



ENABLING AN INNOVATION-LED FUTURE FOR ARKANSAS:

University Research Competencies Aligned with Industry Growth Opportunities

Produced For: Arkansas Research Alliance
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ArkansasResearchAlliance



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PREFACE

The Arkansas Research Alliance (ARA) commissioned this study to show how our state’s combined scientific and engineering research strengths match with the global innovation demands of industry in Arkansas. Overall, the findings reveal a target-rich environment for industry to tap university research and, together, drive societal benefit and economic growth opportunities. Therein lies the key: together.

This project underscored that our first challenge is mutual awareness. University and federal researchers require access to a fuller awareness of the time-sensitive market pressures shaping Arkansas industries’ relentless pursuit to be innovative, stay ahead of the competition, and deliver value. In return, our private sector must be adroit in finding and engaging the state’s specialized areas of relevant research expertise and resources.

This report takes a giant leap toward overcoming this challenge and reframes it as an opportunity. It presents a detailed set of seven, sector-specific “growth opportunities” that emerge from a clear, evidence-based line-of-sight between research assets and industry innovation drivers and needs.

The growth opportunities draw on our state’s unique strengths and advantages. They are derived from a comprehensive examination of deep research competencies and leading industry clusters through the lens of quantitative standards on measures of performance, concentration, and investment. As important is the fact that this data was interrogated by leaders in academia, industry, and government, who added real-world context and meaning to the line-of-sight analysis. As a result, the report offers profiles on each growth opportunity to serve as useful tools in bridging this mutual understanding. It prioritizes target areas where Arkansas has the best chances of job creation, economic growth, and societal benefit.

ARA is looking ahead to expanding its impact and alignment with the state’s innovation and economic evolution. ARA plans to use these findings to guide its investments in programs. They also serve as the backbone for other statewide innovation initiatives, including building awareness of Arkansas’ unique strengths and recruiting and retaining talented knowledge workers in Arkansas.

We recognize, though, that unlocking the economic development potential of these growth opportunities requires a group effort and active public-private partnerships. Whether your lens on these targets is through academia, the private sector, non-profit organizations, or government, it is our collective responsibility to figure out ways to work and invest together. **Our goal is for you to see yourself in this report. We propose the following ways you might collaborate, for example:**

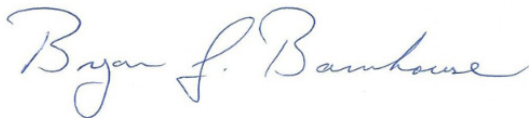
- **Companies and Industry Executives** should use this intelligence to build confidence in seeking Arkansas-based university research expertise and collaborations to complement their innovation strategies and sharpen their competitive edge.
- **Researchers/Academic Leadership** should use this report to orient and develop projects with Arkansas-based industry cluster and societal end-user challenges in mind.

- **Government and Public Officials** should use these findings as checkpoints for developing and endorsing policies to enable and support closer collaborations between research and market application to grow an even healthier statewide innovation ecosystem.

Since our ability to capitalize on these targets boils down to building relationships, ARA stands ready and united with you. Together, we can home in on these sweet spots where research has its highest and best use, where it can be inspired by businesses for not only the growth of our industry sectors but parlayed into meaningful outlets for Arkansans to employ their talent and gifts.

A special thank you goes to all who made the richness of this report possible. It starts with the ARA Board of Trustees and the Arkansas Department of Commerce/Arkansas Economic Development Commission, whose vision and funding enabled this undertaking. We are grateful for the members of the project advisory group who reflect Arkansas' leading industry clusters, research universities, only major federal lab, and economic development leadership. They accepted the challenge to guide the focus of the project to ensure we reached our objectives, provided feedback on findings and recommendations, and connected us with other key stakeholders. Our gratitude extends to those who participated in the 60 one-on-one and small group interviews. You were incredibly generous with insights to test, refine, and validate the findings. Our biggest thank you is reserved for those of you who are encountering this report for the first time and want to do something about it.

Much like this report, the technology- and innovation-led economic future of Arkansas is in your hands. As you see yourself in the following pages, know that you are essential to realizing that future and responsible for it. ARA is excited to join “together” with you in this worthy endeavor to fulfill the promise of these growth opportunities and enhance Arkansas’ competitiveness on a national and global scale.

A handwritten signature in blue ink that reads "Bryan J. Barnhouse". The signature is written in a cursive, flowing style.

Bryan J. Barnhouse
President & CEO
Arkansas Research Alliance



I. INTRODUCTION:

Revisiting the Context of Job-Creating Research in Arkansas

Each state has its unique industry drivers and growth opportunities in which it is best positioned to differentiate itself and build world-class, specialized areas of expertise. At the same time, each university has its own set of core competencies—based on those focus areas where there is demonstrated excellence and a critical mass of activity—in research, talent generation, and shared-use facilities. To maximize the potential for economic development impact, it is critical to identify and activate strategic areas that align a state’s research assets and competencies with the needs and opportunities of its industry innovation drivers—or what has been referred to in Arkansas as “job-creating” research.

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Identifying these strategic areas of alignment within a state between its universities and its industry drivers or clusters can be challenging. The opportunity set of technologies that university research can advance is enormous. Individual industries may have different capacity to tap university research as a competitive differentiator. In reality, each state has its own specific industry innovation drivers and areas of excellence across its university research activities through which it is able to differentiate itself and build specialized areas of expertise, thereby positioning itself as a global leader in commercialization and innovation-led development, or what is termed core technology competencies.

This strategic approach is very much in line with best-in-class efforts. As the Senior Vice Provost at the Georgia Institute of Technology (Georgia Tech), Dr. Stephen Cross, noted in explaining his university’s globally recognized efforts in concurrently advancing research and economic development impact:

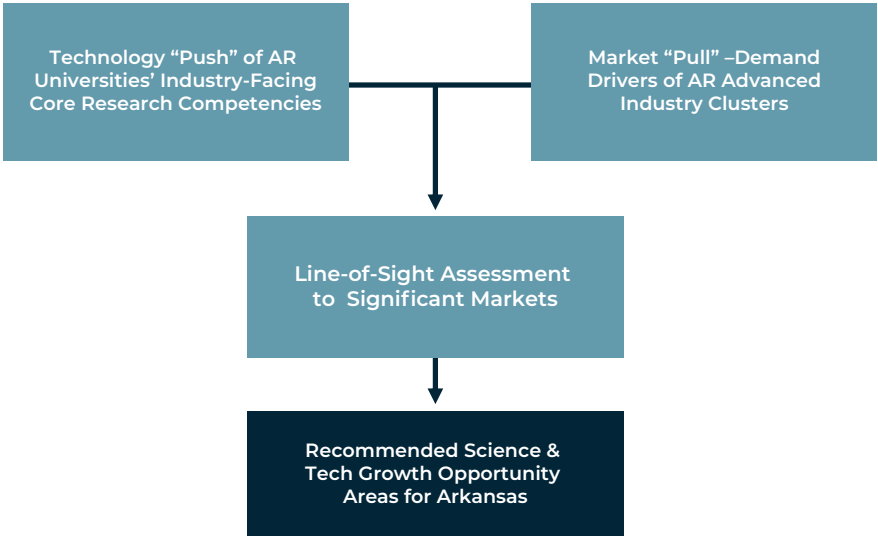
“Georgia Tech defined an industry facing research strategy focused both on leading-edge, use-inspired [university] research and economic development...Georgia Tech pursues a concurrent strategy centered on the core research areas...selected because they are appropriate aggregations of core university competencies represented in over 300 research centers and laboratories at Georgia Tech, their inter-disciplinary and trans-disciplinary nature, the alignment with strategic markets within the region, and the existence of industry partners interested in working with Georgia Tech.”¹

1 Stephen E. Cross, “Strategic Considerations in Leading an Innovation Ecosystem,” *Global Science and Technology Forum Journal of Business Review*, 2013, vol 2, no 3, 104–109.

In this focus on job-creating research, it is important to recognize that it is the translation of research to address specific industry and societal needs that often makes the difference in driving new economic growth. This focus on translational research requires breaking free of the traditional separation between basic and applied research and pursuing “use-inspired” research that identifies research problems to address based on specific industry and societal needs and seamlessly moves from discovery to application.

This strategic approach draws upon the “market pull” of industry innovation drivers found across Arkansas and their alignment with the “technology push” of innovation and technology capabilities, or core technology competencies, of universities and federal labs in the state. This alignment of market pull and technology push is termed a “line-of-sight” to growth opportunities (Figure 1). Linking innovation-led industry drivers and university core competencies requires an understanding of both sectors to identify innovation platforms that can advance economic development statewide. The results of applying this framework to Arkansas’ current research and industry landscape to identify the job-creating research opportunities of tomorrow are the subject of this report.

Figure 1. Depiction of Line-of-Sight Analysis to Identify Growth Opportunities



Source: TEconomy Partners, LLC.

This work builds on and updates a 2009 assessment undertaken by the Arkansas Research Alliance (ARA) that involved a detailed independent assessment of the core research strengths across Arkansas’ universities and government labs to identify opportunities for advancing job-creating research to help jumpstart and guide the strategic efforts and directions of ARA at its inception.² More than two decades later and faced with a dramatic evolution in the technology applications being deployed and the growth of new industry clusters and innovation assets in the state, it is important to undertake a refreshed assessment of how Arkansas’ university research capabilities have evolved and the new opportunities they can help drive in concert and aligned with the state’s industry innovation opportunities.

² Battelle Technology Partnership Practice, “Opportunities for Advancing Job-Creating Research in Arkansas,” April 2009 (available on ARA website).

RESEARCH MATTERS: ARA'S MISSION IN ADVANCING JOB-CREATING RESEARCH

The Arkansas Research Alliance (ARA) was formed in 2008 as an independent, non-profit, public-private partnership organization to meet new competitive challenges and to elevate a fundamental belief—Research Matters. ARA programs help chancellors and other academic leadership at the state's five major research universities recruit, recognize, and retain world-class scientific, technology, and engineering talent in strategic research focus areas. Additionally, ARA plays a lead role for the State of Arkansas in facilitating in-state collaborations with Arkansas' only national laboratory—the U.S. Food and Drug Administration's National Center for Toxicological Research (NCTR).³ A decade-and-a-half later, ARA has matured into a multi-faceted and integral organization leveraging university research and top talent to change the economic trajectory of Arkansas.

ARA's mission is to invest in strategic research talent recruitment, retention, and recognition to generate scientific and engineering breakthroughs that support statewide economic development. The organization's signature effort is the *ARA Scholars Program*, which enables ARA to partner with universities to recruit exceptional research talent and scientific leaders from outside of Arkansas. Its companion effort to recognize and retain talented research leaders already residing on Arkansas' five major research university campuses and at NCTR is through the *ARA Fellows Program*. This combined talent pool is funded via state grants and merged into the ARA Academy of Scholars and Fellows.

While ARA has generated significant impacts for Arkansas⁴, it recognizes there is more work to be done to advance the research growth and economic development momentum in the state. ARA saw the 2009 assessment as a guide and “North Star” for its investments and has a similar need for refreshed strategic intelligence. In this spirit, ARA has engaged TEconomy Partners, LLC (TEconomy) to undertake the analysis. TEconomy is a national leader in innovation-driven economic development consulting having an extensive track record in conducting rigorous and robust assessment studies of R&D assets and overall innovation ecosystems in numerous states, including the original 2009 assessment for ARA.

ARA has outlined the following project objectives and planned use of the study's findings as follows:

- » **To guide ARA investments** in Arkansas research scholars, fellows, and other programs.
- » **To serve as a foundation for statewide innovation initiatives**, such as the Arkansas Economic Development Commission's (AEDC) strategic planning efforts, the state's Science and Technology plan, university and college planning efforts, workforce development programs, and federal grant proposals.
- » **To build awareness** of Arkansas' unique strengths.
- » **To recruit and retain** innovators in Arkansas.

This report aims to meet these objectives by providing robust analysis that:

- Identifies a line-of-sight to growth opportunities for Arkansas, and
- Develops growth opportunity area profiles for Arkansas.

³ The six ARA partner institutions are: Arkansas State University, University of Arkansas, University of Arkansas at Little Rock, University of Arkansas at Pine Bluff, University of Arkansas for Medical Sciences (UAMS), and the National Center for Toxicological Research (NCTR).

⁴ TEconomy Partners, LLC, *Competing for Arkansas' Future: The Economic and Functional Impacts of the Arkansas Research Alliance*, August 2023.

Ultimately seven growth opportunity areas were identified for Arkansas through the line-of-sight assessment. These seven areas can be considered as those in which Arkansas is best positioned to compete in growing innovation-led market opportunities that can help sustain the state's leading industry clusters as well as advance emerging market opportunities in new industries of the future. The future for Arkansas is bright, with a path toward continued economic and innovation competitiveness and resilience illuminated by a unique set of growth opportunities.

The Economic and Functional Impacts of the Arkansas Research Alliance for the State

In 2023, TEconomy partnered with ARA to assess the organization's economic and functional, mission-based impacts for Arkansas.⁵ ARA Scholars and Fellows are generating impacts through research funding and by founding or co-founding companies based on the commercialization of their research. Key findings from the impact assessment include:

- Combined and accumulating over time, these activities directly employed 346 Arkansans in Fiscal Year 2023.
- The jobs and incomes generated by the Scholars and Fellows are high-quality and family-sustaining, with employees earning, on average, just over \$80,000 in total annual compensation.
- ARA has invested in programs to recruit and retain research talent since 2011—their research and startup activities and economic impacts accumulate over time, generating and supporting more than \$1.31 billion in total economic impact within the state.
- This economic activity has generated a cumulative state tax revenue contribution of \$26.1 million, including \$4.4 million in FY 2023.
- This amounts to a better than three-to-one return on the state's investment (ROI) to date—for every \$1.00 of state investment in ARA Academy member support to date, the state has received \$3.13 in tax revenues.

5 TEconomy Partners, Competing for Arkansas' Future: The Economic and Functional Impacts of the Arkansas Research Alliance, prepared for ARA, August 2023.



II. IDENTIFYING A LINE-OF-SIGHT TO GROWTH OPPORTUNITIES FOR ARKANSAS

In the face of ongoing technological innovation and disruption of existing industry business models, an assessment of innovation-led growth opportunities for Arkansas must be forward looking rather than retrospective. Traditional industry targeting analysis relies on examining in-depth trends and competitive position in industry activities that largely shed light on where an economy has been. *While helpful, this is not sufficient to understand the development opportunities that can grow a state's economy into the future in the face of ever-changing technology and market dynamics.* It is equally important to understand where an economy has the capacity to grow and leverage comparative advantage, which is informed by an analysis of core industry-facing technology competencies.

At the same time, growth opportunities must build on the foundation laid by existing core competencies and excellence present within the research and innovation assets of a state. As a result, the concept of core competencies is now widely understood as a critical factor by which industry advances competitive advantage. Gary Hamel and C.K. Prahalad in their landmark study, *Competing for the Future*, explain how a focus on core competencies can improve competitiveness:

*"To successfully compete for the future...requires top management to conceive of the company as a portfolio of core competencies rather than a portfolio of individual business units...core competencies are the gateways to future opportunities."*⁶

From a state economic development perspective, core competencies represent a "critical mass" of know-how found across industry, research universities, and federal labs that enable innovation and technology-based growth as well the translation of research to market applications. It is these core competencies that ultimately differentiate Arkansas and enable the state's existing industry clusters to remain competitive and well-positioned for future growth. It is these same core competencies that also enable Arkansas to position itself in emerging technology opportunities for new industries of the future.

As dictated by the focus on job-creating research that ARA has adopted, technology competencies must also be "industry-facing" to be relevant for economic development. While direct efforts by industry in innovation and research are naturally oriented towards industry use cases and end markets, not all university and federal lab research activities are oriented towards business uses. For research institutional efforts to be industry-facing, it requires that they be focused on use-inspired and applied research activities, offer strong commercialization potential, involve industry collaborations, or offer shared-use facilities and

6 Hamel and Prahalad, "Competing for the Future," Harvard Business Press, 1994, pg. 90 and 217.

capabilities that industry can leverage. Research in “basic” sciences and other non-industry-facing areas of focus still remains important to support foundational capabilities and advancements that subsequently lead to translational and commercialization opportunities, but are not the primary focus of this report.

The innovation-led growth opportunities in which Arkansas is best positioned to differentiate itself reflect the intersection of where the state excels in the “market pull” of innovation activities and growth trends of its existing industry clusters and the “technology push” of industry-facing core competencies to advance innovation and growth in the future. Market pull reflects the ever-present demand from industry for new innovations and technologies that enhance the ability to compete for market share across various sectors’ business activities or allow the industry to disrupt existing business models to enter into or create new markets. Similarly, technology push represents the advancement in scientific discovery and generation of new ideas that have the potential to be used for new applications within industry to drive financial benefits or improve competitive position. Where these two forces are able to meet and be effectively linked, competitive industry clusters are able to flourish, creating a feedback cycle between the translation of research to industry use and the reinvestment of subsequent wealth creation back into growing the research and innovation enterprise to fuel further translation and commercialization.

As depicted in Figure 2, identifying the areas where these linkages are possible involves analyzing a number of key indicators. Taken together, these can offer the line-of-sight to growing innovation-led market opportunities which can help sustain the vibrancy of Arkansas’ leading industry clusters as well as position the state to respond to market opportunities in new industries that evolve in the future.

Figure 2. Key Indicators and Analyses Leveraged for the Line-of-Sight Assessment of Arkansas’ Growth Opportunities



Source: TEconomy Partners, LLC.

Using the framework shown above, TEconomy conducted a line-of-sight assessment of forward-looking, innovation-led, growth opportunities for Arkansas that involved three steps:

- 1. TEconomy assessed Arkansas' core technology competencies across its university and federal lab activities to outline areas of technology push.** In this step, a variety of innovation databases were analyzed to provide insights into specific areas of technology and innovation strengths found in the state to develop insights based on:
 - In-depth analysis of thematic areas of specialization and critical mass in academic research activity by examining peer-reviewed research publications and investigator-initiated grants.
 - Research excellence and the presence of key centers, labs, and other institutes supporting industry-facing innovation and technology development.
 - Research investment activity highlighting where the state's institutions have been growing their research enterprise.
- 2. TEconomy assessed the market pull of innovation activities and growth trends of Arkansas' leading industry clusters.** The assessment of industry's market pull for innovation considered the current position and recent trends of leading industry clusters based on a broad set of measures of industry performance and innovation activities that included:
 - Examination of multiple facets of economic performance of the state's traded industry clusters using a variety of industry performance measures.
 - Identification of areas of active industry-led innovation through examination of indicators related to industry-led spending and investment, intellectual property generation, and other signals of innovative technology or market focus on the part of Arkansas companies.
- 3. TEconomy considered the alignment of the market pull of industry cluster performance and innovation activities and the technology push of core competencies that provide line-of-sight to innovation-led growth opportunities with high market potential.** This involved the synthesis of the analyses noted above in addition to 60 one-on-one or small group discussions with industry and university leaders and stakeholders in Arkansas on key areas of technology focus and opportunities supplemented with intelligence gathered from market research reports to identify how the state is best positioned in innovation-led growth opportunities.

Highlights of Assessment of Arkansas' Technology Push

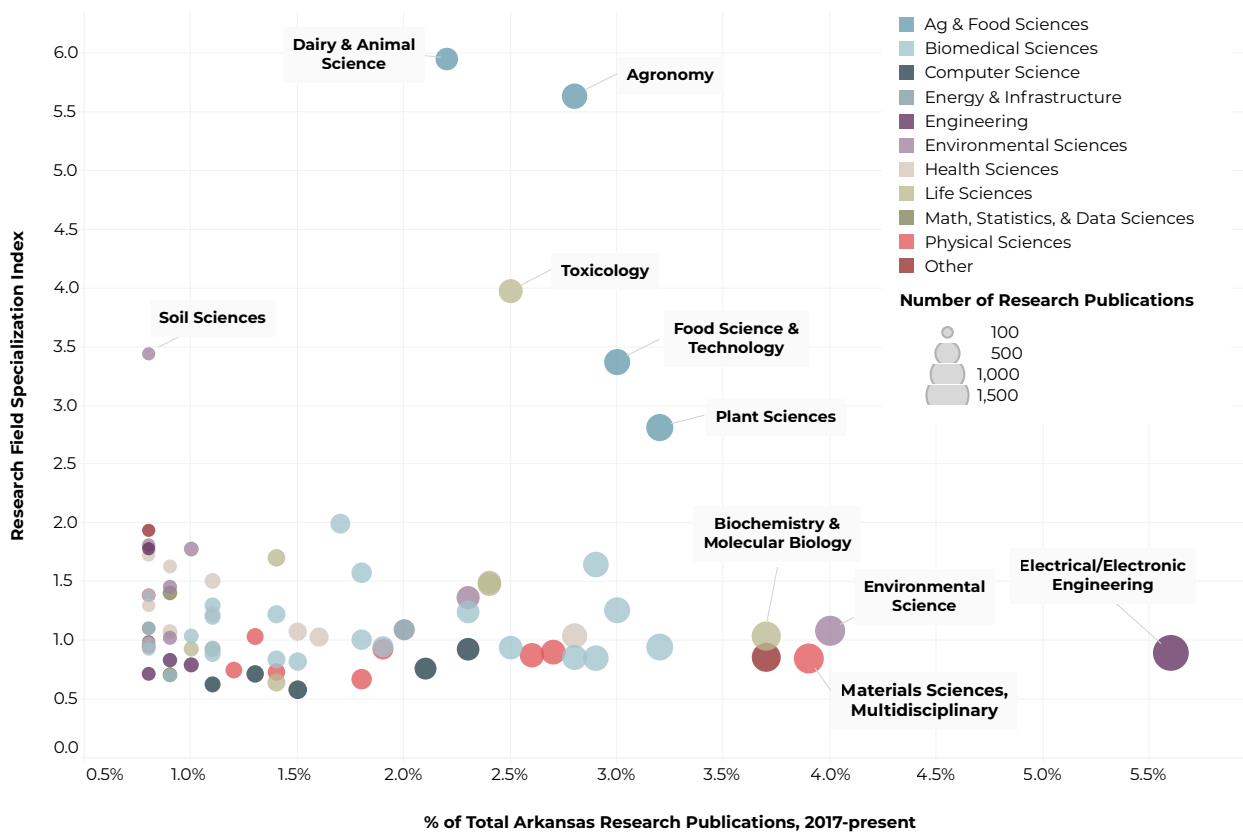
The foundation providing the innovation capital and thought leadership that fuels growth opportunities lies within Arkansas' universities, labs, and other innovation ecosystem assets and organizations. The state has a long history of research excellence that has matured into internationally recognized expertise in key scientific disciplines and is rooted in its thought leaders who manage the major centers and institutes of the state's research institutions.

To better understand the distinct specializations present across this base of research activity in recent years, several analyses were conducted that illuminate areas where Arkansas demonstrates scientific and technical excellence. A first, direct way is analyzing research publications being generated by authors at in-state research institutions that demonstrate a critical mass of activity that can support industry-facing opportunities. Arkansas research institutions generated more than 20,200 peer-reviewed publications in

major STEM and social sciences fields from 2017 through 2023, with leading scientific discipline areas demonstrating both a high volume of publications as well as a high level of specialization.⁷

As shown in Figure 3, Arkansas has a high volume of publication activity in electrical and electronic engineering, accounting for 5.6 percent of all publications activity during this period and indicative of significant research activity occurring in this space. Other high-volume activity areas include environmental science, biochemistry and molecular biology, and materials science. Additionally, there are numerous highly specialized areas in animal, plant, and food sciences, indicating the strength of the state's agricultural biosciences research base. Additionally, the state has a unique foundation of research activity in toxicology sciences centered around the activities and research focus at NCTR.

Figure 3. Profile of Leading Arkansas Research Publications Fields, 2017-2023



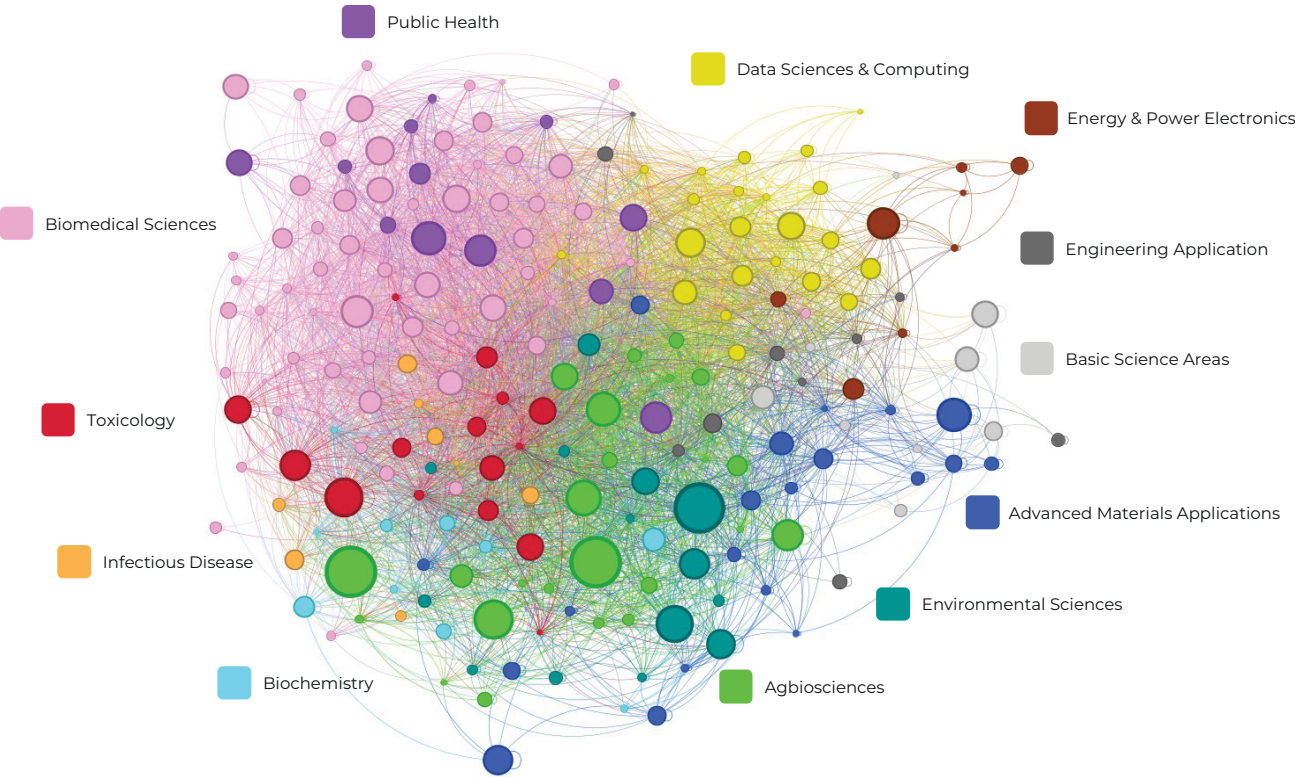
Note: a Research Field Specialization Index ≥ 1.2 indicates highly specialized publishing activity relative to national trends in this field. Source: TEconomy's analysis of Clarivate Web of Science publications data.

⁷ Research disciplines that are 20 percent or more concentrated within Arkansas' publishing activity patterns relative to national publishing activity over this time period are considered "specialized", indicating areas of potential competitive advantage and research leadership.

