

COMPETING FOR ARKANSAS' FUTURE:

The Economic and Functional Impacts of the Arkansas Research Alliance

Prepared For: Arkansas Research Alliance
Prepared By: TEconomy Partners, LLC
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ArkansasResearchAlliance





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PREFACE

“Job-creating research” and “Research Matters” are more than catchphrases summarizing the *raison d'être* of the Arkansas Research Alliance (ARA). They represent a purpose rooted in delivering economic development fueled by intellectual creation at the state's primary research universities. Intellectual creation springs from the minds, energies, and collaborative nature of talented researchers and investigators. Attracting intellectual capital and nurturing it into value for Arkansas is the core of ARA's mission.

This report, *Competing for Arkansas' Future: The Economic and Functional Impacts of the Arkansas Research Alliance*, examines the extraordinary impacts of ARA's investments in scientific talent recruitment, retention, and productivity. Since its inception, ARA has invested a total of \$8.3 million in helping to attract, retain, and energize nearly 40 strategic researchers who now belong to the ARA Academy of Scholars and Fellows.

The results are impressive. Modest, sustained investments have generated outsized returns. Moreover, they represent the difference that focused research talent makes in our state's economy. As expressed in the first half of the report, the quantitative impacts include:

- \$1.3 billion in total economic impact
- \$26 million in state tax revenues: this amounts to better than a three to one return on the state's investment to date—for every \$1.00 of state investment in ARA Academy member research, the state received \$3.13 in state tax revenues
- \$206 million in research funding
- Nearly 350 high-quality jobs averaging more than \$80,000 in annual compensation
- 13 new Arkansas companies.

As a result of ARA's focus, the state's competitive position in the knowledge economy has improved. The second half of the report describes ARA's functional impacts based on more than 30 interviews with university leaders, state economic development officials, and industry collaborators. It also provides mini case studies speaking to those impacts for Arkansas' economy created in serving ARA's mission. They include:

- Building and developing top talent
- Sustaining and growing new areas of research
- Supporting and growing advanced industries
- Connecting the state's science and innovation community

The caliber of these results is only possible with the collaboration of trusted partners. The support and commitments to invest in research talent have come from all corners, especially the university chancellors and private sector leaders who comprise the ARA Board of Trustees, the Governor, the Arkansas Department of Commerce, the Arkansas Economic Development Commission, the legislature, the Arkansas Congressional delegation, and the U.S Food and Drug Administration. We appreciate their embrace of ARA's mission.

There are many takeaways from this report, but the overall message is clear: **ARA is a proven economic development model on which to capitalize.** Since its founding 15 years ago, ARA has eclipsed the proof-of-concept stage multiple times over. It is now emerging as a growth enterprise. This assessment sets the benchmark for ARA and Arkansas to surpass in the coming years.

Sincerely,



Ritter Arnold, Chair of the Arkansas Research Alliance Board of Trustees and Executive Vice President, E. Ritter & Company



Bryan J. Barnhouse, President & CEO, Arkansas Research Alliance

THE ARKANSAS RESEARCH ALLIANCE BOARD OF TRUSTEES

ARA is governed by a board of trustees comprised of chancellors from Arkansas research universities and business leaders from across the state. The board is committed to creating opportunities in the areas of research, commercialization, and job creation. Each member is a champion for research in Arkansas and dedicated to the advancement of ARA's mission. The board of trustees has been critical to the success of the organization and continues to provide unparalleled leadership as ARA launches new programs, forms new collaborations, and gains momentum.

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EXECUTIVE SUMMARY

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 at the state's five major research universities recruit, recognize, and retain world-class scientific, tech, and engineering talent in strategic research focus areas (Figure ES-1). Additionally, ARA plays a lead role for the State of Arkansas in facilitating in-state collaborations with the only national laboratory located in the state—the U.S. Food and Drug Administration's National Center for Toxicological Research (NCTR).

A decade-and-a-half later, the ARA has matured into a multi-faceted and integral organization leveraging university research and top talent to change the economic trajectory of Arkansas.

ARA has cultivated an impressive community of innovation, and since its inception its Academy of Scholars & Fellows has represented or generated for Arkansas:

- **39 World-Class Scholars and Fellows.***
- **\$205.7M in Research Funding**—leveraging ARA grant funding nearly 25 times.
- **13 Science- & Tech-Driven Startup Companies** directly associated with Academy members or their research.**
- **\$1.3B Total Economic Impact in AR** driven by cumulative research funding and startups since 2011.
- **\$80,000 Average Annual Compensation** for jobs generated by Scholars & Fellows—high-quality and family sustaining jobs for Arkansans.
- **\$26.1M Cumulative Contribution to State Tax Revenues—a better than 3-to-1 return on Arkansas' investments (ROI) in ARA to date.**

*29 Academy members are active researchers at AR institutions today.

**Twelve of the 13 startups are active today.

Figure ES-1. The Six Institutional Partners of ARA¹



1 The six institutions and associated abbreviations used throughout this report include: Arkansas State University (A-State or ASU), University of Arkansas (UA or U of A), University of Arkansas at Little Rock (UA Little Rock or UALR), University of Arkansas at Pine Bluff (UA Pine Bluff or UAPB), University of Arkansas for Medical Sciences (UAMS), and the National Center for Toxicological Research (NCTR).

The direct impact of ARA efforts is inherently challenging to quantify but with 15 years since its inception and more than a decade of data available, it is now possible to evaluate, communicate, and continue to refine the investments made into ARA. This report aims to tell the ARA story by developing and providing a comprehensive examination and quantification of both the economic (or expenditure and employment based) impacts and the functional (or mission-based) impacts of the organization to date. It is important to acknowledge that the impacts generated by ARA require strategic and highly collaborative partnerships across Arkansas, and many of these impacts cannot be directly attributed to ARA alone, but rather to the community of innovation it has cultivated.

Against a backdrop of intense state, national, and international competition for advanced industry development and top talent, ARA and its strategic programming efforts represent a critical tool for maintaining and enhancing Arkansas' ability to compete and to lead in the global knowledge economy.

ECONOMIC IMPACTS OF ARA INVESTMENTS FOR ARKANSAS

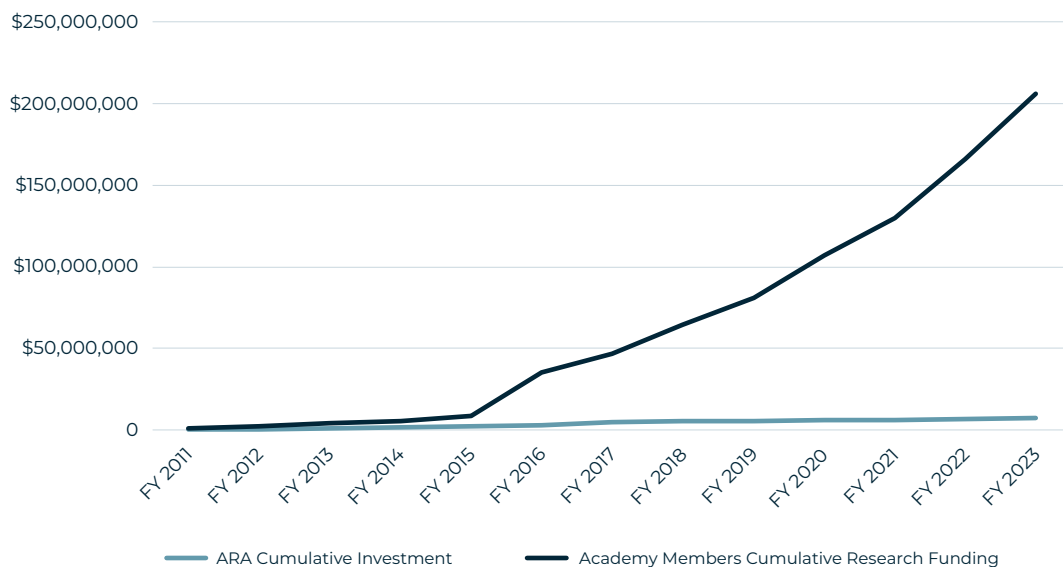
ARA's mission is to invest in strategic research talent recruitment, retention, and recognition to generate scientific and engineering breakthroughs that support statewide economic development. The organization's signature effort is through the *ARA Scholars Program*, where ARA partners with universities 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 those five campuses and at NCTR is through the *ARA Fellows Program*. This combined talent pool is funded via grants and merged into the ARA "Academy" of Scholars and Fellows.

To meet its mission, ARA has invested in a total of 39 research Scholars and Fellows since its inception through 2022, with 29 active members (i.e., members actively conducting research at one of the ARA partner institutions) captured in the FY 2022 and FY 2023 data to date.² As a compounding and leveraging research investment program, the goal of these ARA investments in Arkansas researchers is to "seed" the research activities of the member researcher, enabling them to further their future research activities through additional sponsored research.

Figure ES-2 presents this cumulative investment and funding since ARA's inception. **Since 2011, ARA has invested a total of \$8.3 million in its Scholars and Fellows. Over this entire period through mid-FY 2023 the 39 ARA Academy members have generated a total of \$205.7 million in research funding**, with the 29 active Academy members generating \$39.7 million in research funding through the first half of FY 2023. **Together, the ARA Academy researchers have leveraged their ARA funding nearly 25 times—each dollar of ARA investment has helped support \$24.75 in total research funding.**

² Cumulative membership in the ARA Academy totals 39 researchers with 29 active at the time this study was initiated. In the summer of 2023 (FY 2023), seven additional Scholars and Fellows were named by ARA. The employment and research activities of these seven are not included in this economic impact analysis. It should also be noted that researchers affiliated with the U.S. FDA's National Center for Toxicological Research (NCTR) do not receive direct financial support from ARA.

Figure ES-2. Cumulative ARA Investments in Academy Members and Academy Member Total Research Funding, FY 2011—Mid-FY 2023



Source: TEconomy Partners' analysis based upon reporting from ARA and Arkansas Research Universities.

GENERATING SIGNIFICANT ECONOMIC IMPACTS FOR ARKANSAS

ARA Scholars and Fellows generate economic impacts through both research expenditures and engaging the private sector through startup creation, licensing, or technology development partnerships. These startup and early-stage activities are reflected in 13 Arkansas companies, with 12 active companies directly employing 150 Arkansans in 2023.

Using well-established regional economic analysis techniques of input-output (I-O) analysis, the impact analysis³ estimates the economic “ripple effect” throughout the Arkansas economy originating with the direct employment of the ARA Academy members and related startup employment, flows through Arkansas-based suppliers (indirect impacts), and ultimately through Academy members, their research teams, and supplier workers who spend their wages in Arkansas (induced impacts).

Recent Economic Impacts, FY 2023. In the latest Fiscal Year, the combined startup employment and research expenditures associated with ARA Academy members are estimated to have generated and supported:

- Direct output (including both sales from private firms and expenditures from institutional researchers) of more than \$124 million and direct employment totaling 346 jobs.
- These direct jobs—including the individual scholars and fellows—are high-quality and family-sustaining, averaging more than \$80,000 annually in total compensation.⁴

³ For this analysis, TEconomy used an Arkansas-specific IMPLAN I-O model and underlying data. The IMPLAN model is the most widely used in the nation and is based on the U.S. Bureau of Economic Analysis (BEA) national accounts data, supplemented with state level employment data from the U.S. Bureau of Labor Statistics (BLS), and other economic data from the U.S. Bureau of the Census and other federal agencies.

⁴ Total compensation is inclusive of the value of wages, salaries, proprietor income and employee benefits. For comparison, average labor income for all Arkansas workers is approximately \$55,000.

- A total economic impact of \$209.3 million and 814 Arkansas jobs throughout the State economy accounting for direct impacts as well as the broader multiplier effects of supply chain and employee spending (indirect and induced impacts).
- Tax revenues to the State of Arkansas totaling \$4.4 million.

Cumulative Economic Impacts, FY 2011-FY 2023. The cumulative impacts of the 13 years of research expenditures and 13 Academy-related companies that were active in Arkansas during some portion of this time period are estimated to generate and support:

- Direct output of \$796 million and direct employment totaling 1,976 “job-years” (where one job for one year is equivalent to one job-year).
- A total employment impact of 4,839 job-years combining direct, indirect, and induced effects.
- More than \$1.3 billion in total economic impact across the Arkansas economy during this 13-year period.
- Tax revenues to the State of Arkansas totaling \$26.1 million.

Arkansas’ Return on Investments to date. The total leveraged ARA Academy investments of \$8.3 million have yielded and supported combined state tax revenues over the full 13-year period totaling \$26.1 million. **This amounts to a better than three-to-one return on the state’s investment (ROI)—for every \$1.00 of state investment in ARA Academy member research to date, the state received \$3.13 in state tax revenues,** due to the research and companies formed related to this research.

