Show-Me-State Food, Beverage & Forest Products Manufacturing Initiative

February 2019

Performed For:

Missouri Agricultural Foundation

Performed By:

TECONOMY PARTNERS LLC

In Partnership with:

The CAFNR Foundation
Supporting education and research at the University of Missouri

MFA INCORPORATED

Missouri Cattlemens Association

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MoPORK
Missouri Pork Association

College of Agriculture, Food & Natural Resources
University of Missouri

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MISSOURI FARM BUREAU

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Missouri Agricultural Foundation

February 2019

The Missouri Agriculture Foundation is pleased to share with you the economic feasibility study conducted by TEConomy, Inc., that explored the potential for growing the Missouri economy if the state invests in its food and forest product manufacturing enterprises. The initiative, known as the Show-Me State Food, Beverage and Forest Products Manufacturing Initiative, identified three recommendations, which, if successfully implemented, offer tremendous potential for our great state. The recommendations are:

- Regional Food Systems: Enhance food value chains at a regional and local level across Missouri, and facilitate and accelerate development of regional value-added food product manufacturing businesses.

- Foods for Health: Build a new, research and innovation driven food industry for Missouri rooted in advanced nutritional sciences, an expansion of food science capabilities, and an applied clinical and translational research program.

- Enhanced Commodity Utilization: Develop enhanced value-added processing activities for key commodities grains, dairy products, eggs and livestock.

With leadership from Missouri Governor Mike Parson's office, the next phase of the initiative will focus on establishing an execution plan for each of the three recommendations proposed in the study.

The inaugural guiding coalition for this collaborative initiative was made up of Dan Cassidy, Chief Administrative Officer of Missouri Farm Bureau, Chris Chinn, Director of the Missouri Department of Agriculture; Christopher R. Daubert, Vice Chancellor for Agriculture and Dean of the MU College of Agriculture, Food and Natural Resources; Sen. Brian Munzlinger and Gary M. Wheeler, CEO of the Missouri Soybean Association and Merchandising Council. We thank the guiding coalition for pursuing the initiative and for building a strong alliance of support for the project across the Missouri agricultural landscape. A complete list of partners who supported the project with a financial commitment follows.

It is our hope that this report provides meaningful information for Missouri to grow its number one industry –agriculture – to even higher levels. Questions and suggestions related to this initiative can be directed to Dr. Christopher R. Daubert, Vice Chancellor and Dean of the MU College of Agriculture, Food and Natural Resources, 573-882-3846 or daubertc@missouri.edu.

Sincerely,

Michael Johanning
Board President, Missouri Agricultural Foundation

The CAFNR Foundation
Supporting education and research at the University of Missouri

The Law Firm of Haden & Haden

MFA Incorporated

Missouri Beef Industry Council

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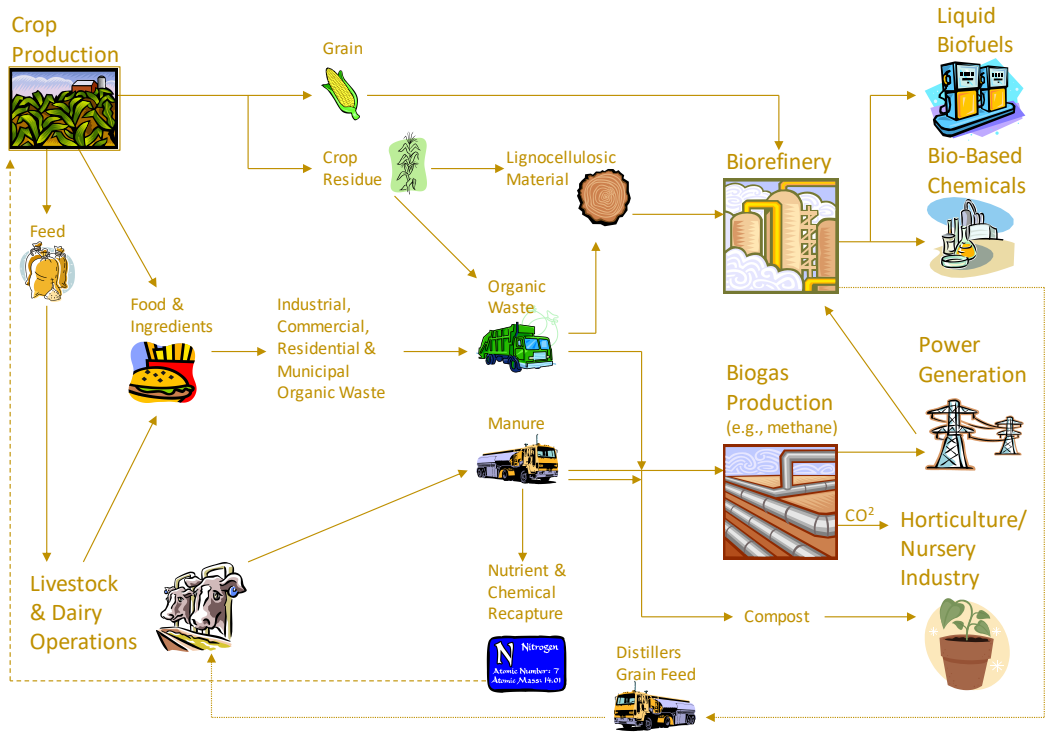
Executive Summary

Missouri's economy is composed of a relatively significant food, beverage, and forestry value-added processing industry, but substantial volumes of commodity crops and livestock are shipped out of the state without having undergone significant value-added processing. Revenue is being lost because large volumes of primary production leave the state without further in-state processing steps adding value to the product. Producing to sell only into commodity markets puts producers in a weak position, subject to intense global competitive forces and fluctuations in commodity prices that are outside of producers' control. **With much of rural and small-town Missouri's economic fortunes tied to the agricultural economy, it is imperative that more economic value be captured from farming and forestry activities.**

There are benefits to be achieved through building enhanced value-chains that increase in-state value-added processing. Companies that produce finished food products, for example, may seek to secure their ingredient supply through contracting with local agricultural processing firms, individual farmers, or farm cooperatives. Working contractually together, producers, processors, and manufacturers can partially decouple themselves from more volatile commodity markets and benefit from a more stable and predictable operating environment. Similarly, farmers can individually or collaboratively engage in value-added business activities themselves to raise their incomes—ranging from the production of specialty processed food products on the farm (for example, artisan cheese) to co-investing in cooperative business ventures (for example, the development of biorefineries).

Figure ES-1 illustrates the multiple potential pathways and interrelationships involved in using an individual crop, here sharing corn as a specific example. Corn could be grown in the state and simply exported as a commodity with no value added to it, or it can be the key input to a complex in-state chain of interrelated economic activity—adding value, economic output, and jobs.

Figure ES-1: Agricultural Products as Inputs to a Complex Value-Added Production Ecosystem: Corn Example



Source: TEConomy Partners, LLC

This report examines opportunities to expand Missouri's economic activity by increasing production of value-added products that use farm and forest outputs as inputs to downstream production. Through further processing and manufacturing activities, significant value can be added to primary crops, livestock, and forest outputs that otherwise leave the state with no value being added. Maximizing value-added opportunities brings benefits in terms of expanding the economy and increasing employment, family incomes, and exports for Missouri.

Figure ES-2 illustrates how the work contained in this project focuses on moving Missouri from its current status to an expanded agriculture and forest processing-based economy that includes manufacturing goods with higher value-added.

- Under the "Current Status," it can be seen that Missouri currently produces considerable farm and forest output that leaves the state with no value added, and a more limited flow of production is directed to Missouri value-added industries. The goal for the "Future Status" is to redirect output so that considerably higher volumes of farm and forest output are further processed within the state.
- The "Missouri Agriculture and Forestry Commodities" circle is larger in the "Future Status" since part of the project's goal is to identify opportunities to grow primary production revenues by creating demand for high-value, specialty inputs to a value-added industry.
- The "Missouri Produced Value-Added Products" circle is enlarged in the "Future Status" given the primary goal of the project to identify opportunities to expand value-added processing and final product manufacturing in the state along food, fiber, chemical, materials, and other value-added biomass-based pathways.
- The importance of research and development (R&D) is reflected in a goal to increase R&D activity relevant to value-added industries and to expand the collaboration between the academic R&D sector and industry to further advance value-added production opportunities.

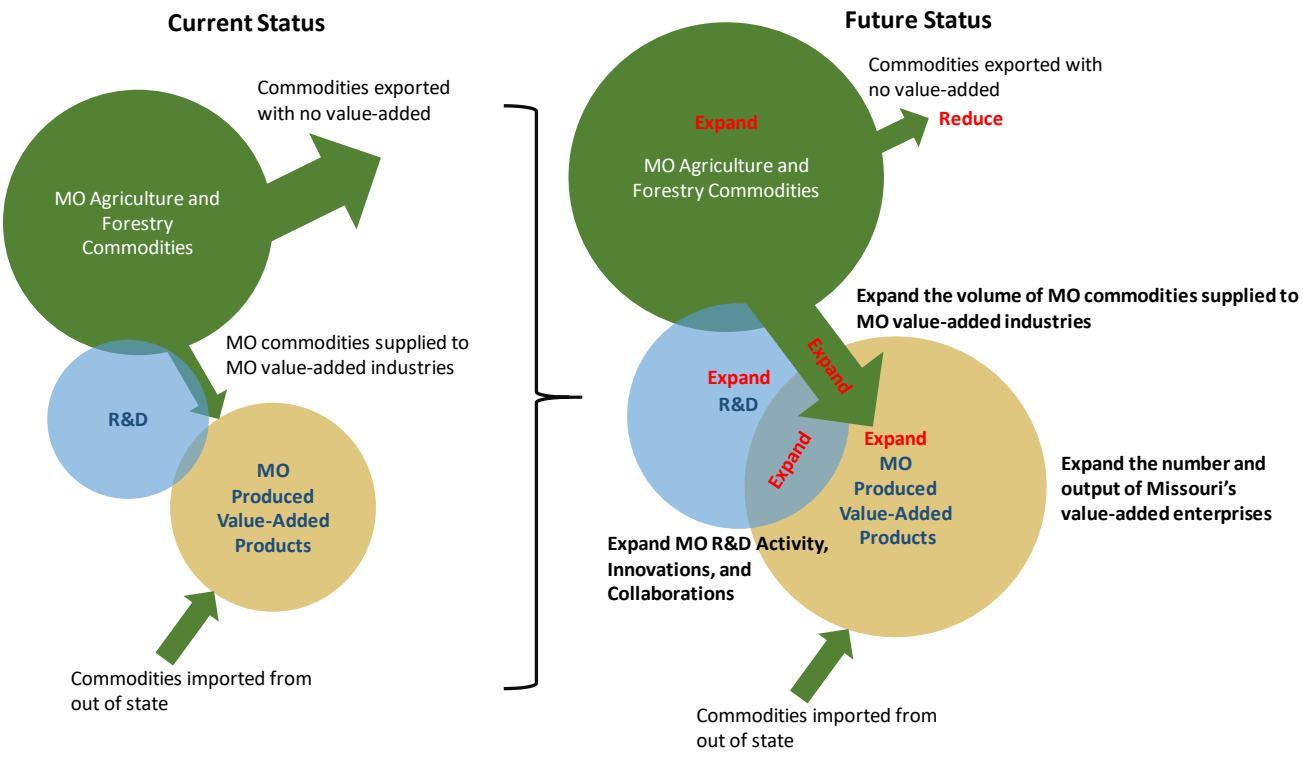
Commissioning a Value-Added Food and Biomass Processing and Manufacturing Initiative Feasibility Study

As Figure ES-1 illustrates, expanding levels of vertical integration maintained within the borders of a state yield expanded levels of economic development potential (in terms of business output and employment levels). The Missouri Agricultural Foundation, understanding the importance of catalyzing more robust post-farmgate food, fiber, timber, and industrial biomass processing and manufacturing capabilities within the state, identified a need to develop a comprehensive economic feasibility study that would explore opportunities for Missouri to increase this important industrial sector of the state's economy.

The feasibility study's goal is to identify the opportunities for Missouri agriculture to achieve greater economic impact by ensuring that the agricultural and forestry commodities produced across the state are transformed in-state into higher-value products that consumers or industrial users desire. Thus, the study seeks to identify opportunities to increase the level of value-added food and beverage, fiber, timber, and industrial biomass processing and manufacturing within Missouri.

TEConomy Partners, LLC was retained to conduct a detailed economic feasibility study that will identify opportunities for Missouri to increase its value-added food and beverage processing and manufacturing capabilities as well as production of other downstream value-added fiber, timber, and industrial biomass-based products.

Figure ES-2: Goals of the Study – A Conceptual Illustration

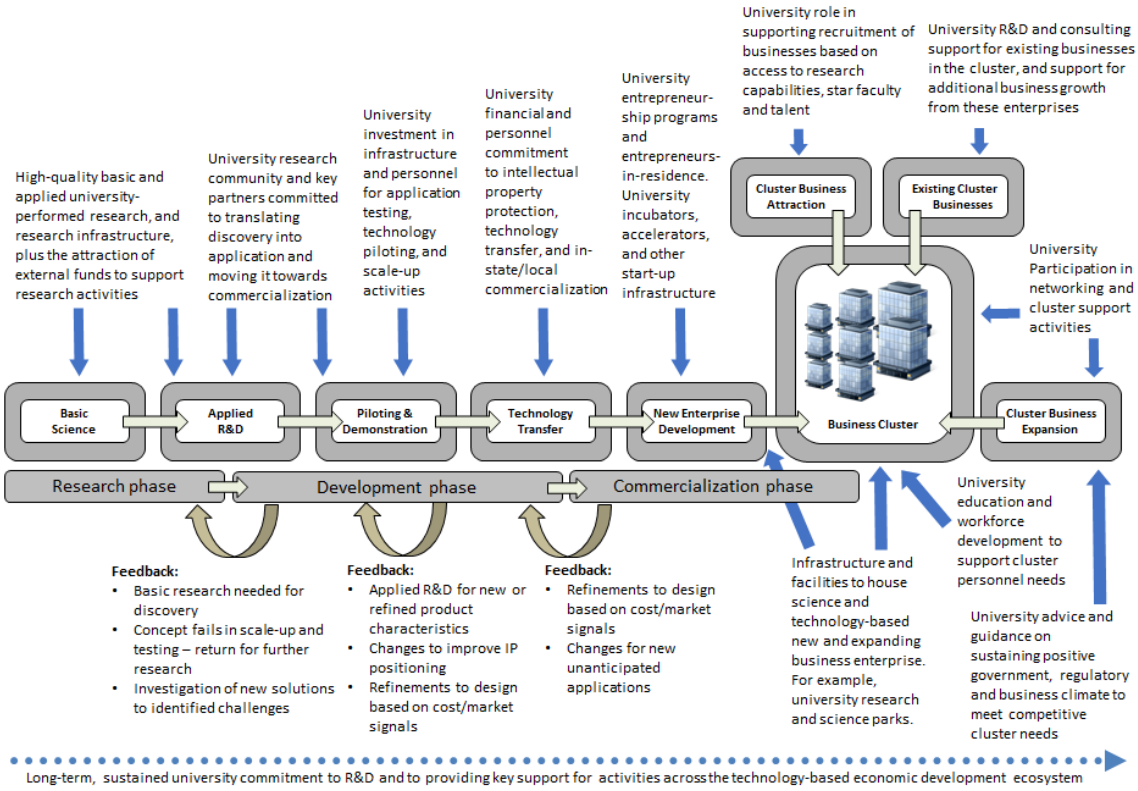


Source: TEConomy Partners, LLC.

Missouri's Value-Added Industrial and Innovation Current Position—Key Findings

For most industry sectors, including agriculture and forestry, forging a pathway to international competitiveness depends on achieving high levels of productivity and product differentiation—typically through the application of R&D-based innovations and the deployment of advanced production and product technologies. **R&D is a critically important component of the modern innovation-based economic development ecosystem (as shown in Figure ES-3) and is key to differentiating U.S. industries in the face of intense and increasing global competition.** This ecosystem supports the development of new technologies and solutions to industry challenges and plays a critically important role in the early-stage incubation of commercial opportunities.

Figure ES-3: The Innovation-Based Ecosystem[1]



Source: TEConomy Partners, LLC.

A key finding from the analysis performed is that Missouri's industry activity in downstream value-added processing is generally more geared toward specialized production of finished value-added products (e.g., dog and cat food manufacturing or bread and bakery product manufacturing) rather than first-level intermediate processing (e.g., grain milling). Basic processing activities (agricultural processing and wood processing and basic wood materials/sawmills) are not specializations for Missouri, and are found, via industry targeting analysis (ITA), to have the most limited prospects for future economic growth in the state. They also demonstrate productivity levels that are below the national averages for these industries. In Missouri, these first-level processing industries are not specialized (in terms of location quotient or LQ), are not growing in employment, and have been losing market share as compared with national employment. **This strongly suggests that a strategy to simply process more basic ag/forest commodities in the state, to boost value-added, is highly unlikely to succeed.** The ITA suggests that the fundamental characteristics of the Missouri operating environment are unfavorable for growth in these primary processing industries (except in meat processing where further in-state finishing and processing is warranted—most notably in beef and pork).

Where opportunities look to be more robust are in the manufacturing of finished food, feed, and associated products. Opportunities reside in categories of higher-value processing into finished rather

[1] Adapted from original graphic in: Simon Tripp, Ryan Helwig, and Dylan Yetter, *The Importance of Research Universities: With Examples of their Functional Role and Impacts Within the State of Indiana*, prepared by TEConomy Partners, LLC, for BioCrossroads and supported by a grant from the Lilly Endowment Inc., 2017, page ES-4.

than intermediate products. Food and feed product manufacturing is the largest major sector (44,922 jobs) with 754 establishments, and it's specialized (LQ=1.31) and growing (6.3 percent, 2014–2017). Wholesale distribution and warehousing is the second largest major sector (28,858 jobs). These two major sectors together account for 61 percent of the total ag/bio economy and 69 percent of the post-farmgate and post-forestgate employment. Food processing is also a high-performance sector for Missouri in terms of labor productivity; the industry performs better than the private sector overall in the state, which demonstrates productivity at only 87 percent of the national level. Taking the average for all food processing sectors, Missouri's productivity (value-added per worker) is at 118 percent of the national average, producing $149,398 in value-added per worker versus $126,271 for the nation overall—a strong performance.

One constraint on Missouri's value-added performance is that Missouri does not stand out as a major leader in research focused on value-added products from agriculture and forestry inputs. There are, however, certain niche areas that present opportunities to build upon. A particularly robust area is in nutrition and associated health research. Multiple clusters of such activity in R&D were evident in the analysis. Related to this research field would be an observed cluster in metabolics R&D. The other strong area of research is in plant sciences, spanning a continuum from fundamental academic research to applied plant sciences (both in academic and industry sectors). These research strengths collectively point to a research-based innovation opportunity around foods for health and advanced nutrition products—ranging from basic research into the effects of various nutritional elements and phytochemicals on health to advanced plant development and metabolic engineering capabilities that could be applied to develop crops with enhanced expression of desirable chemicals and nutrients. Further development in this area would play to Missouri's strengths in highly productive finished food and feed product manufacturing. Research strengths in bioprocessing industrial biotechnology and biochemistry may well be relevant to realizing this opportunity in terms of development of extraction and processing technologies for preserving phytochemical functional activity. **Nutrition and associated health research as well as plant sciences represent innovative R&D area strengths that both academic and industry stakeholders can engage—the ideal situation for technology-based economic development.**

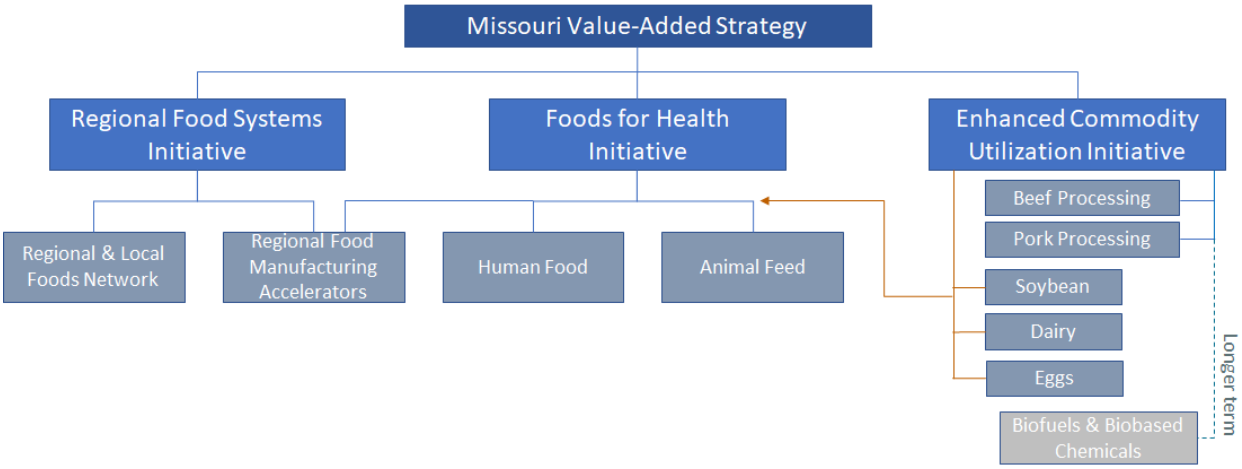
Potential Initiatives to Foster the Growth of the Value-Added Supply Chain in Missouri

The quantitative and qualitative analyses lead to some clear conclusions regarding the assets and opportunities that Missouri possesses to further develop its value-added sectors. The analysis points to the following three primary opportunity areas (termed "initiatives" herein)—each of which represents equally distinctive areas of focus:

- **Regional Food Systems Initiative**—focused on enhancing the food value-chains at regional and local levels across Missouri and facilitating and accelerating the development of regional value-added food product manufacturing business ventures.
- **Foods for Health Initiative**—focused on building a new R&D- and innovation-driven functional foods and advanced nutrition industry for Missouri rooted in nutritional sciences, an expansion of food science capabilities, and an applied program of clinical and translational research.
- **Enhanced Commodity Utilization Initiative**—focused on developing enhanced value-added processing activities for key commodities.

Figure ES-4 shows the three initiatives under the umbrella banner of the Missouri Value-Added Strategy.

Figure ES-4: Key Proposed Elements of Missouri Value-Added Strategy



Source: TEConomy Partners, LLC

Regional Food Systems Initiative

As the findings indicate, Missouri's level of value-added processing activity is undersized compared with the state's agricultural output. In addition, Missouri's agriculture production is highly concentrated in a few commodities and generally lacks diversity in crop production. Missouri is especially lacking in horticultural crops produced for food. Furthermore, there is limited knowledge regarding product development, distribution channels, market placement, etc.

The recommended Regional Food Systems Initiative will help ensure that comprehensive, in-depth business development, product development, and supply-chain services are readily available and easily accessible to start-up and small- and medium-sized food processing and manufacturing companies. The initiative will focus on two complementary activities:

1. A comprehensive network of value-added processing accelerator services and capabilities, and
2. The development of a robust regional and local foods system.

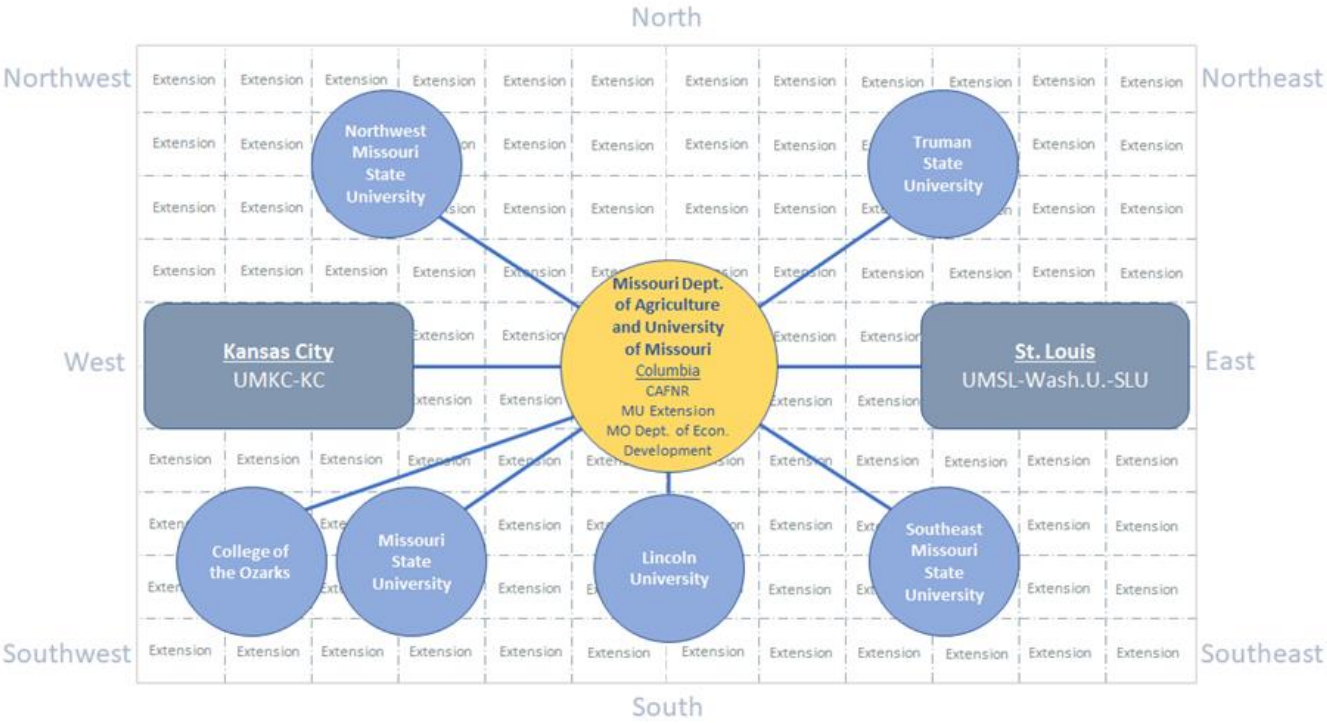
The **Regional Food Manufacturing Accelerators** are envisioned as a model of business and technical assistance that would be available to start-up and small-sized food processors and manufacturers throughout the state. Through a hub-and-spoke model, leveraging existing efforts, businesses would be able to avail themselves of assistance services developed through the following actions:

- Creation of a Process Authority that would focus on product testing, product classification, nutritional label and process authority letter development, label review, and consultation. It is envisioned that this would be an MU Food Science Extension position.
- Development of pilot-size co-packing plants to conduct smaller batch runs.
- In partnership with the Missouri Department of Agriculture, provision of access to initiatives that support food processors and manufacturers, and provision of regulatory guidance and assistance.

- In partnership with either MU Extension Business and Communities Program and/or Missouri Enterprise Manufacturing Extension Partnership (MEP) program, provision of assistance to food manufacturers in production process, cost improvements, and regulatory compliance.
- In partnership with MU Extension's Missouri Small Business & Technology Development Centers (MO SBTDC), provision of assistance with business plans, market analysis, and access to capital.

It is envisioned that a "hub-and-spoke" model of value-added Regional Food Manufacturing Accelerators would be created to ensure that start-up companies were able to be assisted at a regional level while still ensuring that resources were not duplicated for capacity that can be more centrally located. To this end, it is envisioned that up to seven accelerators or nodes would be developed initially in partnership with Missouri's academic institutions and the Missouri Department of Agriculture, one in each region of the state, and two additional hubs in the major urban centers, for a total of nine. All seven nodes would provide a full range of business assistance and market development expertise and would also develop intermediary processing capability that could be utilized by start-up companies in a particular region and tailored to the specific agricultural commodities with the greatest demand for further processing/manufacturing. In addition, a central hub would be created in Columbia to provide not only region-specific services as outlined above, but also unique statewide assistance (such as the processing authority) and help in connecting all companies to the research capacities within MU's College of Agriculture, Food and Natural Resources (CAFNR). County Extension Offices would serve as a referral network into each regional node or central hub as appropriate (Figure ES-5). The central hub would lead/oversee the entire system.

Figure ES-5: Missouri Regional Food Systems Initiative—Utilizing a Hub-and-Spoke Network and County Extension Offices



Source: TEConomy Partners, LLC.

The Regional and Local Foods Network would work actively with small farm producers to examine alternative crop opportunities, niche market opportunities (such as farmers' markets, local food opportunities, etc.), and other entrepreneurial endeavors on the farm. Efforts would include looking for opportunities for adding value to farm commodities in diverse ways, including, for example, organic and specialty markets, direct marketing of products, community-supported agriculture, and agritourism.

It is envisioned that each node of the Regional Food Systems Initiative will be responsible for developing its own Regional and Local Foods Network, which would focus on a variety of issues, including the following:

- Regional and local foods system supply chains
    - Local food production, particularly horticulture
    - Distribution and aggregation
    - Markets and purchasing
    - Local buying preferences
    - Resource and waste recovery
- Regional and local foods access
    - Community gardens
    - Farm to school
    - Farm to Childcare
    - School gardens
    - Local food access and food security
    - Local government, planning, and agriculture policy.

Through the Regional Food Systems Initiative, Missouri will seek to develop integrated value-added processing chains, thereby increasing the level of economic profit retained within the state by Missouri agricultural producers and manufacturers. The bottom line is that finding different and unique ways to support entrepreneurs and the growth of entrepreneurial food processing and manufacturing companies is an important component of Missouri's efforts to develop the industrial base.

Foods for Health Initiative

The Foods for Health Initiative will develop Missouri as a leading center in the research, development, testing, and production of foods for health. Using modern transdisciplinary science capabilities, combined with distinctive capabilities in clinical and translational sciences, Missouri can achieve a leadership position in evidence-based advanced food and nutrition products. Further, a combination of R&D in nutrition and its relationships to phenotype and genotype may unlock a new industry in precision foods for health—diets personalized to the functional characteristics and needs of the individual.

The early assessment of core competencies and assets in Missouri provided early indication of a Foods for Health platform having potential as a major value-added initiative for Missouri. The initiative would work to effectively leverage a rather unique series of research assets and strengths, a flexible agriculture production environment, and a line-of-sight to very large-scale market opportunities. It also closely aligns the food and nutrition space with a stated goal of senior MU administration to position the university to be preeminent in personalized medicine and associated health research. A series of actions are recommended for advancing the Foods for Health platform:

- **Organize and fund a transdisciplinary Foods for Health Initiative.** The initiative should be focused on identifying health-promoting nutrients, developing processing modalities and phytochemical extraction that preserve functional activity, testing for efficacy through animal models and human trials, and evaluating potential commercialization pathways for realizing value through Missouri production of associated value-added products. A key goal, as a focused economic development platform for Missouri, will be the development of a research-based health-promoting value-added products industry. The initiative would be centered at MU, but also incorporate industry and complementary capabilities at other Missouri universities. It is likely that MU Nutritional Center for Health (MUNCH) would be at the core of the initiative and the organizer/manager of the Foods for Health Initiative.

- **Invest to address gaps that are observable in current capabilities, resources, and facilities.** A priority investment area is the Food Science Department within CAFNR at MU. Investment is required in two areas:
    - **Faculty Recruiting.** It is recommended that faculty lines be at least doubled in Food Science. Key areas suggested for recruitment coverage include sensory science, product development, process development, and a Food Science Extension specialist to interface with existing and developing industry.
    - **Facilities and Infrastructure Development.** Investment is recommended in product development, piloting and demonstration, and sensory facilities competitive with those of other leading food science programs.

- **Connect MUNCH/PAW phenotyping and trials capabilities to MU Bioinformatics and genotyping capabilities.** Fundamental and translational/clinical research to connect phenotype response to food ingredients is a core competency for MUNCH (and supported by the MU Physical Activity and Wellness Center [PAW] capabilities). It is logical, given MU leadership's interest in realizing a signature position in personalized medicine, to also integrate genetic research into the proposed Foods for Health Initiative. MU has invested in biomedical informatics (recruiting a well-recognized faculty lead) and has robust sequencing and analytical support capabilities. The MUNCH access to trial cohorts provides an ability to collect unified phenotype and genotype data through participating cohorts. This will build a highly valuable long-term data resource for eventually advancing personalized nutrition models and nutritional genomics.

- **Connect to other Missouri academic institutions.** The Foods for Health Initiative should seek participation of other Missouri-based academic institutions that have capabilities and research core competencies relevant to the initiative's mission. Washington University in St. Louis, for example, has notable expertise in metabolism research, and St. Louis University has teams focused in supply-chain research that could be relevant. Canvasing Missouri's research universities for relevant core competencies and interest in participating in the initiative is encouraged.

- **Engage industry in an advisory board and as active program sponsors and participants.** An industry advisory board should be established to provide input into research programs and guidance regarding potential commercialization pathways. Industry can also provide advice regarding associated university education programs and how they can best meet the needs of an emerging value-added foods for health industry. The industry advisory board should comprise

representatives from food, plant science, feed and pet food, biopharmaceutical, and logistics companies to provide well-rounded input and connectivity.

- **Target early identification of research discoveries and innovations with potential for impact on Missouri production agriculture and the development of value-added processing and retail industries**. Since the initiative is being envisioned as an integral element of the strategy to increase value-added stemming from Missouri's agricultural sector, it will be important to direct research toward identifying nutritional elements that may be sourced from commodities that are suitable (or can be engineered to suit) Missouri farm production environments. In other words, work should not be focused on tropical or exotic crops that would be unable to support Missouri-based production.

- **Conduct research into processing techniques and technologies suited to preservation of functional health-promoting nutritional elements and chemicals.** Identification of health-promoting nutritional elements is important, but it represents only part of the work needed to develop value-added foods for the health industry. It is also critically important to work in parallel to develop harvesting technologies, post-harvest handling modalities, storage and materials handling, extraction techniques, processing technologies, and packaging that preserve the functional characteristics of the nutrient or food product. These have to be developed not only to preserve bioactivity but also to do so in an economically viable manner and in ways that can ideally fit into existing and emerging supply-chain systems.

- **Once capabilities, reputation and care are established, introduce market testing and certification services**. The initiative itself, or a spinout enterprise or subsidiary, can be developed, over the long-term, to leverage the capabilities and knowledge base of the Foods for Health Initiative into a branded testing and certification service. Through establishing standards for bioactivity, purity, or other metrics, the initiative can then test and certify the performance of products for industry under a fee-for-service or contract model. Further, Missouri production of value-added nutritional products may be promoted under a Missouri Foods for Health brand to achieve French-like appellations (certifications of quality and provenance that increase the value of the product).

- **Conduct development work on new value-added product supply chains.** The growth of the local food movement, home food delivery systems, custom meal preparation services, and other trends in supply chains suited to personalized products provides a potential pathway toward personalized foods for healthier lifestyles and disease treatment and prevention. These new models are not a fit to traditional commodity food supply chains, and the Foods for Health Initiative should be involved in supply-chain R&D to innovate supply, distribution, and retail models for personalized products.

Scientific discoveries, technological capabilities, production and supply-chain innovations, and consumer preferences and market demands are converging to make the timing right for advancing a major Foods for Health Initiative. Missouri has a robust base of assets already in place to draw upon; and though gaps in certain capabilities must be addressed, a focused transdisciplinary research initiative can certainly be advanced in the near term to promote cluster-based value-added R&D and industry economic development.

Enhanced Commodity Utilization Initiative

Missouri's production agriculture is currently dominated by a few major commodities (primarily oilseeds, grains, beef cattle, and poultry). The supply chains for using these commodities are well established; and overall, input received from those interviewed throughout the project indicated that the ability to add major value-added components to the current production is quite limited. This was also reported to be the case for forest production in the state. The agriculture and forestry industries in Missouri have developed, over many decades, to produce efficiently and service existing commodity markets and their supply chains.

Situational analysis performed through interviews and analytics during the project, together with some existing published feasibility studies, indicate the following situation and opportunities for enhanced utilization of major crop and livestock commodities produced in the state:

- **Enhanced Value-Added Beef Processing:** A strong and compelling case exists for pursuing an initiative to develop a substantial beef slaughtering/aging/portioning operation in Missouri. The initiative should focus on supporting the recommendations stemming from the analytics—engaging with the Missouri Value-Added Beef Processing Group, LLC, and its consultants Kemker & Associates, LLC, to advance the opportunity.

- **Enhanced Value-Added Pork Processing:** As with beef, there may be potential for an additional pork processing plant to be developed in Missouri, with an increased processing demand leading to more Missouri corn and soybean demand for advancing pigs from a weight of 30 pounds to up to 280 pounds when ready for slaughter. By increasing swine processing in Missouri, the availability of pork for further processing into value-added finished meat products for retail will be enhanced.

- **Industrial Hemp as a New Commodity:** With the signing of the Farm Bill on December 20, 2018, industrial hemp was removed from the Controlled Substances Act, and farmers nationwide may grow the crop. It should be expected that, with the legalization of the growth of industrial hemp, the demand to better understand this market will increase significantly.

- **Poultry Production and Associated Broiler Processing:** This represents an existing vertically integrated industry in Missouri. It is not anticipated that the Missouri Value-Added Strategy is required to address the industry further given its existing level of integration and sophistication. However, in the **layer sector** of poultry, Missouri has been experiencing increased production levels, which are partly being driven by changes in egg production regulations (forming restrictions) at a state level in California and other production centers. Encouraging increased poultry and layer production does have the benefit for Missouri of increasing demand for feed products based on commercially produced Missouri commodities, such as corn.

- **Dairy Industries:** The dairy sector may see future growth, likely as a result of water shortages in western states and the potential growth in consumer preferences for pasture-based dairy production and associated products. Input received for the project, however, indicated that growth of large-scale dairies in Missouri is unlikely in the near term because of county-by-county regulatory constraints on confined animal operations. Similarly, the water shortage issues are not at "crisis" level in the western states yet—thus, a move of dairy operations to states with robust water assets (such as Missouri) is likely a longer-term opportunity.

- **Soybeans and Corn:** Even though these crops are important components of Missouri agriculture production, market volatility and a series of unknowns make it challenging to recommend a strategy focused on soy value-chain enhancement and investment in Missouri at the present time. It is recommended, however, that advanced soy-based nutrition products be partly a focus within the Foods for Health Initiative given the deep level of crop expertise within the Missouri research community and the industrial activity (most notably concentrated at Solae's operations in St. Louis) in soy protein isolates and other advanced soy-based products. Similar attention should be paid to specialty corn products as an opportunity in Missouri. Kansas City's Ingredion is an example of a specialty corn products manufacturer that generates demand for several thousand acres of specialty corn (for example, waxy corn, white corn, etc.) produced under contract to the company in Missouri.

Potential Outcomes and Impacts

The research and analysis highlighted in this report demonstrate that Missouri has distinctive opportunities to further grow its value-added industrial activities that use agricultural inputs. The near-term opportunities are principally found in value-added food (and to a lesser extent feed) product industries.

Development pathways open to Missouri are found to consist of three primary opportunity areas:

1. **Developing regional food product development centers that will operate as food industry accelerators to advance new products from concept through market testing and into pilot-scale production.** Using a central hub at MU, together with satellite regional locations at other Missouri colleges and universities distributed within Missouri's regions, provides an effective means of assuring efficient use of resources and a sound geographic distribution of new business development opportunities around the state in the food sector. Also, at a regional level, it is found that better engagement can occur in local foods—linking potential regional demand with regional producers to leverage the expansion of the local food movement for both domestic and institutional/commercial customers.

2. **Building a new industry in functional foods and advanced nutrition products (foods for health) that leverages academic R&D expertise and infrastructural investments in nutritional sciences and clinical health sciences and the food industry of the state.** Reinforcement of the food science discipline in academe is required to balance the disciplinary strengths required for success in this opportunity area. While this will require significant investment in faculty and infrastructural resources, the investment will help Missouri build and sustain a leadership position in a fast-growing market space and one that, at the present time, sees limited competition from other focused initiatives. The recommended Foods for Health Initiative should pursue this opportunity with a focus on identifying and developing products that may utilize Missouri-grown agricultural commodities (whether existing or new).

3. **Taking a focused approach to near-term opportunities for enhanced utilization of major agricultural commodities produced in Missouri.** The integrated nature of the row crop and livestock industries (with the former providing feed inputs to the latter) means that increasing the volume of beef cattle and swine produced and finished in the state is key to adding

significant value to Missouri agriculture. Increasing the level of finishing of beef cattle and swine and their processing in new facilities developed in the state should be a priority. Increases in advanced nutrition (for both human and animal food applications) product development (accomplished through the Foods for Health Initiative) should be directed toward key Missouri crops (such as soybean, corn, and rice) to create integrated value-chains. Finally, the opportunities for industrial hemp as a result of the 2018 Farm Bill will need to be further explored and vetted.

Through the pursuit of this three-component strategy, **it is anticipated that significant economic benefits may be derived** for Missouri. If these strategic initiatives are successfully implemented, then their impact on Missouri's economy by 2027 is projected to accomplish the following:

- Expand total value-added ag/food manufacturing economic activity to **more than $71 billion**, which is an increase of more than $25 billion compared with 2017.
- Create and support nearly **70,000 new jobs** and generate **nearly $4.4 billion** in new personal income.
- Produce annual state and local tax revenue of **more than $3 billion**, which is growth of more than $1 billion compared with 2017.
- Increase agricultural commodity production sales by approximately **$1 billion annually** to meet new value-added uses.

Chapter I: Introduction

This report examines opportunities to expand Missouri's economic activity in the production of value-added products that use farm and forest output as inputs to downstream production. Through further processing and manufacturing activities, significant value can be added to primary crops, livestock, and forest output that otherwise may leave the state with no additional value added. Maximizing value-added opportunities brings benefits in terms of expanding the economy and increasing employment, family incomes, and exports for Missouri.

The objective of this project is to determine whether a food processing and value-added biomass manufacturing initiative, intended to catalyze the development of value-added food processing and manufacturing businesses statewide, is feasible and recommended based on the agricultural resources, industrial capacity, and research innovation assets present in Missouri today.

