvest. This represents about 417 million pounds of biomass. Buyers without contracts struggled to find markets. Some hemp auctions were used to stimulate transactions between buyers and sellers. Online biomass markets now exist for hemp-derived biomass and retail products. Examples include Hemp Raw Marketplace (hemp.rawmarket.place) and Kush (kush.com).

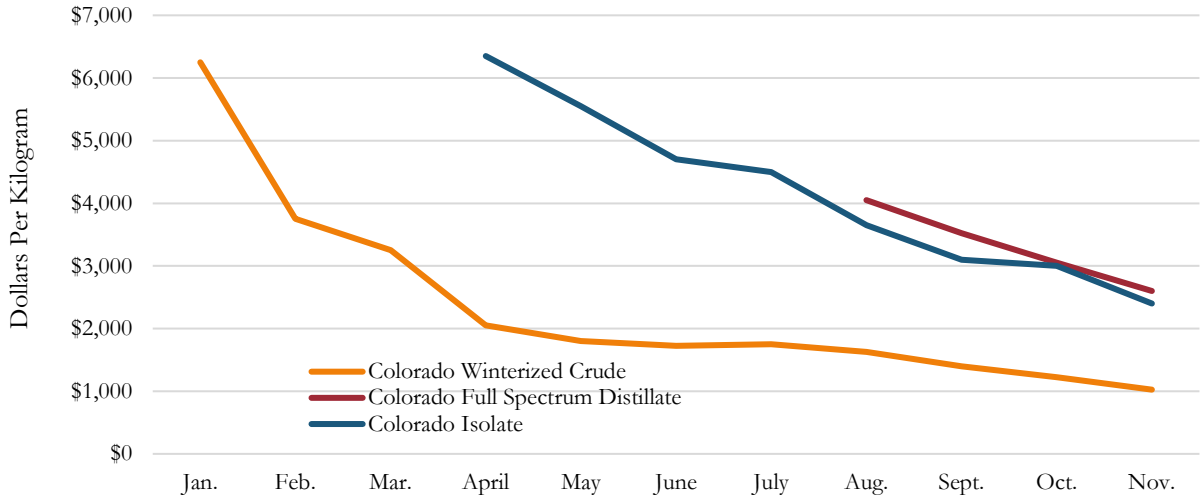
Exhibit 1.3.2 – Pounds of Biomass in Market With and Without Buyers, 2019

Respondent Type	Biomass Pounds	Percent
Buyer	224,554,400	35
No buyer	417,029,660	65

Source: Whitney Economics, LLC. (Allen and Whitney, 2019)

Exhibit 1.3.3 shows refined hemp product pricing in 2019. Products include winterized crude oil, full-spectrum distillate and isolates. For most of 2019, there has been downward movement in prices for each of these hemp products.

Exhibit 1.3.3 – Colorado Refined Hemp Product Pricing, 2019 Midpoint Prices Per Kilogram



Source: PanXchange, Inc. (2019)

1.4 Equipment in Hemp CBD Drying and Processing

Drying Solutions for CBD Hemp Producers

Drying field-harvested, CBD-rich biomass is the first step in the post-harvest value chain. Controlling the drying solution is critical for producers because drying reduces perishability, allows timely harvest and marketing and ensures quality control during storage. Solutions for drying can be as simple as hanging full plants in an unused barn with fans that move air and as complex as hauling to specialty-built dryers run by the extraction company offering vertically integrated contracts.

North Carolina State University's guide on drying hemp (catawba.ces.ncsu.edu/2019/02/drying-hemp-for-cbd-production/) indicates hanging plants inside with fans requires 800 square feet to dry one acre of production over three days.

Small-scale hemp producers report building a variety of low-cost solutions using screened boxes with forced air inside rooms with dehumidifiers that can dry material in a matter of hours. Plans for a mobile hops dryer built as part of a Sustainable Agriculture Research and Education Grant in Ohio may be helpful for ideas. Access more information at projects.sare.org/sare_project/fnc17-1103.

As acreage increases, larger drying solutions may be needed. Companies offering drying solutions for CBD hemp usually come with industry experience in drying tobacco, hops or marijuana. Available online, modular units fired by natural gas that claim to be able to dry up to an acre's worth of hemp biomass per hour have a capital investment of approximately $100,000. A few examples of equipment available in the marketplace include the following:

- hopsdryer.com
- gorstvalleyhops.com/growers/equipment/
- worldtob.com/cannabis-barns
- cannsystems.com/hemp-drying-systems/

Extraction

A variety of companies sell extraction solutions to entrepreneurs and businesses. Technological growth is occurring in extraction processing quickly, and those who wish to enter the industry should do their due diligence in understanding the capital investments, operating costs, throughput potential and operational needs of current technologies for industrial hemp extraction. Common extraction methods include carbon dioxide, steam distillation and solvent extraction. Exhibit 1.4.1 compares these extraction methods and their pros and cons.

Exhibit 1.4.1 – Comparison of Different CBD Extraction Methods

Extraction Method	Pros	Cons
Carbon dioxide extraction	*Efficient *Highest concentration of CBD *Easier to adjust concentration *No toxic residue or chlorophyll	*Expensive
Steam distillation	*Inexpensive *No toxic residue or chlorophyll	*Inefficient *Inconsistent concentration of CBD *Potential for heat to damage CBD oil
Hydrocarbon solvent extraction	*Efficient *Inexpensive *Consistent concentration of CBD *No chlorophyll	*Potential for toxic solvent residue
Natural solvent extraction	*Efficient *Inexpensive *No toxic residue	*Presence of chlorophyll affects taste *Lower concentration of CBD

Source: CBD Awareness Project (2019)

Capital investments have varied by extraction technology and company. June-Wells (2018) developed an example extraction plant model that can give some insight into the capital investments and operational costs incurred to run a carbon dioxide extraction plant. Exhibit 1.4.2 details capital investments, excluding the building structure, necessary for this extraction facility. The facility was assumed to offer 60 percent of its production as bulk full-spectrum oil and 40 percent as distillate. This represented 16.46 kilograms of full-spectrum oil and 8.78 kilograms of distillate produced on a weekly basis.