FUNCTIONAL, MISSION-BASED IMPACTS OF ARA AND ITS PARTNERSHIPS

ARA and the community of innovation it has cultivated through its recruitment and support of Scholars and Fellows is clearly generating substantial economic impacts for Arkansas. Equally important are the “functional” impacts generated via serving out its mission to improve the state’s competitive position in the knowledge economy. **By stimulating innovation, encouraging and enabling collaborations, and strengthening economic opportunity by investing in research, ARA is generating a wide array of strategic functional impacts for Arkansas.**

Considering the full range of activities supported by ARA and generated by its Academy, four functional impact domains are summarized in Figure ES-3 with numerous corresponding impacts emanating outward from each.

Figure ES-3. Functional, Mission-Based Impacts of ARA and its Partnerships



Source: TEconomy Partners, LLC. for Arkansas Research Alliance.

The report walks through and describes each of these areas accompanied by illustrative vignettes or brief case studies of impacts generated by individual Scholars and Fellows. These examples and narratives were identified and categorized via a qualitative approach, specifically a series of 30 one-on-one and small group interview discussions with both ARA Scholars and Fellows and with key stakeholders and selected collaborators including university leaders and administrators, state economic development officials, and industry representatives who can speak first-hand to the impacts of ARA-supported researchers and their research.

LOOKING TO THE FUTURE

ARA and the community of innovation leaders it has cultivated are generating significant impacts for Arkansas—both economically with respect to its outsized contributions in research-related impacts and a sizable cohort of science- and tech-driven startups; and from its mission-based roles as a driver of innovation, cultivator of top

talent, and connector of university research, industry, and government. ARA is evolving appropriately into new areas including establishing the Core Facilities Exchange (CFE) and Impact Grants initiatives (new programs detailed in the report), particularly in light of its relatively modest funding. Its cumulative, compounding impacts are expected to continue to grow and advance.

ARA is proud of its accomplishments, though recognizes there is more work to be done to advance the research growth and momentum in Arkansas.

ARA is looking ahead, and so are its stakeholders, who in interview conversations have illuminated the underlying potential so many in the state see for ARA if its purview were expanded and its funding enhanced. A number of suggestions were brought forth from these conversations, such as recruiting post-doctoral researchers to allow Arkansas to better compete for top young talent; funding grants strategically targeting collaboration between two or more Arkansas institutions; engaging diverse talent in STEM fields to advance equity and inclusion for underrepresented populations; featuring “rising stars” to recognize young star university research faculty in Arkansas today; and levelling up the financial support for ARA to compete against initiatives in other states that are many times its size.

Stakeholders are clearly recognizing the impacts of ARA and its potential to grow and expand, and in the future ARA could evolve even further. With respect to its core mission today to “invest in strategic research talent recruitment, retention, and recognition to generate scientific and engineering breakthroughs that support statewide economic development,” the evidence points to a decade-and-a-half of success.

I. INTRODUCTION

To meet new competitive challenges and to realize the benefits of robust university research capabilities, the Arkansas Research Alliance (ARA) was formed in 2008 as an independent, non-profit public-private partnership organization with a majority private sector-led Board to elevate a fundamental belief—*Research Matters*. A decade-and-a-half later, the ARA has matured into a multi-faceted and integral organization leveraging university research and top talent to change the economic trajectory of Arkansas.

ARA programs help chancellors at the state's five major research universities recruit, recognize, and retain world-class scientific, tech, and engineering talent in strategic research focus areas (Figure 1). The organization's signature effort is through the ARA Scholars Program, where ARA partners with universities to recruit exceptional research talent and scientific leaders from outside of Arkansas through a \$500,000 grant award. Its companion effort to recognize and retain talented research leaders already residing on those five campuses is through the ARA Fellows Program which issues grant awards of \$75,000. This talent pool is merged into the ARA Academy of Scholars and Fellows.

Additionally, ARA plays a lead role for the State of Arkansas in facilitating in-state collaborations with the only national laboratory located in the state—the U.S. Food and Drug Administration's National Center for Toxicological Research (NCTR) in Jefferson. NCTR's work resides at the crossroads of advancing modern scientific techniques and approaches for drug development. This work has critical implications for our nation's public health and economic competitiveness. ARA supports the State of Arkansas' collaboration with NCTR by providing outreach capabilities with Arkansas university partners and other institutions and helping to manage collaborative projects with NCTR involving Arkansas universities.

The direct impact of ARA efforts is inherently challenging to quantify but with 15 years since its inception and more than a decade of data available, it is now possible to evaluate, communicate, and continue to refine the investments made into ARA.

This report aims to tell the ARA story by developing and providing a comprehensive examination and quantification of both the economic and the functional impacts of the organization to date.

It is important to acknowledge that the impacts generated by ARA require strategic and highly collaborative partnerships across Arkansas, and many of these impacts cannot be directly attributed to ARA alone, but rather to the community of innovation it has cultivated.



Figure 1. The Six Institutional Partners of ARA⁵



As ARA has evolved, it has expanded its programmatic activities and interconnections to include two relatively new initiatives—an effort to leverage the extensive set of resources and assets contained in university and national lab “core” research facilities in a new Core Facilities Exchange (CFE) program intended to enhance access and shared-use; and the ARA Impact Grants Program, providing Academy members with targeted funds up to \$75,000 for strategic, 12-month projects.

These efforts expand ARA’s value well beyond its programmatic successes. ARA stands out in bringing together industry and university leaders from across the state and has become a leading champion of the state’s knowledge-economy initiatives to generate new startup companies, high-quality jobs, and rising per capita income in Arkansas.

The direct impact of ARA efforts is inherently challenging to quantify but with 15 years since its inception and more than a decade of data available, it is now possible to evaluate, communicate, and continue to refine the investments made into ARA. This report aims to tell the ARA story by developing and providing a comprehensive examination and quantification of both the economic (or expenditure and employment based) impacts and the functional (or mission-based) impacts of the organization to date. It is important to acknowledge that the impacts generated by ARA require strategic and highly

⁵ The six institutions and associated abbreviations used throughout this report include: Arkansas State University (A-State or ASU), University of Arkansas (UA or U of A), University of Arkansas at Little Rock (UA Little Rock or UALR), University of Arkansas at Pine Bluff (UA Pine Bluff or UAPB), University of Arkansas for Medical Sciences (UAMS), and the National Center for Toxicological Research (NCTR).

collaborative partnerships across Arkansas, and many of these impacts cannot be directly attributed to ARA alone, but rather to the community of innovation it has cultivated.

To capture and describe the results to date, ARA has engaged TEconomy Partners, LLC (TEconomy), a national leader in innovation-driven economic development consulting. TEconomy has an extensive track record in conducting rigorous and robust assessment studies of R&D assets and overall innovation ecosystems in numerous states, including Arkansas. These assessments inform the targeting of innovation-led growth opportunities as well as strategic actions to further technology-driven development. TEconomy also has assisted numerous other state-level technology organizations in evaluating their performance.

ARA's performance assessment recognizes the importance of going beyond the numbers to tell qualitative stories. These mini case studies show how ARA has proven itself to be up to the task of engaging leaders in industry and research institutions in addition to facilitating on-the-ground efforts to translate research into economic development success stories. The results are that industry-university partnerships have flourished, top talent has been generated and retained, and new startups launched.

This report is organized across two major sections—one, measuring the economic impacts of ARA investments for Arkansas, and a second that presents and highlights the functional, mission-based impacts generated by ARA and its strategic partnerships. Against a backdrop of intense state, national, and international competition for advanced industry development and top talent, ARA and its strategic programming efforts represent a critical tool for maintaining and enhancing Arkansas' ability to compete and to lead in the global knowledge economy. This is the ARA story.

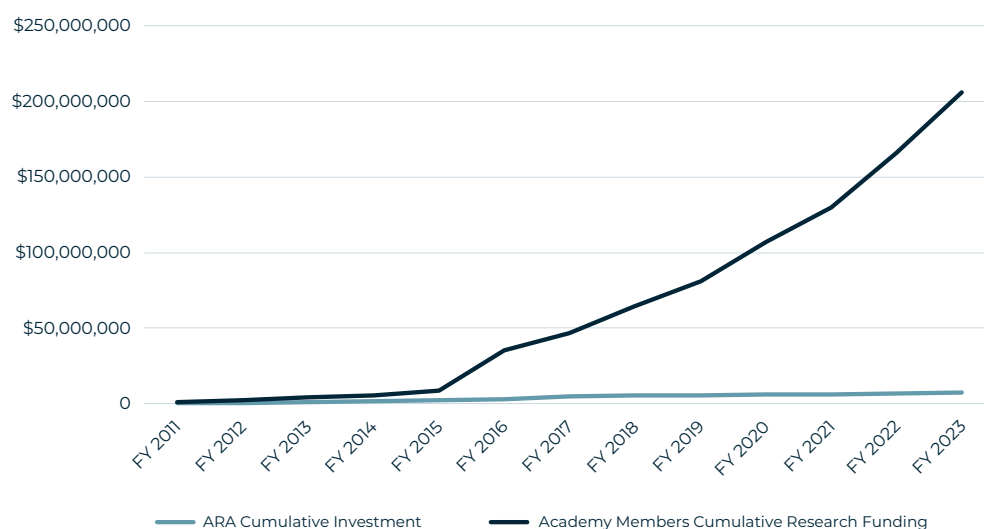
II. ECONOMIC IMPACTS OF ARA INVESTMENTS FOR ARKANSAS

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. To this end, ARA has invested in a total of 39 research Scholars and Fellows (together referred to as the ARA Academy) since its inception through 2022, with 29 active members (i.e., members still conducting research at one of the ARA partner institutions) captured in the FY 2022 and FY 2023 data to date.⁶ For each year of the impact assessment, the analysis presented herein captures the active number of Scholars and Fellows and their total research expenditures, as provided by their institution for that fiscal year.

ARA INVESTMENTS IN RESEARCH SCHOLARS AND FELLOWS (ARA ACADEMY)

As a compounding and leveraging research investment program, the goal of these ARA investments in Arkansas researchers is to “seed” the research activities of the member researcher, enabling them to further their future research activities through additional sponsored research.

Figure 2. Cumulative ARA Investments in Academy Members and Academy Member Total Research Funding, FY 2011—Mid-FY 2023



Source: TEconomy Partners' analysis based upon reporting from ARA and Arkansas Research Universities.

⁶ Cumulative membership in the ARA Academy totals 39 researchers with 29 active at the time this study was initiated. In the Spring of 2023 (FY 2023), seven additional scholars and fellows were named by ARA. The employment and research activities of these seven are not included in this economic impact analysis.

Figure 2 presents this cumulative investment and funding since ARA's inception. **Since 2011, ARA has invested a total of \$8.3 million in its scholars and fellows.⁷ Over this entire period through mid-FY 2023 the 39 ARA Academy members have generated a total of \$205.7 million in research funding,** with the 29 active Academy members generating \$39.7 million in research funding through the first half of FY 2023.

Together, the ARA Academy researchers have leveraged their ARA funding nearly 25 times—each dollar of ARA investment has helped support \$24.75 in total research funding for the Academy members.

OVERVIEW OF ECONOMIC IMPACT METHODOLOGY

ARA Scholars and Fellows generate economic impacts through both research expenditures and engaging the private sector through startup creation, licensing, or technology development partnerships. These startup and early-stage activities are reflected in 13 Arkansas companies, with 12 active companies directly employing 150 Arkansans in 2023 (Table 1).

The economic impacts of the ARA Scholars, Fellows, and related startup companies can be measured using the standard and well-established regional economic analysis technique of input-output (I-O) analysis. For this analysis, TEconomy used an Arkansas-specific IMPLAN I-O model and underlying data. The IMPLAN model is the most widely used in the nation and is based on the U.S. Bureau of Economic Analysis (BEA) national accounts data, supplemented with state level employment data from the U.S. Bureau of Labor Statistics (BLS), and other economic data from the U.S. Bureau of the Census and other federal agencies.

Using the IMPLAN model, the impact analysis estimates the economic “ripple effect” throughout the Arkansas economy originating with the direct employment of the ARA Academy members and related startup employment, flows through Arkansas-based suppliers, and ultimately through Academy members, their research teams, and supplier workers who spend their

⁷ It should also be noted that researchers affiliated with the U.S. FDA's National Center for Toxicological Research (NCTR) do not receive direct financial support from ARA.

ECONOMIC IMPACT TERMINOLOGY

Types of Impacts

- **Direct Effects** – the specific impact of ARA scholars, fellows, their research expenditures, and the employment of related startups.
- **Indirect Effects** – the impact of the spending of these economic actors with their suppliers.
- **Induced Effects** – the additional economic impact of the personal spending of the ARA academy members, related startup firms, and their Arkansas suppliers' employees in the overall Arkansas economy.
- **Total Impacts** – the sum or combination of these three impact effects.