While research disciplines can be illustrative of the state’s critical mass in broad areas of science, today’s institutional research models emphasize multidisciplinary approaches that combine the expertise of multiple faculty across multiple research areas to advance translational work, a perspective not easily captured using simple publications counts by discipline. To examine the context of research publications activity through the lens of specific applied areas of impact, and to identify cross-cutting thematic areas of focus within publications, TEconomy analyzed the unstructured text content in publications records using natural language processing algorithms to identify detailed topic themes within and across the body of research activity.

Figure 4 shows the key themes identified within the topology of thematic areas of activity across research publications records with Arkansas authors, with topic areas of critical mass appearing as more tightly grouped clusters. A community detection algorithm used the structure of the text similarity of the topic contents to identify highly interrelated sets that comprise broad thematic communities, ultimately identifying 12 broad thematic groupings that highlight distinct areas of focus across the collective body of research publications activity.

Figure 4. Broad Thematic Communities of Research Competencies from Topic Modeling of Arkansas Research Publications



Source: TEconomy’s analysis of Clarivate Web of Science publications data.



Bryan J. Barnhouse, President and CEO of ARA, and David Peacock, President and CEO of Hytrol, a world leader in the design and manufacturing of material handling systems for a variety of industries. Hytrol is located in Jonesboro, Arkansas, and recently expanded manufacturing operations to Fort Smith, AR.

Within these 12 broad thematic areas, there are numerous distinct specializations present, and shown in Table 1. Several key narratives about the state's research core competencies emerge from the holistic picture of publications activity and include:

- The presence of a large body of research focused on clinical care applications and public health, which is indicative of a significant clinical and translational research focus in Arkansas' biomedical research institutions. At the same time, there is little presence of therapeutics innovations and applications.
- A distinct cluster of toxicology research is a unique specialization for Arkansas, with evidence of multidisciplinary themes in diagnostics and clinical applications.
- The presence of a distinct cluster of research in data sciences and computing applications reflects the evolution of the Arkansas research base over time in response to emerging advanced analytics technologies, with key applied research themes that reflect use cases in supply chain management, logistics optimization, energy systems and electronics management, and cyber security.
- A strong agbiosciences cluster focused on major state industries such as poultry and rice production is significantly interconnected with environmental sciences research themes, suggesting a focus on integrated agriculture and sustainability.
- Specialized themes in advanced materials demonstrate the presence of key nodes of activity for varied applications in electronic materials, membranes and nanomaterials, and interdisciplinary engineering applications in infrastructure materials.

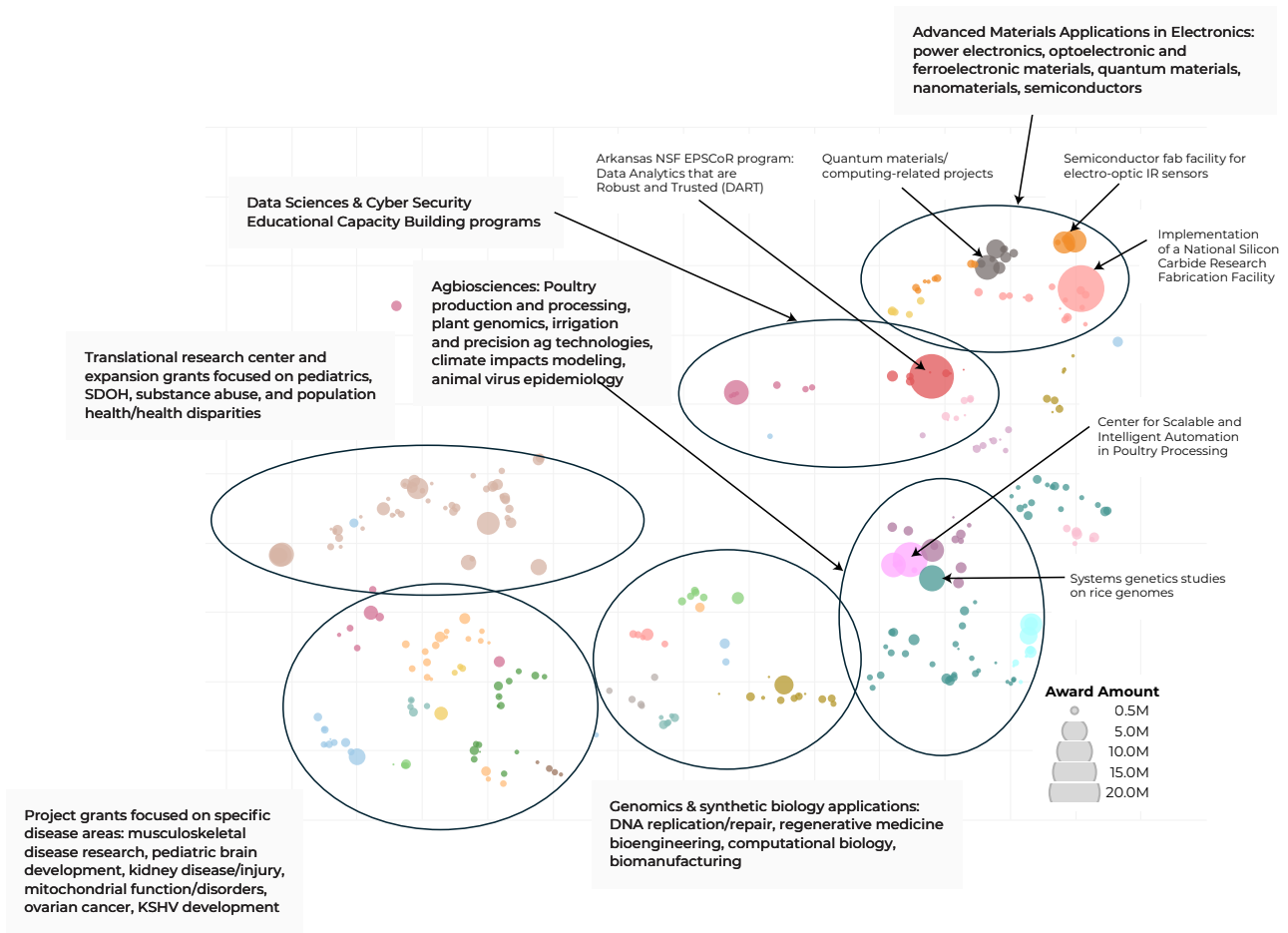
Table 1. Detailed Thematic Research Competencies from Topic Modeling of Arkansas Research Publications

BROAD THEMATIC COMMUNITY	EXAMPLES OF DETAILED TOPIC THEMES PRESENT WITHIN PUBLICATIONS ACTIVITY
Biomedical Sciences	<p>Activity is primarily clinically oriented, but with some areas of multidisciplinary research leveraging toxicology and pharmacokinetics. Distinct subclusters of activity include:</p> <ul style="list-style-type: none"> • Clinical care and diagnostic monitoring: brain activity monitoring, telemedicine and remote healthcare delivery. • Surgical and trauma procedures outcomes: acute stroke care, glaucoma/cataract surgery, pediatric trauma care, postoperative infection and fractures, healthcare-acquired infections. • Oncology: breast cancer, multiple myeloma, and thyroid cancer care, diagnostic imaging. • Neurochemistry: neuroprotective agents, methamphetamine effects on neurotransmitters, induced neurotoxicity, brain glycogen, impacts of cortisol levels.
Public Health	<p>Social determinants of health and health disparities, addiction behaviors and risk factors, COVID-19 response and vaccine hesitancy, public health surveillance and prevalence data gathering.</p>
Toxicology	<p>Genotoxicity testing, drug or disease-induced toxicities (cardiotoxicity, cachexia, liver injury), metabolomic mechanisms of cytotoxicity, drug pharmacokinetics and metabolomic profiles, radiation and environmental hazard exposure impacts.</p>
Infectious Disease	<p>Antibiotic resistance, zoonotic viruses, viral genomics, use of viral vectors for gene therapy and protein engineering.</p>
Biochemistry	<p>Glycoprotein compounds, electrochemical biosensors.</p>
Agbiosciences	<p>Agricultural production (poultry, rice, soybeans, berries), food safety and foodborne pathogens, sensory food perception by consumers, herbicide usage and resistance, plant and animal genomics, environmental impacts of farming.</p>
Environmental Sciences	<p>Ecological and forest modeling, climate change and precipitation patterns, soil properties and microbiome, biomass cycles and production, interactions with agriculture and human habitats.</p>
Data Sciences and Computing	<p>Distinct subclusters of activity include:</p> <ul style="list-style-type: none"> • Analytics applications: social network dynamics, encryption and cyber attack detection, cloud computing for manufacturing and supply chains, fleet and traffic management, trusted hardware configuration, smart grid management, network analytics and management. • Machine learning algorithms: deep learning models for image recognition/segmentation, key phrase learning and natural language processing applications, recommender systems.
Energy and Power Electronics	<p>Silicon carbide power electronics, hydrogen production/power systems, thermal performance of electronics, power module & circuit design, power converters.</p>
Engineering Applications	<p>Asphalt and concrete materials engineering and construction, soft robotics systems, crack detection and seismic modeling, virtual reality systems.</p>
Advanced Materials Applications	<p>Membrane filtration, nanoparticles/nanostructures, graphene and optoelectronic materials, capacitor and battery materials.</p>
Basic Science Areas	<p>Astrophysics, theoretical math.</p>

Source: TEconomy's analysis of Clarivate Web of Science publications data.

In addition to research publications, grant awards to Arkansas project leaders and principal investigators provide another indicator of activity in enabling capabilities anchored by state research institutions. TEconomy reviewed the landscape of current, active Arkansas researcher-initiated project grants from major federal institutions, including 191 National Science Foundation (NSF) awards totaling \$146.3 million in funding, 224 National Institutes of Health (NIH) awards totaling \$137.6 million in funding, 46 U.S. Department of Agriculture (USDA) awards totaling \$38.5 million in funding, and 29 Department of Defense (DoD) awards totaling \$31.2 million in funding. Figure 5 shows this set of research grant awards clustered by the similarity of text content describing the research project activity of the grants. This focus on current project grants aligns closely with the concept of the “R01-equivalent”⁸—individual projects driven by investigator-led research that are often aimed at advancing distinct areas of focus.

Figure 5. Research Themes in Current, Active Project Grants at Arkansas Institutions



Source: TEconomy’s analysis of NSF, NIH, DoD, USDA, and other federal grant awards data.

8 PI-initiated grants are often most indicative of where researchers develop and invest in core competencies at an institution. As per NIH’s definition of the R01 series grant purpose, they are designed “To support a discrete, specified, circumscribed project...in an area representing the investigator’s specific interest and competencies.”

As with publications activity, this analysis of Arkansas' researcher-led grants reveals several key narratives informing the state's core research competencies, including:

- Presence of a significant cluster of activity focused in translational biomedical research center funding, coordinating operations for pediatric clinical research, and public health disparities which indicate capabilities and infrastructure around population health and clinical research capabilities.
- A major cluster of activity focused in agbiosciences and food production in specialized areas where Arkansas has significant industry presence including poultry production, rice production, and integrated agriculture operations.
- A cluster of activity centered around the Arkansas NSF EPSCoR Data Analytics that are Robust and Trusted (DART) program that also includes efforts to advance data sciences and cyber security talent and educational capacity-building.
- A leading cluster of activity in advanced materials applications for high-performance electronics, highlighted by the major NSF grant for establishment of a National Silicon Carbide Research facility.

There are several other clusters of active grant award activity focused in disease area research for human biomedical applications as well as genomics and synthetic biology applications, demonstrating a broader set of emerging competencies in biomedical and clinical applications.

KEY INDUSTRY-FACING ARKANSAS CENTERS AND INSTITUTES ANCHORING RESEARCH EXCELLENCE

Among the varied assets across innovation ecosystems, university research centers play a vital role in anchoring and expanding core competencies, driving innovation, and serving as “aggregators” of industry engagement activity. These centers often serve as hubs of interdisciplinary collaboration, bringing together researchers, students, industry partners, and government agencies to tackle complex challenges and pursue specialized research leveraging unique facilities and equipment. They also offer opportunities for technology transfer, experiential learning, mentorship, and workforce development.

Numerous industry-facing university research centers and institutes were identified via both quantitative and qualitative analyses across Arkansas' institutions that play an especially important role in supporting core competencies for the state. These centers often represent key enablers of linkages to industry applications that form the basis for the line-of-sight to growth opportunities, and their connections are discussed in further detail within the subsequent profiles of each identified growth opportunity area. Many of the identified centers support multiple competencies and growth opportunity areas, and their specific capabilities and associated thought leadership relevant to individual opportunity areas are noted in the context of the technology push for each growth opportunity profile.



ARKANSAS RESEARCH ALLIANCE VISITS BIG RIVER STEEL: The science of steel has become a major industry in Northeast Arkansas. Big River Steel, located in Osceola, AR, is the world's first Flex Mill and is the only steel production facility in the world to be LEED (Leadership in Energy and Environmental Design) certified.

ARKANSAS' RECENT RESEARCH ACTIVITY REVEALS SEVERAL BROAD, CROSS-CUTTING, RESEARCH COMPETENCIES

The various themes identified across the key indicators of academic research activity, research excellence and supporting assets, and research investment ultimately yielded six broad-based, cross-cutting research capabilities where Arkansas has demonstrated a critical mass of excellence in core competencies. These research capabilities can be summarized as:

- **Data Science and Machine Learning Applications**, an area where the state has made significant strides in integrating modern analytics and machine learning approaches into its university research programs. This represents a major evolution of the state's research ecosystem since the 2009 assessment. Today, industry-facing applications are driving applied use of data sciences to address relevant industry issues in major traded sector clusters in areas such as supply chain management and transportation network optimization.
- **Cyber-Physical Systems and Security**, an emerging competency being rapidly scaled at universities, external organizations such as the Forge Institute, and through public-private partnerships such as the Arkansas Cyber Defense Alliance (ACDA). These efforts are increasingly active in driving applied research and talent development initiatives. This competency area is also embedded as a key focus within many of the applications being advanced through university research centers, particularly those associated with research themes leveraging connected systems and Internet of Things (IoT) technologies.

- **Electrical and Industrial Engineering**, an area where the state has a long history of excellence in high performance electronics and packaging as well as industrial engineering degree programs and centers whose activities are highly industry-facing. This competency supports both fundamental scientific advancements in electronics design and performance as well as applied research for the deployment and interoperability of systems in applications such as transportation, logistics, manufacturing, and aerospace and defense.
- **Materials Sciences**, an area where the state is home to key research centers focusing on specialized materials engineering applications such as surface engineering, membranes, nanosciences, and optoelectronic materials. Additionally, the state has a number of research capabilities advancing materials applications for the built environment, ranging from infrastructure materials like asphalt and concrete to sustainable materials and mass timber. This area is multifaceted with significant external research funding, but with more limited linkages to industry-facing applications within the state today.
- **Ag-Food Value Chain**, which is anchored by a strong agricultural Cooperative Extension program, a significant roster of plant and animal science centers of excellence, and deep food science research capabilities. The high level of specialization in research activity in fields across agricultural and food production in combination with newly funded initiatives aimed at integrative health and FoodTech, such as the Institute for Integrative and Innovative Research (I3R), makes this a core competency area with substantial critical mass for the state.
- **Clinical and Translational Research**, which is central to the research capabilities found at University of Arkansas for Medical Sciences (UAMS) in addition to other universities with thought leaders active in biomedical research engineering and materials sciences. This area is the focus of much of the funded research activity occurring at UAMS and supported by other research efforts at hospitals such as the Arkansas Children's Research Institute (ACRI), statewide initiatives such as the health information exchange led by the Arkansas Center for Health Improvement (ARCHI), and federal research labs led by NCTR. This competency area also demonstrates significant critical mass in the state and is being actively leveraged through translational research institutes and clinical research initiatives across several different disease modalities and healthcare delivery areas.

ARKANSAS' ECONOMY IS ANCHORED BY SPECIALIZED INDUSTRY CLUSTERS GENERATING MARKET PULL FOR INNOVATION

The second, simultaneous assessment focused on the market pull for innovation and science- and technology-driven solutions generated by the unique set of industry clusters and drivers of Arkansas' private sector economy. The market pull assessment analyzes the industry demand drivers for innovation by considering the position and recent performance of the state's leading traded sector industry clusters.

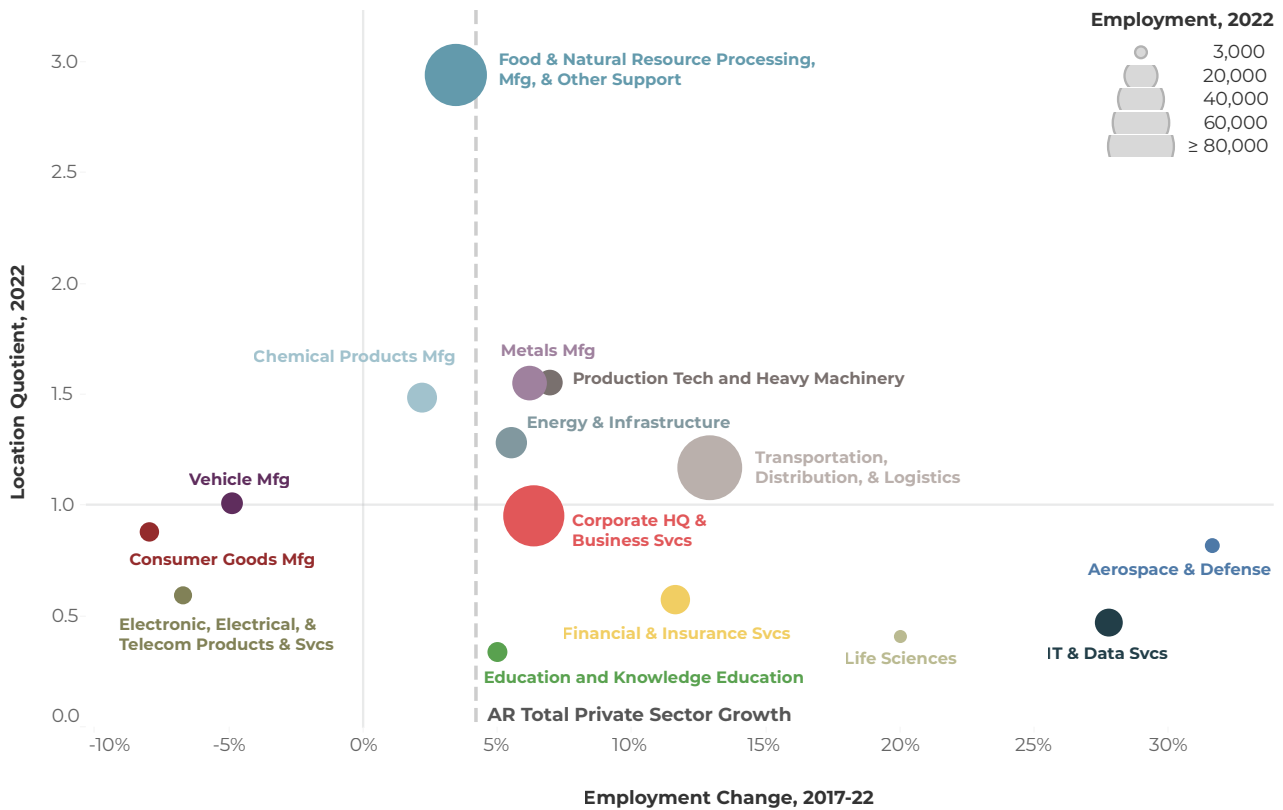
Traded sector industry clusters represent those industries that drive new wealth creation by exporting goods and services to those beyond state borders and therefore form the foundation for Arkansas' valued-added economic growth. In addition, the assessment includes important indicators of each industry's innovation stance—identifying thematic areas of industry-led and market-driven innovation.

An industry economic analysis was conducted as a key starting point, building a set of traded sector industry cluster concepts for Arkansas to understand areas of industrial strength and comparative advantage. Fifteen traded sector clusters were defined and assessed around three key employment-related variables to understand their performance and relative competitive position. These are plotted in the “bubble” chart in Figure 6 and include the relative employment size of the industry in Arkansas (represented by the size of the bubbles), the recent net growth rate for employment in each sector (plotted along the horizontal axis), and the industry's employment concentration relative to the national average, calculated as a location quotient (LQ) and plotted along the vertical axis. A LQ greater than 1.0 indicates an above-average employment concentration in the state relative to national averages. A LQ at or above 1.2—high on the vertical axis in the chart—indicates a significantly greater level of industry concentration that can be considered a “specialized” industry for Arkansas.

What stands out for Arkansas is the strong overall growth context of the clusters, with 12 of 15 positioned to the right side of the vertical axis, indicating net job growth in the state since 2017. Six clusters are positioned in the upper right quadrant of the graphic signaling their status as “star performers” for Arkansas—positioned as both an outsized or specialized concentration for the state as well as a growth sector. For Arkansas these span a highly specialized food and natural resource processing and manufacturing cluster; specialized and growing concentrations in manufacturing-intensive metals, chemicals, and production and heavy machinery clusters; a unique and differentiated strength in energy and infrastructure; as well as a large, fast-growing, and specialized transportation, distribution, and logistics or “TDL” cluster.

Several additional clusters are “emerging” in Arkansas as they have experienced job growth (in several cases at an especially rapid pace) but are not yet specialized in their employment concentrations. These emerging areas include tech-intensive clusters such as aerospace and defense, IT and data services, and life sciences, as well as double-digit growth in financial and insurance services.

Figure 6. Arkansas Traded Sector Industry Clusters—Employment Size, Relative Concentration (Location Quotient), and Employment Change, 2017-22



Source: TEconomy analysis of Lightcast employment data (Datarun 2023.3).

While this economic assessment of the traded sector clusters is extremely helpful for establishing a meaningful structure within which to identify a line-of-sight to growth opportunities, it does not represent an in-depth, customized cluster strategy for Arkansas. Therefore, it is important to complement this assessment by considering those “targeted” clusters identified by the State of Arkansas through AEDC’s economic development leadership as leading traded sector areas for development (Figure 7). Most of the state’s targeted clusters align or overlap well with and reinforce the strengths seen in the industry economic analysis.

Figure 7. Arkansas Economic Development Commission's Targeted Industry Clusters

- Aerospace & Defense
- Corporate & Shared Services
- Distribution & Logistics
- Firearms & Ammunition
- Food & Beverage
- Metals
- Technology
- Timber & Forest Products
- Transportation Equipment

Source: AEDC.

Turning to key gauges and indicators of industry innovation activities and the associated themes arising out of that activity in Arkansas, the analyses include examining patent applications and awards, angel and venture capital investments, and industrial R&D spending.

The analysis of patent applications and awards examined the corporate assignees and patent classes in which they are protecting their intellectual property. The assessment included more than 6,000 patent applications and awards combined over the period from 2017 through mid-2023 associated with at least one Arkansas inventor. Leading companies and the innovation focus of their respective patent activity are presented in Table 2. Highlights and key themes include:

- Walmart accounts for nearly 41 percent of all patent records invented in Arkansas over this period and has a vast patent portfolio that includes a wide range of supply chain, sales, inventory, and consumer analytics applications, as well as other technologies spanning:
 - Digital inventory and product management systems, digital supply chain, and product sales analytics.
 - Customer attribute and segmentation analytics, digital storefront and purchase processing systems.
 - Payment systems and protocols for mobile, point of sale, and transaction processing.
 - Consumer data set creation, household identification and purchasing pattern association, transaction tagging and linking.
 - Autonomous ground vehicles and drones for delivery, item retrieval, storage facility maintenance and surveillance.
- Life science-related patents awarded to the University of Arkansas System spanning agricultural and biomedical application areas; to UAMS via its Bioventures commercialization initiative in diagnostics and therapeutic compounds and biomaterials; and to medical device manufacturers including Tenjin and General Electric.
- Agbioscience themed innovation by companies such as Syngenta, Bayer Crop Science (formerly Monsanto), Mertec, BASF, and by ASU.
- Food safety and processing related innovation by Safe Foods Corporation and Tyson Foods.
- And additional areas including power electronics, and IT and consumer data profiling.

Table 2. Leading Arkansas Assignees in Patenting Activity, 2017 through Mid-2023

PRIMARY PATENT ASSIGNEE	ASSIGNEE INNOVATION FOCUS IN PATENTING	PATENTS APPLICATI-ONS	PATENT AWARDS	TOTAL PATENT RECORDS
Walmart	Wide variety of supply chain, sales, inventory, and consumer analytics applications	1,573	1,011	2,584
University of Arkansas System	Wide variety of ag, biomedical, and materials applications	165	173	338
Bioventures LLC (UAMS)	Diagnostics, therapeutic compounds, & biomaterials	48	51	99
Rheem Manufacturing Company	Heating, cooling, and associated compressor/distributor systems	46	44	90
Molex	Cables, circuits, connectors, & other electronics components	30	50	80
Snap-on Incorporated	Self-calibrating & automated tool control devices	35	42	77
Syngenta Participations Ag	Soybean gene clusters & cultivars	15	46	61
First Orion Corp	Call traffic and content data monitoring for mobile devices	25	31	56
Perfectvision Manufacturing Inc	Coaxial cables & connectors	11	34	45
Cree Inc.	High power/voltage modules and electronic components	21	22	43
Safe Foods Corporation	Antimicrobial compounds and application systems	23	19	42
Pruitt Tool & Supply Co	Pressure drilling tools & components		40	40
Tyson Foods Inc.	Poultry production and processing systems	9	30	39
Monsanto Technology	Hybrid soybean varieties	13	26	39
Roku Inc.	Management of digital content streaming, user identification/access	14	21	35
Innovative Logistics Inc.	Moveable platforms and cross-dock management systems for freight	20	13	33

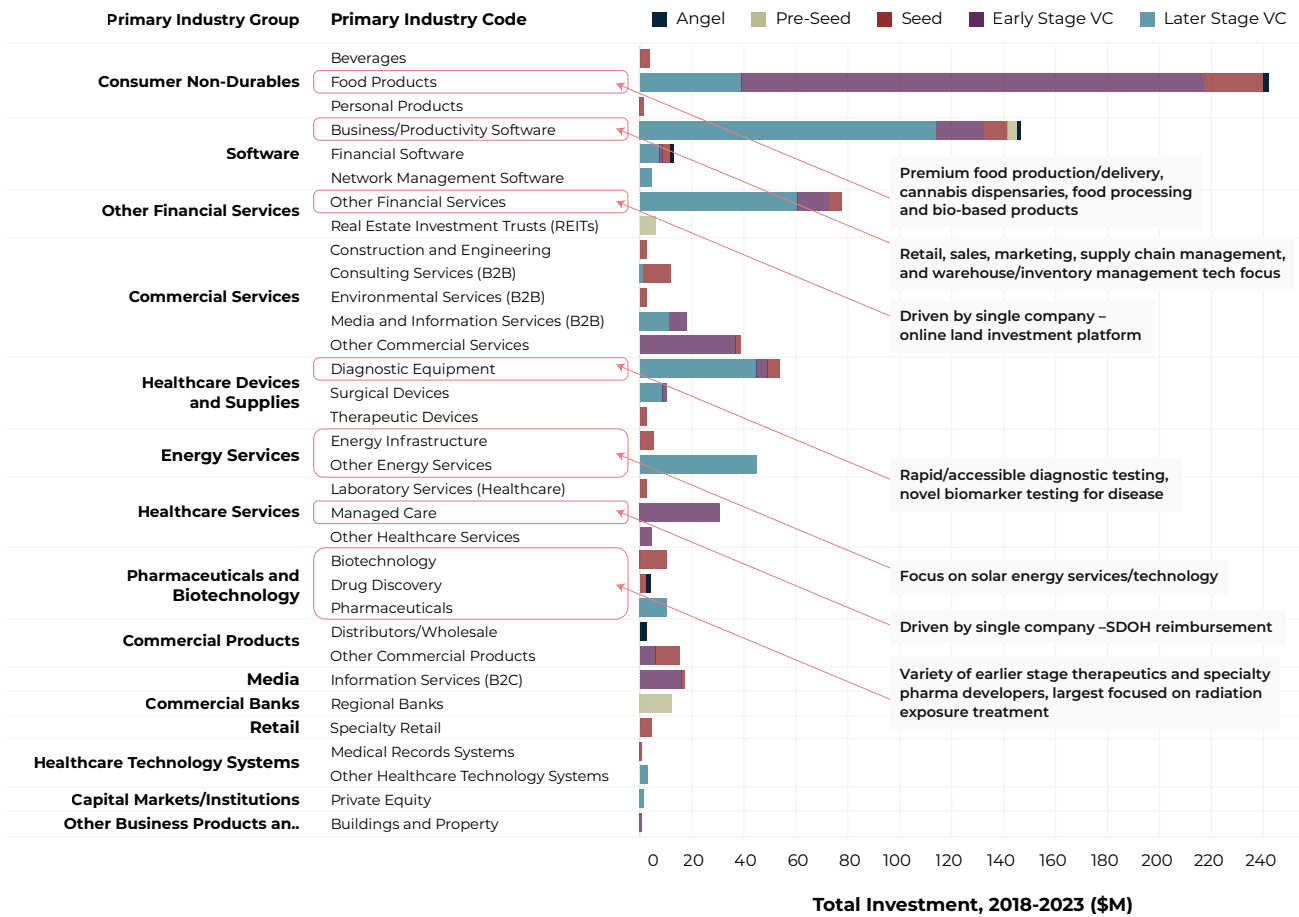
PRIMARY PATENT ASSIGNEE	ASSIGNEE INNOVATION FOCUS IN PATENTING	PATENTS APPLICATI-ONS	PATENT AWARDS	TOTAL PATENT RECORDS
IBM Corporation	Network connection/switching management, location determination	8	24	32
Mertec LLC	Novel soybean varieties	8	23	31
BASF Agricultural Solutions Seed US	Novel soybean varieties	22	7	29
Acxiom Corporation	Data collection, tagging, and secure architectures	13	16	29
Tenjin LLC	Percussive surgical devices & implant placement systems	10	15	25
Regal Beloit America Inc.	Heating systems & associated electronic controllers	10	14	24
Duke Technologies LLC	Hydroprocessing & pyrolysis reactors	11	13	24
Commscope Technologies	Cable hangers & mounting systems	11	13	24
Arkansas State University	Plant genomics, antimicrobial compounds	8	15	23
Liveramp Inc.	Data watermarking & fingerprinting	9	13	22
L&P Property Management Company	Foam materials for bedding	12	9	21
General Electric Company	Biomedical ultrasound imaging	11	10	21
Total, all Arkansas-invented Patents		3,233	3,126	6,359

Source: TEconomy's analysis of USPTO data, retrieved via Derwent Innovation.