A. Missouri's Agriculture and Forestry Industries

Missouri has large and productive primary-production sectors in agriculture and forestry. A 2016 review of the impact of these sectors on the Missouri economy notes that the primary output of "Crops, Livestock, Forestry, and Fisheries Production contributed $9.4 billion" to the Missouri economy.[2] This $9.4 billion comprises 3.6 percent of the total state gross domestic product (GDP). Primary production, however, comprises only part of an integrated ecosystem of economic activity related to agriculture, forestry, and fisheries in Missouri. Activities in agricultural processing, food processing and food and beverage product manufacturing, wood products manufacturing, etc., add significantly to overall impacts, and the aforementioned 2016 study calculated that 9.4 percent of total value added in the Missouri economy comprises activity across the agriculture, forestry, and related industries' value-chain.

B. A Need to Further Grow Value-Added Industries

The above cited data suggest that Missouri already has a significant value-added processing industry for agriculture and forest products. That is true, but it is equally true that substantial volumes of commodity crop and livestock animals are shipped out of the state without significant value-added processing. Missouri's farmers and foresters are highly productive, but money is being left on the table because large volumes of primary agriculture and forest production is leaving the state without further in-state processing steps adding value to the product.

It is also the case that worldwide agricultural commodity markets are highly competitive, and price driven. As a result, even though national agricultural productivity continues to increase, the real value of that production at "the farmgate" continues to decline. Current U.S. Department of Agriculture (USDA) statistics indicate that U.S. net farm income is forecasted to fall for the fifth consecutive year in 2018.[3]

Producing to sell only into commodity markets puts farm and forest producers in a weak position, subject to intense global competitive forces and fluctuations in commodity prices that are outside of their control. With much of rural and small-town Missouri's economic fortunes tied to the agricultural economy, it is imperative that more economic value be captured from farming and forestry activities.

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[2] *Economic Contributions of Missouri Agriculture and Forestry*, prepared by Decision Innovation Solutions for the Missouri Agricultural and Small Business Development Authority of the Missouri Department of Agriculture and the Missouri Farm Bureau, December 2016, page 5.

[3] See: https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/.

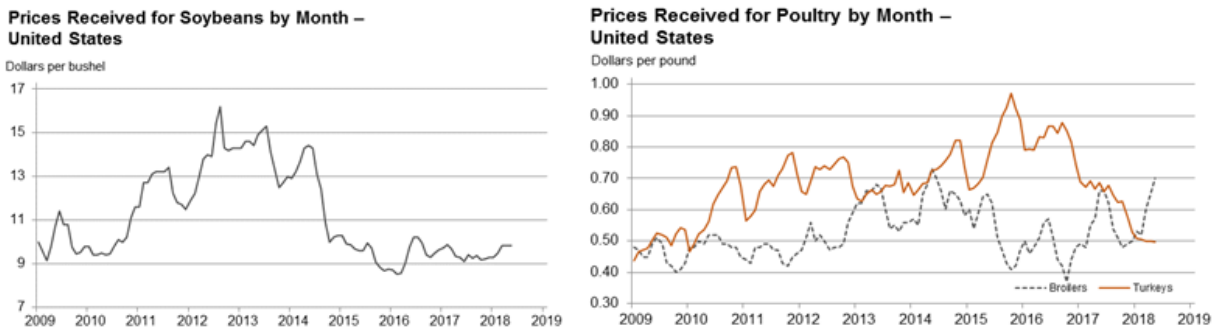
Examples of Commodity Price Variability Substantially Impacting the Farm Economy

The challenge of sustaining rural economies in the face of widely fluctuating agricultural commodity prices is not insignificant. Two examples, representing major agricultural commodities produced in Missouri, illustrate this:

- **Soybeans** comprise the largest crop produced in Missouri. Prices peaked in August 2012 at $17.58 per bushel; but, as of July 2018, prices have more than halved, dropping to just $8.42 per bushel.
- **Broilers** and other meat-type chickens represent a significant component of farm output in Missouri. U.S. market pricing for broilers has varied significantly over the last decade. **Turkey** production is also a substantial component of Missouri agriculture and, again, experiences substantial price fluctuations.

USDA data (Figure 1) show the substantial ups and downs that have been experienced in recent years by U.S. farmers in terms of prices for these critically important commodities.[4]

Figure 1: Price Volatility in Soybeans and Poultry in the United States, 2009–2018



While commodity production will no doubt remain the major component of Missouri's agriculture[5] and forest output for the foreseeable future, benefits could be achieved through building enhanced value-chains that increase in-state value-added processing. Companies engaged in the production of finished food products, for example, may seek to secure their ingredient supply through contracting with local agricultural processing firms, individual farmers, or farm cooperatives. Working contractually together, producers, processors, and manufacturers can partially decouple themselves from more volatile commodity markets and benefit from a more stable and predictable operating environment. Similarly, farmers can individually or collaboratively engage in value-added business activities themselves to raise their incomes—ranging from the production of specialty processed food products on the farm (for example, artisan cheese) to co-investing in corporative business ventures (for example, the development of biorefineries).

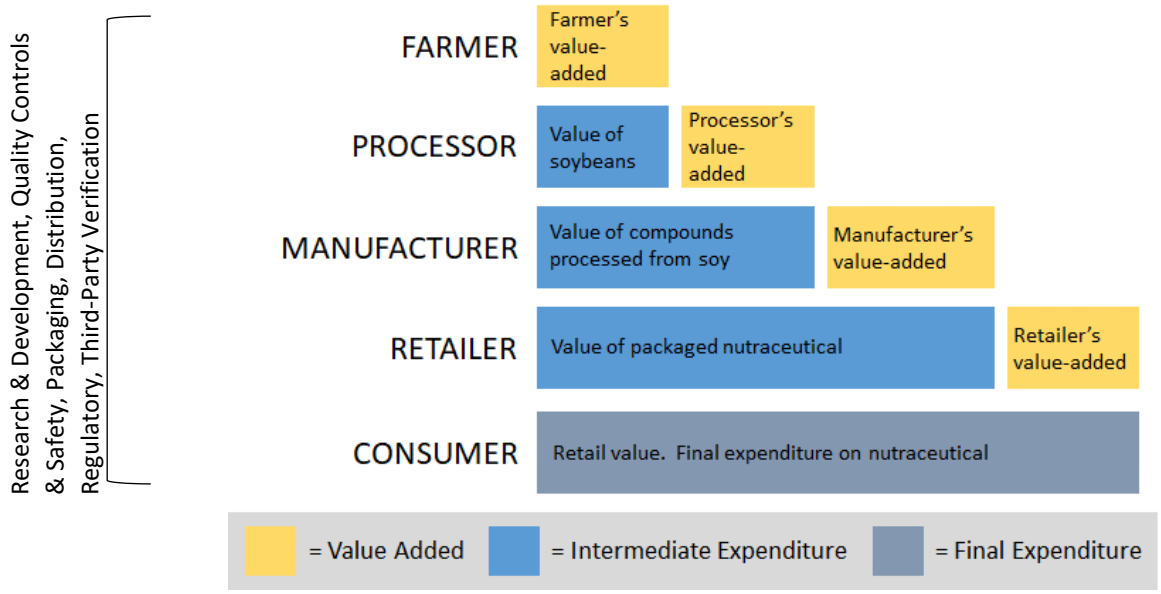
An example value-added concept is shown in Figure 2 and illustrates the difference in potential income between simply growing and selling soybeans (the farmer row) and the total income that may be realized in a state that provides a vertically integrated value-added chain—in this example, by growing

[4] USDA National Agricultural Statistics Service. Charts in Figure 1 can be seen at https://www.nass.usda.gov/Charts_and_Maps/Agricultural_Prices/pricesb.php and https://www.nass.usda.gov/Charts_and_Maps/Agricultural_Prices/pricetb.php.

[5] The terms "agriculture," "agribusiness," and "agbioscience" are used generically herein to incorporate agriculture, forestry, fisheries (including aquaculture), and associated industries producing and processing plant and animal biomass.

soybeans, performing the raw agricultural processing step (soybean crushing), further processing the soy product to obtain components and compounds of nutraceutical value, and then retailing them. For a commodity product like soybeans, which is Missouri's top agricultural commodity and represents nearly one-quarter of the state's farm receipts,[6] an integrated value-chain would capture a far higher percentage of the final dollar figure spent on the product for the state.

Figure 2: Example Value-Added Concept—Soybeans to Nutraceuticals Illustrative Example[7]



Source: TEConomy Partners, LLC.

As noted above, multiple paths can be pursued to capture increased added value, including production of value-added products on the farm; production of value-added products by farmer co-ops; development of individual companies specializing in different steps along the value-chain; and contractual relationships, partnerships, or other business structures engaged between entities.

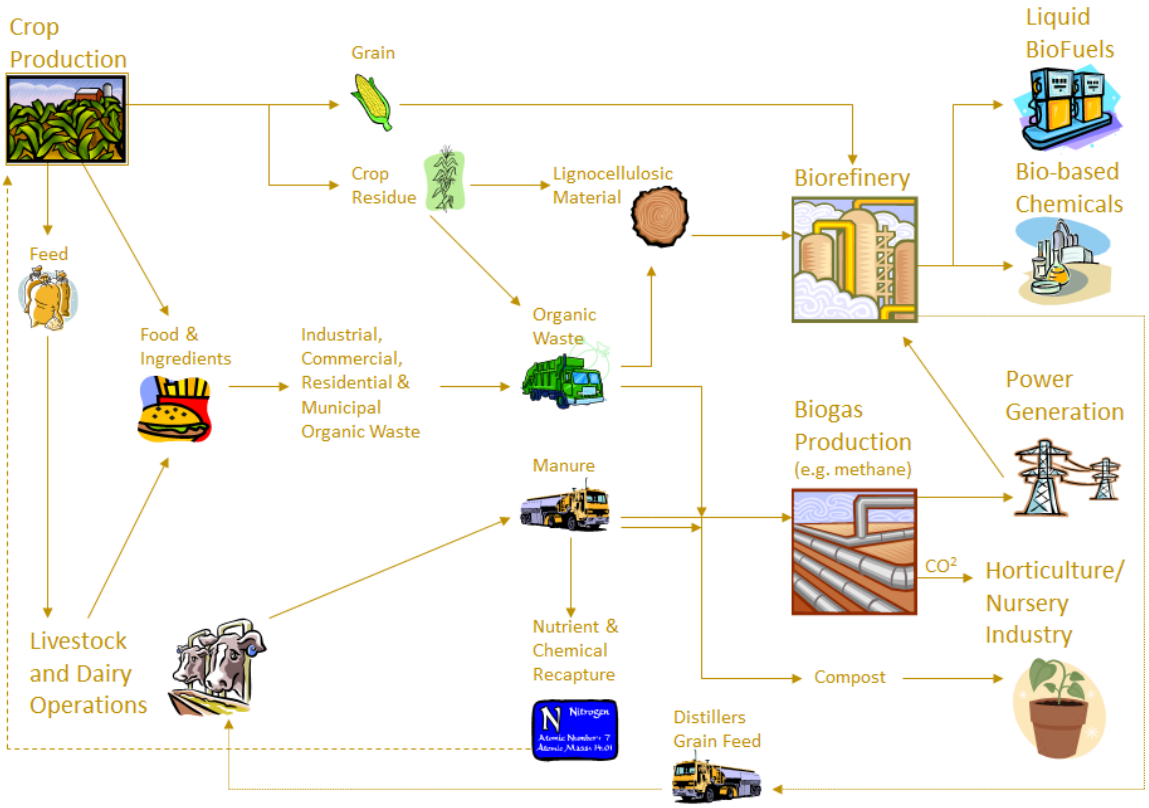
C. Adding Value in Complex Industrial Ecosystems

Figure 2 helps to illustrate "value-added" conceptually; but, in the marketplace, the value-added activity takes place within more complex transactional ecosystems. By example, Figure 3 illustrates this by showing the multiple potential pathways and interrelationships in the uses of an individual crop—with the specific example shown of corn. Corn could be grown in the state and simply exported as a commodity with no value added to it, or, as shown in Figure 3, can be the key input to a complex in-state chain of interrelated economic activity—adding value, economic output, and jobs.

[6] See: https://agriculture.mo.gov/topcommodities.php.

[7] Note: Size of individual bars are illustrative only and not to a specific scale.

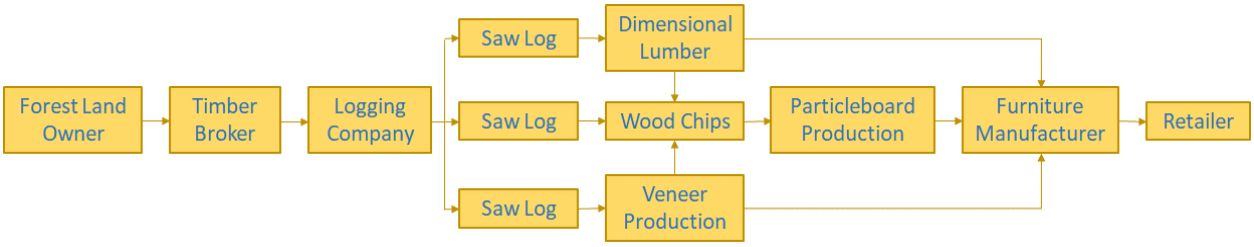
Figure 3: Agricultural Products as Inputs to a Complex Value-Added Production Ecosystem: Corn Example



Source: TEConomy Partners, LLC

Similar ecosystems and value- chains can also emanate from any agricultural commodity to which value may be added and from other biomass production sectors such as the forestry sector. Figure 4 illustrates an example forestry value-added pathway, showing key actors and steps engaged in the conversion of standing lumber in forests into finished wood furniture.

Figure 4: Example Production Steps in the Conversion of Lumber to Wood Furniture[8]



Source: TEConomy Partners, LLC

[8] Illustration by TEConomy adapted from original illustration in: Shanna Appelhanz, Victoria-Sophie Osburg, Waldemar Toporowski, and Matthias Schumann; "Traceability system for capturing, processing and providing consumer-relevant information about wood products: system solution and its economic feasibility"; *Journal of Cleaner Production*, *Special Volume: Improved resource efficiency and cascading utilisation of renewable materials*; Volume 110; January 1, 2016; pages 132–148.

Examining opportunities to build-out such value-added chains and ecosystems within Missouri represents a component of the analysis performed and reported herein (see sidebar).

D. Defining the Sectors of Interest for this Study

With over 97,000 farms in Missouri covering 28.5 million acres, primary agricultural production covers a substantial part of the Missouri landscape. This farmland is used to produce a diversity of crops, livestock, and poultry. Soybeans, corn, and hay comprise the largest components of planted acreage; but, there is also significant production of cotton, wheat, and rice—plus production of fruits and vegetables. Poultry and livestock represent as significant a component of agriculture in the state as crop production (roughly equivalent in terms of total value of production)—with large-scale production of chickens (mostly as broilers), turkeys, hogs, and cattle and calves. The crop production and poultry and livestock production integrate in that much of the soybean and grains produced in Missouri are used as feed products for livestock and poultry production.

Forestry is another key component of Missouri land use. Today, the State of Missouri contains more than 14 million acres of forestland with most of this forestland (85 percent) held in private ownership. Diverse in terms of forest tree species, Missouri has both hardwood and softwood production. Currently, production is sustainably managed with annual growth of forests exceeding the amount harvested.[9]

Missouri also has an aquaculture sector, ranking 10th among all U.S. states in aquaculture production.[10] Production from aquaculture is relatively limited, however, when compared with other agricultural commodities in Missouri, comprising 0.1 percent of the value of all agricultural commodities produced.

Commissioning a Value-Added Food and Biomass Processing and Manufacturing Initiative Feasibility Study

As Figure 3 illustrates, expanding levels of vertical integration maintained within the borders of a state yield expanding levels of economic development potential (in terms of business output and employment levels). The Missouri Agricultural Foundation, understanding the importance of catalyzing more robust post-farmgate food, fiber, timber, and industrial biomass processing and manufacturing capabilities within the state, identified a need to develop a comprehensive economic feasibility study that would explore opportunities for Missouri to increase this important industrial sector of the state's economy.

The feasibility study's goal is to identify the opportunities for Missouri agriculture to achieve greater economic impact by ensuring that the agricultural and forestry commodities produced across the state are transformed in-state into higher-value products consumers or industrial users desire. The goal is thus to identify opportunities to increase the level of value-added food and beverage, fiber, timber, and industrial biomass processing and manufacturing within Missouri.

TEConomy Partners, LLC, was retained to conduct a detailed economic feasibility study that will identify opportunities for Missouri to increase its value-added food and beverage processing and manufacturing capabilities as well as production of other downstream value-added fiber, timber, and industrial biomass-based products.

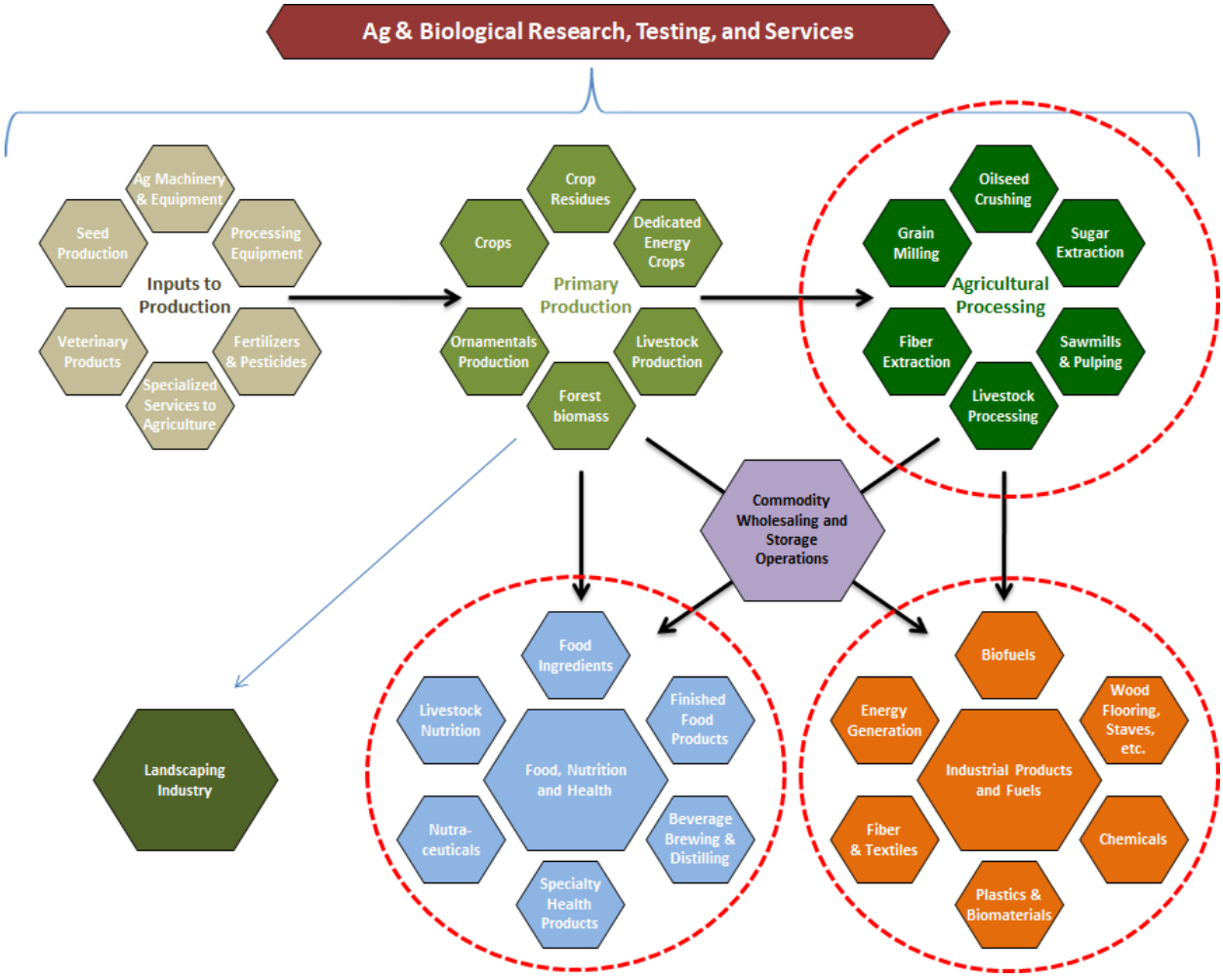
The above elements of agriculture and forest production in Missouri comprise what is termed "primary production." At the most basic level, these operations produce "biomass," which may be used in multiple applications as feed, food, fiber, and lumber or as inputs for industrial processes manufacturing paper, structural materials, chemicals, fuels, and energy. After harvesting, the diverse biomass produced in Missouri either leaves the state as a commodity or feeds into value-added processes that convert it

[9] See: https://mdc.mo.gov/about-us/department-details/missouri-forest-facts.
[10] See: https://data.ers.usda.gov/reports.aspx?ID=17844#P8df8c3bbe9e54907b92b784b5f2b3f40_2_251iT0R0x7.

into a higher-value product in the state. The core focus of this report is on examining opportunities to reduce the former and increase the latter—a focus on increasing the use of primary commodities in Missouri to produce value-added products.

The major components of activity across the U.S. agricultural and forestry value-chain are shown on Figure 5. The areas circled in red comprise the sectors that are the primary subject of this study. These emphasize economic activity that converts crops, livestock, timber, and other agriculture and forest primary outputs into further refined or processed products.

Figure 5: Major Elements of the U.S. Agricultural and Forestry Value-Chain



Source: TEConomy Partners, LLC.

Three primary categories of economic activity, converting biomass into higher-value products, are thus the primary emphasis for this project:

- **Agricultural Processing.** Comprising industries that perform the early steps in value-added processing of farm and forest output—including activities such as grain milling, soybean crushing, livestock harvesting and meat processing, fiber or chemical extraction, and sawmills and pulping operations.

- **Food, Nutrition, and Associated Health Products.** Comprising industries manufacturing food ingredients and food additives, the manufacturing of processed and finished packaged foods and beverages, specialized animal feed and pet foods, nutritional supplements and nutraceuticals, and other specialty health products.
- **Industrial Products and Fuels.** Comprising a broad range of products made using biomass inputs, including wood products, specialty chemicals and chemical intermediates, bio-based plastics and polymers, biofuels, and fibers and textile products.

In evaluating these three primary macro-categories, it is important to consider the manufacturing and distribution activity involved in producing their market value as well as the **research and development (R&D)** advancements that result in, or enable, the development of new technologies and product innovations. Advancements in areas such as food safety, processing technology, packaging technology, materials science, chemical and ingredient formulations, nutrition characterization, etc., and the science and engineering disciplines that underpin them, derive from an R&D ecosystem that comprises industry, academic, independent non-profit and government lab operations, and research funding derived from both private- and public-sector sources. Missouri's ability to realize enhanced economic output through value-added downstream biomass processing thus needs to be reviewed in the context of the overall R&D and production ecosystem that enables it.

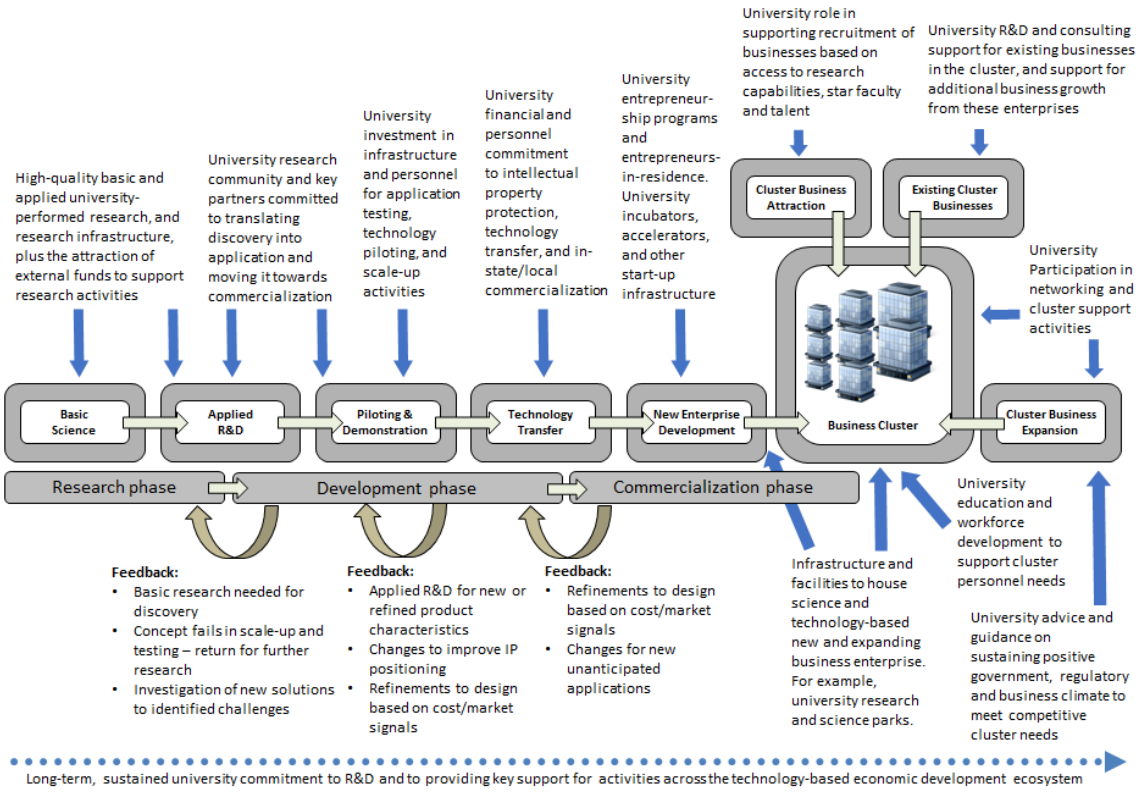
E. The Role of Research and Innovation

As in other industrial sectors, the development of new and improved products is a function of innovation—typically driven by structured R&D activity. R&D activity in agriculture and forest products occurs within industry and is also an emphasis of university-based research—especially at U.S. land-grant universities, which have an historic focus on agricultural sciences and associated disciplines.

Land-grant universities (LGUs), such as MU (an 1862 LGU) and Lincoln University (an 1890 LGU), comprise a special cluster of higher education institutions purpose-designed to not only provide high-quality higher education across the nation, but also to increase the national stock of knowledge through research and to put knowledge to use through ensuring its transfer from the academy to agricultural producers, value-added industries, workers, community leaders, and individuals. While initiated by an Act of Congress in 1862, the land-grant system is as relevant today as it has ever been—perhaps even more so given today's "knowledge economy" and the extreme complexity of industries like modern agriculture and value-added processing that draw upon wide-ranging areas of scientific inquiry and technological innovations. From relatively humble beginnings, the 1862 LGUs have grown to become some of the world's largest and most prestigious research universities—and always embedded within them is the ethos of knowledge generation and a "knowledge put-to-work" translational mission that is a direct fit to projects that aim to build the agricultural and value-added industries economy. The 1862 LGUs saw their number increase with the addition of multiple historically black colleges and universities as 1890 LGUs—with Lincoln University representing this expansion in Missouri.

Universities serve a highly important and multifaceted role in advancing scientific and technological research relevant to agriculture and forestry industries. Moreover, through the integrated research, extension, and higher education functions at LGUs, the academic community generates wide-ranging economic and social impacts that are crucially important to Missouri's success in a knowledge-based, innovation-driven economy. Through the above cited effort, and other activities, the work of Missouri's universities supports the operation of a robust R&D-based innovation and business support ecosystem in the state. This ecosystem supports the development of new technologies and solutions to industry challenges and plays a critically important role in the early-stage incubation of commercial opportunities (Figure 6).

Figure 6: The Role of Academic Research, Education, and Extension in the Missouri R&D and Innovation Ecosystem[11]



Source: TEConomy Partners, LLC.

F. About This Study

As noted previously, the goal of the research and analysis herein is to examine opportunities to expand Missouri's economic activity in the production of value-added products that use farm and forest output as inputs to downstream production. Through further processing and manufacturing activities, significant value can be added to primary crops, livestock, and forest output that otherwise may leave the state with no additional value added.

Figure 7 provides an illustrative overview of the how the work contained in this project focuses on moving Missouri from its current status to a larger, higher-value-added agriculture and forest processing-based economy:

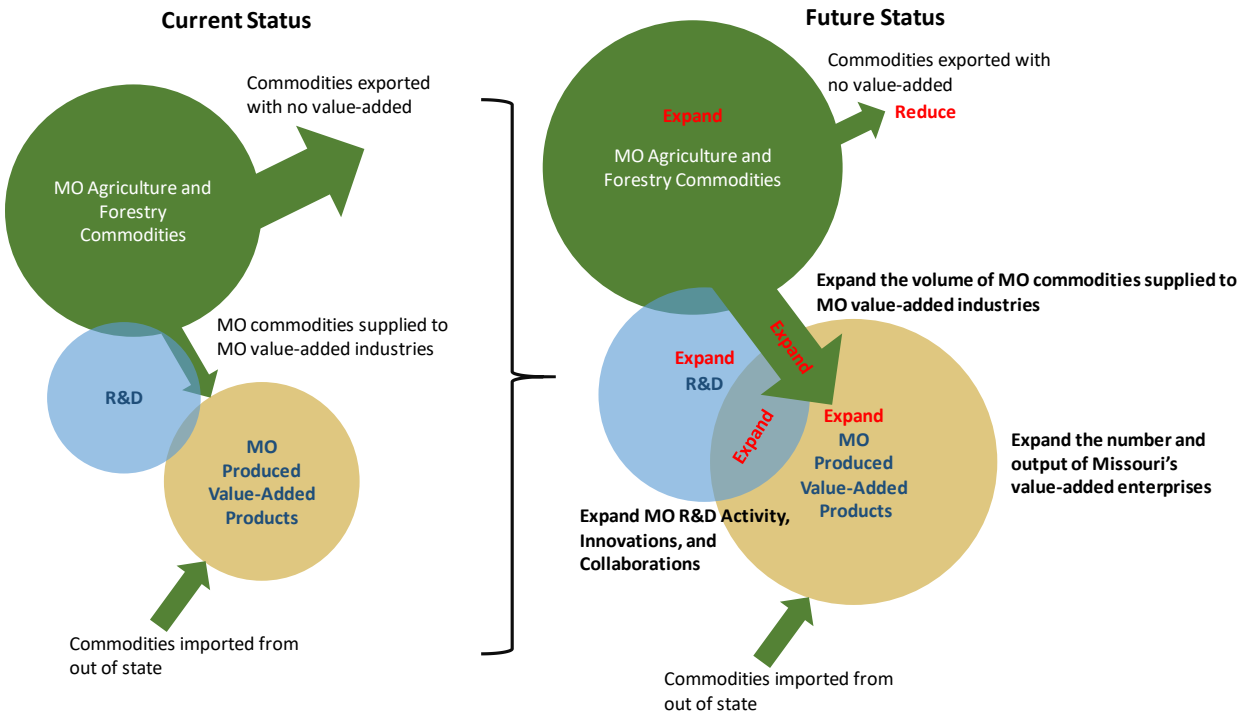
- Under "Current Status," it can be seen that Missouri currently produces considerable farm and forest production that leaves the state with no value added, and a more limited flow of production is directed to Missouri value-added industries. The goal for the "Future Status" is to redirect output so that considerably higher volumes of farm and forest output are further processed within the state.
- The "Missouri Agriculture and Forestry Commodities" circle is shown as larger in the "Future Status" since part of the goal of the project is to identify opportunities to grow primary-

[11] Adapted from original graphic in: Simon Tripp, Ryan Helwig, and Dylan Yetter, *The Importance of Research Universities: With Examples of their Functional Role and Impacts Within the State of Indiana,* prepared by TEConomy Partners, LLC, for BioCrossroads and supported by a grant from the Lilly Endowment Inc., 2017, page ES-4.

production revenues by creating demand for high-value, specialty inputs to a value-added industry.

- The "Missouri Produced Value-Added Products" circle is enlarged in the "Future Status" given the primary goal of the project to identify opportunities to expand value-added processing and final product manufacturing in the state along food, fiber, chemical, materials, and other value-added biomass-based pathways.
- The importance of R&D is reflected in a goal to increase R&D activity relevant to value-added industries and to expand the collaboration between the academic R&D sector and industry to further advance value-added production opportunities.

Figure 7: Goals of This Study—A Conceptual Illustration



Source: TEConomy Partners, LLC.

The report is organized into six additional chapters:

- Chapter II defines the value-chain and provides a detailed examination of the current status of the key sectors that comprise the value-chain. It identifies the scale of the sectors currently in Missouri as defined by output, establishment, employment, and wage data and profiles recent trends in each major component of the value-chain. Regional analysis is also undertaken to illustrate the geographic presence of value-chain elements in key Missouri regions.

- Chapter III examines the R&D and innovation assets and core competencies that relate to advancing value-added industry development in the state rooted in farm and forest production output. Understanding areas in which food, fiber, bio-based chemical, wood product, and other relevant research and innovation are taking place provides guidance as to potential areas for driving growth into the future.

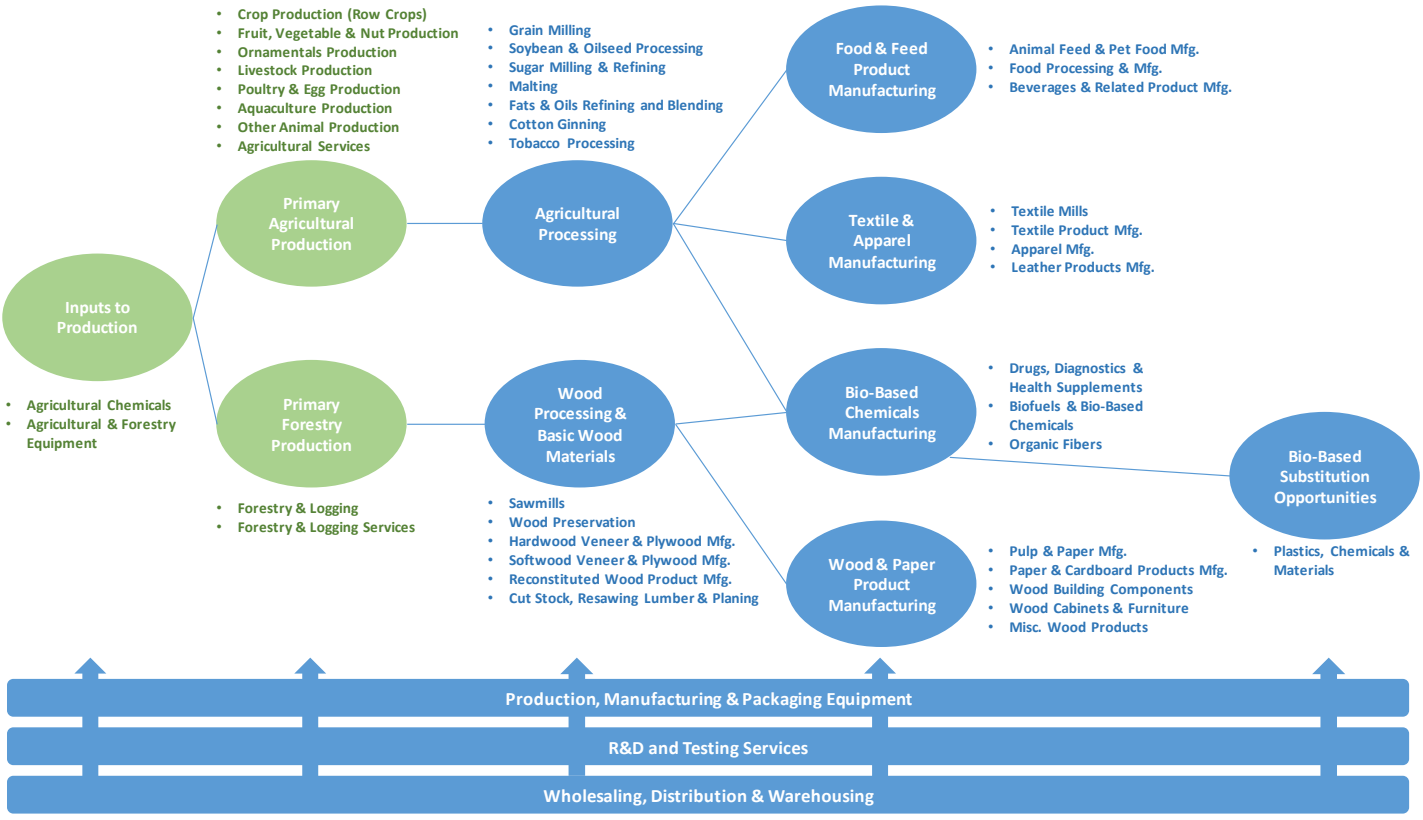
- Chapter IV provides an assessment and summary of potential pathways by which further growth of value-added industries may be catalyzed in Missouri. Strengths and weaknesses of the state are evaluated, and opportunities are considered for development and growth of value-added industries and for the enhanced utilization of R&D assets to drive industry innovation and new commercialization opportunities. Action plans are presented across a series of initiatives recommended for Missouri based on the research and analysis performed.
- Chapter V measures the economic impact and the effect of projected future changes to employment levels in value-added ag/food manufacturing in the state to better understand the implications of strategic decisions to grow and expand the industry through focused initiatives.
- Chapter VI provides a summary of the report's overall findings.

Chapter II: Current Status of Missouri's Value-Added Processing Sectors

A. Defining the Value-Chain

Figure 8 provides an overview of the general structure of the production steps taking place across the value-chain for agriculture and forest products. Shown in green are the primary production components, taking place on farms and forestland. The primary production taking place is considered in this study because it represents currently produced farm and forest output that may be available as inputs to downstream value-added activity. Shown in blue are the sectors of principal concern for this study, comprising three macro categories: "processing," "manufacturing," and "substitution opportunities" (the latter containing chemicals, materials, and other manufacturers items that are presently primarily produced using non-ag/forest inputs but have potential for increased utilization of such inputs). The blue bars across the bottom of Figure 8 illustrate three other areas of direct relevance to the study, comprising the development and manufacturing of equipment used in value-chain activities; the R&D and testing services sector; and the supporting sector of wholesaling, distribution, and warehousing.

Figure 8: Overview of Sectors and Subsectors Evaluated Across the Project



Source: TEConomy Partners, LLC.

The structure of the value-chain shown on Figure 8 is used as an organizing element for analysis and discussions herein.

B. Production Agriculture and Forestry in Missouri, and the Inputs to Production

1. Agriculture in Missouri

Missouri's agricultural output comprises major production of both plant and animal production commodities. The total value of production in 2017 was $10.09 billion (Table 1), of which 57.1 percent ($5.76 billion) was comprised of crops (including row crops, horticultural crops, and forage crops) and 42.9 percent ($4.33 billion) was comprised of animal agriculture (livestock and poultry production, milk, eggs, and wool). The state's agriculture production is characterized by having a relatively small number of commodities that comprise the majority of the state's agricultural output. On the crop side of production, soybean and corn dominate. Soybean production value accounted for 27 percent of all 2017 ag output in the state (47 percent of total crop output) and corn accounted for 18.1 percent (31.6 percent of total crop output). Combined, soybean and corn production account for over three-quarters (78.8 percent) of crop production value in the state.

Missouri's livestock production is relatively diverse, comprising: $1.86 billion in cattle production (including calves) (18.5 percent of all ag output in the state and 43.1 percent of all animal ag value), $0.85 billion in hog production (8.4 percent of all ag output and 19.7 percent of total animal ag), $0.78 billion in chickens (broilers) (7.7 percent of all ag output and 17.9 percent of total animal ag), turkeys (4 percent of all ag output and 9.3 percent of total animal ag), followed by milk, eggs, and wool. The top three animal ag commodities (cattle, hogs, and chickens) account for 80.7 percent of total animal ag within Missouri.

Table 1: Production Value of Missouri's Top Agricultural Commodities, 2017

Sector	Missouri Production Value, 2017	Percent of Total Missouri Production	Missouri's Share of U.S. Production	Missouri's Ranking	Production Value Change, 2010–2017
Soybean	$2,722,146,000	27.0%	7%	6	11%
Cattle (including calves)	$1,864,098,000	18.5%	4%	9	49%
Corn, grain	$1,823,250,000	18.1%	4%	9	-8%
Hogs	$850,265,000	8.4%	4%	7	22%
Chickens—broilers	$775,962,000	7.7%	3%	13	N/A
Hay (excluding alfalfa)	$447,525,000	4.4%	5%	3	7%
Turkeys	$403,207,000	4.0%	8%	4	12%
Cotton, upland	$261,348,000	2.6%	3%	7	16%
Milk	$231,880,000	2.3%	1%	26	-3%
Eggs	$201,090,000	2.0%	3%	14	26%
Wheat	$161,568,000	1.6%	2%	14	173%[12]

[12] The value change for wheat is substantially influenced by an abnormally low production year in 2010. Wheat production in 2017 was lower in Missouri versus 2011 and 2012 output.

Sector	Missouri Production Value, 2017	Percent of Total Missouri Production	Missouri's Share of U.S. Production	Missouri's Ranking	Production Value Change, 2010–2017
Rice	$142,800,000	1.4%	6%	4	-20%
Hay, alfalfa	$108,720,000	1.1%	1%	26	20%
Cotton, cottonseed	$39,824,000	0.4%	4%	6	-1%
Potatoes	$28,107,000	0.3%	1%	18	24%
Watermelons	$8,445,000	0.1%	1%	11	N/A
Sorghum, grain	$7,512,000	0.1%	1%	7	-49%
Peaches (utilized)	$6,740,000	0.1%	1%	13	23%
Grapes (utilized)	$4,282,000	<0.1%	<1%	10	-5%
Oats	$2,704,000	<0.1%	2%	16	138%
Wool	$228,000	<0.1%	1%	22	33%
Total	**$10,091,701,000**	**100.0%**			
Crop Agriculture Total	$5,764,971,000	57.1%			
Animal Agriculture Total	$4,326,730,000	42.9%			

Source: TEConomy's analysis, *USDA National Agricultural Statistics Survey, 2017 Annual Survey*. Includes all commodities with a Missouri value.