Definition of Impact Variables

- **Employment** is the total number of jobs created and includes the direct employment of the ARA scholars, fellows, and related startup companies.
- **Labor Income** is the total amount of compensation, including salaries, wages and benefits, received by employees and others in the supply-chain related to ARA investments.
- **Value Added** is the difference between total output and the cost of intermediate inputs; it is a measure of the contribution to GDP.
- **Output** (also known as production, sales, or business volume) is the total value of the goods and services produced in the economy. Academy member research expenditures are considered part of the output for the purposes of this study.
- **Government Revenues** includes estimates of revenues generated for local, state, and federal governments through the economic activity measured.

wages in Arkansas (Figure 3). It is important to note that this analysis only accounts for the economic impacts occurring within the State of Arkansas—out-of-state purchases and spending are not captured within the impact results.

Figure 3. Graphic Depiction of ARA Economic Impact Components

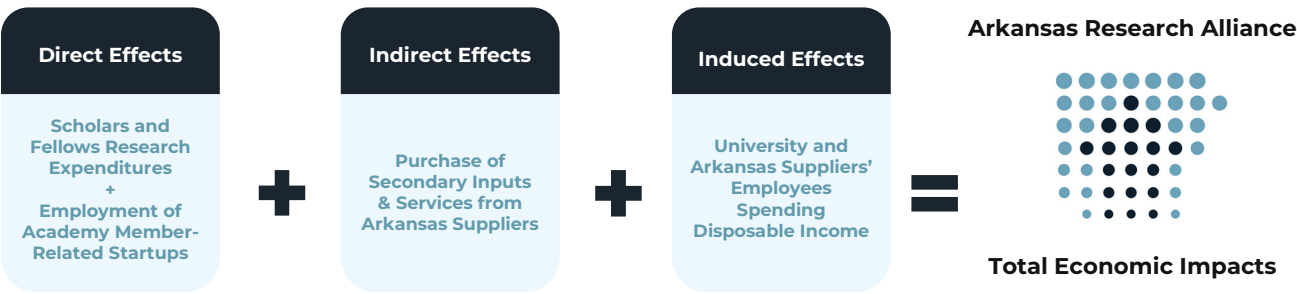


Table 1. Arkansas-based Startups and Emerging Companies Affiliated with ARA Academy Members

COMPANY NAME	ARKANSAS CITY
Acetaminophen Toxicity Diagnostics (ATD), LLC (Founded 2006)	Little Rock
Advanced Plant Technologies	Little Rock
Bastazo	Fayetteville
My Life (HQ in TN, operations in AR)	Little Rock
Nature West, Inc.	Jonesboro
Nushores Biosciences	Little Rock
Ozark IC	Fayetteville
Pellucere® Technologies, Inc. (formerly WattGlass)	Fayetteville
SIEV, LLC	Fayetteville
SurfTec, LLC	Fayetteville
Top Notch Pharma	Little Rock
Vivas, LLC (closed in 2017)	Fayetteville
Wolf Speed (formerly APEI/Cree)	Fayetteville

Source: ARA and individual Academy Members, and TEconomy Partners analysis.

RECENT ECONOMIC IMPACTS: FY 2023

The 29 active ARA Academy researchers generated **\$39.7 million in total research funding in FY 2023 including ARA investments of \$383,300**. This total research funding was used to employ and support an estimated 167 additional university and NCTR employees in 2023. The past and current work of these researchers enabled and supported 12 Academy-related emerging and existing companies in Arkansas. Combined, these 12 firms employ 150 Arkansas residents in 2023.⁸

Together, the employment and research expenditures are estimated to generate direct output (including both sales from private firms and expenditures from institutional researchers) of more than \$124 million in FY 2023. **These direct jobs—including the individual scholars and fellows—are high-quality and family-sustaining jobs, averaging more than \$80,000 annually in total compensation.**⁹

The multiplier effects of these ARA-leveraged investments and related activities, taken together, generate and support a total employment impact of 814 Arkansas jobs throughout the State economy, earning an average compensation of more than \$68,500, and **a total economic impact of \$209.3 million** (Table 2).

Table 2. Economic Impacts of ARA Investments in Research Scholars and Fellows, FY 2023 (as of 5.1.23)

IMPACT TYPE	EMPLOYMENT	IN \$MILLIONS					
		LABOR INCOME	VALUE ADDED	OUTPUT	LOCAL & COUNTY TAX REVENUE	STATE TAX REVENUE	FEDERAL TAX REVENUE
Direct Effect	346	\$27.7	\$52.7	\$124.2	\$0.1	\$1.0	\$6.2
Indirect Effect	270	\$19.0	\$27.8	\$52.6	\$0.4	\$1.5	\$3.7
Induced Effect	198	\$9.4	\$17.9	\$32.4	\$0.5	\$1.7	\$1.7
Total Impacts	814	\$56.1	\$98.4	\$209.3	\$1.0	\$4.4	\$11.8

Source: TEconomy Partners' analysis using IMPLAN 2021 State of Arkansas model. Dollar values are in current 2023 dollars.

⁸ The companies were classified, using their current federal NAICS industry code, into the appropriate IMPLAN industry sector for impact modeling purposes.

⁹ Total compensation is inclusive of the value of wages, salaries, proprietor income and employee benefits. For comparison, average labor income for all Arkansas workers is approximately \$55,000.

CUMULATIVE ECONOMIC IMPACTS: FY 2011 – FY 2023

As discussed earlier, the cumulative research expenditures across the total 39 active and former ARA Academy members reached \$205.7 million from FY 2011 through FY 2023. This total research funding was used to employ and support approximately 202 direct Academy member job-years and 851 direct job-years of additional university and NCTR employees over the FY 2011 to FY 2023 period (one job for one year = one job-year; the same job for all 13 years = 13 job-years).

To incorporate the economic effects and impacts of the 13 Academy-related companies that were active in Arkansas during some portion of the period, a linear growth trend was used to develop an estimate of each startup firms' annual employment from their founding date through their reported 2023 employment. These companies combined to generate and employ an estimated 923 direct job-years for Arkansas residents since ARA's inception.

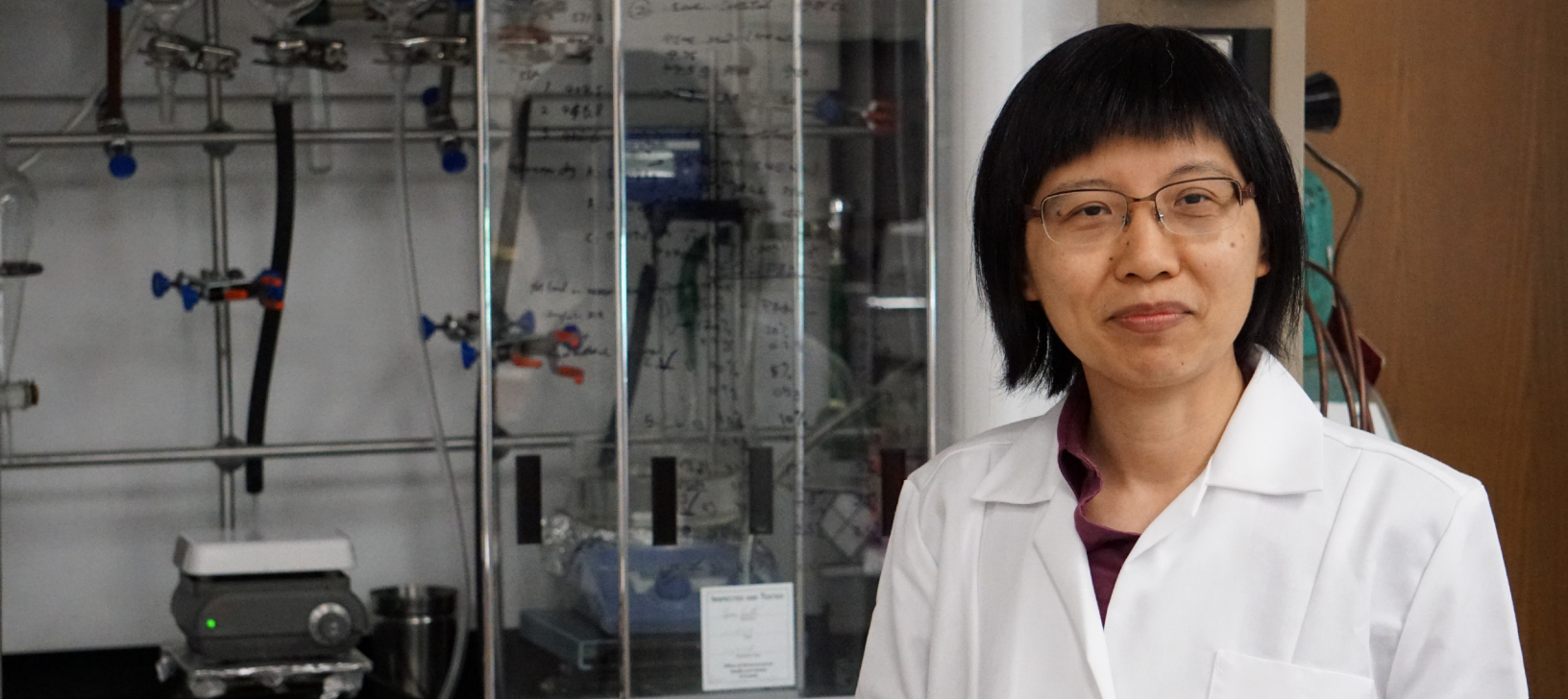
To assess the cumulative economic impacts, an impact model for each of the years (FY 2011-FY 2023) was developed incorporating each year's direct values as inputs. These annual results were added together to generate the estimates in Table 3.

Table 3. Economic Impacts of ARA Investments in Research Scholars and Fellows, FY 2011-FY 2023 (as of 5.1.23)

IMPACT TYPE	EMPLOYMENT (JOB-YEAR)	IN \$MILLIONS					
		LABOR INCOME	VALUE ADDED	OUTPUT	LOCAL & COUNTY TAX REVENUE	STATE TAX REVENUE	FEDERAL TAX REVENUE
Direct Effect	1,976	\$163.5	\$333.8	\$796.2	\$0.4	\$6.0	\$35.9
Indirect Effect	1,659	\$117.9	\$171.4	\$322.0	\$2.5	\$9.5	\$22.2
Induced Effect	1,204	\$55.6	\$105.3	\$190.6	\$3.1	\$9.8	\$9.9
Total Impacts	4,839	\$336.9	\$610.5	\$1,308.8	\$6.2	\$26.1	\$68.8

Source: TEconomy Partners' analysis using IMPLAN 2021 State of Arkansas model. Dollars are totaled from each year's current dollar values.

Over the approximately 13-year period, the ARA Scholars' and Fellows' direct research efforts generated and supported 2,095 Arkansas job-years, while their 13-related startups generated and supported an additional 2,744 Arkansas job-years over the period, for a combined, total employment impact of 4,839 job-years. **Overall, the Academy members' research and startup activities led to more than \$1.3 billion in total economic impact in the State, while adding more than \$610 million to Arkansas' GDP (value added) over the period.**



RETURN ON STATE OF ARKANSAS' INVESTMENTS TO DATE

While the emphasis on ARA Scholars and Fellows investments has been on “job-creating research” the program has also generated returns to the State of Arkansas through a variety of tax-related revenues.

The total leveraged ARA Academy investments of \$8.3 million have yielded and supported \$4.4 million in FY 2023 state tax revenues alone, with combined state tax revenues over the full 13-year period totaling \$26.1 million. **This amounts to better than a three-to-one return on the state's investment (ROI) to date—for every \$1.00 of state investment in ARA Academy member research to date, the state received \$3.13 in state tax revenues**, due to the research and companies formed related to this research.

III. FUNCTIONAL, MISSION-BASED IMPACTS OF ARA AND ITS PARTNERSHIPS

ARA and the community of innovation it has cultivated through its recruitment and support of Scholars and Fellows is clearly generating substantial economic impacts for Arkansas. Equally important are the “functional” impacts generated via serving out its mission to improve the state’s competitive position in the knowledge economy. By stimulating innovation, encouraging and enabling collaborations, and strengthening economic opportunity by investing in research, ARA is generating a wide array of strategic functional impacts for Arkansas.

Considering the full range of activities supported by ARA and generated by its Academy, four functional impact domains are summarized in Figure 4 with numerous corresponding impacts emanating outward from each.

These domains and associated impacts were identified and categorized via a qualitative approach, specifically a series of 30 one-on-one and small group interview discussions with both ARA Scholars and Fellows and with key stakeholders and selected collaborators including university leaders and administrators, state economic development officials, and industry collaborators who can speak first-hand to the impacts of ARA-supported researchers and their research. It is important to note that the objective of this approach is not to provide an exhaustive accounting of all activities, but rather to provide an objective overview and illustration of the many benefits that ARA activities generate.