Exhibit 1.4.2 – Extraction Capital Costs (Excluding the Building), 2018

Item	Cost
Plant-drying infrastructure and grinding equipment	$75,000
Extraction equipment	$650,000
Reactors, filters, temperature control and holding vessels	$135,000
Solvent recovery system and cannabinoid distillation system	$305,000
Ancillary items	$75,000
Total	**$1,240,000**

Source: June-Wells (2018)

2. Value Chain for Industrial Hemp - Grain

2.1 Stages and Needs in the Industrial Hemp Grain Value Chain

The U.S. industrial hemp for grain industry is in its early stages of development. Hemp seeds can be used as whole seeds, undergo hulling to separate the hearts from hulls or be crushed to yield protein meal and oil.

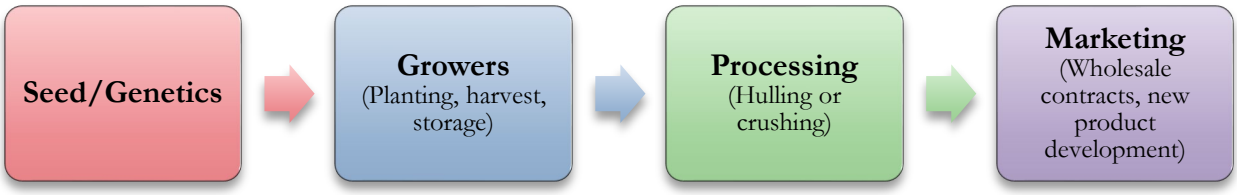
Deep commodity markets for large quantities of quality hemp grain have not yet emerged. Given its early stage, the U.S. hemp grain industry is beginning with smaller companies focused on food-grade processing. France, Canada and China represent a large portion of the world's current hemp seed production.

Exhibit 2.1.1 – Industrial Hemp for Grain Harvest

Historically, Canada has been a major supplier of hemp seeds, hemp oil and hemp seed oilcake to U.S. manufacturers and seed suppliers. Alberta, Manitoba and Saskatchewan in Canada have produced hemp grain since 1998.

Exhibit 2.1.2 provides a general framework for the industrial hemp value chain for grain markets.

Exhibit 2.1.2 – Overview of Industrial Hemp Grain Value Chain



Seed and Genetics Suppliers

Seed companies play an important role in the industrial hemp grain value chain. Missouri's proposed regulatory environment will allow growers to use non-certified seed, but producers must understand the THC testing threshold. Mandatory crop destruction from high THC levels is a real risk. Because Missouri-specific grain hemp variety trials have not been done, growers will look for seed selection guidance from genetics suppliers and companies that mandate certain varieties in their marketing contracts.

Data from other states and other countries at similar latitude may indicate suitable varieties that can grow well under Missouri's soils and climate. Hemp for grain production has been concentrated in Montana and the Canadian provinces of Alberta and Manitoba. U.S. university variety trials will be

Key Need:
Variety trials and development to screen genetics conducive to Missouri's soils and climate for optimal grain production

published as they become available. Some state departments of agriculture maintain lists of approved varieties for their states.

When selecting a variety, look for proven acceptable THC levels, percent germination, seed number per pound and indications the varieties are suitable for grain production. Further considerations are shattering potential and grain quality under Missouri's humid growing conditions. A close working relationship with a seed supplier and contracted hemp grain buyer will be important. Conducting on-farm trials of different varieties may be key to acquiring an early-mover advantage.

Grower Operations

At the farm level, producing hemp for grain is similar to producing other row crops. Hemp seed can be drilled or planted in tight rows.

Industrial hemp for grain can be harvested with traditional combine equipment. Harvesting hemp grain has been noted to be more difficult than harvesting traditional grain crops due to excessive wrapping. Hemp grain must be combined at high moisture to lessen shattering. A draper head on the combine has been suggested to minimize shatter losses.

Key Needs:

- Machinery equipment solutions for on-farm grain screening and low-temperature drying and aeration in segregated storage bins
- Crop insurance
- Access to capital and banking

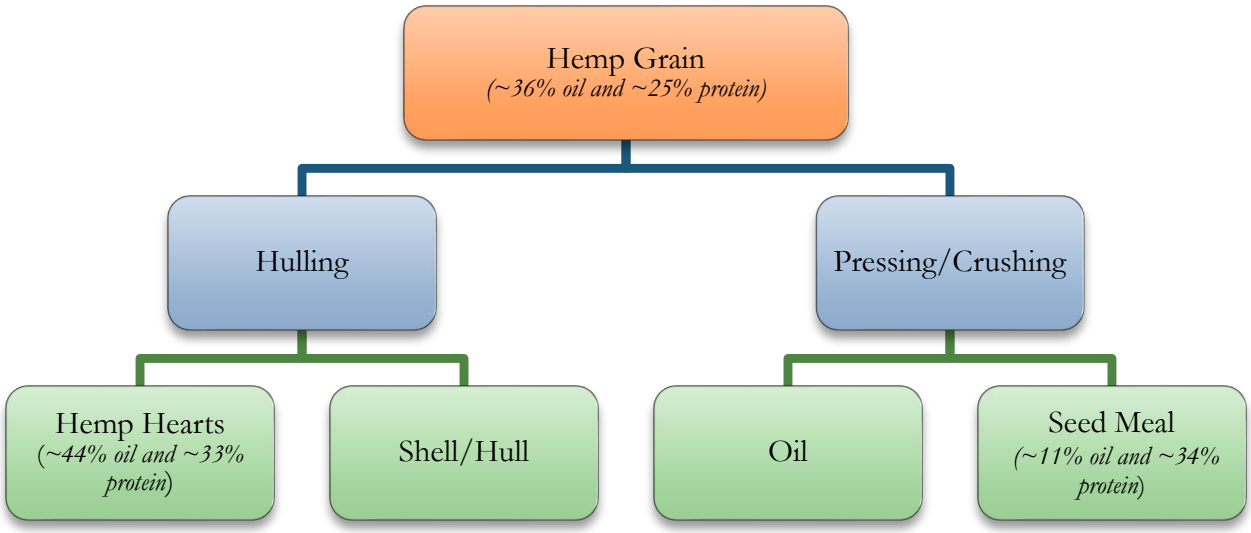
Assembly and storage of hemp grain affect salability. Because of its very high oil content, hemp grain must be dried with low heat. Hemp seed intended for food-grade products must have minimal foreign material and be kept aerated and stirred during storage to minimize molds and bacteria. Contract specifications typically include strict standards for foreign material, low mold spores and low bacteria counts. Food-grade quality control and segregation are important from combine to storage through hauling to final delivery.