It is notable that Missouri's production (not unlike many states in the Midwest United States) is highly concentrated in a few commodities and generally lacks diversity in crop production. Outside of soybean and corn (and hay production as an input to the livestock sector), other crops comprise just 6.6 percent of ag output. In terms of **horticultural crops produced for food**, Missouri is especially lacking in output. The main crops in this category total just over 0.5 percent of total Missouri ag production and include the following:

- Potatoes ($28.1 million in production value, 0.3 percent of total Missouri agriculture production)
- Watermelons ($8.4 million, 0.1 percent of production)
- Peaches ($6.7 million, 0.1 percent of production)
- Grapes ($4.3 million, <0.1 percent of production).

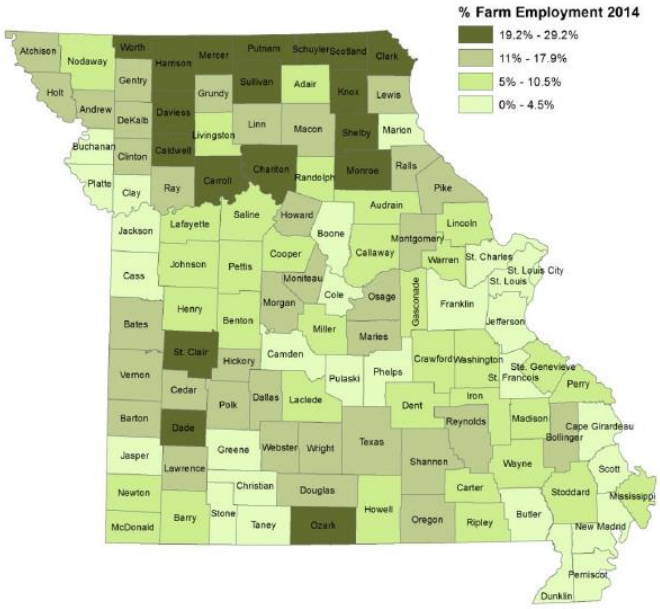
Multiple other small and specialty crops are grown on Missouri farms; but, in each case, they represent substantially less than 0.1 percent of agriculture production in the state. Other crops grown include apples, pumpkins, green beans, tomatoes, squash, and raspberries. There is also a small industry in the production of ornamentals, bedding plants, and nursery plants.

Analysis reported by the Missouri Economic Research and Information Center (MERIC)[13] at the Missouri Department of Economic Development shows agriculture production to be present in all counties in

[13] MERIC studies may be accessed online at: https://www.missourieconomy.org/industry/index.stm.

Missouri. The MERIC analysis, using farm employment to show intensity of farming operations, produced the map shown in Figure 9. The highest intensity of farming operations is in northern Missouri, especially bordering Iowa—but the industry is clearly present throughout the state.

Figure 9: County Share of Farm Employment in Missouri, 2014[14]



Source: MERIC.

2. Forestry in Missouri

In addition to Missouri's intensive agricultural sector production, the state is also an important producer of forest products. The 2017 USDA report on forest resources in the United States reports Missouri containing 15,409,000 acres of forest, representing 35 percent of Missouri's total land area (43,995,000 acres).[15] Of Missouri's forestland, 81.9 percent is in private ownership (versus the national average of 57.9 percent).

Forest production in Missouri primarily comprises hardwoods, which constitute 91.9 percent of production. This is significantly higher than the hardwood production percentage overall in the United States, which is 46.4 percent. Fairly recent (2016) analysis by Forest2Markets[16] for the National Alliance of Forest Owners reports that Missouri's forest (timberland) acreage produced 2016 timber sales totaling $161.1 million and supported an industry of "paper, wood and furniture manufacturing" with sales of $6.97 billion. The overall timber, paper, wood, and furniture manufacturing sector in Missouri directly employed 33,643 personnel and had a total impact of 80,363 jobs in the state (with total payroll totaling $2.46 billion).

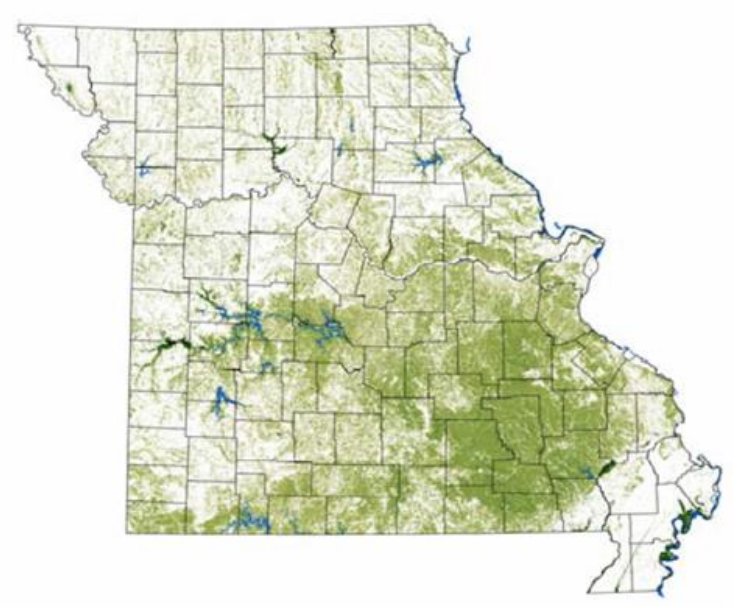
[14] "Missouri Economic Research Brief: Economic Contribution of Agribusiness," April 2016. Accessed online at: https://missourieconomy.org/pdfs/agribusiness_economic_contribution.pdf.

[15] Sonja Oswalt, Patrick Miles, Scott Pugh, and Brad Smith, *Forest Resources of the United States, 2017: A Technical Document Supporting the Forest Service 2020 Update of the RPA Assessment,* Gen. Tech. rep. WO-xxx, Washington DC: U.S. Department of Agriculture, Forest Service, 2018, pages 8–9.

[16] Hannah M. Jefferies, *The Economic Impact of Privately-Owned Forests in the United States*, provided by Forest2Market, Inc., prepared for the National Alliance of Forest Owners, 2016, pages 26 and 28.

Forestland in Missouri is present in most areas of the state; however, it is particularly highly concentrated in the southern half of the state, especially within southwest Missouri. A map produced by the Missouri Economic Research and Information highlights the distribution of Missouri forests (Figure 10). As might be expected, the distribution is generally the inverse distribution of farming as shown on Figure 9.

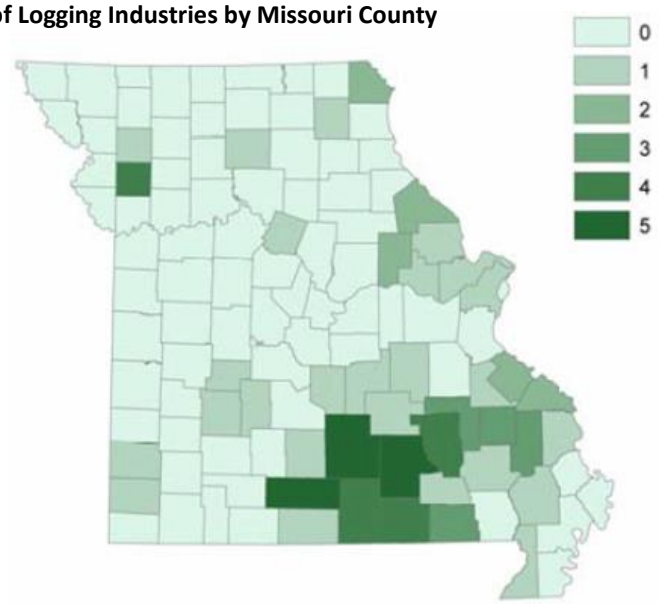
Figure 10: Distribution of Forestland in Missouri[17]



Source: MERIC.

Primary harvesting (logging) of forests in Missouri reflect the geography of timberland in the state. Geographic analysis in the same MERIC report[18] produced the map in Figure 11.

Figure 11: Number of Logging Industries by Missouri County



Source: MERIC.

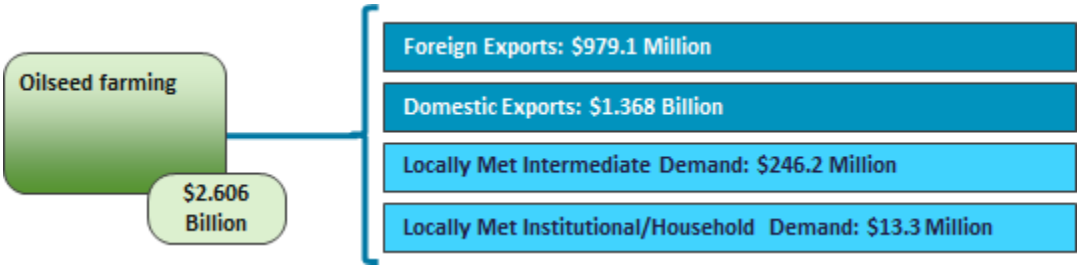
[17] "Missouri Economic Impact Brief: Forest Product Industries," October 2007. Accessed online at: https://www.missourieconomy.org/pdfs/forestproducts.pdf.
[18] Ibid.

C. In-State versus Out-of-State Use of Missouri Produced Commodities

As indicated in the introduction to this report, a key impetus for the study is to seek to increase the amount of Missouri produced commodities that are further processed in the state. The leading question then was this: how much agricultural output presently departs the state without further in-state processing beyond the farmgate?

Using data from the most recent (2016) Missouri state-level IMPLAN model, TEConomy analyzed the trade activity associated with several of Missouri's key commodities. Figures 12 through 15 show the topline findings for several key Missouri commodity categories (full data are presented in Appendix A).

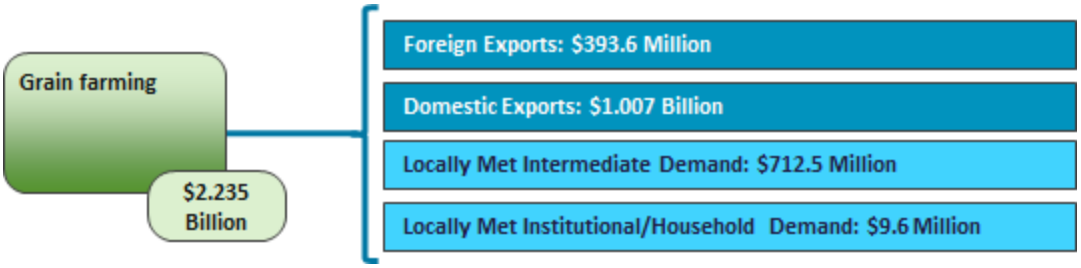
Figure 12: Missouri Demand and Out-of-State Exports of Oilseeds



Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data.

In the case of Missouri's number one commodity, soybeans, it can be seen that $259.5 million out of $2.606 billion in total production of Missouri soybeans is used to meet in-state demand (i.e., approximately 10 percent of the soybeans produced in Missouri are used in Missouri. Of the soybeans produced, $2.347 billion (90 percent) are exported outside of Missouri, with $1.368 billion going to domestic customers and $979.1 million exported internationally. It should be noted, that in some instances these soybeans are exported for further processing, only to return to Missouri as a value-added feed component.

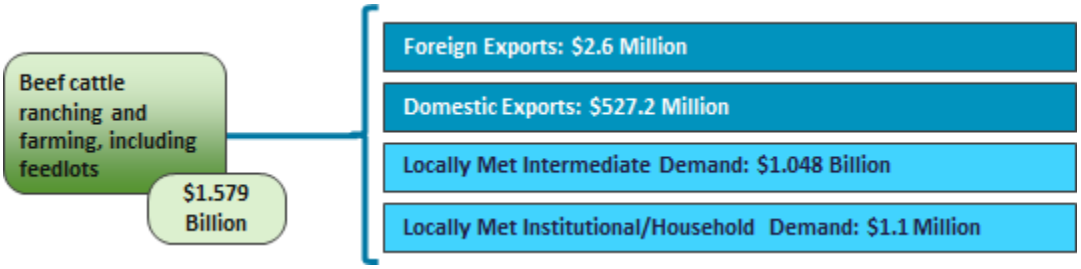
Figure 13: Missouri Demand and Out-of-State Exports of Grain (e.g. corn, wheat, grain sorghum)



Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data.

On the livestock side of the agricultural equation, Figure 14 shows the results for Missouri's beef cattle production. In the case of beef cattle, a higher percentage of production (66.4 percent) is retained in the state for use or further processing—totaling $1.049 billion. Missouri exports $529.8 million in beef cattle (33.6 percent).

Figure 14: Missouri Demand and Out-of-State Exports of Beef Cattle



Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data.

In terms of poultry and egg production, Figure 15 shows that Missouri farmers directly export $741.7 million of product (52.9 percent), with $660.6 million (47.1 percent) being used to meet local Missouri demand in downstream processing industries or direct consumption.

Figure 15: Missouri Demand and Out-of-State Exports of Poultry and Egg Production

Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data.

The export of commodities produced on Missouri's farms brings benefits to the state in terms of balance of trade, but it also represents a potential opportunity for these commodities to be further processed into higher-value products in the state that could then earn higher levels of export value and create increased economic development opportunities and job generation in Missouri. It is for this reason that Missouri stakeholders sought to have this analysis performed regarding opportunities to add value to Missouri agriculture and forestry commodity output.

D. Missouri's Ag/Bio Value-Chain

Table 2 and Figure 16 use the previously defined structure of the overall agriculture and forestry-based value-chain and provide an overview of the recent performance (2014–2017) of these sectors, particularly in terms of employment in Missouri.

Table 2: Missouri Value-Chain Macro Sectors; Recent Performance as Measured by Employment

Macro Sector	2017 Establish-ments	2017 Employment	2017 Location Quotient(1)	Emp. Change, 2014–2017	Relative to U.S. Emp. Change
Inputs to Ag/Forest Production	77	2,260	1.25	9.7%	19.6%
Primary Agricultural Production	1,501	11,762[19]	0.52	0.9%	-1.8%
Primary Forestry Production	112	299	0.22	29.4%	31.3%
AG/FORESTRY PRODUCTION	**1,690**	**14,321**	**0.55**	**2.7%**	**1.2%**
Agricultural Processing	62	1,604	1.03	-5.0%	-7.9%
Food & Feed Product Manufacturing	754	44,922	1.31	6.3%	-3.3%
Wood Processing & Basic Wood Materials	244	2,768	0.97	-3.0%	-5.6%
Wood & Paper Product Manufacturing	636	16,585	0.99	7.2	2.8%
Textile Manufacturing & Apparel Mfg.	229	4,574	0.65	-1.6%	3.5%
Bio-Based Chemicals Manufacturing	53	4,955	1.84	10.0%	-0.1%
AG/FOREST/FOOD PROCESSING/MFG.	**1,978**	**75,408**	**1.15**	**5.5%**	**-0.5%**
Processing & Manufacturing Equipment	34	928	0.90	21.0%	-6.6%
Wholesale Distribution & Warehousing	1,766	28,858	1.02	3.6%	-0.1%
Ag/Food R&D & Testing Services	95	1,156	3.14	11.1%	11.1%
AG/BIO SUPPORTING SECTORS	**1,895**	**30,942**	**1.04**	**4.3%**	**0.0%**
CURRENT TOTAL AG/BIO ECONOMY	**5,563**	**120,671**	**1.00**	**4.9%**	**0.3%**
Bio-Based Substitution Opportunities(2)	*478*	*25,173*	*1.12*	*5.9%*	*1.4%*
POTENTIAL AG/BIO ECONOMY	***6,041***	***145,844***	***1.02***	***5.1%***	***0.5%***

Notes: (1) Location Quotient or LQ values of > 1.00 indicate the sector is more concentrated in the state than the United States and values of < 1.00 are considered to be less concentrated than the United States. Values of ≥ 1.20 are considered to be a regional specialization. (2) Bio-based substitution opportunities include pharmaceuticals, chemicals, materials, and other manufactured items that are presently primarily produced using non-ag/forest inputs but have significant potential for increased utilization of ag-based inputs.
Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

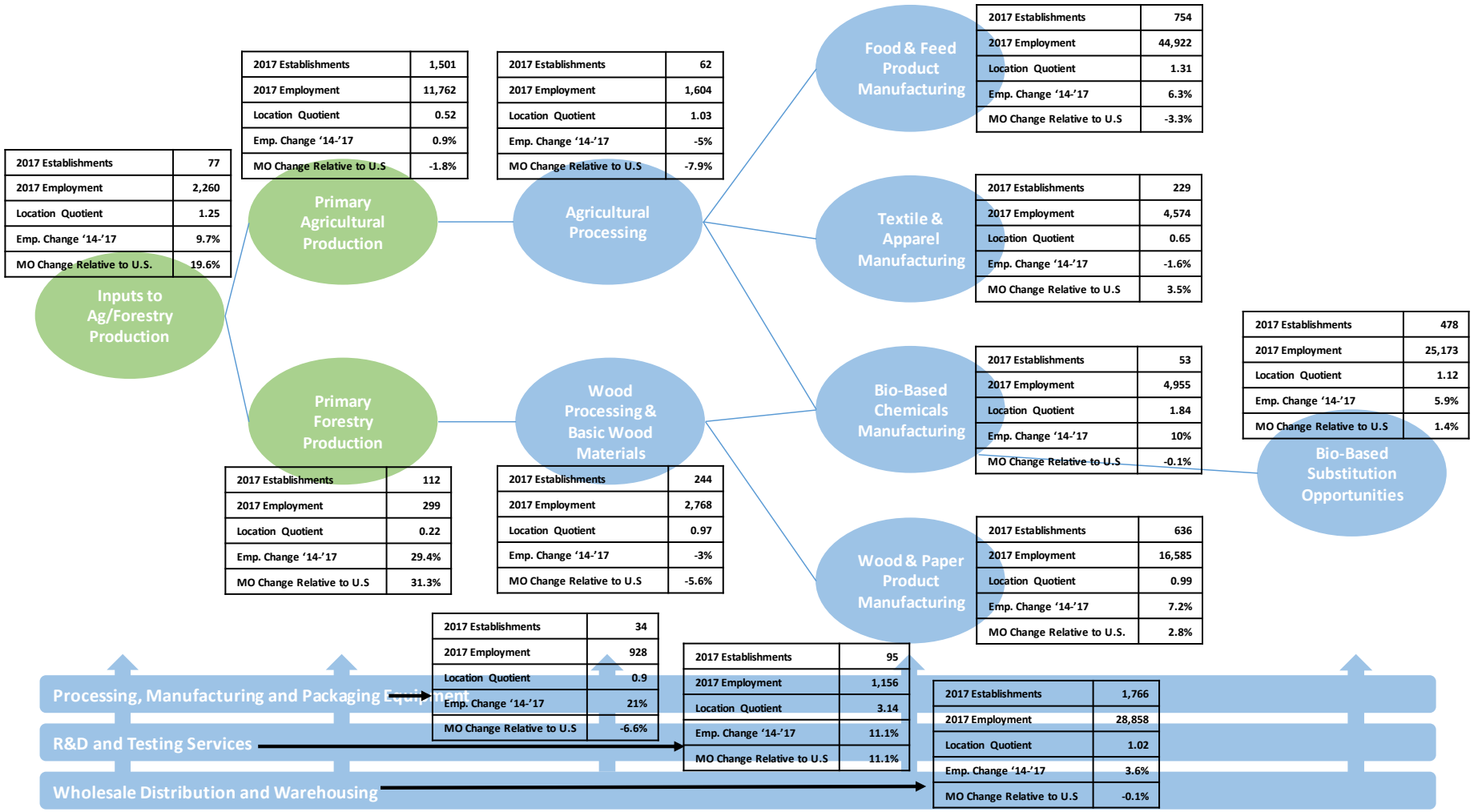
The data show the full value-chain, including inputs to production, primary production, and value-added post-farmgate activity currently spanning 5,563 business establishments with total 2017 employment of 120,671. This level of employment for Missouri puts the state right at a national normative level of employment (an LQ of 1.00)—i.e., Missouri is neither more nor less specialized than the national overall in terms of overall ag/forestry value-chain employment. The data also show that, between 2014 and

[19] Employment figures DO NOT include the employment of individual farm proprietors, which is approximately 89,000 jobs (compared with approximately 12,000 incorporated farm jobs).

2017, the sector saw total employment expand by 4.9 percent and experienced moderately faster growth in employment (0.3 percent) that the nation did overall (representing a moderate employment share gain). For easy reference, these data are placed on their respective sectors on the value-chain graphic (Figure 16).

Value-added activity, after commodities leave the farm or forest, (termed “Ag/Forest/Food Processing/Mfg.” and “Ag/Bio Supporting Sectors” in Table 2), represents 88.1 percent of the total value-chain employment, providing 106,350 jobs in Missouri.

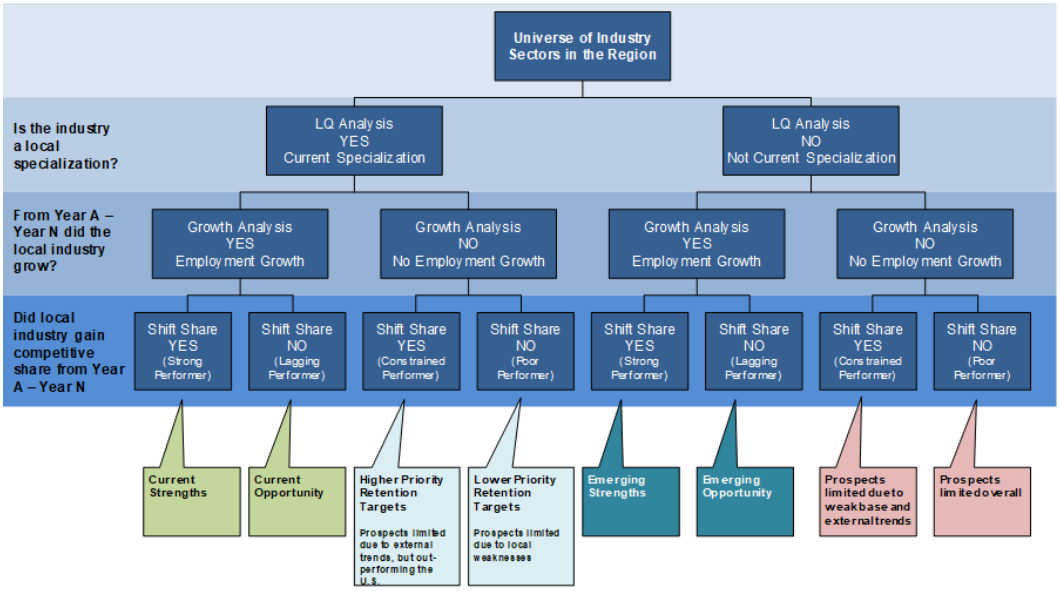
Figure 16: Missouri Value-Chain Macro Sectors; Recent Performance as Measured by Employment



Source: TEConomy's analysis of Enhanced QCEW data from IMPLAN.

This analysis can be further viewed through the lens of Industry Targeting Analysis (ITA), which segments industry sectors based on performance into high-performance versus low-performing sectors for economic development. Figure 17 shows the ITA decision-tree structure used in the analysis, which leads to Table 3 conclusions.

Figure 17: Structure of Industry Targeting Analysis; Segmenting Sectors by Comparative Performance for Economic Development



Source: TEConomy Partners, LLC.

Table 3: Industry Targeting Analysis (ITA) Classification of Missouri Value-Chain Macro Sectors

ITA Categorization	Characteristics	Missouri Macro Sectors (Green = pre-gate) (Blue = post-gate/value-added)
Current Strengths	**Specialized, Growing, Gaining Share**	• **Inputs to Ag/Forest Production** • **Ag/Food R&D & Testing Services**
Current Opportunity	**Specialized, Growing, But Not Gaining Share**	• **Food & Feed Product Manufacturing** • **Bio-Based Chemicals Manufacturing**
Higher Priority Retention Target	Specialized, Not Growing, Losing Employment Slower than United States	None so classified
Lower Priority Retention Target	Specialized, Not Growing, Losing Share	None so classified
Emerging Strength	**Not Specialized, Growing, Gaining Share**	• **Primary Forestry Production** • **Wood & Paper Product Manufacturing** • **Bio-Based Substitution Opportunities**

ITA Categorization	Characteristics	Missouri Macro Sectors (Green = pre-gate) (Blue = post-gate/value-added)
Emerging Opportunity	**Not Specialized, Growing, But Not Growing as Fast as United States Overall**	• **Primary Agricultural Production** • **Processing & Manufacturing Equipment** • **Wholesale Distribution & Warehousing**
Prospects Limited—Constrained	Not Specialized, Not Growing, Losing Employment Slower than United States	• Textile Manufacturing & Apparel Manufacturing
Prospects Limited—Poor Overall	Not Specialized, Not Growing, Losing Share	• Agricultural Processing • Wood Processing & Basic Wood Materials

Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

The ITA of the industry macro sectors in the value-chain indicate that the sectors associated with primary production have been performing relatively well—being a "Current Strength" (Inputs to Ag/Forest Production), an "Emerging Strength" (Primary Forestry Production), and an "Emerging Opportunity" (Primary Agricultural Production).

The following downstream processing/value-added sectors perform comparatively well:

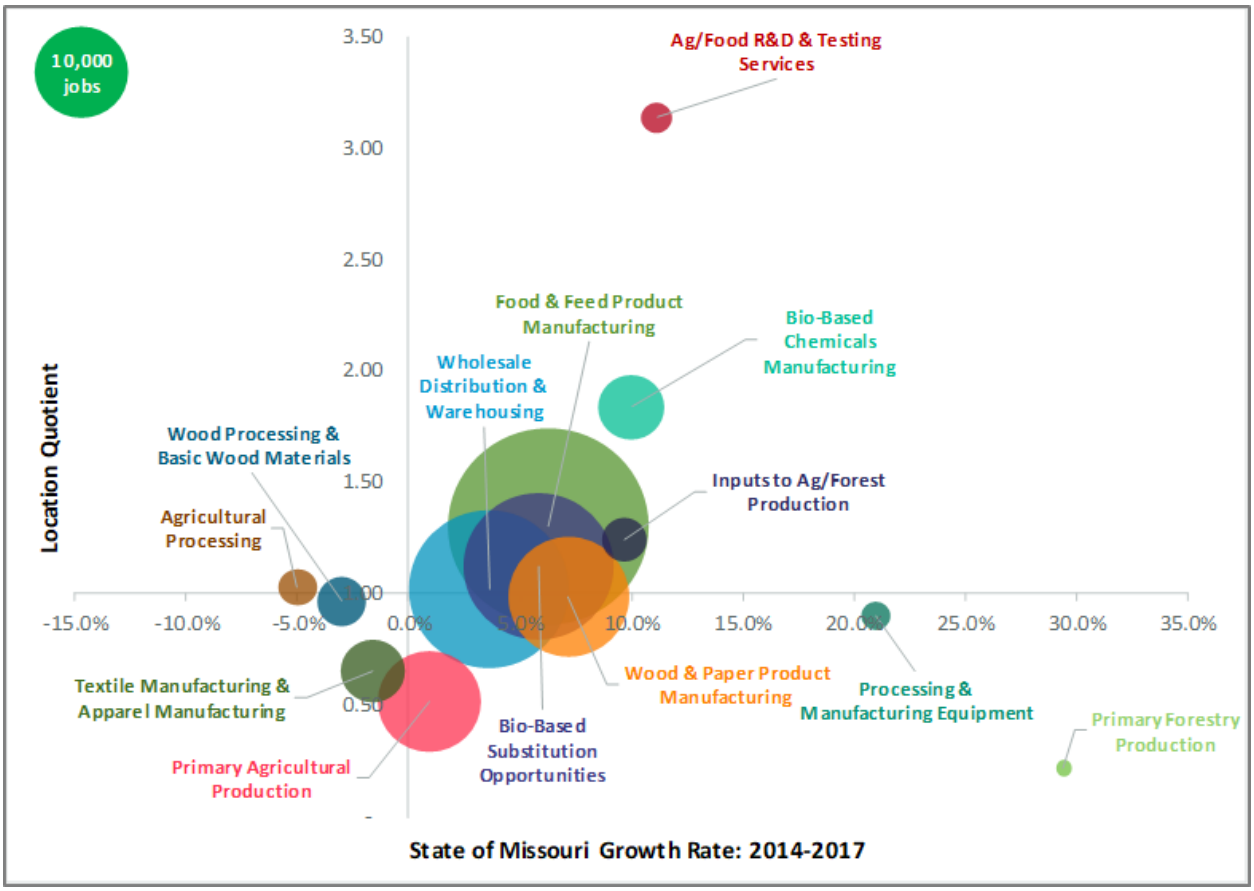
- **Ag/Food R&D and Testing Services** (Current Strength)
- **Food and Feed Product Manufacturing** (Current Opportunity)
- **Bio-Based Chemicals Manufacturing** (Current Opportunity)
- **Wood and Paper Product Manufacturing** (Emerging Strength)
- **Processing and Manufacturing Equipment** (Emerging Opportunity)
- **Wholesale Distribution and Warehousing** (Emerging Opportunity).

It is important to note that the two major industry sectors that perform first-level processing of agriculture or forest production (Agricultural Processing and Wood Processing and Basic Wood Materials) both reside in the lowest performance category of "Prospects Limited—Poor Overall." In Missouri, these first-level processing industries are not specialized (in terms of LQ), are not growing in employment, and have been losing market share as compared with national employment. **This suggests that a strategy to simply process more basic ag/forest commodities in the state, to boost value-added, is highly unlikely to succeed. The ITA suggests that the fundamental characteristics of the Missouri operating environment are unfavorable for growth in these primary processing industries.** The Textile Manufacturing and Apparel Manufacturing sector is also performance constrained, although losing employment at a rate somewhat slower than the nation.

Conclusion: Opportunities appear to reside in categories of higher value-added processing into finished rather than intermediate products. Food and Feed Product Manufacturing is the largest major sector (44,922 jobs), is specialized (LQ=1.31) and growing (6.3 percent 2014–2017), with 754 establishments. Wholesale Distribution and Warehousing is the second-largest major sector (28,858 jobs). These two major sectors account for 61 percent of the Current Total Ag/Bio Economy employment and 69 percent of the post-farmgate/post-forestgate employment.

The relative size (as measured by employment) and performance of the sectors can be further visualized in a "bubble chart", as shown in Figure 18.

Figure 18: Missouri Value-Chain Macro-Sector Positioning in a Four-Quadrant Matrix Based on Employment Specialization and Growth Rate; Size of Each Bubble is Proportionate to Employment Level



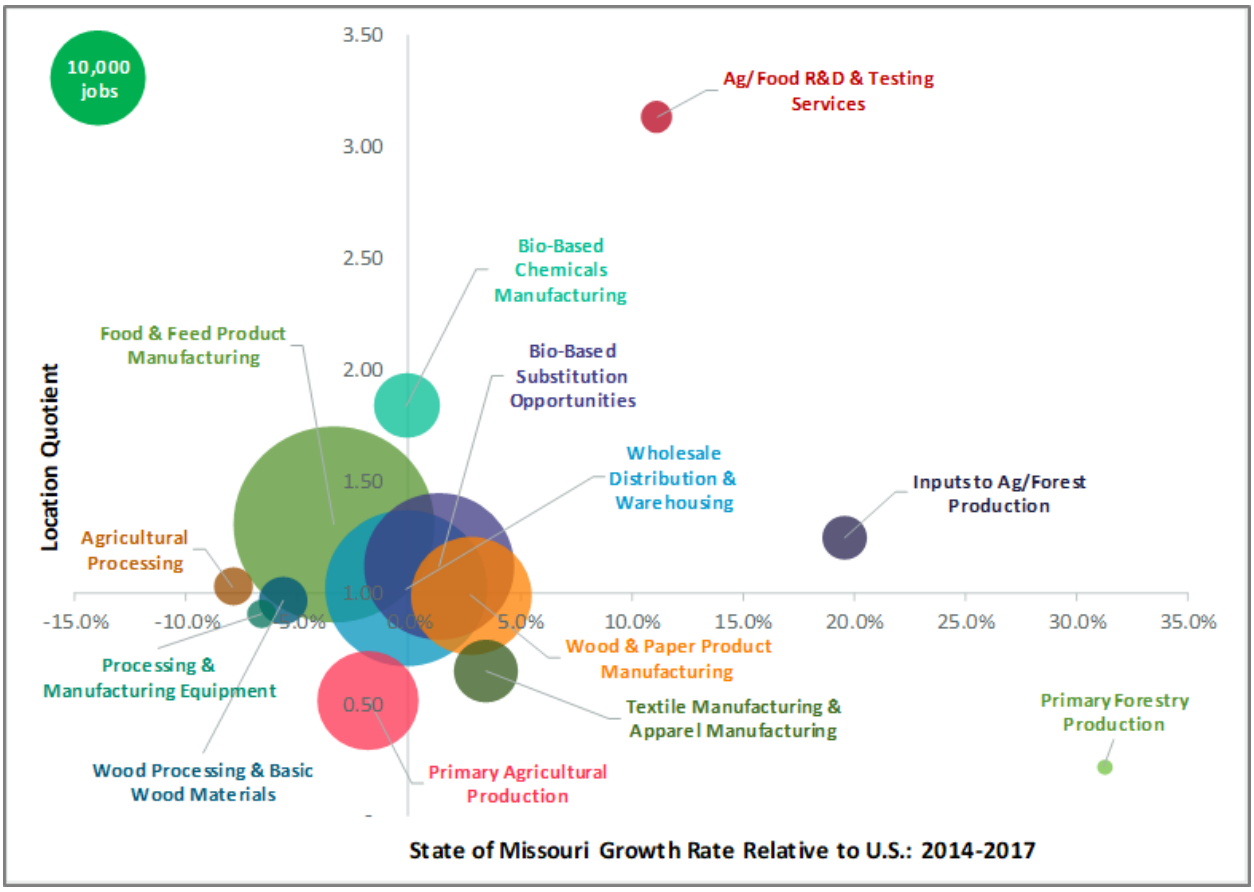
Note: The color of each bubble corresponds to the color of its label. The line leading from the label ends at the 2017 LQ of the bubble's value-chain macro sector.

Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

It is evident that the highest-performing sectors in terms of specialization or growth rate are relatively small in terms of total employment. However, the largest sectors (Food and Feed Manufacturing, Wholesale Distribution and Warehousing, Wood and Paper Product Manufacturing, Bio-Based Substitution Opportunities, and Primary Agricultural Production) are each experiencing employment growth within the State of Missouri.

Figure 19 modifies the x-axis to reflect comparative growth rate versus the United States, changing the picture somewhat. Most notable is that the largest sector (Food and Feed Product Manufacturing) has experienced negative relative performance, losing employment share to other parts of the nation.

Figure 19: Missouri Value-Chain Macro-Sector Positioning in a Four-Quadrant Matrix Based on Employment Specialization and Growth Relative to the United States (Shift Share); Size of Each Bubble is Proportionate to Employment Level



Note: The color of each bubble corresponds to the color of its label. The line leading from the label ends at the percentage of employment change for the bubble's value-chain macro sector relative to the nation.
Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

Employment is a core metric in terms of economic development. However, it is possible for an advanced economic sector to be experiencing only moderate employment growth, or even negative employment growth, but still be comparatively high performing in output (i.e., the sector is performing at a high level of productivity). To evaluate this potential situation for major food-related value-chain sectors in Missouri, TEConomy performed an analysis of value-added per worker for each major sector and compared this with the average value-added per worker in the sector in the nation overall. The results of this analysis are shown on Table 4.

Table 4: Value-Chain Analysis of Productivity per Worker in Food Processing Industries in Missouri and the United States

Sector	Missouri Value-Added per Worker	U.S. Value-Added per Worker	Missouri Comparative Performance vs. United States
Total, All Industries	$83,387	$95,529	87%
Total, Food Processing (Agricultural Processing and Food and Feed Product Manufacturing)	**$149,398**	**$126,271**	**118%**
Poultry processing	$51,915	$50,860	102%
Meat processed from carcasses	$88,372	$82,201	108%
Bread and bakery product, except frozen, manufacturing	$72,893	$53,668	136%
Animal, except poultry, slaughtering	$102,040	$100,165	102%
Dog and cat food manufacturing	$534,734	$339,437	158%
Breweries	$330,586	$354,635	93%
Cheese manufacturing	$107,641	$111,407	97%
Frozen specialties manufacturing	$72,665	$69,981	104%
Other animal food manufacturing	$150,551	$148,853	101%
All other food manufacturing	$86,711	$65,753	132%
Fluid milk manufacturing	$118,110	$129,821	91%
Bottled and canned soft drinks and water	$155,655	$151,676	103%
Wineries	$36,665	$95,627	38%
Dry pasta, mixes, and dough manufacturing	$146,253	$150,588	97%
Soybean and other oilseed processing	$190,839	$224,716	85%

Note: Red text indicates those food processing industries in Missouri that are performing below the United States in value-added per worker.
Source: TEConomy's analysis of IMPLAN State of Missouri Input/Output (I/O) Model data.

The productivity analysis for the overall food processing sector paints a generally positive picture for Missouri. Indeed, this industry is better performing than the private sector overall in the state, which demonstrates productivity at only 87 percent of the national level. Taking the average for all processing sectors, Missouri's productivity (value-added per worker) is at 118 percent of the national average, producing $149,398 in value-added per worker, versus $126,271 for the nation overall. Areas achieving particularly high productivity levels relative to the United States include the following:

- Dog and cat food manufacturing at 158 percent. At $534,734, this sector also has a very high value-added per worker.
- Bread and bakery products, except frozen, manufacturing at 136 percent.

In terms of sectors performing below national productivity levels, the gap is not that large (at 85 percent or more of the national level) for all underperforming sectors, except for wineries, which demonstrate very low levels of productivity in Missouri at the present time.

Table 5 shows the same analysis performed for the value-chain of the forest/wood products industry.

Table 5: Value-Chain Analysis of Productivity per Worker in Forest/Wood Products Industry in Missouri and the United States

Sector	Missouri Value-Added per Worker	U.S. Value-Added per Worker	Missouri Comparative Performance vs. United States
Total, All Industries	$83,387	$95,529	87%
Total, Forest/Wood Products Industry	**$115,104**	**$105,405**	**109%**
Paperboard container manufacturing	$144,342	$105,317	137%
Sawmills	$46,926	$67,429	70%
Wood container and pallet manufacturing	$59,485	$49,210	121%
Other millwork, including flooring	$70,680	$68,448	103%
All other converted paper product manufacturing	$177,336	$107,541	165%

Note: Red text indicates that forest/wood processing industry in Missouri that is performing below the United States in value-added per worker.
Source: TEConomy's analysis of IMPLAN State of Missouri I/O Model data.

Again, it is evident that Missouri is outperforming the nation in terms of productivity in this value-chain overall—operating with a value-added per worker that is 109 percent of the national average. Areas achieving particularly high productivity levels include the following:

- Paperboard container manufacturing at 137 percent
- Wood container and pallet manufacturing at 121 percent
- All other converted paper product manufacturing at 165 percent.

Only one of the sectors is performing below national productivity levels, with sawmills achieving only 70 percent of the national productivity level.

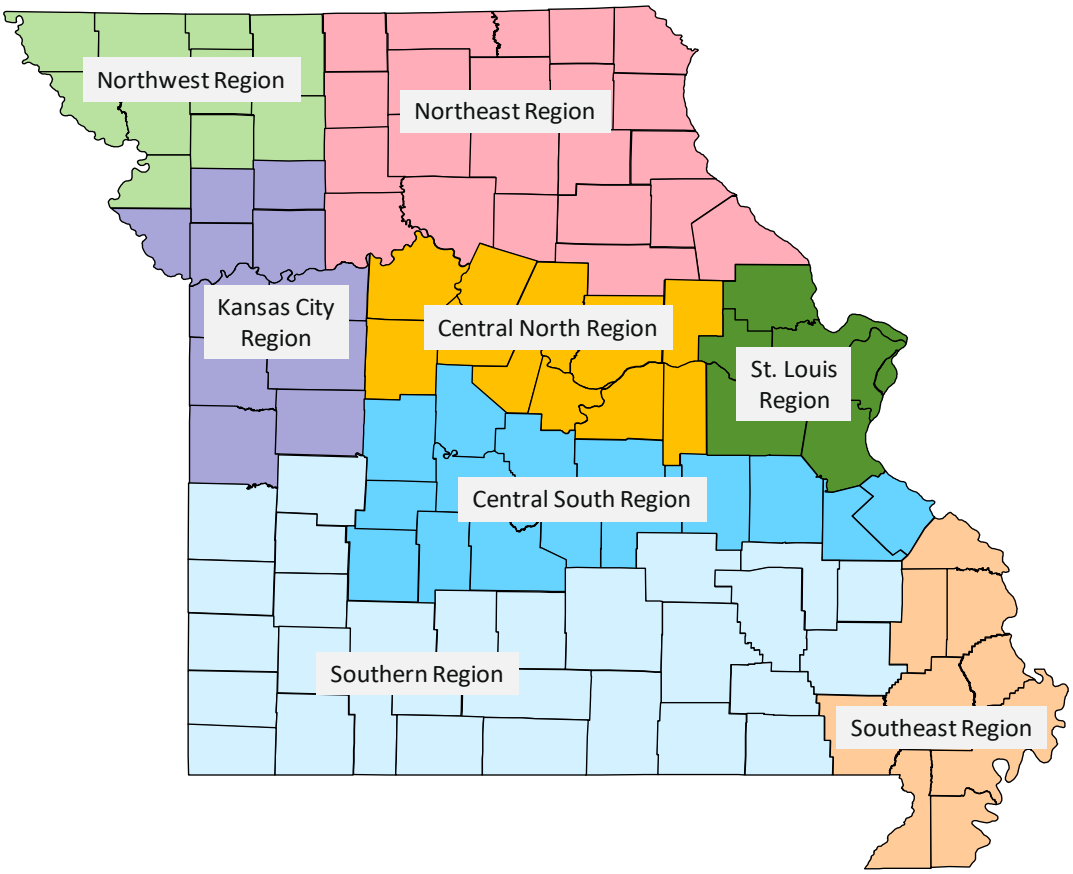
It is interesting to note that, in both the food processing and forest/wood processing industries, early-stage processing appears to struggle to achieve robust productivity figures. This can be seen in the soybean and other oilseed processing category (performing at 85 percent of the national level) and the sawmills category (performing at only 70 percent of the national level).

