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Argonne NATIONAL LABORATORY

ARGONNE ECONOMIC IMPACT REPORT

Innovations to Drive U.S. Prosperity

Prepared by Intelligent Analytics and Modeling (IAMECON)

CONTENTS

EXECUTIVE SUMMARY

Argonne National Laboratory (Argonne) is best known as a scientific and technological powerhouse. A U.S. Department of Energy (DOE) Office of Science national laboratory with 3,523 full-time employees and budget of $1.05 billion in Fiscal Year (FY) 2021, Argonne addresses the greatest scientific, technological, and societal challenges facing our nation. Argonne's technical accomplishments and impact can be seen in its outstanding record of publications and inventions: in 2021 alone, its researchers published more than 1,700 papers in technical journals and more than 2,400 additional items in the form of conference papers and presentations, technical reports, and other documents. Still more papers were published by Argonne facility users.

Argonne also has a large economic impact on the Chicago area, bolsters the Midwest region[1], and ensures the nation's competitiveness. In 2021, in Illinois, Argonne's work supported more than 7,700 jobs and created an economic impact of more than $1.29 billion; in the Midwest, Argonne was responsible for more than 9,000 jobs and more than $1.53 billion in economic activity; across the United States, Argonne's work supported more than 13,300 jobs and had a nationwide economic impact of more than $2.67 billion. In purely financial terms Argonne therefore provides a substantial economic multiplier on the funds that the U.S. government has invested in in its work.[2]

In this report, we will examine several aspects of Argonne's robust economic impact which includes both immediate economic impacts and longer-term through impacts in science and technology.

$2.67B
U.S. economic impact

13,388
U.S. jobs supported

$1.29B
Illinois economic impact

7,706
Illinois jobs supported

3,523
full-time equivalent employees

1,445
scientists and engineers

325
postdoctoral appointees

496
paid students

5,995
user facility users

1,703
technical publications

3
Nobel laureates since inception

78
patents *(2020)*

65
high school visits to the Lab *(2019)*

29,000
people reached *(2019)*

All numbers are for FY 2021, except as indicated

1 The Midwest is defined as Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.

2 Argonne's economic multiplier is very similar to that of other DOE national laboratories (e.g., Lawrence Berkeley National Laboratory, Pacific Northwest National Laboratory, etc.) and major research organizations such as NASA.

1. ABOUT ARGONNE

1.1 OVERVIEW

From the start, Argonne National Laboratory (Argonne) has been at the forefront of research and innovation to ensure U.S. prosperity and security. In 1946, as an outgrowth of the Manhattan Project at the University of Chicago, Argonne was established as a chemistry, materials, and nuclear engineering laboratory to develop peaceful uses for a revolutionary new source of energy: nuclear power. Argonne was the first national laboratory established in the United States.

The world has changed greatly since Argonne opened its doors. Growing demands on energy and water resources, the social and economic impacts of climate change and associated extreme weather events, the dangers posed by COVID-19 and potential future pandemics, the threat of nuclear proliferation, aging infrastructure, and the requirement for bio- and cyber-preparedness, have given rise to new needs for knowledge and solutions. In response, Argonne has evolved into a collaborative, multidisciplinary research powerhouse.

Today, as a U.S Department of Energy (DOE) Office of Science (SC) national laboratory with 3,523 full-time equivalent employees and a budget of $1.05 billion in Fiscal Year (FY) 2021,[3] Argonne addresses the greatest scientific, technological, biological, societal, and climate-related challenges facing our nation:

- Basic science that seeks to understand how nature works, through experimental and theoretical studies in materials science, nuclear physics, particle physics, chemistry, biology, and atmospheric science.
- Computation and analysis, grounded in applied mathematics and computer science, that enable quantum computing and next-generation supercomputing, provide methods to defeat cyberthreats, and inform decisions about complex technological and societal issues.
- Engineering of advanced energy systems to drive practical advances in nuclear power, transportation, battery performance, grid resilience, renewable fuels, and speed the transition to a carbon-free economy.

ARGONNE FACTS

- Chartered in 1946, the first U.S. national laboratory
- Developed nuclear reactors for the U.S. civilian nuclear energy program
- Co-discoverer of two elements
- First direct observation of neutrinos
- Home to the brightest X-ray light source in the United States
- Home to one of the world's fastest supercomputers (2023)

1.2 WHAT ARGONNE DOES

Argonne is a multidisciplinary science and engineering research facility, where talented researchers work together to answer the biggest questions facing humanity. At the end of FY 2021, the laboratory employed almost 3,500 workers focused on science, technology, engineering, and mathematics (STEM). Argonne's research programs directly employed 1,445 scientists and engineers, and 325 postdoctoral fellows.

1.2.1 Argonne Research Facilities

Argonne maintains a comprehensive suite of research facilities that are central to the laboratory's scientific enterprise. From particle accelerators to automotive testbeds, these facilities give Argonne scientists and their collaborators access to tools and techniques that—in many instances—are found nowhere else in the world.

Argonne's scientific researchers unveil new discoveries and technologies that secure the nation and transform how it generates, distributes, and uses energy. Argonne does this by tapping its researchers' expertise in physics, materials and chemistry, math and computer science, life sciences, nuclear energy, and more. Researchers eschew barriers and work together every day, regardless of their scientific discipline.

3 Argonne's fiscal year runs from October 1 to September 30.

Argonne's diverse and dynamic research agenda spans more than 20 research divisions, 12 centers, and 6 national user facilities. This rich scientific environment provides its researchers—and users who visit from across the globe—with an extraordinary range of cutting-edge facilities and scientific tools that support in-depth research, drive technological breakthroughs, and improve the nation's competitiveness and people's quality of life.

1.2.2 Argonne Scientific User Facilities

In addition to its research facilities, Argonne operates six national user facilities that offer extraordinary insights into the structure of matter and physical, biological, and societal processes. Argonne's user facilities provide researchers from across the nation with open access to the most advanced tools of modern science. Each year, several thousand researchers from academia, industry, and government laboratories use these facilities. Many of the researchers travel to Argonne to use the facilities in person, which brings business to local hotels and restaurants and to providers of transportation.

The user facilities are:

- Advanced Photon Source (APS)
- Argonne Leadership Computing Facility (ALCF)
- Center for Nanoscale Materials (CNM)
- Argonne Tandem Linac Accelerator System (ATLAS)
- Atmospheric Radiation Measurement Research Facility (ARM)
- Intermediate Voltage Electron Microscope (IVEM)

In FY 2021, 5,995 individuals used these facilities to conduct groundbreaking studies in nearly every field of science and engineering; 1,320 of the users visited Argonne in person.[4] The ARM facility is located in, and brings benefits to, Oklahoma.

1.3 HOW ARGONNE CREATES ECONOMIC IMPACT

Argonne creates economic impact in several ways:

Spending: With a FY 2021 budget in excess of $1 billion, Argonne has a substantial economic presence in the Chicago area. This spending, which enables some of America's most groundbreaking science and engineering projects, is the source of Argonne's most immediate and direct impact on local and national economies. Most of this spending goes to operations, which includes salaries and expenses incurred in day-to-day site operation, and on capital improvements. We discuss this in detail in Section 2.

Research, Innovation, and Scholarship: The scientific and engineering advances created by Argonne's research and core activities form a major source of economic impact. National laboratories exist to tackle particularly difficult problems that fall beyond the capabilities of private industry or individual universities. As part of this endeavor, Argonne clearly creates economic value, for example in its work to increase reliability of the power grid, improve the robustness of the national infrastructure, and develop models of disease spread through communities.

Compared to spending, this impact is more difficult to quantify in dollar terms; technologies and advances that result from basic science research may not reach the marketplace until years after the initial discoveries. This impact can, however, be measured in other ways, such as the number of journal articles published, patents obtained, and partnerships with institutions with whom Argonne collaborates—and who expand the influence of Argonne's work. Argonne's six national user facilities are a key part of this impact; they provide users with a suite of tools that are beyond the capabilities of private industry or individual universities. We discuss this source of impact in detail in Section 3.

Technology Development: Another source of Argonne's economic impact is the technology the lab develops directly or in partnership with industry or outside users. This development can take many forms: some technology is developed at Argonne, by Argonne researchers, sometimes in collaboration with industry via mechanisms such as Strategic Partnership Projects (SPPs) and Cooperative Research and Development Agreements (CRADAs); some technology is developed at Argonne user facilities, principally APS and ALCF. This technology has substantial impacts on the local and national economy, although such impacts can be difficult to quantify precisely.

Many technologies developed at Argonne result in patents, which are available to industry for license. License fees represent a quantifiable lower limit on the value of Argonne inventions; the value of the inventions when transferred to the market is higher. Argonne makes other technologies available to the public, usually in the form of open-source software tools and models. This clearly generates value for workers across the United States and the world, as shown by the tens of thousands of times some tools and models have been downloaded. Another way Argonne participates in technology development is via the Chain Reaction Innovations (CRI) technology incubator. We discuss Argonne's technology development activities in detail in Section 4.