Processing

Once grain has been dried and cleaned, processing commonly takes one of two forms. One process is hulling, which takes the "meat" out of the shell. Larger seeds are preferred. The meat, also known as hemp hearts, is sold as a food ingredient to be eaten directly or added to a variety of health foods.

The other process is cold pressing or crushing the seed, which yields hemp seed oil and seed cake. The oil can be used for cooking but has a relatively short shelf life and low burning temperature, so it is not ideal for frying. Hemp oil can be used as a healthy salad dressing. The seed cake is high in protein and can be used to make powdered high-protein health supplements. See Exhibit 2.1.3 for the processing methods of industrial hemp grain and nutritional compositions of hempseed products (Callaway, 2010). A bushel of hemp seed weighs 44 pounds.

Exhibit 2.1.3 –Industrial Hemp Grain Processing Products and Nutritional Composition



Hemp grain processing facilities typically contract some local hemp production acreage to ensure a supply but may buy additional seed on the open market. Processors buy delivered seed as needed throughout the year and require producers to store the grain.

Key Needs:
- Critical mass of hemp grain producers to stimulate variety development and handling infrastructure
- Processing firm with contract standards attainable with Missouri production conditions
- Financial incentives to attract processor prospects
- Access to capital and banking

Given that hemp grain currently trades at roughly $1,200 per ton, transportation costs to distant processors are not a major part of the crop's value. Hence, producers may reach out to distant processors in other states.

Successful hemp grain producers must understand the food-grade quality concerns of processor contracts. Learning to correctly harvest, screen, air dry and segregate hemp grain is an important skill set.

Wholesale and Retail

Hemp grain processors typically sell to wholesalers and distributors. They sell hemp seed hearts, hemp seed oil and hemp seed protein powders as packaged products to health food distributors either with their own brand or as a contracted private label.

Key Needs:
- New product development with industrial hemp grains
- Completion of hemp grain feed safety studies for animal species
- Promotion of Missouri-based businesses or industries adapting to hemp grain use

Because hemp seed-derived products are typically targeted for food-grade applications, the U.S. Food and Drug Administration (FDA) evaluates submissions from companies about product food safety. In 2018, FDA responded with no questions about a company's submission (Fresh Hemp Foods Ltd.) that hulled

seed, protein powder and seed oil derived from whole hemp seeds were generally recognized as safe (GRAS). Other companies may receive the same conclusion if they produce goods with similar product specifications.

Hemp seed that doesn't qualify as a food-grade product for human consumption may not be legally incorporated into animal feed. Animal feed safety studies have not yet been completed for hemp seed-derived ingredients in the U.S.

Exhibit 2.1.4 – Current Examples of Retail Hemp Grain Products by Industry

Hemp Protein
Source: store.nutiva.com

Shelled Hemp Seed
Source: manitobaharvest.com

Hemp Seed Oil
Source: irwinnaturals.com

2.2 Situational Analysis for Missouri Stakeholders

A strengths (S), weaknesses, (W), opportunities (O) and threats (T) analysis — or SWOT analysis — is used to summarize the development of a hemp grain value chain in Missouri. External factors include opportunities available in the marketplace and threats that pose challenges to Missouri having a place in the industrial hemp for grain industry. Internal factors include understanding the strengths that Missouri stakeholders could leverage as they pursue industrial hemp opportunities and the weaknesses that may create barriers.

Exhibit 2.2.1 – SWOT Analysis for Missouri Industrial Hemp for Grain Industry

Strengths	**Weaknesses**
• Raising hemp seeds involves a production system similar to systems used to raise other grains or oilseeds in Missouri • Only minimal specialized investments may be needed such as draper head for combine, grain screens before storage and low-heat drying and storage systems on farm	• Production issues include overcoming weed pressure, dicamba drift, preharvest shatter, bird damage and fiber wrapping on combine • High-humidity conditions in Missouri pose a risk • Maintaining food-grade product quality entails storage risks: removing foreign material, quickly applying low-heat drying, maintaining segregated storage, stirring and ensuring proper aeration until processor calls for product
Opportunities	**Threats**
• Health food market has potential to grow for hemp seed oil, hemp hearts and hemp protein powders • Plant-based milk substitutes are expected to be a growing market for hemp seed • Hemp grain currently has a market value of more than $1,200 per ton, which allows transport to long-distance processing markets if needed • Hemp for birdseed may with fit with existing birdseed suppliers packaging in Missouri	• Competition from production in other states and imports from Canada, China and Europe • Grain failing contract specifications may have few other markets until regulatory changes allow hemp grain into livestock and pet diets • Other production areas with drier climates and few cropping alternatives may have competitive advantages in producing hemp for grain

2.3 Industry Value Proposition

The industrial hemp industry is in its early stages in the U.S. Hemp grain is sold based on pounds of grain delivered. In their production contracts, buyers and processors may detail quality specifications, delivery point, form, acceptability, final pricing mechanics and deductions that will apply to crops. Hemp grain in the U.S. has limited price history. Quoted U.S. hemp grain prices in fall 2019 ranged from $0.60 to $0.70 per pound.