E. The Regional Footprint of Value-Added Processing and Manufacturing Industries in Missouri

A key consideration regarding the economic strengths and viability of the various value-added food and forest/wood products industries in Missouri is the regional variability that exists within the state among the various sectors. Using the county-based regional structure shown in Figure 20, an analysis similar to the state-level employment analysis was conducted with the detailed tables included in Appendix B. To highlight and provide insights to this regional variability, Table 6 provides, for each of the eight Missouri regions, the largest and most concentrated/specialized macro sector in the ag/food economy and the largest and most concentrated/specialized detail industry (six-digit North American Industry Classification System [NAICS] code).

Food and feed product manufacturing is the largest macro sector in six of the eight regions, with wholesale distribution and warehousing the largest in the remaining two. Ag/food R&D and testing services has the highest macro sector concentration/specialization in three regions—the three regions making up the I-70 Corridor from St. Louis to Kansas City. Wood processing and basic wood materials is most concentrated in two regions and agricultural processing the most concentrated in two other regions. From a detailed industry perspective, the variability of the overall food and wood processing sectors becomes more apparent. Meat and poultry processing sectors are the largest industries in four of the eight regions, with the other four regions each having their own specialties.

Figure 20: Missouri Regions for Ag/Food Processing and Manufacturing Assessment



Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

Table 6: Missouri Regional Ag/Food-Related Strengths—Macro Sectors and Detailed Industries

Missouri Region	Macro Sectors		Detailed Industries	
	Largest Employment Sector	Most Concentrated or Specialized Sector	Largest Employment Sector	Most Concentrated or Specialized Sector
St. Louis Region	Food and Feed Product Manufacturing	Ag/Food R&D and Testing Services	Breweries	Fats and Oils Refining and Blending
Kansas City Region	Wholesale Distribution and Warehousing	Ag/Food R&D and Testing Services	Corrugated and Solid Fiber Box Manufacturing	Folding Paperboard Box Manufacturing
Central North Region	Food and Feed Product Manufacturing	Ag/Food R&D and Testing Services	Poultry Processing	Turkey Production
Central South Region	Wholesale Distribution and Warehousing	Wood Processing and Basic Wood Materials	Wood Container and Pallet Manufacturing	Wood Container and Pallet Manufacturing
Northeast Region	Food and Feed Product Manufacturing	Agricultural Processing	Meat Processed from Carcasses	Soybean and Other Oilseed Processing
Northwest Region	Food and Feed Product Manufacturing	Bio-Based Chemicals Manufacturing	Animal (except Poultry) Slaughtering	Leather and Hide Tanning and Finishing
Southeast Region	Food and Feed Product Manufacturing	Agricultural Processing	Breakfast Cereal Manufacturing	Breakfast Cereal Manufacturing
Southern Region	Food and Feed Product Manufacturing	Wood Processing and Basic Wood Materials	Poultry Processing	Turkey Production
State of Missouri, Total	Food and Feed Product Manufacturing	Bio-Based Chemicals Manufacturing	Poultry Processing	Dog and Cat Food Manufacturing

Note: A sector must have at least 50 employees (500 at state level) to be included as a concentration/specialization in the table.
Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

A key perspective on the overall ag/bio strengths of Missouri can be achieved by examining and comparing the size, concentration, and employment growth (relative to the United States) of the key macro sectors within the combined six regions that make up the state's **Core Agricultural Area (CAA; removing the effects of the St. Louis and Kansas City metropolitan statistical areas (MSAs) on state totals, and hence, resulting in a more rural geography overall)** (Table 7). The Missouri CAA accounts for only 38 percent of Missouri's total private-sector employment (all industries), but accounts for 63 percent of the current total ag/bio economy. In every macro sector, except Bio-Based Substitution Opportunities, the Missouri CAA's employment was more concentrated in the region than it is in the state as a whole, with many sectors specialized in the CAA (LQ $\geq$ 1.20) that were not even concentrated at the overall state level (Figure 21).

Table 7: Missouri Regional Macro Sector Strengths—State of Missouri and Core Agricultural Area

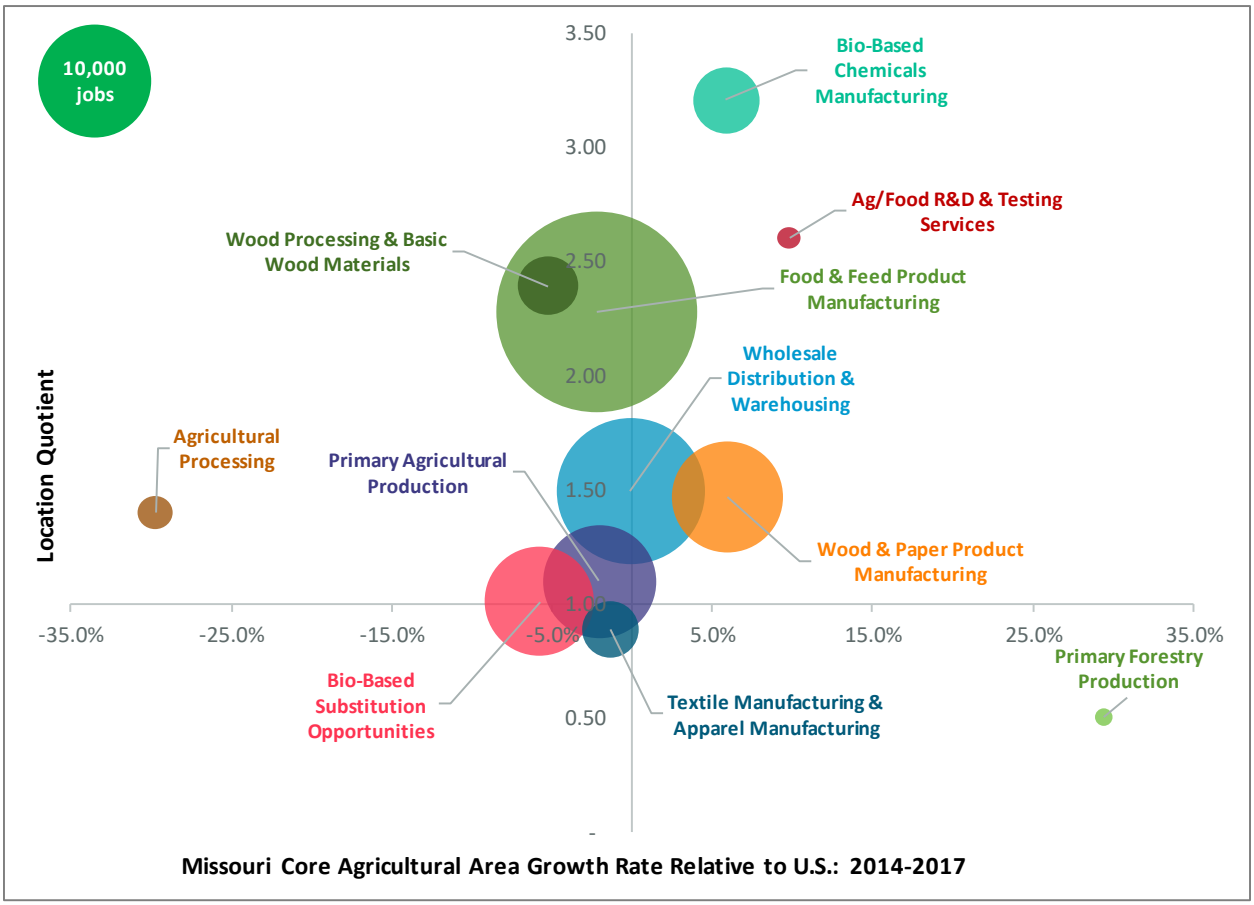
Macro Sector	State of Missouri			MO Core Agricultural Area		
	Employment	2017 LQ(1)	Relative Emp. Chg., 2014–2017	Employment	2017 LQ(1)	Relative Emp. Chg., 2014–2017
Inputs to Ag/Forest Production	2,260	1.25	19.6%	1,197	1.72	40.8%
Primary Agricultural Production	11,762	0.52	-1.8%	9,556	1.10	-2.1%
Primary Forestry Production	299	0.22	31.3%	264	0.50	29.4%
AG/FORESTRY PRODUCTION	**14,321**	**0.55**	**1.2%**	11,017	1.11	2.3%
Agricultural Processing	1,604	1.03	-7.9%	838	1.40	-29.8%
Food & Feed Product Manufacturing	44,922	1.31	-3.3%	30,064	2.28	-2.2%
Wood & Paper Product Manufacturing	16,585	0.99	2.8%	9,440	1.47	5.9%
Wood Processing & Basic Wood Materials	2,768	0.97	-5.6%	2,627	2.39	-5.2%
Textile & Apparel Manufacturing	4,574	0.65	3.5%	2,389	0.89	-1.4%
Bio-Based Chemicals Manufacturing	4,955	1.84	-0.1%	3,313	3.21	5.9%
AG/FOREST/FOOD PROCESSING/MFG	**75,408**	**1.15**	**-0.5%**	48,671	1.95	0.3%
Processing & Manufacturing Equipment	928	0.90	-6.6%	354	0.90	66.3%
Wholesale Distribution & Warehousing	28,858	1.02	-0.1%	16,187	1.49	-0.1%
Ag/Food R&D & Testing Services	1,156	3.14	11.1%	368	2.60	9.8%
AG/BIO SUPPORTING SECTORS	**30,942**	**1.04**	**0.0%**	16,909	1.49	0.4%
CURRENT TOTAL AG/BIO ECONOMY	120,671	1.00	0.3%	76,597	1.65	1.0%
Bio-Based Substitution Opportunities(2)	25,173	1.12	1.4%	8,701	1.01	-5.8%
POTENTIAL AG/BIO ECONOMY	145,844	1.02	0.5%	85,298	1.55	0.2%

Notes: (1) Location Quotient or LQ values of > 1.00 indicate the sector is more concentrated in the state than the United States and values of < 1.00 are considered to be less concentrated than the United States. Values of $\geq$ 1.20 are considered to be a regional specialization.

(2) Bio-based substitution opportunities include pharmaceuticals, chemicals, materials, and other manufactured items that are presently primarily produced using non-ag/forest inputs but have significant potential for increased utilization of ag-based inputs.

Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

Figure 21: Missouri Value-Chain Macro-Sector Positioning in a Four-Quadrant Matrix Based on Employment Specialization and Growth Relative to the United States for the Missouri Core Agricultural Area



Notes: The size of each bubble is proportionate to employment level. The color of each bubble corresponds to the color of its label. The line leading from the label ends at the 2017 LQ of the bubble's value-chain macro sector in the Missouri CAA.
Source: TEConomy's analysis of enhanced BLS QCEW data from IMPLAN.

F. SWOT Analysis: Input from Quantitative Analytics and Industry Interviews

To supplement and build upon the findings of the quantitative economic analytics, TEConomy performed a series of interviews with industrial stakeholders, commodity representatives, and economic development officials engaged in value-added production sectors in Missouri. The results of these interviews led to the following strengths, weaknesses, opportunities and threats (SWOT) assessment.

STRENGTHS

- With over 97,000 farms in Missouri covering 28.5 million acres, primary agricultural is a substantial component of Missouri's economy. The crop production and poultry and livestock production integrate in that much of the soybeans and grains produced in Missouri are used as feed products for livestock and poultry production.
- Crop production comprises mainly commodity products, dominated by corn and soybean production. Combined, soybean and corn production account for over three-quarters of crop production value in the state.
- Missouri's livestock production is relatively diverse, comprising cattle (including calves), hogs, chickens (broilers), turkeys, milk, eggs, and wool production. The top three animal ag commodities (cattle, hogs, and chickens) account for 80 percent of total animal ag within Missouri.
- The state has a number of successful value-added, direct-to-consumer, meat processing operations, including Western's Smokehouse, US Wellness Meats, Burgers' Smokehouse, and Middleton's All Natural Meats.
- Missouri's central location provides good proximity to U.S. production and processing industries for inputs and robust distribution advantages.
- Missouri has ample water resource availability in comparison with many competitor states.
- The Missouri Agricultural and Small Business Development Authority provides New Generation Cooperative Incentive Tax Credits to catalyze investment into new generation processing entities that process Missouri agricultural commodities and agriculture products into value-added goods.
- The Missouri Value-Added Grant Program provides grants for projects that add value to Missouri agriculture products and aid the economy of a rural community. Grants can cover expenses related to feasibility studies, marketing studies and plans, business plans, etc.
- Other incentives exist to encourage the local food movement, including the Missouri Value-Added "Farm to Table" Grant Program that assists producers in serving institutions.

WEAKNESSES

- Missouri's level of value-added processing activity is undersized in comparison with the state's agricultural output.
- Missouri's agriculture production is highly concentrated in a few commodities, and generally lacks diversity in crop production. Outside of soybean and corn (and hay production as an input to the livestock sector), other crops comprise less than 7 percent of agricultural output. Missouri is especially lacking in horticultural crops produced for food.
- There is limited interaction between industry and Missouri academia. Concerns were expressed regarding level of research capacity, focus of research, cost of services, and age of facilities. Some Missouri companies work with other regional LGUs for research and testing services.
- Missouri has no processing authority in the state –Nebraska is the nearest authority that companies use to have products certified to meet USDA and U.S. Food and Drug Administration (FDA) labeling requirements.
- Limited assistance is available for companies and/or farmers interested in developing value-added products. There is also limited knowledge regarding product development, distribution channels, market placement, etc.
- The state has a limited investment ecosystem to support value-added businesses. Traditional sources of funding are difficult to obtain, governmental sources have significant "red-tape," and economic development and venture capital sources are typically not interested.
- Limited availability of co-packing operations for smaller runs stymies smaller value-added operations.
- Access to a skilled workforce, particularly in the rural parts of the state, is a limiting factor.

- Infrastructure, particularly in rural parts of the state, can be a limiting factor, including lack of connectivity for business-to-consumer (B2C) operations, deteriorating roads and bridges, and distance to airports.

OPPORTUNITIES

- Realize benefits through building enhanced value-chains that increase in-state value-added processing. Direct attention at linking food manufacturers with local agricultural processing firms, individual farmers, and/or farm cooperatives. Working contractually together, producers, processors, and manufacturers can partially decouple themselves from more volatile commodity markets and benefit from a more stable and predictable operating environment.
- Diversify not only the crops grown in the state, but also how they are grown, including a focus on varieties that are organic and are not a genetically modified organism (GMO). By diversifying products and/or the value-added traits associated with traditional products, new niche market and local opportunities can be explored.
- Realize potential benefits around a new generation of cooperatives for bulk commodities, taking advantage of state statute that encourages cooperatives to be formed. Focus on efforts such as non-GMO soybean crushing plants, by-products from commodity processing, plant-based proteins, etc. Help stimulate efforts using checkoff dollars.
- Focus on adding downstream value to beef operations, which is viewed as a near-term opportunity for the state.
- Build upon plant science efforts in St. Louis and animal health (including meat and milk protein) efforts in Kansas City to create additional opportunities across the state.
- Further enhance the Missouri Grown (branding program) to tailor efforts to local buying preferences and develop marketing campaigns for both urban and rural environments. In addition, communicate to producers consumer preferences as well as online, e-commerce opportunities.
- Develop business assistance programs to work with producers and processors, leveraging the efforts that are currently ongoing.
- Stimulate private funds to leverage the state incentive efforts to develop additional value-added processing opportunities.
- Address workforce/talent shortages by creating specific certificate/training programs in partnership with the regional community colleges.

THREATS

- Worldwide agricultural commodity markets are highly competitive, and price driven. As a result, even though national agricultural productivity continues to increase, the real value of that production at "the farmgate" continues to decline.
- An anti-agricultural movement is growing in the state that is hindering agricultural development, including value-added production. Agricultural communication around topics such as GMOs, corporate farming practices, conditions for livestock, etc., must be addressed to combat misinformation.
- County health ordinances in approximately 25 counties have stopped (or have the power to stop) value-added production development. It will take state legislation to set statewide standards.

Chapter III: Missouri's Agriculture and Forest Product-Related Innovation

For much of American industry, including agriculture and forestry industries, forging a pathway to international competitiveness depends on achieving high levels of productivity and product differentiation—typically through the application of R&D-based innovations and the deployment of advanced production and product technologies. As in other industrial sectors, the development of new and improved products is a function of innovation—typically driven by structured R&D activity, as noted earlier. R&D is a critically important component of the modern innovation-based economic development ecosystem (as shown in Figure 6) and is key to differentiating U.S. industries in the face of intense and increasing global competition.

R&D activity in agriculture and forest products occurs within industry and is also a major emphasis of university-based research—especially at U.S. LGUs, which have an historic focus on agricultural sciences and associated disciplines.

A. Academic-Based Innovation and R&D Activity

While global ranking systems for universities are controversial, especially where subjective measures are concerned (such as "reputation"), they do provide a basis for establishing a starting point for consideration of academic strengths in a state and its institutions across relevant academic disciplines. TEConomy finds the most detailed ranking system, in terms of reviewing individual disciplines or major fields of research inquiry, is the QS World University Rankings.[20].

Overall, the MU-Columbia is ranked in the cadre of universities reported by QS as being in the range of 201st to 300th among universities globally. The alternative *Wall Street Journal/Times Higher Education* College Rankings for 2019 put MU-Columbia at an overall rank of 414th in the United States and 98th among public colleges and universities.[21] For the purposes of evaluating agriculture and forestry-related innovation areas, the overall ranking of the university is less useful than an examination of rankings in individual academic fields. Looking across disciplines of relevance to this study, it is found that QS places MU as follows:

- Agricultural sciences (Rank = 49th)
- Chemistry (Rank = 151–200 group)
- Food science and technology (Rank = 201–300 group)
- Energy science and engineering (Rank = 401–500 group)
- Pharmacy and pharmaceutical sciences (Rank = 401–500 group)
- Chemical engineering (not in top 500).

These rankings, while certainly imperfect, do point (as are expected to point) to MU (being an LGU) being in the premier top-50 group of universities globally in agricultural sciences. However, when examining disciplines more likely to be in support of downstream value-added processing industries, it is evident that MU slips down in the QS rankings. For the food science and technology discipline, for example, MU ranks in the 201–300 peer group.

An examination of levels of ag/food/forestry-related research also reflects similar strengths within the state. The University of Missouri System (UMS) performs important levels of ag/food/forestry research,

[20] The QS rankings are produced by Quacquarelli Symonds Limited. Details at: https://www.topuniversities.com/university-rankings-articles/world-university-rankings/out-now-qs-world-university-rankings-2019.
[21] In the *Wall Street Journal/Times Higher Education* College Rankings for 2019, Missouri University of Science and Technology (Rolla) ranks 237th in the United States and 53rd among public colleges and universities.

but is led by significant research in agricultural sciences, which accounts for nearly $63 million in research in 2017 or 20 percent of the system total (Table 8). At the level of agricultural sciences, UMS is more than four times as concentrated as it is in the United States overall. Natural resources and conservation (which includes forestry) also shows a significant concentration of more than four times the United States overall at nearly $14 million in R&D performance. Other engineering (which includes agricultural engineering) exceeds $31 million in 2017 R&D within UMS and is more than three times as concentrated as it is nationally. Other key disciplines, with potential connections to ag/food/forestry-related collaborative research include biological/biomedical sciences (which may include basic plant science/botany research) and health sciences (which includes research into areas such as nutrition).

Table 8: Missouri Ag/Bio Economy-Related R&D—University of Missouri System

Discipline	2017 R&D ($M)	R&D Concentration	R&D Growth, 2014–2017
Total, All R&D	319,277	1.00	1.3%
Agricultural sciences	62,791	4.37	-18.8%
Natural resources and conservation	13,867	4.61	N/A
Other (including agricultural) engineering	31,291	3.39	-16.1%
Bioengineering/biomedical engineering	2,173	0.41	--%[22]
Biological/biomedical sciences	66,291	1.10	181.5%
Chemistry	8,464	1.08	-10.4%
Chemical engineering	2,035	0.50	116.3%
Health sciences	53,849	0.51	-32.5%

Source: TEConomy's analysis of the National Science Foundation (NSF) Higher Education Research and Development (HERD) Survey, 2014 and 2017. Includes only University of Missouri System institutions with ag science and other related discipline research.

Ag/food/forestry-related research in Missouri is not limited to UMS. Both Lincoln University and Missouri State University also perform both agricultural sciences and natural resource and conservation research (Tables 9 and 10). Agricultural sciences, at more than $3 million in research performance, accounts for 61 percent of the research expenditures at Lincoln University, making it more than 13 times as concentrated at the university than within the United States overall. Missouri State University performed $465,000 in agricultural sciences R&D in 2017.

Table 9: Missouri Ag/Bio Economy-Related R&D—Lincoln University

Discipline	2017 R&D ($M)	R&D Concentration	R&D Growth, 2014–2017
Total, All R&D	4,938	1.00	-26.8%
Agricultural sciences	3,032	13.64	-16.8%
Natural resources and conservation	255	5.49	N/A
Biological/biomedical sciences	252	0.27	-40.6%
Chemistry	53	0.44	N/A

Source: TEConomy's analysis of NSF HERD Survey, 2014 and 2017.

[22] Near zero value in 2014, thus very high growth rate in percentage terms.

Table 10: Missouri Ag/Bio Economy-Related R&D—Missouri State University

Discipline	2017 R&D ($M)	R&D Concentration	R&D Growth, 2014–2017
Total, All R&D	3,215	1.00	1.3%
Agricultural sciences	465	3.21	-79.6%
Natural resources and conservation	281	9.28	N/A
Biological/biomedical sciences	431	0.71	36.0%
Chemistry	17	0.22	-86.0%
Health sciences	48	0.05	-81.0%

Source: TEConomy's analysis of NSF HERD Survey, 2014 and 2017.

B. Industry R&D

A key indicator of private-sector innovation potential in the value-added ag/food/forestry sector is the level of R&D performed by the state's companies in key industry sectors (Table 11). Within core industry sectors such as food, beverage, wood, and paper, R&D levels are relatively low, with the food sector performing the most R&D at $28 million in 2016. At this level, Missouri's food processing industry performs about 60 percent of the expected level of research in this sector based upon its total industry R&D levels of nearly $3.5 billion. At $21 million, the beverage and tobacco products sector is the second-largest core sector in terms of R&D performance. However, given the limited R&D performed by this sector nationally, the presence of Anheuser-Busch operations in St. Louis and IBS in Cameron help drive this sector's R&D performance to be nearly twice as concentrated in Missouri as in the United States overall.

Table 11: Missouri Ag/Bio Economy-Related R&D—Industry

Key Related Industry Sector	2016 Industry R&D ($M)	R&D Concentration	R&D Growth, 2014–2016
All industries	$3,466	1.00	-14.1%
Manufacturing industries	$2,679	1.16	-11.8%
Food	$28	0.56	-28.2%
Beverage and tobacco products	$21	1.95	-4.5%
Textile, apparel, and leather products	$5	0.40	150.0%
Wood products	$0	0.20	-60.0%
Paper	$1	0.11	-50.0%
Chemicals*	$1,562	2.23	1.1%
Agricultural implements	$1	0.06	150.0%
Furniture and related products	$1	0.25	-50.0%
Scientific R&D services	$27	0.88	-28.9%
Biotechnology R&D	$1	0.12	-50.0%
Physical, engineering, and life sciences (except biotech) R&D	$23	1.04	-36.1%

* Nearly all of Chemicals R&D is captured within Ag Chemicals and Pharmaceuticals (both nondisclosed).

Source: TEConomy's analysis of NSF Business R&D and Innovation Survey (BRDIS), 2014 and 2016.

A potentially related sector, the chemicals industry (including both ag chemicals and pharmaceuticals) is the largest component of all Missouri manufacturing R&D at nearly $1.6 billion (58 percent of state

manufacturing R&D and 45 percent of total state R&D). Certain aspects of increasing the value-added proposition of ag/food/forestry in the state may have relevance to this sector, especially in the area of nutrition, healthy foods, and nutraceutical development.

C. OmniViz™ Cluster Analysis of Publications, Major Grants, and Patents

While using existing categorization data for research can provide a useful perspective, TEConomy also finds it informative to perform an objective text-based clustering of all publications and patents related to the sectors of interest with Missouri-based authors or patent assignees.

TEConomy performed text-based clustering, using proprietary OmniViz™ clustering software, to provide a mechanism to cluster research themes based on their textual content, rather than using any *a priori* classification schemata (see Appendix C for more details). The dataset used in the analysis included primarily "postharvest" oriented publications (e.g., journal articles, conference proceedings); patents (including those invented in Missouri and/or assigned to a Missouri entity); and competitive research grants funded by the USDA through the Agriculture and Food Research Initiative (AFRI, including Small Business Innovation Research [SBIR] awards). Data were analyzed for 2013 through July 2018. The distribution of the records incorporated in the clustering by institution is shown in Table 12:

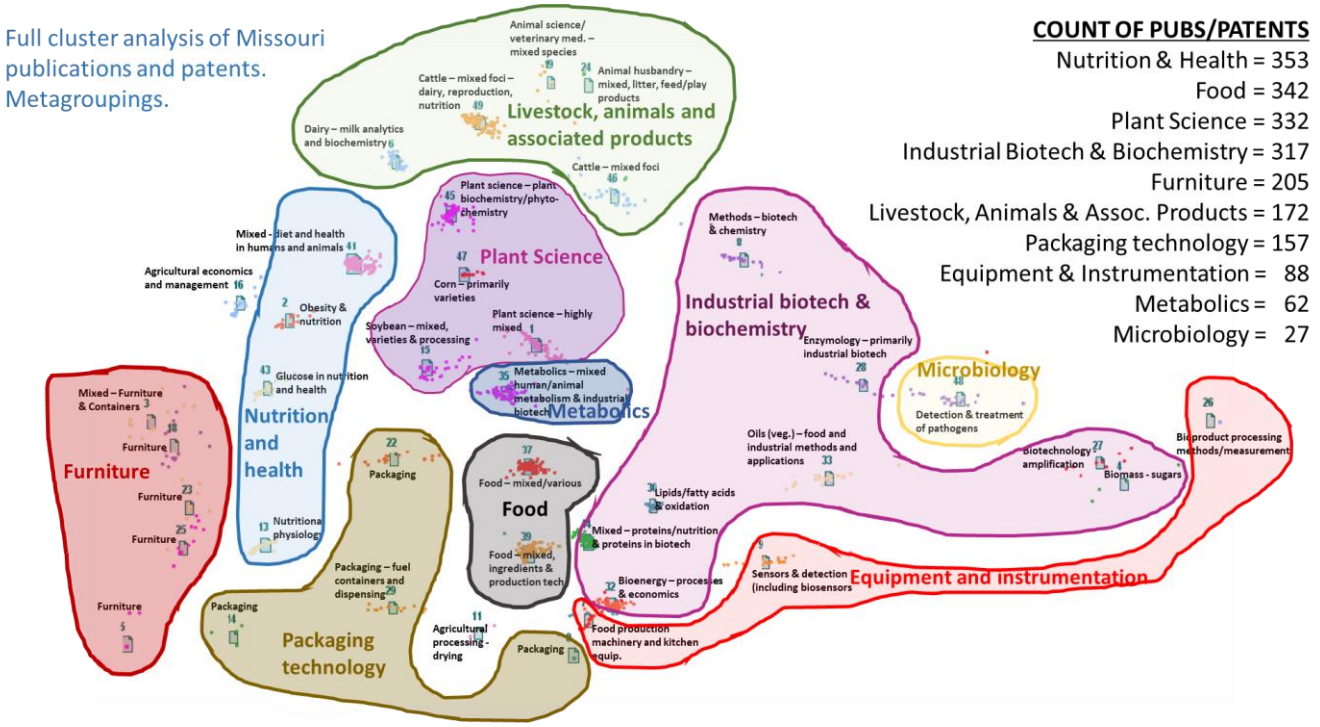
Table 12: Publication and Patents Records by Missouri Institution in the Cluster Analysis Dataset (2013 through July 2018)

Research Record Entities	Total Records
University of Missouri System	569
Washington University, St. Louis	233
Monsanto	154
Nestec S.A.	32
Hussmann Corporation	29
Lincoln University	24
Purina	21
bioMerieux S.A.	19
Bunge Oils	16
Abengoa Bioenergy	10
Duke Manufacturing	10
Total, All Records	***2,265***

Note: The majority of publication records are assigned to one or more universities and the majority of patent records are assigned to a company.
Source: TEConomy's analysis of data from Clarivate Analytics' Web of Science and Derwent Innovation databases and USDA Current Research Information System (CRIS) database.

The resulting analysis identified 10 thematic metagroupings of clusters as illustrated on Figure 22.

Figure 22: Clusters and Metagroupings for Relevant Research and Innovation Records for Missouri



Source: TEConomy's analysis of data from Clarivate Analytics' Web of Science and Derwent Innovation databases and USDA CRIS database.

The above metagroupings are useful as topline descriptors of themes, but significant further intelligence may be gleaned by examining the individual clusters within these themes. For example, nutrition and health as a metagrouping becomes more useful, analytically, when the more focused clusters within it are observed (Table 13).

Table 13: Metagroupings and Associated Clusters for Missouri

Metagrouping	Individual Cluster (Size and Primary Records Type)
Nutrition and health (353)	• **Mixed—diet and health in humans and animals** (251, almost all are publications) • **Nutritional physiology** (57, all are publications) • **Glucose in nutrition and health** (26, almost all are publications) • **Obesity and nutrition** (19, all are publications)
Food (342)	• **Mixed—ingredients and production technologies** (201 mix of patents and publications) • **Food—mixed, various** (241 mix of patents and publications)
Plant science (332)	• **Plant science—plant biochemistry/phytochemistry** (87, almost all are publications) • **Soybeans—mixed, varieties and processing** (85, mix of patents and publications) • **Plant science—highly mixed** (84, mix of patents and publications) • **Corn—primarily varieties** (76, mix of patents and publications)

Metagrouping	Individual Cluster (Size and Primary Records Type)
Industrial biotech and biochemistry (317)	• **Mixed—proteins/nutrition and proteins in biotech** (149, mix of patents and publications) • **Bioenergy—processes and economics** (57, almost all are publications) • **Oils (vegetable)—food and industrial methods and applications** (32, mix of patents and publications) • **Lipids/fatty acids and oxidation** (26, almost all are publications) • **Methods—biotechnology and chemistry** (24, all are publications) • **Enzymology—primarily industrial biotech** (15, mix of patents and publications) • **Biotechnology amplification** (10, almost all are patents) • **Biomass—sugars** (4, mix of patents and publications)
Furniture (205)	• **Furniture** (105, all are patents) • **Mixed—furniture and containers** (33, almost all are patents) • **Furniture** (28, all are patents) • **Furniture** (20, almost all are patents) • **Furniture** (19, almost all are patents)
Livestock, animals, and associated products (172)	• **Cattle—mixed foci—dairy, reproduction and nutrition** (80, all are publications) • **Cattle—mixed foci** (30, almost all are publications) • **Dairy—milk analytics and biochemistry** (30, almost all are publications) • **Animal husbandry—mixed, litter, feed/play products** (almost all are patents) • **Animal science/veterinary medicine—mixed species** (13, almost all are publications)
Packaging technology (157)	• **Packaging** (110, all are patents) • **Packaging** (28, all are patents) • **Packaging—fuel containers and dispensing** (13, almost all are patents) • **Packaging** (6, all are patents)
Equipment and instrumentation (88)	• **Food production machinery and kitchen equipment** (36, all are patents) • **Bioproduct processing methods and measurement** (27, all are patents) • **Sensors and detection (including biosensors)** (25, mix of patents and publications)
Metabolics (62)	• **Metabolics—mixed human/animal metabolism and industrial biotech** (62, almost all are publications)
Microbiology (27)	• **Detection and treatment of pathogens** (27, mix of patents and publications).

Source: TEConomy's analysis of data from Clarivate Analytics' Web of Science and Derwent Innovation databases and USDA CRIS database.

The metagroupings and individual associated clusters vary in whether they are more academic-facing (characterized by primarily being publications-based) or more industry-facing (characterized by being more heavily focused toward patents). Table 14 summarizes the findings by metagroupings and associated clusters.

Table 14: Cluster Focus on an Academic to Industrial R&D Continuum for Missouri

More Academic Research Focused	←		→	More Industry R&D Focused
All are publications	**Almost all are pubs**	**Mix of patents & pubs**	**Almost all are patents**	**All are patents**
NUTRITION & HEALTH Nutritional physiology **NUTRITION & HEALTH** Obesity & nutrition	**NUTRITION & HEALTH** Mixed—diet & health in humans & animals **NUTRITION & HEALTH** Glucose in nutrition/health			
		FOOD Mixed—ingredients & production technologies **FOOD** Food—mixed, various		
	PLANT SCIENCE Plant science—plant biochemistry/ phytochemistry	**PLANT SCIENCE** Soybeans—mixed, varieties/processing **PLANT SCIENCE** Plant science—highly mixed **PLANT SCIENCE** Corn—primarily varieties		
INDUSTRIAL BIOTECH & BIOCHEMISTRY Methods—biotechnology & chemistry	**INDUSTRIAL BIOTECH & BIOCHEMISTRY** Bioenergy—processes & economics **INDUSTRIAL BIOTECH & BIOCHEMISTRY** Lipids/fatty acids & oxidation	**INDUSTRIAL BIOTECH & BIOCHEMISTRY** Mixed—proteins/ nutrition & proteins in biotech **INDUSTRIAL BIOTECH & BIOCHEMTRY** Oils (veg.)—food & industrial methods & applications **INDUSTRIAL BIOTECH & BIOCHEMTRY** Enzymology—primarily industrial biotech **INDUSTRIAL BIOTECH & BIOCHEMTRY** Biomass—sugars	**INDUSTRIAL BIOTECH & BIOCHEMTRY** Biotechnology amplification	
			FURNITURE Mixed—furniture & containers **FURNITURE** Furniture	**FURNITURE** Furniture
LIVESTOCK, ANIMALS & ASSOCIATED PRODUCTS Cattle—mixed foci—dairy, reproduction & nutrition	**LIVESTOCK, ANIMALS & ASSOCIATED PRODUCTS** Cattle—mixed foci **LIVESTOCK, ANIMALS & ASSOCIATED PRODUCTS** Dairy—milk analytics & biochemistry **LIVESTOCK, ANIMALS & ASSOCIATED PRODUCTS** Animal science/veterinary medicine—mixed species		**LIVESTOCK, ANIMALS & ASSOCIATED PRODUCTS** Animal husbandry—mixed, litter, feed/play products	
			PACKAGING Fuel containers and dispensing	**PACKAGING** Packaging
		EQUIPMENT & INSTRUMENTATION Sensors & detection (including biosensors)		**EQUIPMENT & INSTRUMENTATION** Food production machinery & kitchen equipment **EQUIPMENT & INSTRUMENTATION**

More Academic Research Focused	←		→	More Industry R&D Focused
All are publications	**Almost all are pubs**	**Mix of patents & pubs**	**Almost all are patents**	**All are patents**
				Bioproduct processing methods & measurement
	METABOLICS Mixed human/animal metabolism & industrial biotech			
		MICROBIOLOGY Detection & treatment of pathogens		

Source: TEConomy's analysis of data from Clarivate Analytics' Web of Science and Derwent Innovation databases and USDA CRIS database.

- It is evident that work in nutrition and health skews toward publishing, with no specific clusters focused around patenting.
- Food is a more mixed metagrouping, with both publishing and patenting showing up regularly.
- Industrial biotechnology and biochemistry is also mixed, but also skews more toward publishing.
- Furniture is almost exclusively driven by industry, with the majority of records in the cluster being patents. The packaging metagrouping is similarly structured.
- Livestock, animals, and associated products skews toward publishing much more than patenting —except for the more product-oriented cluster containing manufactured animal husbandry and feed/play products.
- The two small metagroupings of metabolics and microbiology are mixed in terms of publications and patents, with the metabolics metagrouping skewing somewhat more toward publishing.

D. SWOT Analysis: Missouri Value-Added Innovation

To supplement and build upon the findings of the quantitative economic analytics, TEConomy performed a series of interviews with academic and industry researchers engaged in value-added sectors and relevant research in Missouri. Also, reference was made to existing published research regarding relevant industries, research programs, and technologies relevant to Missouri's value-added innovation environment. The results of these interviews and assessment of research lead to the following SWOT assessment.

STRENGTHS

- At MU, the Food Science Department's principal strengths lie in food safety—especially in microbial food safety and analytical methods for identifying and quantifying contamination (especially in terms of rapid assay development). Innovations have generated some applied-for patents, and the faculty interact with nanomaterials personnel within the university with a focus around development of biosensors. However, while well recognized and published, this is still a small group, primarily centered on two faculty. Food Science faculty do some limited engagements with industry in Missouri around special projects, product testing, and microbial spoilage.
- The MUNCH represents the coming together of a world-class group of 19 faculty covering multiple aspects of nutritional science. Nutritional Science at MU is part of three colleges, providing a bridge between the College of Agriculture, Food and Natural Resources (CAFNR), the School of Medicine, and the College of Human Environmental Sciences. Expertise is robust across a range of scientific areas

pertaining to advanced nutritional studies in glycolysis, metabolism and metabolomics, lipid metabolism, and smooth muscle cells. The MUNCH comprises a research metabolic kitchen able to produce precisely controlled meals for up to 50 trial subjects and also an observational behavior lab. MUNCH enables Missouri to very precisely study effects of a controlled diet on clinical trial participants.

- MU PAW is a state-of-the-art designated (human) clinical research facility (containing 2,250 square feet) for the assessment of (semi)-invasive physiological and behavioral health-related outcomes. Located in the same building at MUNCH, MU PAW can support "feed and bleed" studies, able to draw blood for analysis, conduct muscle biopsies, and process and analyze blood in the building. The facility contains a full suite of analytical instruments for conducting body composition analysis, ultrasound, autonomic nervous system flow, and metabolic and resting metabolic rate analysis, etc.
- MU Hospital in Columbia has an inpatient facility able to support the work of MUNCH/PAW and able to facilitate overnight studies of food intake and exercise. This is a rather unique facility and is engaged in a large, 5-year funded weight loss clinical study.
- Missouri State University's Mountain Grove campus operates the Missouri State Fruit Experiment Station and has a Fruit Science program. The station contains a small Fruit Processing Education Building together with the Missouri State Winery and Distillery. R&D is primarily focused around plant science for fruit improvement and agronomy, together with some processing research.
- Lincoln University is active in outreach to small operations and minority and disadvantaged farmers. A growth area has been in vegetable production by small producers using high tunnel production. Lincoln University also has a commercial kitchen that is used for demonstrations with potential value-added producers.
- The MU Center for Agroforestry has been developing alternative agronomy systems that mix trees and shrubs with crop production and livestock. The model is found to be environmentally beneficial, but also encourages the production of a more diverse range of marketable crops and livestock. The systems are being used to produce nuts (pecans, walnuts, Chinese chestnuts), and other crops such as elderberries, gourmet mushrooms, etc. R&D is active in improving nut meat yield in black walnuts. The diversity of crops available to be produced through agroforesty production systems may be a good fit to production of niche value-added products and health products.
- Good expertise exists in soybean chemistry research with Solae very active in soy protein isolates, and USDA Agricultural Research Service (ARS) at MU engaged in research related to fatty acid composition and health, low linoleic acid soybeans, high-oleic acid soybeans, and seed composition and molecular genetics. Plus, of course, there is the deep expertise in soybean cultivar development and transgenics contained in both academe and industry (such as Monsanto). Missouri (and surrounding states) has a mature soybean production and rotation system, with significant elevators, processing facilities, and a central location for materials transportation. Between MU and USDA-ARS, there are 15 researchers focused on soybeans as a crop (with very strong capabilities in breeding, plant physiology, nematology, variety testing, quantitative genetics, etc.). Casting the net more broadly to encompass agronomics, economics, etc., would estimate that there are upwards of 40 people associated with the Soybean Center at MU.
- MU's Grape and Wine Institute and enology program have been helping to grow the state's wine industry. There are currently 135 wineries in Missouri. The industry has been scaling well, moving beyond just tasting room sales and into regional stores and broader wine distribution systems. The industry is quite well distributed around the state and has grown to the extent that fruit production is not keeping pace with demand and Missouri wineries are having to import some grapes. The university's work in support of the industry is sustained by part of an 8-cents-per-gallon tax on wine sold in Missouri. Providing $1.6 million in support for its program, the university is able to sustain meaningful R&D and Extension activity.