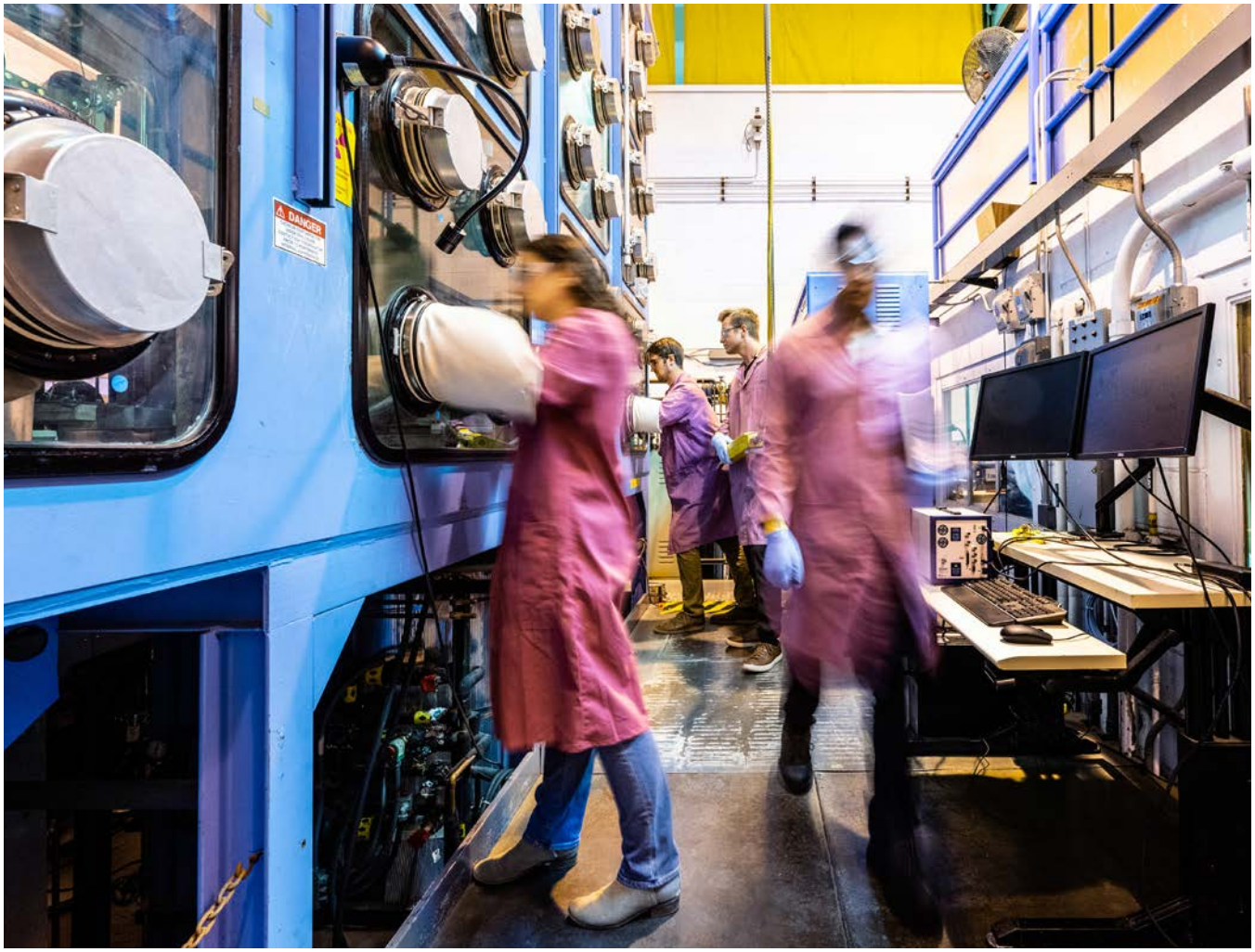
4 Note that the number of visitors—and therefore facility users—was depressed in FY 2021 by access restrictions resulting from the COVID-19 pandemic. The number of facility users in a typical pre-pandemic year (FY 2019 and earlier) is approximately 8,000.

Community Outreach and Alumni Presence: Some of Argonne's economic impact occurs over a very long period and is extremely difficult to quantify. Interesting the public—especially youth—in STEM and encouraging them to participate in STEM activities is one of the most impactful things we can do over the long term. Although it may take years for this encouragement to bear fruit, helping to recruit and train the next generation of scientists and engineers is extremely important. We also have an obligation to the community to share with them the significance of the work we do and to show that we are responsible stewards of their tax dollars. To this end, Argonne participates in community outreach and educational activities. Finally, for those employees who advance their careers beyond the laboratory, Argonne's impact is felt in the contributions they make throughout their careers in industry, academia, and government. We discuss this in detail in Section 5.

1.4 METHODOLOGY USED TO PREPARE THIS REPORT

Argonne hired Intelligent Analytics and Modeling (IAMECON), a Texas-based firm of financial and economic consultants, to lead the preparation of this report. IAMECON's mandate from Argonne was to capture the economic, scientific, technological, and societal impacts associated with Argonne activities. While generating the impact measures in this report, IAMECON used Argonne data along with publicly available methods and data sources. In some cases, which are explicitly discussed, IAMECON processed and analyzed underlying data in order to generate impact measures and associated figures. In other cases, they generated metrics and figures directly from data supplied by Argonne.

A more detailed discussion of methodology is presented in Appendix A.



2. ARGONNE SPENDING

2.1 OVERVIEW

The economic impact of Argonne's spending is large and relatively easy to quantify. The laboratory has a substantial economic presence in the Chicago area. The economic impact of Argonne's spending extends throughout the Midwest and across the nation.

Economic impact at the local, regional, and national levels can be broken down into three components: direct, indirect, and induced effects. A direct effect measures the effect of the deposit of money into the economy by Argonne, through employee salaries, purchases of goods and materials, and spending on contractor services. Activity at Argonne influences other sectors of the economy, such as materials suppliers and contract workers. Businesses initially benefiting from the direct effects will subsequently increase spending at other local businesses. These effects, beyond Argonne's direct expenditure, are referred to as indirect effects. In other words, for every dollar that Argonne directly produces, there is a multiplier effect of how many additional dollars the economy receives. Finally, induced effects capture the impact of increased income caused by the direct and indirect effects. For example, businesses receiving increased revenue will increase payroll expenditures by hiring more employees, increasing payroll hours, and raising salaries. Likewise, households will increase spending at local businesses.

The same basic analysis applies to jobs: Argonne directly employs several thousand people. The spending enabled by the income these employees receive from Argonne results in indirect employment in the amount of almost 3,000 additional jobs. The increased income caused by direct and indirect effects results in an additional 6,000 induced jobs.

2.2 DIRECT EFFECTS OF ARGONNE SPENDING

Argonne's spending is the source of the laboratory's most immediate and direct economic impact. In FY 2021, Argonne injected a total of more than $1 billion into the local, regional, and national economies through its spending activities: paying salaries and wages, hiring contractors, procuring goods and services, and undertaking capital improvement and construction projects. In line with standard financial practice, the laboratory's expenditures are categorized as operational funding and capital funding.

In FY 2021, operational funding, which includes salaries and benefits, along with procurement expenses, totaled $856 million (81% of Argonne's total budget), whereas capital funding, which includes construction and capital improvements expenses, totaled $195 million (19% of Argonne's total budget). The largest single component of Argonne's FY 2021 spending was salaries and benefits: $496 million. Categories of spending are shown in Table 2.1. Almost all (93%) of Argonne's 4,379 employees (including full-time employees, part-time employees, postdoctoral researchers, and students) are located in Illinois; consequently, Argonne paid almost half a billion dollars to its employees in the form of salaries and benefits that are above the Illinois average. Argonne's FY 2021 operational expenses (excluding salaries and benefits) and capital expenditures totaled $556 million. Most of Argonne's spending went to scientific and technical services as well as computers, software, and lab equipment.

Argonne's operational funding and capital funding for FYs 2010–2021, shown in Figure 2.1, highlight how Argonne's operational funding increased by an average of 2.7% annually over the last 10 years while the average annual increase of capital funding during the same time period was 8.5%.[5]

Table 2.1: Argonne FY 2021 spending by category.

		FY21 SPENDING
STAFF EXPENSES		
Salaries and Benefits	**$**	**496 M**
PROCUREMENTS *Estimated Allocation of Purchases by Sector*		
Scientific and Technical Services	**$**	**189 M**
Computers, Lab Equipment, Software, Wholesale and Retail Trade	**$**	**148 M**
Construction	**$**	**96 M**
Transportation, Utilities, Publishing, Educational and Other Services	**$**	**49 M**
Finance, Insurance and Real Estate	**$**	**8 M**
Other Industries	**$**	**66 M**
TOTAL PROCUREMENTS	**$**	**556 M**
TOTAL SPENDING	**$**	**1,052 M**

5 Most capital funding in FY 2021 and the previous few financial years is attributed to construction expenses related to Argonne's investments in the acquisition and installation of the new Aurora supercomputer and the upgrade to the APS facility.

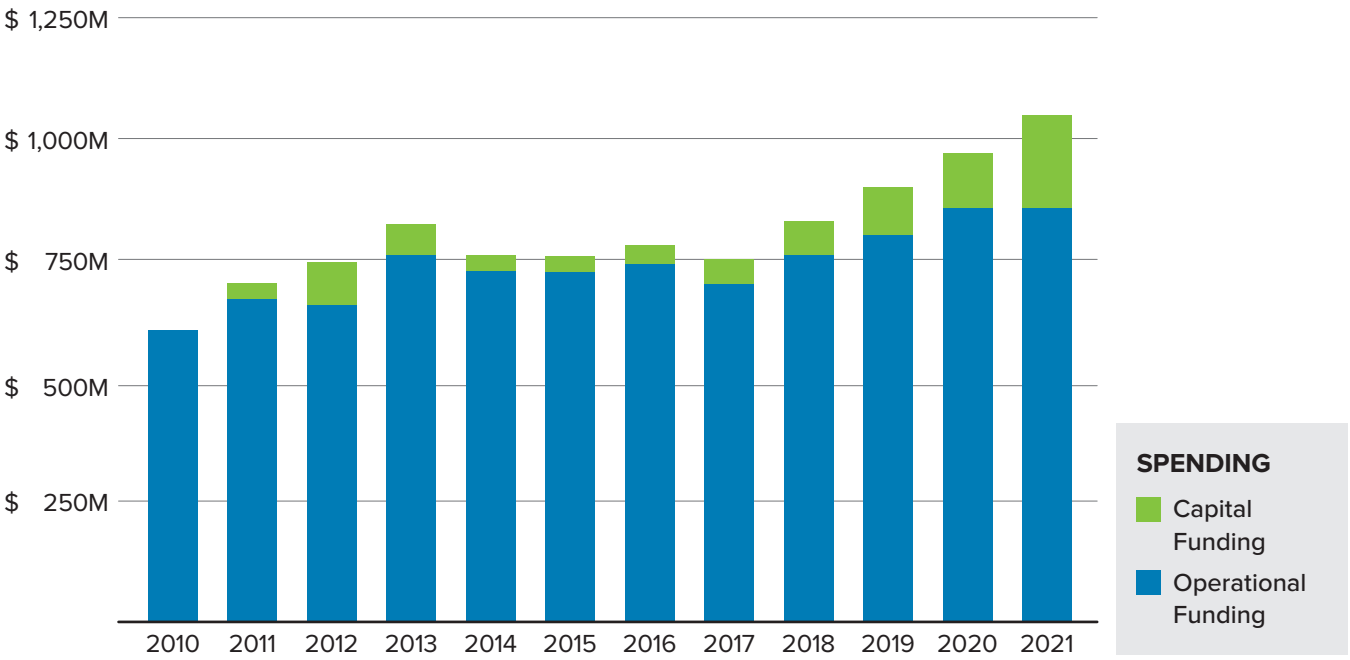


Figure 2.1: Argonne spending, FYs 2010–2021. Spending is divided between operational funding and capital funding.