2.4 Equipment for Processing Hemp Grain

Entrepreneurs interested in processing hemp grain into products such as birdseed, hemp oil, hemp hearts, hemp protein powders and hemp cosmetics may find processing equipment using simple google searches for "hemp seed huller" or "oilseed press."

Small-scale equipment is available, often from overseas sellers. Potential processors must be careful to ensure equipment purchased will meet U.S. standards for food-grade material if that is their intended market. A succinct factsheet on "Oilseed Processing for Small-Scale Producers" may be found at sustainablenations.org/Resources/oilseed.pdf.

2.5 U.S. Hemp Grain Processors

The following U.S. companies are examples of firms working in hemp grain processing. This listing is not meant to highlight one company above another or omit a certain company. This information is simply provided to give context about companies that exist in the current industry.

Victory Hemp (victoryhempfoods.com) focuses on making products from whole hemp seeds. Examples include hemp protein powders, oils, hearts and roasted hemp seeds. Based in Carrollton, Kentucky, the company has the capacity to produce 8,000 gallons of hemp seed oil and about 50,000 pounds of hemp protein powder monthly. The firm uses a mechanical screw press system for oil and protein extraction.

Colorado Hemp Works (coloradohempworks.com) has an industrial hemp seed processing facility in Longmont, Colorado. It sells wholesale hemp hearts, hemp seed oil, seed cake, hemp flour and shell casings. Colorado Hemp Works also offers hemp grain toll-processing services for other businesses. Throughput for its plant is 6,000 pounds per day.

3. Value Chain for Industrial Hemp - Fiber

3.1 Stages and Needs in the Industrial Hemp Fiber Value Chain

Missouri has roots in hemp fiber production dating from the mid- to late 19th century. However, the state has not commercially produced industrial hemp fiber for almost 100 years. The industry is poised to reemerge in the state with new technology, increased scale and new markets. Exhibit 3.1.1 shows industrial hemp raised for fiber purposes.

The U.S. industrial hemp fiber industry is in its early stages of development. Deep commodity markets for large quantities of hemp fiber with a defined quality have not yet emerged. Because it's in its early stages, the U.S. hemp fiber industry is restarting using smaller scale decorticator lines. Hemp fiber companies are simultaneously building farm production acreage, refining processes and generating fiber in a form and at a scale appropriate only to fill new contracts and meet new product demand. In contrast, European industrial hemp fiber companies operate in a more mature industry and can provide examples for potential development in the U.S.

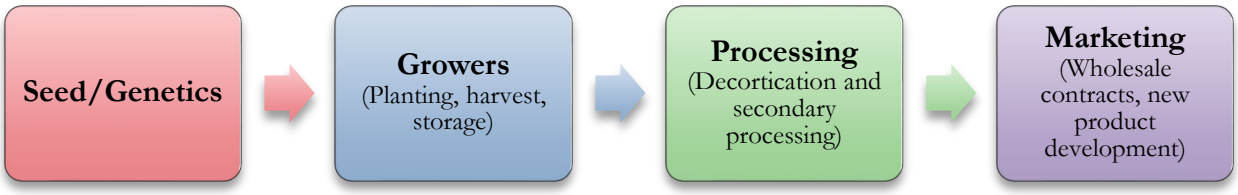
Exhibit 3.1.1 – Industrial Hemp for Fiber

European hemp processors typically operate capital-intensive and high-volume equipment. Specialized European processing equipment suppliers include companies such Laroche (laroche.fr/en) in France and Temafa (temafa.com/) in Germany.

European processors may specialize in contracting hemp for fiber production, use specific varieties with defined levels of retting, designate farm-level quality standards and have processes calibrated to meet industrial customers' contract specifications. Customers may include automobile parts manufacturers, plastics suppliers and the construction materials and specialty paper industries.

Exhibit 3.1.2 provides a general framework for the reemergence of an industrial hemp fiber value chain in Missouri. It illustrates what needs to evolve for industrial hemp fiber crop acreage to grow and how value can be added to products sold in wholesale and retail markets. Further discussion about these industrial segments and business opportunities can be found later in this section.

Exhibit 3.1.2 – Overview of Industrial Hemp Fiber Value Chain



Seed and Genetics Suppliers

Seed companies play an important role in the industrial hemp fiber value chain. Missouri's proposed regulatory environment will allow non-certified seed to be used, but producers must beware of the THC testing threshold. Potential mandatory crop destruction is a real risk. Growers will look for seed selection guidance from genetics suppliers and firms that mandate certain varieties in their marketing contracts.

Data from other states and other countries at similar latitude may provide suitable varieties that can grow well under Missouri's soils and climate. Published Canadian, European, Chinese and multistate U.S. university variety trials have been published. Some state departments of agriculture maintain lists of approved varieties for their states.

Key Need:
Quality fiber variety genetics conducive to Missouri's soils and climate for optimal biomass production

Key components to identify when selecting a variety are proven acceptable THC levels, percent germination, seed number per pound and indications the varieties are suitable for the specific fiber production specified within any marketing contract. A close working relationship with a seed supplier and fiber buyer will be important.

Grower Operations

Hemp produced for fiber has the simplest farm-level production system of all the hemp crops. Seed is drilled or planted in tight rows into a finely tilled field. As flowering approaches, the field is cut with a sickle bar mower to lay the hemp flat on the stubble for retting.