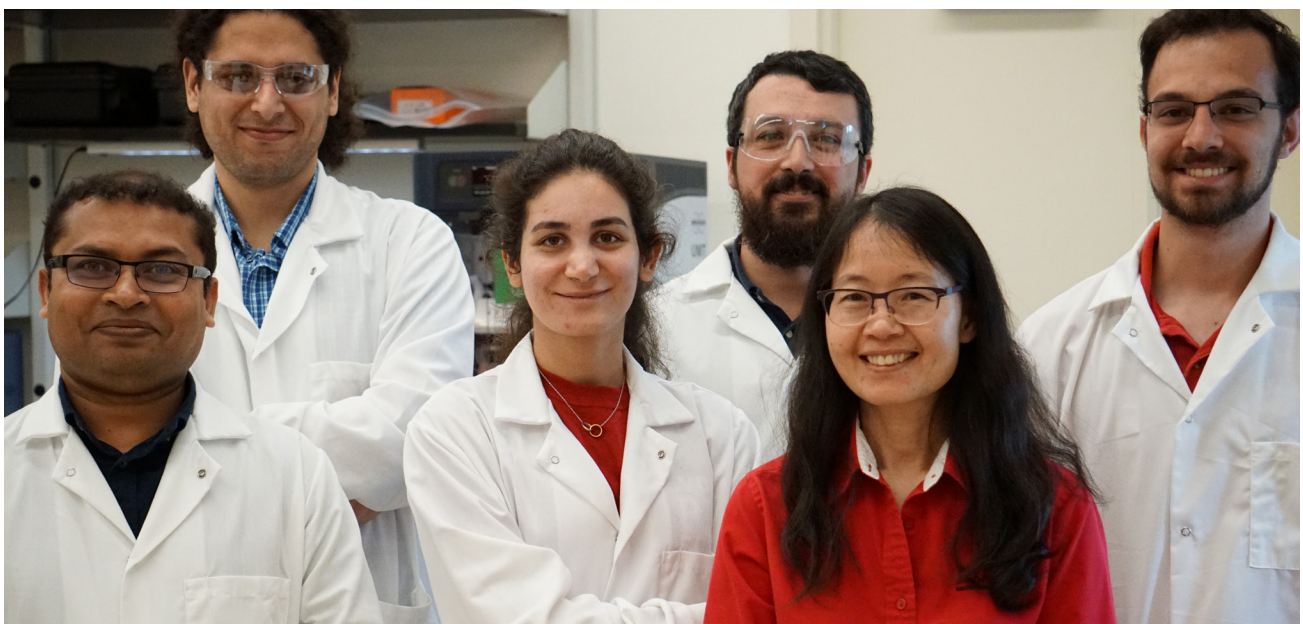


Figure 4. Functional, Mission-Based Impacts of ARA and its Partnerships



Source: TEconomy Partners, LLC. for Arkansas Research Alliance.

The diversity of functional impacts can be summarized and organized across the following four domains:

1. Sustaining & Growing New Areas of Research for Arkansas' Economy
2. Supporting & Growing Arkansas' Advanced Industries
3. Convening & Connecting Arkansas' Science & Tech Community
4. Building & Developing Top Talent for Arkansas

This assessment does not attempt to rank or weight the importance of any of the four domains or associated functional impacts. The varied stakeholders and audiences for this report will no doubt have their own perspectives on the relative importance of particular domains. This section of the report walks through and describes each of these areas accompanied by illustrative vignettes or brief case studies of impacts generated by individual Scholars and Fellows. Some impact areas overlap domains but are described within a domain with which it is best aligned.

SUSTAINING & GROWING NEW AREAS
OF RESEARCH FOR ARKANSAS' ECONOMY

New Income Streams & Economic Diversification; Economic Output and Employment Growth

As illustrated in Section 2 of this report, ARA Academy members represent a powerful and important economic engine for Arkansas. Whether in starting up new science- and technology-driven companies, preparing top talent in STEM fields for Arkansas' advanced industry workforce, or through the sheer magnitude of research funding brought into the state, ARA Scholars and Fellows are important to economic diversification for Arkansas.

The 12 active startups associated with the research of ARA Academy members and employing 150 today in Arkansas represent significant levels of high-paying, family-sustaining jobs for Arkansans and hundreds of others supported by these companies' supply chains and employee spending. But importantly, these companies are in advanced industries driven by homegrown science and technology innovation where Arkansas has typically had lower concentrations of companies and jobs relative to national averages. By establishing companies in leading-edge, high-growth market areas such as bone and tissue regeneration, surface engineering, toxicity diagnostics, rugged integrated circuits, and more, Arkansas is seeing an economic diversification dividend from its relatively modest annual investments in ARA.

The nearly \$206 million in R&D funding received by ARA Academy members since their induction is truly impressive and represents the highly productive nature of these individuals in securing funding from varied sources beyond Arkansas, in particular federal grants. To illustrate:

- Academy members outperform their state and national counterparts in securing research funding. In the latest year of available data, each ARA Academy member received, on average, \$1.53 million in total sponsored research funding versus levels approximately one-third of that total for their counterparts across both Arkansas and the U.S. (Table 4).

Table 4. Average Total Sponsored Research per Principal Investigator, ARA Academy Members vs. AR and U.S. Research University Peers, Latest Year Available

	DATA YEAR	SPONSORED RESEARCH, \$ PER PI
Academy Members	2023	\$1,525,324
All Arkansas Research Universities	2019	\$418,660
All U.S. Research Universities	2019	\$492,348

Source: TEconomy Partners' analysis of Arkansas university-provided sponsored research data for ARA Academy Members; NSF Higher Education R&D Survey.

Critical also to economic diversification and growth is the role played by ARA Academy members in STEM talent development. Touched on more extensively in the "Top Talent" impact domain discussion, ARA Scholars and Fellows are attracting, developing, and retaining critical top talent for Arkansas via their academic programming, employment in research laboratories, engagement in entrepreneurial incubation and acceleration activities, and placement at Arkansas universities, as well as both established and startup companies.

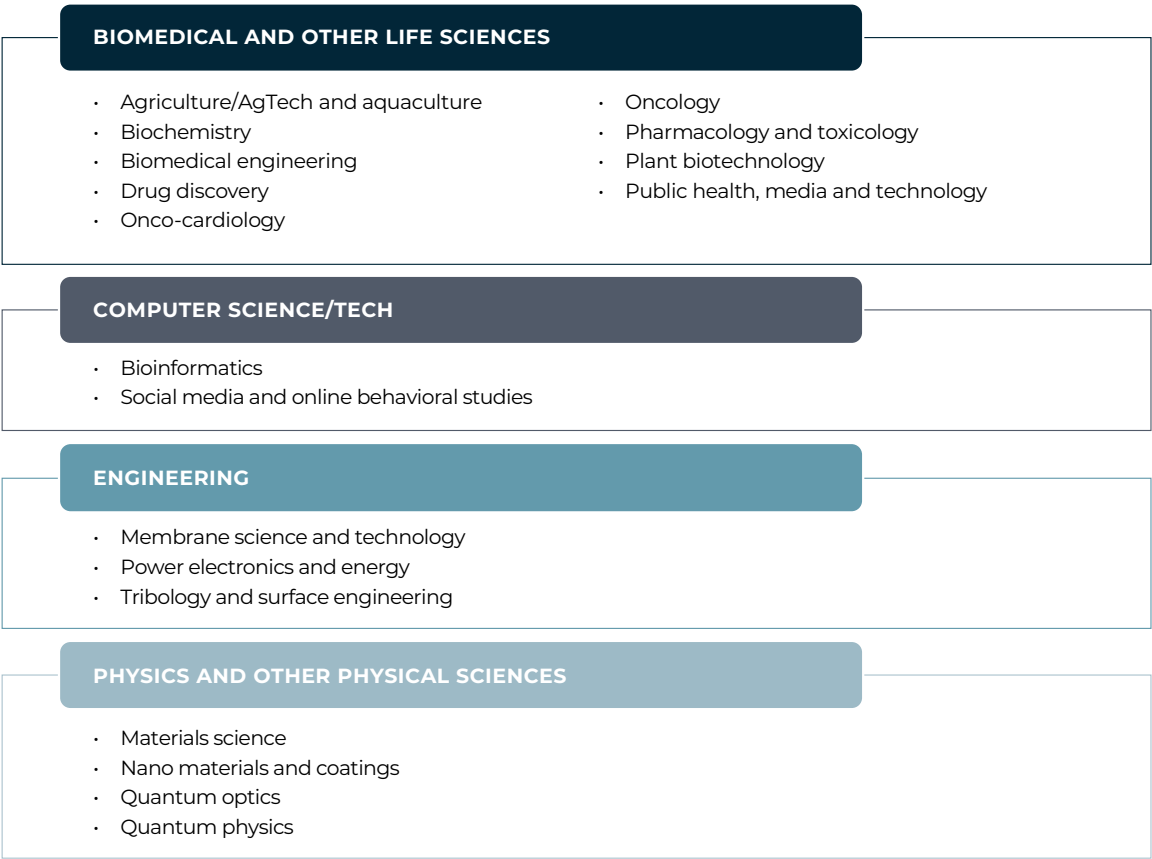
Local & State Government Revenue

The research and economic outputs generated by ARA Academy members generate significant returns to state and local governments in the form of tax revenues. The economic impact analysis in Section 2 estimates the cumulative, 13-year contribution to combined state and local government coffers exceeded \$26 million, representing a strong “ROI” for the State of Arkansas and benefits to local communities across the state.

Scientific Innovation & Advancement

While economic impacts and benefits are critical, at its core the mission of ARA and the community of innovation it has built is driven by advancing innovation through scientific research and discovery, ultimately for job-creating research. ARA and its university and national lab partners have cultivated a research and innovation community that is especially diverse in its science and technology areas of focus. Examples of the many unique areas of research in which ARA Scholars and Fellows are focused are highlighted in Figure 5.

Figure 5. Example Areas of Scientific and Technological Research Enhanced in Arkansas by ARA Scholars and Fellows



One illustration of the extensive impacts of ARA Academy scientific innovation and advancements is the volume of research publications they have authored. ARA Scholars and Fellows have combined to publish more than 1,700 research publications in peer-reviewed journals since their induction into the Academy.

ARA is proactively supporting future research funding and other key collaborations and high-return goals via its **Impact Grants program**. The program provides Academy members with targeted funds of up to \$75,000 for strategic, 12-month projects that fall into one of the following three categories:

- **Future Extramural Funding** – includes projects that better position Academy members to compete for future research funding; that accelerate data development allowing for larger research grants; and that strengthen funding competitiveness via strategic collaboration among ARA Academy members and/or Arkansas public universities.
- **Industry Engagement/Commercialization** – includes projects that conduct commercially-oriented proof-of-concept, prototype development requested by industry or a prospective investor; or that transition novel ideas into testable prototypes focused on customer-identified problems.
- **Scholarly Advancement** – includes projects that accelerate discovery in high-risk/high-reward endeavors that align with Arkansas-specific challenges.

In 2018, ARA launched its pilot round of Impact Grants with \$1 million invested across 15 projects and has tracked outcomes associated with this initial round and find it has generated \$13 million in follow-on extramural funding into Arkansas.¹⁰ The program's second round was launched in late 2020, funding 16 projects for \$1 million and has generated a similar level of return.

In 2018, ARA launched its pilot round of Impact Grants with \$1 million invested across 15 projects and has tracked outcomes associated with this initial round and find it has generated \$13 million in follow-on extramural funding into Arkansas.

Source: Arkansas Research Alliance calculations based on data provided by Impact Grant recipients.

¹⁰ Follow-on funding totals from the pilot round of ARA Impact Grants are based on data reported directly by grant recipients to ARA.

R&D Driven Intelligence to Solve Needs and Challenges

Arkansas' companies and government are leveraging the science and technology expertise of the ARA Academy. The corporate engagement is a focus of the Advanced Industries impact domain area section, but a key example from government is provided here as an illustration of utilizing homegrown Arkansas-developed tech innovation to help Arkansans and law enforcement during the recent pandemic-related public health crisis.

During the COVID-19 pandemic, ARA connected ARA Fellow Dr. Nitin Agarwal and the Collaboratorium for Social Media and Online Behavioral Studies or "COSMOS" center at UA Little Rock with the Arkansas' Attorney General's office to leverage their expertise in identifying and tracking COVID-related misinformation, disinformation, and scams that spread online during the pandemic. Dr. Agarwal, the Jerry L. Maulden-Entergy endowed chair and a professor of information science at UA Little Rock, founded COSMOS to survey vast quantities of social media data and information online and identify emerging threats. Since its founding, the COSMOS has tracked and assessed varied threats globally including around the Islamic State, Singapore's elections, anti-NATO propaganda from Russian state-sponsored agents, and autism awareness campaigns. Dr. Agarwal and his team of 30 students at COSMOS have developed data analysis tools and methodologies

to sweep and track online blogs, social media sites, and YouTube videos to identify so-called "bad actors" who aim to spread misinformation and steal consumers' money and/or identities. The team protected Arkansas consumers by partnering with the Office of the Attorney General to develop and regularly update a website reporting scams and misinformation regarding COVID-19.¹¹

The ability to leverage this type of tracking and capability for Arkansans provided an economic advantage to the state during a difficult public health crisis, enhanced publicity for UA Little Rock's expertise in this niche research space, and changed human behavior, communication, and information dissemination tactics. Ultimately, the COVID-related assessment work led to additional U.S. Department of Defense (DoD) grants for Dr. Agarwal and COSMOS, including a new 2-year, \$5 million grant from the U.S. Army.