Table 2.2: Economic impact of Argonne's spending in FY 2021.

	ILLINOIS		MIDWEST		USA	
	EMPLOYMENT	**IMPACT**	**EMPLOYMENT**	**IMPACT**	**EMPLOYMENT**	**IMPACT**
TYPE OF IMPACT						
Direct	**4,010**	**$ 0.64 B**	**4,137**	**$ 0.70 B**	**4,392**	**$ 0.96 B**
Indirect	**798**	**0.15 B**	**1,240**	**0.21 B**	**2,945**	**0.58 B**
Induced	**2,900**	**0.50 B**	**3,688**	**0.62 B**	**6,051**	**1.13 B**
TOTAL IMPACT	**7,708**	**$ 1.29 B**	**9,065**	**$ 1.53 B**	**13,388**	**$ 2.67 B**

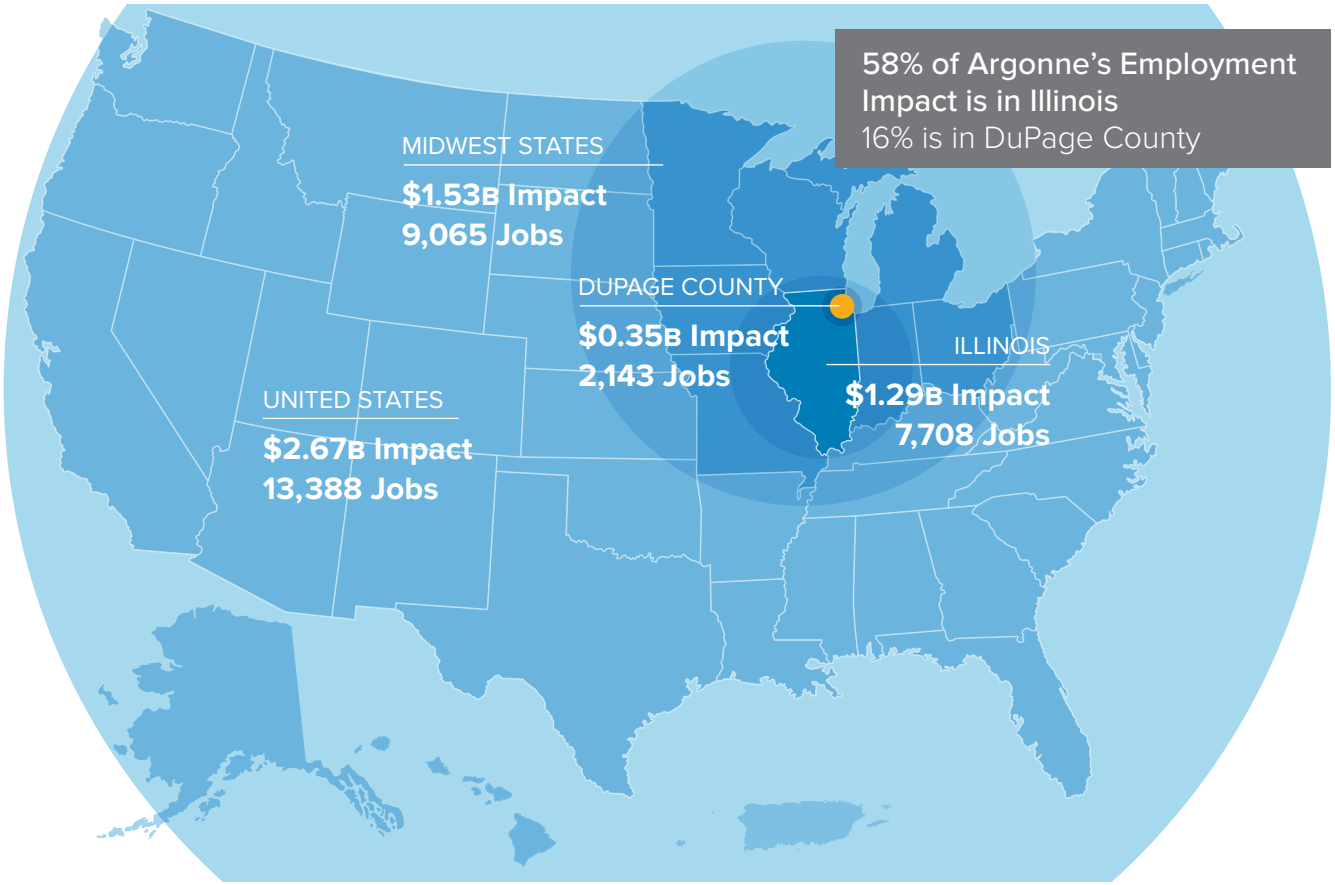


Figure 2.2: Argonne's FY 2021 economic impact is felt across the state, region, and country.

2.3 OVERALL IMPACT OF ARGONNE SPENDING

Argonne's operational and capital improvement activities not only directly create jobs and increase demand for goods and services across multiple sectors throughout the nation, but also enable Argonne's employees and suppliers to put their revenue and income, (i.e., Argonne's spending) back into the economy. This creates indirect and induced economic impacts in the local, regional, and national economies. As a result, Argonne's spending generated a significant economic impact on the local and regional economies, supporting more than 13,300 jobs across the United States, with an overall national economic impact of $2.67 billion in FY 2021 alone. This is summarized in Table 2.2. The underlying methodology is discussed in detail in Appendix A.

Argonne's economic impact is felt across the country as shown in Figure 2.2. Note that 58% of the jobs for which Argonne is responsible are in Illinois. In this case, the Midwest is defined as Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.

Argonne's economic impact in the United States also took the form of tax revenues through county, state, and federal taxes. As illustrated in Figure 2.3, Argonne's spending generated total taxes of $223 million in FY 2021.[6]

Although Argonne's spending activities were distributed nationwide, its impact on the local economy was especially significant, with 37% of all procurements coming from Illinois, as shown in Figure 2.4.

6 The "Sub-County General" category includes tax revenues attributed to city and township governments, and "Sub-County Special Districts" include fire and public-school districts.

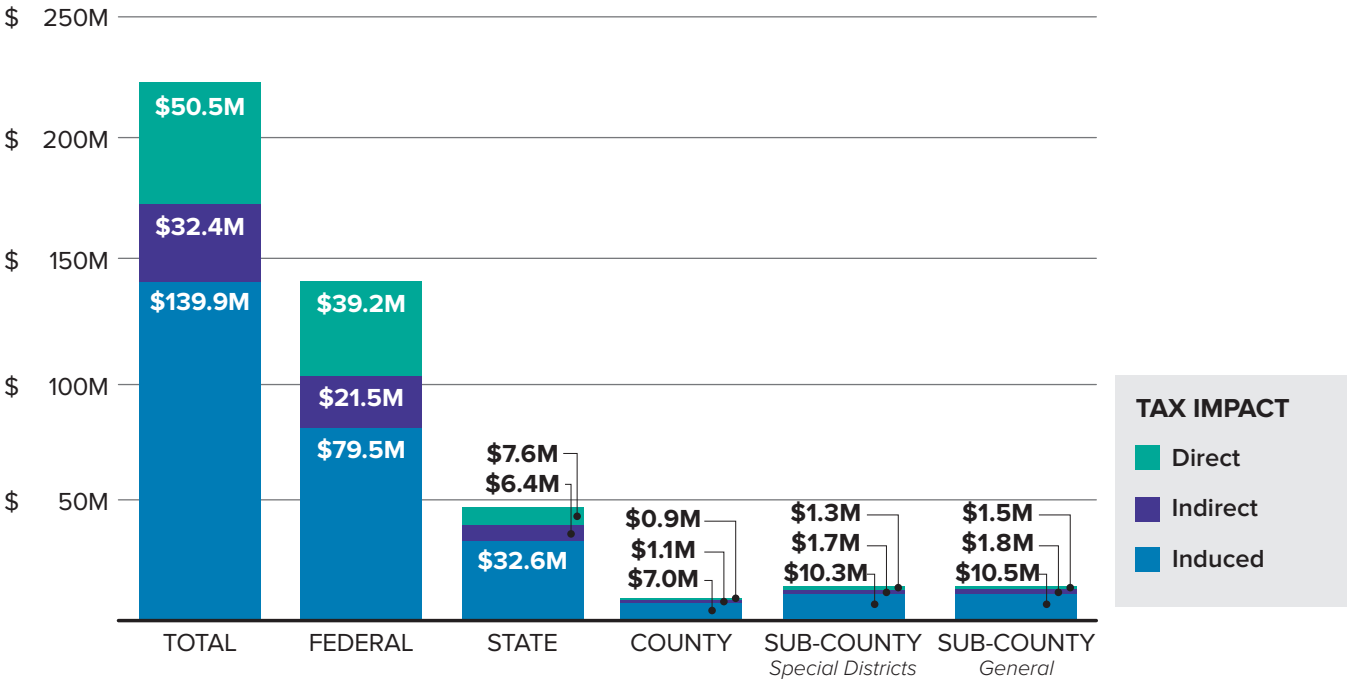


Figure 2.3: Argonne's FY 2021 contribution to county, state, and federal tax revenues.