- Significant expertise exists in animal science in regard to livestock nutrition and reproductive physiology (especially in cattle, but also in pigs).
- MU has a meat processing facility and meat science labs. Facilities are USDA inspected and able to produce meat from slaughter through to retail sale.
- At the MU St. Louis, there is notable capacity and capabilities, within the College of Business, in logistics and supply-chain analytics. Six tenure track faculty are focused in the area, and it directly links to the St. Louis areas cluster of expertise in distribution and logistics. There is interest in setting up a Center for Innovative Agricultural Supply Chains that could pursue opportunities related to local foods, the application of new technologies (such as artificial intelligence [AI] and Blockchain), approaches to emerging consumer preferences, methods for delivering personalized foods, reduction of food waste through the supply chain, etc. Industry needs to get engaged in innovative food supply chains and the Supply Chain and Analytics program at the College of Business that has a 14-member industry advisory board that could be expended further.
- MU has a good campus culture for transdisciplinary collaboration, and this is being further encouraged through the senior administration at the university.
- There are industry (especially in the St. Louis area) and MU strengths in enzymology, including both basic through applied research. Broad applicability in applications range from food and beverage production, through biofuels and bio-based chemicals and biopharmaceuticals.

WEAKNESSES

- At MU there is a distinct lack of critical mass in terms of faculty and research activity within the Food Science Department. There is a particular need to add faculty in food engineering (including process development), product development, sensory sciences, and the functional foods/nutraceuticals area to interface with MUNCH.
- There is no food processing facility at MU, serving the Food Science Department, able to conduct piloting and process development for value-added products. This significantly limits the scope of R&D that can be performed and is especially limiting in terms of ability to work with industry and entrepreneurs.
- MU does not have a forest products or wood products development lab, nor a wood products program.
- Missouri farmers are relatively conservative, and it is challenging to get them to engage in new production practices, introduce new crops, or be open to new market opportunities.
- There is no central Missouri clearinghouse or advisory service for interested potential business people and entrepreneurs to understand market opportunities or come together with one another to pursue opportunities. Kansas City has, however, formed the Cultivate Kansas City program that is bringing together producers, restaurant operators, retailers, etc., to discuss linking up for integrated supply chains. Stakeholder meetings are now being held monthly.
- There are no Food Science Extension faculty to work with industry or help build relationships with industry.

OPPORTUNITIES

- There is a potential to build upon vegetable and fruit production, and meat production, by smaller producers and leverage new models of direct-to-consumer distribution. It is felt that farmers' markets are too small in scale to have significant income impacts for producers.
- Is there an opportunity with larger institutional customers (schools, hospitals, etc.) across the state to create standardization of food recipes and menus? This could create standard specifications to which

producers could work. Producers could collaborate to provide coverage of the menu needs. This would need an organization with significant influence to bring institutions together to standardize as customers.

- To make a significant push in value-added food, MU needs to invest in a pilot-plant/food-engineering and R&D center facility. Examples at the University of Nebraska, Penn State, and Cornell (Geneva campus) are felt to represent the type of facilities that may need to be developed. Facilities need to be able to handle product development through pilot-scale processing.
- MUNCH provides MU with a signature research program with both the facilities and critical mass of researchers required to advance nutritional science and the testing and development (potentially) of advanced food, functional food, and nutraceuticals. In combination with MU PAW (focused on physical activity and wellness and having blood-draw and blood-analysis capabilities in the building), MU has the ability to advance personalized health in the nutrition and exercise spaces. The capabilities at MU in Columbia provide capacity to advance the evaluation, testing, and development of healthy foods, nutrition projects, and personalized diet plans. In effect, it has characteristics of the North Carolina (NC) Research Campus in Kannapolis; but it has the advantage of being located on a campus with a complete suite of capabilities in medicine, veterinary medicine, agricultural sciences, engineering, analytical chemistry, etc., i.e., the resources of a comprehensive research university (versus the rather remote location of Kannapolis). A key opportunity brought by the work focus of MUNCH is the ability to access the much larger funding streams available through the National Institutes of Health (NIH) versus the more limited funding available via the USDA National Institute of Food and Agriculture (NIFA).
- Supply-chain analytics capabilities should be leveraged to develop novel value-added food system models, delivery systems, and personalized foods; the means to label foods (such as meats) with the source; and other novel systems that appeal to the consumer and could support premium pricing.
- There may be potential for Missouri to bring back some of its lost dairy production. Water constraints in other states are likely, over the longer term, to promote moves back into places like Missouri that have robust water resources. Missouri's dairy production is largely in grazing dairies, yet not enough is being done to market this more appealing model to consumers.
- There is potential to link the tremendous capabilities of MU and industry in the state regarding plant science to longer-term functional phytochemical research findings to engineer in-plant production systems (e.g., via plant metabolic engineering) or plants with increased yield levels of desirable phytochemicals.

THREATS

- A lack of investment in Food Science within CAFNR represents a barrier to realizing fully integrated programs with other groups across the university system in terms of value-added product development. Without investment in sensory sciences, process development and process engineering capabilities, consumer behavior and preferences, etc., the ability to construct appropriately complete multidisciplinary teams is hampered.
- Small size of Food Science Department places heavy teaching loads on the existing faculty, limiting time for R&D activities.
- Relatively limited current connectivity between MU and value-added industries in the state reduces ability to conduct collaborative projects at scale.
- Individual county health regulations have effectively limited livestock herd sizes to a level that does not sustain major commercial operations. For example, a 1,000-cow ranch is a starting size for many commercial operations in other states; but, for much of Missouri, such sizes of operations are restricted by county regulations. Legislative change is needed, but it has proven to be a difficult nut to crack.

- Labor shortages and immigration policies may negatively impact the ability to grow the horticultural crops sector. It is also a challenge in the dairy sector.

E. Conclusions: Research and Innovation Themes

While Missouri does not stand out as a leader in research focused on value-added products from agriculture and forestry, there are certain niche areas that present opportunities to build upon. A particularly robust area is in nutrition and associated health research, with multiple clusters of activity evident in the analysis. Related to this research field would be the cluster in metabolics also. The other strong area of research is in plant sciences, spanning a continuum from fundamental academic research through to applied plant sciences (both in academic and industry sectors). These research strengths collectively point to a research-based innovation opportunity around foods for health and advanced nutrition products—ranging from basic research into the effects of various nutritional elements and phytochemicals on health through to advanced plant development and metabolic engineering capabilities that could be applied to development of crops with enhanced expression of desirable chemicals and nutrients. Research strengths in bioprocessing industrial biotechnology and biochemistry may well be relevant to realizing this opportunity in terms of development of extraction and processing technologies for preserving phytochemical functional activity. The above innovation strengths represent R&D areas around which both academic and industry stakeholders can engage—the ideal situation for technology-based economic development.

Chapter IV: Potential Initiatives to Foster the Growth of the Value-Added Supply Chain in Missouri

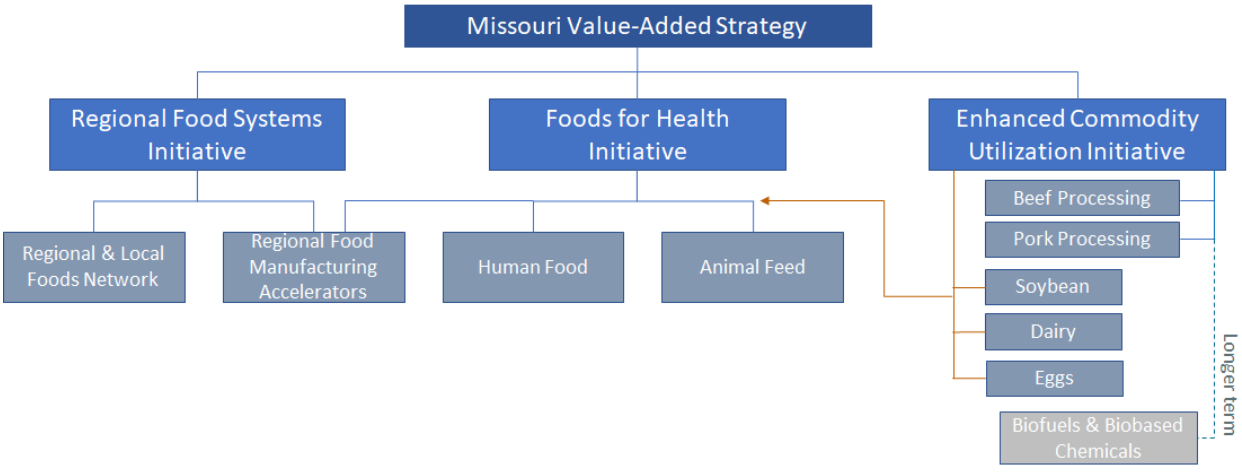
A. Catalyzing the Growth of Value-Added Agriculture and Forest Product Manufacturing in Missouri

The quantitative and qualitative analyses reported in Chapters II and III, and subsequent discussion of the findings with the project advisory committee, lead to some clear conclusions regarding the assets and opportunities that Missouri possesses to further develop its value-added sectors. The analysis points to three primary opportunity areas (termed "Initiatives" herein)—each of which represent equally distinctive areas of focus:

- **Regional Food Systems Initiative**—focused on enhancing the food value-chains at a regional and local level across Missouri and facilitating and accelerating the development of regional value-added food product manufacturing business ventures.
- **Foods for Health Initiative—**focused on building a new, R&D- and innovation-driven functional foods and advanced nutrition industry for Missouri rooted in nutritional sciences, an expansion of food science capabilities, and an applied program of clinical and translational research.
- **Enhanced Commodity Utilization Initiative—**focused on the development of enhanced value-added processing activities for key commodities.

Figure 23 shows the three Initiatives under the umbrella banner of the Missouri Value-Added Strategy.

Figure 23: Key Proposed Elements of Missouri Value-Added Strategy



Source: TEConomy Partners, LLC.

B. Regional Food Systems Initiative

1. Description: The recommended Regional Food Systems Initiative will help ensure that comprehensive, in-depth business development, product development, and supply-chain services are readily available and easily accessible to start-up and small- and medium-sized food processing and manufacturing companies. The initiative will focus on two complementary activities: (1) a comprehensive network of value-added processing accelerator services and capabilities; and (2) the development of a robust regional and local foods system. Through the creation of the Regional Food Systems Initiative, Missouri will seek to develop integrated value-added processing chains, thereby increasing the level of economic profit retained within the state by Missouri agricultural producers and manufacturers.

2. Why is this important: Worldwide agricultural commodity markets are highly competitive and price driven. As a result, even though national agricultural productivity continues to increase, the real value of that production at "the farmgate" continues to decline. The future of agricultural and rural sustainability in Missouri will very much depend on the ability to construct "value-added" chains of production that vertically integrate the food-related business model/value supply chain. The basic value-added concept was shown in Figure 2 in the first chapter and illustrates the substantial difference in potential income between simply growing and selling any agricultural commodity (the farmer row) and the total income that may be realized in a state that provides a vertically integrated value-added chain.

Producers involved with adding value will become more than commodity producers absorbing all the shocks brought about by global markets. They will think of themselves as producing products for end users, instead of producing only raw commodities. This, however, requires a different way of doing business and will require agricultural diversification as well as coordination throughout the value-added supply chain.

Diversification can take the form of both crop variety (i.e., adding horticultural crops to diversify potential food processing/manufacturing opportunities) as well as plant characteristics (i.e., growing organic or non-GMO cultivars to increase potential market opportunities as well as food processing/manufacturing opportunities). Through diversifying the agricultural base of the state, food processing and manufacturing opportunities will increase.

Coordination focuses on arrangements among those that produce and market farm products. Horizontal coordination involves pooling or consolidation among individuals or companies from the same level of the food chain. An example would be independent livestock producers combining their production to enter into processing contracts with a local small-scale meat processor to expand processing operations and become USDA certified, which allows the livestock producers to become direct marketers of value-added meat products across the country. Vertical coordination includes contracting, strategic alliances, licensing agreements, and single ownership of multiple market stages in different levels of the food chain. Vertical coordination, either through ownership integration or contractual arrangements, is necessary to link production processes and product characteristics to the preferences of consumers and processors.

Fundamental changes through diversification and coordination are altering traditional marketing relationships that link consumers, food retailers and wholesalers, food processors and producers.

3. Why in Missouri: To provide further perspective on the Missouri food processing and manufacturing industry, the Missouri IMPLAN model was examined to better understand the production flows within Missouri's top food processing and product sectors.[23] Specifically, the analysis examined the following:

- **Total Commodity Supply:** Total value of the commodity (agriculture product or food product) produced in the State of Missouri.
- **Foreign Exports:** Value of commodities shipped to foreign (non-U.S.) countries.
- **Domestic Exports:** Value of commodities shipped to other U.S. states.
- **Locally Met Intermediate Demand:** Value of commodities flowing to the same or other commodity groups as a downstream production input.
- **Locally Met Institutional/Household Demand:** Value of commodities sold to in-state consumers for final consumption.
- **Inventory:** Value of production retained to be used for meeting future demand.

Together, these values, shown in Table 15, provide an understanding of the state food processing and product output and what happens to this output. The data, sorted by total commodity supply, generally correspond to the industry size described in the economic analysis. Though there are obviously exceptions, most sectors with total commodity supply exceeding $500 million likely have a significant corporate presence providing much of the total commodity supply from the state (e.g., Nestle Purina, Anheuser-Busch, Smithfield, Tyson Foods, and Triumph Foods). While these sectors may provide fewer or more limited opportunities for food accelerator-related initiatives, as can be seen across the United States in the craft beer and direct-to-consumer organic beef and poultry markets, there is room for small, niche production in nearly every food product category.

Table 15: Demand Distribution of Missouri Food Processing and Products Commodity Supply ($Millions)

IMPLAN Sector	Total Commodity Supply (Output)	Exports		Locally Met Demand		Inventory
		Foreign	Domestic	Intermediate	Institutional/ Household	
Dog and cat food	$5,525.84	$305.33	$4,984.48	$22.60	$186.29	$27.13
Animal, except poultry, slaughtering	$3,173.81	$351.06	$2,355.50	$320.61	$146.64	$0.00
Meat processed from carcasses	$3,168.66	$98.18	$2,344.71	$453.67	$272.06	$0.03
Breweries	$2,303.07	$156.27	$1,612.93	$80.51	$446.45	$6.92
Cheese	$2,295.44	$63.46	$1,925.23	$216.36	$90.24	$0.15
Other animal food	$2,108.54	$99.24	$1,428.25	$527.21	$41.05	$12.78
Poultry processing	$2,097.13	$114.38	$1,581.43	$206.82	$194.23	$0.27
Soybean and other oilseed processing	$1,999.26	$339.61	$1,428.31	$224.87	$6.47	$0.00
Flour milling	$1,069.10	$43.15	$739.23	$252.57	$34.07	$0.09
Fluid milk	$994.89	$10.99	$494.64	$225.28	$262.16	$1.83
Dry, condensed, and evaporated dairy product	$975.42	$108.36	$611.50	$153.61	$101.63	$0.32
Bread and bakery product, except frozen	$881.95	$13.53	$691.15	$24.83	$151.90	$0.54

[23] I/O analysis uses commodity (product) flows to measure the value of production and how this value flows throughout the economy. The use of commodities allows for industries to produce goods outside of their core industry definition. For example, companies classified as bakeries could also produce snack foods or cookies and crackers. These figures are developed and derived by IMPLAN, Inc., but are estimates.

IMPLAN Sector	Total Commodity Supply (Output)	Exports		Locally Met Demand		Inventory
		Foreign	Domestic	Intermediate	Institutional/ Household	
Bottled and canned soft drinks and water	$866.80	$17.50	$360.79	$63.92	$422.99	$1.60
Frozen specialties	$738.65	$8.18	$527.73	$25.28	$176.38	$1.08
Dry pasta, mixes, and dough	$577.30	$30.75	$514.60	$5.99	$25.94	$0.02
Breakfast cereal	$533.73	$32.29	$472.57	$1.97	$26.87	$0.03
Distilleries	$530.97	$34.73	$483.01	$7.58	$5.36	$0.29
All other food products	$507.55	$76.78	$392.39	$9.36	$28.74	$0.29
Flavoring syrup and concentrate	$504.46	$7.93	$463.85	$31.50	$1.18	$0.01
Fats and oils refining and blending	$393.05	$19.94	$339.37	$28.38	$5.35	$0.01
Ice cream and frozen dessert	$382.58	$6.26	$319.93	$31.89	$23.09	$1.41
Mayonnaise, dressing, and sauce	$312.69	$39.58	$251.37	$8.47	$12.96	$0.30
Wineries	$290.32	$20.37	$258.17	$2.22	$9.14	$0.43
Confectionery from purchased chocolate	$266.82	$27.69	$219.90	$1.13	$17.94	$0.16
Coffee and tea	$263.41	$26.08	$215.60	$7.44	$14.09	$0.20
Canned fruits and vegetables	$256.93	$19.75	$207.40	$6.81	$22.75	$0.22
Spice and extract	$242.32	$9.54	$220.94	$5.38	$6.30	$0.16
Other snack food	$167.48	$3.71	$109.87	$7.81	$46.09	$0.00
Frozen fruits, juices, and vegetables	$130.82	$15.15	$97.40	$6.36	$11.85	$0.06
Cookie and cracker	$124.10	$2.88	$102.74	$2.10	$16.32	$0.07
Rendering and meat byproduct processing	$110.66	$9.74	$87.19	$10.02	$3.70	$0.00
Creamery butter manufacturing	$86.18	$5.42	$40.30	$16.02	$24.42	$0.03
Manufactured ice	$48.24	$1.45	$31.04	$2.41	$13.31	$0.02
Rice milling	$47.81	$21.82	$22.42	$1.97	$1.51	$0.09
Malt manufacturing	$47.34	$11.84	$14.59	$14.71	$4.17	$2.04
Nonchocolate confectionery	$42.98	$3.97	$36.28	$0.23	$2.49	$0.01
Frozen cakes and other pastries	$31.39	$2.68	$25.93	$0.39	$2.38	$0.01
Tobacco product manufacturing	$28.94	$0.15	$25.85	$0.01	$2.92	$0.00
Chocolate/confectioneries from cacao beans	$17.78	$1.72	$14.72	$0.34	$1.00	$0.01
Dehydrated food products manufacturing	$16.62	$1.91	$2.23	$2.91	$9.53	$0.04
Roasted nuts/peanut butter manufacturing	$10.45	$0.81	$2.66	$1.07	$5.88	$0.03
Canned specialties	$6.18	$0.29	$5.37	$0.12	$0.39	$0.00
Tortilla manufacturing	$5.90	$0.07	$1.53	$0.44	$3.86	$0.00
Total, Food Processing and Products	**$34,183.58**	**$2,164.53**	**$26,065.12**	**$3,013.17**	**$2,882.08**	**$58.68**

Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data. Additional non-food manufacturing sector detail is provided in Appendix A.

From Table 15, potential candidate sectors for the Regional Food Systems Initiative are those sectors where institutional/household demand substantially exceeds intermediate demand (whether or not the sector is also a key exporter), but are capable smaller, niche production including bread and bakery products, frozen specialties, canned fruits and vegetables, and other snack food. Such sectors represent markets where locally produced food products are meeting local consumer demands versus providing an input to further processing activities. Smaller entrepreneurial ventures typically require local market success before moving into out-of-state sales and foreign exports. A key consideration for such initiatives to succeed from an economic development perspective is the extent to which key inputs/ingredients can also be sourced from within the state, to increase both overall demand and intermediate supply. This will be part of the challenge of a Regional Food Systems Initiative in Missouri as many of the non-commodity agricultural inputs are currently produced at relatively low production volumes in the state (see Appendix A). The ultimate success of a Regional Food Systems Initiative will be determined by in-state value-added production spurring new and expanded in-state agriculture product supply.

The bottom line is that Missouri's level of value-added processing activity is undersized in comparison with the state's agriculture output. Missouri's agriculture production is highly concentrated in a few commodities and generally lacks diversity in crop production. Missouri is especially lacking in horticultural crops produced for food. Furthermore, Missouri has limited knowledge regarding product development, distribution channels, market placement, etc., as a result, in part, of an ecosystem that lacks the following:

- Assistance available for companies and/or farmers interested in developing value-added products;
- Research capacity, which has some Missouri companies working with out-of-state universities for research and testing services;
- A processing authority;
- An investment ecosystem to support value-added businesses; and
- Sufficient co-packing operations for smaller runs (this lack stymies smaller value-added operations).

A key takeaway is that, for the food processing and manufacturing industry sector to achieve maximum economic impact, Missouri must strive to increase the level of value-added food manufacturing occurring within the state and to ensure, to the extent possible, that Missouri producers are available to supply key inputs to in-state food manufacturers.

4. Best practices: The University of Nebraska–Lincoln's Food Processing Center (FPC) was created to capture more of the value-added processing and manufacturing efforts enabled by commodity production. It seeks to enhance value throughout the process, from idea through ongoing market support [via a] unique combination of technical and business development services.

The FPC addresses all food groups and has managerial custody of all the processing capacity associated with the Department of Food Science and Technology. It serves as the department's primary vehicle for industrially sponsored and other applied research in the department. It is especially well known for its extrusion equipment.

The FPC's signature program is the National Food Entrepreneur Program, which begins with the one-day "Recipe to Reality" seminar and proceeds to "Product to Profit," a second phase in which confidential

services are provided to any participants who launch their own business. The FPC makes no distinction between "lifestyle" and scalable entrepreneurial start-ups.

The FPC also provides the following:

- Laboratory services, including general microbiology testing, food screens for contamination, acidified foods testing, water analysis, and pathogen detection
- Sensory analysis, including informal/qualitative testing, consumer testing (acceptance/ difference/preference), in-depth descriptive analysis, and sample preparation for both consumer and expert panels
- Food properties testing
- Product and process development, including creative concept (ideation) and benchtop prototype development for testing, ingredient application and substitution and supplier evaluation, line extensions, and product and process scale-up (standards and issue identification at smaller dimension)
- Labeling and regulatory compliance, including label review, nutrition facts panel based on database, ingredient statement and allergen declaration (while protecting trade secrets), and nutritional claims (review for allowable and appropriate phrasing)
- Pilot plants.

The Rutgers Food Innovation Center (FIC) is a combined pilot-plant and incubator facility. The FIC offers technical assistance in business-concept development, mentoring/acceleration services for new launches, and networking with and among established food entrepreneurs. It also offers entrepreneurs shared access to cold, hot, and dry process areas operated to FDA/USDA standards, as well as assembly and packaging. It also includes a test kitchen, sensory evaluation center, microbiology and analytical laboratory, and capacity for consumer research and focus groups.

Additional revenue-generating services include online courses for entrepreneurs, established food companies, and farmers' markets. The website includes links to many active commercial kitchens for rent, and to co-packers active in the state.

The Michigan State University Product Center grew out of interest in capturing within Michigan more of the "value-added" from what is primarily a commodity-oriented agricultural economy. The Product Center helps develop and commercialize high-value products and businesses in the food, agriculture, and natural resource sectors.

The two defined target audiences are entrepreneurs or early-stage businesses at the concept stage and established businesses wanting to move to the next level of performance. The Product Center targets different services to its two distinct audiences:

- Start-up entrepreneurs
    - Concept development
    - Business development
    - Market research and data
    - Interactive supply-chain data for Michigan
- Established businesses
    - Economic and market analyses
    - Feasibility assessments

- Product development
- Resource development
- Supply chain and marketing
- Packaging and labeling planning
- Strategic planning
- Regulatory compliance.

The Product Center is an USDA/FDA-certified facility available by lease for periods of between 3 and 21 days by one client at a time 24 hours/day for test runs. The Product Center partners with co-packers, to steer them clients that have already been through the pilot phase, have a stabilized product, and know what their volumes will be. These are desirable customers for co-packers. It also works with a number of local kitchen incubators.

5. What to do: It is recommended that the Regional Food Systems Initiative comprise two discrete activities:

1. Regional Food Manufacturing Accelerators, and
2. A Regional and Local Foods Network.

Regional Food Manufacturing Accelerators

Start-ups and small businesses indicate that their greatest obstacles are access to the following:

- Sector-specific business expertise,
- Specialized equipment and capital-intensive infrastructure, and
- Customers and markets.

Of these, the most significant obstacle to creating and growing value-added food processing and manufacturing companies is the lack of sector-specific business expertise. For many states, there simply is no cadre of experienced, food processing and manufacturing entrepreneurs who know how to turn a food product into a successful venture. Such expertise is needed not only to lead new ventures but also to serve as mentors to help fledgling entrepreneurs develop their skills and increase their chances of success. They have contacts in the food-related supply chain, can recognize quality products, and help to develop distribution networks and marketing relationships that generate sales.

The second challenge facing food processing and manufacturing entrepreneurs is access to specialized equipment and capital-intensive infrastructure. Entrepreneurs require access to equipment and specialized facilities at each stage of their development, from early-stage, product and process innovation through to large-scale manufacturing runs. States that have limited to no access to specialized equipment and capital-intensive infrastructure leave entrepreneurial companies unable to scale and reach their growth potential.

The third challenge that food processing and manufacturing entrepreneurs face is to find customers and markets. Few resources are available to assist companies in finding customers, identifying new markets, and generally increasing sales—all factors that will determine the level of their contribution to the economic health of the communities in which they reside. In addition, firms have difficulty keeping up with the competition, being aware of new products and changing consumer behavior that may affect their markets and supporting continued product development.

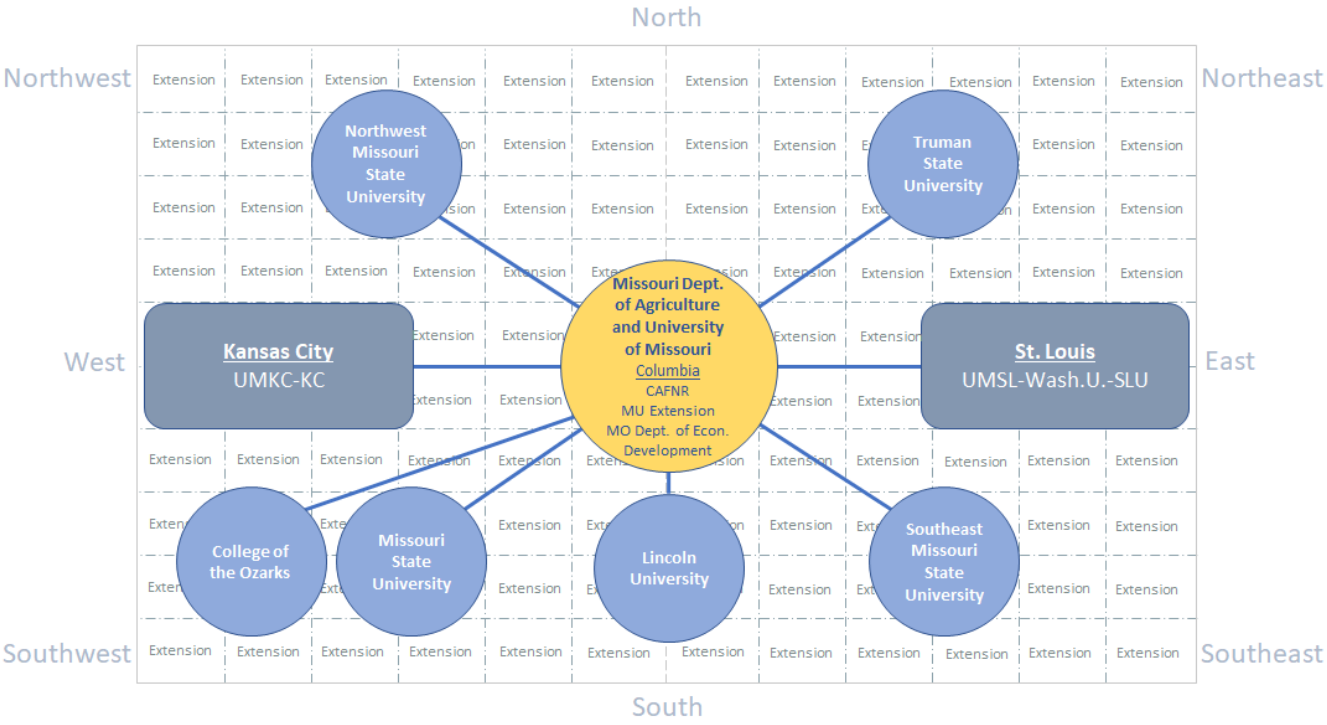
The Regional Food Manufacturing Accelerators are envisioned as a model of business and technical assistance that would be available to start-up and small food processors and manufacturers throughout

the state. Through a hub-and-spoke model, leveraging existing efforts, businesses would be able to avail themselves of assistance services, such as the following:

- Creation of a Process Authority that would focus on product testing, product classification, nutritional label and process authority letter development, label review, and consultation.
- Development of pilot-size co-packing plants to conduct smaller batch runs.
- In partnership with the Missouri Department of Agriculture, provision of access to initiatives that support food processors and manufacturers, and provision of regulatory guidance and assistance.
- In partnership with either MU Extension Business and Communities Program or Missouri Enterprise Manufacturing Extension Partnership (MEP) program, provision of assistance to food manufacturers in production process, cost improvements, and regulatory compliance.
- In partnership with MU Extension's Missouri Small Business & Technology Development Centers (MO SBTDC), provision of assistance with business plans, market analysis, and access to capital.

It is envisioned that a "hub-and-spoke" model of value-added Regional Food Manufacturing Accelerators would be created to ensure that start-up companies were able to be assisted at a regional level while still ensuring that resources were not duplicated for capacity that can be more centrally located. To this end, it is envisioned that up to seven accelerators or nodes would be developed initially in partnership with Missouri's academic institutions and the Missouri Department of Agriculture, one in each region of the state and two additional hubs in the major urban centers, for a total of nine. All seven nodes would provide a full range of business assistance and market development expertise and would also develop intermediary processing capability that could be utilized by start-up companies in a particular region and tailored to the specific agricultural commodities with the greatest demand for further processing/manufacturing. In addition, a central hub would be created in Columbia to provide not only region-specific services as outlined above, but also unique statewide assistance (such as the processing authority) and help connect all companies to the research capacities within CAFNR. County Extension offices would serve as a referral network into each regional node or central hub as appropriate (see Figure 24). The leadership/oversight of the entire system would also be overseen from the central hub.

Figure 24. Missouri Regional Food Systems Initiative—Utilizing a Hub-and-Spoke Network and County Extension Offices



Source: TEConomy Partners, LLC.

The bottom line is that finding different and unique ways to support entrepreneurs and the growth of entrepreneurial food processing and manufacturing companies is an important component in Missouri's efforts to develop the industrial base.

Regional and Local Foods Network

Recognizing that small farms can have a challenging time sustaining profitability if only supplying into large, price-constrained commodity markets, the Regional and Local Foods Network would work actively with small farm producers to examine alternative crop opportunities, niche market opportunities (such as farmers' markets, local food opportunities, etc.), and other entrepreneurial endeavors on the farm. Efforts include looking for opportunities for adding value to farm commodities in diverse ways, including for example, organic and specialty markets, direct marketing of products, community-supported agriculture, and agritourism.

Local food systems generally refer to the geographic context in which food is produced, marketed, and consumed and all other intermediary supply-chain steps taking food from farm to table. Additionally, localized food systems are place-specific and seek to embed the production, distribution, and consumption of foods in community relationships. Farms, from large to small and from conventional to certified organic, are finding opportunities to engage in local foods market opportunities across the supply chain.

It is envisioned that each node of the Regional Food Systems Initiative will be responsible for developing its own Regional and Local Foods Network, focused on the following of various issues:

- Regional and local foods system supply chains
    - Local food production, particularly horticulture
    - Distribution and aggregation
    - Markets and purchasing
    - Local buying preferences
    - Resource and waste recovery
- Regional and local foods access
    - Community gardens
    - Farm to school
    - Farm to childcare
    - School gardens
    - Local food access and food security
    - Local government, planning, and agriculture policy.

It may be necessary to develop intermediary aggregators and processors in order to develop a critical mass, or economies of scale, to ensure the economic viability of such efforts. NC State's NC Growing Together project can serve as a best practice in that endeavor.

It is envisioned that each node of the Regional Food Systems Initiative will be responsible for developing its own local food system initiative.

C. Foods for Health Initiative

1. Description: The recommended initiative will develop Missouri as a leading center in the research, development, testing, and production of foods for health. Using modern transdisciplinary science capabilities, combined with distinctive capabilities in clinical and translational sciences, Missouri can achieve a leadership position in evidence-based advanced food and nutrition products. Further, a combination of R&D in nutrition and its relationships to phenotype and genotype may unlock a new industry in precision foods for health—diets personalized to the functional characteristics and needs of the individual.

2. Why is this important: The old adage that "we are what we eat" is a truism. On average, an adult needs to replace circa 300 billion cells per day, and the building blocks for every cell in the body come from the nutrients extracted from the foods consumed. As a biological organism, the human body is built and fueled by the foods eaten, and the quality and composition of those foods very much influence performance and health. Unfortunately, in the United States, and increasingly throughout the developed world, unhealthy diets and low levels of physical activity have become a leading cause of premature death. In the United States, it is estimated that 678,000 deaths occur annually that are due to diseases strongly correlated with poor nutrition and obesity—diseases such as cardiovascular disease, cancer, and type 2 diabetes, for example. It is also an expanding problem, with the Centers for Disease Control and Prevention (CDC) reporting that, over the past 30 years, rates of obesity have quadrupled in adolescents, tripled in children, and doubled in adults.[24]

While consumers are presented with unprecedented choice in terms of fresh and processed food products in America's grocery stores, the level of consumer knowledge regarding evidence-based nutritional recommendations and benefits is relatively poor. Competing claims of health benefits,

[24] Centers for Disease Control and Prevention (CDC), NCHS Health E-Stats: "Prevalence of Overweight and Obesity among Children and Adolescents Aged 2–19 Years: United States, 1963–1965 Through 2013–2014" and "Prevalence of Overweight, Obesity, and Extreme Obesity among Adults, United States, 1960–1962 through 2011–2012."

changing recommendations, misleading marketing messages, and deliberate misinformation campaigns by special interests serve to confound consumers' ability to make rational choices regarding their nutritional intake. Some consumers seek to make up for perceived or real deficiencies in their diets though the use of health supplements and other over-the-counter products from health supplement stores and online vendors, yet this unregulated industry is rife with products of dubious value. Indeed, the National Center for Natural Products Research at the University of Mississippi noted in an interview with Battelle researchers that the great majority of the marketed products they test either do not contain the labelled ingredients or have been processed in such a way that the desired active ingredients have been rendered inert and of nominal health value. There is a need for a trusted, academic institution to step forward in the nutrition space to conduct trials-based research to confirm nutrient impacts on health and study the best methods to preserve and process ingredients possessing positive health benefits.

It is also the case that each person is unique in terms of genome, lifestyle, environmental interactions, and resulting phenotype. Knowing the health benefits of foods *en masse* and their individual nutritional components is important, but equally important is knowing which foods and nutrients will have the most positive impact given individual characteristics. This need for personalization is being recognized in the growth of the "precision medicine" or "personalized medicine" discipline—providing significant leaps forward in medicinal efficacy based on providing the right drug, at the right time, in the right dose, for the right person. No less important, and impactful, will be prescriptive nutrition, and nutritional genomics, adopting a similar approach to determining optimal nutritional profiles based on personal physiological characteristics.

3. Why in Missouri: Several assets and core competencies serve to advance Missouri as a logical location for intensive pursuit of this platform.

- **Transdisciplinary R&D Assets and Core Competencies:** MU is perhaps uniquely positioned among major research universities in terms of the assets it has to deploy in the arena of foods for health. As a leading LGU, MU has long-standing expertise in agriculture and food production research and stands among the preeminent universities in terms of advanced plant science and has deep animal science expertise in nutrition. Furthermore, on the same campus as CAFNR in Columbia is the MU School of Medicine, the MU College of Veterinary Medicine, and the MU College of Engineering. The MU College of Human Environmental Sciences also contains significant expertise in nutrition and exercise physiology. Research expertise in Missouri (at MU, within other academic institutions in the state, and within industry) in metabolomics and metabolism, lipids, enzymology, fermentation, protein isolates, bioprocess development, and other areas of associated science is also directly relevant to developing a Foods for Health platform.

- **Distinctive Investment in Relevant Clinical and Translational Research:** The opportunity to move toward preeminence in foods for health has already been partially realized through MU's investment in two distinctive centers— MUNCH and MU PAW. These and other university assets provide for the quantitative study of the beneficial effects of food components and the measurement of their impacts on health—providing the ability to create an evidence-based healthy foods and nutrients model. Advanced and functional agricultural produce and processed food products can be tested in humans in fully controlled feeding trials lasting between 1 and 4 months through MUNCH. The center is equipped to handle fully controlled diets in cohorts of up to 150 people. Diets are prepared by a full-time research chef and dietician, and the facility even has a drive-up location where participants pick up 3-day completely prepared meal portions. In

these, and longer-term studies (2–3 years), MUNCH and other MU assets, working cooperatively, will be able to provide rigorous validation of impacts on human health.

- **Expanding Production of Specialty Food Crops:** Other aspects of R&D and agricultural sector development in Missouri also lend themselves to pursuit of this platform. Work at multiple Missouri universities has been promoting the development of a more diversified agronomic output through promoting the growth of alternative horticultural crops, in terms of fruits, vegetables, nuts, and other products—especially for small farms. The growth of specialty crops and an expanding acceptance of alternative crops, cropping systems, and value-added production opportunities outside of the top commodities by producers provide a potential pathway to diversifying farm incomes and realizing distributed rural economic development in the production of value-added food products and specialty food for health ingredients. An example of work to promote diversification in Missouri crops is the Agroforestry Initiative at MU, which is using techniques such as forest farming, alley cropping, and silvopasture to create intensive and diversified use of farmland and forestland (with specialty crops such as mushrooms, pecans, and walnuts being produced).

- **Relevant and Adjacent Animal Science Core Competencies:** It should also be noted that Missouri has a large and specialized pet food and livestock feed industry. Nutrition advancements may flow in two directions—from an animal science perspective, with advanced evidence-based animal nutrition findings translating potentially to humans, and vice versa. Livestock nutritional sciences have, in many respects, already moved into a research-based precision nutrition model. Animal science capabilities at MU are very relevant (and ranked in top 10 PhD programs by the National Research Council), and much research learning may be portable to human application. MU also operates the National Swine Resource and Research Center, federally funded and supporting the use of pigs, including transgenic pigs, in biomedical research. Research should likely focus not only on plant-based foods; for example, potential exists for dairy product analytics and specialty food ingredients from milk. Milk is used more widely than almost any other agricultural commodity; and there is a need to systematically identify bioactive compounds, determine processes for extraction and isolation of bioactives, and legitimize/quantify health claims. Conjugated linoleic acid alone, for example, has 28 different isomers, which may have numerous beneficial effects on health.

- **Supply-Chain Innovations:** Also of relevance to this opportunity in Missouri is research expertise in logistics and supply-chain analytics that can be brought to bear on opportunities for unique models in production and distribution under a more personalized foods marketplace. Missouri also benefits from its central location in the United States and the enhanced financial viability of personalized delivery models for fresh and perishable food products (as the shipping industry adapts to home shopping and home delivery modalities). The local food movement is also beneficial as it starts to direct consumer preferences toward more localized, niche products and specialty foods rather than mass-market homogeneous processed foods.

In combination, the above assets make for a compelling case for pursuit of a Foods for Health platform in Missouri.

4. The state has many relevant assets, but there is need for further investment to realize the vision: While assets in the state are considerable, this is no focused and organized transdisciplinary platform and there are observable gaps in the R&D ecosystem that need to be addressed.

Perhaps the most notable gap is at MU in terms of the Food Science Department and its infrastructure and faculty resources. Currently, the Food Science Department is very small, in terms of faculty, and lacks the type of infrastructure (such as product development labs, pilot-plant equipment, and demonstration facilities) that are seen at major leaders in the space (such as Cornell, Penn State, the University of Nebraska, and others). The lack of capacity and investment in Food Science within CAFNR was raised in most interviews with CAFNR faculty but was also highlighted by leadership outside of the college. MUNCH leadership, for example, noted that they very much need to see the Food Science Department receive investment to complement their work—with at least six faculty positions suggested for Food Science to build back to any sort of critical mass. MUNCH leadership noted that a lack of critical mass in the CAFNR Food Science Department is a major gap. It was felt that capabilities must be recruited, for example, in hunger and satiety studies, consumer food preferences and behavior, and sensory sciences.

There is also a need to connect the phenotyping work that MUNCH research teams are conducting to the genetics and genotyping capabilities of MU and its Center for Biomedical Informatics (CBMI). In discussing the potential of connecting genotype and phenotype, the Director of Biomedical Informatics noted that there is university funding available through CBMI to help support faculty positions, and a very real potential for having a significant funded program leveraging the university leadership's interest in building capacity in personalized/precision medicine.

There is a robust likelihood that the work of a Foods for Health Initiative in Missouri will generate innovations and discoveries able to be translated into commercial opportunity. As such, investment in the Regional Food Systems Initiative concept at MU and regional universities throughout Missouri will be a critical element in translating discoveries; piloting associated innovations as commercial products; and helping introduce value-added products to producers, processors, and new industries.

5. Competition: Perhaps surprisingly, given the impact of nutrition on health, the landscape of competing advanced nutrition research centers is quite sparsely populated. The NC Research Campus in Kannapolis certainly has a robust program and exceptional facilities and instrumentation, but the model there is hampered by the development being separate from the main campus of NC State University and other participating universities (Duke and the University of North Carolina). Purdue University has a good feeding center and has pig models for health studies; but, unlike Missouri, it does not have a medical school. USDA in Beltsville performs work in this space, but again, does not have a comprehensive research university to draw upon. Duke and Vanderbilt both do good work in metabolism, but the work is quite narrowly focused and niche oriented. Penn State University is more focused in its work on consumer behavior and food choice. Appendices D and E provides further detail on the competitive landscape in the United States, but the overall conclusion is that competition in advanced foods and associated health effects is significantly more limited than in many other areas of scientific inquiry and health sciences.