Venture capital and angel investments in Arkansas companies rose significantly in both 2021 and 2022 to reach more than \$276 million in 2022 across 36 deals. The investment totals and segments presented in Figure 8 represent cumulative amounts for Arkansas during the 2018 through 2023 period and serve to highlight key areas of emerging, high-growth companies and concentrated investments.

Areas that stand out for Arkansas during this 6-year period include food products, software companies with a focus in retail and supply chain management technology solutions, financial services, and some emerging areas of life sciences including diagnostic testing. While investment totals have been rising and offer signals of key emerging companies, one must be careful reading into leading areas for Arkansas as they often are driven by outsized investment deals in just one or two emerging companies.

Figure 8. Emerging Market Focus Areas from Recent VC Investment Activity in Arkansas Companies, Cumulative Investment Totals, 2018-23 (\$ in Millions)



Source: TEconomy's analysis of Pitchbook venture capital data.

The third analysis of industry-led innovation activity examines levels and trends regarding industrial R&D expenditures that occur in Arkansas. Unfortunately, these federal survey data lag and are currently available only through 2020. Still, the data provide useful insights of high-level industrial spending in R&D and direct signals regarding the innovation stance of state industries. Table 3 shows the leading areas of industrial R&D for Arkansas, with food and beverage manufacturing the single-largest totals, and other significant totals accruing in IT sectors including data processing and software, as well as in machinery, chemicals, and electronics manufacturing.

Table 3. R&D Spending by Leading Arkansas Industry Sectors (those at \$5 Million or More in Expenditures), 2020

DETAILED INDUSTRY CLUSTER	2020 INDUSTRY R&D (\$M)	SHARE OF AR 2020 INDUSTRY R&D TOTAL	2020 R&D CONCENTRATION (LQ)	ARKANSAS CHANGE, 2017-2020	U.S. CHANGE, 2017-2020
All Industries Total	\$360	100%		-18.6%	37.5%
Food & Beverage Manufacturing	\$45	12.5%	11.69	-18.2%	11.9%
Data Processing, Hosting, & Related Services	\$40	11.1%	1.26	-63.30%	156.3%
Machinery Manufacturing	\$37	10.3%	3.18	236.4%	23.0%
Chemicals Manufacturing	\$35	9.7%	0.51	-16.7%	41.3%
Computer & Electronic Products Manufacturing	\$32	8.9%	0.47	18.5%	26.5%
Software Publishing	\$26	7.2%	0.98	73.3%	3.8%
Transportation Equipment Manufacturing	\$24	6.7%	1.03	-20.0%	-12.7%
Paper Products Manufacturing	\$19	5.3%	26.54	-76.8%	-28.3%
Computer Systems Design & Related Services	\$18	5.0%	1.63	157.1%	22.5%
Medical Equipment & Supplies Manufacturing	\$9	2.5%	0.73	125.0%	19.4%
Fabricated Metal Products Manufacturing	\$8	2.2%	3.11	300.0%	58.9%
Plastics and Rubber Products Manufacturing	\$7	1.9%	3.48	0.0%	-28.3%
Primary Metals Manufacturing	\$6	1.7%	9.77	100.0%	7.3%

Source: TEconomy's analysis of NSF Business R&D and Innovation Survey (BRDIS).

Arkansas' 15 traded industry clusters were analyzed across indicators that examined their employment-driven industry position, state targeting status, and innovation stance (Table 4). **Arkansas industry clusters that indicated strong or emerging positions across all, or nearly all, elements of the assessment include:**

- Food and natural resource processing and manufacturing
- IT and data services
- Life sciences
- Production technology and heavy machinery, and
- Transportation, distribution, and logistics.

While these clusters are not the only ones that are ripe for forward-looking, innovation-led, growth opportunities for Arkansas, they do represent those that are well primed for future growth—they have been growing, largely outpacing national growth, have large and/or emerging footprints in the state today, and are leading forward-looking innovation activities.

Table 4. Summary of Arkansas Industry Cluster Activity Across Indicators of Industrial Innovation, Specialization, and Growth

● = strong presence of traded sector cluster, ○ = some presence of traded sector cluster

TRADED INDUSTRY SECTORS	Leading Industry Position*	AEDC Target Industry with Existing Anchor Companies	Evidence of Emerging Companies in VC Investment & SBIR Awards	Evidence of Significant Shares of Industrial R&D Spending	Evidence of Significant IP Generation Activity
Aerospace & Defense	○	●		●	
Chemical Products Manufacturing	●	●			
Consumer Goods Manufacturing					
Corporate HQ & Business Services		●			
Education and Knowledge Creation					
Electronic, Electrical, & Telecomms Products & Svcs			○	●	●
Energy & Infrastructure	●		●		
Financial & Insurance Services	○		○		
Food & Natural Resource Processing, Mfg, & Other Support	●	●	●	●	●
IT & Data Services	○	●	●	●	●
Life Sciences	○		●	●	○
Metals Manufacturing	●	●		○	
Production Tech and Heavy Machinery	●	●		●	●
Transportation, Dist., & Logistics	○	●	●		●
Vehicle Manufacturing		●			●

*Considers measures of employment size, recent growth in Arkansas relative to the U.S., and relative employment concentration/specialization in the state relative to national averages (LQs).
Source: TEconomy's analyses.

ARKANSAS' GROWTH OPPORTUNITIES THAT EMERGE FROM LINE-OF-SIGHT ANALYSIS

The detailed quantitative technology push and market pull assessments identified preliminary areas of growth opportunity for Arkansas. However, the retrospective leaning quantitative analyses are not sufficient to understand forward-looking investments and strategic priorities. To finalize the growth opportunity areas, guidance from industry, academia, economic development, and other innovation ecosystem thought leaders was sought. This input was gathered via two key qualitative approaches:

These seven growth opportunity areas can be considered those in which Arkansas is best positioned to compete in growing innovation-led market opportunities that can help sustain the state's leading industry clusters as well as advance emerging market opportunities in new industries of the future.

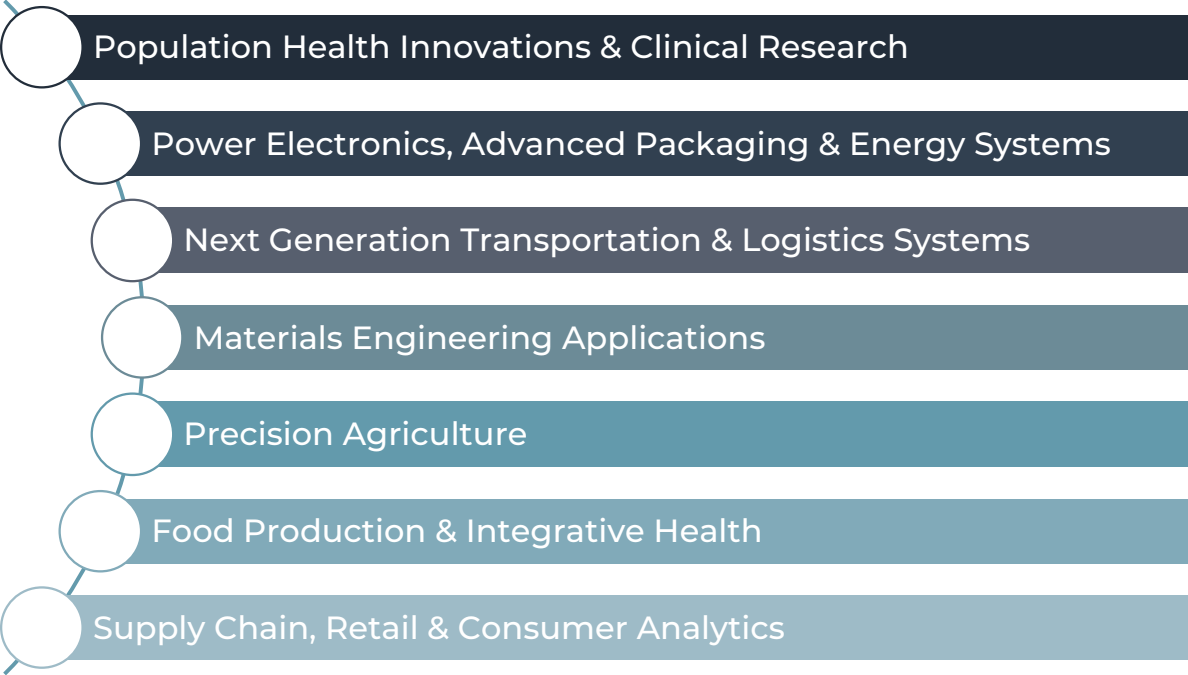
- **Guidance from a 17-member Project Advisory Committee**, with members strategically selected to reflect Arkansas' leading industry clusters, its research universities, its federal lab, and its economic development leadership. Committee meetings and one-on-one interview discussions were held to ensure appropriate feedback and guidance.
- **One-on-one or small group interviews with 60 state leaders**, representing industry and innovation ecosystem leaders in market or research areas relevant to the growth opportunity areas considered.

In some cases, the qualitative input and feedback confirmed initial recommended growth opportunity areas, and in others it helped to further refine or alter the area to better reflect present realities and planned future investments. Each area has been informed by intelligence gathered from market research reports to verify its future growth potential and to understand key drivers and future dynamics.

Ultimately, seven growth opportunity areas were identified for Arkansas through the line-of-sight assessment (Figure 9). These seven areas can be considered those in which Arkansas is best positioned to compete in growing, innovation-led, market opportunities that can help sustain the state's leading industry clusters as well as advance emerging market opportunities in new industries of the future.

These growth opportunities are strategic in building upon the technology push of innovation activities and growth trends of Arkansas' existing research core competencies and the investments that ARA has helped to make in advancing the state's significant base of science and technology funding and talent. At the same time, these growth opportunities are forward-looking by aligning the technology push with the market pull of industry-facing core competencies where Arkansas has the know-how to advance innovation in growth-oriented markets.

Figure 9. Identified Innovation-Led Growth Opportunity Areas for Arkansas



Source: TEconomy's analyses.



III. INNOVATION-LED GROWTH OPPORTUNITY AREA PROFILES

This section of the report presents a profile for each of the seven innovation-led growth opportunities identified for Arkansas. The profiles detail the line-of-sight assessment and explain the innovation context and how it relates to Arkansas' ongoing activities.

The profiles are organized to provide the following intelligence gathered for each opportunity area:

- An explanation of the targeted opportunity as an area of innovation and the key technologies that support it.
- An explanation of why this opportunity is a fit for Arkansas in the context of the market pull of emerging or existing industry clusters and the technology push of core technology competencies.

Arkansas' Research Core Competencies Provide Multifaceted Support for Growth Opportunities

Each of the seven identified growth opportunities leverage one or more of the broad research core competencies identified in the technology push assessment. As illustrated in the following diagram, these competencies provide cross-cutting support for growth areas either by directly enabling the scientific discovery and translational research that fuels industry-facing applications or by supporting the growth area with complementary expertise.

Broad-based, Crosscutting Research Competencies	Population Health Innovations & Clinical Research	Power Electronics, Advanced Packaging, & Energy Systems	Next Generation Transportation & Logistics Systems	Materials Engineering Applications	Precision Agriculture	Food Production & Integrative Health	Supply Chain, Retail, & Consumer Analytics
Data Sciences & Machine Learning Applications							
Cyber-Physical Systems & Security							
Electrical & Industrial Engineering							
Materials Sciences							
Ag-Food Value Chain							
Clinical & Translational Research							

Critical enabling research competency
 Supporting research competency

POPULATION HEALTH INNOVATIONS AND CLINICAL RESEARCH

What is the opportunity?

The concept of population health is expansive and encompasses the health outcomes and well-being of entire demographics of people, including the health disparities across demographic groups. It emphasizes a holistic approach to health that considers social, economic, environmental, and behavioral determinants of health, in addition to medical care. The ecosystem of institutions and actors that make up the population health landscape consists of various components working together to improve clinical outcomes and address health disparities across populations, ranging from healthcare providers, public health agencies, community organizations, policymakers, researchers, and healthcare solutions companies.

The best way to conceive of the pathway for innovations in population health is as an adaptive system that knits together, through feedback loops, several discrete components, including:

- The overall healthcare system involving healthcare providers, patients, underserved population groups, community groups, and insurers.
- An enabling infrastructure of healthcare data exchange and health analytics.
- Research assets found in the state that can drive innovations leading to new health products and solutions, new venture startups, and industry partnerships.

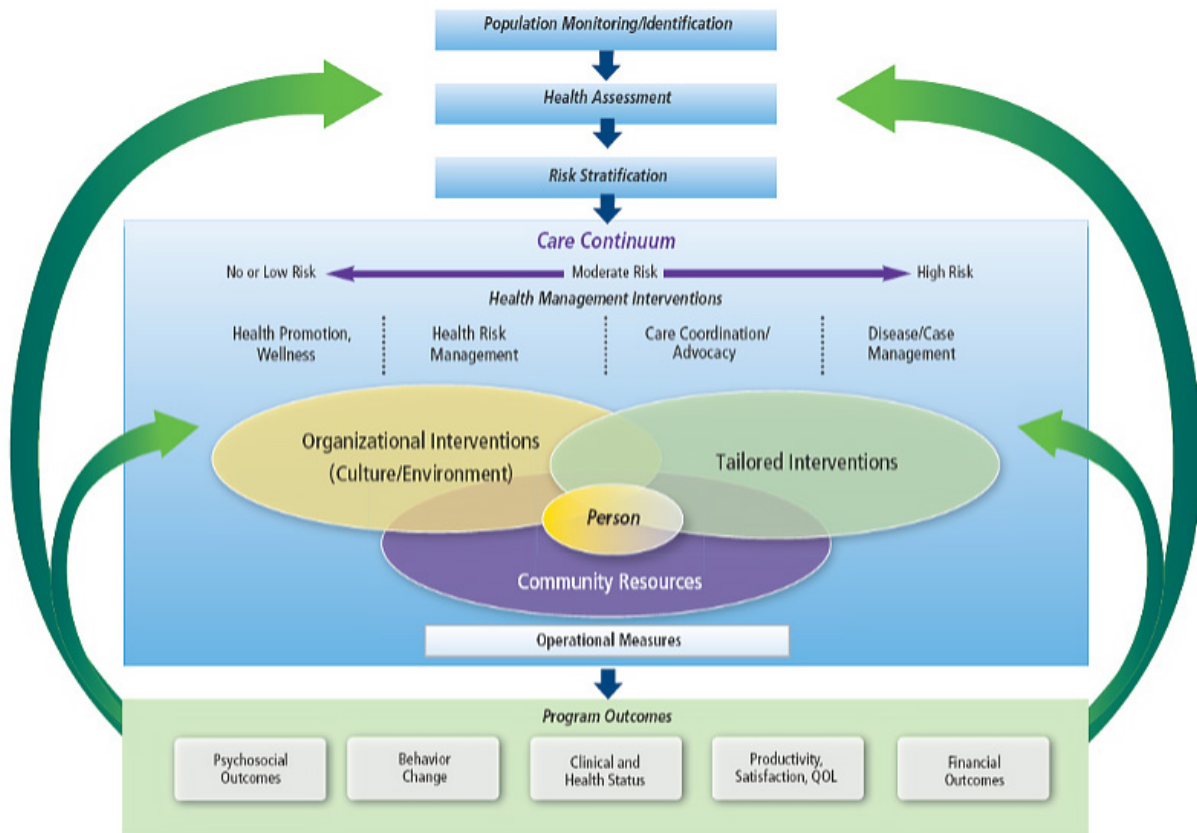
The connective “tissue” for this value creation system is the ability to advance the enabling infrastructure for data exchange and health analytics. Without this component, Arkansas will be limited in its ability to guide new solutions generated by applied research activities to ultimately improve healthcare delivery. The infrastructure for data exchange and health analytics provides insights into costs, risks, and patient outcomes that improved healthcare depends upon.

Figure 10 illustrates an example of the “feedback cycle” of a well-functioning population health ecosystem. Leveraging existing clinical and population health infrastructure along with clinical and translational research drives clinical deployment and outcomes across the care continuum, which in turn drives the generation of further data and insights that can be used to iteratively drive innovation and improvement in new clinical research efforts.



Dr. Alan Tackett leads a cutting-edge proteomics operation at the University of Arkansas for Medical Sciences. This proteomics resource serves the entire United States, impacting the ability of researchers to better understand and develop novel therapies for human disease.

Figure 10. Example of a Population Health Management Framework Generating Positive Feedback Cycles



Source: Population Health Alliance PHM Conceptual Framework, 2010.

Clinical research is a key enabler for advancing successful innovations of population health interventions. A strong base of clinical research within healthcare delivery, educational, and scientific discovery institutions plays a vital role in providing the evidence for preventive interventions, treatment strategies, and health promotion initiatives aimed at improving outcomes across entire populations.

Furthermore, clinical research activity contributes to the development and validation of clinical diagnostics tools and technologies that enable accurate and timely disease detection, diagnosis, and monitoring. Leveraging clinical research infrastructure, researchers can assess the sensitivity, specificity, and reliability of diagnostic tests, imaging modalities, and molecular assays, ensuring their effectiveness in clinical practice. In turn, translating these scientific discoveries into clinically actionable insights supports the implementation of personalized diagnostic and treatment strategies that improve patient outcomes and enhance healthcare delivery across the entire population.

For Arkansas, significant health disparities exist amongst the resident populations of the state that stand to benefit significantly from the deployment of clinical research infrastructure to advance population health innovations. Importantly, there are also significant commercialization and technological advancement opportunities that are enabled by a high-functioning population health ecosystem that provide economic benefits beyond improvements to patient quality of life.

Within the population health ecosystem, a number of technologies enable various components of clinical deployment and the flow of information, including areas such as:

- **Digital Health Platforms**, including elements such as electronic health records (EHRs), patient portals, and health information exchanges (HIEs).
- **Mobile Health (mHealth), Telehealth, and Telemedicine**, including technologies such as video conferencing platforms, remote patient monitoring devices, and mobile health applications.
- **Wearable and Connected Devices**, including consumer wearables, such as fitness trackers, as well as other wearable medical devices and biosensors able to operate remotely in the home or other alternative care environments.
- **Precision Medicine and “Multi-omics” Diagnostic Platforms**, including various genomics, metabolomics, and other biomarker-based diagnostics able to gather personalized healthcare information that can be used to analyze individual biomarker variations.
- **Healthcare Data Management and Interoperability Platforms**, including harmonized data “lakes” of patient interactions with various healthcare institutions in addition to interoperability within clinical environments across various devices, patient records, and testing platforms that a patient may interact with during a healthcare visit.

As a result, despite not primarily serving a traded sector industry in Arkansas, this growth opportunity has the potential to be a powerful driver of economic impact across several dimensions: cost savings to healthcare systems and the state through improved health outcomes, commercialization and testing of new healthcare monitoring and delivery technologies that can build out new industry clusters, attraction and buildout of clinical infrastructure that supports industry partners and further external research

investment, and improvements to the state's quality of life that enhances the state's ability to attract and retain workers across all other industries.

Key Market Forces Driving Growth

Broad-based population health management represents an issue that every state will continue to face in the coming decades, with implications that stretch beyond economic development to overall quality of life as well as a state's fiscal health given the significance of rising healthcare costs on state budgets. At the same time, it is more critical than ever to link advances in population health involving basic, translational, and clinical research to commercialization opportunities as regions and states compete for external federal, philanthropic, and industry research funding, seek to enhance their biomedical startup and venture capital ecosystem, and attract industry site locations in high value-added industry sectors like medical devices and drug development. Further complicating these dynamics is a complex regulatory and reimbursement landscape that imposes specific constraints on the operations of healthcare institutions and commercialization potential of new healthcare innovations.

Amidst the interplay of these dynamics, there are several broader market forces and challenges driving the growth of population health approaches and key enabling technologies, including:

- **Escalating healthcare costs and public spending on healthcare** which is driving the adoption of population health approaches that aim to reduce healthcare spending by focusing on preventive care, chronic disease management, and addressing social determinants of health.
- **Aging populations and the increasing prevalence of chronic diseases** are driving the need for new healthcare approaches that focus on managing chronic conditions, preventing complications, and enabling proactive interventions to reduce intensive utilization of healthcare resources.
- **The shift toward value-based care and alternative payment models** has incentivized healthcare providers to focus on improving health outcomes, reducing readmissions and complications, and addressing patient satisfaction in new ways. Population health technologies enable providers to better track and manage their patients in order to meet care quality and patient engagement metrics and better segment patient populations based on risk and the need for targeted interventions.

Growth Markets for Population Health Innovations and Clinical Research

- Estimated \$20 billion U.S. market size for precision medicine solutions in 2023, Compound Annual Growth Rate (CAGR) of 13.6 percent through 2028.
- Estimated \$17.7 billion U.S. market size for patient monitoring devices in 2023, CAGR of 9 percent through 2027.
- Estimated \$16.8 billion U.S. market size for mobile health technologies in 2021, CAGR of 32.1 percent through 2026.
- Estimated \$29.6 billion North American market size for clinical diagnostics in 2023, CAGR of 6.3 percent through 2028.

Source: BCC Research.

- **Rising consumer demand for personalized healthcare**, both in preventative care as well as for management of acute and chronic disease, has created demand for technologies that can proactively address patient concerns as well as biometric monitoring via wearables or other devices that enable individuals to track their own health metrics, monitor chronic conditions, and better collaboratively manage their care with providers. Rising usage of digital health platforms and mobile apps that access individual healthcare utilization data are also generating demand for digital health infrastructure to support comprehensive access to patient information across various healthcare system interactions.
- **Advancements in digital health and incorporation of advanced analytics approaches into healthcare workflows** require significant population health infrastructure able to identify, collect, characterize, and synthesize vast amounts of disparate sources of patient information. As new predictive machine learning technologies are integrated into clinical environments, new clinical decision support platforms will need to be continuously improved and refined through collection and integration of health outcomes data for individual patients as well as other metrics about healthcare utilization and preventative care. At the same time, significant advancement in the ability to monitor patients in real-time as well as incorporate large amounts of patient biomarker data will continue to drive the need for comprehensive digital health platforms that allow population level insights into segmentation and risk stratification.
- **The management of federal regulations, including compliance with federal HIPAA (health information) requirements, across providers** represents a significant challenge for implementing statewide population health solutions. Population health management links a broad spectrum of distinct providers who may or may not be otherwise jointly owned or affiliated. This type of proactive clinical management creates potential legal and regulatory exposures that healthcare providers need to address.
- **Population health solutions face significant challenges in reimbursement and financing models**, especially for complex molecular diagnostics. Even after the success of molecular testing for COVID-19, the process for getting reimbursed for many molecular tests is viewed as arduous, adversarial and uncertain for laboratory test providers, often requiring extensive documentation of the medical necessity of the tests. The concern by insurers and government payors is that the uptick in molecular testing may be overused and they are requiring better evidence involving significant documentation of the clinical utility of those tests. Ultimately, laboratories may be caught in the middle between having to run them at the request of providers with the possibility that they may not get reimbursed by insurers.

Why Arkansas?

Arkansas has an opportunity to be a national leader in advancing innovations in population health because of its strengths in the enabling infrastructure of healthcare data exchange and health analytics, combined with a strong emphasis on clinical research at UAMS and active efforts underway in digital health innovations by healthcare providers and payors. The market pull for population health is also quite strong given the significant health disparities Arkansas faces, especially in its rural communities. The opportunity that stands out for Arkansas is to become a “living lab” for population health technology commercialization that gives the state a competitive advantage in generating external research funding, launching startups, and attracting existing and emerging companies to the state.