ARA Fellow Dr. Nitin Agarwal's Partnership with the AR Attorney General to Combat COVID Disinformation, Scams

"Scammers are working overtime to exploit coronavirus fears. We are grateful for the ongoing efforts in Arkansas by Dr. Agarwal and his team at UA Little Rock helping identify the schemes thieves employ so we can stop these fraudulent activities, hold offenders accountable and prevent Arkansans from being fooled by bogus claims."

- U.S. Sen. John Boozman (R-Ark.)

11 UA Little Rock, "Nitin Agarwal: Flattening the Misinformation Curve—The Internet, The Virus and Digital Forensics," April 15, 2020.

Importance of ARA Fellows in Seeding Emerging Industries in Arkansas

Dr. Fabricio Medina-Bolivar, a 2021 ARA Fellow, is a Professor of Plant Metabolic Engineering within the Department of Biological Sciences at Arkansas State University and is Executive Director of the American Council for Medicinally Active Plants (ACMAP). Dr. Medina-Bolivar is one of the world's leading scientists using hairy root cultures as production systems of valuable natural products. His cutting-edge technology has provided means to study the biological activity of novel natural products and identify their benefits to human health.

Hairy roots, also known as transformed roots, are a type of plant tissue culture that holds several important applications and benefits as bioproduction systems to discover natural products with important applications in human health. Under normal conditions, plants only produce enough of the relevant antioxidant, anti-inflammatory, or anticancer compounds they need—a very small amount. Dr. Medina-Bolivar and his team have designed an innovative approach to produce more compounds that can be used to help humans, specifically by mimicking natural “stresses” in the laboratory, which causes the plants to react by producing more chemicals that help them survive. The varied applications and benefits from this research include:

- **Secondary Metabolite Production:** Hairy roots have the unique ability to produce a wide range of secondary metabolites, including pharmaceuticals, phytochemicals, and other valuable compounds. These metabolites often possess medicinal properties, such as antimicrobial, antioxidant, and anticancer activities. Hairy root cultures provide a controlled and sustainable source for the production of these valuable compounds.
- **Genetic Manipulation:** Hairy roots can be genetically engineered to express specific genes or pathways of interest. Genetic manipulation techniques, such as gene insertion, gene silencing, or overexpression, can be applied to hairy roots to enhance the production of desired compounds or to study gene function. This allows researchers to explore and optimize the production of specific molecules with industrial or medical applications.
- **Disease Resistance Studies:** Hairy roots provide a convenient system for studying plant-pathogen interactions and testing disease resistance. By introducing specific genes or pathogens into hairy roots, researchers can evaluate the plant's response to infection and gain insights into plant defense mechanisms. This knowledge can be valuable for developing disease-resistant crop varieties and improving agricultural practices.
- **Crop Improvement:** Hairy roots can be employed in crop improvement programs. By introducing genes associated with desirable traits, such as increased yield, enhanced nutritional value, or improved stress tolerance, researchers can develop genetically improved varieties. Hairy root transformation provides a powerful tool for evaluating gene function and its impact on crop performance.
- **Environmental Applications:** Hairy roots can be utilized for phytoremediation, which involves using plants to clean up or remove pollutants from contaminated environments. Certain hairy root cultures have shown the ability to absorb heavy metals, organic pollutants, and other toxic substances from soil or water. This makes them a potential tool for environmental cleanup and restoration.

Recognizing the commercial potential of his research, Dr. Medina-Bolivar is Co-Founder and Chief Scientific Officer of Nature West, Inc., a biotech company founded in 2005 and based in Jonesboro, Arkansas. Nature West's pioneering technology uses a plant root culture production platform to produce a suite of plant compounds that have potential application to human health and wellness. Based on Dr. Medina-Bolivar's ongoing research and current patent portfolio, there is an opportunity to develop this emerging technology further and link it to other biomedical and plant bioscience research opportunities and competencies.

SUPPORTING & GROWING ARKANSAS' ADVANCED INDUSTRIES

Science & Tech-Based Startups

As highlighted in the previous section, ARA Scholars and Fellows have founded or co-founded 13 companies based on the commercialization of their research. In addition to generating new science- and technology-based and innovation-driven startups rooted in Arkansas themselves, ARA Scholars and Fellows are supporting startup development through incubation and acceleration activities.

Dr. John Imig, a 2022 ARA Scholar, was recently recruited into the state as Chair of the Department of Pharmaceutical Sciences at UAMS. Coming from the Medical College of Wisconsin (MCW) where he was an Eminent Scholar and inaugural Director of its Drug Discovery Center, Dr. Imig had seen first-hand the emergence and growth of Wisconsin's life sciences cluster at the intersection of university R&D and corporate partnerships. At MCW, the Drug Discovery Center facilitates and accelerates drug discovery via its Therapeutic Accelerator Program. With his experiences in accelerator programming, and founding three therapeutics companies himself, Dr. Imig has arrived in Arkansas excited to help advance a biotech-focused accelerator in partnership with UAMS BioVentures. As a VP of Technology Acceleration with BioVentures, Dr. Imig will help companies and research investigators to accelerate therapeutics development. Dr. Imig has been pleased to find a cadre of entrepreneurial-minded UAMS students and post-doctoral researchers in the drug discovery space that were recruited by Dr. Peter Crooks, another ARA Scholar who recently stepped down as Department Chair. In addition, Dr. Imig is also helping to lead BIOArkansas, a newly forming state affiliate of the national Biotechnology Innovation Organization (BIO).

Among several attractive opportunities in coming to UAMS, "the opportunity to advance as an entrepreneur, and to help people along their entrepreneurial journey, was especially attractive about coming to UAMS ... I see opportunities here [to advance life sciences cluster development] I saw 15 years ago in Milwaukee."

- Dr. John Imig, Department Chair, Pharmacology and ARA Scholar, UAMS

Dr. Laura James, a Professor of Pediatrics and Associate Vice Chancellor for Clinical and Translational Research at UAMS, founded in 2006 and has continued to develop Acetaminophen Toxicity Diagnostics (ATD), a Fayetteville-based startup in the clinical toxicology space. While the company was founded prior to her ARA Fellows award, Dr. James credits ARA for its support and guidance in her entrepreneurial journey. In a state with few resources for early-stage science- and technology-driven ventures, ARA has been "extremely helpful in improving the entrepreneurial climate," said Dr. James. She cites the important and invaluable "intangibles" of ARA including its guidance regarding the inevitability of dealing with failure in a high-risk endeavor and the challenges of tech commercialization, as well as its success in providing a highly accessible community providing encouragement and support.

Dr. Alan Mantooth, featured in the callout below, has been affiliated with four companies in the power electronics space, three of which are currently active and operating in Fayetteville today.

Dr. Alan Mantooth and the UA Power Group: An ARA Fellow Driving Major Economic Impacts in Power Electronics Innovation as a Global Leader

Dr. Alan Mantooth serves as a Distinguished Professor and the Twenty-First Century Research Leadership Chair in Engineering within the Department of Electrical Engineering at the University of Arkansas and has worked for two decades to establish the University and its Power Group as world leaders in power electronics innovation. Dr. Mantooth has advanced the Power Group and its innovation prowess and significant economic impacts through several avenues—as an electrical engineering professor, educator, and researcher; as a founder, co-founder, and advisor to several companies; as Executive Director of several federally-funded Centers of Excellence; and recently in establishing a national facility leveraging UA's global expertise in advancing semiconductor fabrication. Dr. Mantooth was recognized and funded as an ARA Fellow in 2014, among the many honors and recognitions he has received during his career as an engineer in industry as well as an academic. Dr. Mantooth hails from Arkansas and earned both his BS and MS degrees in electrical engineering from the University of Arkansas.

Dr. Mantooth is generating substantial impacts for Arkansas on several fronts, including his own research portfolio where from his induction into the ARA Academy starting in FY 2015 through FY 2023 he has been awarded \$67.4 million in sponsored research funding with the vast majority and largest components from the federal government (91%) but also with a significant tranche from industry sponsorship totaling \$3.6 million.

To date, Dr. Mantooth has founded, co-founded, and advised many different startup companies, three of which are currently active and operating in Arkansas:

- **Arkansas Power Electronics International** located in Fayetteville at the UA Research Park and established in the early 2000s, the company has focused on advanced electronics packaging and silicon carbide innovation. It has employed many of Dr. Mantooth's students and was sold to Cree in 2015 as a successful exit. Now doing business as Wolfspeed, the company remains in Fayetteville and today employs 75 including 50 PhDs earning high wages.
- **Lynguent**, established in 2003 and headquartered in Oregon, the company is no longer in business.
- **Ozark Integrated Circuits (Ozark IC)** was co-founded by Dr. Mantooth and also established at the UA Research Park in Fayetteville, the company develops electronics designed to operate in “rugged” environments including for the aerospace, energy, space, and other industrial sectors and environments. The company remains active today with about 25 employees and is currently headed by Matt Francis, a former student of Dr. Mantooth.
- **Bestazo**, established in 2020 by Dr. Mantooth and three UA professor colleagues as a virtual software business, is focused on cybersecurity solutions for the electrical system and expecting an initial product offering this year. The company is licensing technology from UA for royalties. In addition to the professors, the company is employing several former students and expecting to hire additional employees.

At the same time, Dr. Mantooth has been instrumental in establishing several federally-funded Centers of Excellence and associated facilities and infrastructure under the UA Power Group umbrella, including:

- Grid-connected Advanced Power Electronic Systems (GRAPES)
- The High-Density Electronics Center (HiDEC)
- The Center for Power Optimization of Electro-Thermal Systems (POETS)
- Cybersecurity Center for Secure Evolvable Energy Delivery Systems (SEEDS)
- The National Center for Reliable Electric Power Transmission (NCREPT)

The Centers have acted as a key mechanism for training and talent connections with industry as well as extensive direct engagement with numerous large and leading companies who function as members of the consortia. Dr. Mantooth and the UA Power Group have had extensive interactions on innovation challenges and solutions and collaborative agreements with national and global companies such as Caterpillar, Eaton, Sandia, Honeywell, John Deere, Toyota, Ford, TSMC (Taiwanese semiconductor company, the world's largest), and more.

In Arkansas, Dr. Mantooth and the UA Power Group have had partnerships and sponsored research engagements with several electric power and utility companies, including AECC, Southwest Power Pool, American Electric Power, and OG&E. These engagements have led also to placing students in full time jobs following graduation, with approximately 30 to 40 students placed into regional utility companies in and across Arkansas.

Establishing a Unique Global Capability at U of A in Commercializing and Fabricating Silicon Carbide Semiconductors

Among the many exciting innovations driven by Dr. Mantooth and the UA Power Group, one of the most recent developments is likely to have perhaps the greatest impacts. In 2020-21, the UA Power Group was awarded nearly \$19 million from the NSF and \$5.4 million from the Army Research Laboratory to establish the Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC) to address several needs and challenges as well as gaps in the current capacity and capability within the U.S. to lead in commercializing silicon carbide semiconductors.

The new “fab” facility is a first of its kind, enabling U of A to fill a void both nationally and globally for lower volume manufacturing runs with a unique semiconductor material able to address high-temperature applications (for example in hybrid electric bulldozers and airplanes). In a recent article describing the facility¹², the University notes several key functions, roles, and applications for the new facility, including:

- Training students and producing the next generation of well-trained leaders in the semiconductor community.
- Attracting leading faculty to the U of A.
- Attracting new industry to Arkansas.
- Producing new technology that becomes a source for startup companies.
- Serving as a bridge between traditional university research and high-volume manufacturing of SiC circuits, thus filling a vital gap in U.S. semiconductor manufacturing for universities, national labs and businesses of all sizes that need low-volume prototyping.

Dr. Mantooth expects the Fab to attract companies to Arkansas to be in close proximity to the facility as well as supply chain impacts related to key equipment. In an interview, Dr. Mantooth notes “Fabs are like magnets, they attract [companies].”

Dr. Mantooth recognizes the value of ARA in recruiting new and supporting existing faculty and cites the ARA Fellows award as a key resource specifically for securing a patent that helped start a new company. He is a prime example of how ARA supports and recognizes not only its 5-star recruits from beyond Arkansas, but the importance of retaining the state’s homegrown talent and highly impactful academic researchers within the state today.