During retting, the material may be turned with a wheel rake before baling, either in big round bales or big square bales, for transport. Once fiber hemp is cut, field-retted, raked and baled, it is covered and stored under cover until the processor is ready to use it.

Key Needs:
- Missouri-specific agronomic and harvest recommendations
- Effective equipment solutions for harvest and transportation
- Development of custom equipment operators
- Crop insurance program
- Access to capital and banking

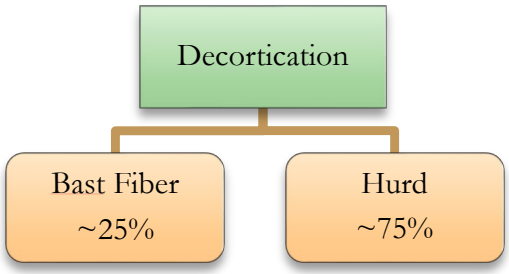
Stacking tarped bales field-side offers a low-cost storage solution for this relatively bulky, low-value fiber crop. Australian producers have experimented with field chopping retted hemp. Then, they pack the hemp into cotton modules that are tarped at the side of the field and transported by chain bed truck to reduce handling and storage costs prior to decortication (Bouloc, 2013).

For industrial hemp grown for fiber, custom operators may be the most cost-effective assembly solution. Custom harvesting with large cutters and heavy square or round balers has developed around wheat straw and miscanthus industries in Missouri. Custom harvesting with knowledge of proper harvest date and retting period may be important for quality control. Likewise, specialized large-scale and heavy-duty baling equipment similar to that used for miscanthus or corn stover would expedite harvest. Integrating custom harvest with contract trucking may allow matching equipment to efficient load sizes and reducing logistical costs.

Decortication and Secondary Processing

Hemp fiber is delivered to a processor with a decorticator. Decorticator equipment divides the stalks into distinct parts. (See Exhibit 3.1.3.) Of the hemp stalk's total volume, the hurd represents about 75 percent, and the bast fiber represents about 25 percent. Bast fibers are long, stringy fibers around the stalk. Hurds are the inner part of the hemp stalk. The short hurd fibers have a woody characteristic. Dust is another byproduct from decortication. Secondary processing or refinement (e.g., softening, combing, spinning) of hemp fibers may be necessary depending on the end market.

Exhibit 3.1.3 – Industrial Hemp Fiber Decortication Products and Mass Balance



Industrial hemp processors will schedule pickup or delivery as needed throughout year, but they may leave the fiber bales with the producer to control inventory and storage costs. Quality control starts at the farm level with weed control; harvest timing; proper retting; and clean, dry storage.

Processors examine the bales for quality control, and then, they feed the hemp bales into a line of decortication equipment for processing. Continual refinement and sorting of fiber can be continued in the line to add value and meet contractual product specifications.

Key Needs:
- Clusters of quality fiber crop acreage to supply regional decorticator capacity
- Financial incentives to attract processor prospects or stimulate business development
- Access to capital and banking

For fiber producers, decortication investments either individually or as collective entrepreneurs will be needed within a short haul from production areas to minimize the cost of trucking for the bulky materials of relatively low value. Hemp fiber processors often sell intermediate industrial products for specific customers under contracts with little branding or retailing. As more U.S. decorticators are built, the industry may evolve toward a commodity model.

Attaining a critical mass of production acreage, quality control and market contracts at the same time creates a need for a vertically integrated approach to the emerging industry.

Farmers entering fiber hemp production need an assured market. Processors need an assured supply of standard quality. A regional new generation cooperative may be an ideal model to capitalize and manage the business. Such an entity would attach delivery rights and responsibilities to the farmer-owners and share risks and returns according to contributions.

Business functions of a regional farmer-owned decorticator plant would include the following:

- Create and manage contracts to purchase baled fiber hemp from farmers who use similar genetics with field service available to assist with producers' questions.
- Create a viable local market for hemp fiber by aggregating acreage for custom harvesting contractors to adopt machinery innovation.
- Provide and organize transportation, storage and quality control for hemp fiber from the grower.
- Create the solid business counterparty required by industrial companies desiring to execute long-term and large-volume hemp fiber supply contracts.
- Provide an incubator for hemp fiber product development and new businesses.

Wholesale and Retail Markets

Bast and hurd fibers have many potential uses. Bast fibers may work well in textiles; paper; and industrial products, such as composites, caulking and brake and clutch linings. Hurd fibers may be used to make paper, building materials and animal bedding (Johnson 2018). See Exhibit 3.1.4 for examples of retail industrial hemp fiber products in the marketplace.

Exhibit 3.1.4 – Current Examples of Retail Fiber Products by Industry

Textile Industry
Source: Patagonia.com

Building Materials
Source: Plainshemp.com

Growing Medium
Source: Biocompositesgroup.com

The majority of currently processed hemp fiber tonnage is marketed into relatively low-value channels such as animal bedding or insulation. This makes logistics critical to the business proposition. Domestically produced hemp fiber also competes with international supplies. China serves as the main hemp fiber supplier internationally, so U.S. hemp fiber prices and supplies would compete with Chinese product (Journal-Advocate 2018).

As the U.S. industrial hemp for fiber industry is in its infancy, much of the value chain development revolves around creating a market and demand for industrial hemp fibers. This will involve entities such as processors or brokers securing large-volume contracts with existing businesses to stimulate demand.

Key Needs:
- New product development with industrial hemp fibers
- Entities securing large-volume industrial hemp fiber contracts with existing businesses
- Promotion of Missouri-based businesses or industries adapting to hemp fiber use

Marketing efforts with Missouri-based companies that can utilize hemp fibers in industrial applications may generate local demand for hemp fibers. Succeeding in the marketplace depends highly on how a business manages its operations and executes on branding and messaging about its products. Entrepreneurs may be able to carve out a competitive advantage and position themselves successfully in the marketplace.