Highlights of Arkansas’ Technology Push

- **Arkansas stands out in its extensive clinical informatics capacities that are available for improving healthcare delivery as well as supporting translational and clinical research in the state.** Led by the Arkansas Center for Health Improvement (ACHI), Arkansas proactively uses its statewide health information exchange’s All Payers Claims Database for evidence-based analysis to guide state health policy and assist in health program development. In addition, UAMS has advanced Arkansas clinical informatics capabilities by creating the Arkansas Clinical Data Repository (AR-CDR), which serves as a data warehouse that integrates electronic health records for UAMS and the state’s health information exchange’s All Payers Claims Database into a single and secure source of data for use in clinical and translational research. UAMS continues to enhance the AR-CDR with technical capabilities that empower researchers through self-service access and the ability to ask disease-specific research questions, integrate clinical and genomic data to offer personalized treatments, and leverage natural language processing (NLP) technology to extract knowledge from unstructured data.
- **Bioinformatics is a leading focus for collaborative research in Arkansas across its universities and NCTR.** With the support of the state’s National Science Foundation (NSF) Established Program to Stimulate Competitive Research (EPSCoR) program and the Arkansas Bioinformatic Consortium, there is a growing strength in Arkansas in advancing machine learning research to inform clinical knowledge. Among specific institutional bioinformatics strengths, the UAMS Department of Biomedical Informatics, in addition to leading the Arkansas Clinical Data Repository and the Biomedical Ontologies Arkansas research group to improve the gathering, managing, transforming and sharing of biomedical data, is a national leader in imaging informatics through its past efforts as the informatics resource in National Lung Screening Trials and its involvement with the NCI Imaging Data Commons, including maintaining and enhancing The Cancer Imaging Archive for NCI. Also active at UAMS is the NIH-supported National Resource for Quantitative Proteomics, which was established in 2016 to provide state-of-the-art quantitative proteomics services and outreach opportunities to researchers across the nation. The program employs a 20-person staff, including highly skilled bioinformaticians trained in the analysis of both discovery and targeted proteomics data. The Quantitative Proteomics Center also collaborates with Arkansas Children’s Center for Translational Pediatric Research, which advances a systems biology approach incorporating quantitative proteomics to identify therapeutic targets. Arkansas is also home to NCTR’s Division of Bioinformatics and Biostatistics, which applies bioinformatics and artificial

intelligence for molecular modeling and data analytics for biomarker discovery, drug safety and repurposing, pharmacogenomics and toxicogenomics, and precision medicine. From discussions with research leaders in Arkansas, what stands out is the breadth of activities leveraging bioinformatics across the state, including clinical informatics, proteomics, metabolomics, and microbiomics that scales to humans and involves biosurveillance (especially focused on COVID) and informing health disparities.

- **Digital Health is also a growing focus at universities in Arkansas.** Through the Institute for Digital Health & Innovation (IDHI) at UAMS, there is an emphasis on addressing health disparities through digital health delivery and innovation. On the delivery side, IDHI supports real-time interactive video patient consultations, continuing medical education, and patient education across Arkansas. This includes a Rural Telehealth Evaluation Center, which offers a testbed for innovations with an annual call for competitive proposals funded by IDHI. Additionally, the Institute's Healthcare Analytics Division leverages UAMS' strong clinical informatics capacities to serve as a lab for digital health innovations focusing on addressing high-risk patient populations, remote patient monitoring and value-based patient contacts, with a particular focus on high-risk births, stroke and trauma care. IDHI also collaborates with UAMS efforts in implementation sciences to help advance digital health software and tools at scale. IDHI and its co-directors have collaborated with the Arkansas Department of Health, the Federal Emergency Management Agency (FEMA), the UAMS College of Public Health, private industry, and startup accelerators to model disease spread, PPE supply and distribution, pilot new technologies, and co-develop new intellectual property via grants and other opportunities. A new initiative tapping into health tech and cyber for advancing Integrative Health is the University of Arkansas Fayetteville's new Institute for Integrative & Innovative Research (I3R), an initiative supported by a transformational gift from the Walton Foundation. The initial strategic focus of I3R's activity is the area of integrative health, which includes innovative technologies that enable a healthier lifestyle as well as advance novel treatments of metabolic disease. Whole-person physical and mental health will be enabled by diagnostic and therapeutic technologies that are client-centered, wearable, ingestible, embeddable, and deployable at the point-of-care, at home, or in the community. Innovations in data science, computational modeling, AI/ML, IoT, and cyber security will underpin future digital health advances by I3R.
- **Arkansas has established leading centers for translational and clinical research.** The UAMS Translational Research Institute (TRI) is supported by a NIH Clinical and Translational Science Award to provide services and resources to ensure the swift translation of research into healthcare advances. TRI was established in 2009 with the mission of advancing translational and clinical research to address the complex health challenges of Arkansas' rural and under-represented populations. Among its recent accomplishments are: helping to launch and conduct 292 clinical trials since 2019; expanding clinical research into rural areas of the state through the TRI-supported UAMS Rural Research Network; advancing new early-career researcher training programs including its long-standing Mentored Research Career Development Scholars Program that had its largest ever cohort in 2022 and starting a new training program, Strategies for Training and Advancing underrepresented Researchers (STARs) that is having good success in helping participants in securing grants; and launched initiatives to support the growth of team science and community engagement. Additionally, Arkansas Children's Hospital has received support from NIH since 2016

for a State Pediatric Clinical Trials Network with the primary mission to engage rural children in Arkansas in innovative clinical trials opportunities. Both TRI and the State Pediatric Clinical Trials Network make use of data coordinating and comprehensive informatics support from the UAMS Department of Biomedical Informatics for its clinical trials efforts.

Table 5. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Population Health Innovations and Clinical Research

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/ STRONG/ SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
Presence of Leading Fields in Recent Research Publications Trends	Strong	<p>Large body of clinical and translational research anchored by UAMS focused in:</p> <ul style="list-style-type: none"> • Public health surveillance and data gathering • Telemedicine and remote healthcare delivery • Health disparities and social determinants of health • Behavioral health and health risk behavior • Addiction and substance abuse
Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records	Strong	<ul style="list-style-type: none"> • Public Health: Social determinants of health and health disparities, addiction behaviors and risk factors, COVID-19 response and vaccine hesitancy, public health surveillance and prevalence data gathering. • Clinical care and diagnostic monitoring: brain activity monitoring, telemedicine, and remote healthcare delivery. • Surgical and trauma procedures outcomes: acute stroke care, glaucoma/cataract surgery, pediatric trauma care, postoperative infection and fractures, healthcare-acquired infections. • Oncology: Breast cancer, multiple myeloma, and thyroid cancer care, diagnostic imaging. • Neurochemistry: Neuroprotective agents, methamphetamine effects on neurotransmitters, induced neurotoxicity, brain glycogen, impacts of cortisol levels.
Presence of Active Research Project Awards Supporting Competency	Leading	<ul style="list-style-type: none"> • Numerous grants supporting expansion of public and population health capacities – Translational Health Expansion (\$4.3M), METH Use Disorder (\$14M), Pediatric Clinical Trials Coordination (\$7.9M), other health disparity/inequality and community health projects.

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/ STRONG/ SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
<p>Presence of Supporting Industry-Facing University and Federal Lab Research Centers and Innovation Ecosystem Activity/Assets</p>	<p>Strong</p>	<ul style="list-style-type: none"> • UAMS Translational Research Institute (TRI) supported by NIH Clinical Translational Science Award (CTSA) • UAMS Institute for Digital Health & Innovation • Arkansas Biosciences Institute (ABI) • UALR Emerging Analytics Center • BioVentures (UAMS) • HealthTech Arkansas • Catalyst Innovation Center (ASU) • Arkansas Center for Health Improvement (ACHI) • NSF Engines Development Award: Advancing equitable access to food and health technologies in the Delta (AR, LA, MS) • UAMS Key Research Cores: <ul style="list-style-type: none"> • AR Clinical Data Repository

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

- **Healthcare is a large industry in Arkansas and can be an economic driver by focusing on population health innovations.** Although healthcare is often considered a non-traded sector by economists, it is a large industry in Arkansas with over 47,000 private sector employees in hospital operations. Through a focus on population health, Arkansas has an opportunity to advance innovation that can have significant economic results for the state, including supporting new external research funding, launching new startups, attracting industry to the state, and improving the state's quality of life. Notably, across the employment base of all public and private hospital industry sectors, the state is 18 percent more concentrated than national employment patterns in this sector suggesting that the industry is an economic driver for the state by bringing in new wealth through out-of-state patient populations seeking to leverage healthcare services.⁹
- **Leading healthcare companies and providers are focusing on advancing population health through digital health innovations.** Arkansas Blue Cross Blue Shield (AR BC/BS) is particularly active in population health using digital innovation. It is a member of Echo Health Alliance that helps seed and advance digital health companies. Discussions with leadership at AR BC/BS revealed its focus on being a national leader in primary care innovations, including the use of team-based approaches for primary care clinics and a strong interest in advancing maternal health innovations. St. Bernard's Healthcare is an example of a leading healthcare provider in Arkansas that has a dedicated team working on population health through numerous initiatives involving digital health applications, such as a telehealth effort focused on use of remote telemetry

⁹ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

for patient monitoring, a retinal artery scan for assessing coronary disease, and virtual nursing applications using artificial intelligence.

- **The non-hospital life science industry is a high-growth industry nationally and is making outsized gains in Arkansas.** Though modest in its size, the industrial life sciences sector— involving medical devices, commercial research and testing, biopharmaceuticals, agbiosciences, and distribution— grew by nearly 25 percent in Arkansas from 2017 to 2022, well outpacing national growth of less than 15 percent.¹⁰ By 2022, the Arkansas industrial life sciences sector stood at 3,394 jobs. Over the next ten years, it is projected that Arkansas will continue to outpace national growth and realize a gain of 23 percent, or an additional 780 jobs in industrial life sciences.
- **Arkansas is home to emerging, innovative, high-growth potential startups in the life sciences that are attracting venture capital investments** and supported by university commercialization programs, such as BioVentures. Arkansas received \$54 million in venture capital investment in diagnostic equipment companies and \$24 million in pharmaceuticals and biotechnology companies over the 2018 to 2023 period. This includes several companies developing novel diagnostics tests such as NOWDiagnostics, Namida Lab, and Ascendant Dx, as well as companies developing protein and enzyme-based therapeutics such as Greenlab and Infinite Enzymes.

Table 6. Summary of Market Pull: Demand Drivers of Arkansas’ Advanced Industry Clusters and Associated Innovation Activities Aligned with Population Health Innovations and Clinical Research

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Emerging
AEDC Target Industry with Existing Anchor Companies	n/a
Presence of Emerging Companies in VC Investment & SBIR Awards	Emerging
Significant Shares of Industrial R&D Spending	Emerging
Evidence of Significant IP Generation Activity	Some
END MARKETS FOR POPULATION HEALTH INNOVATIONS AND CLINICAL RESEARCH	
End markets span a variety of traded sectors with limited but emerging presence in AR economy: <ul style="list-style-type: none"> • Health IT • Medical Device/MedTech Manufacturing • Biopharmaceutical and Diagnostics Manufacturing 	

*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
Source: TEconomy’s analyses.

¹⁰ Ibid.

POWER ELECTRONICS, ADVANCED PACKAGING, AND GRID MANAGEMENT SYSTEMS

What is the opportunity?

Modern electronics technologies represent an interconnected “system of systems” from the microscale level of individual semiconductor devices and circuits to the macroscale level of the power grid and energy infrastructure. At the micro level, semiconductor devices form the foundation of electronic systems, enabling functions such as signal processing, power conversion, and control. These devices are integrated into complex circuits, modules, and subsystems, which are in turn embedded into devices and equipment that are then embedded into larger systems and interoperate with one another. At the macro level, electronic systems interface with the broader landscape of energy usage and resilience at the grid level, supported by distribution managers and utility providers who manage the flow of power to enable grid stability and the integration of renewable energy sources and energy storage systems into the grid.

Across the continuum of microscale devices to large scale energy management, Arkansas has a long legacy of excellence in electrical and electronics engineering that has continued to drive modern research and innovation activity.

Across this continuum of microscale devices to large scale energy management, Arkansas has a long legacy of excellence in electrical and electronics engineering that continues to drive modern research and innovation activity. Ranging from fundamental material science applications for electronics components to design, assembly, and packaging¹¹ expertise for integrated circuits, the state has a broad base of expertise in developing advanced microelectronics systems.

At the same time, Arkansas’ research base has also continued to build expertise in managing how components and systems interact across a broader landscape of energy usage and resilience at the grid level in conjunction with major distribution and utility provider operations anchored in the state. The interconnection between the micro-level components and circuits and the broader portfolio of energy systems generating, routing, and consuming power represents a fundamental enabler of modern electric vehicles (EVs) and equipment as well as the optimization of electrical grids.

In particular, Arkansas’ research strengths and its line-of-sight to industry applications highlight three key specialties within the electronics ecosystem where Arkansas is poised to pursue major growth opportunities:

- **Power electronics** serve as the backbone of energy conversion within electrical systems facilitating the efficient conversion of electrical power from one form to another and enabling the adaptation of electrical properties to meet specific application requirements. These technologies are the foundation for a variety of downstream applications, including renewable energy integration, EVs, and smart grid infrastructure to name only a few. Leveraging a combination of materials properties and electrical circuit design capabilities, power electronic devices play a vital role in improving energy efficiency, reducing losses, and enhancing grid stability.

11 Electronic packaging encompasses the design and production of enclosures for electronic devices, ranging from individual semiconductors and circuits to larger devices and electrical subsystems.



Dr. Alan Mantooth leads an internationally recognized, award-winning electronics research program at the University of Arkansas (UA). Dr. Mantooth's work advances semiconductor technology to drive energy efficiency and innovation across various applications—often in extreme conditions, such as on the International Space Station.

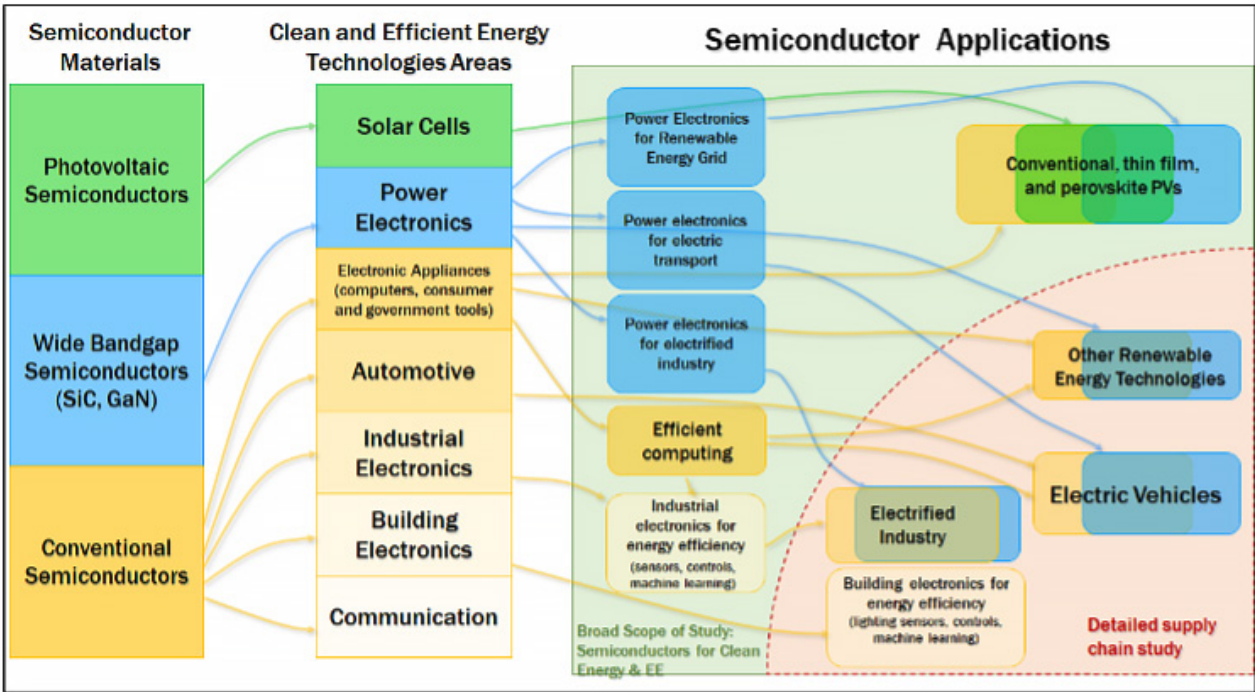
- **Advanced packaging techniques** enable improvements to the performance, reliability, and thermal management of power electronic devices through techniques focusing on the design and fabrication of compact, high-density packages/configurations that house semiconductor components, ensuring optimal heat dissipation and electrical connectivity. By leveraging advanced materials, such as wide-bandgap semiconductors and innovative packaging architectures, designers of electronic circuits can minimize power losses and improve the power density of electronic systems. Ultimately, these technologies enable the development of smaller, lighter, more efficient, and more resilient power electronic modules, which are critical for applications where space, weight, and harsh operating environment constraints are significant factors.
- **Grid management systems** play a central role in orchestrating the operation and coordination of power generation, transmission, and distribution assets within the electrical grid. These systems utilize advanced control algorithms, real-time monitoring, and communication technologies to optimize grid performance, balance energy supply and demand, and ensure broader system reliability. With the increasing integration of renewable energy sources, energy storage systems, and distributed generation assets, the grid is becoming increasingly complex. At the same time, grid operations are increasingly expected to adapt to consumer behavior and environmental conditions in near real-time across a massive network of systems. Both factors are contributing to the rise of “smart grid” technologies that seek to predict and proactively respond to conditions.

A recent U.S. Department of Energy study on the semiconductor supply chain highlights the multi-faceted nature of these technologies in enabling different elements of the electronics supply chain as well as downstream application areas (Figure 11).¹² The focus of Arkansas' opportunities in this space

¹² Semiconductor Supply Chain Deep Dive Assessment, U.S. Department of Energy Response to Executive Order 14017, “America’s Supply Chains”, February 24, 2022.

interweaves with virtually every element of this supply chain, highlighting the way in which the state can position its innovation and research enterprise for significant federal and industrial investment opportunities targeted at strengthening this industry domestically.

Figure 11. Multifaceted Role of Electronics Materials, Design, and Assembly Technologies in Semiconductor Applications Areas



Source: U.S. Department of Energy.

Key Market Forces Driving Growth

Amidst a renewed focus on the strategic importance of the domestic semiconductor industry, the interplay of circuit, device, and grid-scale electronics is witnessing remarkable growth propelled by several key market forces. From the imperative of grid resilience and reliability to the surge in electrification and IoT proliferation, market forces are reshaping industries and driving demand for cutting-edge solutions for which Arkansas can position itself to capitalize on in the years to come. These market forces and drivers include:

- **Strategic investment in domestic semiconductor production and supply chain initiatives** based on the various projects and subsidies provided by the CHIPS and Science Act¹³, which are expected to fuel growth of semiconductor production, supply chain, and adjacent support industries in the coming years alongside a renewed focus on mitigating semiconductor supply chain disruptions. States and regions that can leverage innovation strengths in key electronic materials and engineering capabilities to develop competitive advantages and attract new parts of a growing domestic industry ecosystem will benefit economically.
- **Electrical grid modernization and the Reliability Imperative:** Aging infrastructure, cyber security threats, and extreme weather events underscore the importance of grid modernization and resilience. Investments in grid upgrades, distributed energy resources, microgrids, and grid hardening initiatives all require a portfolio of new device-scale and grid-scale technologies. The increasing adoption and integration of renewable energy sources is also driving demand for electronics solutions that can efficiently integrate these intermittent sources into the grid. Systems operators such as MISO in Arkansas will continue to generate demand for these solutions through initiatives to improve grid reliability.

Growth Markets for Power Electronics, Advanced Packaging, and Grid Management Systems

- Estimated \$137.9 billion North American market size for semiconductor fabrication, assembly, testing, and packaging in 2023, CAGR of 9.1 percent through 2027.
- Estimated \$77.8 billion North American market size for IoT chips and integrated circuits in 2024, CAGR of 12.4 percent through 2027.
- Estimated \$55.4 billion North American market size for electronics contract manufacturing and design services in 2024, CAGR of 7.9 percent through 2028.
- Estimated \$62.9 billion U.S. market size for digital utilities hardware and integrated solutions in 2024, CAGR of 12.1 percent through 2028.
- Estimated \$562 million U.S. market size for “smart” transformers in 2024, CAGR of 13.1 percent through 2028.
- Estimated \$22.1 billion North American market size for distributed energy generation and management technology in 2023, CAGR of 10.0 percent through 2028.

Source: BCC Research.

¹³ CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China, White House Press Release, August 9, 2022.

- **Electrification and Electric Vehicles (EVs):** The electrification of transportation and logistics operations alongside the growing market for consumer electric vehicles are driving innovation in power electronics and energy storage technologies. Advanced power management and battery systems as well as charging infrastructure require sophisticated engineering and design solutions to meet the performance, reliability, and safety requirements of EVs and grid-tied charging stations. In addition, other vehicle systems markets such as defense and aerospace have begun to embrace a transition to electrification as a part of their strategic goals. As adoption of these technologies continues to increase, demand for innovation and refinement of vehicle systems is likely to increase.
- **Rapid expansion of IoT devices, edge computing, and data centers:** The proliferation of IoT devices and edge computing applications is driving demand for miniaturized, low-power electronics with advanced packaging technologies. System-on-Chip (SoC) designs and the integration of other new architectures enable the development of compact, energy-efficient devices with integrated sensors, processors, and wireless connectivity which in turn support the growth of embedded sensing infrastructure in smart cities, industrial automation, and consumer electronics markets. At the same time, the expansion of cloud computing infrastructure is driving demand for high-performance power electronics and advanced packaging solutions to support back-end infrastructure and associated data centers. These technologies need to meet stringent requirements for efficiency, reliability, and miniaturization to support the increasing demands of high-speed communication networks and computational workloads.
- **Environmental sustainability and efficiency:** Increasing environmental regulations and sustainability goals are driving the adoption of energy-efficient power electronics and packaging solutions. Innovations in materials, manufacturing processes, and thermal management enable the development of eco-friendly products with reduced energy consumption, emissions, and environmental impact throughout their lifecycle. There are corresponding expectations for energy demand management and integration of alternative and renewable energy goals on the part of generation, transmission, and distribution stakeholders involved in the effective management of the power grid.

Why Arkansas?

Arkansas has a deep scientific research strength in the core research fields supporting new electronics applications, anchored by recognized thought leaders and excellence in its key research centers. At the same time, the state's industry base has a number of direct and indirect consumers of electronics technologies in addition to leading companies and utility providers actively advancing innovative solutions.

Highlights of Arkansas' Technology Push

- **The state's researchers are at the leading edge of developing power electronics and advanced packaging technologies around their interplay with device- and grid-level systems innovations.** Analysis of peer-reviewed publications and grant awards over the past five years identified research themes with a critical mass of activity in areas such as silicon carbide and other high performance electronic materials, integrated circuit design and testing, smart grid and microgrid management and modeling, power electronics interoperability applications, and trusted electronics and related grid cyber security applications (Table 7). All of these competencies, as well as highly specialized levels of activity in electrical engineering research more broadly, indicate that Arkansas is at the forefront of the "basic science" of emerging technologies in this space and has distinct specialties that can attract research investment and commercialization opportunities.
- **In addition to a critical mass of research activity, Arkansas is home to a cluster of key research centers, innovation assets, and thought leaders focused on leading electronics applications related to the themes of power electronics, advanced materials, design, and packaging.** Anchored by the University of Arkansas Power Group's affiliated centers and supported by world-class engineering and materials sciences researchers across the state's other research institutions and labs, research efforts recently yielded an \$18 million grant from NSF to establish a national silicon carbide research fabrication facility (Multi-User SiC, or MUSiC, facility).
- **The state has organically grown a significant cluster of innovative small- and mid-sized enterprise (SME) engineering service firms developing novel advanced electronics packaging solutions and conducting applied research to meet the needs of defense, aerospace, and energy missions.** A source of deep, longstanding technical expertise in areas like custom packaging, high-density electronics, integrated circuit design and end assembly, and extreme operating environment electronics, these firms often have roots in university research centers such as University of Arkansas' High-Density Electronics Center (HiDEC) and are a key source of capacity to support translational innovation in new areas of technology development.
- **Arkansas also has significant research strengths in supporting competency areas such as cyber security and data sciences, which can provide opportunities for multidisciplinary applications and support embedded technology applications in electronics.** Cyber-physical systems security and trusted electronics are increasingly becoming necessary complements to devices deployed as a part of critical infrastructure, vehicle systems, and networking devices. Similarly, analytical processing is increasingly being pushed to the chip level to enable devices to operate reliably even without connectivity to cloud systems.

Table 7. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Power Electronics, Advanced Packaging, and Grid Management Systems

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/STRONG/ SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
Presence of Leading Fields in Recent Research Publications Trends	Leading	Highest share of recent publications activity focused in Electrical/Electronic Engineering topics (over 1.1k pubs, 5.5 percent of total activity since 2017).
Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records	Leading	Unique capabilities in power electronics applications present in publications, including: <ul style="list-style-type: none"> • High performance electronic materials • Integrated circuit design and testing • Smart grid/Microgrid management and power electronics modeling • Trusted electronics and power grid cyber security
Presence of Active Research Project Awards Supporting Competency	Leading	<ul style="list-style-type: none"> • Signature grant activity supporting advancement of research infrastructure - \$18M NSF award for Implementation of a National Silicon Carbide Research Fabrication Facility. • Additional DoD grants for fabrication facility for Electro-Optic IR Sensors as well as research projects in ferroelectric materials.
Presence of Supporting Industry-Facing University and Federal Lab Research Centers	Leading	<ul style="list-style-type: none"> • UA High-Density Electronics Center (HiDEC) • UA GRid-connected Advanced Power Electronic Systems (GRAPES) • UA Center for Power Optimization of Electro-Thermal Systems (POETS) • UA Cyber security Center for Secure Evolvable Energy Delivery Systems (SEEDS) • UA National Center for Reliable Electric Power Transmission (NCREPT) • UA Multi-User Silicon Carbide Research and Fabrication Facility (MUSIC)

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

- **The Arkansas energy industry and utilities sector comprises a diverse range of employers with a highly specialized workforce, providing a natural market for power electronics, packaging, and energy systems innovation being advanced at research institutions.** In 2022, the state had nearly 18,300 employees in the energy and infrastructure sector, making it 28 percent more concentrated than the employment footprint of the nation.¹⁴ The presence of a unique constellation of utility providers and managers, such as Entergy, Southwestern Electric Power Company (SWEPCO), Southwest Power Pool, and Midcontinent Independent System Operator (MISO), generates a critical mass of demand for new technology applications. In combination with recent venture capital investments in emerging solar energy companies and existing electronics component manufacturers, this environment provides a significant customer base of partners for ongoing piloting and commercialization of advanced electronics and grid management technologies.
- **In addition to core energy and utilities sectors, Arkansas is home to a number of major traded sector industry clusters that are increasingly faced with the need to electrify their systems or deploy new types of embedded electronics systems that fundamentally rely on this growth area.** These include:
 - Arkansas' large and leading transportation, distribution, and logistics sector anticipates significant future demand for power electronics systems from major shipping and warehousing companies as they seek to electrify their existing fleets of trucks and material moving equipment.
 - Aerospace and defense as well as the production technology and heavy machinery manufacturing clusters in the state are facing the need to electrify key subsystems and embed new types of sensing and control systems that rely on packaging and circuit design to operate effectively.
- **The state's major research centers focused on electronics and energy applications continue to produce startups and skilled talent that anchor and attract leading electronics engineering services and applied research firms within the state.** The University of Arkansas Power Group has historically been at the center of a variety of spinout and industry partnership activity that includes new companies such as Arkansas Power Electronics International (acquired by Wolfspeed), Ozark Integrated Circuits, and Space Photonics, as well as existing multinational companies that leverage the R&D capabilities of these research centers.
- **There are significant opportunities emerging in new markets where Arkansas can leverage its thought leadership position to advance new or emerging industry clusters and drive economic growth.** Examples of new emerging markets where the state can be competitive in leveraging its research base include:
 - The newly emerging opportunity in lithium extraction anchored by the state's underground brine reservoirs, where the materials extracted will require significant downstream processing and production. The state's electronics and materials engineering expertise can support these supply chains in end-stage processing and usage of lithium in battery systems.