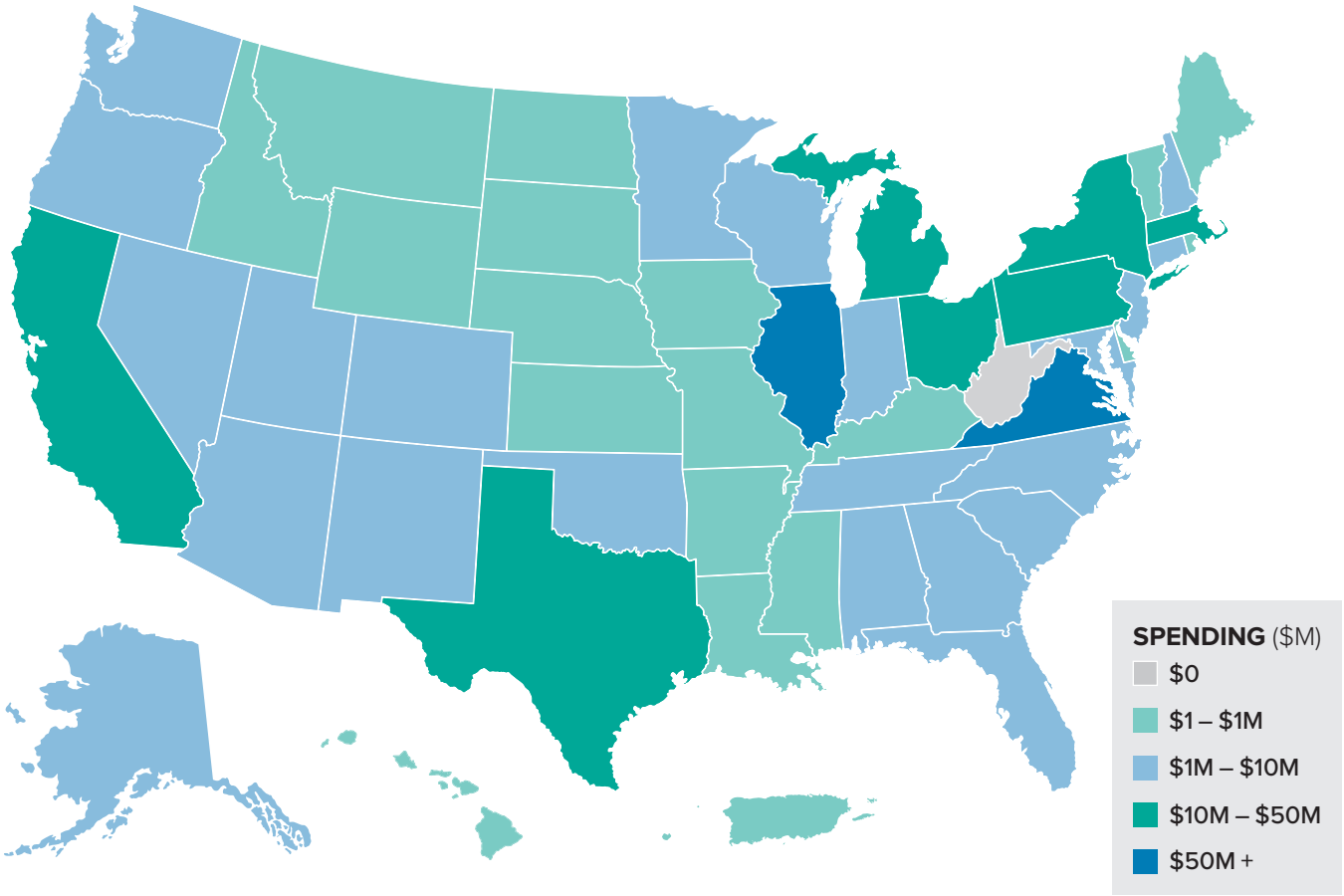


Figure 2.4: Argonne's FY 2021 spending by state.

Figure 2.5 illustrates the destination of Argonne spending on procurements. More than 80% went to corporations, while almost 18% went to educational and nonprofit institutions. 1.3% went to partnerships, which include entities such as law firms, physician groups, and accounting groups.

As shown in Table 2.3, more than 44% of Argonne's FY 2021 procurement spending went to small businesses. Small disadvantaged businesses,[7] women-owned small businesses, veteran-owned small businesses, and service-disabled veteran small businesses also received substantial fractions of Argonne's spending.

Table 2.3: Argonne's FY 2021 spending with small businesses. Note that percentages do not add up to 100% because category definitions overlap.

SUPPLIER CATEGORY	FY21 SPENDING
Total Procurement Spend	**100.0 %**
Other than Small Business *(Large Business, Foreign, Universities)*	**55.9 %**
Small Business	**44.1 %**
Small Disadvantaged Business	**7.2 %**
Woman Owned Small Business	**10.6 %**
HUBZone	**1.4 %**
Veteran Owned Small Business	**2.3 %**
Service-Disabled Veteran Owned Small Business	**1.6 %**

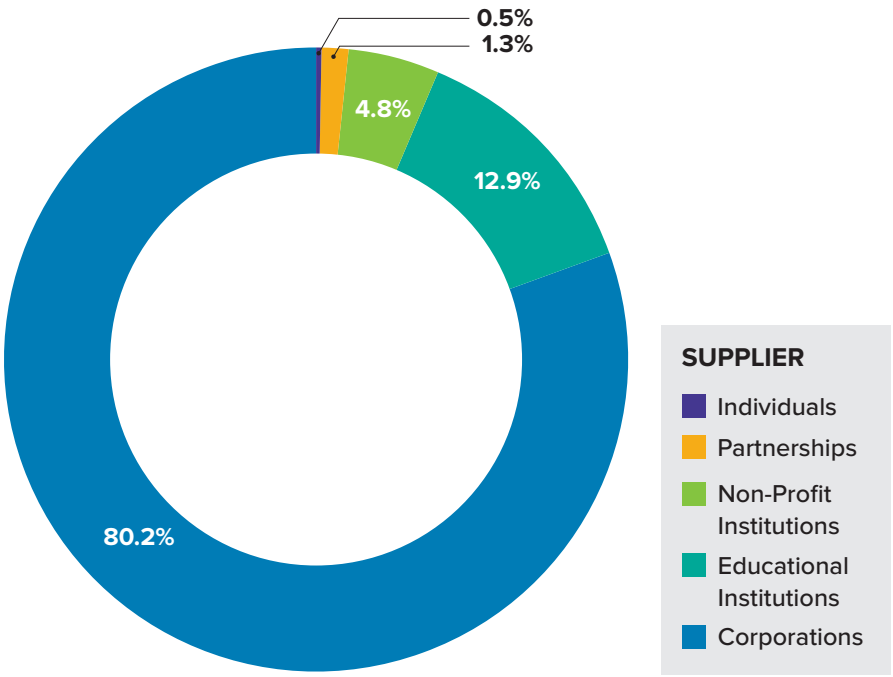


Figure 2.5: Argonne's FY 2021 spending categorized by supplier type. Note that the percentages do not sum to 100% because of rounding.

7 Per the definition used by the Economic Development Agency (EDA).

3. ARGONNE RESEARCH, INNOVATION, AND SCHOLARLY IMPACT

3.1 OVERVIEW

Research and innovation are the heart of Argonne's mission and are a major source of the laboratory's economic impact. Argonne is a multidisciplinary science and engineering research center, where talented researchers work together to answer some of the biggest questions facing humanity, from how to obtain affordable clean energy to protecting ourselves and our environment. The laboratory works in concert with universities, industry, and other national laboratories on questions and experiments too large for any one institution to do by itself. Through collaborations in the United States and around the world, our scientific research drives energy innovation, creates novel materials molecule by molecule, and achieves deeper understanding of our planet, our climate, and the cosmos. Surrounded by one of the highest concentrations of top-tier research organizations in the world, Argonne leverages its Chicago-area location to lead discovery and to power innovation in a wide range of core scientific capabilities, from high-energy physics and materials science to biology and advanced computer science.

In addition to the core science and engineering research facilities used by its employees, Argonne operates six national user facilities that offer extraordinary insights into the structure of matter and physical and biological processes. Argonne's user facilities provide a large number of researchers from across the nation and the world open access to the most advanced tools of modern science.

Through the work of its employees and of those who access its user facilities, Argonne clearly creates economic value by, for example, developing batteries that cost less and have a higher energy storage capacity, assisting pharmaceutical companies to develop new medications, and developing materials that can be used to clean up oil pollution.

MAJOR ARGONNE SCIENCE RESULTS

- First peacetime generation of electricity from nuclear energy
- Discovered thousands of protein structures, enabling the creation of drugs for conditions ranging from AIDS to COVID
- Helped found quantum computing and built foundation for a quantum internet
- Developed major component of many of today's lithium-ion electric vehicle batteries
- Helped create the science of molecular dynamics, involved in modeling a wide range of physical and biological processes
- Worked to modernize the electric grid and make it more resilient
- Developed models of infection propagation in human populations
- Explained structure of atomic nuclei
- Developed models of Earth's weather and climate
- Improved our understanding of dark matter and dark energy

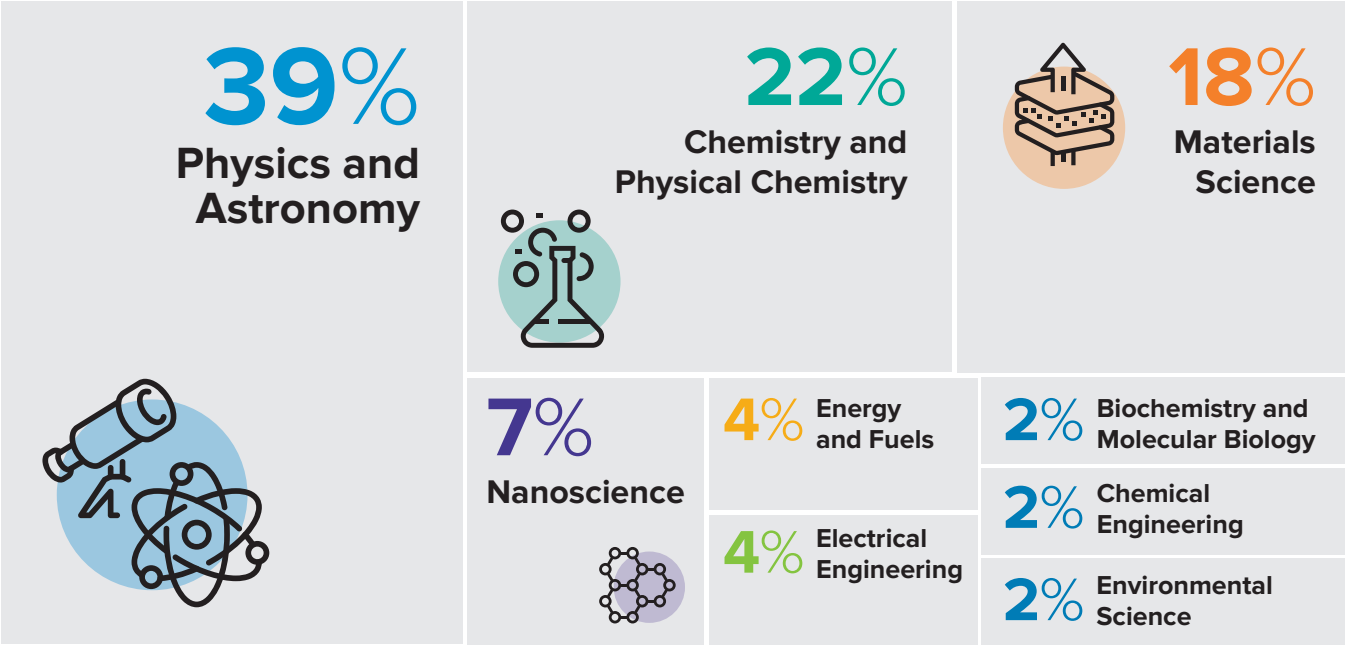


Figure 3.1: Argonne's published research by discipline during calendar years 2011–2022.