12 University of Arkansas News, “Mantooth Presents New MUSiC Facility to Arkansas Legislative Council,” April 21, 2022.

Supporting Arkansas-Based Corporate Innovation: ARA Fellow Dr. Min Zou Partners with Hytrol Conveyor Company to Solve Innovation Challenges

Hytrol Conveyor Company, based in Jonesboro since 1962, is a global leader in designing and manufacturing material handling systems for a wide range of industries from healthcare to food to consumer goods. The company has long had an innovation mindset and approach to advancing its products and market solutions, which has helped it to grow to more than 1,600 employees today.¹³ At the same time, it proudly reinvests in its facilities and local communities. As it faced a recent innovation challenge, the company's leadership likewise turned to local Arkansas talent and expertise for solutions.

Belt conveyors, along with other types, have seen an explosion in demand in recent years due to the significant demand from e-commerce. This multi-billion dollar market is critical to Hytrol, but all conveyors have costly problems, namely, they waste a massive amount of energy due to friction and they are especially loud, with facility operators demanding quieter work environments for their employees. The energy consumption is significant, with high sliding friction between the belts and the slider bed materials responsible for more than half of the energy lost in a flat conveyor system. Not only is this costly from a business perspective, but it is misaligned with the company's focus on sustainability with respect to so much wasted energy consumption.¹⁴ There is an industry-wide need to address these problems and challenges, and by doing so, Hytrol could be positioned on the leading edge.

To solve these challenges, Hytrol's leadership turned to **Dr. Min Zou**, a professor of mechanical engineering at the University of Arkansas and an ARA Fellow who holds the Twenty-First Century Chair of Materials, Manufacturing, and Integrated Systems, and her team for assistance. Dr. Zou is an international expert in surface engineering and tribology—"the study of the science and technology of interacting surfaces in relative motion and encompasses the study and application of friction, wear, lubrication and related design aspects."¹⁵ Dr. Zou's research has focused on nanoscale materials and manufacturing applications, and she has designed, refined, and tested solid lubricant coatings for many applications. These coatings are typically thinner, environmentally superior, and more durable compared to traditional petroleum-based lubricants. Dr. Zou's technology represents a patented bonding approach in which graphite coatings adhere to substrate material.

ARA facilitated an introduction to Dr. Zou and an industry-university R&D team was formed, partnering Hytrol's Product Innovation and Chief Engineering leads with Dr. Zou and her research team at UA, along with researchers at Arkansas State University. The team was successful in securing a National Science Foundation grant in 2022 totaling \$550,000 to develop low-friction, graphite-lubricant coatings for Hytrol's industrial conveyor systems aimed at substantially reducing energy consumption and equipment failure.

At the same time, the project and grant funding will allow for other positive impacts for Arkansas, namely developing student talent and advancing other potential innovative applications for the technology. The research team and grant support a doctoral student at the U of A (serving as an entrepreneurial lead), a master's student at A-State, and undergraduate student researchers from underrepresented groups.

The multi-year joint project is underway with initial deliverables expected in the next year. The project has

¹³ Corporate employment sourced from Hytrol Conveyor Company website: <https://hytrol.com/company/about/>.

¹⁴ Drawn, in part, from University of Arkansas, "Research to Develop Solid Lubricant Coatings for Conveyor Systems," May 4, 2022.

¹⁵ *Machinery Lubrication*, see: <https://www.machinerylubrication.com/tribology-31340>.

been undertaken in the spirit of Hytrol's culture of investing in local communities and U.S. jobs, rather than offshoring production to other countries as its competitors have done. At the same time, the project should yield sustainability benefits, important to the company and increasingly to its younger employees in particular.

"This partnership allows us to investigate a novel solution that benefits the industry from a noise and energy consumption perspective, allows us to work with potential future employees (students), and drives advancements within our industry's sustainability efforts. These factors continue Hytrol's role as an industry leader."

-Ty Keller, Former Product Innovation Manager, Hytrol Conveyor Company

Translational Research & Tech Commercialization

A strong foundation in academic research is vital to initiating and propelling innovation in a state economy. However, research activity and spending in and of itself does not lead to broad-based or significant economic growth and development. Rather it is the translation of market-driven research activity into commercially viable products or technological processes that ultimately lead to job creation and economic gains. How well universities and individual research faculty can successfully navigate and execute the translation and commercialization process is of importance for reaping the economic and societal benefits of innovative research and development. Key steps and outcomes in this commercialization process can include protecting intellectual property (IP) by patenting inventions and licensing university-developed technologies to startups or existing companies. So, university technology transfer programs and resources are especially important, in combination with a robust entrepreneurial ecosystem throughout the state to enable Academy members to realize the full commercial and societal benefits of their research.

Many ARA Academy members have a strong orientation toward commercializing their research. Among the Scholars and Fellows, there is a substantial volume of science- and technology-based startups. Additionally, there is a focus on technology licensing and intellectual property (IP) generation. **With respect to IP, ARA Academy members are especially productive when it comes to patenting, generating 0.46 patents per \$1 million in research funding, a level well above their peers both in Arkansas and among all U.S. research universities** (Table 5).

Just some examples of technology commercialization activities and outcomes among Academy members include:

- Dr. Min Zou, professor of mechanical engineering at the University of Arkansas and an ARA Fellow has in place three technology licenses based on technology emerging from her lab and associated with at least two companies operating in Arkansas today—SurfTec, based in the Arkansas Research and Technology Park and WattGlass (acquired by Pellucere Technologies, Inc.).
- Dr. Edward Yeh, ARA Scholar recently recruited into UAMS, is advancing an NIH-funded clinical trial at UAMS based on research begun at his former institutions, MD Anderson Cancer Center and the University of Missouri. His unique research area of onco-cardiology has resulted in a promising

therapeutic candidate to treat heart complications related to cancer treatments. His NIH grant related to this research is for 3 years and \$5 million.

- Dr. Peter Crooks, ARA Scholar with UAMS, is close to being awarded his 100th issued patent over his career.

Table 5. Patents Issued per \$1M in Research Funding, ARA Academy Members vs. AR and U.S. Peers, 2011-2021

	PATENTS PER \$1M OF RESEARCH FUNDING
ARA Academy Members	.46
All Arkansas Research Universities	.15
All U.S. Research Universities	.10

Source: TEconomy Partners' analysis of Arkansas university-provided patent data for ARA Academy Members; Derwent Innovations Data; AUTM.

Sustaining Arkansas' Agriculture Industry: The Contributions of Three ARA Fellows

As one of the largest industries in Arkansas, agriculture is of paramount importance to the Arkansas economy. The agricultural sector generates billions of dollars in revenue each year and provides employment opportunities to a substantial portion of the state's population. Sustaining productivity and output increases in agriculture is a constant challenge given the unique characteristics of the industry and its operational environment. The sector comprises nearly 50,000 small and midsize businesses that must operate in a uniquely variable and challenging production environment. For the agriculture sector to remain competitive, Arkansas' producers must be equipped with the knowledge, skills, tools, and inputs required to produce quality products at competitive prices in a changing environment. The industry, perhaps more than any other industry, requires specialized local research to remain competitive—research that the Arkansas Research Alliance is helping to support.

Agriculture in Arkansas is driven, in part, by **rice production**. Arkansas is the leading producer and processor of rice in the nation. In 2022, Arkansas farmers grew nearly half of all the rice produced in the U.S.—1.1 million acres of production, resulting in more than 8 billion pounds of the crop, valued at \$1.374 billion.¹⁶ Rice is the state's second highest-value commodity, its top agricultural export, and accounts for approximately 25,000 jobs that are crucial to rural communities.¹⁷ However, this critical industry is being threatened by climate change that is causing rising night-time temperatures that are hazardous to rice crops and which cause lower yields. **Dr. Argelia Lorence**, Professor of Metabolic Engineering, Co-Lead of the Plant Imaging Consortium, and Director of the Plant High-Throughput Phenotyping Facility at Arkansas State University is a **2015 ARA Fellow**. Dr. Lorence's research focuses on equipping farmers with the latest tools and technologies to maximize their yields and adapt to changing growing conditions.

16 https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=ARKANSAS

17 <https://www.arfb.com/pages/arkansas-agriculture/commodity-corner/rice/>

As a result of Dr. Lorence's efforts, the Wheat and Rice Center for Heat Resilience (WRCHR) was created through a \$6 million NSF EPSCoR grant forming a collaboration between Arkansas State University, the University of Nebraska-Lincoln, and Kansas State University. WRCHR is developing the foundational knowledge needed to improve wheat and rice yields under stressful environments. To ensure global food security, there is an urgent need to improve crop resilience in cases of high night temperature stress-induced yield and quality losses. The research aims to elucidate the physiological and genetic basis of high night temperature resiliency of rice and wheat, translate these discoveries into genetic and phenotypic markers for public and private breeding programs, and develop a broad continuum of educational opportunities.

In the coming decades, farmers in Arkansas and elsewhere may see not only a rise in temperatures but also more drought, outbreaks of plant diseases, and changes in the salt content of their soil. Each of these factors can decrease the quality and quantity of rice that farmers can produce. Overcoming these stresses is critical for Arkansas' economy. Dr. Lorence and her research team are collaborating with RiceTec, Inc., a producer of rice seeds, that has experimental fields in Harrisburg, Arkansas. Through this public/private partnership, RiceTec is covering the costs of growing the rice trials and in exchange, the scientists included some rice plants produced by RiceTec in their study as well as participated in Field Days where producers from all over the state can come to learn more about the research and the opportunity to deploy its findings into practice.

Dr. Lorence was recently featured as part of a broad-based New York Times investigation into the future of rice globally, as it faces these challenges and gets "reimagined".¹⁸

"I am convinced that decades from now, farmers are going to need very different kinds of seeds."

-Dr. Argelia Lorence, interviewed by the New York Times

Complimenting the work of Dr. Lorence is the research of **Dr. Mariya Khodakovskaya**, Professor of Plant Biology and Director of Applied Science Graduate Program at Donaghey College of Science, Technology, Engineering and Mathematics, University of Arkansas at Little Rock, and a **2021 ARA Fellow**. Dr. Khodakovskaya is a research pioneer in the area of crop improvement through the application of a wide range of carbon-based nanomaterials. She and her research team have developed innovative approaches for the enhancement of plant tolerance to environmental stress using advanced methods of genetic engineering, molecular biology, and nanotechnology. She was the first person to demonstrate that carbon-based nanomaterials can affect plants at genomic and metabolomic levels by activating genes involved in water transport, cell division, and response to environmental stress. She has also established new methods for increasing seed germination and plant and cell growth using nanomaterials. To commercialize her work, Dr. Khodakovskaya founded a new company, Advanced Plant Technologies, LLC, based in Little Rock.

The Economic Impact of a One-Percent Increase in Rice Output in Arkansas

The research of ARA Fellows dedicated to improving and growing the agriculture sector of the state's economy is significant, and as such has an annual impact on state economic performance. To identify a potential scale of this impact, TEconomy analyzed the effect that every one-percent increase in total rice production would have on the State of Arkansas. Use of the IMPLAN Arkansas input/output models enables TEconomy to quantify the total effect on Arkansas' economic output, employment, and other variables of an increase in rice output (dollar value).

In terms of total rice production, a 1% increase would generate the following impacts:

- **\$28 million increase in total Arkansas economic output, comprising direct, indirect and induced**

¹⁸ Sengupta, Somini and Tran Le Thuy, "Rice Gets Reimagined, From the Mississippi to the Mekong," New York Times, May 20, 2023.

impact components.

- **\$7.2 million increase in value-added within the Arkansas economy.**
- **174 jobs created and supported.**
- **\$5.5 million annually in additional labor income for Arkansans.**

Another important subsector of Arkansas' agriculture industry being supported by ARA investments is **aquaculture**. Arkansas is the birthplace of warm water aquaculture in the U.S. The first commercial fish farms were built in Arkansas in the 1940s to raise goldfish. The industry in Arkansas has diversified into production of more than twenty species of fish and crustaceans. These species supply food-fish markets, recreational fishing markets and waters, retail pet markets, gardening supply markets, and markets for aquatic weed and snail control.

Arkansas had approximately 70 aquaculture operations with \$68 million in sales in 2018, the latest year for which data is available.¹⁹ The state leads in the production of baitfish (live fish bought by anglers as bait for recreational and sport fishing), large-mouth bass for stocker fish, hybrid striped bass fry, and Chinese carp. It is third nationally in catfish production. The world's largest bait-fish farm (Lonoke County), large-mouth bass farm (Monroe County), goldfish farm (Lonoke County), and hybrid striped bass hatchery (Lonoke County) can all be found in Arkansas.²⁰

This important agriculture subsector is being supported by the research of **Dr. Rebecca Lochmann**, Chair of the Department of Aquaculture and Fisheries and Director of the Aquaculture/ Fisheries Center of Excellence at the University of Arkansas at Pine Bluff and a **2017 ARA Fellow**. Dr. Lochmann's research focuses on evaluating the efficacy of alternative dietary protein and lipid sources, prebiotics and probiotics, and other feed additives on the growth, health, product quality and reproductive performance of baitfish, catfish, largemouth bass, hybrid striped bass and tilapia. Cost-effectiveness of these ingredients is assessed where possible, to estimate the effects of diet manipulations on production profitability of these species. This research is critical to Arkansas aquaculture farmers since feed comprises roughly 50% of operating costs and significantly impacts the quality of the farm's product. Reducing the cost of feed while ensuring the same if not improved output would greatly benefit fish growers.