¹⁴ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

- Despite some challenges, solar energy and the related photovoltaic cell materials and systems integration for utility-scale deployment continue to see some growth and investment in emerging companies.
- Electrified steel production is an emerging area of emphasis for manufacturers where electrified arc furnaces are used to produce steel instead of traditional blast furnaces. Recently opened U.S. Steel facilities in northeast Arkansas are focused around this method, which is expected to continue to grow in importance as metals manufacturers look to integrate sustainable practices into their operations.
- EV and battery manufacturing operations have begun to emerge as a growing sector in Arkansas, bolstered by announcements made by mid-size and specialty EV companies, including EnviroTech Vehicles that announced its decision to locate operations in Arkansas. As the industry continues to grow, the ability to locate in proximity to sources of skilled talent and leading research infrastructure will be important competitive drivers for the state.

Table 8. Summary of Market Pull: Demand Drivers of Arkansas’ Advanced Industry Clusters and Associated Innovation Activities Aligned with Power Electronics, Advanced Packaging, and Grid Management Systems

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Strong/Leading
AEDC Target Industry with Existing Anchor Companies	Some/Emerging
Presence of Emerging Companies in VC Investment & SBIR Awards	Strong/Leading
Significant Shares of Industrial R&D Spending	Some/Emerging
Evidence of Significant IP Generation Activity	Strong/Leading

END MARKETS FOR EMBEDDED POWER ELECTRONICS AND ENERGY/GRID MANAGEMENT SOLUTIONS

End markets span a variety of traded sectors with significant presence in AR economy, but high-end electronics and packaging industry focused around SME firms rather than large anchor companies. Significant potential in downstream end markets in the state exists in sectors such as:

- Energy & Infrastructure
- Manufacturing
- Aerospace & Defense
- IT & Data Services
- Vehicle Manufacturing

*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
Source: TEconomy’s analyses.

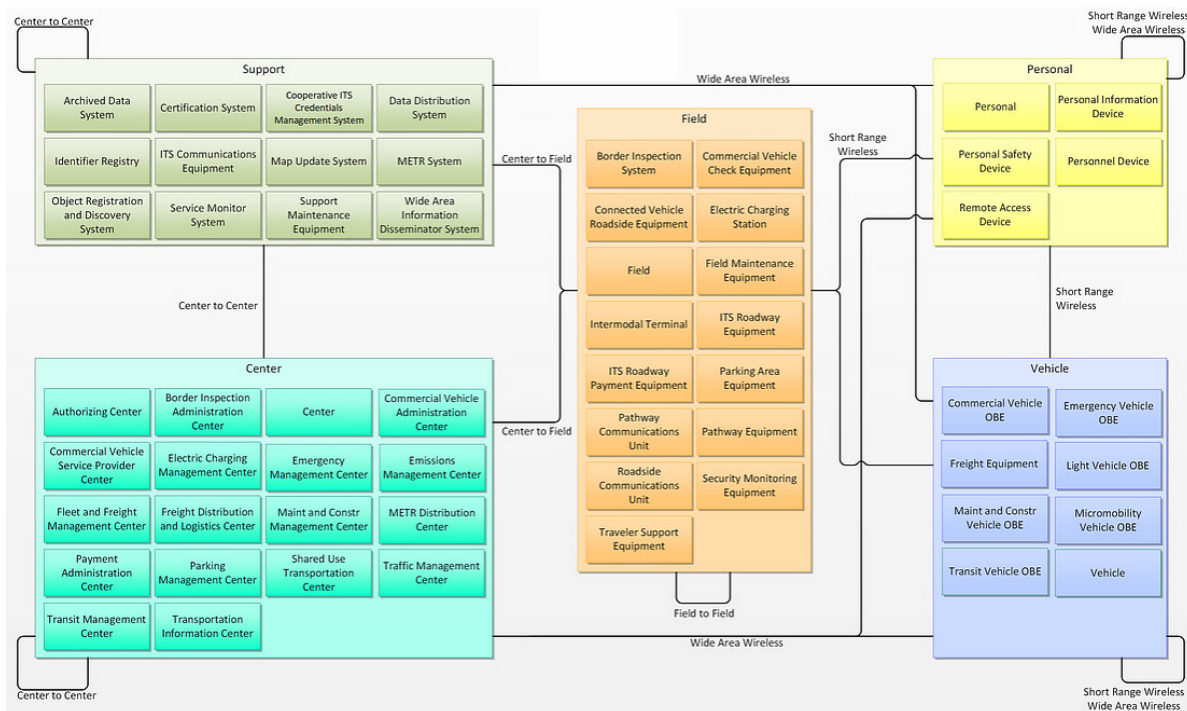
NEXT GENERATION TRANSPORTATION AND LOGISTICS SYSTEMS

What is the opportunity?

Many of Arkansas' major traded industry sectors rely on the ability to move goods and access inventories in highly efficient ways. The systems and technologies that comprise increasingly complex and interconnected transportation and distribution networks are rapidly evolving to include an array of new digitized and automated systems that are being leveraged to improve reliability and lower costs. This next generation of transportation and logistics systems represents a strategic investment area in order to translate research innovation into solutions that can boost the competitive profile of the state's major industry clusters.

There are several key technology verticals that underpin the ability to operate modern intermodal transportation systems that move goods from point to point in conjunction with the warehousing and distribution systems that maintain inventories of those goods. These span vehicle and equipment-level technologies that are designed to improve the connectivity and responsiveness of transportation and material moving functions to intelligent transportation systems and infrastructure that manage the high-level data collection and traffic flows of fleets of vehicles. Arkansas has deep complementary strengths in the analytics and modeling solutions designed to optimize these systems and their deployment (discussed in the Supply Chain, Retail, and Consumer Analytics growth opportunity area profile); however, the research and innovation strengths highlighted here represent the design and implementation of the “hardware” of these operations and their physical systems as opposed to the “software” of analytics and data sciences. As shown in Figure 12, the various physical systems that make up the key capabilities of a transportation ecosystem still represent a complex interplay of information exchanges and interoperability that requires constant innovation to integrate emerging technologies and respond to new usage trends.

Figure 12. Variety of Physical Systems and Associated Information Exchanges that Support Intelligent Transportation Architecture

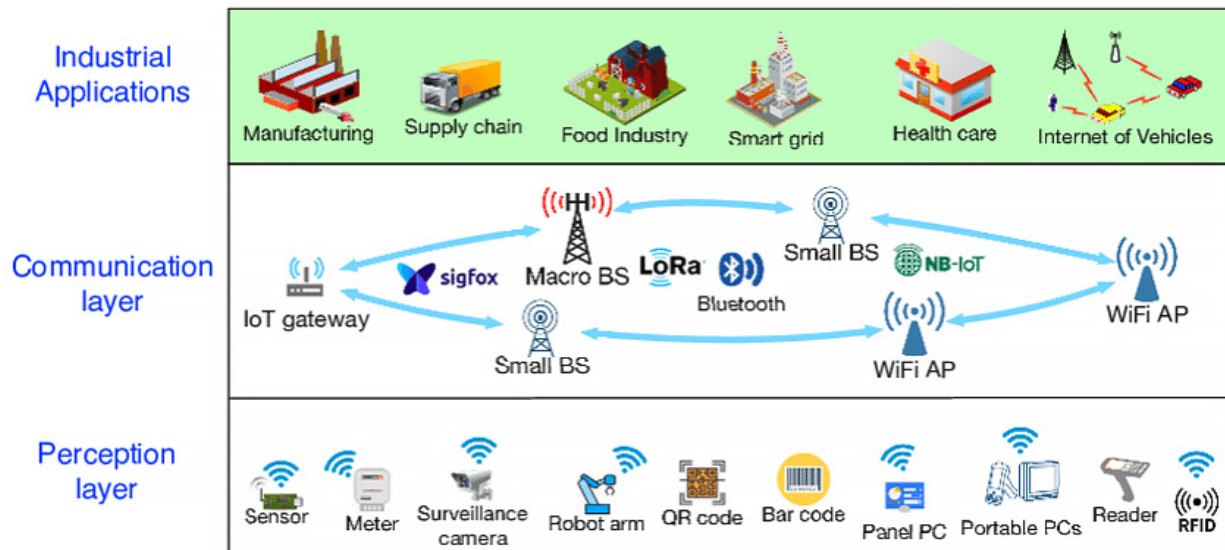


Source: U.S. Department of Transportation, National Intelligent Transportation Systems Architecture.

For Arkansas, the context of intelligent transportation systems can be used to help translate research capabilities into deployment of systems and infrastructure that can directly benefit some of the state’s largest industries centered around freight trucking and use of intermodal transportation networks that include unique transportation modalities such as the state’s inland waterways.

These same technology applications are also leveraged into the hardware systems of logistics operations, such as material moving and distribution centers, as well as inventory storage and warehousing facilities. As illustrated in Figure 13, the “perception” layer of IoT devices that are at the core of “smart” distribution and warehouse implementations represents an interconnected network of sensors, autonomous and semi-autonomous systems, and other hardware devices that incorporate a mix of track and trace technologies, industrial IoT sensors, automated handling and material moving, and mobile systems (e.g., forklifts, autonomous mobile robots, drones, etc.). Companies with significant distribution operations are constantly seeking to innovate in order to improve delivery time and costs while also moving inventory in ways that augment the productivity of human workers and protect their safety.

Figure 13. Role of Interconnected Hardware Systems as an Enabler of Smart Logistics Applications



Source: Dai, Hong-Ning & Zheng, Zibin & Zhang, Yan. (2019). Blockchain for Internet of Things: A Survey. 6. 8076 - 8094. 10.1109/JIOT.2019.2920987.

Amongst these complex hardware ecosystems, Arkansas' mix of research competencies and large anchor industries support several growth opportunities that focus on critical portions of the broader transportation and logistics environment. These growth opportunities include:

- **Vehicle Area Network (VAN) Applications for Shipping and Commerce**, which revolves around the integration of various devices and communication technologies within vehicles to enable seamless connectivity and communication between different onboard systems, sensors, and external entities. VANs serve as the backbone for in-vehicle networking, facilitating data exchange, control signals, and information sharing to enhance vehicle functionality and safety. For freight transportation and other shipping applications, the VAN is often inclusive of the onboard telematics, control systems, and sensor integrations contained onboard a vehicle.
- **“Smart” Transportation Infrastructure and Intermodal Connectivity**, which describes the ways in which transportation infrastructure is becoming increasingly "smart" through the integration of sensors, communication technologies, and data capture via embedded hardware systems. Smart infrastructure enables real-time monitoring of traffic flows, infrastructure conditions, and environmental parameters allowing for proactive maintenance, congestion management, and optimization of transportation networks. These capabilities, in turn, support intermodal transportation hubs, such as Arkansas' inland waterways and company logistics centers, and facilitate seamless transfer of freight between different modes, reducing congestion, emissions, and transportation costs. Embedded hardware and the ability to coordinate large ecosystems of connected assets also allows transportation networks to be designed and operated with resilience and disaster preparedness in mind to withstand and recover from natural disasters, extreme weather events, and other disruptions.
- **Augmentation and Tracking Systems for Logistics and Distribution Operations**, which enable the warehouse management systems (WMS) and logistics platforms that are increasingly being adopted by major companies. These similarly involve large, connected, hardware ecosystems of IoT sensors and autonomous systems deployed throughout distribution centers to monitor inventory levels, track asset locations, and optimize storage space utilization in real-time. An additional layer of mobile systems sensing and monitoring is becoming common, whether user-operated vehicles such as forklifts or autonomous mobile robotic platforms for materials moving or inventory monitoring. Worker augmentation and assistance technologies are also being rapidly deployed, ranging from augmented reality to wearable assistance devices to collaborative robotics and semi-autonomous systems.

Each of these connected hardware ecosystems requires engineering expertise to optimize operational capabilities at the device level, the systems level, the ecosystems level, and the ability to facilitate interoperable communication and networking between various elements of the architecture. Arkansas has distinct engineering strengths aligned with the engineering of systems involved at these various levels, as well as an industry consumer base with high demand for new innovations that can improve competitiveness in traditionally low-margin businesses.

Key Market Forces Driving Growth

The varied connected technologies encompassed under the systems framework described above are being rapidly adopted by logistics and distribution companies due to the confluence of several market trends. Despite high initial investment costs and lack of standardization around information exchange and interoperability between systems, significant cost and workforce pressures combined with ongoing growth of electronic commerce services mean that these trends have been significantly accelerated. Important market forces and drivers include:

- **Emerging technology trends such as electrification and automation in vehicle and mobile material handling equipment systems** are requiring more purpose-built components and other hardware systems incorporating systems engineering approaches to meet the specific needs for shipping and logistics companies. Electrification of shipping fleets and material handling equipment requires reconfiguring routes and working environments around charging infrastructure, while integrating autonomous mobile systems into a hybrid environment with human workers requires machine vision, geofencing and other technologies to ensure safety. Many of these emerging technologies will require new hardware systems and design approaches to realize the potential of their operating efficiencies and cost savings.
- **Skilled operator shortages and labor market challenges** such as a shortage of qualified drivers and warehouse equipment operators is leading to increased demand for technology solutions that improve productivity and enhance the capabilities of the existing workforce.
- **Ongoing online commerce growth and last-mile delivery demands** prompted by a broader ongoing transition to direct-to-consumer deliveries from traditional retail locations are driving demand for technology-enabled solutions in distribution and shipping. Companies are leveraging optimization and tracking systems that are reliant on real-time data from transportation systems and infrastructure to compete at scale in consumer products markets.

Growth Markets for Next Generation Transportation and Logistics Systems

- Estimated \$23.2 billion U.S. market size for commercial vehicle telematics in 2023, CAGR of 14.7 percent through 2027.
- Estimated \$16 billion North American market size for logistics automation in 2024, CAGR of 12 percent through 2028.
- Estimated \$11.7 billion market for warehousing storage and management solutions.
- Estimated \$4.4 billion market for transportation management solutions.
- Estimated \$11.2 billion North American market size for RFID technologies in 2023, CAGR of 6.2 percent through 2027.
- Estimated \$56.2 billion North American market size for industrial IoT technologies in 2024, CAGR of 21.3 percent through 2028.

Source: BCC Research.

- **Supply chain visibility and quality assurance concerns** are a constant driver of innovation and technology deployment for stakeholders across the supply chain. New devices and hardware systems improve visibility and transparency in freight transportation to track shipments, monitor delivery status, and ensure compliance with service level agreements, while passive and active sensors can monitor indicators of damage, spoilage, or other shelf-life concerns.
- **Resilient and sustainable transportation networks** are becoming increasingly critical to mitigate supply chain disruptions as well as the need to operate intermodal and long-haul vehicle fleets in ways that minimize environmental impacts. Embedded sensing and other real-time monitoring technologies can help enable redundancy planning, emergency response protocols, and integration of resilient design principles into infrastructure projects to minimize downtime and ensure continuity of transportation services.

Why Arkansas?

Major segments of Arkansas' economy critically depend upon the hardware of transportation and logistics encompassing the areas described above, in particular major logistics operations at companies within the state that maintain large fleets of shipping and distribution vehicles as well as material moving equipment. Similarly, the complementary area of supply chain, retail, and consumer analytics that represents the data and analytical software provides data-driven decisions for these systems which enables the state's large TDL cluster to modernize their systems. The ability to provide a specialized source of talent and research expertise to these companies is one of the key reasons that the state has developed a leading logistics ecosystem.

Highlights of Arkansas' Technology Push

- **Arkansas research institutions have developed a cluster of specialized expertise in industrial and transportation infrastructure engineering being actively leveraged by industry and public partners.** Key university research centers at the University of Arkansas, including the Center of Excellence in Logistics and Distribution (CELDi), the Mack-Blackwell Transportation Center, a U.S Department of Transportation University Transportation Center, the Maritime Transportation Research and Education Center (MarTREC), and the J.B. Hunt Innovation Center of Excellence (ICE), are all closely affiliated with the university's industrial engineering program, which has been cited by Arkansas industry stakeholders as a key resource for talent and thought leadership around transportation systems applications. Many of these centers operate in close partnership with Arkansas companies or public infrastructure management agencies around joint research projects and faculty embedding and sabbatical programs.
- **Arkansas research centers are advancing applications in cyber-physical and material handling systems driven by use-inspired research in logistics systems applications.** The focus in research programs on the integration of new systems into logistics and distribution operations to drive outcomes has created a strong history of generating undergraduate, graduate, and postdoctoral talent with real-world experience in addressing systems and operations issues. Researchers cited a number of examples of collaborative projects, including development of automated unloading systems for freight trucking using student-led teams, an associate faculty member embedded within a company's intermodal engineering group, a federally-funded joint research project to

develop low-friction lubricant coatings for industrial conveyor systems in conjunction with Hytrol, an Arkansas industrial machinery company, and augmented reality industry case studies advanced by the Emerging Analytics Center at the University of Arkansas at Little Rock. Evidence from recent research publication analysis reinforces this focus, with the presence of themes such as localization and tracking technologies (e.g. RFID systems), machine-to-machine communication systems, soft robotics and material handling automation, augmented and virtual reality (AR/VR) systems for logistics environments, and industrial IoT hardware reliability and cyber security supporting innovation areas with real-world applications.

- **Arkansas research centers are also developing and deploying embedded systems to help manage resilient intermodal transportation networks.** The state's research centers have a long legacy of working with federal organizations such as the U.S. Department of Transportation and the Army Corps of Engineers to maintain and improve the state's diverse transportation infrastructure as well as conduct broader multimodal transportation network management research through inter-institutional centers such as MarTREC. Arkansas is also home to a unique set of inland waterways, with research institutions playing a key role in helping manage resiliency and disaster response as well as leveraging this element of the state's transportation network to more efficiently route shipping. Similarly, the state's industrial and civil engineering researchers are evaluating new types of sustainable and enhanced infrastructure materials, such as concrete, asphalt, and steel, as well as developing new ways to test and monitor transportation infrastructure through centers such as the University of Arkansas' Steel Structures Research Lab (SSRL) and the newly announced Arkansas State University Center for Advanced Materials and Steel Manufacturing.

Table 9. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Transportation and Logistics Systems

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/ STRONG/ SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
<p>Presence of Leading Fields in Recent Research Publications Trends</p>	<p>Strong</p>	<ul style="list-style-type: none"> • Multidisciplinary support from high volume fields in electrical and electronic engineering, materials sciences. • Specialized fields with smaller volume of overall publications activity: <ul style="list-style-type: none"> • Industrial engineering • Operations research and management science
<p>Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records</p>	<p>Strong</p>	<ul style="list-style-type: none"> • Transportation network optimization, fleet and traffic management • Localization and tracking technologies (e.g., RFID systems) • Machine-to-machine communication systems and systems interoperability • Soft robotics and material handling automation • Augmented and virtual reality (AR/VR) systems for logistics environments • Industrial IoT hardware reliability and cyber security • Asphalt and concrete materials engineering • Infrastructure fatigue and crack detection
<p>Presence of Active Research Project Awards Supporting Competency</p>	<p>Strong</p>	<ul style="list-style-type: none"> • Renewal of 6 year, \$2M per year grant from U.S. DoT supporting Maritime Transportation Research and Education Center (MarTREC). • Variety of industry-sponsored research projects related to systems and industrial engineering applications.
<p>Presence of Supporting Industry-Facing University and Federal Lab Research Centers and Innovation Ecosystem Activity/ Assets</p>	<p>Strong</p>	<ul style="list-style-type: none"> • UA Center of Excellence in Logistics and Distribution (CELDi) • UA Mack-Blackwell U.S. DoT University Transportation Center • UA Maritime Transportation Research and Education Center (MarTREC) • UA J.B. Hunt Innovation Center of Excellence (ICE)

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

- **Arkansas is home to some of the nation's largest companies leveraging transportation and logistics systems in day-to-day operations, creating a high demand for new hardware solutions.** Physical systems and infrastructure are a key enabler of the state's TDL cluster, which accounted for nearly 81,000 jobs in 2022. Additionally, the state's highly specialized energy and infrastructure and production technology and heavy machinery clusters, which totaled over 18,000 jobs and 12,000 jobs in 2022 respectively, are dependent on these systems to manufacture their products and support their operations.¹⁵ These totals do not include the further support these applications provide to nearly all other traded sectors in the state's economy, making translational research in this growth area a high-impact, job-supporting investment. A cohort of the nation's largest transportation and distribution companies are based in Arkansas and will continue to act as a hub for deployment of physical systems in daily operations, including Walmart, J.B. Hunt, ArcBest, Murphy USA, Tyson Foods, and Hytrol, amongst many others.
- **Arkansas companies that rely on collections of fleet and industrial IoT assets are responding to key market drivers leveraging emerging technology areas in this space.** Arkansas industry stakeholders have cited significant efforts to proactively respond to emerging technology trends that are expected to impact their industry operations, including issues such as electrification of vehicles and industrial equipment, autonomous vehicle and drone platforms, "smart" logistics solutions that leverage networks of connected sensors and localization technologies, and industrial automation systems. The sheer scale of fleet and physical distribution and warehousing operations presents a challenge as these large companies seek to navigate integration and deployment of these technologies, driving demand for a responsive innovation ecosystem that can support these applications at scale. Industry intellectual property generation from 2017 to 2023 reveals that companies are developing new technologies such as automated inventory and environmental monitoring systems for warehouse environments, advanced mobility solutions for last mile delivery, containerization and automated inventory retrieval systems, and industrial IoT solutions for manufacturing and materials moving. There has also been significant industrial R&D spending in machinery manufacturing by Arkansas companies in recent years, totaling \$37 million in 2020, nearly three times more concentrated than the nation.¹⁶
- **The state has a large, interconnected, intermodal transportation network that represents a natural deployment environment for the next generation of transportation systems.** The state has a unique intermodal environment where existing industry is leveraging a combination of road, railway, and inland waterway networks to transport products and materials, representing a natural testbed environment where the latest technologies can be deployed and analyzed in the field. The state's central geographic location also makes it a natural distribution and logistics hub for the nation.

¹⁵ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

¹⁶ Based on TEconomy's analysis of NSF, Business R&D and Innovation Survey (BRDIS).

Table 10. Summary of Market Pull: Demand Drivers of Arkansas' Advanced Industry Clusters and Associated Innovation Activities Aligned with Transportation and Logistics Systems

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Strong/Leading
AEDC Target Industry with Existing Anchor Companies	Strong/Leading
Presence of Emerging Companies in VC Investment & SBIR Awards	Some/Emerging
Significant Shares of Industrial R&D Spending	Strong/Leading
Evidence of Significant IP Generation Activity	Strong/Leading

END MARKETS FOR TRANSPORTATION AND LOGISTICS SYSTEMS

End markets span the majority of traded sectors in the Arkansas economy, but with particular focus in:

- Transportation, Distribution, and Logistics
- Energy and Infrastructure
- Production Technology and Heavy Machinery
- Vehicle Manufacturing

*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
Source: TEconomy's analyses.

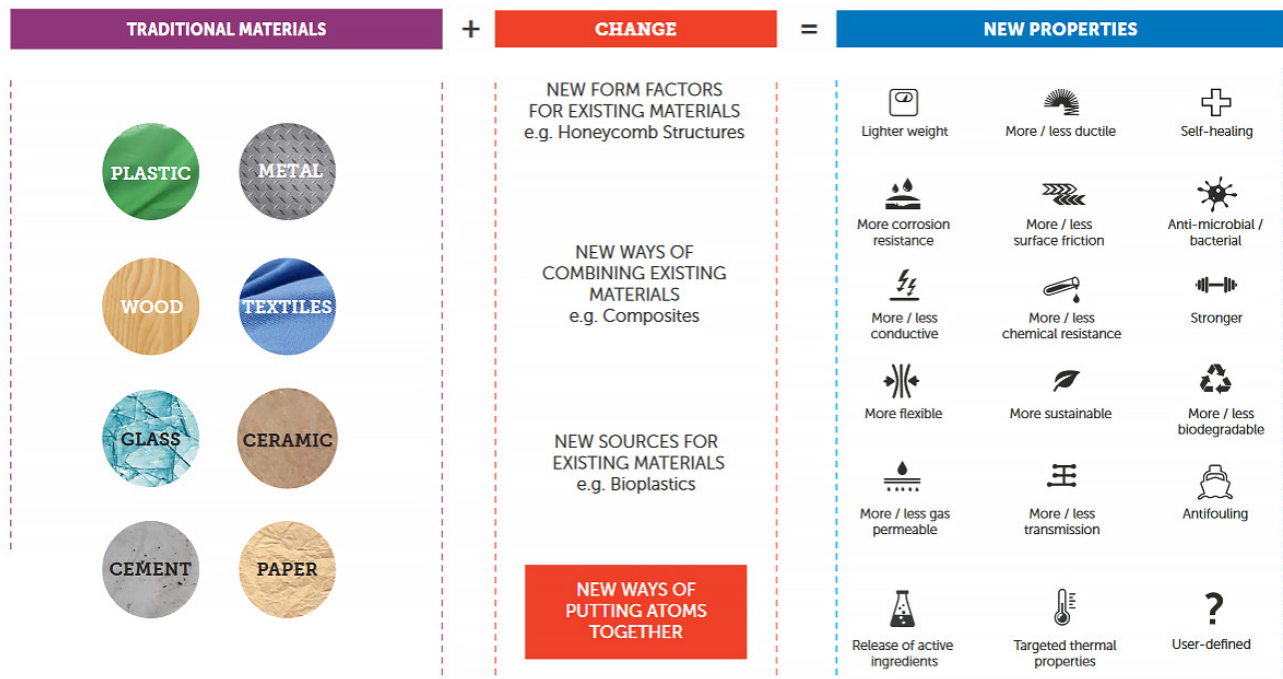
MATERIALS ENGINEERING APPLICATIONS

What is the opportunity?

The deep research expertise in Arkansas related to materials science has produced a number of nascent technology commercialization areas that all fundamentally rely on materials engineering capabilities as well as the ability to characterize, test, and produce them. Engineered materials, also often referred to as advanced or high-performance materials, are substances designed and tailored to exhibit specific properties or functionalities that exceed those of traditional materials. Unlike natural materials, engineered materials are synthesized or modified through controlled processes to achieve desired characteristics, such as strength, conductivity, flexibility, or durability. The applications where these materials are leveraged toward industry use cases often result from interdisciplinary research, drawing from fields such as chemistry, physics, materials science, and engineering.

Engineered materials encompass a broad spectrum of substances, including polymers, ceramics, metals, composites, and nanomaterials, each offering unique properties and applications. Key industry verticals that depend on sourcing new materials engineering applications to remain competitive include automotive, aerospace and defense, biomedical, electronics, manufacturing, energy, wood products, and infrastructure with applications that are wide-ranging and span many material types and industry needs (Figure 14). These industries represent critical drivers of Arkansas' traded sector economy as well as industry verticals where the state increasingly competes internationally to deliver cost effective manufacturing and cutting-edge products, and thus is a place where the state's research strengths can play a key role in driving growth. Additionally, materials engineering is a critical upstream enabler of other growth opportunities, such as power electronics and advanced packaging.