3.2 Situational Analysis for Missouri Stakeholders

A strengths (S), weaknesses, (W), opportunities (O) and threats (T) analysis — or SWOT analysis — is used to summarize the development of a hemp fiber value chain in Missouri. External factors include opportunities available in the marketplace and threats that pose challenges to Missouri having a place in the industrial hemp for fiber industry. Internal factors include understanding the strengths that Missouri stakeholders could leverage as they pursue industrial hemp opportunities and the weaknesses that may create barriers.

Exhibit 3.2.1 – SWOT Analysis for Missouri Industrial Hemp for Fiber Industry

Strengths	**Weaknesses**
• Hemp fiber production fits into a rotation on Missouri farms with minimal specialized investments in new equipment on the farm • Missouri has a history of biomass (miscanthus) and forage and hay production	• Transportation costs for bulky materials are high and act as a barrier to production profitability in any area that does not have a nearby decorticator
Opportunities	**Threats**
• Intermediate hemp co-product contracts typically fit into high-volume markets such as auto parts, building materials and pet bedding that can support significant production acreage increases • Among consumers, hemp textiles are considered more sustainable than those made from cotton • First high-volume processors attract cluster of related industries to build volume, lower costs, enhance technology adoption and innovate new products	• Existing textile industry is overseas and may not retool for long-length fibers unless industrial hemp can capture significant market share from other natural and man-made fibers • Buyers of hemp fiber co-products may face limited markets that can be glutted quickly as national supply grows; this makes product innovation critical • With few barriers to entry in producing fiber hemp, oversupply could damage profitability and make contracts important

3.3 Industry Value Proposition

Fiber hemp is sold based on retted and baled tonnage (dollars per ton) — similar to hay crops. Buyers and processors have specifications in their farmer production contracts that detail delivery point, form, acceptability, final pricing mechanics and deductions that will apply. The U.S. has a limited price history for hemp fibers. More transparent market pricing is expected to evolve over time as larger quantities are produced and traded. Exhibit 3.3.1 shares a snapshot of pricing available in fall 2019 for various industrial hemp fiber products.

Exhibit 3.3.1 – Gross Return Potential at Farm and Processor Stages, Fall 2019 Pricing

Baled Fiber Biomass
$140 to $272 per ton

Bast
$2,190 per ton

Hurd
$709 per ton (Chinese)
$800 per ton (American)

Sources: Hemptraders.com and private reporters

3.4 Capital and Operational Costs in Hemp Fiber Decortication

European cost studies may not be directly comparable to capital investment costs in the U.S., but the historical costs in Exhibit 3.4.1 may provide guidance for future large-scale U.S. industrial hemp fiber production. The range of capital investment costs was attributed to the degree of refinement and purity, equipment sophistication, pollution controls and storage area for feedstock and product.

Exhibit 3.4.1 – Estimated Capital Investment Costs in Fiber Extraction, 2005

Hourly Volume (U.S. tons/hr.)	**Volume Processed** (U.S. tons per year)	**Acreage Processed Annually** (assumed 5 tons yield/acre)	**Capital Investment** (U.S. dollars)	**Capital Investment** (Dollars per ton of annual volume)
1.7	5,500	1,100	$3,330,000	$600
5.5	17,794	3,559	$5,550,000	$312

Source: Derived from Bouloc (2013)

Operating cost surveys from industrial hemp processors in Europe are listed in Exhibit 3.4.2. Energy usage is 100 kWH to 150 kWH per ton. One person is required for every 2,200 tons of material processed per year, and maintenance workers must also be engaged. Operating costs do not include feedstock cost.

Exhibit 3.4.2 – Estimated Operating Costs in Fiber Extraction

Cost Category	Average Cost (U.S. dollars per ton)
Salaries and benefits	$50.26
Debt service (principal and interest)	$51.45
Energy	$12.14
Maintenance	$9.57
Other costs	$28.98
Total	**$152.40**

Source: Derived from Bouloc (2013)

3.5 Gross Margin from Hemp Fiber Decortication

Prices for industrial hemp for fiber bales, bast fiber and hurd fiber are expected to change as acreage expands, new products are brought to market and high-volume industrial contracts emerge. This makes detailed business planning around decortication difficult.

To give potential entrepreneurs a rough guide to the business of decortication, Exhibit 3.5.1 presents gross margin per ton estimates for decorticating baled and retted industrial hemp. Various selling prices for bast fiber and hurd fiber are represented to show price sensitivity to gross margin. Mass yield balance from decortication is estimated in this example to be 20 percent bast fiber, 75 percent hurd fiber and 5 percent shrink. Feedstock cost was estimated at $175 per ton for industrial hemp bales stored on-site at the processing plant. An example explanation would be a $312.50 gross margin is yielded given sales prices per ton of $1,500 for bast and $250 for hurd.

Highlighted in green are gross margins above $300 per ton. This was chosen as a gross indicator of potential profitability in this hypothetical example, which should cover the feedstock costs, operating costs and invested capital in an industrial hemp decortication business.