Aquaculture has a major economic impact in Arkansas, especially in the Delta where the majority of aquaculture production in Arkansas occurs. This region is characterized by high rates of poverty and unemployment. Fish farms frequently are some of the largest businesses in the region and provide employment and demand for other services from electricians, plumbers, equipment and truck dealerships, supply companies, and other service providers.²¹ The research of Dr. Lochmann and her research team is dedicated to improving and growing the aquaculture sector of the state's economy, and as such has an annual impact on state economic performance. To identify a potential scale of this impact, TEconomy analyzed the effect that every one-percent increase in total aquaculture production would have on the State of Arkansas. Use of the IMPLAN Arkansas input/output models enables TEconomy to quantify the total effect on Arkansas' economic output, employment, and other variables of an increase in aquaculture output (dollar value).

In terms of total aquaculture production, a 1% increase would generate the following impacts:

- **\$912,739 increase in total Arkansas economic output, comprising direct, indirect and induced impact components.**
- **\$629,603 increase in value-added within the Arkansas economy.**

19 https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Aquaculture/aqua_1_0001_0001.pdf

20 <https://www.arfb.com/pages/arkansas-agriculture/commodity-corner/aquaculture/>

21 <https://www.agriculture.arkansas.gov/plant-industries/regulatory-section/aquaculture/>

Placing Top Talent at Arkansas Companies

ARA Academy members are placing top-tier STEM talent in Arkansas companies and startups related to the research of Scholars and Fellows. For example, Dr. Alan Mantooth and the UA Power Group have had partnerships and sponsored research engagements with several electric power and utility companies, including AECC, Southwest Power Pool, American Electric Power, and OG&E. These engagements have led also to placing students in full-time jobs following graduation, with approximately 30 to 40 students placed into regional utility companies in and across Arkansas in recent years.

Importance of ARA Fellows in Seeding Emerging Industries in Arkansas

Dr. Alexandru Biris was named a **2015 ARA Fellow** and has been the Chief Scientist of the University of Arkansas Little Rock Center for Integrative Nanotechnology Sciences (CINS) since it began in 2005, serving as director since 2009. He leads the research at CINS, exploring the science of nanostructures that can be used to alter the properties of other substances at the atomic level. Dr. Biris is also Professor in the Systems Engineering Department at the Donaghey College of Engineering and Information Technology and is the Roy and Christine Sturgis Charitable Trust Nanotechnology Chair. Since 2015, Dr. Biris has received \$15 million in research funding, been issued 14 patents, and written prolifically in leading scientific journals.

But possibly most impactful for the State of Arkansas, Dr. Biris has recognized the commercial potential of his research and seeks to help develop an emerging bioscience industry in Arkansas through the company he co-founded and serves as Chief Technology Officer, NuShores Biosciences, LLC (NuShores). NuShores, founded in 2014, was formed to commercialize patented bone and tissue regeneration technologies developed at the University of Arkansas at Little Rock through Dr. Biris' research. Today, there is currently no commercially available satisfactory solution for major bone injuries caused by accidents, warfare, and/or cancer, especially complex and large segmental bone loss. Currently, in severe fractures and deficits, bone fillers or cements are used to help bridge the fractured bone and promote healing; however, their contribution to the healing process is limited. Orthopedic appliances may be needed for extra support in early stages of healing. Natural or synthetic bone grafts have drawbacks and limitations — using either an autograft (patient's own bone via an additional painful procedure) or allografts (cadaveric donor bone); both are complicated procedures that can require long recovery periods. Shortages exist in availability of donor tissue traditionally used in such reconstructions and the size of these grafts is limited.

NuShores' vision is to improve the quality of life for people globally and to compete successfully in the bone and tissue regenerative materials industry. NuShores' NuCress™ bone scaffold technology has been shown to promote healing of large segmental bone breaks in large and small animals with no infections, inflammation, rejection or adverse bone response. NuShores collaborates with UAMS Fellow, Dr. Mark Smeltzer, to ensure the scaffold remains free of infection.

Early studies suggest that NuShores' licensed, patented technology could deliver improved solutions for bone regeneration while cutting healthcare costs, lowering treatment risks, and reducing healing times. Research results show that NuShores' NuCress™ scaffold could offer several benefits that to date are not achieved by currently marketed bone regeneration products, therefore promising to bring better treatment outcomes to millions of people with severe injuries.

NuShores currently employs 14 people in Little Rock, with a large share of these employees being alumni of UA Little Rock. Dr. Biris' vision is to grow the company in Arkansas, creating further economic opportunities for the region. But his vision does not end with his own company. He also is working through CINS to conduct an aggressive outreach program to train and educate young people and other world class scientists who will serve and attract other businesses and emerging industry to Arkansas from across the nation.

CONVENING & CONNECTING ARKANSAS’ SCIENCE & TECH COMMUNITY

ARA is often described by members of its Academy and other Arkansas leaders and stakeholders as a “convener,” “connector”, “matchmaker”, and other terms that illustrate its role in the Arkansas science and technology and broader innovation ecosystem as critical connective tissue. Across the 30 interview discussions conducted during this effort, these stakeholders were asked to share one-word adjectives that best describe ARA and its role in this vital ecosystem for economic and innovation development. Figure 6 below shares a “word cloud” with the adjectives shared, and those most often cited in larger fonts. Furthermore, state leaders and stakeholders recognize the value of ARA as an “independent, autonomous” and “trusted” organization playing a highly valuable and needed role in maintaining Arkansas’ economic and innovation competitiveness.

“It’s important for scientists to be able to get together outside of the boundaries of their institution.”

—Dr. Laura James, Professor of Pediatrics, Associate Vice Chancellor for Clinical and Translational Research at UAMS and ARA Fellow regarding the value of the ARA Academy and its retreats

Figure 6. Word Cloud of Adjectives Used to Describe ARA by Selected Academy Members, Stakeholders in Interviews



Facilitating Academic Research Partnerships

Both Scholars and Fellows and broader stakeholders cite ARA's annual retreat for Academy members as a key activity for connecting the research community. Connections made at the annual retreat are resulting in strategic research and leadership collaborations, including the following as examples cited during interview conversations:

- ARA has added university Vice Presidents/Provosts of Research (VPRs) to its Academy Retreats and the results have been extremely beneficial, at least according to one of those attending from a smaller institution to hear key conversations on research needs and limitations, connecting with counterparts at the partner institutions, and even resulted in regular meetings for this key group of university and federal laboratory leaders within Arkansas. Chief research officers represent a birds-eye-view of the campus landscape. Their sense of strategic, campus-wide objectives and priorities, along with their deep knowledge of programs and initiatives, provide a sounding board for meaningful, productive dialogue.
- Dr. John Imig, a recent recruit into the state with UAMS as an ARA Scholar, cited the ability to immediately connect into this community of innovation as a major benefit of the ARA Academy upon his arrival into Arkansas in 2022.
- Through ARA meetings, Fellows Dr. Min Zou (U of A) and Dr. Mark Smeltzer (UAMS) connected and moved forward to collaborate in their respective areas of expertise in surface engineering and anti-bacterial surface technologies for research on artificial implants, representing a new area of biomedical application research for Dr. Zou. They received a UA Chancellor's Innovation and Collaboration Fund grant to sponsor joint multidisciplinary research.
- ARA plays a key role in engaging Arkansas' only federal laboratory, NCTR. ARA's collaboration began in 2011 with the signing of a Memorandum of Understanding (MOU) between the State of Arkansas and the U.S. Food and Drug Administration (FDA). The MOU has since been renewed in 5-year intervals and ARA continues to collaborate on strategic research efforts with NCTR and to date, there have been five ARA Fellows from NCTR. Several stakeholder and leadership interviews noted the inherent difficulty in collaborating with NCTR as a stand-alone federal entity with built-in, nationwide protocols, that can be perceived as barriers to engagement at the state research level. ARA, through the State's arrangement with the lab, is uniquely designed to act as a "liaison" to NCTR and key researchers there.
- ARA has developed and cultivated a statewide bioinformatics organization that connects the five research institutions along with bioinformatics leadership at NCTR to form the **Arkansas Bioinformatics Consortium (AR-BIC)**. ARA, with funding support from FDA and other partners, has convened eight annual conferences under the AR-BIC framework since 2015, which have grown to include 250 attendees. The Consortium effort has resulted in two FDA contracts:
 - A nanomaterial research project aimed at determining the public health impacts of graphene (\$1.5 million contract).
 - Research on liquid biopsies to further the development of lung cancer-based precision medicine (\$2.0 million contract with a recent \$1.5 million extension).



ARA Connects Arkansas' Smaller Institutions in Broader Strategic S&T Efforts

ARA's role as a "convener" and "matchmaker" has been especially important for elevating the voice and input of smaller universities in Arkansas. As noted by Brian Berry, Vice Provost of Research and Dean of the Graduate School at UA Little Rock, "As an R2 university without a strong research base we tend to get overlooked in strategic statewide discussions, but when it came to key initiatives such as BIOArkansas or the NSF Engines Planning Grant, [ARA President/CEO] Bryan Barnhouse called and made [our participation] happen."

Fostering Industry Connections

ARA and its Academy members are utilizing varied approaches to connecting with industry, including:

- Proactively engaging industry on key research challenges through several Federal Industry–University Cooperative Research Centers (IUCRCs) and Centers of Excellence, for example the extensive local, national, and global industry research and innovation collaborations established by the UA Power Group and ARA Fellow Dr. Alan Mantooth spanning the following:
 - Grid-connected Advanced Power Electronic Systems (GRAPES)
 - The High-Density Electronics Center (HiDEC)
 - The Center for Power Optimization of Electro-Thermal Systems (POETS)
 - Cybersecurity Center for Secure Evolvable Energy Delivery Systems (SEEDS)
 - The National Center for Reliable Electric Power Transmission (NCREPT)
 - The Multi-User Silicon Carbide Research and Fabrication Facility (MUSiC)
- ARA acting as a gateway or "front door" for companies with innovation challenges to access a talented research community with impressively varied expertise, for example Hytrol in Arkansas.
- Engaging in discussions and convening across research institutions to advance a thriving biosciences industry cluster and community for Arkansas via the BIOArkansas initiative.

Importance of ARA Scholar in Attracting New Federal Research Dollars that Lead to Ground-Breaking Public-Private Partnerships and Collaborations

ARA's recruitment of **Dr. Ranil Wickramasinghe**, Professor and Ross E. Martin Chair in Emerging Technologies in the Ralph E. Martin Department of Chemical Engineering at the University of Arkansas and a 2010 ARA Scholar, has greatly benefited the State of Arkansas as Dr. Wickramasinghe has successfully established the NSF Membrane Science, Engineering and Technology (**MAST**) Center at the University of Arkansas as part of the Federal IUCRC program.

The IUCRC program accelerates the impact of basic research through close relationships between industry innovators, world-class academic teams, and government leaders. IUCRCs are designed to help corporate partners and government agencies connect directly and efficiently with university researchers to achieve three primary objectives.

- Conduct high-impact research to meet shared industrial needs in companies of all sizes;
- Enhance U.S. global leadership in driving innovative technology development, and;
- Identify, mentor, and develop a diverse high-tech, exceptionally skilled workforce.

The National Science Foundation (NSF) provides funding to support Center administrative costs and a governance framework to manage membership, operations, and evaluation.

The MAST Center was originally designated as an IUCRC as a partnership between the New Jersey Institute of Technology and the University of Colorado Boulder. However, as a result of Dr. Wickramasinghe's research and his relationships with the University of Colorado Boulder, the University of Arkansas joined the MAST Center as the third university campus in 2014 and Dr. Wickramasinghe was named the Director of the Center and leads its research efforts today.

Over the years, MAST Center researchers from the University of Arkansas, University of Colorado Boulder, Pennsylvania State University, and the New Jersey Institute of Technology have worked on collaborative research projects with industry sponsors. In addition, the team has worked with collaborators from several other institutions, including Colorado State University, Clemson University, the Colorado School of Mines, the University of Maine at Orono, and Ben Gurion University of the Negev in Israel.