3.2 PUBLICATIONS

A key indicator of the value generated by Argonne's scientific work is the number of publications appearing in leading scientific journals. From 2011 to 2022, Argonne published 26,883 academic articles in top journals.[8] Argonne researchers work in a variety of academic disciplines. The distribution of Argonne's research across several broad academic disciplines paints a strong picture of Argonne's diverse work and highlights the laboratory's principal focus on physics, chemistry, and materials science. Figure 3.1 shows Argonne's published research by discipline during the period from calendar years 2011 to 2022.[9]

Through the years, Argonne has maintained a steady research output. The laboratory consistently produces a high quantity of research documents.

Figure 3.2 shows a time series of Argonne's publications over the period 2011 to 2021 in its top four research areas: physics, chemistry, materials science, and nanoscience.[10, 11]

Argonne prides itself on the high quality of its research. This quality is demonstrated in Figure 3.3, which highlights the proportion of Argonne publications that appear in high-impact journals, as identified by the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), Arts and Humanities Citation Index (AHCI), and ESCI journal sets in the Web of Science platform.[12]

The quality of Argonne's research output compares favorably with that of other institutions in Illinois and the United States.[13] Figure 3.4 shows that across the disciplines of physics, chemistry, materials science, and nanoscience, Argonne outperforms similar institutions in these geographic areas in terms of the percentage of documents in the top 10% of all cited documents in the InCites and ESCI datasets.

8 The top journals were selected as having a 5-year Journal Impact Factor greater than 7, meaning the yearly average number of citations per article in these journals were greater than 7 across all publications.

9 To simplify the distribution in Figure 3.1, several categories were aggregated. For example, a broad "Physics" class was created to include applied physics, particles and fields, condensed matter physics, astronomy and astrophysics, nuclear physics, and multidisciplinary physics.

10 More specifically, these are the following categories. Physics: nuclear physics; applied physics; fluid and plasma physics; atomic, molecular, and chemical physics; condensed matter physics; multidisciplinary physics; and particle and field physics. Chemistry: inorganic and nuclear chemistry; organic chemistry; applied chemistry; multidisciplinary chemistry; physical chemistry; and analytical chemistry. Material Sciences: multidisciplinary materials science; coatings and films materials science; characterization and testing materials science; composites materials science; and ceramics materials science. Nanoscience: nanoscience and nanotechnology.

11 The underlying numbers used to generate Figure 3.2 come from the InCites and Emerging Sources Citation Index (ESCI) datasets.

12 The Web of Science platform contains journal collections defined by general subject area and impact and quality criteria. For more information, see clarivate.com/webofsciencegroup/solutions/web-of-science/.

13 All institutions in Illinois and in the United States that have published in the many journals tracked by Clarivate's Web of Science platform are included in this comparison. See clarivate.com/webofsciencegroup/solutions/web-of-science/.

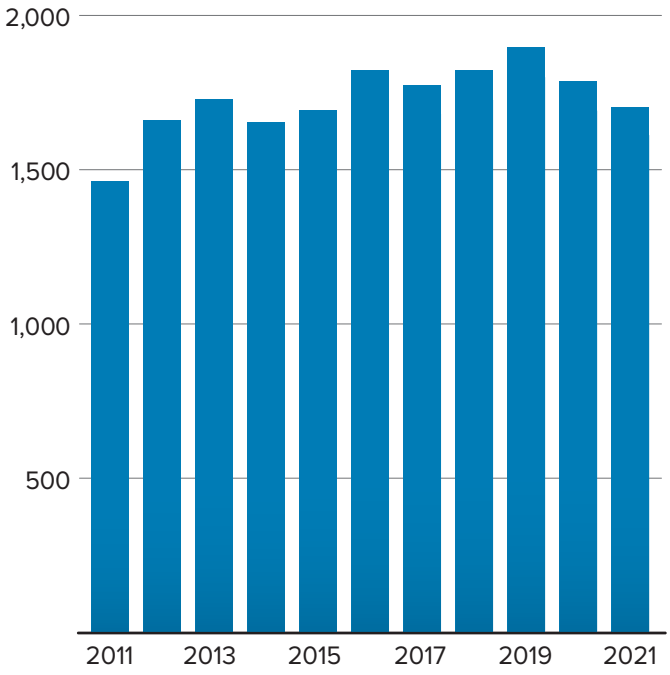


Figure 3.2: Publications by Argonne in its top four research areas (physics, chemistry, materials science, nanoscience), 2011–2021.

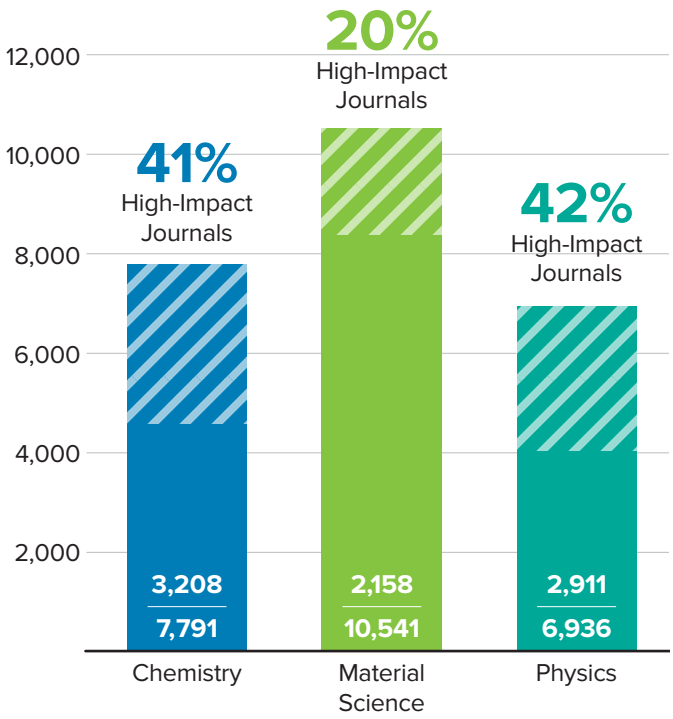


Figure 3.3: Argonne publications in high-impact journals, 2011–2022.

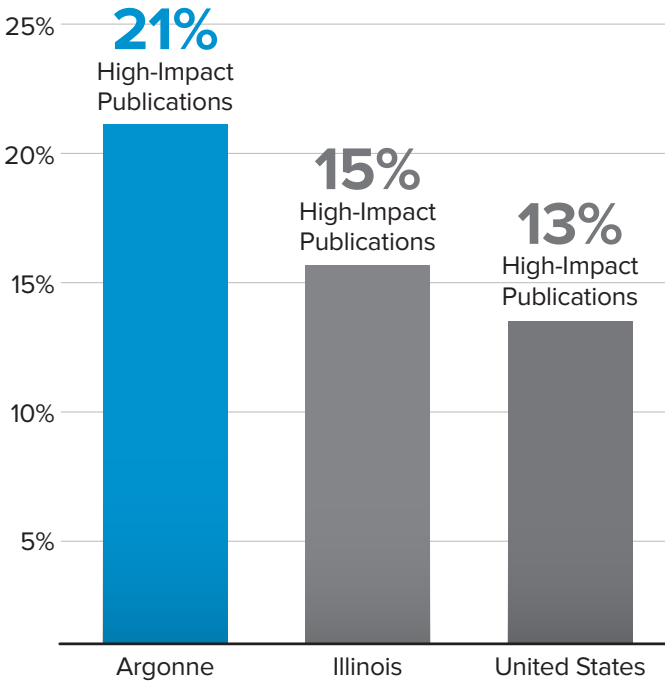


Figure 3.4: Percentage of Argonne publications in the disciplines of physics, chemistry, materials science, and nanoscience in high-impact journals compared with other entities in Illinois and the United States, 2011–2022.

3.3 USER FACILITIES

Another source of Argonne's impact is its user facilities. Argonne is home to five SC national user facilities and one DOE Office of Nuclear Energy (NE) national user facility. These user facilities enable scientists and technologists from universities, industry, national laboratories, and federal agencies to carry out experiments and pursue groundbreaking discoveries that would otherwise not be possible.

The user facilities and their capabilities are listed below. The first five are the SC facilities, and the last is the NE facility:

Advanced Photon Source (APS): A source of extremely bright X-ray photon beams that was used by almost 4,000 scientists in FY 2021, resulting in the publication of more than 2,000 journal articles. The APS is in the process of being upgraded; a $815 million investment by the federal government is supporting jobs via construction, and through equipment procurement and installation.

Argonne Leadership Computing Facility (ALCF): Enables breakthroughs in science and engineering by providing supercomputing resources and expertise to the research community. The ALCF was used by more than 1,600 users in 2021. The ALCF is in the process of installing Aurora, an exascale-class supercomputer

that will be one of the highest performing machines in existence when it comes online in 2023. The $500 million investment in the computer, a building extension to house it, and infrastructure upgrades is supporting jobs in construction, equipment procurement, and installation.

Center for Nanoscale Materials (CNM): A facility dedicated to nanoscience and nanotechnology that houses the most advanced facilities for nanoscience research with the goal of discovering, understanding, and exploiting functional nanomaterials for society's benefit. In FY 2021, 428 researchers visited CNM; 90% of those researchers were based in the United States and employed by universities or the DOE.

Argonne Tandem Linac Accelerator System (ATLAS): The premier national facility for research on the structure of atomic nuclei. More than 2,000 users from around the world have conducted thousands of experiments at ATLAS since it was built in 1978.