6. What to do: The early assessment of core competencies and assets in Missouri provided early indication of a Foods for Health platform having potential as a major value-added initiative for Missouri. Over the course of the project, in conducting interviews with researchers, stakeholders, and industry representatives in Missouri, the general concept for such an initiative was introduced and tested. Input received was overwhelmingly positive that a Foods for Health Initiative is a "must do" for Missouri—working to effectively leverage a rather unique series of research assets and strengths, a flexible agriculture production environment, and a line of sight to very large-scale market opportunities. It also closely aligns the food and nutrition space with a stated goal of senior MU administration to position the university to be preeminent in personalized medicine and associated health research. So what is needed to realize the opportunity?

The following series of actions are recommended for advancing the Foods for Health platform:

- **Organize and fund a transdisciplinary Foods for Health Initiative.** The initiative should be focused on identifying health-promoting nutrients, developing processing modalities and phytochemical extraction that preserve functional activity, testing for efficacy through animal models and human trials, and evaluating potential commercialization pathways for realizing value through Missouri production of associated value-added products. A key goal, as a focused economic development platform for Missouri, will be the development of a research-based, health-promoting, value-added products industry. The initiative would be centered at MU, but also incorporate industry and complementary capabilities at other Missouri universities. It is likely that MUNCH would be at the core of the initiative and the organizer/manager of the Foods for Health Initiative.
- **Invest to address gaps that are observable in current capabilities, resources, and facilities.** A priority investment area is the Food Science Department within CAFNR at MU. Investment is required in two areas:
    - **Faculty Recruiting.** It is recommended that faculty lines be at least doubled in Food Science. Key areas suggested for recruitment coverage include sensory science, product development, process development, and a Food Science Extension specialist to interface with existing and developing industry.
    - **Facilities and Infrastructure Development.** Investment is recommended in product development, piloting and demonstration, and sensory facilities to make them competitive with those of other leading food science programs.
- **Connect MUNCH/PAW phenotyping and trials capabilities to MU biomedical informatics and genotyping capabilities.** Fundamental and translational/clinical research to connect phenotype response to food ingredients is a core competency for MUNCH (and supported by MU PAW capabilities). It is logical, given MU leadership's interest in realizing a signature position in personalized medicine, to also integrate genetic research into the proposed Foods for Health Initiative. MU has invested in biomedical informatics (recruiting a well-recognized faculty lead) and has robust sequencing and analytical support capabilities. MUNCH access to trial cohorts provides an ability to collect unified phenotype and genotype data through participating cohorts. This will build a highly valuable long-term data resource for eventually advancing personalized nutrition models and nutritional genomics.
- **Connect to other Missouri academic institutions.** The Foods for Health Initiative should seek participation of other Missouri-based academic institutions that have capabilities and research core competencies relevant to the initiative's mission. Washington University in St. Louis, for example, has notable expertise in metabolism research, and St. Louis University has teams focused in supply-chain research that could be relevant. Canvassing Missouri's research universities for relevant core competencies and interest in participating in the initiative is encouraged.
- **Engage industry in an advisory board and as active program sponsors and participants.** An industry advisory board should be established to provide input into research programs and guidance regarding potential commercialization pathways. Industry can also provide advice regarding associated university education programs and how they can best meet the needs of an emerging value-added foods for health industry. The industry advisory board should

comprise representatives from food, plant science, feed and pet food, biopharmaceutical, and logistics companies to provide well-rounded input and connectivity.

- **Target early identification of research discoveries and innovations with potential for impact on Missouri production agriculture and the development of value-added processing and retail industries.** Since the initiative is being envisioned as an integral element of the strategy to increase value-added stemming from Missouri's agricultural sector, it will be important to direct research toward identifying nutritional elements that may be sourced from commodities that are suitable (or can be engineered to suit) Missouri farm production environments. In other words, work should not be focused on tropical or exotic crops that would be unable to support Missouri-based production.
- **Conduct research into processing techniques and technologies suited to preservation of functional health-promoting nutritional elements and chemicals.** Identification of health-promoting nutritional elements is important, but it represents only part of the work needed to develop value-added foods for the health industry. It is also critically important to work in parallel to develop harvesting technologies, postharvest handling modalities, storage and materials handling, extraction techniques, processing technologies, and packaging that preserve the functional characteristics of the nutrient or food product. These have to be developed not only to preserve bioactivity but also to do so in an economically viable manner and in ways that can ideally fit into existing and emerging supply-chain systems.
- **Once reputation and capabilities are established, introduce market testing and certification services.** The initiative itself, or a spinout enterprise or subsidiary, can be developed, over the long term, to leverage the capabilities and knowledge base of the Foods for Health Initiative into a branded testing and certification service. Through establishing standards for bioactivity, purity, or other metrics, the initiative can then test and certify the performance of products for industry under a fee-for-service or contract model. Further, Missouri production of value-added nutritional products may be promoted under a Missouri Foods for Health brand to achieve French-like appellations (certifications of quality and provenance that increase the value of the product).
- **Conduct development work on new value-added product supply chains.** The growth of the local food movement, home food delivery systems, custom meal preparation services, and other trends in supply chains suited to personalized products provides a potential pathway toward personalized foods for healthier lifestyles and disease treatment and prevention. These new models are not a fit to traditional commodity food supply chains, and the Foods for Health Initiative should be involved in supply-chain R&D to innovate supply, distribution, and retail models for personalized products.

Scientific discoveries, technological capabilities, production and supply-chain innovations, and consumer preferences and market demands are converging to make the timing right for advancing a major Foods for Health Initiative. Missouri has a robust base of assets already in place to draw-upon, and while gaps in certain capabilities need to be addressed, a focused transdisciplinary research initiative can certainly be advanced in the near term to promote cluster-based, value-added R&D and industry economic development.

D. Enhanced Commodity Utilization Initiative

The recommended initiatives previously outlined focus on diversification of agriculture output in the state to provide inputs to smaller-scale, value-added food and nutritional product industries. There is, however, marginal potential to add additional value in some of the major commodities already produced in Missouri.

As discussed in Chapter II, Missouri's production agriculture is currently dominated by a few major commodities (primarily oilseeds, grains, beef cattle, and poultry). The supply chains for using these commodities are well established; overall, throughout the project, input received from those interviewed indicated that the ability to add major-value-added components to the current production is quite limited. This was also reported to be the case for forest production in the state. The agriculture and forestry industries in Missouri have developed, over many decades, to produce efficiently and service existing commodity markets and their supply chains.

Situational analysis performed through interviews and analytics during the project, together with some existing published feasibility studies, indicate the following situation and opportunities for enhanced utilization of major crop and livestock commodities produced in the state:

- **Enhanced Value-Added Beef Processing:** Missouri is among the national leaders in terms of cattle production but stops well short of realizing the full value-added potential from beef finishing, slaughtering, processing, and distribution. At the present time, Missouri-based operations are engaged in the front end of the value-chain with cow/calf rearing operations on farms, backgrounding (the pasture-based gazing of cattle post weaning), and transportation to feedlots. The state has very limited presence in the feedlot industry (so cattle are being transported out of state for most finishing); and the bulk of slaughtering, rendering, portioning, and associated downstream activities, as a result, is being done out of state also. USDA data indicate that out of a production volume of circa 1.7 million head in Missouri, less than 100,000 head (<6 percent) are slaughtered and processed in Missouri. MU has reported in the past that the number is similarly limited in terms of feedlots, with less than 9 percent of Missouri cattle getting to that stage in the state. In effect, Missouri is leaving money on the table when it comes to realizing the full value of its beef production. Confidential data, in a report shared by independent analysts with TEConomy, indicate that between $1.2 and $1.7 billion in revenue opportunities are being lost. Analysis associated with the confidential report shared with TEConomy makes a strong and compelling case for timing currently being right to pursue an initiative to develop a substantial beef slaughtering/aging/portioning operation in Missouri. Having reviewed the analytics performed, TEConomy concurs with the conclusions and recommends that the Missouri Value-Added Strategy include an initiative focused on supporting the recommendations stemming from the analytics—engaging with the Missouri Value-Added Beef Processing Group, LLC, and its consultants Kemker & Associates, LLC, to advance the opportunity further.
- **Enhanced Value-Added Pork Processing:** Missouri benefits from significant swine and hog production. USDA National Agricultural Statistics Service (NASS) data show the Missouri hogs inventory stood at 3.4 million head at the end of December 2017, and the state ranks seventh in production volume. While the state does contain multiple swine finishing and processing operations, a considerable volume of Missouri's pigs are shipped out of state relatively early in their full growth cycle for finishing and processing. As with beef, there may be potential for an additional pork processing plant to be developed in Missouri, with an increased processing

demand leading to more Missouri corn and soybean demand for advancing pigs from a weight of 30 pounds to upward of 280 pounds when ready for slaughter. By increasing swine processing in Missouri, the availability of pork for further processing into value-added finished meat products for retail will be enhanced.

- **Industrial Hemp as a New Commodity:** With the signing of the Farm Bill on December 20, 2018, industrial hemp has been removed from the Controlled Substances Act and farmers nationwide will be free to grow the crop. Industrial hemp is a cannabis plant containing a low concentration of the chemical tetrahydrocannabinol (THC), which is the regulated chemical in marijuana. Rather than being grown for THC, industrial hemp is grown for use in a wide range of products, including fibers and textiles, paper, construction and insulation materials, cosmetic products, animal feed, food, and beverages. The National Conference of State Legislatures notes that "the plant is estimated to be used in more than 25,000 products spanning nine markets: agriculture, textiles, recycling, automotive, furniture, food/nutrition/beverages, paper, construction materials and personal care."[25] Valuable components of the industrial hemp plant are primarily expressed in the flowers, seeds, and stalk. Depending on economics and market development, industrial hemp may play various roles within the Missouri agricultural system. It is an effective crop for use in rotations and can be grown on underutilized pasture land or replace some existing crops. Neither a market at scale nor the processing entities from manufacturing various products from the hemp plant exist yet. Infrastructure is particularly lacking in industrial processing of hemp fiber (even in Canada where growth has been legal for many years). Because of a lack of infrastructure at scale, most early processing tends to be of hemp seeds and processing the plant for bioactive oils. It should be expected that, with the legalization of the growth of industrial hemp, MU Extension will see significant demand from farmers interested in the crop and specialized resources may need to be added in both research and Extension at MU to address the opportunity. In Canada, it has been found that the principal hemp markets are for hemp seed. The Canadian Hemp Trade Alliance notes that "hemp seed attracts commercial interest because of high protein and excellent Essential Fatty Acid profile" and that "most hemp seed whether in seed, oil, flour/powder or and in finished foods goes into the health food and nutraceutical sectors."[26] There is also a growing market in cosmetics and bodycare products for hemp oil. This Canadian experience suggests a direct fit of the crop into supporting the Foods for Health Initiative as a new specialty crop for Missouri.
- **Poultry Production:** Poultry production and associated broiler processing represents an existing vertically integrated industry in Missouri. It is not anticipated that the Missouri Value-Added Strategy is required to address the industry further given its existing level of integration and sophistication. However, in the **layer sector** of poultry, Missouri has been experiencing increasing production levels, which are partly being driven by changes in egg production regulations (forming restrictions) at a state level in California and other production centers. Ranking 13th in the nation in egg production in 2017, up from 15th in 2012, Missouri produced 3 billion eggs with a combined value of $201 million.[27] Encouraging increased poultry and

[25] National Conference of State Legislatures, "State Industrial Hemp Statutes: 8/8/2018." Accessed online at: http://www.ncsl.org/research/agriculture-and-rural-development/state-industrial-hemp-statutes.aspx.
[26] See: http://www.hemptrade.ca/grow-hemp.
[27] The Poultry Federation. Accessed online at: https://www.thepoultryfederation.com/resources/facts-figures.

layer production has the benefit for Missouri of increasing demand for feed products based on commercially produced Missouri commodities, such as corn.

- **Dairy Industries:** The dairy sector may see future growth, likely as a result of water shortages in western states and the potential growth in consumer preferences for pasture-based dairy production and associated products. Input received over the course of the project, however, indicated that large-scale dairies in Missouri are unlikely to grow in the near term because of county-by-county regulatory constraints on confined animal operations. Similarly, water shortages are not at a "crisis" level in the western states yet—thus, a move of dairy operations to states with robust water assets (such as Missouri) is likely a longer-term opportunity.

- **Soybeans:** Soybeans are the leading row crop produced in Missouri, with 5,250,275 acres of production in 2017 (the fourth-highest soybean acreage nationally). The crop sees various uses in terms of the sale of whole beans, soybean crushing to produce oil and soybean meal (integrated with the livestock value-chain in the state), and supply to soy-diesel operations. The soybean commodity marketplace has been experiencing some significant changes, and a series of unknowns are facing the industry. Soy oil market demands have changed significantly, rooted in regulatory restrictions in the use of hydrogenated and now partially hydrogenated vegetable oils in foods. Researchers, including at MU and the USDA ARS in Columbia, are evaluating alternative processes for stabilization of soy oil that may impact the food-grade oils market in the future. Future application of soy oil in biofuels markets is also unknown, with this future partly tied to demands for food-grade oils and effects on prices. The other new challenge is the tariffs imposed by China on U.S. soybeans as a reaction to U.S. tariffs on certain Chinese products. The tariffs have had a widespread impact on soybean agriculture in the United States, with Chinese buyers switching to supply from South America, and the U.S. soybean harvest exceeding the capacity of available and affordable storage in the United States. Even though the crop is an important component of Missouri agriculture production, this market volatility and series of unknowns make it challenging presently to recommend a strategy focused around soy value-chain enhancement and investment in Missouri. It is recommended, however, that advanced soy-based nutrition products be partly a focus within the Foods for Health Initiative given the deep level of expertise in the crop contained within the Missouri research community and the industrial activity (most notable concentrated at Solae's operations in St. Louis) in soy protein isolates and other advanced soy-based products. Similar attention should be paid to specialty corn products as an opportunity in Missouri. Kansas City's Ingredion Incorporated is an example of a specialty corn products manufacturer that generates demand for several thousand acres of specialty corn (for example, waxy corn, white corn, etc.) produced under contract to the company in Missouri.

- **Using Corn and Soybeans for Biofuels and Bio-Based Chemicals/Polymers:** Both corn and soybean prices and associated farm income and land values have benefitted from the growth of the biofuels industry in Missouri. Both corn ethanol and soy-based biodiesel have created a new industry in liquid fuels production, and co-products (distillers' grain, soy meal, etc.) have been well utilized and integrated into the livestock feed chain. Biofuels production from corn kernels and soybeans both are well-established processes, with economic variability more determined by corn and soy feedstock prices (which represent the bulk of costs in operating a plant) and government mandates on renewable fuel blending that promote relatively stable demand. Input received from stakeholders through the project indicates that current market conditions, uncertainty in ongoing government support for blending mandates, and other factors mean that the industry is not anticipated to expand significantly in Missouri.

Technology development in the use of woody cellulosic biomass in biofuels production should certainly be monitored, especially given Missouri's forest assets; but, for the most part, forestry industries in the state noted that forest resources are already well utilized in the state. The overall assessment is that the current corn and soy-based biofuels industries are well established with well-understood economics, and private industry will respond to market signals if and when they are favorable to more plant construction—a special initiative is not required to promote this. Similarly, while Missouri has a substantial chemicals and plastics industry, a significant near- or mid-term movement to using bio-based inputs is not anticipated given trends in oil prices and the lack of a reliable environmental policy imperative within the United States.

- **Pet Food Utilization of Agricultural Commodities:** As noted in the analytics section of the report, dog and cat food manufacturing in Missouri is a high productivity industry. Indeed, among all processed food and feed industries in the state, the dog and cat food sector has the highest value-added per worker ($534,734) and significantly outperforms the national average in value-added per worker by 158 percent. Having a robust pet food industry in Missouri is beneficial to both the crop and livestock sides of agricultural commodity production. Most pet foods contain mixed ingredients comprising protein, carbohydrate sources, vitamins, minerals, fats, and preservatives. Protein sources can come from fresh meats (such as chicken and beef) or from meat "meal" principally composed of the ground-up parts of livestock and poultry that are not used for human consumption. The use of these materials provides a market for the full use of livestock and poultry processed in the state. Dog food may also contain protein from plant-based sources (especially corn and wheat gluten meals and soy protein), again creating demand for Missouri-produced grain and oilseed commodities. Carbohydrates in pet food may come from soy, rice, oats, corn, barley, wheat, beans, and vegetables—again, with relevance to Missouri produced commodities. The pet food industry in Missouri is highly efficient, as measured by productivity, and the state is clearly a preferred location for pet food manufacturers. It is not anticipated that the Missouri Value-Added-Strategy is required to specifically address the industry since its locational characteristics are well established and any growth experienced in the industry will likely not require outside supports.

Based on the situational analysis, it is recommended that, in the near term, the focus on improving Missouri utilization of major agriculture products should initially be on further assessment of the opportunity to develop a substantial beef slaughtering/aging/portioning operation in Missouri together with expanded swine processing operations. In addition, with the recent signing of the 2018 Farm Bill, industrial hemp, both in terms of agriculture production as well as processing, provides significant new opportunities for Missouri to explore. It is also recommended that soybeans, dairy, and egg products be major foci within the Foods for Health Initiative and that translational opportunities be pursued, as the Foods for Health Initiative develops to integrate the pet food and livestock feed industries as a component of the work.

Chapter V: Economic Impact of Implementing the Recommended Strategy

The two Missouri sectors, agricultural processing and food and feed product manufacturing (combined and referred to as value-added ag/food manufacturing), provide jobs for many employees across a variety of industries and represent a significant portion of state economic activity. Measuring the economic impact and the effect of projected future changes to employment levels in value-added ag/food manufacturing in the state can serve as a way of understanding the implications of strategic decisions to grow and expand the industry through focused initiatives.

A. Overview of Economic Impact Analysis

The economic impact analysis for the Missouri value-added ag/food manufacturing industry makes use of a custom economic input/output (I/O) model that quantifies the interrelationships between economic sectors in the state economy. I/O data matrices track the flow of commodities to industries from producers and institutional consumers within the state. The data also show expenditure and consumption activities by workers, owners of capital, and exports and imports. These financial and trade flows are built into the model and provide the ability to estimate the impacts of one sector on all other sectors in the state economy with which it interacts.

The measured economic impacts of the value-added ag/food manufacturing industry in Missouri consist of three types:

- **Direct effect:** The dollar valuation of all goods and services provided as output by a value-added ag/food manufacturing industry,
- **Indirect effect:** The valuation of all inter-industry transactions between a value-added ag/food manufacturing industry and other companies that supply the materials or services required to produce output, and
- **Induced effect:** The valuation of household income supported by the value-added ag/food manufacturing industry through expenditures its employees make at other local industries.

Together, these three effects comprise **total economic impact.** I/O analysis thus models the financial flows that originate from Missouri's value-added ag/food manufacturing industry expenditures in the state's economy and the ongoing ripple (multiplier) effect of these expenditures. In other words, economic impact models are based on the concept of the "multiplier"—every dollar spent in the state economy is re-spent one or more times in the state economy, thereby generating additional economic activity and impact. I/O analysis represents the generally accepted standard for measurement of economic impacts.

The current estimated impacts of the value-added ag/food manufacturing industry were calculated using the Missouri-specific I/O model developed by IMPLAN. The model is developed upon a foundation of employment data included within the IMPLAN I/O model that is built primarily from the U.S. Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW, tied to unemployment insurance reporting) as shown elsewhere in this report. These data provide detailed intelligence on the number of establishments, monthly employment, and quarterly wages, by North American Industry Classification System (NAICS) industry, by county geography, by ownership sector, and for the entire United States. The IMPLAN model employment data are further enhanced by U.S. Bureau of Economic Analysis data to account for sole proprietorships and other very small firms that fall outside of the

QCEW data collection protocols. The IMPLAN model is structured around more than 530 sectors of the economy ranging from specific agriculture production sectors to the U.S. Postal Service and includes both private- and public-sector activities. For this analysis, a customized model was developed to quantify the direct, indirect, and induced effects of the value-added ag/food manufacturing industry in the state.

The following data are output from each model: ***employment*** (combined number of full- and part-time workers); ***personal income*** (measures wages, benefits, and non-cash payments received by individuals in the economy); ***value added*** (the difference between an industry's or an establishment's total output and the cost of its intermediate inputs); and ***output*** (the dollar value of sales, goods, and services produced in an economy, and represents the typical measure often expressed as "economic impact" in a standard economic impact study).

B. Current and Projected Employment for Missouri's Value-Added Ag/Food Manufacturing

Employment data, shown previously, are used to model the current (2017) economic impacts of the value-added ag/food manufacturing industry in Missouri using a Missouri-specific I/O model from IMPLAN.[28] Given the focus of the recommended initiatives and investments, only the two broad industry sectors are included in the economic impact assessment—agricultural processing and food and feed product manufacturing—which has been divided into five subsectors for modeling purposes.

To develop the customized impact models for Missouri, TEConomy aggregated sector-level employment into five key subsectors of the value-added ag/food manufacturing industry (Table 16). This approach was chosen to minimize the impact of the changing of NAICS codes between the 2017 NAICS classification scheme used in the employment analysis in Chapter II and the 2012 NAICS classification scheme used as the core of the 2016 IMPLAN model. These employment values are used to drive the impact models as the direct employment effect.

Table 16: Missouri Key Subsectors of the Value-Added Ag/Food Manufacturing Industry

Key Value-Added Ag/Food Manufacturing Subsectors	2017 Current Employment	2027 Projected Employment		
		Steady State Scenario	Slower Pace Scenario	Strategic Investment Scenario
Agricultural Processing	1,604	1,323	1,182	1,758
Animal Food and Feed	4,813	7,670	6,384	7,670*
Meat and Poultry Processing	18,220	23,410	20,815	23,410*
All Other Food Products and Processing	16,200	19,911	18,056	21,566
Beverages and Related Products	5,689	6,029	5,876	10,878
Total, Value-Added Ag/Food Manufacturing	**46,526**	**58,343**	**52,312**	**65,282**

***Note: Missouri recent growth rate-based projection is also used for the strategic investment scenario, due to Missouri's recent growth rate exceeding the United States.

Source: TEConomy's analysis and projections.

[28] At the time of this analysis, the 2016 IMPLAN model is the most currently available.

Table 16 also provides 2027 employment values based upon three conservative "growth" scenarios[29]:

1. **Steady State:** growth at 100 percent of Missouri's recent (2014–2017) average annual levels;
2. **Slower Pace:** growth at 50 percent of Missouri's recent average annual levels; and
3. **Strategic Investment:** growth, assisted by the initiatives and initiatives described in Chapter IV, reaching the U.S. average annual levels (unless, as in the case with the meat and poultry processing sector, where Missouri's current growth rate exceeds that of the United States).

To develop these scenarios, instead of using compound annual growth rates, which can at times lead to extremely optimistic growth projections, TEConomy based the growth on actual numbers of recent employment growth (annual average over the last 4 years, 2014–2017) in Missouri and the United States. For example, if a sector added 90 jobs over this 4-year period, the ***Steady State Scenario*** projects that this sector can, on average, add 30 jobs per year each year to 2027. In the ***Slower Pace Scenario***, which provides a projection for a "worst-case" scenario where recent growth was overly influenced by post–Great Recession expansion, this sector can add 15 jobs per year each year to 2027. It should be noted that individual NAICS codes could easily surpass these conservative growth estimates. In the final ***Strategic Investment Scenario***, where Missouri performance reaches or exceeds recent national performance, it is projected that the initiatives described in this report will, at a minimum, move Missouri's performance to the relative growth context of the United States or continue its above-average growth.

As shown in these scenario projections, a continuation of recent performance as depicted in the steady state scenario is projected to add nearly 12,000 value-added ag/food manufacturing jobs over the next decade. However, even the Slower Pace scenario would yield nearly 6,000 additional jobs by 2027.[30] Both of these scenarios recognize some of the strong recent growth in components of the value-added ag/food manufacturing industry. Yet, these projections, by their nature, assume limited external influence on the long-term performance of these sectors. Standing still, in effect, lets external market conditions and actors completely determine the ultimate growth achieved by the value-added ag/food manufacturing industry in the state**. The Strategic Investment Scenario drives the industry forward, with a projected employment increase of over 18,700 jobs that, at best, expands this important industry in Missouri and, at a minimum, will help shield the industry from externally driven changes beyond the state's control.**

C. Economic Impact Analysis of Missouri Value-Added Ag/Food Manufacturing

The economic impact analysis results, for the current (2017) Missouri value-added ag/food manufacturing industry's economic footprint, are shown in Table 17. **The existing employment of over 46,000 supports more than 125,000 additional jobs in the Missouri economy** through the employment of suppliers and jobs supported through the industry's workforce wages and purchases. This supported employment yields a strong 3.70 employment multiplier for the industry (e.g., **every 1 job in the value-added ag/food manufacturing industry supports an additional 2.7 jobs in the Missouri economy**).

[29] TEConomy attempted to also model a scenario using the most recent long-term MERIC industry forecasts; but, due to data comparability issues with the employment analysis elsewhere in this report, it was not possible.
[30] Given the recent (2014–2017) employment declines in agricultural processing, the Steady State Scenario continues this decline and the Slower Pace Scenario, in effect, increases the rate of these declines.

Table 17: Economic Impact: 2017 Missouri Value-Added Ag/Food Manufacturing

Impact Type	Employment	Labor Income ($M)	Value Added ($M)	Output ($M)	Federal Tax Revenue ($M)	State/Local Tax Revenue ($M)
Direct Effect	46,526	$3,149.9	$6,684.6	$28,920.8	$580.2	$808.6
Indirect Effect	84,320	$3,082.2	$5,669.9	$11,226.3	$424.1	$726.1
Induced Effect	41,492	$1,754.4	$3,179.1	$5,502.9	$274.1	$416.8
Total Impact	172,338	$7,986.5	$15,533.6	$45,650.0	$1,278.4	$1,951.5
Multiplier	3.70	2.54	2.32	1.58		

Source: TEConomy's analysis and projections, using IMPLAN Missouri-specific model.

This employment generates nearly $29 billion in direct output (or business volume) and an additional $16 billion in indirect and induced output, for a **total economic impact of the value-added ag/food manufacturing industry of more than $45.6 billion in 2017**.

From a contributing economic perspective, **the industry directly generates nearly $7 billion to the state's GDP** (represented by value added in Table 17) and, through the multiplier effect, a total of more than $15 billion to the state's overall economy. Additionally, **the industry, its suppliers, and its employees generate nearly $2 billion in annual state and local tax revenues**.

D. Projections for Future Value-Added Ag/Food Manufacturing Industry Economic Impact

The following sections describe the projected impact results across each of the three modeled scenarios. ***The financial data shown in these tables are in 2027 dollars.***

Steady State Scenario

As described, the steady state scenario projects a continuation of recent growth levels to 2027, leading to more than 58,000 direct value-added ag/food manufacturing jobs in 2027. These direct jobs will support more than 162,000 additional jobs in 2027, generating a total employment impact of over 221,000 jobs (Table 18). The total projected economic output of the industry sector steady state scenario is expected to grow to nearly $65 billion in 2027, compared with $45 billion in 2017, and would contribute $22 billion to the state's GDP (value added).

Table 18: Steady State—Economic Impact: 2027 Missouri Value-Added Ag/Food Manufacturing

Impact Type	Employment	Labor Income ($M)	Value Added ($M)	Output ($M)	Federal Tax Revenue ($M)	State/Local Tax Revenue ($M)
Direct Effect	58,343	$4,291.8	$9,341.5	$41,201.3	$714.1	$1,113.3
Indirect Effect	109,407	$4,278.7	$7,872.1	$15,655.7	$588.0	$1,007.9
Induced Effect	53,274	$2,412.6	$4,372.0	$7,474.4	$377.0	$573.1
Total Impact	221,024	$10,983.1	$21,585.5	$64,331.3	$1,679.0	$2,694.4
Multiplier	3.79	2.56	2.31	1.56		

Source: TEConomy's analysis and projections, using IMPLAN Missouri-specific model.

Slower Pace Scenario

Under the slower pace scenario, while industry employment still increases, the direct employment level reaches only 52,313 by 2027, which generates substantially less indirect and induced employment, reaching a total employment impact of nearly 196,000 jobs (as opposed to the 221,000 jobs in the steady state scenario (Table 19). Total output and contributions to state GDP also would slow under this scenario, reaching only $53 billion and $18 billion, respectively.

Table 19: Slower Pace—Economic Impact: 2027 Missouri Value-Added Ag/Food Manufacturing

Impact Type	Employment	Labor Income ($M)	Value Added ($M)	Output ($M)	Federal Tax Revenue ($M)	State/Local Tax Revenue ($M)
Direct Effect	52,313	$3,583.4	$7,748.8	$33,550.9	$624.6	$927.8
Indirect Effect	97,060	$3,548.3	$6,526.1	$12,955.6	$487.6	$835.8
Induced Effect	47,481	$2,007.6	$3,638.0	$6,297.3	$313.7	$476.9
Total Impact	196,854	$9,139.3	$17,913.0	$52,803.8	$1,425.9	$2,240.5
Multiplier	3.76	2.55	2.31	1.57		

Source: TEConomy's analysis and projections, using IMPLAN Missouri-specific model.

Strategic Investment Scenario

The recommended initiatives and investments will further enable and assist in the growth and expansion of Missouri's value-added ag/food manufacturing industry. The analysis of this strategic investment scenario provides a conservatively structured growth estimate, one that could be easily surpassed, reaching attainable national levels of growth for the three Missouri industry components that are not currently exceeding U.S. growth levels.

Table 20 provides the impacts generated by this projected level of employment of more than 65,000 Missouri workers. This direct employment will support nearly 177,000 other Missouri jobs for a total employment impact of 242,000 jobs. It should be noted that the employment multiplier declines slightly from the two previous scenarios, since Missouri's animal food and feed and meat and poultry processing sectors already outpace U.S. growth. If these sectors also expand over the next decade above and beyond recent trends, the strategic investment scenario would yield even larger overall impacts.

Table 20: Strategic Investment—Economic Impact: 2027 Missouri Value-Added Ag/Food Manufacturing

Impact Type	Employment	Labor Income ($M)	Value Added ($M)	Output ($M)	Federal Tax Revenue ($M)	State/Local Tax Revenue ($M)
Direct Effect	65,282	$4,866.3	$10,888.9	$45,705.4	$1,056.5	$1,298.8
Indirect Effect	116,846	$4,768.4	$8,680.9	$17,172.3	$644.6	$1,117.8
Induced Effect	59,891	$2,712.4	$4,915.1	$8,403.0	$423.8	$644.4
Total Impact	242,019	$12,347.2	$24,484.9	$71,280.7	$2,124.8	$3,060.9
Multiplier	3.71	2.54	2.25	1.56		

Source: TEConomy's analysis and projections, using IMPLAN Missouri-specific model.

At the level of employment generated by the strategic investment scenario, total output impacts would exceed $71 billion and would contribute more than $24 billion to the state's GDP (value added). This expansion of economic activity will also generate more than $3 billion in annual state and local tax revenues by 2027.

E. Summary

If these strategic initiatives are successfully implemented, then their impact on Missouri's economy by 2027 is projected to do the following:

- Expand total value-added ag/food manufacturing economic activity to **more than $71 billion**, which is an increase of more than $25 billion compared with 2017.
- Create and support nearly **70,000 new jobs**, and generate **nearly $4.4 billion** in new personal income.
- Produce annual state and local tax revenue of **more than $3 billion**, which is growth of more than $1 billion compared with 2017.
- Increase agricultural commodity production sales by approximately **$1 billion annually** to meet new value-added uses.

Chapter VI: Conclusion

There are significant opportunities for Missouri to expand its economic activity by increasing production of value-added products that use farm outputs as inputs to downstream production. Through further processing and manufacturing activities, significant value can be added to primary crops and livestock outputs that otherwise leave the state with no value being added. Maximizing value-added opportunities brings benefits in terms of expanding the economy and increasing employment, family incomes, and exports for Missouri.

The research and analysis highlighted in this report that Missouri has distinctive opportunities to further grow its value-added industrial activities that use agriculture inputs. The near-term opportunities are principally found in value-added food (and to a lesser extent feed) product industries.

Development pathways open to Missouri are found to consist of three primary opportunity areas:

1. **Developing regional food product development centers that will operate as food industry accelerators to advance new products from concept through market testing and into pilot-scale production.** Using a central hub MU, together with satellite regional locations at other Missouri colleges and universities distributed within Missouri's regions, provides an effective means of ensuring efficient use of resources and a sound geographic distribution of new business development opportunities around the state in the food sector. Also, at a regional level, it is found that better engagement can occur in local foods—linking potential regional demand with regional producers to leverage the expansion of the local food movement for both domestic and institutional/commercial customers.

2. **Building a new industry in functional foods and advanced nutrition products that leverages academic R&D expertise and infrastructural investments in nutritional sciences and clinical health sciences and the food industry of the state.** Reinforcement of the food science discipline in academe is required to balance the disciplinary strengths required for success in this opportunity area. While this will require significant investment in faculty and infrastructural resources, the investment will help Missouri build and sustain a leadership position in a fast-growing market space and one that, at the present time, sees limited competition from other focused initiatives. The recommended Foods for Health Initiative should pursue this opportunity with a focus on identifying and developing products that may utilize Missouri-grown agricultural commodities (whether existing or new).

3. **Taking a focused approach to near-term opportunities for enhanced utilization of major agricultural commodities produced in Missouri.** The integrated nature of the row crop and livestock industries (with the former providing feed inputs to the latter) means that increasing the volume of beef cattle and swine produced and finished in the state is key to adding significant value to Missouri agriculture. Increasing the level of finishing of beef cattle and swine and their processing in new facilities developed in the state should be a priority. Increases in advanced nutrition (for both human and animal food applications) product development (accomplished through the Foods for Health Initiative) should be directed toward key Missouri crops (such as soybean, corn, and rice) to create integrated value-chains. Finally, the opportunities around industrial hemp as a new commodity that will avail themselves as a result of the 2018 Farm Bill will need to be further explored and vetted.

Through the pursuit of this three-component strategy, **it is anticipated that significant economic benefits may be derived** for Missouri. If these strategic initiatives are successfully implemented, then their impact on Missouri's economy by 2027 is projected to do the following:

- Expand total value-added ag/food manufacturing economic activity to **more than $71 billion**, which is an increase of more than $25 billion compared with 2017.
- Create and support nearly **70,000 new jobs,** and generate **nearly $4.4 billion** in new personal income.
- Produce annual state and local tax revenue of **more than $3 billion**, which is growth of more than $1 billion compared with 2017.
- Increase agricultural commodity production sales by approximately **$1 billion annually** to meet new value-added uses.

Appendices

Appendix A: Non-Food Sectors Supply and Demand Summary Data

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Appendix E: Lessons Learned from Benchmarking Value-Added Food Processing Centers

Appendix A: Non-Food Sectors Supply and Demand Summary Tables

Missouri Agricultural Production Supply and Demand ($Millions)

IMPLAN Sector	Total Commodity Supply (Output)	Exports		Locally Met Demand		Inventory
		Foreign	Domestic	Intermediate	Institutional-Household	
Oilseed farming	$2,606.38	$979.14	$1,367.70	$246.21	$13.32	$0.00
Grain farming	$2,234.79	$393.56	$1,007.03	$712.46	$9.64	$112.09
Beef cattle ranching and farming, including feedlots	$1,578.79	$2.63	$527.18	$1,047.88	$1.10	$0.00
Poultry and egg production	$1,402.53	$13.95	$727.80	$608.60	$52.05	$0.13
Animal production, except cattle, poultry, and eggs	$952.90	$18.68	$375.02	$515.00	$32.39	$11.80
Support activities for agriculture and forestry	$453.71	$0.58	$32.71	$412.91	$7.51	$0.00
Dairy cattle and milk production	$232.02	$0.00	$28.83	$202.13	$1.03	$0.04
Cotton farming	$225.06	$129.43	$61.02	$28.05	$6.56	$0.00
Commercial logging	$209.52	$13.90	$35.05	$160.57	$0.00	$0.00
All other crop farming	$181.00	$20.04	$23.78	$134.80	$2.39	$0.00
Greenhouse, nursery, and floriculture production	$86.31	$1.85	$67.23	$5.41	$11.79	$0.03
Vegetable and melon farming	$50.09	$6.03	$16.01	$5.34	$22.70	$0.01
Fruit farming	$37.06	$7.18	$2.70	$12.25	$14.93	$0.00
Forestry, forest products, and timber tract production	$25.51	$1.57	$7.97	$15.97	$0.00	$0.00
Tree nut farming	$16.49	$9.73	$0.55	$1.59	$4.62	$0.00
Commercial hunting and trapping	$13.65	$0.00	$2.42	$1.90	$9.33	$0.00
Tobacco farming	$1.20	$0.51	$0.64	$0.05	$0.01	$0.00
Total, Agricultural Production	**$10,307.01**	**$1,598.80**	**$4,283.65**	**$4,111.11**	**$189.37**	**$124.10**

Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data.

Missouri Wood and Paper Processing and Products Supply and Demand ($Millions)

IMPLAN Sector	Total Commodity Supply (Output)	Exports		Locally Met Demand		Inventory
		Foreign	Domestic	Intermediate	Institutional-Household	
Paperboard container	$1,970.02	$55.10	$1,193.48	$709.54	$8.96	$2.94
Sawmills	$752.83	$63.31	$379.41	$309.57	$0.51	$0.03
Wood container and pallet	$468.59	$16.44	$328.56	$56.35	$32.29	$4.79
All other converted paper product	$433.50	$44.26	$351.27	$30.63	$6.94	$0.40
Paper mills	$369.61	$21.66	$295.14	$38.32	$14.48	$0.01
Stationery product	$359.88	$3.40	$299.84	$16.56	$39.31	$0.77
Paper bag and coated and treated paper	$334.72	$44.21	$244.32	$42.20	$3.98	$0.01
Other millwork, including flooring	$268.27	$2.68	$169.99	$95.35	$0.24	$0.00
Sanitary paper product	$238.48	$16.46	$192.71	$18.61	$10.66	$0.03
Cut stock, resawing lumber, and planing	$135.67	$6.10	$64.98	$64.23	$0.25	$0.02

IMPLAN Sector	Total Commodity Supply (Output)	Exports		Locally Met Demand		Inventory
		Foreign	Domestic	Intermediate	Institutional-Household	
Engineered wood member and truss	$126.20	$1.97	$97.62	$25.70	$0.73	$0.00
Wood preservation	$57.47	$3.70	$25.64	$27.66	$0.06	$0.40
All other miscellaneous wood product manufacturing	$55.96	$5.72	$18.28	$24.63	$3.81	$0.11
Prefabricated wood building manufacturing	$39.93	$0.25	$8.76	$27.40	$0.88	$0.03
Wood windows and door manufacturing	$34.89	$0.30	$4.55	$29.95	$0.08	$0.01
Reconstituted wood product manufacturing	$20.51	$1.12	$14.10	$5.13	$0.15	$0.00
Manufactured home (mobile home) manufacturing	$2.02	$0.02	$0.14	$0.01	$0.46	$0.00
Veneer and plywood manufacturing	$1.14	$0.05	$0.56	$0.51	$0.02	$0.00
Total, Wood and Paper Processing and Products	**$5,669.69**	**$286.77**	**$3,689.34**	**$1,522.37**	**$123.80**	**$9.56**

Source: TEConomy analysis of IMPLAN State of Missouri I/O Model data.