The MAST Center focuses on all forms of membrane-based separations. Membrane-based separations have broad industrial applications—including, but not limited to: chemical, biopharmaceutical, pharmaceutical, food production, biomedical devices, oil and gas production, desalination of seawater, and water recycle and reuse. The MAST Center is largely sponsored by corporations, as well as federal agencies and national laboratories. The industrial members represent major membrane manufacturers and users. By bringing them together, the MAST Center catalyzes the development of new membranes, devices, and processes for emerging separations challenges. The new membranes and membrane-based separation processes developed in the MAST Center can lead to more affordable human therapeutics, new specialty chemicals, and accelerated efficiency for water recovery and reuse. The education and training opportunities provided to students and researchers at the University of Arkansas site are directly leading to the development of a highly trained workforce that is attracting new high-tech industries to Arkansas.

Since FY2015, through the efforts of Dr. Wickramasinghe and the MAST Center, more than \$2.5 million of federal funds have been awarded to the University of Arkansas, which in turn has been matched by industrial-sponsored research on a nearly 1:1 basis. In addition, Dr. Wickramasinghe has served as a highly collaborative research partner on other efforts involving membrane research with other Arkansas principal investigators. These efforts include, for example:

- In vitro blood clot formation and dissolution for testing new stroke-treatment devices in collaboration with **Dr. Morten Olgaard Jensen, a 2015 ARA Scholar** with the Department of Biomedical Engineering at the University of Arkansas. Dr. Jensen's research focuses on experimental cardiovascular surgery. Collaboratively, Dr. Jensen and Dr. Wickramasinghe are conducting research on the production of stroke retrieval devices with advanced membrane technologies that can efficiently and effectively remove clots from patients with low mortality rates and little/no damage to the surrounding vessels. If successful, this will greatly improve the mortality rates of stroke victims, one of the leading causes of death worldwide.
- Developing membranes for use in vaccine production in collaboration with Dr. Xianghong Qian, Professor of Biomedical Engineering at the University of Arkansas. The University of Arkansas received a \$6 million grant from NSF to develop purification membranes for future large-scale manufacturing of viral vectors and virus-like particles. Successful development of commercial-grade purification membranes will improve human health by increasing access to new treatments for genetic and chronic diseases. Currently, biopharmaceutical manufacturers struggle to produce membrane filters to purify viral vectors and virus-like particles, primarily because of capacity and fouling of membranes, which causes delays in vaccine production. The research is working to create a scalable, downstream manufacturing platform for purification that will replace the standard processes of centrifugation and resin-based chromatography, both of which are difficult to scale up in manufacturing.

Dr. Wickramasinghe and Dr. Qian co-founded SIEV Technologies in the Fall of 2020 to commercialize their catalytic membrane technology with the goal of creating bio-based platform chemicals and byproducts from agricultural residues and low value biomass waste or feedstocks. The company has been awarded a Phase I federal SBIR award and is working on a Phase II application with support from ARA. SIEV is taking the next steps to bring this technology to the market.

Enhancing Access to University Research Core Facilities & Specialized Equipment

So-called “core” university research facilities, instrumentation, and accompanying services represent highly valuable resources and a unique asset base of specialized capabilities. Access to core facilities has traditionally been limited to a select few researchers working and conducting research within a single university for which they are directly employed, or in many cases limited to a specific research lab and its members who actually purchased or acquired the equipment using grant funding or other means. In recent years, however, there has been a more coordinated push and wider recognition within certain states for cross-departmental and cross-institutional access to these critical, enabling resources as a potential competitive advantage with respect to advancing innovation, including among companies.

ARA has established the Arkansas Core Facilities Exchange (CFE), a publicly available online platform showcasing 340+ scientific instruments and services available for use in labs across Arkansas.

For more information visit:
<https://aralliance.org/core-exchange/>

This functional impact area represents a key opportunity identified by ARA leadership, leading to the establishment of the ARA Core Facilities Exchange (CFE). And while in its early-stages and with a primary focus on establishing an accurate inventory and protocols for shared-use, an ultimate objective of the program could be enhancing corporate access to core facilities across Arkansas. Key facilities, either established or coming online soon, can be leveraged for access by advanced industry companies to further their R&D and product development efforts via prototyping, conducting key experiments, or other critical functions for early-stage companies or product design efforts. ARA has the unique ability to coordinate across the five research universities and NCTR, as well as the Arkansas Children’s Research Institute (ACRI), for this new strategic effort for the state.

ARA sees the CFE program as having distinct benefits for Arkansas and its research community, namely:

- Stimulating and improving research
- Enhancing grant competitiveness
- Fostering collaboration
- Reducing redundancy in capital expenditures
- Increasing utilization.

Among ARA Academy members and other researchers, some early use cases are emerging:

- UA Little Rock ARA Academy member, Dr. Mariya Khodakovskaya, collaborated with the UAMS Bioinformatics core facility, completed a project, and is now working on a manuscript.

- Connected Hydralyze, a Northwest Arkansas-based startup that launched out of the UA with various options from within the CFE, as well as outside the CFE (Georgia's core exchange), for ion chromatography.
- Dr. Jeff Massey at Harding University will be utilizing resources at A-State, UA Little Rock, and NCTR instead of sending samples to Texas as he did previously.
- Dr. Mariya Khodakovskaya will be utilizing UAMS' proteomics core facility instead of sending her samples to a private company in China as she did previously.

BUILDING & DEVELOPING TOP TALENT FOR ARKANSAS

Top Talent Recruitment & Retention

ARA programs help chancellors at Arkansas' five major research universities recruit, recognize, and retain world-class scientific and engineering talent. The signature effort is through the ARA Scholars Program, which recruits scientific leaders from outside Arkansas. Its companion effort, the ARA Fellows Program, which is also available to the executive director of NCTR without the grant award, recognizes and retains talented research leaders already residing on those five campuses.

Since its inception, ARA has recruited 13 Scholars into positions at three of the state's research universities. These individuals would most likely not be in Arkansas were it not for the proactive recruiting approach by and the resources provided through ARA. The benefits, impacts, and ripple effects of recruiting top talent into Arkansas extend outward, beyond just the Scholars themselves, to the talented graduate and other students and post-doctoral researchers these faculty members ultimately employ and/or often bring with them from other institutions.

Top talent recognition and retention is the focus of the ARA Fellows program, where since 2011 ARA has supported 26 university faculty in Arkansas with \$75,000 awards to be directed toward expenditures of their choosing. These faculty span all six partner institutions, including Fellows at NCTR, and like the Scholars, are working in a varied set of STEM disciplines.

The benefits, impacts, and ripple effects of recruiting top talent into Arkansas extend outward, beyond the Scholars themselves, to the talented graduate and other students and post-doctoral researchers these faculty members ultimately employ and/or often bring with them from other institutions.

Dr. Nitin Agarwal, an ARA Fellow at UA Little Rock currently employs 35 graduate and post-doctoral students in his lab heralding from all over the world, and with the growth of his research program, he has plans to double this level of students and staff in the near-term.

ARA Academy leaders act as talent magnets. They are attracting diverse students and advancing the education and training of diverse STEM talent within Arkansas. Within Dr. Nitin Agarwal's COSMOS, at least four student researchers have been awarded the prestigious Acxiom Diversity Scholarship for U.S.-based students from diverse backgrounds enrolled in tech-, engineering-, and/or math-related post-secondary programs.

ARA Fellow Dr. Min Zou has seen firsthand the retention of graduates from her PhD program in Mechanical Engineering at U of A, with five doctoral students graduating in recent years and taking faculty positions at A-State, UA Little Rock, and John Brown University. Two other PhD students remained in Arkansas to establish new startup companies.

Jennifer Fowler, Program Director for Arkansas' NSF Established Program to Stimulate Competitive Research or "EPSCoR" housed within the Arkansas Economic Development Commission (AEDC), succinctly summarized the role ARA plays in top talent cultivation, "ARA is the best tool we have to attract and retain scientific talent in Arkansas."

New Academic Programs

By recruiting new faculty, ARA is assisting its partner institutions in establishing, growing, and maintaining new academic programs and associated research capabilities. When Dr. Peter Crooks was recruited into Arkansas in 2011, UAMS had nascent capabilities in drug discovery. Dr. Crooks was brought in to Chair the Department of Pharmaceutical Sciences and enable drug discovery as a new UAMS capability. He helped start the graduate program, which has about 30 students enrolled today in its doctoral program, and there are several faculty today with funded programs in anti-cancer and other therapeutic development.

New Core Research Capabilities & Infrastructure

ARA Academy members are continually building out, equipping, and updating research cores and specialized research infrastructure. Dr. Alan Mantooth's silicon carbide research and fabrication facility is under development for low volume prototyping and training. Dr. Nitin Agarwal's rapidly growing research lab and associated cadre of student employees is requiring UA Little Rock to build out a new floor to expand capacity. These space and new building requirements generate economic impacts of their own with respect to construction, materials, tax revenue, and supply chains seeing expenditure boosts within the universities.

Engaging Students in Translational, Market-Driven Research & Training

With a focus on life sciences company incubation and acceleration, UAMS BioVentures and Dr. John Imig, ARA Scholar, are also focusing on student entrepreneurial development. Through its prestigious Clinical and Translational Science Awards (CTSA) grant, the acquisition of which was led by ARA Academy member Dr. Laura James, UAMS not only has resources to advance scientific breakthroughs into life-saving treatments in the clinic, but also an entrepreneurial training grant for post-doctoral researchers, a critical cohort for advancing new startup activity in the biosciences and for boosting Arkansas' innovation ecosystem.

IV. LOOKING TO THE FUTURE: EXPECTED CONTINUED IMPACTS AND A CALL TO FURTHER ACTION BY ARA STAKEHOLDERS

ARA and the community of innovation leaders it has cultivated are generating significant impacts for Arkansas—both economically with respect to its outsized contributions in research-related impacts and a sizable cohort of science- and tech-driven startups; and from its mission-based roles as a driver of innovation, cultivator of top talent, and connector of university research, industry, and government. ARA is evolving appropriately into new areas including the CFE and Impact Grants initiatives, particularly in light of its relatively modest funding. Its cumulative, compounding impacts are expected to continue to grow and advance.

ARA is proud of its accomplishments, though recognizes there is more work to be done to advance the research growth and momentum in Arkansas. The organization is looking ahead to maintaining its impact and alignment with the state's innovation and economic evolution, with plans in place to update the important core research competencies study developed by Battelle early in ARA's lifetime and oriented toward advancing "job-creating research" in Arkansas.²² The 2009 study identified strategic focus areas for Arkansas that leveraged the following key characteristics and acted as a guide and "North Star" for ARA's investments:

- Opportunities drawing upon multiple core research competencies and organizations;
- Opportunities for external funding;
- High-growth market potential; and
- Direct economic linkages with Arkansas industries.

ARA is generating significant impacts and considering its next phase, though it is operating with a relatively modest annual budget totaling \$1.9 million, with two-thirds of its funding provided by the state through AEDC, 28% through its Board of Trustees, and 5% through federal funds. ARA is operating in a highly competitive space nationally, where comparable initiatives such as the Georgia Research Alliance are operating with annual revenues approaching \$7 million, and multi-billion dollar initiatives such the Cancer Prevention and Research Institute of Texas (CPRIT) also have as a key priority the recruitment of world-class research talent. To advance further impacts and expand into further domain areas, ARA will require significant additional resources.

22 Battelle's Technology Partnership Practice, "Opportunities for Advancing Job Creating Research in Arkansas: A Strategic Assessment of Arkansas' University and Government Lab Research Base," April 2009.



Still, the interview conversations with Arkansas leaders and ARA stakeholders have illuminated the underlying potential so many in the state see for ARA if its purview were expanded and its funding enhanced. A number of suggestions were brought forth from these conversations as to potential areas of growth for ARA, including a sampling of specifics and themes shared here:

- ARA can further develop into a major recruitment tool for Arkansas as has been done with CPRIT in Texas and in California with its Stem Cell Initiative. For Arkansas to compete effectively for top researcher talent against these multi-billion dollar state initiatives, ARA has to be one of the major tools utilized and appropriately resourced.
- Recruiting post-doctoral researchers is highly competitive nationally, and to ensure that Arkansas can continue to attract top young talent, the state and ARA should consider funding recruitment resources into an “ARA Post-Doctoral Fellows” program.
- To enhance/encourage further collaborations, consider state-funded grant programs targeted toward participation by two or more Arkansas institutions.
- Diversity, Equity, and Inclusion in the innovation ecosystem and among top-tier talent cohorts are critical and woefully behind in Arkansas. Consideration should be given to exploring more opportunities to engage underrepresented populations in STEM and in translational capacity building.
- Consider a “rising stars” feature, for example, a “40 under 40” recognition to address young star university research faculty and their risks of leaving the state.

Stakeholders are clearly recognizing the impacts of ARA and its potential to grow and expand, and in the future ARA could evolve even further. With respect to its core mission today to “invest in strategic research talent recruitment, retention, and recognition to generate scientific and engineering breakthroughs that support statewide economic development,” the evidence points to a decade-and-a-half of success.