Atmospheric Radiation Measurement Research Facility (ARM): ARM is a multi-platform scientific user facility with instruments at fixed and mobile locations worldwide for obtaining continuous field measurements of atmospheric data. Argonne manages the Southern Great Plains and ARM Mobile Facility 3 observatories.

Intermediate Voltage Electron Microscope (IVEM): Used for in situ electron microscope studies of defect structures in materials under controlled ion irradiation and sample conditions.

In FY 2021, Argonne's user facilities hosted a total of 5,995 users. Of these, 89% were from U.S.–based institutions, and 27% of these users were based outside of Illinois. In FY 2021 most users accessed the user facilities remotely, with 1,320 visiting in person (all ALCF users in FY 2021 accessed the facility remotely). The number of facility users in a typical year (pre-pandemic, i.e., FY 2019 and before) is approximately 8,000. The difference between the number of users in FY 2021 compared with FY 2019 and earlier is due to the smaller number of visitors. In a typical year, approximately 3,000 users would be expected to visit Argonne in person. In addition to the impacts of their technical work, visitors to user facilities bring business to local hotels and restaurants.

Figure 3.5 details the number of FY 2021 Illinois visitors and their home institutions, while Figure 3.6 shows nationwide visitors to Argonne facilities by state. Figure 3.7 illustrates Argonne visitors of the user facilities by employer type. Most users of Argonne's facilities come from academia, followed by DOE researchers, other governmental researchers, and industry users.

Figure 3.5: Facility users from Illinois-based institutions, FY 2021.

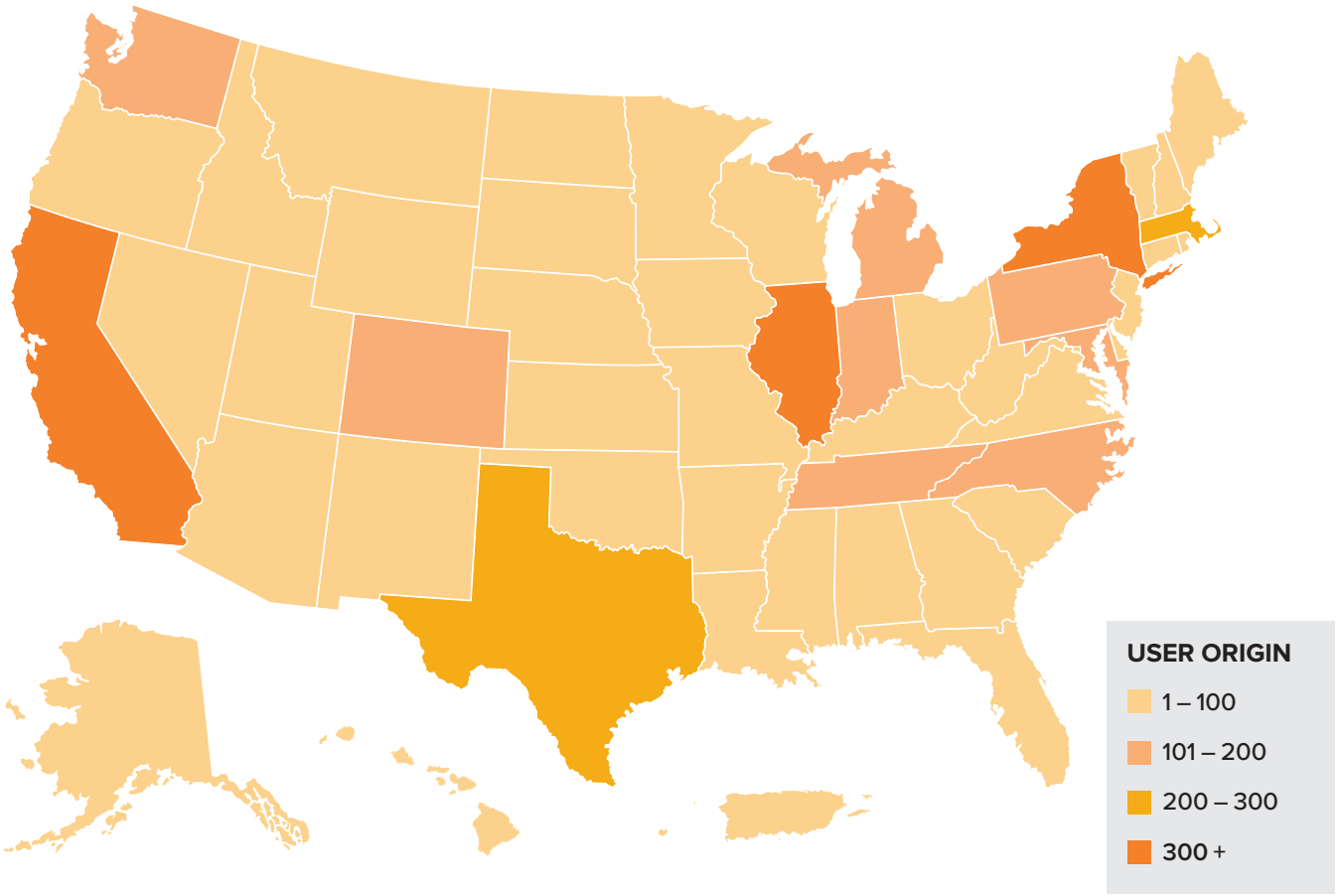


Figure 3.6: Users visiting at least one of Argonne's user facilities by user's state of origin, FY 2021.

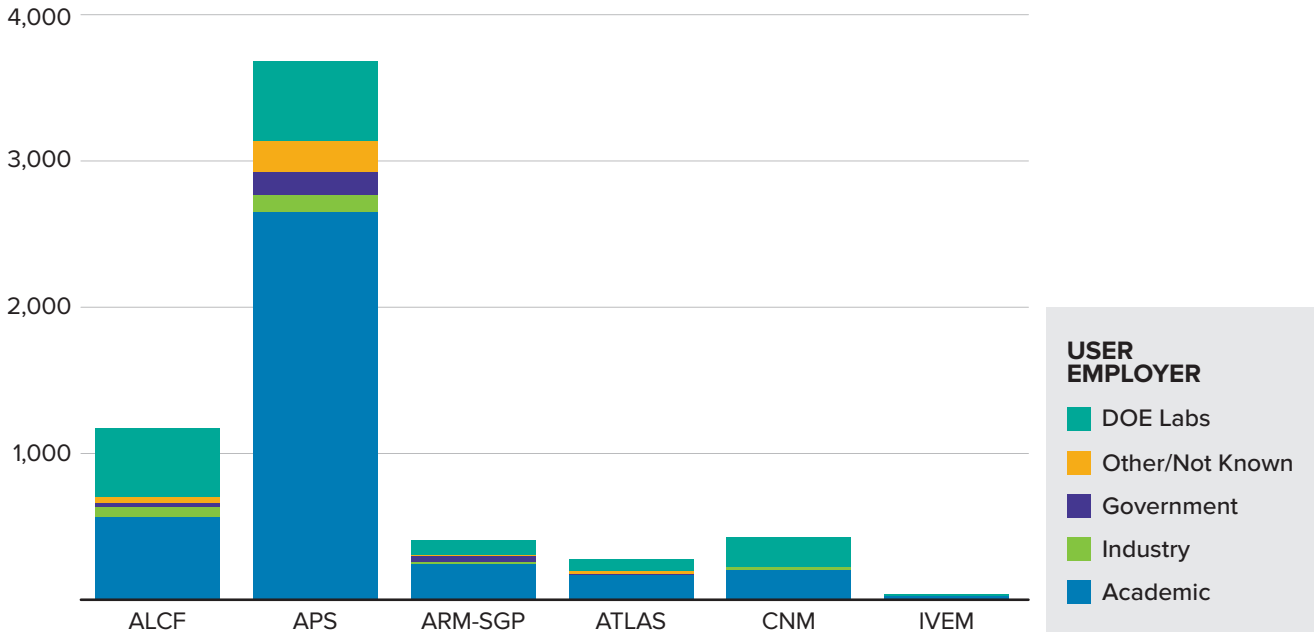


Figure 3.7: Users of each user facility by employer type, FY 2021.

In addition to using Argonne's resources to create scientific impact, visitor spending during their stay creates economic impact within the region. To estimate the economic impact generated by Argonne's visitors, we use Argonne data on visitor profiles, and industry-standard methods to identify the origin of visitors (only non-locals generate economic impact) and estimate how much they spent in the local economy. We repeated this procedure using DuPage County, Illinois, the Midwest, and the United States as a whole as the basis for the location being visited (i.e., impacted by visitors). The number of visitors varied for each of the four locations, since visitors from the University of Chicago would generate positive economic impact for DuPage County, whereas for Illinois, those visitors are local; hence, only out-of-state visitors are included when computing impact at the state level. Details of our estimation are discussed in Appendix A.4, and our results are shown in Table 3.1.

3.4 SCHOLARLY COLLABORATIONS

Argonne's impact is enhanced by the collaborations its scientists undertake with their colleagues in other institutions. These collaborations allow the effect of Argonne's work to be felt across Illinois, the United States, and the world. A gauge of this impact is the number of journal articles jointly published with authors from other institutions. Since 2011, Argonne has published 26,883 journal articles, most of which were jointly authored in affiliation with approximately 8,000 institutions worldwide, as accounted for by the Science Citation Index (SCI) database published by Web of Science.[14] The top 10 collaborating institutions include three from Illinois—the University of Chicago, which was a collaborator on 20.4% of publications, the University of Illinois System (15%), and Northwestern University (14.4%)—illustrating Argonne's significant impact on the regional scientific ecosystem.

Table 3.1: Economic impact of visitors to user facilities, FY 2021. Financial numbers indicate the net additional impact to the region of Argonne user facilities.

	ILLINOIS		MIDWEST		USA	
	EMPLOYMENT	**IMPACT**	**EMPLOYMENT**	**IMPACT**	**EMPLOYMENT**	**IMPACT**
TYPE OF IMPACT						
Direct	**84**	**$ 9,148,546**	**79**	**$ 7,746,853**	**13**	**$ 1,357,888**
Indirect	**18**	**$ 3,517,482**	**19**	**$ 3,592,955**	**4**	**$ 841,560**
Induced	**27**	**$ 4,600,973**	**26**	**$ 4,279,489**	**6**	**$ 1,133,769**
TOTAL IMPACT	**129**	**$ 17,267,001**	**124**	**$15,619,297**	**23**	**$ 3,333,217**

14 For more information, see clarivate.com/webofsciencegroup.

4. ARGONNE TECHNOLOGY DEVELOPMENT

4.1 OVERVIEW

A major source of economic impact for Argonne is the technology that is developed in the laboratory. This technology development can take many forms: some technology is developed at Argonne by the lab's scientists and technologists. Some technology is developed in Argonne user facilities, principally APS, ALCF, and CNM. Another mechanism for technology development is collaboration between laboratory staff and industry partners via mechanisms such as SPPs and CRADAs. Finally, Argonne assists in technology development in startup companies via the CRI technology incubator.