Appendix B: Economic Analysis Regional Food Value-Chain Summary Employment Tables

Table B1: Missouri Regional Strengths – St. Louis Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	16	392	$49,978	0.53	9.0%	18.9%
Agricultural Processing	127	948	$33,222	0.10	8.0%	5.3%
Bio-Based Chemicals Manufacturing	3	23	$27,110	0.04	49.3%	51.2%
Food & Feed Product Manufacturing	5	488	$94,352	0.77	115.0%	112.1%
Inputs to Ag/Forest Production	251	10,625	$68,146	0.76	1.4%	-8.2%
Primary Agricultural Production	8	65	$33,415	0.06	-1.1%	-3.7%
Primary Forestry Production	151	3,463	$51,616	0.50	3.4%	-1.0%
Processing & Manufacturing Equipment	95	1,568	$46,352	0.55	0.1%	5.2%
Textile & Apparel Manufacturing	18	1,601	$80,145	1.45	2.6%	-7.5%
Wholesale Distribution & Warehousing	8	325	$70,531	0.77	19.8%	-7.8%
Wood & Paper Product Manufacturing	361	7,884	$60,349	0.68	5.1%	1.3%
Wood Processing & Basic Wood Materials	38	579	$95,692	3.84	14.4%	14.4%
Total BioEconomy Vertical Industry	1,081	27,961	$62,867	0.57	4.4%	-0.2%
Bio-Based Substitution Opportunities	210	11,847	$61,970	1.29	11.0%	6.5%
Total Potential BioEconomy Vertical Industry	1,291	39,808	$62,600	0.68	6.3%	1.7%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B2: Missouri Regional Strengths – Kansas City Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	7	671	$87,121	1.78	-14.6%	-4.7%
Agricultural Processing	175	1,258	$39,123	0.27	-2.2%	-5.0%
Bio-Based Chemicals Manufacturing	9	12	$34,744	0.04	37.7%	39.5%
Food & Feed Product Manufacturing	8	278	$70,803	0.86	-11.9%	-14.8%
Inputs to Ag/Forest Production	135	4,233	$44,041	0.59	11.1%	1.5%
Primary Agricultural Production	10	76	$27,775	0.13	-16.5%	-19.1%
Primary Forestry Production	107	3,682	$47,939	1.05	3.2%	-1.2%
Processing & Manufacturing Equipment	41	617	$36,456	0.42	16.7%	21.8%
Textile & Apparel Manufacturing	1	41	$51,429	0.07	-52.9%	-63.0%
Wholesale Distribution & Warehousing	16	249	$86,646	1.16	-20.5%	-48.1%
Wood & Paper Product Manufacturing	291	4,787	$60,715	0.81	1.3%	-2.4%
Wood Processing & Basic Wood Materials	14	210	$64,469	2.73	5.2%	5.2%
Total BioEconomy Vertical Industry	814	16,114	$52,326	0.64	2.5%	-2.1%
Bio-Based Substitution Opportunities	110	4,625	$52,828	0.99	7.7%	3.2%
Total Potential BioEconomy Vertical Industry	924	20,739	$52,438	0.69	3.6%	-1.0%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B3: Missouri Regional Strengths – Central North Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	4	128	$54,129	1.09	26.9%	36.8%
Agricultural Processing	131	1,077	$36,312	0.73	7.1%	4.3%
Bio-Based Chemicals Manufacturing	14	32	$36,862	0.36	58.2%	60.0%
Food & Feed Product Manufacturing	2	69	$55,607	0.68	27.3%	24.4%
Inputs to Ag/Forest Production	63	5,000	$41,388	2.24	9.2%	-0.4%
Primary Agricultural Production	20	152	$37,026	0.82	-0.1%	-2.7%
Primary Forestry Production	48	800	$34,945	0.74	14.0%	9.6%
Processing & Manufacturing Equipment	12	192	$32,186	0.42	-16.3%	-11.2%
Textile & Apparel Manufacturing	2	72	$79,820	0.41	-7.7%	-17.8%
Wholesale Distribution & Warehousing	3	56	$62,361	0.84	188.6%	161.0%
Wood & Paper Product Manufacturing	149	2,418	$41,039	1.32	20.1%	16.4%
Wood Processing & Basic Wood Materials	6	79	$62,863	3.33	30.8%	30.8%
Total BioEconomy Vertical Industry	454	10,075	$40,814	1.29	11.7%	7.1%
Bio-Based Substitution Opportunities	25	1,675	$48,010	1.15	33.5%	29.0%
Total Potential BioEconomy Vertical Industry	479	11,750	$41,840	1.27	14.4%	9.8%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B4: Missouri Regional Strengths – Central South Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	6	85	$35,689	1.12	64.0%	73.9%
Agricultural Processing	77	457	$24,570	0.48	-5.7%	-8.4%
Bio-Based Chemicals Manufacturing	22	40	$25,125	0.70	20.4%	22.2%
Food & Feed Product Manufacturing			N/A	-	N/A	N/A
Inputs to Ag/Forest Production	50	720	$38,843	0.50	7.4%	-2.2%
Primary Agricultural Production	33	253	$25,423	2.12	-10.4%	-13.1%
Primary Forestry Production	60	1,117	$37,205	1.60	23.3%	18.9%
Processing & Manufacturing Equipment	20	352	$28,926	1.20	-7.8%	-2.7%
Textile & Apparel Manufacturing	3	81	$51,046	0.72	15.6%	5.5%
Wholesale Distribution & Warehousing	1	12	$37,144	0.28	820.0%	792.4%
Wood & Paper Product Manufacturing	116	1,520	$34,653	1.29	7.1%	3.3%
Wood Processing & Basic Wood Materials	3	5	$58,847	0.34	-23.3%	-23.3%
Total BioEconomy Vertical Industry	391	4,642	$34,244	0.92	7.7%	3.1%
Bio-Based Substitution Opportunities	27	1,430	$39,759	1.53	0.1%	-4.4%
Total Potential BioEconomy Vertical Industry	418	6,072	$35,543	1.02	5.8%	1.2%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B5: Missouri Regional Strengths – Northeast Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	10	246	$46,545	4.67	52.1%	62.0%
Agricultural Processing	195	1,528	$31,454	2.31	9.3%	6.6%
Bio-Based Chemicals Manufacturing	6	8	$29,336	0.20	-49.1%	-47.3%
Food & Feed Product Manufacturing	7	333	$48,086	7.34	-34.9%	-37.8%
Inputs to Ag/Forest Production	35	3,778	$44,679	3.78	13.3%	3.7%
Primary Agricultural Production	18	79	$27,365	0.95	-9.9%	-12.5%
Primary Forestry Production	31	512	$34,241	1.05	13.8%	9.5%
Processing & Manufacturing Equipment	6	99	$33,543	0.48	-47.8%	-42.7%
Textile & Apparel Manufacturing	7	297	$64,538	3.79	86.1%	76.0%
Wholesale Distribution & Warehousing			N/A	-	N/A	N/A
Wood & Paper Product Manufacturing	162	2,243	$45,674	2.73	2.8%	-1.0%
Wood Processing & Basic Wood Materials	2	11	$29,406	1.02	48.6%	48.6%
Total BioEconomy Vertical Industry	479	9,134	$42,644	2.60	7.5%	2.9%
Bio-Based Substitution Opportunities	12	738	$46,295	1.13	-19.8%	-24.3%
Total Potential BioEconomy Vertical Industry	491	9,872	$42,917	2.37	4.8%	0.2%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B6: Missouri Regional Strengths – Northwest Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	8	425	$47,788	9.66	-4.8%	5.1%
Agricultural Processing	96	541	$33,500	0.98	24.4%	21.7%
Bio-Based Chemicals Manufacturing	2	3	$37,215	0.09	88.7%	90.5%
Food & Feed Product Manufacturing	4	453	$56,629	11.97	-0.2%	-3.1%
Inputs to Ag/Forest Production	26	4,118	$48,084	4.93	5.7%	-3.9%
Primary Agricultural Production	5	70	$26,359	1.01	-18.3%	-20.9%
Primary Forestry Production	13	169	$35,220	0.42	20.8%	16.4%
Processing & Manufacturing Equipment	6	200	$50,784	1.17	-16.0%	-10.9%
Textile & Apparel Manufacturing	2	1,123	$102,380	17.17	16.3%	6.2%
Wholesale Distribution & Warehousing			N/A	-	N/A	N/A
Wood & Paper Product Manufacturing	90	1,279	$47,014	1.86	0.8%	-2.9%
Wood Processing & Basic Wood Materials	2	44	$64,777	4.89	10.9%	10.9%
Total BioEconomy Vertical Industry	254	8,425	$54,376	2.87	5.7%	1.1%
Bio-Based Substitution Opportunities	9	284	$58,118	0.52	-49.7%	-54.2%
Total Potential BioEconomy Vertical Industry	263	8,709	$54,498	2.50	2.0%	-2.6%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B7: Missouri Regional Strengths – Southeast Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	8	223	$59,209	2.86	119.2%	129.1%
Agricultural Processing	414	2,084	$34,424	2.13	-11.8%	-14.5%
Bio-Based Chemicals Manufacturing	6	13	$29,834	0.22	551.9%	553.7%
Food & Feed Product Manufacturing	32	426	$43,914	6.34	-18.3%	-21.2%
Inputs to Ag/Forest Production	32	3,011	$37,829	2.03	-8.9%	-18.5%
Primary Agricultural Production	14	263	$39,905	2.13	4.9%	2.2%
Primary Forestry Production	42	2,768	$49,480	3.83	5.0%	0.6%
Processing & Manufacturing Equipment	10	86	$23,179	0.28	-20.9%	-15.8%
Textile & Apparel Manufacturing	1	15	$78,179	0.13	17.1%	7.0%
Wholesale Distribution & Warehousing			N/A	-	N/A	N/A
Wood & Paper Product Manufacturing	202	2,506	$47,692	2.06	1.8%	-2.0%
Wood Processing & Basic Wood Materials	2	8	$45,510	0.51	52.0%	52.0%
Total BioEconomy Vertical Industry	763	11,403	$42,835	2.19	-3.1%	-7.7%
Bio-Based Substitution Opportunities	18	1,425	$47,285	1.47	-1.5%	-6.0%
Total Potential BioEconomy Vertical Industry	781	12,828	$43,329	2.08	-2.9%	-7.5%

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Table B8: Missouri Regional Strengths – Southern Region

Macro Sector	Estabs.	Employment	Average Wage	Emp LQ	Emp 14-17 Growth Rate	Emp 14-17 Relative Growth Rate
Ag/Food R&D & Testing Services	16	400	$50,852	1.52	41.7%	16
Agricultural Processing	267	2,602	$32,280	0.79	15.7%	267
Bio-Based Chemicals Manufacturing	52	176	$27,951	0.88	87.8%	52
Food & Feed Product Manufacturing	3	160	$48,166	0.71	37.8%	3
Inputs to Ag/Forest Production	153	13,077	$45,269	2.61	9.3%	153
Primary Agricultural Production	135	1,274	$26,890	3.06	-10.6%	135
Primary Forestry Production	184	4,614	$38,824	1.89	6.0%	184
Processing & Manufacturing Equipment	40	740	$25,439	0.72	5.1%	40
Textile & Apparel Manufacturing	19	601	$48,351	1.53	-16.1%	19
Wholesale Distribution & Warehousing	6	248	$53,454	1.66	72.2%	6
Wood & Paper Product Manufacturing	317	6,198	$47,563	1.51	13.5%	317
Wood Processing & Basic Wood Materials	7	64	$60,392	1.19	10.4%	7
Total BioEconomy Vertical Industry	1,199	30,154	$42,520	1.72	9.4%	1,199
Bio-Based Substitution Opportunities	55	2,266	$41,661	0.69	5.4%	55
Total Potential BioEconomy Vertical Industry	1,254	32,420	$42,460	1.56	9.1%	1,254

Source: TEConomy's analysis of enhanced U.S. Bureau of Labor Statistics (BLS) Quarterly Census of Employment and Wages (QCEW) data from IMPLAN.

Appendix C: OmniViz Clusters – Key Terms

TEConomy performed text-based clustering, using proprietary OmniViz clustering software, to cluster research themes based on their text content. The dataset used for the analysis included primarily "postharvest" oriented publications (e.g., journal articles; conference proceedings), patents (including those invented in the Missouri and/or assigned to a Missouri entity) and competitive research grants funded by the USDA through the Agriculture and Food Research Initiative (AFRI; including SBIR awards).

The analysis generated 50 clusters containing the key terms indicated on the tables below. These were ultimately grouped into 10 thematic "metagroupings" that capture these clusters and demonstrate key themes in Missouri's R&D environment.

Missouri AgBio Post-Harvest Focused Publications (Articles, Conference Proceedings, Reviews), Patents, and USDA Grants					**Key Terms** Color key is to the right. **Bold term** is single largest term within the Major/Minor Topics.	Represent ***Major Topics*** contained within 20% or more of the cluster's records	Represent ***Minor Topics*** contained within 20% or more of the cluster's records	Represent ***Other Non-Clustering*** terms useful for context contained within ~35% or more of the cluster's records				
Cluster ID (0-49)	**Order (0-49)**	**# of Records**	**MetaCluster Name**		**% of Records with Bold Term**	**Key Terms**						
42	0	63	ARTIFACT Cluster		***19***	**biotechnology**						
40	1	16	Artifact (too mixed for use)		100	**bioproduct**	biological	feedstock	animal			
26	2	27	Bioproduct processing methods and measurement	Patents	100	**bioproduct**	compound	synthesis				
12	3	7	Artifact (too mixed for use)		100	**enzyme**	bioproduct	solution	udp-glycosyltransferase	sweetener	steviol	rebaudioside
28	4	15	Enzymology - primarily industrial biotech	Mixed patents and pubs	100	**enzyme**	bioproduct	oxidizer	profile	biotechnology	biological	modification
33	5	32	Oils - food and industrial methods and applications	Mixed patents and pubs	100	**oil**	bioproduct	fatty acid	food	enzyme	lipid	fat
30	6	26	Lipids/fatty-acids and oxidation	Almost all are pubs	81	**lipid**	oxidizer	nutrition	fat	fatty acid	antioxidant	composition
35	7	62	Metabolics - Mixed human/animal metabolism and industrial biot	Almost all are pubs	65	**metabolic**	metabolism	energy	nutrition	fatty acid	microbial	metabolite
43	8	26	Glucose in nutrition and health	Almost all are pubs	92	**glucose**	nutrition	insulin	consume	obesity	diet	meal
41	9	251	Mixed - diet/health in animals & humans	Almost all are pubs	73	**feed**	nutrition	nutrient	protein	fat	liver	diet
44	10	149	Mixed - proteins/nutrition + proteins in biotech	Mixed patents and pubs	95	**protein**	food	nutrition				
37	11	141	Food - mixed.	Mixed patents and pubs	91	**food**	nutrition	protein	agriculture	feed	environment	
39	12	201	Food - mixed, ingredients & production tech	Mixed patents and pubs	100	**food**	product					
7	13	36	Food prodn machinery & kitchen equip.	Patents	100	**machinery**	**food**	beverage	dispense			
16	14	21	Agricultural economics & mgmt.	Pubs	86	**agriculture**	economic	farm	market	management	policy	
6	15	30	Dairy - milk analytics/biochem.	Almost all are pubs	97	**milk**	dairy	bovine	farm	food	cattle	lactate
49	16	80	Cattle - mixedfoci - dairy, repro, nutrition	Pubs	93	**bovine**	dairy	milk	cattle	serum	beef	reproductive
46	17	30	Cattle - mixed foci	Almost all are pubs	80	**beef**	cattle	reproductive	bovine	breed	animal	heifer
19	18	13	Animal science/veterinary - mixed species	Almost all are pubs	92	breed	cattle	**animal**	genetics	traditional	genotype	correlation
24	19	17	Animal husbandry, mixed - litter and feed/play products	Almost all are patents	100	**animal**	litter					
45	20	87	Plant science - plant biochem/phytochemicals	Almost all are pubs	56	**food**	agriculture	seed	chemistry	protein	soybean	corn
47	21	76	Corn - primarily varieties	Mixed patents and pubs	96	**corn**	hybrid	food	seed	cross	plant	genetics
1	22	84	Plant science - highly mixed	Mixed patents and pubs	89	seed	**plant**					
15	23	85	Soybean mixed - varieties and processing	Mixed patents and pubs	92	**soybean**	seed	food	regenerate	derivative	cross	plant
32	24	57	Bioenergy - processes and economics	Almost all are pubs	86	**biomass**	biofuel	energy	solid	environment	fuel	bioenergy
29	25	13	Packaging - Fuel containers and dispensing	Almost all are patents	100	**fuel**	package	operation	energy	dispense	operate	valve
0	26	110	Packaging	All are patents	100	package	container					
22	27	28	Packaging	All are patents	100	**package**	insert	shape	dispense	container		
14	28	6	Packaging	All are patents	100	**shape**	package	matrix	film	tobacco		
18	29	20	Furniture	Almost all are patents	85	**furniture**	insert	profile	vertical	adjustable	individual	
23	30	19	Furniture	Almost all are patents	100	**furniture**	insert	vertical	side	secure		
5	31	105	Furniture	All are patents	100	**furniture**						
25	32	28	Furniture	All are patents	100	**furniture**	bed	spring	adjustable	assembly	seat	secure
3	33	33	Mixed: Furniture & Containers	Almost all are patents	100	**storage**	furniture	package	position			
10	34	8	Artifact (too mixed for use)		100	**storage**	package	food	machinery	agriculture		
36	35	11	Artifact (too mixed for use)		100	**removal**	package	form	container			
9	36	25	Sensors and detection (inclusing biosensors)	Mixed patents and pubs	92	**detection**	bioproduct	microbial	spectroscopy	assay	sensitive	load
8	37	24	Methods - biotech/chemistry	Pubs	75	**chemical**	spectroscopy	natural	biotechnology	product		
34	38	46	Artifact (too mixed for use)		87	**environment**	nutrition	water				
38	39	7	Artifact (too mixed for use)		86	**location**	nutrition	grow	device			
13	40	57	Nutritional physiology	Pubs	100	**nutrition**	enteral	parenteral	patient	therapy	child	
2	41	19	Obesity and nutrition		100	**obesity**	nutrition	food	fat	energy	body mass index	prevention
17	42	6	Artifact (too mixed for use)		100	**preparation**	bioproduct	virus	transamination	process	keto-cyclopamines	enzymatic
48	43	27	Detection and treatment of pathogens	Mixed patents and pubs	67	**infection**	**bacterium**	bioproduct	treatment	detect		
27	44	10	Biotechnology amplification	Almost all are patents	100	**deoxyribonucleic acid (dna)**	bioproduct	plasma	biotechnology	molecule	amplification	
4	45	4	Biomass - sugars	Mixed patents and pubs	100	**sugar**	bioproduct	feedstock	fermentable	yield	production	ethanol
11	46	7	Agricultural processing - drying	Mixed patents and pubs	71	**grain**	food	dry	operate	content	apparatus	
21	47	6	Artifact (too mixed for use)		83	**harvest**	sustainable	economic	crop	biomass	environment	feedstock
31	48	9	Artifact (too mixed for use)		100	**carbon**	oil	fiber	bioproduct	bacterium	polymer	
20	49	5	Artifact (too mixed for use)		80	**chromatography**	mass spectrometry	determination	zearalenone	trichothecene	toxin	spice
Total		2,265										

Appendix D: Lessons Learned from Benchmarking State Policies

Introduction

This appendix summarizes four key issues across states identified by Missouri as benchmarks for policy and programs in post-farmgate agricultural value-added processing. It concludes with capsule profiles of each state, with footnoted references.

Strategic approach

The four state governments all recognize the significant economic impact of postharvest processing, both in dollar terms and as percentages of overall agricultural activity and total state value-added output. However, the Indiana and Kansas state agriculture departments have commissioned and published consulting studies to lay out explicit strategies for development.

Within the agricultural colleges and their research/extension divisions, the most aggressive approach is in Iowa, which regards development of value-added processing technology as a key component of its service to the state's economy. For the most part, the agricultural colleges in the other states address processing technology as a contribution they can make to overall knowledge, but not explicitly within the context of their respective states' economic development.

State	State ag department	Ag school plan of work
Arkansas	Recognizes $7b impact of postharvest processing (33% of total ag)	Views processing technology as a contribution to knowledge
Indiana	Commissioned studies on food hubs and dairy strategy	Views processing technology as a contribution to knowledge
Iowa	Recognizes $4.9b impact of biofuels and biorenewables	Value-added processing a central focus of research & extension
Kansas	Commissioned "AgGrowth" strategy supporting food as key industry sector	Processing only a peripheral focus of the plan

Financial incentives for processors

Of the four state agriculture departments, only Indiana's offers a grant to promote processing – a 1:1 match for market development in the livestock sector, including processing. However, there are no analogous grants for crops. The other three state departments promote federal value-added grants where available, but they offer none of their own.

There has been a general trend across the Midwest to sector-agnostic development incentives offered through state tax or commerce departments. The current focus of both as-of-right and discretionary incentives is often on high-wage (or "quality") jobs, regardless of sector. In fact, both Arkansas and Iowa have within the last decade repealed credits aimed at value-added food processing (among other targeted incentives) in favor of these broader programs.

Of the remaining incentives, the ones that stand out are all for bio-based chemicals in the energy and industrial sectors. One that is heavily promoted by the state's economic-development agency is Iowa's Renewable Chemicals Production credit, which is $0.05/pound with a $1 million ceiling for startups, and just $500,000 for established companies. The state bills this as the first of its kind in the nation.

State	Grants from state agriculture department	Incentives from state tax or commerce department
Arkansas	None	All incentives are sector-agnostic now
Indiana	Pays half cost of market development for livestock including processing	All incentives are sector-agnostic
Iowa	None	A major Renewable Chemicals Production Credit
Kansas	None	Minor energy production credits for biodiesel and ethyl alcohol

Laws and regulations

The capsule profiles which follow include detailed references to the sections of law and administrative code that govern food processing safety (generally distinct from restaurant safety). In general, these laws and codes to not mention what TEConomy understands to be Missouri's interest in preventing interference by local authorities in state regulation of processing operations.

The laws generally do give certain law-enforcement authority to county attorneys, but generally do not mention county health departments.

The issue of county/state coordination and preemption is not a stated focus of the policy or advocacy agendas of the farm bureaus in any of the benchmark states.

State	Reference to county authorities	Other provisions	Mention in farm bureau policy/advocacy agenda
Arkansas	None except to define county health officers, but no role in food/beverage processing	Cottage Food Law exempts certain single-person operations on-site or at farmers' markets from oversight	None
Indiana	Gives authority in condemnation proceedings to county attorneys, but no mention of county health departments	Home-Based Vendor Law exempts individuals producing in home kitchens and selling at farmers' markets or roadside stands	None
Iowa	Gives certain enforcement authority to county attorneys, but no mention of county health departments	None	Not accessible to non-members/general public
Kansas	Gives certain enforcement authority to county attorneys, but no mention of county health departments	None	Simply encourages federal, state, and local authorities to coordinate on protection of crops and livestock from bioterrorism or disease

Government/university/industry collaborations

Three of the four states include some kind of extension center or entrepreneurial education program aimed at startups and existing businesses in the food processing industry, helping them with new-product ideation, formulation, sensory testing, regulatory issues, and marketing.

The land grant universities in Indiana and especially Iowa have rosters of traditional research centers, including several sponsored by the National Science Foundation, that address postharvest processing. By the nature of NSF centers (and those structured on similar models), these involve support and participation from leading industrial players. Many multinational and global food companies with operations in-state are well represented in these efforts. However, and especially in Iowa, the focus is predominantly on bioeconomy applications: renewable energy, non-petroleum chemical feedstocks, and so on. Most of these larger R&D initiatives do not focus heavily on food products.

In Indiana it is worth noting two unusual initiatives:

- The Ag-Celerator Fund is one of several industry vertical venture accelerators managed at Purdue's "Foundry" in partnership with the university's Office of Technology and Commercialization. The Ag-Celerator is funded at $2 million and will invest up to $100,000 in startups based on Purdue intellectual property. Excluding crop-oriented startups, those related to value-added markets include one in specialty chemicals, one in software for yield management among winemakers, and one for detection of E. coli contamination in food processing environments.
- AgriNOVUS, which is still in formation and development, is a regional initiative catalyzed by support from the Lilly Endowment of Indianapolis.

State	Assistance to in-state entrepreneurs in value-added processing	Broad-based R&D collaborations with industry, including in-state	Other
Arkansas	Arkansas Food Innovation Center in Fayetteville, focusing on northwest Arkansas		
Indiana	Center for Food and Agricultural Business	• AgriNOVUS Indiana collaborative • AgSEED, included in the state-funded component of the research/extension system, includes processing projects	Ag-Celerator Fund at Purdue Foundry

		• Biological Engineering Department work on renewable energy	
Iowa		• BioEconomy Institute as broad-based umbrella for Biobased Industry Center and other activities • CenUSA multistate collaborative based in Iowa • BioCentury Research Farm, integrated RD&D facility for biomass • Center for Crop Utilization Research • NSF ERC in Biorenewable Chemicals • NSF I/U CRC in Bioplastics and Biocomposites	Division of Chemical and Biological Sciences at DOE Ames Laboratory, managed by Iowa State
Kansas	Value-Added Food Labs in Manhattan & Food Innovation Accelerator in Olathe	Kansas State Food Sciences Institute includes thrusts in food processing and product development University of Kansas Center for Environmentally Benign Catalysis	AIB International, a not-for-profit tech transfer center for baking and food processing

Arkansas

The Center for Agricultural and Rural Sustainability of the University of Arkansas Division of Agriculture estimates that postharvest processing contributes $7 billion to the Arkansas economy, representing 33 percent of the total contribution of agriculture and 8.6 percent of total "value-added" in the entire state economy.[31] The 2010 strategic plan for University of Arkansas agricultural research and extension addresses the importance of processing technology, but as a contribution to knowledge rather than as a specific development strategy for the state.[32]

Financial incentives for processors

The state's former tax credits for biotechnology and advanced biofuels at Arkansas Code §2-8-101 —2 - 8-109[33] were repealed in favor of a generally sector-agnostic set of as-of-right incentives for job creation, capital investment, equity investment, and R&D. Bio-based products are now just one of many sectors eligible for the discretionary "targeted business incentives" by the Arkansas Economic Development Commission. Food and beverage processing are not among this set, except to the extent included under "agricultural medicine."[34]

Indirectly, the state also supports bio-based products through a procurement preference at Arkansas Code §25-37-102.[35]

The Arkansas Department of Agriculture roster of grant programs does not include any that incentivize food or beverage processing.[36]

Laws and regulations

Food processing is regulated under the Food, Drug and Cosmetic Act at Arkansas Code §20-56-201 – §20-56-223[37] and implemented by regulation of the state Department of Health.[38] Neither the act nor implementing regulation makes any material mention of the role of county authorities, either to define or pre-empt such a role.

There is a separate "Cottage Food Law" at Arkansas Code §20-57-201,[39] which exempts certain foods from departmental oversight. This law is aimed at single-person operations that sell direct to consumers from the site where the products or produced or through a farmer's market.

The department's description of the role of County Health Officers makes no mention of any role in policing food or beverage processing.[40]

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[31] See https://division.uaex.edu/docs/2017%20AR%20Ag%20profile.pdf.
[32] See https://aaes.uark.edu/strategic%20plan%202010.pdf.
[33] See https://law.justia.com/codes/arkansas/2017/title-2/subtitle-1/chapter-8/.
[34] See https://www.arkansasedc.com/why-arkansas/business-climate/incentives.
[35] See https://law.justia.com/codes/arkansas/2010/title-25/chapter-37/.
[36] See https://www.agriculture.arkansas.gov/aad-grants.
[37] See https://law.justia.com/codes/arkansas/2017/title-20/subtitle-4/chapter-56/subchapter-2/.
[38] See https://www.healthy.arkansas.gov/images/uploads/pdf/Food_Drug_and_Cosmetic_Act.pdf.
[39] See https://law.justia.com/codes/arkansas/2017/title-20/subtitle-4/chapter-57/subchapter-2/section-20-57-201/.
[40] See https://www.healthy.arkansas.gov/county-health-officers.

The public policy/advocacy agenda of Arkansas Farm Bureau makes no mention of issues relevant to food or beverage post-farm processing.[41]

Government/university/industry collaborations

The University of Arkansas sponsors an Arkansas Food Innovation Center (established 2013) in Fayetteville.[42] Its mission is to serve farmers, entrepreneurs, and nonprofit organizations in Northwest Arkansas in product development, market expansion, and prevention of waste of surplus crops. The program is facilities based but also offers analytical services and consultations in food safety, processing, packaging, labeling, and regulatory issues. The Center is a collaboration of the university Division of Agriculture's Institute of Food Science and Engineering, the Department of Food Science, and other university departments. The Institute also offers a "Better Process Control School"[43] and produces guides on "Starting a Food Processing Business in Arkansas"[44] and "Choosing and Using a Co-Packer."[45]

[41] See https://www.arfb.com/pages/legislative-issues/.
[42] See https://afic.uark.edu/.
[43] See https://food-science.uark.edu/workshops-distance-education.php.
[44] See https://cpb-us-e1.wpmucdn.com/wordpressua.uark.edu/dist/1/313/files/2018/06/Starting-Factsheet-16bliar.pdf.
[45] See http://arkansas-ag-news.uark.edu/pdf/985.pdf.

Indiana

In 2015, the Indiana State Department of Agriculture Commissioned a study from Thomas P. Miller Associates that recommended establishing a statewide network of "food hubs" to "facilitate the marketing and purchase of specialty crops" with an emphasis on processing of local foods.[46] It is unclear how much progress if any has been made on this effort.

Also in 2015, the department commissioned from Orrani Consulting a Dairy Strategy that recommended an opportunity to produce up to 4 million pounds of milk that are currently exported out of state, with specific focus on cheese and yogurt.[47]

The work plan for agricultural research and extension at Purdue treats processing much as does Arkansas: as an important area for knowledge development, but not necessarily as a strategy for in-state economic development.[48]

Financial incentives for processors

Indiana Economic Development Corporation offers incentives and programs that are generally sector-agnostic and do not specifically target food or beverage processing.[49]

The Indiana State Department of Agriculture will underwrite half the cost of market development for livestock, including production, processing and distribution. None of the other grant programs appears relevant to food or beverage processing.[50]

Laws and regulations

Food and beverage processing are generally regulated under Indiana Code Title 16 Article 42 Chapters 1-27[51] as implemented under regulations at Title 410 IAC 7-21 – 410 IAC 7-24.[52] The act gives authority in condemnation proceedings to county attorneys but does not otherwise address or pre-empt county authorities.

There is a separate Home-Based Vendor law that exempts from health department rules individuals producing in a home kitchen and selling at farmer's markets and roadside stands.[53]

The state-level public policy/advocacy agenda does not address issues relevant to food or beverage processing.[54]

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[46] See https://foodhubresources.wordpress.com/2015/07/03/indiana-state-dept-of-agriculture-feasibility-study/.
[47] See https://www.in.gov/isda/files/Indiana_Dairy_Strategy_Summary_ISDA_16Mar15.pdf.
[48] See https://ag.purdue.edu/extension/Documents/plan_of_work_2007-11.pdf.
[49] See https://www.iedc.in.gov/incentives and https://www.iedc.in.gov/programs.
[50] See https://www.in.gov/isda/2474.htm.
[51] See https://law.justia.com/codes/indiana/2016/title-16/article-42/ and overview at https://www.extension.purdue.edu/extmedia/fs/fs-16-w.pdf.
[52] See https://www.in.gov/isdh/21660.htm.
[53] See https://www.in.gov/isdh/files/HEA_1309_Guidance_Growing_for_Market_ICDC_Farm_Bureau_2010.pdf.
[54] See https://www.infarmbureau.org/public-policy/state-issues.

Government/university/industry collaborations

AgSEED (Agricultural Science and Extension for Economic Development)[55] is Purdue's initiative to support the food and agriculture sector, funded through the agricultural research and extension component of the state's budget for the university. Current projects include those with both farm and post-farm processing orientation.[56]

Still in formation is AgriNovus Indiana,[57] an innovation collaborative in the food sector catalyzed by support from the Lilly Endowment.

The highest-profile collaboration relevant to food processing is the Ag-Celerator Fund, a $2 million startup fund operated by the Purdue Foundry in partnership with the university Office of Technology and Commercialization. The fund will invest up to $100,000 in startups based on Purdue intellectual property.[58] The currently highlighted portfolio of six startups includes Gen3Bio (transforming waste algae into specialty chemicals);[59] VinSense (software platform for grapegrowers and winemakers to optimize quality and yields);[60] phicrobe (detection of E. coli in food product environments).[61]

The Center for Food and Agricultural Business[62] at Purdue offers both curriculum and research partnerships, though it tends to integrate agriculture and food so tightly it is not easy to pull out food-specific programming.

Another significant locus of university/industry collaboration is the Purdue Agricultural and Biological Engineering Department, which includes research focus areas on Anaerobic Digestion Technology; Manure Management; and Renewable Energy;

[55] See https://ag.purdue.edu/agseed/Pages/default.aspx.
[56] See https://ag.purdue.edu/agseed/Pages/projectList.aspx.
[57] See https://www.agrinovusindiana.com.
[58] See https://gallery.mailchimp.com/be6204870c00064fde189070d/files/Ag_Celerator_Info_Handout_Year_Round.pdf.
[59] See http://www.gen3bio.com.
[60] See http://www.vinsense.net.
[61] See http://www.phicrobe.com.
[62] See http://agribusiness.purdue.edu/about.

Iowa

Iowa Economic Development Authority estimates that biofuels and biorenewables added $4.9 billion to the state's economy in 2017, supporting 46,000 jobs.[63] In 2017 the Iowa Renewable Fuels Association released an economic-impact study commissioned from ABF Economics concluding that renewable fuels account for about 3.5 percent of Iowa GDP and support 42,000 jobs or 3 percent of total state employment.[64]

Value-added processing is the central focus of the 2017 Combined Research and Extension Plan of Work submitted by Iowa State University to the USDA.[65] In 2012, the Value-Added Agriculture Program of Extension and Research published an impact study on the dairy industry that includes discussion of the impact of dairy production on processing employment in-state.[66]

Financial incentives for processors

In addition to its generally sector-agnostic incentives, the Iowa Economic Development Authority offers a Renewable Chemicals Production credit, which it claims is the first in the nation. The credit is calculated at $0.05 cents/pound and is limited to is $1 million for startups and $500,000 for established businesses.[67]

The former Value-added Agricultural Products Refundable Tax Credit was repealed in 2010.

The Iowa Department of Agriculture does not offer grants relevant to food or beverage processing.

Laws and regulations

Food processing is regulated under Title IV Subtitle 2 Chapter 137F of the Iowa Code,[68] implemented by regulations at Chapter 31 of the Iowa Administrative Code.[69] The code gives enforcement authority to county attorneys but does not otherwise mention or pre-empty county authorities.

Iowa Farm Bureau's advocacy/policy agenda at the state level is members-only content and cannot be reviewed without further contact.[70]

Government/university/industry collaborations

The Bioeconomy Institute at Iowa State University has operated since 2002 and now includes more than 230 affiliated faculty and staff from 35 departments across all eight colleges, with

[63] See https://iowaeconomicdevelopment.com/userdocs/documents/ieda/BIOwcbro.pdf.
[64] See https://iowarfa.org/wp-content/uploads/2018/02/2017-Iowa-Economic-Impact-Final.pdf.
[65] See https://portal.nifa.usda.gov/web/areera/plans/2017-2021/2017-Iowa-State-University-Combined-Research-and-Extension-Plan-of-Work.pdf.
[66] See https://www.extension.iastate.edu/dairyteam/files/page/files/Iowa%20dairy%20industry%20report%20020612.pdf.
[67] See https://www.iowaeconomicdevelopment.com/Business/RenewableChem.
[68] See https://law.justia.com/codes/iowa/2014/title-iv/subtitle-2/chapter-137f/.
[69] See https://www.legis.iowa.gov/docs/iac/chapter/481.31.pdf.
[70] See https://www.iowafarmbureau.com/Farmer-Resources/GovernmentPublic-Policy/Policy-Development-Issue-Surfacing/Iowa-Farm-Bureau-Policy.

industry and federal sponsorship of $80 million over the past five years.[71] It includes research thrusts in thermochemical processing; hybrid processing; modular manufacturing for bioprocessing; computational thermochemical conversion; and algae research. The institute manages the Biobased Industry Center[72] and the RAPID Institute (Rapid Advancement in Process Intensification Deployment).[73]

Additional industry-relevant research is conducted at ISU in:

- CenUSA Bioenergy, a USDA/NIFA-funded multistate collaborative based at the university and whose commercialization collaborators include ADM and Renmatix;[74]
- BioCentury Research Farm, which ISU claims is the first in the nation integrated research and demonstration facility dedicated to biomass production and processing;[75]
- The Center for Crops Utilization Research;[76] and
- The Center for Agricultural and Rural Development.[77]
- An NSF-sponsored Engineering Research Center for Biorenewable Chemicals with a broad roster of industry sponsors[78]
- An NSF-sponsored Industry/University Cooperative Research Center for Bioplastics and Biocomposites, also with a wide range of industry sponsors;[79]
- The Division of Chemical and Biological Sciences at Ames Laboratory,[80] a U.S. Department of Energy National Laboratory managed by the university;

ISU does not have what other states call a food innovation center, but it does dedicate a section of its Extension and Outreach program to Value-Added Agriculture, with resources available on production.[81] Also, the Agricultural Marketing Resource Center, funded by USDA Rural Development, offers training in various aspects of marketing agricultural products, including but not limited to renewable energy and food processing.[82]

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[71] See https://www.biorenew.iastate.edu/about/.
[72] See https://www.biobasedindustrycenter.iastate.edu.
[73] See https://www.biorenew.iastate.edu/research/rapid/.
[74] See https://cenusa.iastate.edu. Other university members of this consortium are Purdue, Wisconsin, Minnesota, Nebraska (Lincoln), Illinois (Urbana-Champaign) and Vermont.
[75] See http://www.biocenturyresearchfarm.iastate.edu.
[76] See http://www.ccur.iastate.edu/about.html.
[77] See https://www.card.iastate.edu/about/.
[78] See https://www.cbirc.iastate.edu and https://www.cbirc.iastate.edu/industry/.
[79] See http://www.cb2.iastate.edu/about.html and http://www.cb2.iastate.edu/industrymembers.html.
[80] See https://www.ameslab.gov/cbs.
[81] See https://www.extension.iastate.edu/valueaddedag/ and https://www.extension.iastate.edu/valueaddedag/production.
[82] See https://www.agmrc.org.

University of Iowa offers:

- The Center for Biocatalysis and Bioprocessing, which received an NSF Engineering Research Center Award for Environmentally Beneficial Catalysis.[83]

[83] See https://cbb.research.uiowa.edu/about-cbb.

Kansas

Kansas Department of Commerce considers food manufacturing one of its key industry sectors,[84] and the Department of Agriculture incorporates much of the same material in its AgGrowth strategy.[85] The Department publishes a resources guide summarizing the state's production assets and research supports in the university sector.[86] The plan of work for Kansas State University's agricultural research and extension mentions value-added and bio-processing, but not as a central focus.[87]

Financial incentives for processors

Kansas Department of Commerce business incentives are almost entirely sector-agnostic except for minor energy production credits for biodiesel fuel and ethyl alcohol production.[88] The Department of Agriculture only promotes federal grants and passthroughs and offers none of its own for value-added producers.[89]

Laws and regulations

Food processing is regulated mainly under Kansas Code Chapter 65 Article 6,[90] as implemented by Kansas Administrative Regulations that incorporate by reference a document produced by the Department of Agriculture Division of Food Safety.[91] Certain additional provisions appear at Kansas Annotated Statutes Chapter 74 Article 5,[92] as implemented by Kansas Administrative Regulations Article 16.[93] The statute gives enforcement authority to county attorneys but does not otherwise mention or pre-empty county authorities.

The Kansas Farm Bureau's State Policy Resolutions for 2018[94] do address county issues, but not generally in the context of pre-empting inspections or permitting. The closest is a paragraph on Food Safety and Security which reads, "We encourage federal, state and local units of government, research institutions and the agricultural industry to make every reasonable effort to protect livestock and crop production in Kansas from acts of bioterrorism and from accidental infestations of animal and plant pests or diseases. Agencies and producers should develop

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[84] See http://www.kansascommerce.com/DocumentCenter/View/9597/Commerce_industy_dist_master--Food-Mfg?bidId=.
[85] See https://agriculture.ks.gov/docs/default-source/ag-growth-summit/january-2018-documents/2018-growth-book-for-web.pdf?sfvrsn=460380c1_12.
[86] See https://www.kansascommerce.com/DocumentCenter/View/3857/Kansas-Value-Added-Agriculture-and-Food-Processing-Brochure?bidId=.
[87] See https://www.ksre.k-state.edu/employee_resources/programming/impacts/FINAL2017PlanWork.pdf.
[88] See http://www.kansascommerce.com/459/Business-Incentives and http://www.kansascommerce.com/93/Business-Community-Finance-Incentives and http://www.kansascommerce.com/1032/Energy-Incentives.
[89] See https://agriculture.ks.gov/kda-services/grants-and-cost-share-programs.
[90] See https://law.justia.com/codes/kansas/2011/Chapter65/Article6/.
[91] See https://agriculture.ks.gov/docs/default-source/statutes-foodsafety-lodging/kda_food_code_7_1_2012.pdf?sfvrsn=6.
[92] See https://law.justia.com/codes/kansas/2014/chapter-74/article-5/.
[93] See http://www.kssos.org/pubs/pubs_kar.aspx.
[94] See https://www.kfb.org/page/file?path=Files%2Fpage-117%2F2018%20State%20Resolutions.pdf/

voluntary science-based biosecurity protocols to address their specific operations. Any on-farm inspection should be pre-arranged."

Government/university/industry collaborations

Kansas State University's signature program in this area is a Value-Added Foods Lab in North Manhattan.[95] The lab also collaborates with a Food Innovation Accelerator at the K-State campus in Olathe.[96] Like similar centers, it is based in a test kitchen and through the Foods Lab offers consultation on product development, scale up, food safety, labeling, and analytics. K-State also supports a Bioprocessing & industrial Value-Added Products Innovation Center within it Grain Science and Industry thrust.[97] This facility includes incubator space, but little information is available on industrial interaction.

Since 2001 K-State in Manhattan has had a Food Science Institute,[98] which integrates activities of 47 faculty across 11 departments in five colleges. Among the eight research thrusts are dairy processing; food chemistry; and product development. The center does not explicitly highlight industry interactions, although they appear to exist.

AIB International in Manhattan (founded 1919) is a not-for-profit technology transfer and information center for the baking and food-processing industries.[99]

The University of Kansas in Lawrence has for 15 years maintained a Center for Environmentally Benign Catalysis, with a strong industry advisory board,[100] whose charge is "helping the State chart a course toward a thriving renewable chemicals industry."

[95] See http://www.k-state.edu/kvafl/.
[96] See http://olathe.k-state.edu/research/centers-institutes/food-programs/food-innovation-accelerator.html.
[97] See https://www.grains.k-state.edu/facilities/bivap/.
[98] See https://foodsci.k-state.edu.
[99] See https://www.aibonline.org/About-Us/Contact-Us.
[100] See http://cebc.drupal.ku.edu/currentpast-members.

Appendix E: Lessons Learned from Benchmarking Value-Added Food Processing Centers

Summary Findings

This appendix begins with summary tables covering the programs surveyed, followed by capsule profiles of each initiative including references to material available online.

Mission and Objectives

The six universities surveyed (Kansas State has two interlinked programs) generally define their mission as assisting in economic development by advancing food-related businesses that add value to regional farming. Several address entrepreneurs directly, while others speak to the overall state business and economic climate:

Initiative	Mission statement excerpt
Cornell Food Venture Center	"to provide comprehensive assistance to beginning and established food entrepreneurs thus promoting sustainable economic development"
Kansas State University Value-Added Foods Lab	"help you develop your product safely and under current regulations so you can start, or add to, your business"
Kansas State University Food Innovation Accelerator (linked)	"to rapidly solve industry challenges and expand economic development by overcoming resource limitations within companies"
Michigan State University Product Center	"help you develop and commercialize high-value products and businesses in the food, agricultural, and natural resource sectors" or "accelerating innovation and growth for Michigan business, industry and entrepreneurs in food, agriculture, and bio-manufacturing"
Oregon State University Food Innovation Center	"advancing Northwest foods"
Rutgers Food Innovation Center	"provides business and technology expertise to startup and established food and value-added agriculture businesses in New Jersey"
University of Nebraska Lincoln Food Processing Center	"to enhance value through the process, from idea through ongoing market support [via a] unique combination of technical and business development services to accurately reflect the nature of the food industry

Target Audiences

Nearly all the surveyed programs target both entrepreneurs and established businesses including those of modest size that wish to scale, but also in several cases genuinely large enterprises. There is no explicit focus on farmers, although it possible some of the food businesses served may be non-farm-related activities of active farms. Generally, these programs cast a wider net to seek entrepreneurs.