Exhibit 3.5.1– Gross Margin Estimates from Decorticating Industrial Hemp, Per Ton

		Bast Price (dollars per ton)						
		$500	$750	$1,000	$1,250	$1,500	$1,750	$2,000
Hurd Price (dollars per ton)	$50	-$37.50	$12.50	$62.50	$112.50	$162.50	$212.50	$262.50
	$150	$37.50	$87.50	$137.50	$187.50	$237.50	$287.50	$337.50
	$250	$112.50	$162.50	$212.50	$262.50	$312.50	$362.50	$412.50
	$350	$187.50	$237.50	$287.50	$337.50	$387.50	$437.50	$487.50
	$450	$262.50	$312.50	$362.50	$412.50	$462.50	$512.50	$562.50
	$550	$337.50	$387.50	$437.50	$487.50	$537.50	$587.50	$637.50
	$650	$412.50	$462.50	$512.50	$562.50	$612.50	$662.50	$712.50
	$750	$487.50	$537.50	$587.50	$637.50	$687.50	$737.50	$787.50
	$850	$562.50	$612.50	$662.50	$712.50	$762.50	$812.50	$862.50

3.6 North American Decorticator Companies

The following descriptions summarize some North American companies working in hemp fiber decortication. This listing is not meant to highlight one company above another or omit a certain company. This information is simply provided to give context about companies, technologies and capital investments that exist in the current industry.

Canadian Greenfield Technologies (canadiangreenfield.com) is a firm that develops specialized equipment and processing solutions for industrial hemp decortication. Its equipment is based on high-speed kinematic technology that separates industrial hemp into bast fiber, hurd and CBD extraction-ready green microfiber co-product. Per a company news release, the first U.S. HempTrain™ Advanced Processing Plant was sold to Wyndridge Farm located in Dallastown, Pennsylvania. Exhibit 3.6.1 details the basic components and specifications of the dry industrial hemp processing plant. According to the company website, pricing in U.S. dollars for the HempTrain™ Advanced Processing Plant in 2019 was $1,550,000, which included equipment, warranty, shipping, installation, commissioning and training.

Exhibit 3.6.1 – HempTrain™ Advanced Processing Plant (Dry Processing)

Category	Details
Equipment	Bale opener, processing units, dust collection, electrical/touchscreen control
Throughput	~2,000 pounds/hour (approx. 10-12 million pounds per year)
Area required	~1,500 ft^2
Machine height	16 feet (19 feet required for installation)
Machine weight	~32,000 pounds
Feedstock bale size	Up to 8 ft. x 5 ft. x 6 ft.
Hurd fiber particle length	From 1/8 inches to 2 inches
Power requirement	70 kVA

Source: Canadian Greenfield Technologies (2019)

Formation Ag (formation-ag.com) is based in Monte Vista, Colorado, and it is working to provide mobile-engineered solutions in the industrial hemp industry. It has developed a Fiber Track 600 model that is a portable decorticator capable of processing one ton of material per hour with throughput depending on variety, moisture and degree of retting. This model is manual in both feeding material and material removal. It uses 480-volt, three-phase electricity to power four electric 3HP motors. The unit sells for $93,500 plus $7,500 for a suggested shaker table attachment.

Formation Ag is also currently developing the Fiber Track Genesis model to be a portable hemp decorticator with a higher capacity than the 600 Model. Fiber Track Genesis will process around 5 tons per hour. Material feed and product removal will be automatic through a bale accumulator.

Based in St. Louis, Missouri, **Tiger Fiber Hemp Company** (tigerfiberhemp.com) is working to evolve fiber production and industrial hemp decortication in Missouri and nearby states. It donated hemp fiber variety seed to the University of Missouri agricultural experiment stations to begin variety tests at plots throughout Missouri after the Missouri industrial hemp law passed in June 2019. Tiger Fiber has also been commercializing modular decortication technology developed by Natural Fibre Technologies. Exhibit 3.6.2 is an example of an innovative modular decorticator, installed in St. Louis in 2019 by Tiger Fiber Hemp Company using technology developed by **Natural Fibre Technologies** (naturalfibretech.com), which is located in Alberta, Canada.

Exhibit 3.6.2 – Tiger Fiber Hemp Company Mobile Decortication Machine Prototype

4. Potential Economic Impact for Industrial Hemp in Missouri

Industrial hemp production represents a new industry for Missouri that has the potential to add value to the agricultural industry. Local production of industrial hemp can provide pathways for new and existing farmers to begin a new agricultural enterprise. Local industrial hemp processing plants could provide further economic development and purchase commodities from nearby farmers. Businesses and market outlets can sell new Missouri hemp-derived products and help stimulate further economic growth.

Industrial hemp cultivation and processing also provide workforce opportunities. Whitney Economics (Allen and Whitney, 2019) conducted a survey to assess the employment and wages associated with industrial hemp cultivation in the U.S. Based on the survey responses received from 20 U.S. states, the average cultivator business would have 4.53 full-time employees (FTE) and 4.34 part-time employees (PTE). Processors required more labor and provided higher wages than cultivators. An average processing business had 9.83 FTE and 7.77 PTE. Wages provided to FTE employees for an industrial hemp processor averaged $18.96 per hour.

Exhibit 4.1 – Industrial Hemp Businesses, Average Workers and Wages, 2019

Business Type	Full-Time (FTE)	Avg. FTE Hourly Wage	Part-Time (PTE)	Avg. PTE Hourly Wage
Cultivator	4.53	$17.34	4.34	$13.98
Processor	9.83	$18.96	7.77	$14.25

Source: Whitney Economics, LLC. (Allen and Whitney, 2019)

Estimations were prepared in this report to simulate economic effects associated with new industry sales in industrial hemp production by using IMPLAN economic impact software. IMPLAN is an input-output model, and it includes economic data sets, multipliers and demographic statistics for the entire U.S. economic infrastructure. A robust tool, it assesses the effects of economic changes by sector, and economists and analysts widely use it. Estimations in this report used the 2017 IMPLAN data set for Missouri. University of Missouri Extension 2020 industrial hemp budget assumptions were used to perform an analysis-by-parts technique to quantify economic impacts. See Exhibit 4.2 for these gross revenue assumptions from the MU budgets.