Many technologies developed at Argonne result in patents, which are available to industry for license. License fees represent a quantifiable lower limit on the value of Argonne inventions; the value of the inventions when transferred to the market is higher. Other technologies, usually in the form of software tools and models, are made available to the public in open-source format. This clearly generates value for workers across the United States and the world, judging by the tens of thousands of times some tools or models have been downloaded.

IMPACTFUL ARGONNE TECHNOLOGY

- Advanced energy storage materials and batteries, both lithium-ion and beyond
- Diamond coatings that prevent engine wear
- Reusable sponge to clean up oil spills
- Advanced transistor structures
- Pioneering quantum computing hardware
- Producing medical isotopes using a particle accelerator
- Improved efficiency, resilience, and robustness of public infrastructures
- Foundation for pharmaceuticals including drugs for AIDS and COVID

4.2 TECHNOLOGIES DEVELOPED BY ARGONNE RESEARCHERS

To maximize the impact of Argonne's research and development, it is important that new technologies be made available to the public. To enable this, Argonne grants licenses for lab-developed intellectual property to existing and startup companies that are technically and financially capable of turning early-stage technology into commercial products.[15] Two mechanisms used by Argonne to distribute the fruits of its work are patent licensing and providing open-source software tools and models.

4.2.1 Patent Acquisition and Licensing

Patent Acquisition

One measure of the value of Argonne's inventions is the number of patents it has been granted: Argonne received 589 patents over the period between 2011 and 2020. The breakdown over time of patents issued is shown in Figure 4.1.[16] The data show an upward trend in Argonne's patent activity, with 76 patents issued in 2020, the last year for which we have complete data. Another measure of the impact of Argonne's work is the number of times its patents were cited in other patents.

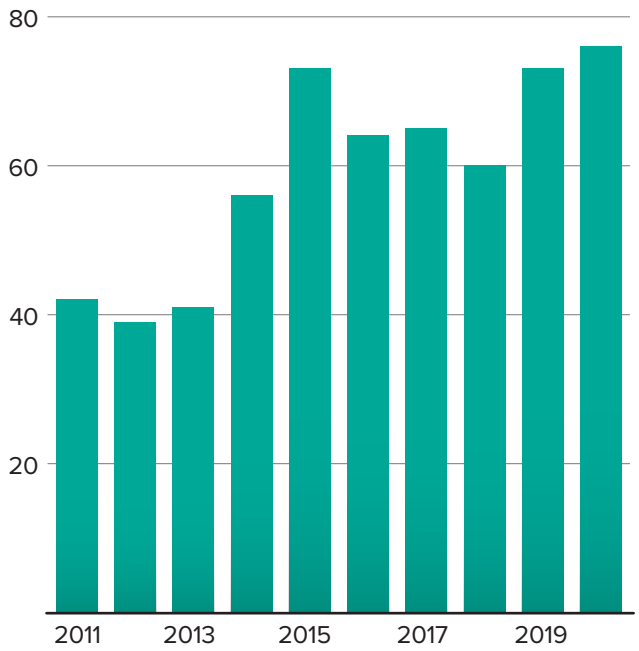


Figure 4.1: Number of patents granted to Argonne by year, 2011–2020.

15 See www.anl.gov/partnerships/available-for-licensing.

16 Data for 2021 is not shown in the chart because new patent applications are still in the review process.

From 2011 to 2020, Argonne received more than 1,750 citations of its 589 patents, demonstrating Argonne's substantial influence on other developing technologies and intellectual property.

While the raw number of patents granted to Argonne is significant, it is also important to note the technology categories in which these patents have been granted. Innovative and cost-effective clean energy sources are one of Argonne's main themes of research, and this is reflected in Argonne's patent record. The laboratory has a portfolio of more than 150 battery-related patents and inventions available for licensing.[17] Moreover, the lab has invented a wide range of technologies in the "beyond lithium-ion" space and has produced more than 30 patents in this technology area since 2013.[18]

Patent Licensing

Argonne licenses a broad range of cutting-edge technologies to private industry. Argonne seeks as licensees companies that have the requisite financial, research and development, manufacturing, marketing, and management functions necessary to successfully commercialize innovations resulting from Argonne research. License fees are negotiated between the company and Argonne. The value of the fees is an indicator of the value the market assigns to Argonne's technology. However, note that the license fee is very much a floor value: the true value of the technology may be much higher depending on the use to which the licensee puts it.

Between 2012 and 2021, Argonne collected over $30 million in licensing revenue from industry, for technologies ranging from car batteries to educational tools. Argonne's revenues highlight the value of the licensed technology to Argonne; the value of the technology is higher when transferred to the commercial sector. Finance literature proposes that the value of a piece of intellectual property comes from how valuable that investment would be in the hands of a successful for-profit company.[19] In particular, finance researchers use the price-to-book ratio to assess the relationship between costs and the market value of an investment or an asset. Table 4.1 also shows estimated revenues generated by licensors of Argonne patents in various broader segments, estimated using publicly available average industry licensing rates.

Table 4.1 also shows estimated revenues generated by licensors of Argonne patents in various broader segments, estimated using publicly available average industry licensing rates.[20] These estimated revenues and the wide range of industry sectors covered indicate the broad commercial outreach of technology developed by Argonne. It is important to note that none of these estimated figures include the value provided to the public from open-source uses of Argonne technologies.

Table 4.1: Market value of technologies licensed to the private sector, 2012–2021.

INDUSTRY	ACTUAL LICENSING REVENUES 2017–2021	ESTIMATED TOTAL LICENSING REVENUES 2012–2021	PRICE-TO-BOOK RATIO BY SECTOR	ESTIMATED MARKET VALUE 2012–2021	ESTIMATED ROYALTY RATES	BROADER COMMERCIAL OUTREACH *Estimated sales of covered products*
Educational Services	$ 0.08 M	$ 0.11 M	2.35	$ 0.26 M	1 – 10 %	$ 2.6 M – 26 M
Finance and Insurance	7.51 M	11.05 M	1.33	14.70 M	1 – 10 %	147 M – 1.5 B
Manufacturing	11.18 M	16.46 M	4.54	74.81 M	2 – 6 %	1.2 B – 3.7 B
Professional, Scientific, and Technical Services	1.61 M	2.37 M	4.86	11.52 M	1 – 10 %	115 M – 1.2 B
TOTAL	**$ 20.38 M**	**$ 30.00 M**	—	**$ 101.30 M**	—	**$ 1.5 B – 6.4 B**

17 See www.anl.gov/article/argonne-battery-technology-confirmed-by-us-patent-office.
18 See www.anl.gov/article/center-advancing-beyond-lithium-battery-technologies-generates-30plus-patents-for-licensing.
19 Use of price-to-book ratio for valuation of intellectual property is standard in the literature. See, for example, DeSouza, G. (1997). Royalty methods for intellectual property. Business Economics, pp. 46–52.
20 Argonne is unable to disclose licensing royalty rates due to confidentiality. Therefore, we use average rates from techtransfercentral.com/wp-content/uploads/2018/03/Royalty-Rates-for-Technology-7th-Edition-TOC.pdf.

TECHNOLOGY HIGHLIGHT

EV BATTERY INNOVATIONS

Through its work in batteries, Argonne has been a leader in helping the world shift to cleaner technologies. The laboratory's work on battery technology has produced numerous patents, which have been licensed to General Motors (GM) (Detroit, MI) and to other manufacturers, including LG Chem (Atlanta, GA), BASF (Florham Park, NJ), Envia Systems (Newark, CA), and Toda Kogyo (Battle Creek, MI).

In 2011, GM signed an agreement with Argonne to license the lab's patented nickel-manganese-cobalt cathode material technology. LG Chem also licensed the technology from Argonne and used the materials to create the battery used in the 2011 Chevy Volt. The move furthered GM's role as a tech leader, pushing innovation and making breakthroughs that are changing the auto industry and society. The Volt, the first mass-produced plug-in hybrid vehicle, led the way as a game-changer in the introduction of electric vehicles (EVs) to the United States.

Argonne continues to develop advanced battery technology in the Joint Center for Energy Storage Research (JCESR), one of DOE's energy innovation hubs. JCESR's research focuses exclusively on the development of next-generation, beyond-lithium-ion batteries. Such batteries could allow inexpensive EVs to drive five times farther on a single charge, surpassing the 400-mile range of conventional gasoline cars. They would also make storing and releasing electricity on the grid just as cheap as generating it with natural gas turbines.

Argonne is not only creating a cleaner and more sustainable future, but also creating jobs and helping the United States move toward energy independence. New jobs arise out of this effort as factories are needed to build the batteries, employing additional workers.

TECHNOLOGY HIGHLIGHT

ADVANCED DIAMOND TECHNOLOGIES

Argonne's patented technology is also licensed and used in small, Illinois-based firms. An example of this is Advanced Diamond Technologies (ADT), is an innovative company based in Romeoville, IL, which was founded by two former Argonne researchers in 2003. ADT provides expertise in developing diamond films for industrial, electronic, mechanical, and medical applications.

The technology behind ADT is rooted in research conducted by Argonne in the 1990s that led to the invention of ultrananocrystalline diamond (UNCD) technology. UNCD made it possible to grow a material with diamond-like properties through a patented chemical vapor deposition process. The material then can be rendered in the form of extremely thin films for coating and sealing.

Using Argonne's patented technology, ADT became an industry leader in the development and application of diamond films. In 2019, ADT was acquired by John Crane, a global provider of engineered products and services headquartered in Chicago.

4.2.2 Open-Source Tools and Models

Argonne has created a wealth of powerful software and models with broad-ranging applications, such as simulation and modeling, computation, internet usage, and more. Argonne has both commercially available software and open-source (free) software. Licenses are available for commercial software products. Commercial software can be licensed directly from Argonne.