Figure 14. Example of the Breadth of Advanced Materials Technology Applications



Source: Callaghan Innovation (NZ).



Jingyi Chen is a Professor of Physical Chemistry at the University of Arkansas at Fayetteville, leading a research team that designs and creates tiny, powerful materials called nanomaterials. These materials are revolutionizing processes in energy conversion and medical treatments, making them more efficient and sustainable.

Due to the broad nature of materials engineering use cases, this growth area often represents a technology strength for institutions and regions that have specialized materials science research bases with different market applications rising in strategic importance in response to demand from industry and federal funding priorities. This often makes it difficult to characterize the collective body of technologies that make up engineered materials with respect to their growth potential, and instead makes specific industry applications a key driver of how these technologies are advanced and deployed.

Within the broader portfolio of materials engineering research activity in Arkansas, several highly active, uniquely positioned, or industry-aligned application areas with forward-looking growth potential emerge, including:

- **Steel production and processing**, involving both the design of new alloys and product development that optimizes steel for specific industry use cases (e.g., lightweight, corrosion-resistant or high temperature variants) as well as production process optimization, quality control and defect detection, and recycling and sustainability integration into manufacturing processes.
- **Infrastructure materials development**, such as composition for key construction materials like concrete and asphalt, use of alternative materials and sustainable practices in production and design, reinforcement and other durability enhancements for existing infrastructure, and testing and monitoring methods leveraging structural health sensing and analysis.
- **Mass timber products and design**, including development and refinement of mass timber products, development of new wood composites, bonding methods, and hybrid materials, new structural engineering and construction techniques, and sustainable life cycle engineering of mass timber products.
- **Surface engineering**, in particular the tribological performance of materials to reduce friction and wear in materials moving and industrial machinery applications, as well as creation of functional surfaces with tailored properties for specific industrial applications. Additionally, surface engineering is a key component of advanced electronics and optics fabrication.

- **Membrane engineering**, where materials engineering techniques play a key role in membrane material identification and selection, fabrication and surface modification based on end use, integration of nanomaterials or other composites into membranes, and evaluation of performance of membrane structures in key applications such as remediation, biomedical, and industrial applications.
- **Bioengineering and bioproducts production and processing**, where engineered materials are used either for biomedical applications such as biocompatible materials, medical devices, biotherapeutic, and drug delivery applications, or for production and refinement of bioproducts via bioreactors and bioprocessing, creation of biofuels, and design of biodegradable and other sustainable biomaterials.
- **High performance electronics materials**, in particular production processes for microelectronic components such as semiconductors, components with customized properties for enabling advanced packaging, and high tolerance materials for use in electronics systems in extreme environments (see additional detail in Power Electronics, Advanced Packaging, and Energy Systems growth area).
- **Lithium extraction and processing**, where materials engineering capabilities aid in primary extraction and separation operations (particularly “clean” extraction methods), processing and refining of lithium into downstream materials for use in end products and systems, and design and production of battery systems and electrodes for various vehicle and energy storage markets.

Key Market Forces Driving Growth

The numerous portfolio technologies encompassed within materials engineering span a wide range of potential markets and needs which also have a diverse set of growth drivers. As noted above, demand from industry for novel materials to address key challenges is expected to drive market “winners” in terms of specific applications which generate the most commercialization investment and attention within the “portfolio” of materials applications. Leveraging its significant research enterprise spanning numerous enabling materials engineering core competencies, Arkansas can position itself to rapidly respond to whichever specific applications and demand drivers have near-term ability to drive growth and investment for the state by accelerating emerging research activity in that focus area. Several broad market forces expected to drive ongoing innovation across the portfolio of materials-related technologies include:

- **Manufacturing digitization and Industry 4.0 will continue to enable cost effective production of more customized, use-driven materials.** Rapid digitization of manufacturing operations and supply chains, including integration of predictive analytics, additive manufacturing, and industrial IoT, are expected to increasingly enable the ability to cost-effectively produce, process, and combine feedstock and other intermediate materials at smaller batch sizes that are more closely aligned with specific industry and customer needs. The ability to rapidly identify and integrate novel composites and hybrid materials in addition to increasing use of nondestructive materials testing and quality control processes means that the interface of materials engineering research and industrial production is more important than ever.
- **Sustainability and environmental concerns will continue to shape the way industry produces, uses, and reuses materials.** Heightened awareness of environmental issues and regulatory pressures

are driving industries to seek materials engineering solutions that reduce resource consumption, minimize waste generation, and lower environmental impact. Sustainable materials and life cycle engineering processes have been increasingly prioritized to meet sustainability goals, while at the same time proactively positioning industry for future shifts in the regulatory and consumer demand landscape.

- **Future urbanization and infrastructure development will require novel materials engineering solutions.** National urbanization trends and infrastructure investment initiatives are driving demand for modern construction materials, transportation systems, and energy infrastructure. Materials engineering applications play a crucial role in developing durable, high-performance materials for construction, transportation, and energy applications, which are increasingly driven by space, environmental, and energy footprint concerns. At the same time, existing infrastructure faces aging and reliability issues that are driving the need for mitigation solutions, led primarily by new types of engineered materials that can be applied to legacy structures and construction as well improved ability to monitor risk of materials degradation and failure “in situ.”

- **Solutions that improve supply chain resilience and efficiency remain a strategic priority to combat volatility across global materials supply chains.** Globalization and supply chain disruptions have highlighted the importance of materials engineering technologies that enhance supply chain resilience, optimize raw material utilization, and improve manufacturing efficiency across numerous materials-intensive industries. Companies are seeking new materials with superior properties, traceability, and reliability to ensure supply chain stability and minimize risks associated with disruptions and the corresponding fluctuations in raw material prices. This is especially true for opportunities to consolidate domestic supply chains in key industries such as semiconductors, electric vehicles, and biopharmaceuticals, where industries are looking to invest in growing clusters of talent and commercialization around anchor research institutions with well-aligned capabilities.
- **Growth of biomanufacturing and bioprocessing applications will continue to be driven by expanding consumer markets.** The therapeutics and biological products industry is experiencing significant growth driven by an aging population and increasing prevalence of chronic diseases which has resulted in an ongoing increase in innovation of biomanufacturing processes, such as

Growth Markets for Materials Engineering Applications

- Estimated \$90.9 billion market size in the Americas for green and sustainable building materials in 2023, CAGR of 12.0 percent through 2028.
- Estimated \$22.5 billion U.S. market size for nanotechnology applications in 2023, CAGR of 22.5 percent through 2028.
- Estimated \$1.2 billion U.S. market size for microfiltration membrane applications, CAGR of 8.3 percent through 2027.
- Estimated \$64.4 million market size in North America for brine-sourced lithium mining applications in 2024, CAGR of 9.1 percent through 2028.

Source: BCC Research.

automation, single-use systems, and continuous bioprocessing, This growth is fueling demand for a wide array of materials engineering technologies that enable the development of bioprocessing equipment, bioreactors, and biocompatible materials for drug production, purification, and delivery. There has been a similar growing need for materials engineering technologies that enhance bioproduction efficiency in agricultural bioproducts, biofuels, and other sustainable biomaterials that is expected to continue.

Why Arkansas?

Within Arkansas' research enterprise, there are many pockets of excellence across various facets of materials engineering supported by significant external funding and world-class research centers. However, a critical mass in any one applications area that is directly aligned with the state's industry base is still emerging, meaning that the ability to cultivate industry-facing pilot use cases across the portfolio of potential applications is critical for rapidly identifying and supporting applications of interest to existing or emerging industry.

Highlights of Arkansas' Technology Push

- **Arkansas has a diverse portfolio of specialized application areas of materials science led by recognized thought leaders and supported by significant external research funding.** An analysis of the peer-reviewed research publications activity from 2017 to 2023 reveals the presence of a critical mass of materials science activity (nearly 800 total publications over the period representing 4 percent of all academic publishing activity), which is spread across numerous specialized themes in advanced materials, including ferroelectric and graphene-based materials, composite membranes and ultrafiltration, nanoparticles and nanostructures, batteries, fuel cells, concrete, asphalt, mass timber, and electrocatalysts, coatings and tribological engineering in addition to other infrastructure materials engineering and testing.¹⁷ There is also significant presence of external federal research funding, with leading grants in membrane sciences for biomanufacturing (\$3 million), ferroic materials engineering (\$3 million), and silicon carbide materials for power electronics (see additional growth area profile Power Electronics, Advanced Packaging, and Energy Systems for further detail).
- **Investments in materials science research have allowed the state to build a base of specialized university research centers complemented by supporting labs and infrastructure.** Across the state's institutions, there are numerous research institutes and centers with specialized infrastructure and equipment to conduct world-class research in key materials engineering application areas. These include the University of Arkansas' Membrane, Science, Engineering and Technology Center (MAST), the University of Arkansas Center for Advanced Surface Engineering (CASE), the University of Arkansas Institute for Nanoscience and Engineering, the University of Arkansas Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC), the University of Arkansas at Little Rock Center for Integrative Nanotechnology Sciences (CINS), and the newly approved Arkansas State University Center for Advanced Materials and Steel Manufacturing. The collective body of research infrastructure in the state allows for significant testing and piloting efforts that can advance early-stage commercialization opportunities or ideation.

¹⁷ Based on TEconomy's analysis of Clarivate Web of Science Publications.

Table 11. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Materials Engineering Applications

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/STRONG/SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
<p>Presence of Leading Fields in Recent Research Publications Trends</p>	<p>Leading</p>	<p>Critical mass of materials sciences activity (nearly 800 total publications over the period, 4 percent of all activity). Supporting strengths in Electrical and Electronic Engineering (5.6 percent of all activity), Applied Physics (2.7 percent of all activity), and Multidisciplinary Chemistry (2.6 percent of all activity).</p>
<p>Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records</p>	<p>Strong</p>	<p>Unique specializations exist within materials sciences applications areas, including:</p> <ul style="list-style-type: none"> • Ferroelectric and graphene-based materials • Composite membranes and ultrafiltration • Nanoparticles and nanostructures • Batteries, fuel cells, and electrocatalysts • Coatings and tribological engineering • Concrete, asphalt, mass timber, and other infrastructure materials engineering and testing
<p>Presence of Active Research Project Awards Supporting Competency</p>	<p>Leading</p>	<ul style="list-style-type: none"> • \$3M NSF grant for membrane biomanufacturing platform leveraging MAST center • \$3M NSF grant for ferroic materials engineering • \$4M DoD grant for electro-optic IR sensor fabrication • Signature grant activity supporting advancement of materials science in electronics applications - \$18M NSF award for Implementation of a National Silicon Carbide Research Fabrication Facility • Numerous other grant activities by Arkansas PI's supporting materials sciences capabilities
<p>Presence of Supporting Industry-Facing University and Federal Lab Research Centers</p>	<p>Leading</p>	<ul style="list-style-type: none"> • UA High-Density Electronics Center (HiDEC) • UA Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC) • UA Membrane, Science, Engineering and Technology Center (MAST) • UA Center for Advanced Surface Engineering (CASE) • UA Institute for Nanoscience and Engineering • UA Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC) • UALR Center for Integrative Nanotechnology Sciences (CINS) • ASU Center for Advanced Materials and Steel Manufacturing

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

- **Materials engineering applications present a wide range of potential traded sector growth opportunities for Arkansas, supporting numerous use cases within the existing industry base.** While the growth area does not currently have a strong line-of-sight to a primary materials manufacturing cluster in the state, a key advantage of Arkansas' wide range of materials science expertise is the ability to address innovation needs across much of the advanced industry base. Various engineered materials applications are directly relevant to the state's clusters in chemical products manufacturing, aerospace and defense, energy and infrastructure, food and natural resource processing, life sciences, metals manufacturing, production technology and heavy machinery, and vehicle manufacturing industries, in total representing over 42 percent of the employment within Arkansas' traded sector economy.¹⁸ Despite the broad potential industry market for these applications, outside of power electronics and advanced packaging applications there has been limited direct joint research and commercialization to companies within the state to-date, primarily focused on low friction coating applications for use in industrial machinery manufacturing and material moving systems.
- **Materials engineering capabilities show strong alignment with emerging market opportunities in Arkansas that have the potential to develop into future growth drivers for the state economy.** In particular, three areas of emerging industry activity in the state with strong future growth prospects are well aligned with the need for materials engineering applications:
 - **Lithium extraction and processing:** In late 2023, Exxon Mobil announced plans to drill for lithium in southern Arkansas, creating a new potential opportunity for innovation-led economic development in the state. Arkansas' lithium resources are based around saltwater reservoirs, and extraction operations are expected to leverage direct lithium extraction (DLE) technology. These technologies are still being developed and span a variety of novel approaches, with no clear market winner yet established amongst the various startups and established oil and gas companies developing different methods. Given the limited industry presence in the state today in the intermediate and downstream lithium processing and battery production sectors, there is substantial opportunity to explore the role that the materials science research base can play in anchoring this sector in Arkansas.
 - **Novel steel manufacturing methods and materials:** The existing steel manufacturing cluster in northeast Arkansas represents a highly specialized set of primary production facilities and their associated suppliers that has not yet been fully connected to the state's materials science research community. A variety of new steel production techniques and materials are coming online within this cluster, with a major focus on low-carbon sustainable steel that was the focus of U.S. Steel's \$3 billion mini-mill investment in 2022 as well as subsidiary Big River Steel's nongrain-oriented (NGO) electrical steel line that produces key materials for the EV market. Regional buildout of highly advanced steel mill operations by companies such as Hybar are indicative of the ongoing demand for innovation, which the state's research base can become a key partner in addressing. The newly announced Arkansas State University

¹⁸ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

Center for Advanced Materials and Steel Manufacturing is a key first step in developing research and credentialing programs focused on metallurgy and steel manufacturing.

- **Sustainable materials and bioproducts:** A key focus of R&D investments across Arkansas industries is sustainable production and operations, a field where materials sciences are expected to play a major role. Given Arkansas' large agricultural and food production industry, sustainable bioproducts are often a key focus. There are significant sustainable fiber and biomass production operations in the state that have a continual need to incorporate new materials sciences applications, while the state's forests are a key natural resource that is expected to fuel new mass timber applications for building and wood products.

Table 12. Summary of Market Pull: Demand Drivers of Arkansas' Advanced Industry Clusters and Associated Innovation Activities Aligned with Materials Engineering Applications

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Some/Emerging
AEDC Target Industry with Existing Anchor Companies	Some/Emerging
Presence of Emerging Companies in VC Investment & SBIR Awards	Some/Emerging
Significant Shares of Industrial R&D Spending	Some/Emerging
Evidence of Significant IP Generation Activity	Some/Emerging
END MARKETS FOR MATERIALS ENGINEERING APPLICATIONS	
<p>A variety of potential end markets exist for materials engineering applications, but little activity in pureplay advanced materials manufacturing. Some traded sectors where potential for further connectivity with industry exists are:</p> <ul style="list-style-type: none"> • Chemical Products Manufacturing • Metals Manufacturing • Production Tech and Heavy Machinery • Energy and Infrastructure • Vehicle and Aerospace Manufacturing 	

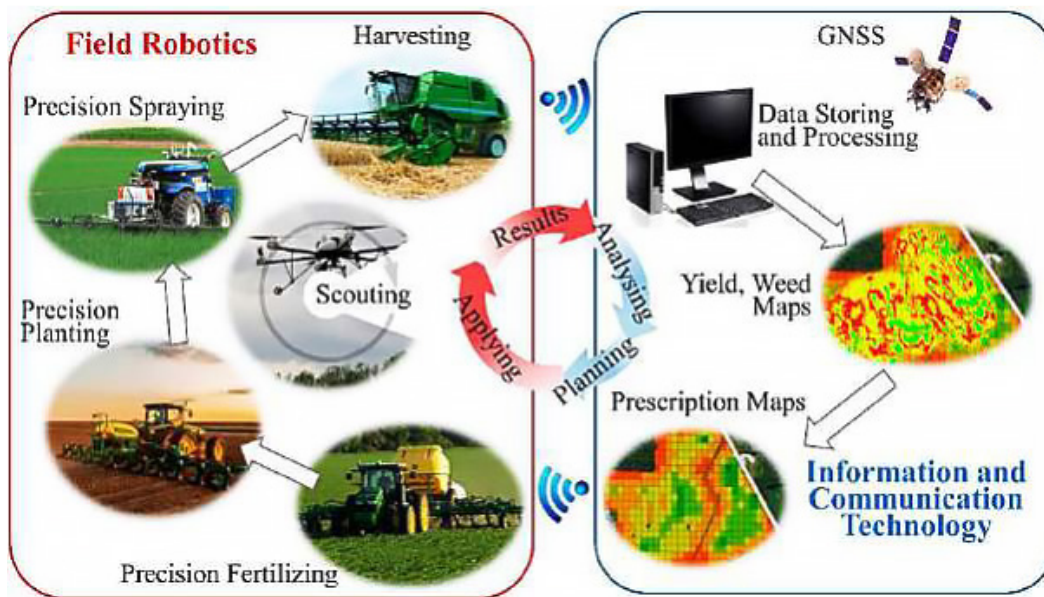
*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
Source: TEconomy's analyses.

PRECISION AGRICULTURE

What is the opportunity?

Technology is transforming agricultural production to realize the goals and meet the global grand challenges of enhanced productivity, food security, and sustainability and environmental stewardship on a global scale. Precision agriculture merges traditional agricultural practices with advanced technology to address and confront the major challenges of modern farming. Increasingly “smart”, precision farming leverages the capabilities of sensing technologies, automation, data analytics, and interconnected technologies to optimize the multi-faceted components of agricultural production and processing, from enhancing soil quality and vitality to crop and animal monitoring and surveillance to allocating resources and streamlining supply chains. Optimal, resource-efficient, and increasingly automated agricultural practices are in high demand as the world faces growing populations and diminishing natural resources as well as workforce and talent challenges in the agriculture sector—specifically, persistent labor shortages and rising labor costs globally as fewer people are choosing careers in agricultural production.¹⁹ As illustrated in Figure 15, precision agriculture aims to meet and address these challenges through an integrated ecosystem of agricultural machinery, sensing hardware, and analytics solutions.

Figure 15. Example of Ecosystem of Technologies Involved in Precision Agriculture



Source: Nath, Dibyajyoti. (2023). Smart Farming: Automation and Robotics in Agriculture.

Agriculture is Arkansas' single largest industry, contributing nearly \$21 billion annually to the state's economy and creating or supporting more than 235,000 jobs.²⁰ It is therefore both imperative, and unsurprising, that the state's major research institutions and its large agricultural, food, and forestry value chain are focusing on increasingly smart and data-driven approaches to optimizing agricultural production and processing. Led by the University of Arkansas System Division of Agriculture (Division of Agriculture),

¹⁹ BCC Research, "Global Markets for Precision Farming," December 2023.

²⁰ Arkansas Department of Agriculture, Annual Report 2023.

the state stands out in several thematic areas of research strengths within which it is applying precision agriculture approaches and data-driven practices. These include but are not limited to:

- Animal and plant health
- Poultry processing, and
- Sustainable agricultural production.

Key Market Forces Driving Growth

Modern farmers and agricultural producers are adopting precision agriculture technologies and approaches on a macro-level to address food security, environmental sustainability and climate resilience, food quality concerns, and market competitiveness. While at the same time, they are driven on a micro-level to enhance profitability and market competitiveness and address workforce and talent shortages on their own farms. Numerous market forces are driving adoption and implementation of precision agriculture including the following dynamics.²¹

- **Workforce shortages and rising labor costs** are driving the adoption of precision farming technologies via automation solutions enabled by robotics, autonomous vehicles such as tractors and drones, and AI-driven machinery which combine to reduce the industry's traditional labor-intensive reliance. Fewer individuals are choosing to work in the agricultural sector and labor costs have steadily increased, creating challenges for producers, and they are finding solutions in precision farming technologies.

In Arkansas and other Midwest states, the COVID-19 pandemic severely affected meat processing operations with infections spreading quickly among workers, disrupting supply chains. This illustrated the challenges of the extensive ag/food value chain where reliance on manual labor makes the system vulnerable to disruptions and is driving increasing investments in automation.

- **Digital transformation of agricultural operations** is itself a major driver of precision farming. Technologies such as GPS are enabling accurate field mapping and navigation; remote sensing technologies such as drones and satellites are enabling enhanced and real-time monitoring for crop health, disease detection, and resource allocation. Global connectivity and integration of web-enabled IoT devices has enabled proactive decision making for adjusting, for example, irrigation schedules from a farmers' smartphone. And AI algorithms are being leveraged in service of precision agriculture—for example, analyzing data to detect early signals of pest infestations, diseases, and nutrient deficiencies. AI-driven image recognition, for example, is able to identify specific plant diseases from aerial imagery. Given the large-scale labor shortage and wage cost inflation experienced in agriculture (and agricultural processing), robotics is a technology with a particular

The global market value for precision agriculture—spanning components, hardware, software, and applications—is estimated at nearly \$8.5 billion and forecast to grow to \$14.9 billion by 2028, a compound annual growth rate of 11.9 percent.

Source: BCC Research.

21 BCC Research, "Global Markets for Precision Farming," December 2023.

appeal. Rapid advancements in AI systems, machine vision systems, integrated sensor technology, and high-resolution guidance systems are converging to enable advancement in the sector.

- **Access to novel data sources and integration of data analytics technologies for agricultural use** has opened up new opportunities for agricultural decision support tools. New sensing technologies, availability of satellite imagery, and IoT devices, combine to provide extensive data and intelligence on soil conditions, crop health, weather patterns, and more. These data collection technologies, which farmers are increasingly able to combine using specialized software, enable agricultural producers to make informed, and even predictive decisions about optimizing planting, irrigation, and pest control. By analyzing historical data and current conditions, farmers can leverage predictive analytics to anticipate the likelihood of disease outbreaks and pest infestations, for example, or to target their watering approaches to conserve resources. The goals of driving decisions based on data include both optimizing yields and resource inputs—which simultaneously act as good business practices, with profit maximization an additional driver of precision agriculture adoption.
- **Consumer demand for sustainable and traceable food** is increasingly becoming a differentiator in consumer purchasing patterns, with upstream companies pushing requirements back to producers to track and trace their products. Consumers are placing high brand value and quality perceptions on food products that are produced sustainably, ethically, and with transparency throughout the supply chain. In response, farmers are turning to precision agriculture technologies to enable supply chain visibility and track and trace capabilities within their production operations.

Why Arkansas?

Precision agriculture represents a growth opportunity area for Arkansas that leverages significant assets, including a large and leading agricultural production and processing industry and a multi-faceted and significant set of industry-facing university R&D strengths and competencies. The opportunity addresses innovation in products and services that can enhance the competitiveness of Arkansas' largest industry—production agriculture—while offering pathways to launch new technology-driven research collaborations and entrepreneurial ventures.

Highlights of Arkansas' Technology Push

Arkansas' research universities have a large and outsized focus in agricultural sciences, spending \$75.4 million in R&D activities in 2021, representing nearly one-in-five total university research dollars. This level of agricultural research in Arkansas is nearly five times more concentrated than the national average.²² Led by the University of Arkansas-Fayetteville, which performs 89 percent of agricultural sciences R&D in the state, the Division of Agriculture supports state agricultural producers and foresters across several campuses, four research and Extension centers (with a fifth under construction), and Cooperative Extension offices in all 75 Arkansas counties. This structure of research and other support is reflective of the institution's role as a designated Land-grant University, whose mission statement is shared below.

*The University of Arkansas System Division of Agriculture's mission is to strengthen agriculture, communities, and families by connecting trusted research to the adoption of best practices. Through the Agricultural Experiment Station and the Cooperative Extension Service, the Division of Agriculture conducts research and extension work within the nation's historic land grant education system.*²³

Key themes and highlights supporting this growth opportunity from a university technology push perspective include:

- **Animal and plant health, which are standout areas of strength for Arkansas' university system, encompasses monitoring and surveillance technologies as well as genomic advances leverage precision agriculture technologies across a number of research fields.** Research leaders emphasized the University of Arkansas' strengths and focus in animal health with respect to extensive vaccine research and associated intellectual property, partnerships with industry around field trials, and nutrition recommendations that span poultry, cattle, swine, and others. In plant health, there are strengths in plant pathology, clean plant networks around fruit production, and large breeding programs. One example of collaborative surveillance is the University's participation in a national consortium effort:
 - The Division of Agriculture is a member of a large consortium led by the University of Notre Dame in the Remote Emerging Disease Intelligence-NETwork, or REDI-NET. The initiative leverages a collaborative network to address surveillance efforts to effectively detect, predict, and contain emerging zoonosis relevant to humans and to improve the accuracy and timeliness of the data-to-decision pipeline. REDI-NET has implications for both animal and human health with real-time xenosurveillance that utilizes a system-of-systems approach based on next-generation sequencing across global computing platforms. The Division of Agriculture is contributing its expertise in veterinary entomology and vector-borne diseases of animals to the project.

The state's leading position in core agricultural science fields, including highly specialized concentrations of research publication activity in plant science, agronomy, animal science, and soil science is further enhanced by a critical mass of research publications relevant to precision agriculture,

²² Based on NSF, Higher Education in R&D Survey and TEconomy's calculations.

²³ See: <https://uada.edu/about/default.aspx>.

including crop monitoring, agricultural sensing and decision-support technologies, soil properties and microbiome profiling, and forest and timber management.

- **Advancing sustainable agricultural production practices is a research priority for Arkansas universities.** These practices represents another thematic area of focus for the University of Arkansas and its partners in the ecosystem, including Arkansas State University, with significant recent grant funding awarded to researchers focused in several key areas in response to a warming planet and the imperative to feed global populations relying on critical water and other resources—all of which utilize some manner of precision agriculture tools and technologies for production and resource optimization. Examples include:
 - A nearly \$10 million U.S. Department of Agriculture (USDA) grant that includes funding to address water resource use and efficiency in broiler production, aiming to ensure the industry is sustainable in its water consumption as well as feed inputs.
 - Investigating water recycling as an integrated component of agricultural water resource management.
 - Systems genetics studies on rice genomes to understand grain yields and quality under heat stress, which includes research efforts to breed rice for impending rises in nighttime temperatures amidst climate change.
 - A focus on soil health for irrigated row crop production aiming to demonstrate the benefits of soil conservation practices in improving soil health and productivity while maintaining environmental health and sustainability.
 - Addressing invasive plant species, with a grant awarded for a national-scale early detection and ecosystem impact assessment tool for invasive terrestrial plants.
- **The state has numerous research centers that advance research, develop talent and provide critical research equipment and infrastructure that support Arkansas' agricultural commodities.** These industry-facing university centers and institutes reflect the state's unique strengths in a variety of agricultural commodities spanning rice, aquaculture, poultry, forestry, and more. One prominent example is the newly established Center for Agricultural Data Analytics (CADA) that seeks to drive research, education and training, and collaboration in data science. CADA recognizes the value of data science in agricultural research to harness the power of Big Data for domain-specific applications. In addition to infrastructure and associated consulting, CADA also offers applied statistics and data science courses for graduate students in agriculture, food, and life sciences. More broadly, Arkansas has significant research strengths in data sciences and machine learning that can further support and reinforce technology applications in precision agriculture.