Exhibit 4.2 – Production and Revenue Assumptions from Industrial Hemp Budgets

Production System	Selling Price	Units	Gross Revenue Per Acre
CBD	$2 per percent/CBD	1,200 lbs. @ 10 percent CBD	$24,000
Grain	$0.60 per pound	1,200 pounds	$720
Fiber	$125 per ton	5 tons	$625

Source: University of Missouri Extension (Massey and Morrison, 2019)

IMPLAN categorizes impacts into three different economic effects: direct, indirect and induced. A direct effect can be defined as a direct change in an area that results from a change in an industry. For example, additional new sales revenue from industrial hemp production would have a direct economic effect. These operations would create an indirect effect when they purchase goods or

services from other industries (e.g., seed, machinery, transportation). Induced effects are changes in household spending that originate from income generated by direct and indirect effects. For instance, employees will spend their income to buy real estate, shop at grocery stores or spend on other goods or services in the local economy. For the following economic impact examples, all three economic effects — direct, indirect and induced — were totaled and reported.

One measure of demonstrating annual economic impact is value-added. Value-added consists of labor income including wages, benefits and proprietor income; indirect taxes; and other income such as corporate profits, net interest and rent. Additionally, value-added measures gross domestic product generated by the industry. Exhibit 4.3 shows the value-added impact to Missouri's economy for industrial hemp production (CBD, grain or fiber) in Missouri for different acreage models.

Exhibit 4.3 –Total Value-Added Impact to Missouri's Economy with Industrial Hemp Production

Production Acres	Industrial Hemp for CBD	Industrial Hemp for Grain	Industrial Hemp for Fiber
1,000	$14.6 million	$422 thousand	$395 thousand
5,000	$73.0 million	$2.1 million	$2.0 million
10,000	$146.0 million	$4.2 million	$4.0 million

Source: University of Missouri, using data from IMPLAN

Another measure of annual economic impact is jobs. Jobs that would be supported by industrial hemp production through direct, indirect and induced effects are displayed in Exhibit 4.4. Employment refers to jobs, either full-time or part-time, as an annual average.

Exhibit 4.4 – Total Jobs Supported in Missouri's Economy with Industrial Hemp Production

Production Acres	Industrial Hemp for CBD	Industrial Hemp for Grain	Industrial Hemp for Fiber
1,000	222.6	5.2	4.9
5,000	1,113.0	26.0	24.5
10,000	2,226.0	52.0	49.0

Source: University of Missouri, using data from IMPLAN

Please note that information reported in Exhibit 4.3 and Exhibit 4.4 refers to gross economic impact from industrial hemp cultivation and has not accounted for change in land use. It is possible that some of the industrial hemp acres would be converted from existing crops or uses (e.g., corn, soybeans). If that is the case, then a net analysis would factor in the difference between a new industrial hemp enterprise and economic activity from the prior land use. This would be more representative of the change in local economic activity, but it is hard to quantify as it is unknown exactly where the land use changes will occur in Missouri.

Economic benefits to the state of Missouri reported in Exhibit 4.3 and Exhibit 4.4 would be improved if Missouri-raised industrial hemp were utilized in Missouri processing plants and further hemp-derived products were sold into Missouri retail markets. IMPLAN analysis only captures backward linkages when computing economic impacts, and the analysis presented in this section only captures the farm-gate value of raw industrial hemp products. Further processing or retail sales of industrial hemp products would generate more economic activity in Missouri.

References

Allen, Clarissa and Beau Whitney. 2019. The Field of Dreams – An Economic Survey of the U.S. Hemp Cultivation Industry. Whitney Economics, LLC. Available online at https://whitneyeconomics.com/.

Bouloc, Pierre. 2013. Hemp: Industrial Production and Uses. eBook. CAB International.

Callaway, J.C. 2010. Hempseed oil in a nutshell. INFORM. Accessed June 6, 2019, at https://www.aocs.org/stay-informed/inform-magazine/featured-articles/hempseed-oil-in-a-nutshell-march-2010.

Canadian Greenfield Technologies. 2019. Accessed December 15, 2019, at https://canadiangreenfield.com/

CBD Awareness Project. 2019. CBD Extraction Methods. Accessed on November 12, 2019 at https://www.cbdoil.org/cbd-extraction-methods/.

Johnson, Renee. Hemp as an Agricultural Commodity. Congressional Research Service. Accessed Oct. 12, 2019, at https://fas.org/sgp/crs/misc/RL32725.pdf.

Journal-Advocate. 2018. Hemp can be lucrative, but there are drawbacks. Journal-Advocate. Accessed May 23, 2019, at http://www.journal-advocate.com/sterling-local_news/ci_31699721/hemp-can-be-lucrative-but-there-are-drawbacks.

June-Wells, Mark. 2018. How to Estimate an Extraction Lab's Revenue. Cannabis Business Times. Accessed on December 10, 2019 at https://www.cannabisbusinesstimes.com/article/how-to-estimate-an-extraction-labs-revenue/.

Massey, R. and Morrison, C. 2019. Industrial Hemp Planning Budgets. University of Missouri Extension Guidesheets G668, G669 and G671. Accessed on December 19, 2019 at https://extension2.missouri.edu/programs/industrial-hemp.

PanXchange, Inc. 2019. Hemp Market News. Accessed on December 11, 2019 at https://panxchange.com/hemp-news/.

Sandy, Eric. 2019. How to Handle Post-Harvest Hemp Storage Efficiently and Safely. Hemp Grower. Accessed on December 13, 2019 at https://www.hempgrower.com/article/hemp-post-harvest-storage-efficiently-and-safely-drying/

Sterns, James A. 2019. "Is the Emerging U.S. Hemp Industry Yet Another Boom-Bust for U.S. Farmers?" Choices. Quarter 3. Available online at www.choicesmagazine.org/choices-magazine/submitted-articles/is-the-emerging-us-hemp-industry-yet-another-boombust-market-for-us-farmers.

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