Initiative	Entrepreneurs	Established Firms	Other
Cornell Food Venture Center	√		Large regional retailers
K-State Value-Added Food Lab	√	√	
K-State Food Innovation Accelerator	√	√	Restaurateurs, bakers, sous vide, pet food
MSU Product Center	√	?	
Oregon State Food Innovation Center	√	√	
Rutgers Food Innovation Center	√	√	Notable interest in providing "soft landing" resources to support inward investment in New Jersey by overseas food firms
UNL Food Processing Center	√	√	Notable out-of-state practice

Services Offered

All the surveyed programs provide assistance in ideation/new-product development. Most also provide regulatory services (certification and training for scheduled processes) and analytical services (either laboratory based or consumer-sensory testing). Only about half include an entry-level workshop in food entrepreneurship, but those that do consider it a central element of their programs. Two the programs pay attention to supply-chain issues – either buyers of food products, or sellers of ingredients and packaging – and at least one functions as an extension of state government's inward-investment/attraction program in the food sector.

Initiative	Entry-level food entrepreneurship	Ideation / product / process development	Regulatory compliance / testing / training	Lab analysis / sensory testing	Other
Cornell Food Venture Center		√	√	√	
K-State Value-Added Food Lab		√	√	√	Sourcing of ingredients/packaging
K-State Food Innovation Accelerator		√	√	√	Pet food R&D
MSU Product Center		√			Annual conference for entire supply chain

Oregon State Food Innovation Center	√	√	√	√	Strong database of regional testers
Rutgers Food Innovation Center	√	√	√	√	Non-equity quasi-accelerator for promising ventures
UNL Food Processing Center	√	√	√	√	Professional development workshops

Facilities

Two of the surveyed programs have recently moved into major new facilities that offer unusually broad selections of pilot plant equipment. Most offer at least some pilot facilities, analytical labs, and office space for training and mentoring. Several offer small suites for consumer sensor testing needed as part of new-product development.

Initiative	Pilot plants	Other
Cornell Food Venture Center	Fruit and vegetable; wine and beer; high-pressure processing	
K-State Value-Added Food Lab		
K-State Food Innovation Accelerator		5 test kitchens; suites for consumer testing focus groups and interviews
MSU Product Center	Comprehensive multi-food lines (see right)	New Food Processing and Innovation Center is a multipurpose USDA/FDA facility available for 24-hour/day rental
Oregon State Food Innovation Center	Modest 40x40 pilot facility	Some companies are resident in processing space; collocation of state ag marketing operations and consumer testing functions
Rutgers Food Innovation Center	Beverages, hot processing, dry processing in south of the state; USDA/FDA facility in the north; analytical labs also in north	
UNL Food Processing Center	Comprehensive multi-food lines (see right)	New Food Innovation Center on Nebraska Innovation Campus research park

Partnerships

Only two of the surveyed programs interact heavily with the extension division of their parent agricultural college. Several partner with but do not directly control pilot facilities owned by meat and grain departments. Three partner with parallel (but often less well developed) programs in industrial value-added products from plants.

Initiative	Primary	Note	Secondary	Note
Cornell Food Venture Center	Institute for Food Safety	Extensive training	Cornell Technology Farm	Ag-Food Technology Park
K-State Value-Added Food Lab	Meat Science Value-Added Lab; Grain Science & Industry Bioprocessing	Both on Manhattan campus; grain science focuses on industrial value-added products		
K-State Food Innovation Accelerator	Value-Added Food Lab			
MSU Product Center	Extension		Center for Economic Analysis	
Oregon State Food Innovation Center	Extension		State ag department commodity specialists in residency	
Rutgers Food Innovation Center	Eco complex	Parallel activity in industrial value-added		
UNL Food Processing Center	Agricultural Products Center	Parallel activities in industrial value-added		

Cornell Food Venture Center

Mission and Objectives

The Cornell Food Venture Center[101] (established 1988) is in part a revitalization and rebranding of the Northeast Center for Food Entrepreneurship, which Cornell operated from 1999 to 2004 in partnership with the University of Vermont with funding provided by the USDA.[102] The current mission is "to provide comprehensive assistance to beginning and established food entrepreneurs thus promoting sustainable economic development."[103]

The newly strengthened program builds on and leverages several pilot plants and other resources at the Cornell College of Agriculture and Life Science. Since the 1950s, Cornell has concentrated horticulture and viticulture research and extension at Geneva, and meat and dairy at Ithaca, but this firm separation has begun to change.

Since the time of the predecessor center, Cornell CALS has reorganized in a way that binds the Geneva station much more tightly to the main campus in Ithaca than ever before. Instead of reporting through an independent line in Geneva, the center now reports to the director of the Ithaca-based Cornell Institute of Food Systems,[104] a powerful multidisciplinary research and thought-leadership initiative that involves a range of major food processors and brands and does its own industrial outreach, and which connects also with a state-sponsored center of excellence.[105] Therefore, while the Food Venture Center is fairly narrowly targeted at entrepreneurship and small-scale processing, it is now deeply embedded in a broad range of resources (including traditional extension) in Geneva, Ithaca, and New York City that make it powerful as a statewide outreach tool.

The set of resources surrounding the Food Venture Center fits well with the state's agricultural profile, which emphasizes horticultural crops and dairy, but is increasingly emphasizing value-added processing. In fact, New York State, which delivers its economic-development subsidies and project funding on a regional basis, has found that every single region has identified either value-added agriculture or food processing or both as targets of opportunity, and several have invested their state-provided funding in food-related business incubators or accelerator-like programs. Following are brief quotes from the regional plan updates from all 10 regions, ranging from super-urbanized to rural and remote:[106]

- Central New York targets "Agriculture and Agribusiness" as a key priority and identifies as its pillars of investment: controlled environment agriculture; aseptic packaging; shovel-ready sites for ag-based projects; and a cross-regional ag-business

[101] See https://cfvc.foodscience.cals.cornell.edu/.
[102] See https://portal.nifa.usda.gov/web/crisprojectpages/0184714-northeast-center-for-food-entrepreneurship-necfe.html.
[103] See https://cfvc.foodscience.cals.cornell.edu/about/.
[104] See https://cifs.cornell.edu.
[105] See https://agritech.cals.cornell.edu/programs-partners/center-excellence-food-and-agriculture/.
[106] These summaries and quotes are all from the regional progress reports available at https://regionalcouncils.ny.gov.

accelerator. In this region, Cornell's "tech" incubator in downtown Ithaca has also given significant attention to networking local food entrepreneurs and encouraging those considered "scalable."[107]

- Finger Lakes notes that "Technology is advancing rapidly in the Agriculture and Food sector. Startup companies using digital technology and big data are ready to transform the industry. They are studying ways to reduce food waste, increase farm productivity, adapt to new environments, and provide alternative sources of proteins to supply the demands of the consumers." Constituent counties such as Genesee are investing heavily in ag- and food-oriented industrial parks. [108]
- Long Island aims to "promote the food industry as a growth cluster" with attention to projects seafood and specialty, ethnic foods.
- Mid-Hudson "identified the Food and Beverage Manufacturing Supply Chain as a manufacturing-based industry cluster to prioritize," leveraging the New York City market's interest in fresh, farm-based foods (aka the locavore movement).
- Mohawk Valley targets "Agribusiness & Food Systems" as a regional priority, stressing innovative year-round and indoor farming, creation of new cooperatives, and support for craft food entrepreneurs.
- North Country identifies "Value-Added Agriculture" as a goal for the regional dairy industry and will "focus on three key strategies. . . advancing high-tech, year-round food production; expanding value-added food production; and fostering a new generation of farms
- New York City, while not identifying food explicitly as a target, uses state funding to support dozens of food-related projects, including incubators, expansions of specific businesses, experiments in urban agriculture, and creation of a hub to enable vending of farm-to-table products grown upstate.
- Southern Tier identifies as a key goal "Transform the Food and Agriculture Industry" with attention to projects that "transform and grow agriculture and food production, processing and distribution across the region, while also strengthening links to growing tourism and manufacturing industries

[107] See http://revithaca.com/event/scalable-food-and-entrepreneurship/.
[108] See http://www.gcedc.com/index.php?cID=238.

- Western New York identifies “Agriculture” as a key sector and its strategy is to “Make agriculture more competitive through branding, innovation & career readiness”

In addition, the Upstate Capital Association of New York – essentially a venture capital club representing venture and private-equity investors operating outside New York City and Long Island – has mounted an event on “The Future of Food,”[109] featuring investment perspectives from food and agtech investors, and highlighting cases of food companies raising capital and gaining traction.

Target Audience

The explicit target of the Food Venture Center is small-scale entrepreneurs and processors, but it has also served large retailers like the regional Wegmans supermarket chain.[110] However, this focus may be misleading because the pilot plants and other resources leveraged by the center have statewide constituencies spanning the full range of farming and processing businesses, from small to large.

Services Offered

The Food Venture Center says it offers four principal services: business and product/process development; product safety; technology transfer; and product commercialization. In direct services, the center provides training and support for small scale entrepreneurs, emphasizing regulatory compliance that would otherwise be beyond the reach of startups and small operators. The services advertised by the center alone are fairly narrow. There is a one-time registration fee $25 or $50 for out of state and then

- Lab analysis ($20/sample, $30 for out of state companies)
- Analysis and review ($37/product)
- Scheduled process ($80/product, $140 out of state)
- Scheduled process for meat ($120/product, $210 out of state)
- Modifications/amendments of scheduled processes ($37/product, $70 out of state)
- Vacuum pack letter/hazard analysis ($150 for first, then $75—$200/$100 out of state)
- Heat penetration study ($350 per product size, $600 out of state)
- Classification/shelf life letter ($70/product, $100 out of state)

However, through referral to partner organizations in the Cornell CALS extension system, the center also advertises additional training in food safety and specific advice on:

- Acidified (pickled) foods

[109] See http://upstatecapital.org/upstate-capital-event/future-of-food/.
[110] See https://cals.cornell.edu/news/cornell-food-venture-center-helps-wegmans-innovate/.

- Standards for home and commercial kitchens
- Business plan basics
- Cheese production
- Fermented Sausages
- Financial resources
- Food container selection tips
- Low acid foods
- Marketing considerations for small-scale suppliers
- Equipment suppliers
- Pros and cons of starting specialty business
- Purchasing pH meters and used equipment
- Required analyses for various types of products
- Science & technology of preserves
- Small scale processing equipment
- Steam kettles
- Yogurt production

Facilities

The Food Venture Center draws primarily on three pilot plants based at Geneva:

The Fruit and Vegetable Pilot Plant[111]

This 10,000 square-foot facility offers:

- High pressure cookers
- Low pressure cookers
- Dryers and dehydrators
- Juice extractors
- Juice pasteurizer
- Filters
- Freezing
- Blanchers

[111] See https://foodscience.cals.cornell.edu/about-us/facilities/geneva-facilities/fruit-and-vegetable-processing-pilot-plant/.

- Packaging
- Raw products and cold rooms

Vinification and Brewing Technology Laboratory[112]

This facility builds on the existing Wine Analytical Laboratory subsidized for NY wineries through the New York Wine and Grape Foundation and provides capacity for wineries in the Finger Lakes and Long Island regions to test new varieties and wine-making processes.

High Pressure Processing (HPP) Validation Center[113]

Operated by the Geneva based Institute for Food Safety, this facility offers validation and shelf-life studies.

Ithaca[114]

Cohoused with the CIFS in Ithaca are several additional pilot facilities:

- Food Processing and Development Lab (Pilot Plant)
- Sensory evaluation center
- dairy processing plant
- teaching winery
- product development kitchen

Also on the Ithaca campus is a USDA approved meats laboratory.

NYC

Cornell Food Venture Center @NYC (established 2017) targets the city's specialty and ethnic food manufacturers.

Partnerships

One key partner for the Food Venture Center is the Geneva-based Institute for Food Safety,[115] a research and extension function whose mission "supports the production of safe and novel foods that increase the economic viability and sustainability of the food industry in New York and beyond." Among the training programs and pilot facilities of the Institute to which the Food Venture Center can refer are:

- The National Good Agricultural Practices (GAPs) Program is a comprehensive extension and education program for growers and packers to reduce microbial risks in fruits and vegetables.

[112] See https://foodscience.cals.cornell.edu/about-us/facilities/geneva-facilities/vinification-brewing-technology-laboratory/.
[113] See https://foodscience.cals.cornell.edu/about-us/facilities/geneva-facilities/hpp-validation-lab/.
[114] See https://foodscience.cals.cornell.edu/about-us/facilities/ithaca-facilities/.
[115] See https://instituteforfoodsafety.cornell.edu.

- The Dairy Extension Program provides comprehensive extension and education programs for dairy production, dairy processing, and consumers.
- The Produce Safety Alliance (PSA) is a collaboration between Cornell University, FDA, and USDA to prepare fresh produce growers to meet the regulatory requirements included in the FSMA Produce Safety Rule.
- The Food Safety Laboratory and Milk Quality Improvement Program (MQIP) provide innovative research, education, and outreach to improve the microbial safety and quality of the global food supply.
- The High-Pressure Processing (HPP) Validation Center is a cutting-edge research facility that uses HPP, a non-thermal alternative to thermal pasteurization.
- The New York Integrated Food Safety Center of Excellence is a collaboration between Cornell University and the NYS Department of Health that was established by the CDC to strengthen foodborne disease surveillance and outbreak investigations.

The other key partner is the Cornell Ag and Food Tech Park aka "The Technology Farm."[116] This is not a direct Cornell activity, but it operates on land owned by Cornell (directly across the road from the Geneva station) and leased to the county development agency. Anchored by a 20,000 square-foot multitenant facility with processing capability, this is intended as an ag/food tech research park, although it has been slow to develop. Recently, local politicians announced they had secured funding for a state-sponsored center of excellence to be based at the park.[117]

[116] See http://thetechnologyfarm.com.
[117] See http://thetechnologyfarm.com/wp-content/uploads/2018/04/Center-of-Excellence-FLT.pdf.

Kansas State University

Motivation and Objectives

Work in value-added food processing at Kansas State University is anchored in Manhattan but extended to Olathe, a suburb of Kansas City.

Kansas Value-Added Foods Lab

The Value-Added Foods Lab at Kansas State University's main campus in Manhattan describes its goal as to "help you develop your product safely and under current regulations so you can start, or add to, your business."[118] It operates as an applied research and consulting arm funded partly by fees and partly by the Kansas Department of Agriculture.

Food Innovation Accelerator

The goal of the Food Innovation Accelerator at KSU's Olathe campus is "to rapidly solve industry challenges and expand economic development . . . by overcoming resource limitations within companies."[119] It is a linked initiative, originally funded in 2013 by the U.S. Economic Development Administration.

K-State Olathe Innovation Campus is a research and educational facility, a joint initiative of several local entities and the Kansas Bioscience Authority. It is situated 115 miles east of the main Manhattan campus, in what is essentially a suburb of Kansas City. Its presence provides the Value-Added Foods Lab and the College of Agriculture generally with access to industrial partners in the state's largest metropolitan area and to the Animal Health Corridor initiative that grew from bistate cooperation on life sciences in the Kansas City metro.[120]

In announcing the $250,000 operating award in 2013, the EDA said the Accelerator's goal was "advancing the technology development and commercialization of innovations that will increase the global competitiveness of the companies concentrated throughout the animal health corridor and the region's food production industry cluster."[121]

For the most part, the food activities (including a related sensory testing facility) seem quite distinct from additional collocated research on animal health, [122] but there is overlap in a research focus on pet food.[123]

Target Audience

The targets for the Accelerator activities are professionals and companies in sectors such as food handling and food safety; restaurateurs; artisan bakers; sous vide and cook/chill operations; and pet food R&D;

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[118] See http://www.k-state.edu/kvafl/.
[119] See https://olathe.k-state.edu/research/centers-institutes/innovation-accelerator/.
[120] See research description at http://olathe.k-state.edu/about/our-story/index.html.
[121] See https://www.k-state.edu/today/announcement.php?id=9485 or https://www.eda.gov/archives/2016/news/press-releases/2013/08/14/innovation_economic_growth_initiatives.htm.
[122] See https://olathe.k-state.edu/research/centers-institutes/1data/index.html and https://olathe.k-state.edu/research/centers-institutes/microbial-lab/index.html
[123] See https://olathe.k-state.edu/research/centers-institutes/food-programs/petfood.html#prettyPhoto.

Services Offered

Kansas Value-Added Foods Lab[124]

- Support in food product development (screening, feasibility, test marketing, commercialization)
- Process Authority services
- Nutrition facts panel generation and ingredients listing
- Chemical and physical testing (pH, Brix, Aw, color, microbiological, accelerated shelf-life)
- Regulatory compliance (label review, nutritional analysis)
- Sourcing of ingredients and packaging
- Workshops and short courses (GMPs, HACCP, etc.)
- Expertise on farmers markets and kitchen incubators

Food Innovation Accelerator[125]

- Product development consulting
- Scale-up assistance
- Facility rentals
- Food safety and food handler training
- Hazard Analysis Critical Control Point, or HACCP, consulting
- Nutritional labeling
- Product analysis testing (pH and water activity)

Through the Pet Food R&D activity:[126]

- "Gold standard" recipes
- Sensory testing
- Process development
- Small-scale R&D

Additionally, through the Sensory and Consumer Research Lab collocated at Olathe:[127]

- Consultation

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[124] See http://www.ksre.k-state.edu/kvafl/doc/instatefees.pdf.
[125] See https://olathe.k-state.edu/research/centers-institutes/food-programs/documents/FIA_RackCard_2018_FNL-2_Digital.pdf.
[126] See https://olathe.k-state.edu/research/centers-institutes/food-programs/petfood.html#prettyPhoto.
[127] See https://olathe.k-state.edu/research/centers-institutes/consumer-research/index.html

- Project management
- Experimental design
- Quantitative research (central location or home-based)
- Qualitative research (exit interviews, discussion groups, focus groups)
- Statistical analysis
- Data interpretation and reporting

Additionally, through the Value-Added Food Lab:

- Color, brix, shelf life
- Fat/protein
- Microbial testing (total and aerobic plate counts, yeast/mold, pathogens)

Through the Meat Value-Added Lab:[128]

- Nutrition labeling
- Product and process development
- Shelf-life evaluation
- Chemical analysis
- Microbiological and quality assessment

Facilities

Facilities in Manhattan are mainly under the control of academic departments such as Meat Science and Grain Science.

In Olathe, the Food Innovation Accelerator leverages a loose agglomeration of capabilities under one roof, including a combination of five test kitchens (sample photo linked in footnote)[129] and a Sensory and Consumer Research Center:[130]

- Multipurpose rooms for large consumer studies (<45)
- Focus group rooms with video streaming capability
- Theater-style rooms
- 7 individual testing booths

Through the Grain Science & Industry Bioprocessing and Industrial Value-Added Products Innovation Center in Manhattan:[131]

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[128] See http://www.asi.k-state.edu/research-and-extension/meat-science/value-added/index.html.
[129] See https://olathe.k-state.edu/research/centers-institutes/food-programs/food-innovation-accelerator.html#prettyPhoto[119019]/0/.
[130] See https://olathe.k-state.edu/research/centers-institutes/consumer-research/index.html.
[131] See https://www.grains.k-state.edu/facilities/bivap/.

- Biomaterials and technology laboratory
- Extrusion pilot facility and laboratory
- Bioprocessing and renewable energy laboratory

Partnerships

The principal partner for the Food Innovation Accelerator—the entity that provides all sophisticated analytical work and R&D capacity—is the Kansas Value-Added Food Lab back in the main campus in Manhattan.

University

The Value-Added Foods Lab partners in turn with two other entities on the Manhattan campus:

- The Meat Science Value Added Lab[132]
- The Grain Science & Industry Bioprocessing and Industrial Value-Added Products Innovation Center[133]

[132] See http://www.asi.k-state.edu/research-and-extension/meat-science/value-added/index.html.
[133] See https://www.grains.k-state.edu/facilities/bivap/.

Michigan State University Product Center

Motivation and Objectives

Economic research conducted and posted recently by the Michigan State University Product Center shows that Michigan ranks 19th in food manufacturing, similar to its ranking in farm output, and last in the Great Lakes Region. Weakness in animal processing is compensated by relatively strong position in fruit and vegetable processing, reflecting the diverse climate base. The Product Center grew out of interest in capturing within Michigan more of the "value-added" from what is primarily a commodity-oriented agricultural economy.

The stated objective the Product Center (established 2003) is to "help you develop and commercialize high-value products and businesses in the food, agricultural and natural resource sectors,"[134] or more formally "accelerating innovation and growth for Michigan business, industry and entrepreneurs in food, agriculture and bio-manufacturing."[135] Its strategic vision is "The Product Center will be the go-to place for assistance with venture development, growth strategies, and market assessments in the food, agriculture, natural resource and bio-manufacturing sectors of Michigan."

The Product Center is entirely a unit of the MSU College of Agriculture and Natural Resources and was seeded by its research and extension units, supported by a $1 million grant from the USDA Agricultural Innovation Centers program.

Target Audience

The two defined target audiences are "entrepreneurs or early-stage businesses" at the concept stage and "established businesses [aka "second-stage" businesses] wanting to move to the next level of performance." Services targeted at these two in-state audiences are currently funded by distinct funding streams: the MSU Extension budgets support programs for existing businesses, and services for startup entrepreneurs are supported through Project GREEN, a state initiative for industrially relevant research and extension in plants and agriculture.[136]

Services Offered

The Product Center targets different services to its two distinct audiences:

Startup Entrepreneurs

- Concept development
- Business development
- Market research and data
- Interactive supply chain data for Michigan

Established businesses

- Economic and market analyses

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[134] See http://www.canr.msu.edu/productcenter/.
[135] See http://www.canr.msu.edu/productcenter/uploads/Product%20Center%20Fact%20Sheet_2016.pdf.
[136] See https://www.canr.msu.edu/research/plant-agriculture/project_greeen/index.

- Feasibility assessments
- Product development
- Resource development
- Supply chain and marketing
- Strategic planning
- Regulatory compliance

The Product Centers draws on both MSU faculty and industry consultants for "specialized services."

Make it in Michigan Conference

The Product Center's signature annual event is the Make it in Michigan Conference and Marketplace Trade Show, described as "valuable educational sessions and retail buyer interaction to help expand your food or agricultural product business."[137]

Facilities

With a $2.7 million grant from the U.S. Economic Development Administration matched by the state and the university, the Product Center has opened[138] its Food Processing and Innovation Center (FPIC). This a $5.6 million project ($3.5 million for renovation, $1.75 for equipment, $0.25 million for first-year operations) involving major refurbishment of a building in Okemos, a mile off campus, that was formerly a food commissary for a regional restaurant chain and is now owned by the university. The Product Center itself is headquartered in an academic building on campus.

The FPIC is not an incubator. It is a USDA/FDA-certified facility available by lease for periods of between 3 and 21 days by one client at a time 24 hours/day for test runs. Promotional material notes: "Having the flexibility of leasing your own plant allows multiple opportunities in exploring options or trying various pieces of processing and packaging equipment to create new or existing products for the marketplace. Once you have your product processing and packaging solutions identified, the FPIC allows you to snap together and create operational production lines to begin full production runs."[139] The goal is to create $15-20 million in sales growth and 50 new jobs for each project served. At full capacity of 5-10 clients per year, MSU projects annual economic impact of $100 million in sales and 300 jobs.

The FPIC is capable of handling:[140]

- Low-acid foods
- Meat & seafood
- Fruits & vegetables

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[137] See http://www.canr.msu.edu/miim/.
[138] See http://www.canr.msu.edu/news/a-thank-you-to-all-who-helped-make-fpic-a-reality.
[139] See http://www.canr.msu.edu/fpic/how-it-works.
[140] See http://www.canr.msu.edu/fpic/processing,

- Refrigerated products
- Frozen products and meals
- Snack foods
- Bakery & confectionary
- Sauces and condiments
- Desserts & IQF products
- Drinks (non-carbonated)

The Product Center also facilitates client access to facilities owned and operated by allied academic departments: a dairy foods complex; a fruit and vegetable processing line; a food sensory laboratory; an experimental foods laboratory; a cereal milling and product laboratory; a meat laboratory (in the separate animal science complex); and an artisan distilling program (also a standalone facility).

Partnerships

Extension

The Center conducts outreach throughout the state through a select group of extension agents who have been trained specifically in the two key programs. These individuals were selected at the same time as MSUE was reorganizing from a 60-county program into 14 regional districts.

Research

The Product Center can draw for economic research on the agriculture college's Center for Economic Analysis.[141]

Both "Food Processing and Quality Enhancement" and "Food Safety and Toxicology" are two processing-related areas among the research strengths (four in total) identified by the MSU Department of Food Science & Human Nutrition. Faculty working in these areas are the ones who co-apply with the Product Center for federal and industrial grants.

Industry

The Product Center partners with copackers, to steer them clients that have already been through the pilot phase, have a stabilized product, and know what their volumes will be. These are desirable customers for copackers. It also works with a number of local kitchen incubators.

Both graduate students and undergraduate seniors are involved in capstone courses (in agribusiness management, food industry management, and food science and packaging) that may take as their subjects Product Center client jobs.

[141] See http://www.canr.msu.edu/cea/.

Oregon State University Food Innovation Center

Motivation and Objectives

The Oregon State University Food Innovation Center (established 1999)[142] has the broadly defined mission of "Advancing Northwest Foods." The College of Agricultural Sciences considers it an agricultural experiment station, but one different from any of the others because it is focused on the food-processing industries and situated not in a farming community but rather in the City of Portland, where most of the state's food entrepreneurs are found and where the state Department of Agriculture could easily collocate certain statewide market-development functions.

The Center received seven or eight years of special state appropriations to start the program but none after 2009. A USDA grant for multi-commodity value-added work expired in 2012. As a consequence, the Center is now much more fee-based. Rental income produces about $530,000 annually.

Target Audiences

The Center targets both aspiring/early-stage entrepreneurs and established businesses in all size ranges, although it is mainly small companies that use the center's expertise in product formulation because these are functions that well established companies prefer to hold in house.

There is no specific preference by crop or food type. Through its partners (see below), the Center receives referrals from the rural counties. These companies are offered short courses either in the field or remotely by videoconference, but they are also encouraged to visit Portland for a half-day with the Center's product development group. Subsequently, advice on nutrition labeling or formulation can be handled over the Internet.

Services Offered

The Food Innovation Center considers it has three areas of excellence:

Product and Process Development[143]

This program is currently managed by an individual recognized as master taster:[144]

- Introductory sessions (7 for $700)[145]
- Ideation
- Product development
- One-on-one consulting
- Food photography

[142] See http://fic.oregonstate.edu/.
[143] See https://fic.oregonstate.edu/fic/food-product-development.
[144] See news coverage at https://www.nytimes.com/2018/06/11/dining/sarah-masoni-food-designer-oregon-state.html.
[145] See https://fic.oregonstate.edu/fic/events/fridays-fic.

- Packaging (including RFID) selection and testing

Consumer Testing Laboratory[146]

One of the Food Innovation Center's key assets is its development of cost-efficient access to a 20,000-person database of testers clustered around the Portland metro area, which is considered a home to highly sophisticated food consumers.

- Difference/preference testing & evaluation of in-home uses
- Qualitative research (e.g., focus groups and interviews)

Food Safety Hub[147]

- Outreach & training in good manufacturing practice
- Quality analysis
- Shelf-life testing

The Innovation Center also operates a Food Entrepreneur Network.[148]

Facilities

The Center is located in a 32,000 square foot building financed by the state government through $9.5 million in bonds. Both the building and the associated debt were subsequently turned over to the university, but the state leases back about two-thirds of the building for use by the Department of Agriculture's development and marketing division, as well as units involved in certification, pesticide management, and export validation.

The building includes a modest 40x40 pilot facility that allows a wide range of process testing. While the building also includes analytical and testing laboratories, many crop-specific pilot plant assets (dairy, fruit and vegetable, and juice, beer and wine) remain back at the main campus in the small city of Corvallis (85 miles up the Willamette River) and seafood processing is based at the Marine Experiment Station. Sensory labs are at both Portland and Corvallis. There is no meat processing at Portland.

The Food Innovation Center usually has one or two food companies resident in its processing space for up to six months, but OSU's only formal incubator for food businesses is a dairy incubator at Corvallis. Although the Center actively refers its clients to a list of copackers, many of whom are also clustered around Portland, there is also need for companies to control their own space. Therefore, the Center is asking other actors in the region to set up quality incubation programs.

Partnerships

Research, Extension, and State Agencies

The Center describes its primary partnerships as with:

[146] See https://fic.oregonstate.edu/fic/sensory-testing.
[147] See https://agsci.oregonstate.edu/fic/food-safety.
[148] See https://fic.oregonstate.edu/food-innovation-center/events/food-entrepreneur-network.

- The Department of Food Science and Technology at the main campus for educational programming and subject-matter expertise, especially in sensory evaluation, a core strength;
- Resident staff of the state Department of Agriculture for linkage to the 24 commodity commissions, to a "farm to school" program to supply school cafeterias, and to a statewide network of farmers markets (which are not specifically state supported);
- The college's network of 30 extension agents statewide for referrals.

Other

The Innovation Center also works with Portland Community College on a targeted course on "Getting your recipe to market," which was created by the Center but now offered by the College. [149]

[149] See https://www.pcc.edu/climb/small-business/getting-your-recipe-to-market/.

Rutgers Food Innovation Center

Motivation and Objectives

Rutgers University's main program for development of value-added processing business is the Food Innovation Center (FIC),[150] a combined pilot plant/incubator in Bridgeton. This is an economically depressed city in rural southern New Jersey, nearly two hours' drive from the main New Brunswick campus. While New Jersey has historic strengths as a corporate and R&D headquarters for food firms, these are mainly in the north. The south is agricultural, and the FIC represents an attempt to bring value-added closer to the farming community.

In defining its mission, the FIC says it "provides business and technology expertise to startup and established food and value-added agriculture businesses in New Jersey and the surrounding region, and we utilize our outreach capacity to reach the food industry throughout the world. We support domestic US companies, as well as international businesses looking to establish a presence in the USA, with the marketing, technical, regulatory, and manufacturing expertise that are critical for success."[151]

The overall Center opened in 2001, and the 23,000 square-foot incubator in 2008, with support partly from the USDA Rural Development Program. The Food Innovation Center is a unit of the cooperative extension function of the School of Environmental and Biological Sciences (SEBS), formerly known as the College of Agriculture. The Center is led by an executive with substantial food-industry experience. It reports not the SEBS associate director for economic growth and development, who is also the university's associate VP for economic development. It is staffed by a range of technical and business specialists, including one extension specialist affiliated with the Department of Plant Biology and Pathology.

Target Audience

Operating both as a "bricks and mortar" and "virtual" incubator, the Innovation Center targets three audiences: startups, existing companies seeking to scale up, and inward recruitments to New Jersey from elsewhere in the U.S. or from overseas.

Services Offered

Food Business Basics Workshop[152]

The standard entry point for all services and all target audiences is a Food Business Basics Workshop, offered quarterly for $250.

Business and Technical Mentoring[153]

- Business ideation
- Product development
- Sensory evaluation
- Quality assurance, food safety, and regulatory

[150] See http://foodinnovation.rutgers.edu.
[151] See http://foodinnovation.rutgers.edu/FIC-About.html.
[152] See http://foodinnovation.rutgers.edu/FIC-FBB.html.
[153] See http://foodinnovation.rutgers.edu/BTM2017.html.

Industry training[154]

Both standard curricula and customized training options are offered to industrial clients in these areas:

- Preventive Controls for Human Food (PCQI) certificate training
- HACCP certificate training (USDA or non-seafood FDA)
- Foreign supplier verification
- Food safety auditor fundamentals
- Seafood HACCP certificate training

Business Acceleration

Using funding from an SBA Growth Accelerator award in 2014,[155] FIC created an agricultural business quasi (non-equity) accelerator as part of the broader RutgersX[156] family of accelerators. Selected FIC clients were invited to pitch.[157]

Global Services[158]

FIC seeks to promote inward investment by international food companies and entrepreneurs in New Jersey. Through its global services program, FIC maintains partnerships overseas and also offers in New Jersey:

- Training in U.S. market trends, technologies through customization of the Food Business Basics Workshop, offered in the U.S. or abroad
- Specialized training in FDA Food Safety Modernization Act and courses in General HACCP and Seafood HACCP (20 hours each).
- Customized mentoring and access to FIC North (see below) pilot canning plant.
- Partnerships with county and state agencies for incentives and marketing assistance.

FIC reports it is partnering with the Cumberland County Improvement Authority to develop a new Food Commercialization Center smaller than FIC North but designed to enable rapid market entry. It is still in the concept stage.[159]

Talent network[160]

Although details are sparse, the FIC operates a talent network that seeks to connect educational institutions to the needs of operating food manufacturing businesses.

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[154] See http://foodinnovation.rutgers.edu/TSS2017.html.
[155] See https://www.sba.gov/about-sba/sba-newsroom/press-releases-media-advisories/sba-spurs-economic-growth-announces-50-awards-accelerators.
[156] See http://x.rutgers.edu/indexfic.html.
[157] See http://foodinnovation.rutgers.edu/112315RutgersX-PostEventRelease-Final.pdf.
[158] See http://foodinnovation.rutgers.edu/G-Services.html.
[159] See https://www.ccia-net.com/project/food-commercialization-center/.
[160] See http://foodinnovation.rutgers.edu/NJTN2017.html.

Facilities

The main FIC facility in Bridgeton is branded as "FIC South," [161] but the center has also taken responsibility for two additional assets in central New Jersey.

FIC South

FIC South is the main incubator and site for business counseling and product development. It offers shared use processing in:

- Refrigerated foods
- Beverages and hot processing
- Bakery and dry processing
- Cold assembly/clean room

FIC North (USDA pilot plant)[162]

Just off the main Rutgers engineering campus in Piscataway, FIC operates a 31,000 square-foot canning plant operated under constant USDA inspection and FDA license. FIC has positioned this facility as the core of its "Global Services" and its iNBIA "Soft Landings" program[163] to provide support for international firms seeking to establish a presence in New Jersey.

FIC Chemistry[164]

FIC has branded access to the advanced analytical facilities in the Department of Food Science at the SEBS agricultural complex in New Brunswick as "FIC Chemistry."

Partnerships

The FIC is a parallel report (to the associate director for economic growth) with an analogous activity in clean-energy development, the EcoComplex,[165] situated in Bordentown, on the Delaware River. This program has partnered with FIC on the RutgersX accelerator.

[161] See http://foodinnovation.rutgers.edu/L-South.html and more detail at http://foodinnovation.rutgers.edu/F-South.html.
[162] See http://foodinnovation.rutgers.edu/L-North.html.
[163] See https://inbia.org/global-programs/soft-landings/.
[164] See http://foodinnovation.rutgers.edu/L-Chemistry.html.
[165] See http://ecocomplex.rutgers.edu.

University of Nebraska Lincoln Food Processing Center

Motivation and Objectives

The Food Processing Center (FPC)[166] at University of Nebraska Lincoln (established 1983) was created to capture in-state more of the value-added enabled by commodity production. It defines its role as "to enhance value throughout the process, from idea through ongoing market support [via a] unique combination of technical and business development services to accurately reflect the nature of the food industry."

The FPC considers itself "a major food processing and applied research hub because it integrates applied research with state-of-the-art pilot plants, laboratory services, a team of product developers, and a team that supports food entrepreneurs." Further, the FPC states: "Food is both a science and a business, and we understand the dynamic relationship of these two different, yet interconnected worlds." The FPC is one of 13 organized research centers that report to university's Institute of Agriculture and Natural Resources. It is now embedded in a new Food Innovation Center on the university's new Nebraska Innovation Campus research park off campus (see below under facilities).

UNL has a separate Agricultural Products Center, affiliated with the Department of Biological Systems Engineering. This is a smaller unit, which focuses on new industrial uses for agricultural products.[167] It also seeks industrial partnerships for its research program and offers access to its own analytical equipment as well as specialized equipment in extrusion; extraction and evaporation; enzymatic hydrolysis and fermentation; and centrifugation. This unit has not moved to the Innovation Campus but still operates on the main academic campus.

Target Audience

The FPC addresses all food groups and has managerial custody of all the processing capacity associated with the Department of Food Science and Technology. It serves as the department's primary vehicle for industrially sponsored and other applied research in the department. It is especially well known for its extrusion equipment.

Discounted rates to the FEP and all services are provided to companies that are based in Nebraska, but the FPC sees itself as a national program, and overall about half the center's clients come from outside the state. Among these are many larger, established companies. In-state, the audience is split between large and small.

The FPC believes that there are many other extension entities on campus that work with farmers, food coops, or do general entrepreneurship work; FPC maintains a strict focus on value-added food processing businesses.

Services offered

National Food Entrepreneur Program[168]

The FPC's signature program, established in 1989, is the National Food Entrepreneur Program, which begins with one day "Recipe to Reality" seminar and proceeds to "Product to Profit," a second phase in

[166] See http://fpc.unl.edu/..
[167] See https://agproducts.unl.edu.
[168] See https://fpc.unl.edu/nfep.

which confidential services are provided to any participants who launch their own business. The FPC makes no distinction between "lifestyle" and scalable entrepreneurial startups.

Laboratory services[169]

- General microbiology testing
- Food screens for contamination
- Acidified foods testing
- Water analysis
- Pathogen detection
- Miscellaneous / customized

Sensory analysis[170]

- Informal/qualitative testing
- Consumer testing (acceptance/difference/preference)
- In-depth descriptive analysis using Quantitative Descriptive Analysis
- Facilities including areas for sample preparation and both consumer and expert panels

Food Properties Testing[171]

- Wide range of analytical testing

Product & process development[172]

- Creative concept (ideation) and benchtop prototype development for testing
- Ingredient application and substitution and supplier evaluation
- Line extensions
- Product and process scaleup (standards and issue identification at smaller dimension)

Labeling & regulatory compliance[173]

- Label review
- Nutrition facts panel based on database
- Ingredient statement & allergen declaration (while protecting trade secrets)
- Nutritional claims (review for allowable and appropriate phrasing)

Pilot Plant

See below under facilities.

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[169] See https://fpc.unl.edu/lab_services.
[170] See https://fpc.unl.edu/sensory_lab.
[171] See https://fpc.unl.edu/food-properties-testing-service.
[172] See https://fpc.unl.edu/product_development
[173] See https://fpc.unl.edu/labeling.

Professional development workshops[174]

- Food processing management (for mid-career professionals)
- Extrusion (product development in a variety of food categories)
- Food microbiology (with hands-on lab experience)
- Recipe to Reality (targeted at individuals)
- Better process control school (FDA-approved)
- Hazard Analysis & Critical Control Points (HACCP)
- Food Safety Preventive Controls Alliance (FSPCA) curriculum
- Craft brewers' workshop[175]
- Science of Safe Food[176]
- Online certificate (distance learning) in food safety, food processing, and business growth strategies/human resources[177]

Applied Research and Engineering[178]

Customized applied research intended as the translational bridge between basic research and the food industry. Entities that have supported projects currently active in the Applied Research and Engineering unit include: NE Dry Bean Commission; Midwest Dairy Association; NE Department of Agriculture; Kimmel Foundation; the Defense-funded National Strategic Research Institute also at the University of Nebraska; and USDA.

Facilities

Within the last two years, the FPC moved to a new building known as the Food Innovation Center, the first building on the Nebraska Innovation Campus (NIC), a new research park being developed a nearby former state fair grounds.[179] The Food Innovation Center also includes related activities in the Departments of Food Science and Technology, Biological Systems Engineering, Nutrition and Health Sciences, Animal Science, and Mechanical and Materials Engineering. Companies will be offered residency in part of the space, effectively creating an incubator for larger, inward-recruitments to the research park.

This facility includes or provides access to the following elements:[180]

- Extrusion
- High-pressure processing

[174] See https://fpc.unl.edu/professional_development.
[175] See http://fpc.unl.edu/unl-craft-brewers-workshop.
[176] See http://fpc.unl.edu/science-safe-food.
[177] See https://fpm.unl.edu.
[178] See https://are.unl.edu.
[179] See https://innovate.unl.edu/food-innovation-center.
[180] See https://fpc.unl.edu/pilot_plants.

- Dairy [still operates from the main academic campus]
- Dehydration & drying
- Baking
- Confectionary
- Canning
- Filtration & separation
- Liquid processing (soups & sauces)
- Milling
- Vegetable processing
- Packaging
- Tortilla
- Environmental (shelf-life) chambers

The concept document for the facility previously reviewed by TEConomy states that the Food Innovation Center will help FPC continue its self-sufficient program of applied research, while adding champions for industrial interaction, and laying groundwork for multidisciplinary basic research aimed at the "food factory of the future." As part of this project, it will acquire equipment that is useful "transforming Nebraska-grown commodities and specialty crops into valuable food, feed, fuel and fiber products." The Food Innovation Center is expected to reach out to adjacent industries such as pet foods, biofuels, and pharmaceuticals (and includes 1,500 square feet set aside for future BSL 3 labs).

Partnerships

Research and Extension

In view of its place in the vision for the Food Innovation Center, the FPC places strong emphasis on partnering its non-tenured research faculty with departmental tenure-track faculty on applied research projects funded by industry or federal agencies.