Table 13. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Precision Agriculture

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/STRONG/SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
<p>Presence of Leading Fields in Recent Research Publications Trends</p>	<p>Leading</p>	<p>Several highly specialized agbiosciences fields over 2.5 times more concentrated than U.S. activity:</p> <ul style="list-style-type: none"> • Plant Sciences (3.2 percent of records) • Agronomy (2.8 percent of records) • Animal Science (2.2 percent of records) • Soil Sciences (0.8 percent of records)
<p>Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records</p>	<p>Leading</p>	<p>Critical mass of agricultural sciences and management applications within detailed publications themes:</p> <ul style="list-style-type: none"> • Crop monitoring • Agricultural sensing and decision support technologies • Forest and timber management • Soil properties and microbiome profiling
<p>Presence of Active Research Project Awards Supporting Competency</p>	<p>Leading</p>	<ul style="list-style-type: none"> • Large body of institutional R&D spending and grant award supporting plant genomics and precision agricultural research led by \$5.6M NSF grant for systems genetics studies of rice genomes. • Agbiosciences focus in project awards: poultry production and processing, plant genomics, irrigation and precision ag technologies, climate impacts modeling, animal virus epidemiology. • Outsized role of supporting agricultural sciences R&D spending by AR universities – \$75M total, nearly 5 times more concentrated than national average.
<p>Presence of Supporting Industry-Facing University and Federal Lab Research Centers</p>	<p>Leading</p>	<ul style="list-style-type: none"> • UA Pine Bluff: Aquaculture/Fisheries (AQFI) Center of Excellence • UA Center of Excellence for Poultry Science • Arkansas Biosciences Institute (ABI) • Arkansas Clean Plant Center • Arkansas Forest Resources Center • Center for Agricultural Data Analytics • Center for Arkansas Farms and Food • Wheat & Rice Center for Heat Resistance

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

- **Arkansas has a large and leading base of crop, animal, and timber production industries that can and should leverage precision agriculture technologies.** The state is the leading U.S. producer of rice and ranks among the top 10 states in nine commodities, and among the top 24 states in 15 different agricultural commodities.²⁴ Leading crops include rice, cotton, cottonseed, peanuts, and soybeans, and leading animal production includes broilers, turkeys, catfish, and beef cattle. Agricultural production, forestry, and support industries in the state employed nearly 32,000 in 2022, representing a specialized concentration of employment for Arkansas that is 91 percent greater than the national average.²⁵ According to the Arkansas Department of Agriculture, the industry contributes more than \$20.9 billion to the state's economy on an annual basis and accounts for one of every seven state jobs.²⁶ Arkansas benefits economically from direct connections to downstream food production and processing industries via an integrated ag-food value chain.
- **Several existing large and leading agricultural and agbiosciences companies are advancing innovations in crop sciences in Arkansas,** generating new intellectual property in the form of patent awards that include at least one Arkansas inventor. These companies are global leaders in precision agriculture approaches and technologies and are focused in Arkansas on advancing genetic variations in soybeans that complement the plant genomics work of the state's research universities. Agbioscience-related patent innovations were among the leading thematic areas identified among Arkansas-invented patents. These include:
 - Syngenta, with 46 patents awarded since 2017 with a focus on soybean gene clusters and cultivars.
 - Bayer Crop Science (formerly Monsanto), with 26 patents awarded since 2017 with a focus on hybrid soybean varieties.
 - Mertec, with 23 patents awarded since 2017 with a focus in novel soybean varieties.
 - BASF Agricultural Solutions, with 7 patents awarded since 2017 with a focus in novel soybean varieties.

²⁴ Arkansas Department of Agriculture, Annual Report 2023.

²⁵ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

²⁶ Arkansas Department of Agriculture, Annual Report 2023.

Table 14. Summary of Market Pull: Demand Drivers of Arkansas' Advanced Industry Clusters and Associated Innovation Activities Aligned with Precision Agriculture

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Strong/Leading
AEDC Target Industry with Existing Anchor Companies	Strong/Leading
Presence of Emerging Companies in VC Investment & SBIR Awards	Strong/Leading
Significant Shares of Industrial R&D Spending	Strong/Leading
Evidence of Significant IP Generation Activity	Strong/Leading
END MARKETS FOR PRECISION AGRICULTURE	
<p>End markets span a key, leading traded sector with a strong presence in the AR economy:</p> <ul style="list-style-type: none"> • Food Processing and Production 	

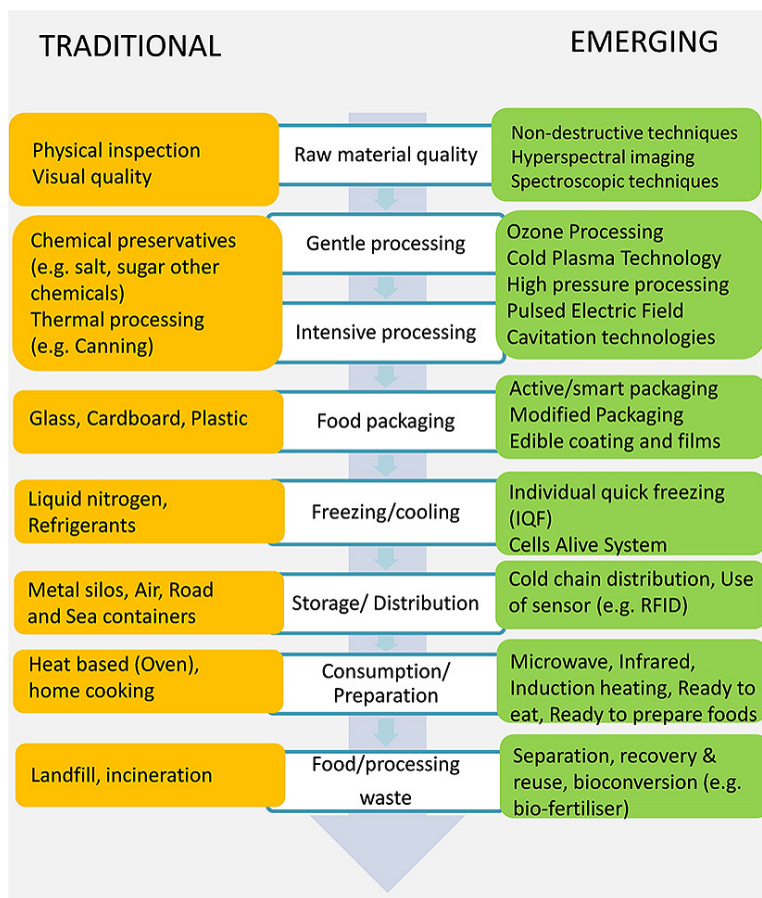
*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
Source: TEconomy's analyses.

FOOD PRODUCTION AND INTEGRATIVE HEALTH

What is the opportunity?

The food processing industry is in the midst of a transition from existing technologies and production methods. Advanced food processing technologies leverage techniques such as high-pressure processing, pulsed electric field processing, and ultraviolet light treatment to enhance food safety, extend shelf life, and preserve nutritional quality while maintaining favorable taste or texture. Automation and robotics are increasingly being integrated into food processing operations in an effort to streamline production processes, improve efficiency, and reduce labor costs. Furthermore, digital technologies, such as IoT and blockchain, are transforming food processing by enabling real-time monitoring, traceability, and quality control throughout the supply chain. Sustainable food processing practices, including waste reduction, energy efficiency, and water conservation, are also gaining prominence as the industry responds to environmental concerns and consumer preferences for eco-friendly products. The plethora of technologies being integrated into food processing operations reflects a convergence of different emerging systems that all aim to improve quality and lower costs. Figure 16 provides examples of just some of the new types of processing systems and methods rapidly being introduced.

Figure 16. Examples of Traditional and Emerging Technologies and Processing Methods Used Within the Food Processing Value Chain



Source: Knorr D, Augustin MA, and Tiwari B (2020) Advancing the Role of Food Processing for Improved Integration in Sustainable Food Chains. *Front. Nutr.* 7:34. doi: 10.3389/fnut.2020.00034.

Food and beverage manufacturing represents a leading industry for Arkansas with a long history of production that integrates a vast agribusiness complex across leading commodity production as well as a portfolio of other established value-added activities across the state. The food and broader natural resource processing industry in Arkansas has a three times greater concentration than the nation—a highly specialized industrial strength for Arkansas, and one that continues to grow.²⁷

Arkansas' research institutions demonstrate a complementary and critical mass of R&D excellence related to food production and processing that spans from deep expertise in core agricultural sciences fields to animal and crop processing to food sensory attributes and consumer preferences and perceptions. Arkansas' universities have invested in supporting research centers and institutes in well-aligned areas such as food science, poultry science, food innovations, and food safety.

There are significant new investments and initiatives underway in Arkansas aimed at leveraging the state's strengths at the intersection of both the technology push of its university R&D and the market pull of its industries to address health and nutrition needs and priorities for Arkansans. State research, health, and industrial leaders are coalescing around major in-state philanthropic and federal investments in “integrative health” approaches that aim to address major health challenges and significant long-term health disparities in Arkansas, and food and nutrition innovation and expertise will play a central role. These include:

- **The recently awarded NSF Engines Development Award for advancing equitable access to food and health technologies in the Mississippi Delta Region** (Arkansas, Louisiana, and Mississippi). With the intent of laying the groundwork for a future NSF Engine in the Mississippi Delta region, the Development Award is focused on workforce development and commercializing new technologies to achieve better and more equitable health and economic outcomes in a region long-struggling with health disparities. The initiative is led by ACHI and includes a broad coalition of academic research institutions, companies, state governments, and nonprofit organizations. The vision of the NSF Engine will, in part, “revolve around new delivery models for healthy food...”²⁸ The initiative will seek to develop more effective methods for climate resilient agriculture and for the production (a state strength addressed in the Precision Agriculture growth opportunity), distribution, and accessibility of fresh, healthy food as well as the creation of new specialty crop strategies including growth, distribution, accessibility, and business models to support food access in rural areas.
- **The major investments in the Institute for Integrative and Innovative Research (I3R) at the University of Arkansas, Fayetteville and its initial Grand Challenge focus on Integrative Health.** I3R represents a major commitment to regional economic development in Arkansas, bringing together academic, industry, government, and non-profit expertise to address Grand Challenges as set out by NSF. The interdisciplinary Institute has been funded by a transformational, \$195 million grant from the Walton Family Charitable Support Foundation. Integrative health represents I3R's initial research and economic development thrust with a focus in promoting well health and prevention paired with innovations in MedTech and FoodTech. There is a recognized need to distribute these technologies and their production and associated jobs throughout the state. In addition, I3R sees opportunities to advance new food innovations, such as the potential

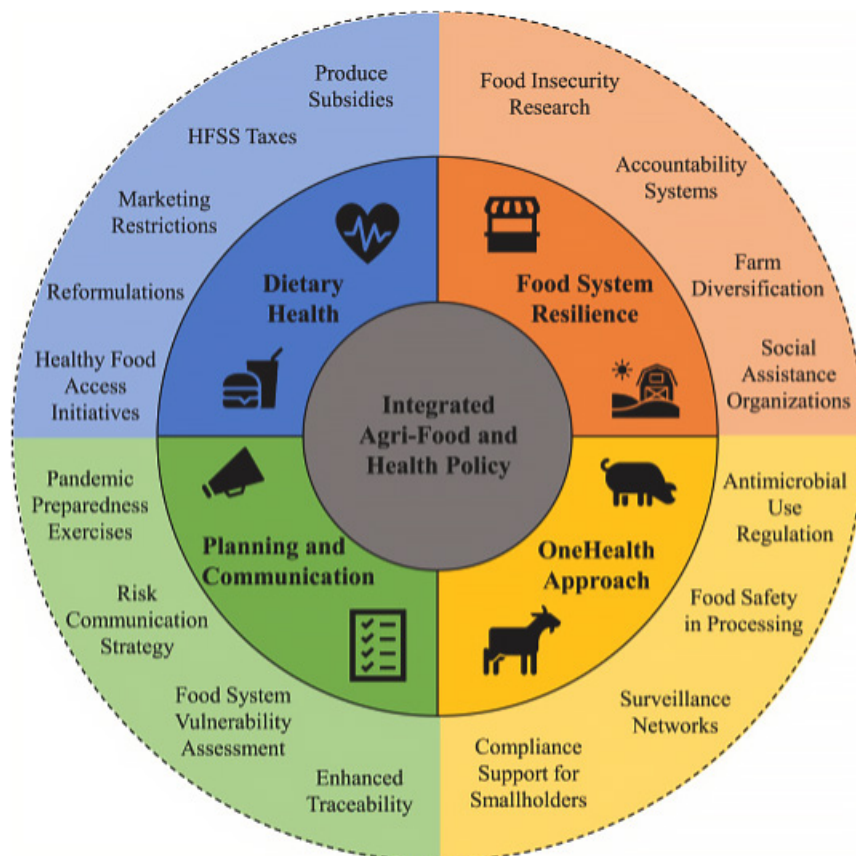
²⁷ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

²⁸ See: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2304299&HistoricalAwards=false.

opportunity to develop sustainable proteins—cell-cultivated proteins in high demand in other countries that address land and resource limitations.

Integrative health or medicine approaches recognize the multiple factors that contribute to human health and quality of life, including physiological, social, and environmental, and therefore utilize a holistic and “integrative” strategy to impact and enable healthy lifestyles and treatments—including and importantly, with respect to accessing healthy foods and improving nutrition. As illustrated in Figure 17, multiple elements of the food production and processing cycle are linked to downstream health and socioeconomic outcomes. In this respect, Arkansas’ broad and deep ag-food value chain has an important role to play in enabling an integrative health agenda to achieve broader population health outcomes and goals for Arkansas. Notably, a better integrated food-health system achieves several outcomes that are important to industry, namely increased long-term access to reliable consumer markets as well as avoidance of food safety incidents through increased transparency and incorporation of monitoring technologies into food processing operations.

Figure 17. Example of Integrated Agri-Food and Health Policy Framework Incorporating Food Production and Processing Elements



Source: Grace T. Patterson, Lian F. Thomas, Lucy A. Coyne, Jonathan Rushton, Moving health to the heart of agri-food policies; mitigating risk from our food systems, Global Food Security, Volume 26, 2020.

Arkansans are struggling with poor health. The state consistently ranks poorly in the annual report published by the United Health Foundation in partnership with the American Public Health Association that tracks health outcomes.²⁹ The 2022 annual report, which is the latest report available, found Arkansas to be one of the unhealthiest states in the nation, ranking below the national average in 38 of the organization's 51 scoring measures. Key measures of health outcomes are worsening, including the measure related to food insecurity, defined as the share of households unable to provide adequate food due to lack of resources. In this measure, Arkansas ranked 49th with 15 percent of households being food insecure.³⁰

Arkansas' research base is well positioned to contribute to both upstream food processing and downstream integrative health solutions and to leverage its strengths in nutrition-related research and associated assets—whether that takes the form of functional food³¹ development (integrating new production and processing technologies into industry operations), enhancing food safety and access in rural areas (leveraging the state's broader strengths in TDL solutions), creating new products like sustainable proteins, or informing rural and broader regional nutrition strategies for children and adults.

Key Market Forces Driving Growth

- **With the rise in chronic diseases spanning diabetes, heart disease, and obesity, there is growing interest, awareness, and demand for preventive healthcare, a key tenant of integrative health.** Diet and nutrition play a central role in maintaining good health and preventing disease. There is rising interest in and demand for functional foods, along with dietary supplements and other nutrition strategies designed to support specific health outcomes such as immune function, metabolic, and cognitive health. In addition, consumers are increasingly utilizing technology such as food-tracking apps to monitor food and nutrient intake and AI to identify patterns and correlations for more precise recommendations. The rapidly aging population represents another driver of preventive healthcare, including nutrition, to address age-related health challenges such as cardiovascular disease, osteoporosis, and cognitive decline.

Growth Markets for Food Production and Integrative Health

- Estimated \$11 billion North American market size for personalized nutrition in 2023, CAGR of 11.8 percent through 2028.
- Estimated \$56 billion U.S. market size for functional foods and beverages in 2022, expected CAGR of 8.2 percent through 2027.
- Estimated \$11.4 billion U.S. market size for food safety testing in 2023, expected CAGR of 7.8 percent through 2026

Source: BCC Research.

²⁹ For their 2022 report, see: <https://www.americashealthrankings.org/learn/reports/2022-annual-report>.

³⁰ Ibid, the indicator specifically measures the percentage of households unable to provide adequate food for one or more household members due to lack of resources.

³¹ Functional foods, sometimes also referred to as nutraceutical compounds, collectively refer to ingredients, supplements, or additives that offer health benefits that extend beyond their nutritional value.

- **Markets for functional foods are expected to grow as consumers continue to show interest** into the links between certain food ingredients and disease prevention and/or treatment with thousands of studies being conducted globally. Health Canada defines functional food as that “similar in appearance to, or may be, a conventional food, is consumed as part of a usual diet and is demonstrated to have physiological benefits and/or reduce the risk of chronic disease beyond basic nutritional functions.”³²
- **Food safety and testing solutions are becoming a critical element of risk management for food processors and distributors**, the market for which is expected to continue to grow and be driven by overall growth of the food and beverage market, increasing international trade in food and the corresponding need to track and trace foods to their original source, trends in foodborne illnesses, and stringent government regulations to ensure food safety, including under the U.S. Food Safety Modernization Act (FSMA). Food processors are generating demand for new technology platforms such as microbial detection systems, automated sanitation processes, and real-time monitoring systems to detect contaminants and ensure compliance with regulatory standards.
- **Food processors are facing labor shortages, efficiency pressures, and the need to manage the risk of disruption to operations** which in turn are driving the adoption of automation, robotics, real-time monitoring, and predictive analytics solutions in food processing. Automated sorting, packaging, and labeling systems, robotic pick-and-place systems, and AI-powered predictive maintenance tools help optimize production processes, reduce reliance on manual labor, and improve overall efficiency. Technology solutions such as blockchain, IoT sensors, and digital tracking platforms also enable real-time monitoring and traceability of food products from farm to table. Integration and operation of increasingly digitized food production and processing environments is driving demand from large food companies for technology solutions and systems integrators that can help them navigate these challenges.

32 Health Canada Policy Paper: Nutraceuticals/functional foods and health claims on foods. Available at: http://www.hc-sc.gc.ca/fn-an/label-et-iquet/claims-reclam/nutra-funct_foods-nutra-fonct_aliment-eng.php.

Why Arkansas?

Highlights of Arkansas' Technology Push

The University of Arkansas Division of Agriculture's Department of Food Science touts a top national ranking in research productivity in food science, ranking 8th among all states.³³ The department, along with others in the ag-food research ecosystem, combine to form a leading position in food science and technology research, with strong research publications activity that is three times more concentrated in Arkansas relative to national averages.³⁴ The research and affiliated research institutes and centers in the food production and processing space form a strong foundation of research competencies well-aligned with Arkansas' vast food manufacturing industry and demonstrate alignment with nutrition strengths that can be leveraged in the context of integrative health approaches supported by major new investments and federal grant initiatives.

- **Food safety is a major research, education, and training thrust for the Division of Agriculture through its academic departments, centers and institutes, and Cooperative Extension activities.** Topic modelling across Arkansas research publications identified a thematic concentration and strength in food safety and foodborne pathogens. Experiential learning opportunities are provided for undergraduate students related to food safety, quality, and security through the Future of Food Fellowship. It awards a Preventive Controls Qualified Individual (PCQI) certification as well as an online Master of Science in Food Safety. The Division's Center for Food Safety works to develop technologies and methodologies for detection and identification of food-borne pathogens, toxins, and chemicals impacting food safety and quality; determine effective interventions to control hazards in the food chain; and assist processors with technologies to reduce contamination and foodborne pathogens using pre- and post-harvest strategies.
- **Nutrition is a key thematic area of research and education activity across Arkansas institutions,** and one that should be leveraged for integrative health solutions. While not rising to the same levels of the aforementioned areas of strength, there are key centers of gravity and critical mass across the research ecosystem that can and should support the integrative health opportunities arising from the investments in I3R and associated with the NSF Engines Development Award. Nutrition research has been a major focus of the Arkansas Biosciences Institute (ABI) since its inception. One of the five designated focus areas set out in the legislative Act establishing ABI in 2000 is nutritional and other research aimed at preventing and treating cancer, congenital and hereditary conditions, or other related conditions.
- **The Division of Agriculture's Center for Human Nutrition represents a 30-year initiative of the Department of Food Science that aims to facilitate and advance interdisciplinary human nutrition research and education** that improves health, productivity, and quality of life. The Center works to meet this mission by developing resources to support nutrition research programs and translating nutrition research outcomes to stakeholders and communities. One thrust of the Center is to develop new value-added functional foods incorporating health-promoting compounds as well as ways to motivate individuals to include these in their daily diets. The Center represents a

³³ Department of Food Science homepage: <https://food-science.uark.edu/>.

³⁴ Based on TEconomy's analysis of Clarivate Web of Science Publications.

cross-campus effort bringing together interdisciplinary faculty conducting nutrition R&D at the University of Arkansas, Fayetteville and the University of Arkansas for Medical Sciences Northwest. Further, recent grants have been awarded from the USDA in nutrition-related research activities that span: a nearly \$1 million grant to improve the food security and nutritional health outcomes of low-income, food insecure individuals with Type 2 Diabetes; as well as a nearly \$1 million grant award to develop an integrated, multimedia approach to delivering food, exercise, and nutrition education for prevention of chronic disease.

- **Arkansas Children’s Hospital has been awarded significant funding to address childhood obesity and has established the Arkansas Children’s Nutrition Center**, a growing research center exploring the links between food and child nutrition and the biology of the childhood brain and metabolic processes. Located in Little Rock, the Center is able to leverage strong partnerships with the Arkansas Children’s Research Institute and UAMS.
- **Poultry science and processing represents a core research, education, training, and demonstration strength at Arkansas universities.** The University of Arkansas, Fayetteville is noted as a top-ranked program in poultry science and is advancing digital automation in poultry processing. The University maintains and has recently renovated its Poultry Pilot Processing Plant for demonstrating technologies and advancements in processing. A new \$5 million grant in 2023 from the USDA is aimed to advance digital automation aligned with Industry 4.0 principles for poultry processing in a new Center for Scalable and Intelligent Automation in Poultry Processing (CSI-APP). The grant aims to implement robotics, artificial intelligence, digital sensing, biosensing, and food safety technologies with a long-term goal of transforming current mass manufacturing protocols in large-scale centralized processing plants to mass customization capabilities for processing plants at different scales. Digital, cyber-physical processing technologies squarely in the precision agriculture and processing space can enable large-scale customization while optimizing production resources. Arkansas ranks 3rd nationally in broiler production—producing around 1 billion annually. Poultry processing was severely strained during the COVID-19 pandemic as employees became ill, plants struggled to adapt to remote work and maintain safety standards and robotic automation may help alleviate that strain in the future. The Center’s team includes leading partnering institutions including the Georgia Institute of Technology, University of Nebraska-Lincoln, Fort Valley State University, and the USDA-ARS National Poultry Research Center.

Table 15. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Food Production and Integrative Health

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/ STRONG/ SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
Presence of Leading Fields in Recent Research Publications Trends	Leading	<ul style="list-style-type: none"> • Leading position of Food Science and Technology research publishing activity (605 records, over 3 times more concentrated than national activity). • Applied themes present in publications related to food production: <ul style="list-style-type: none"> • Poultry sciences, production and processing • Crop processing (rice, soybean) • Aquaculture • Food sensory attributes and consumer perceptions
Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records	Leading	<ul style="list-style-type: none"> • Agricultural production (poultry, rice, soybeans, berries) • Food safety and foodborne pathogens • Sensory food perception by consumers • Herbicide usage and resistance • Plant and animal genomics • Environmental impacts of farming
Presence of Active Research Project Awards Supporting Competency	Leading	Major grant activity supporting food processing led by \$5M USDA award for Center for Scalable and Intelligent Automation in Poultry Processing.
Presence of Supporting Industry-Facing University and Federal Lab Research Centers	Leading	<ul style="list-style-type: none"> • UA Center of Excellence for Poultry Science • UA Institute of Food Science and Engineering • UA Center for Scalable and Intelligent Automation in Poultry Processing • Arkansas Biosciences Institute (ABI) • Arkansas Food Innovation Center • Center for Food Safety • Rice Processing Program

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

Arkansas' food production and processing industry is large, highly specialized, and growing. The industry demonstrates a strong innovation stance in the state, representing a strong and logical market pull well aligned for partnering on university innovation, associated technology solutions, and talent placement in the industry (Table 16).

- **Arkansas' food and natural resources processing, manufacturing, and other support sectors are very large and growing**, representing more than 79,000 total jobs in 2022 after 3.3 percent employment growth over the latest 5-year period.³⁵ The industry, which includes food and beverage processing and manufacturing as its largest component as well as forestry and wood products, is nearly three times more concentrated in Arkansas relative to the national average for the cluster (location quotient is 2.96). Among its detailed industries, the sector is closely aligned with agricultural production strengths in Arkansas with its largest employment totals seen in poultry and rice processing. Based on the strength and extensive impacts of this sector, AEDC has appropriately designated food and beverage manufacturing as a targeted industry for Arkansas.
- **Arkansas' food industry undertakes significant innovation activities and is well positioned to be a partner on sponsored or other research partnerships in strategic areas**, as demonstrated across the following components:
 - The food and beverage manufacturing industry spent \$45 million on R&D in Arkansas in 2020 (latest year of data available), representing the leading area of industrial R&D in the state. This level of R&D spending relative to the total of all industry R&D expenditures in Arkansas is nearly 12 times the national average.³⁶
 - The industry represents one of the leading areas for venture capital (VC) investments in Arkansas. During the 2018-23 period, Angel and VC investments in Arkansas food products companies totaled nearly \$140 million, although that was highly concentrated in multiple deals to one emerging company.³⁷
 - Arkansas corporate inventors have been awarded patents related to food innovations assigned to Safe Foods Corporation in antimicrobial compounds and application systems technologies around food safety, and to Tyson Foods in poultry processing systems.³⁸ As demonstrated by the patent awards, core university research strengths in food safety and poultry processing and production are well aligned with the innovation and market focus of leading Arkansas companies.
- **Large, multinational food manufacturers are embracing advanced digital technologies in the Industry 4.0 space.** Arkansas corporate leaders indicate a need to be on the forefront of investments and adoption of artificial intelligence, edge computing, robotics, automated systems, and computer vision combined with AI, geofencing for safety applications and translation systems

³⁵ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

³⁶ Based on TEconomy's analysis of NSF, Business R&D and Innovation Survey (BRDIS).

³⁷ Based on TEconomy's analysis of Pitchbook Venture Capital Database.

³⁸ Based on TEconomy's analysis of USPTO data, retrieved via Derwent Innovation.

for non-native English-speaking employees. Food manufacturing leaders further indicate their major emphasis, as seen across other traded sectors, on the high value of data science and analytics as well as cyber security expertise. Discussions with industry leaders recognize some areas of expertise exist in Arkansas, particularly around data sciences and cyber security but they are primarily working with national or global tech companies to address a majority of the aforementioned tech implementation. To stay relevant to corporate partners operating large scale manufacturing plants, Arkansas universities will need to continue to invest in and stay current with leading Industry 4.0 technology areas.

- **Arkansas-manufactured food and nutrition products and innovations can play a role in the context of integrative health initiatives moving forward in the state, but it will require focused, intentional partnership efforts.** University researchers are focused on advancing nutrition to address health disparities and are moving into innovative areas such as functional foods and even sustainable proteins. But in order to have FoodTech be a pillar of key health-related initiatives moving forward, exploring viable partnering efforts will be important.
- **Arkansas is advancing efforts in food-related entrepreneurship. The Arkansas Food Innovation Center (AFIC) serves as a resource to entrepreneurs** with affordable services to launch food startups. Often targeted toward producers operating small- to mid-sized farms, the AFIC provides facilities and equipment for value-added processing to enable food to be sold year-round. Food entrepreneurs also have access to technical expertise provided by the Division of Agriculture’s Department of Food Science and other departments.

Table 16. Summary of Market Pull: Demand Drivers of Arkansas’ Advanced Industry Clusters and Associated Innovation Activities Aligned with Food Production and Integrative Health

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Strong/Leading
AEDC Target Industry with Existing Anchor Companies	Strong/Leading
Presence of Emerging Companies in VC Investment & SBIR Awards	Strong/Leading
Significant Shares of Industrial R&D Spending	Strong/Leading
Evidence of Significant IP Generation Activity	Strong/Leading
END MARKETS FOR FOOD PRODUCTION AND INTEGRATIVE HEALTH	
End markets include a key traded sector with an emerging presence in the AR economy: <ul style="list-style-type: none"> • Food Processing and Production • Life Sciences (Functional Foods; Agbiosciences) 	

*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
Source: TEconomy’s analyses.

SUPPLY CHAIN, RETAIL, AND CONSUMER ANALYTICS

What is the opportunity?

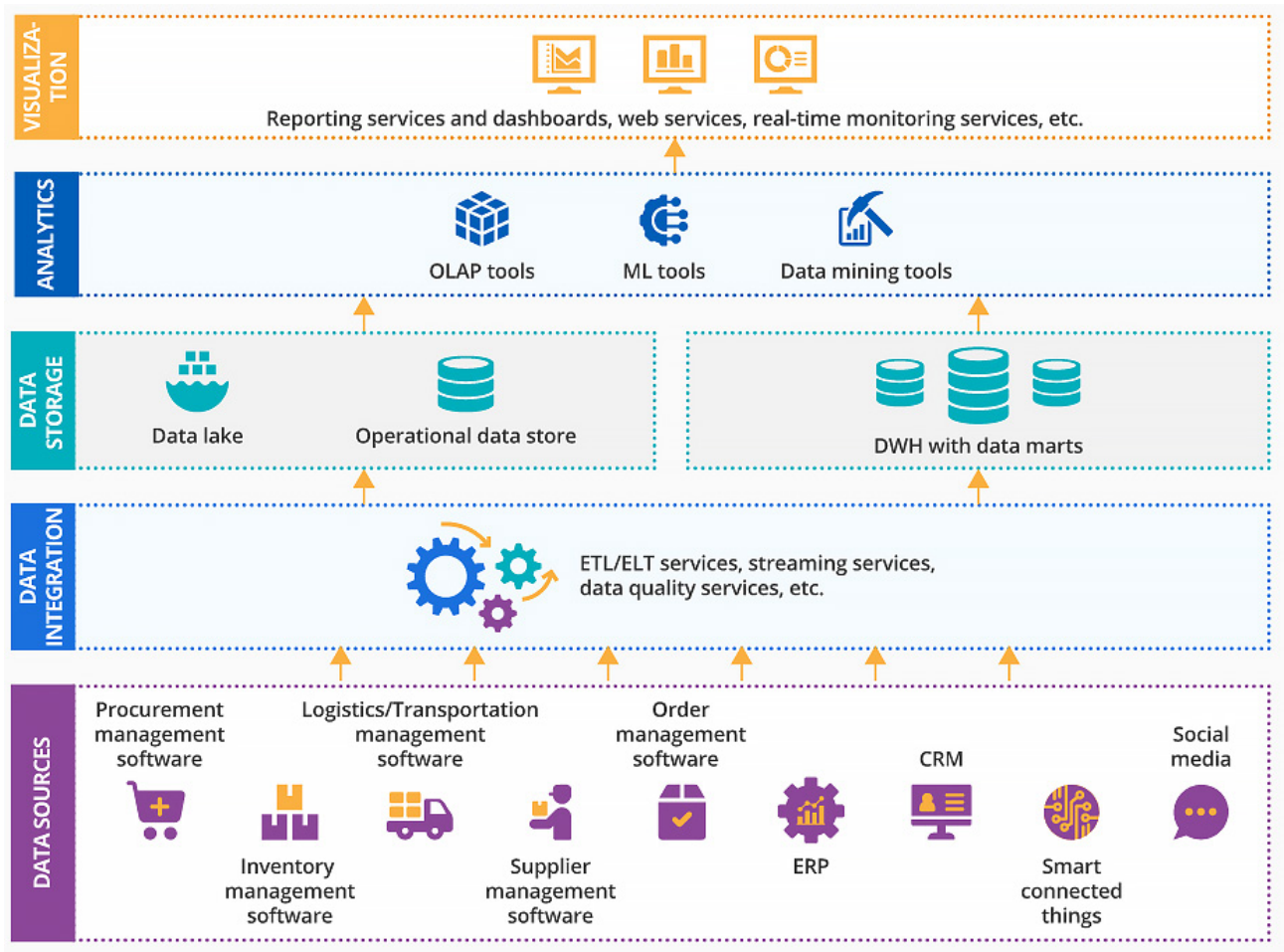
Supply chain management, the operation of retail establishments, and the ability to create detailed profiles of a business' target consumers have all evolved significantly in recent years, driven by advances in the ability to capture meaningful data at scale and then use advanced data mining and predictive modeling approaches to derive insights that impact real-world outcomes. Analytics applications across these environments have come into their prime, with new ways of leveraging data to gather insights expected to play a crucial role in optimizing operations, improving decision support, and enhancing customer experiences and retention.

While their specific deployment varies across these environments, a common set of core technologies related to data capture, data storage, and machine learning modeling approaches of varying complexity drive the core business outcomes of analytics applications. Increasingly, higher-end tools with transformative potential, such as generative artificial intelligence (genAI), are being integrated into these data pipelines to further drive impact for business operations.

The commercial analytics applications for Arkansas encompass a variety of specific use cases and combinations of these environments, but the context of supply chains, retail establishments, and consumer profiles are useful for describing the main “verticals” that are anticipated to be used amongst Arkansas' existing industry base. These three “flavors” of analytics technology deployments, which often overlap and interface with one another, include:

- **Supply Chain Analytics** enables real-time monitoring of supply chain performance, demand forecasting, and inventory optimization. Supply chain visibility platforms integrate data from various sources, including suppliers, manufacturers, logistics providers, and retailers, to provide end-to-end visibility and traceability of goods throughout the supply chain. Additionally, distributed ledger platforms, often referred to as blockchain, are increasingly being used as a way for various stakeholders to enhance transparency, security, and quality assurance in supply chain transactions. As illustrated in Figure 18, these technologies rely on significant foundational data and IT architectures that require design, maintenance, and refinement. Major aspects of supply chain analytics for anchor companies in Arkansas include demand forecasting and delivery route optimization. By analyzing historical sales data, market trends, and external factors such as seasonality and economic indicators, organizations can develop accurate demand forecasts and optimize inventory levels to meet customer demand while minimizing carrying costs and stockouts.

Figure 18. Layers of Data Ingest and Processing Involved in Enabling Supply Chain Analytics Solutions

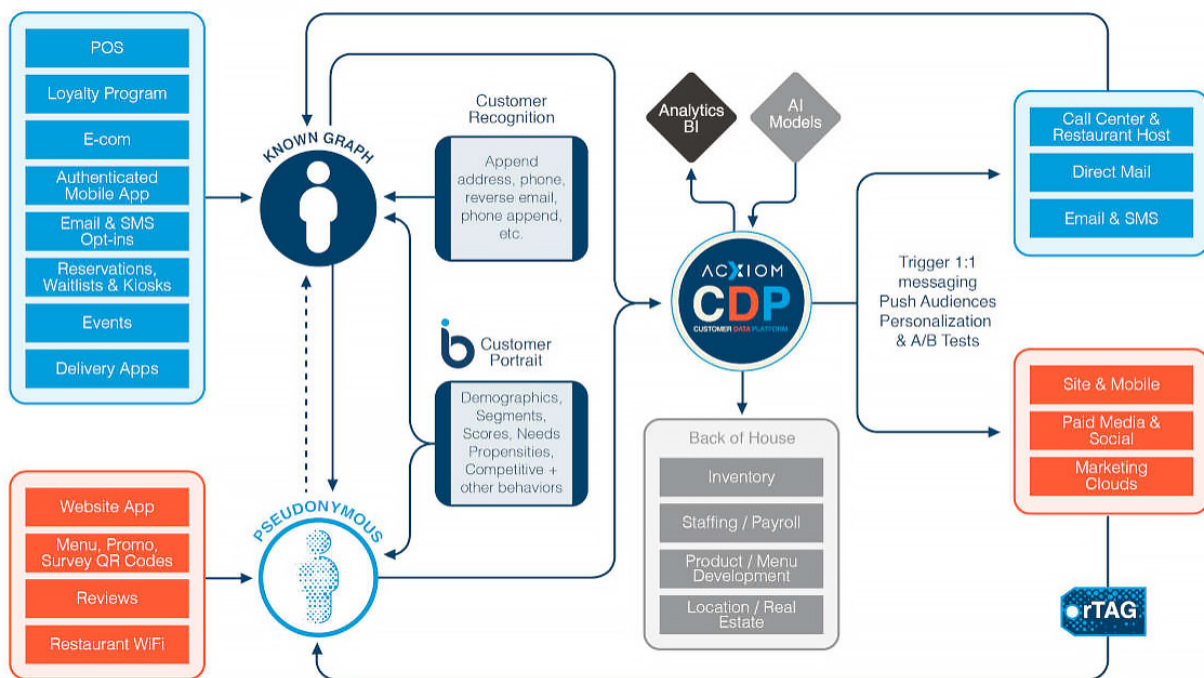


Source: ScienceSoft.

- Retail Analytics** focuses on customer transactions and experiences, utilizing analytic techniques such as customer segmentation and sentiment analysis, to personalize promotional initiatives, optimize product assortments, and improve pricing strategies. Retail analytic platforms integrate data from multiple sources, including point-of-sale systems, e-commerce platforms, social media, and loyalty programs, to provide a comprehensive view of customer interactions across channels. Additionally, the proliferation of mobile devices has led to the emergence of location-based analytics and proximity marketing, enabling retailers to deliver targeted offers and promotions to consumers based on their location and context. Analytic approaches can also be used to optimize customer experience and product placement within physical storefront locations, as well as monitor traffic across retail locations to identify trends.
- Consumer Analytics** are aimed at collecting and collating data on target consumers to develop the “customer DNA” that can provide deeper insights into consumer preferences, behaviors, and sentiments for the purposes of marketing and engagement. Social media monitoring tools, sentiment analysis algorithms, and natural language processing (NLP) techniques enable

retailers to analyze conversations, reviews, and feedback to understand consumer sentiment and identify emerging trends. Furthermore, the integration of consumer data from many different sources enables retailers to create detailed customer profiles and tailor marketing campaigns and product recommendations to individual preferences. Personalization technologies, such as recommendation engines and dynamic pricing algorithms, seek to improve the customer experience by delivering relevant content and offers to consumers in real time. Figure 19 shows how these various data points and analytical insights are integrated and analyzed in a Customer Data Platform to enable the creation of customer “personas” that in turn can be leveraged for marketing and engagement efforts by businesses as well as enabling further downstream analytical insights.

Figure 19. Example of Customer Data Platform Implementation for Restaurant Diners to Enable Consumer Analytics



Source: Acxiom.

Across these various analytic application verticals, new predictive modeling and process automation technologies are continuously being introduced and integrated, spearheaded by recent advances in the commercial viability of generative AI and enabled by more ubiquitous deployment of wireless connectivity and data harvesting systems. **Arkansas’ research institutions, and in particularly key sectors of its industry, are already leveraging these technologies to compete in the global marketplace, and they will remain critical to the state’s future success in tech-enabled business operations.**

Key Market Forces Driving Growth

Advanced analytics technologies represent a rapidly growing and evolving set of opportunities, with new software capabilities steadily coming online and companies seeking to rapidly adopt and embed new applications within their business operations. As enabling digital technologies, massive data gathering and management, and powerful AI tools continue to advance, several key market forces are influencing their integration into supply chain management, logistics, retail businesses, and consumer engagement, including:

- **Management of complex, global supply chains in the face of increasing competition and cost pressures is forcing logistics-based businesses as well as their suppliers to adopt technologies** that provide greater transparency and real-time decision support within the deepest tiers of their supply chain. Supply chain disruptions have the potential to cause significant impacts to business revenue given tight margins and increasing multinational competition across a global economy, and companies are turning to new analytics solutions to optimize their supply chains, both proactively and reactively. Supply chain analytics solutions are leveraging the data streams from hardware technologies such as those outlined in the Next Generation Transportation and Logistics opportunity area to provide insights into vehicle performance, route efficiency, inventory levels, chain of custody, and the environment of goods in transit, enabling companies to make responsive, real-time decisions about their fleets and supplier relationships.
- **Customer expectations and brand management are becoming critical for companies to navigate with major impacts for revenue**, as increasing conversion to digital services has driven consumers to expect personalized and seamless experiences across various interactions with a company or brand. New suites of analytics tools help companies identify strategic interventions for customer retention and loyalty as well as enabling the increasing personalization of marketing and discounts based on customer preference.

Growth Markets for Supply Chain, Retail, and Consumer Analytics

- Estimated \$7.4 billion market size in the Americas for supply chain management software in 2023, CAGR of 10.1 percent through 2028.
- Estimated \$4.3 billion market size in the Americas for supply chain management services in 2023, CAGR of 12.0 percent through 2028.
- Estimated \$389 million North American market size for predictive analytics solutions in retail and e-commerce in 2023 (20.4 percent CAGR through 2027) and estimated \$264 million North American market size for predictive analytics solutions in TDL in 2023 (14 percent CAGR through 2027).
- Estimated \$1.4 billion North American market size for marketing analytics in 2021, CAGR of 14 percent through 2026.
- Estimated \$12.6 billion U.S. market size for smart retail solutions in 2024, CAGR of 25.6 percent through 2028.
- Estimated \$19.9 billion North American market size for “Internet of behavior” data applications in retail and e-commerce in 2024, CAGR of 26.6 percent through 2027.

Source: BCC Research.

- **Proliferation of data from consumer devices and interactions with online and physical commerce platforms** has resulted in an explosion of information that companies are continuously seeking to mine to derive further insights about their business. Customer data is often scattered across various systems and touchpoints, making it challenging for companies to create a unified view of their customers. Modern analytics solutions often seek to characterize and link these disparate sources of data into a single, centralized repository, enabling companies to gain a comprehensive understanding of their current business flows and customer bases.
- **Digital process automation is having significant impacts on business operations**, in particular the ability to seamlessly integrate multiple data sources and inventory or customer management systems via partially automated or low-code/no-code platforms. In the face of competitive labor markets for tech talent and increasing need to quickly process and mine extremely large datasets, process automation and data retrieval leveraging integrated software platforms are critical enablers of higher value analytics and decision support capabilities. Additionally, low-code and other software platforms aimed at “non-technical” users are providing the ability to quickly adapt to changing operational or market conditions with much lower development costs.
- **Concerns about data privacy and compliance as well as the constant threat of data breaches impacting consumers** have heightened awareness of public perception and regulatory requirements and prompted companies to invest in robust data management and governance solutions. New analytics platforms offer capabilities for securely storing, managing, and analyzing customer data while ensuring compliance with data protection regulations while also mitigating the risk of data breaches and subsequent penalties.

Why Arkansas?

As home to a number of the nation's largest retailer, distribution, and shipping companies, Arkansas has a significant stake in remaining at the forefront of research and innovation in key analytic application areas that enable its sizable TDL cluster. The presence of large anchor companies has allowed the state's research and talent generation efforts to align with these critical industry partners and build a sizeable base of activity centered around key university centers, joint research projects, and access to world-class talent specialized in supply chain and logistics operations.

Highlights of Arkansas' Technology Push

- **Arkansas is home to a cluster of nationally recognized colleges and centers that specialize in supply chain management, operations research, and industrial engineering oriented toward industry-facing application areas.** In particular, the University of Arkansas' Walton College of Business is home to the Supply Chain Management Research Center (SCMRC) focused on conducting specialized research on various aspects of supply chain management, including supply chain optimization, logistics, inventory management, procurement, distribution, and sustainability. The Walton College's supply chain management and business degree programs are regularly ranked amongst the top in the U.S. There is further institutional excellence oriented towards the TDL cluster through other key centers such as the University of Arkansas' Center for Excellence in Logistics and Distribution (CELDi) and various industrial engineering and operations management degree programs.
- **The state's research themes are focused on emerging analytic applications, with a variety of industry partners engaging with thought leaders around joint research projects.** Key thematic areas evident in recent research publication activity that are highly relevant to analytic applications include recommendation and classification engines for consumer analytics, supply chain performance and optimization algorithms, operations management metrics, logistics outcomes measurement and benchmarking, fleet management and routing analytics, and measurement of operational performance through localization and tracking technologies. Additionally, the state's research enterprise has engaged with industry around emerging analytic applications through joint research projects as well as interdisciplinary, industry-driven centers such as the J.B Hunt Innovation Center of Excellence and the Walton School's Blockchain Center of Excellence, both of which are working in emerging technology spaces leveraging industry partner project funding.
- **Major anchor companies are also advancing innovation through their own internal R&D teams, leveraging the unique talent pipeline that the state's universities provide.** Across key industry sectors that are dependent on logistics solutions, Arkansas companies are investing in internal analytics teams that are developing industry-led innovations. These internal groups are being driven by skilled talent being sourced from state institutions through relationships with Fortune 500 companies like J.B. Hunt, Murphy USA, and Walmart, who in turn are investing significant amounts of capital into development of new analytic solutions spearheaded by these personnel. Although not a traditional technology transfer metric, the skilled talent pipelines being generated from Arkansas institutions with the technical capabilities, and more importantly the specialized knowledge of TDL business operations, are a major enabler of corporate-led innovation that in turn is pushed out to various suppliers and partners.

Table 17. Summary of Technology Push: Arkansas Universities' Industry-Facing Core Research Competencies in Supply Chain, Retail, and Consumer Analytics

INDICATORS OF RESEARCH ACTIVITY	PRESENCE OF CORE COMPETENCY THEMES (LEADING/ STRONG/ SOME PRESENCE)	THEMATIC AREAS OF RESEARCH EXCELLENCE EMERGING FROM ANALYSIS
<p>Presence of Leading Fields in Recent Research Publications Trends</p>	<p>Strong</p>	<ul style="list-style-type: none"> Major body of publications, white papers, and conference proceedings associated with Walton College of Business focused on supply chain management, retail and e-commerce, and sustainability in logistics operations. Specialized levels of activity in operations research and management science (41 percent more specialized than national publication trends). Significant levels of computer sciences publications in fields such as information systems and artificial intelligence.
<p>Presence of Industry-Facing Themes in Topic Modeling of Research Publications Records</p>	<p>Strong</p>	<ul style="list-style-type: none"> Recommendation and classification engines for consumer analytics Supply chain performance and optimization algorithms Operations management metrics Logistics outcomes measurement and benchmarking Fleet management and routing analytics Measurement of operational performance through localization and tracking technologies Simulation and forecasting of large scale intermodal transportation networks
<p>Presence of Active Research Project Awards Supporting Competency</p>	<p>Strong</p>	<p>Supporting capacity through multi-institutional \$24M, 5 year Data Analytics that are Robust and Trusted (DART) EPSCoR grant focused on big data management, security and privacy, model interpretability, and data sciences workforce.</p>
<p>Presence of Supporting Industry-Facing University and Federal Lab Research Centers and Innovation Ecosystem Activity/ Assets</p>	<p>Leading</p>	<ul style="list-style-type: none"> UA Walton College of Business and Supply Chain Management Research Center (SCMRC) UA Center for Excellence in Logistics and Distribution (CELDi) UA J.B Hunt Innovation Center of Excellence UA Blockchain Center of Excellence UA Retail Advisory Board UALR Emerging Analytics Center UALR Collaboratorium for Social Media and Online Behavioral Studies (COSMOS) Lab

Source: TEconomy's analyses.

Highlights of Arkansas' Market Pull

- **Arkansas is home to some of the nation's largest companies driving demand for innovation across the key analytic application "verticals," creating a natural testbed and consumer base for research commercialization.** The TDL cluster accounted for almost 81,000 jobs in 2022, which equates to nearly 5 percent of the state's total traded sector industry base, making it one of the pillars of the Arkansas economy.³⁹ As previously noted, the state is home to the headquarters and logistics operations hubs of several leading national companies that rely on logistics and transportation networks as a fundamental component of their value to customers. Additionally, the presence of Acxiom's operations in the state anchors a base of consumer analytics and data management industry activity that is an active source of technology development.
- **Arkansas companies in supply chain and logistics-intensive industry sectors are actively investing in digital change adoption initiatives, creating a dynamic environment where the state can integrate industry partnerships and talent development initiatives into the research environment.** Maintaining competitiveness of this industry base is a critical concern for industry stakeholders both in terms of generating talent that has exposure to the latest research and thought leadership as well as the ability to work with university thought leaders to commercialize new technology solutions. The ongoing investment by industry in sourcing and developing the latest technology is evidenced by significant increases in industry R&D spending in software publishing and computer systems design and related services, where Arkansas industry R&D spending has increased by over 73 percent since 2017 (to \$26 million in 2020) and by over 157 percent since 2017 (to \$18 million in 2020), respectively.⁴⁰ Intellectual property generation by industry is also heavily focused in this sector with specialization in areas such as digital inventory and product management systems, digital supply chain applications, customer analytics, and data streaming and change management platforms.
- **Arkansas has begun to develop an emerging startup and entrepreneurial ecosystem focused on supply chain, logistics, and consumer analytic technology solutions with several successful companies that have demonstrated the ability to scale.** More than \$146 million in VC was invested from 2018 through 2023 in business software firms focused on retail, sales, and marketing analytics, supply chain management, and warehouse and inventory management.⁴¹ The state is home to an emerging cluster of successful and growing companies in this space, including more established companies like ArcBest, which provides digital supply chain and AI-based optimization integrations, and SupplyPike, a developer of cloud-based supply chain management software that has raised significant later-stage VC funding. Additionally, there are growing investments in supporting entrepreneurial ecosystem organizations that serve as facilitators for major anchor companies, such as the Northwest Arkansas Plug and Play Innovation Network, that are focused on supply chain digitalization and predictive analytics.

³⁹ Based on TEconomy's analysis of BLS, CEW data from Lightcast, datarun 2024.1.

⁴⁰ Based on TEconomy's analysis of NSF, Business R&D and Innovation Survey (BRDIS).

⁴¹ Based on TEconomy's analysis of Pitchbook Venture Capital Database.

Table 18. Summary of Market Pull: Demand Drivers of Arkansas' Advanced Industry Clusters and Associated Innovation Activities Aligned with Supply Chain, Retail, and Consumer Analytics

TRADED INDUSTRY SECTOR & KEY INDICATORS OF INDUSTRIAL INNOVATION, SPECIALIZATION, GROWTH	INDUSTRY PRESENCE IN EACH CATEGORY (STRONG/LEADING VS. SOME/EMERGING)
Leading Industry Position*	Strong/Leading
AEDC Target Industry with Existing Anchor Companies	Strong/Leading
Presence of Emerging Companies in VC Investment & SBIR Awards	Strong/Leading
Significant Shares of Industrial R&D Spending	Strong/Leading
Evidence of Significant IP Generation Activity	Strong/Leading
END MARKETS FOR SUPPLY CHAIN, RETAIL, AND CONSUMER ANALYTICS	
<p>End markets in applications for nearly all major traded sectors, but with particular impact in:</p> <ul style="list-style-type: none"> • Transportation, Distribution, and Logistics • IT and Data Services • Manufacturing Clusters and Related Supplier Industries • Corporate Headquarters and Business Services 	

*Note: Considers measures of employment size, recent growth in AR and relative to U.S., and relative concentration/specialization in AR relative to national averages (LQs).
 Source: TEconomy's analyses.



IV. CONCLUSION

The science- and technology-related growth opportunity areas identified in this study represent a unique portfolio of Arkansas' strengths and a potential playbook for the state's innovation-led future. While some individual areas are more primed and ready for advancement in the near-term, others will require nurturing, longer-term investments, and serve as a guide as new market opportunities present themselves in the coming years (Figure 20). But ultimately, the seven identified opportunities are those in which Arkansas is best positioned to globally compete and that can help sustain the state's leading industry clusters as well as advance emerging market opportunities in new industries of the future.

Figure 20. Summary of the Overall Position of Arkansas' Growth Opportunity Areas

GROWTH OPPORTUNITY AREA	BREADTH OF RESEARCH COMPETENCIES & INNOVATION ASSETS	RESEARCH INVESTMENT & GROWTH	MARKET POTENTIAL & ALIGNMENT WITH EMERGING TECH TRENDS	EXISTING INDUSTRY BASE
	<ul style="list-style-type: none"> • Leading based on unique research assets providing competitive advantage • Established based on extensive depth of core research competencies • Emerging based on more limited depth of core competencies 	<ul style="list-style-type: none"> • Significant/Moderate/Limited based on R&D spending levels, investments in new innovation assets • Public or Private-led based on whether universities and labs or industry is the primary driver of activity 	<ul style="list-style-type: none"> • Significant/Moderate/Limited based on various estimates of potential market size • Immediate/Near-Term/Long-Term based on when market applications are expected to unfold 	<ul style="list-style-type: none"> • Significant/Moderate/Limited based on presence of established traded sector industry clusters supporting market deployment
Population Health Innovations & Clinical Research	Leading	Significant, Public-led	Significant, Immediate	Significant (mix of traded and local healthcare delivery sectors)
Power Electronics, Advanced Packaging, & Energy Systems	Leading	Significant, Public-led	Significant, Immediate	Significant
Next Generation Transportation & Logistics Systems	Established	Significant, mix of Public & Private	Moderate, Near-Term	Significant
Materials Engineering Applications	Mix of Established & Emerging depending on end market	Moderate, Public-led	Moderate, Long-Term	Moderate
Precision Agriculture	Established	Moderate, Public-led	Moderate, Near-Term	Moderate
Food Production & Integrative Health	Established	Significant, mix of Public & Private	Moderate, Immediate	Significant
Supply Chain, Retail, & Consumer Analytics	Established	Significant, Private-led	Significant, Immediate	Significant

Source: TEconomy's analyses.

Successfully seizing these opportunities will require intentional connections, investments, and a collaborative culture. In interviews with key thought leaders, concern was expressed regarding a disconnected ecosystem in which industry and academic interests align, but due to a lack of awareness, individuals pursuing complementary efforts are not connecting with one another. This is not a unique dynamic to Arkansas, but the degree to which it occurs is troubling. ARA is uniquely positioned and has a strong track record of bringing Arkansans together to seize innovation-led opportunities, and these efforts to foster collaborations need to continue.

As ARA looks to the future, these opportunity areas can serve as a guide or “North Star” for ARA and its strategic partners to inform investments, to serve as a foundation for statewide innovation initiatives, to build awareness of the state’s unique strengths, and to recruit and retain world-class innovators in Arkansas.



APPENDIX

The Arkansas Research Alliance and TEconomy Partners wish to thank the following members of the project Advisory Committee, who dedicated their time and provided valuable insights and feedback throughout this effort.

COMMITTEE MEMBER	ORGANIZATION OR INSTITUTION
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Scott Anderson , Executive Director	Forge Institute
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