Argonne has more than 250 tools and models available for use. Since the 2000s, Argonne has increased its focus on developing open-source tools and models, as illustrated in Figure 4.2.

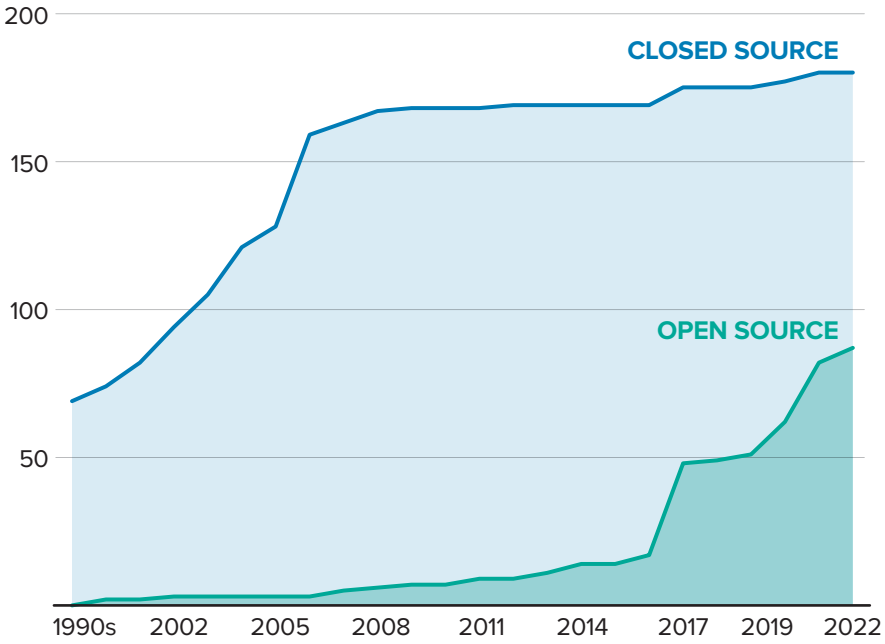


Figure 4.2: Software tools and models developed by Argonne.

TECHNOLOGY HIGHLIGHT

THE GREET TOOL

GREET (the Greenhouse gases, Regulated Emissions, and Energy use in Technologies model) is an open-source graphical toolbox developed by Argonne and provided free of charge to users anywhere. GREET performs lifecycle analysis simulations of alternative transportation fuels and vehicle technologies in real time.[21]

As shown in Figure 4.3, GREET has been downloaded more than 50,000 times since its original release. Users include industry, academia, nonprofits, and government agencies. Users are worldwide: most downloads are from North America, but there are a large number of users on other continents, principally Europe and Asia.

21 See greet.es.anl.gov/index.php

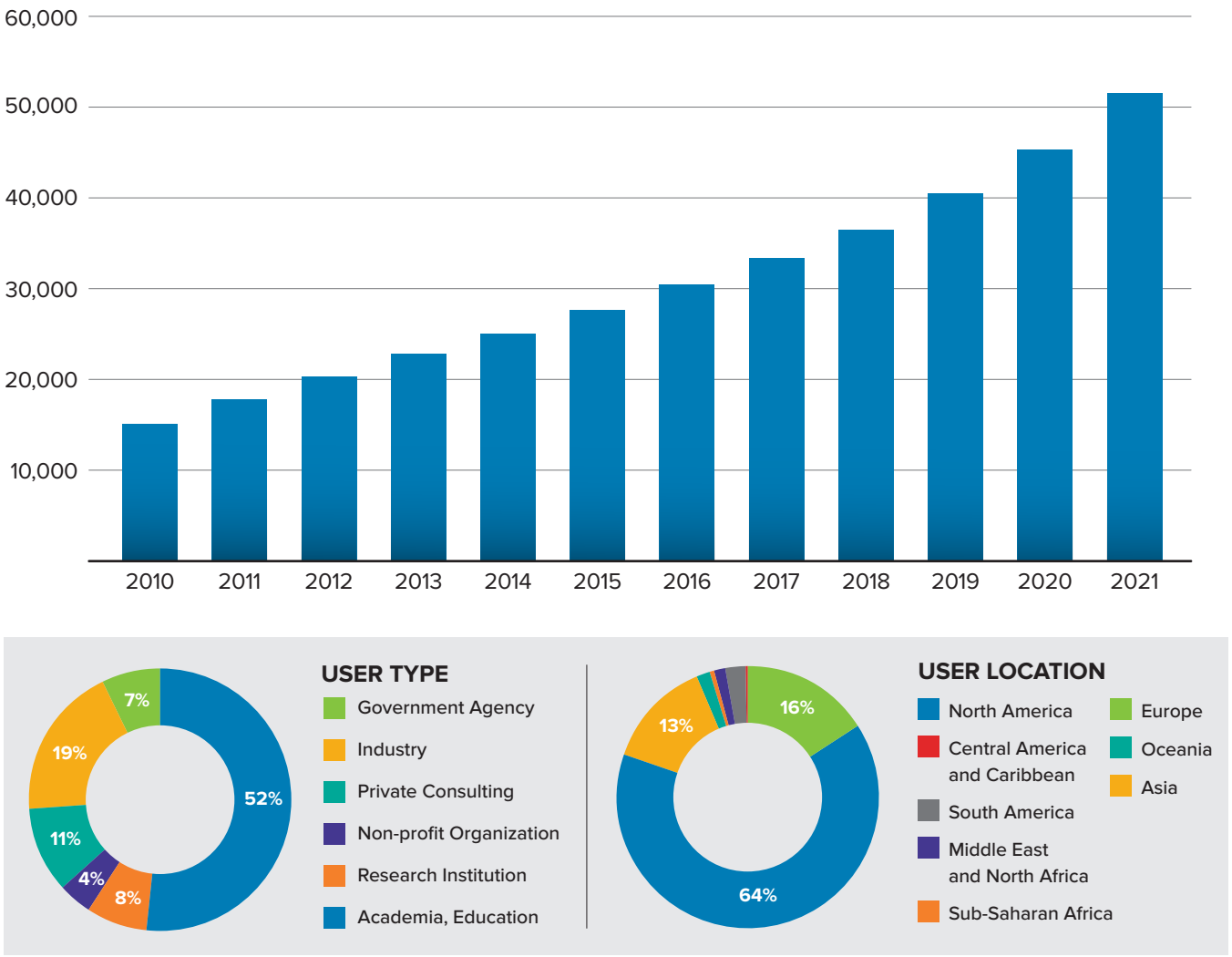


Figure 4.3: Downloads of the GREET open-source tool.
Top: Cumulative downloads by entity type, 2011–2022. *Bottom:* User type and geographic area of user download.

4.3 USER FACILITIES

Technology is also developed in Argonne at the laboratory's user facilities. Argonne operates six national user facilities that offer extraordinary insights into the structure of matter and physical, biological, and societal processes. Argonne's user facilities provide scientists and technologists in academia, industry, and other national laboratories with open access to the most advanced tools of modern science. Argonne allows academic researchers and commercial users to use its facilities at no cost if they publish their results. Should users prefer not to publish their results, they pay a fee that allows Argonne to recover the costs of operating the facility. The user facilities are typically oversubscribed: the number of would-be users far exceeds the available capacity. Access to the user facilities is obtained on a competitive basis: would-be users must submit a research proposal which is subject to review by Argonne.

Of Argonne's six national user facilities, the APS and the ALCF are the principal contributors to technology development.

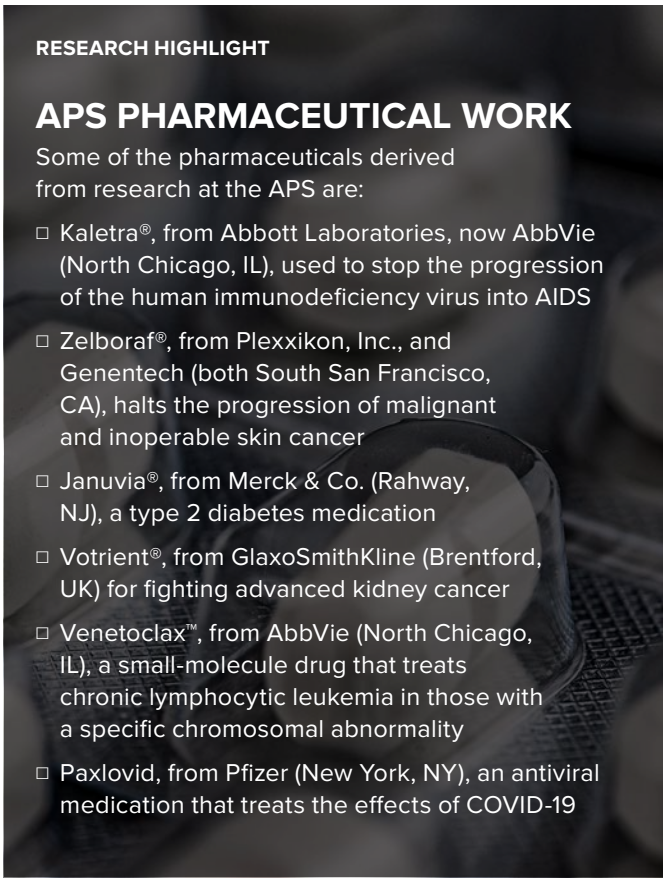
4.3.1 Advanced Photon Source

The APS is the most heavily used of the five DOE light sources: in FY 2021 it hosted almost 3,700 users from across the United States and the world. They conducted more than 5,700 experiments. The number of users in a typical (pre-pandemic) year is closer to 5,500.

APS provides the nation's brightest high-energy X-ray beams and is used in multiple scientific disciplines, including materials science, biology, chemistry, environmental, geological, and planetary science, and fundamental physics. The knowledge APS users gain has real and positive impacts on technology, healthcare, the economy, and our fundamental understanding of the materials and processes that make up our world.

One of the most immediately economically and socially impactful uses of the APS is in pharmaceutical discovery. The APS is used for protein crystallography, which allows scientists to determine the shape and therefore the function of pharmaceutically active proteins. APS users have deposited more protein structures in the Protein Data Bank than any other X-ray light source in the world. These pharmaceuticals generate enormous economic value for the companies that produce them and for society as a whole. Some of that value was clearly created by APS and the Argonne employees who operate and maintain it (see text box for more detail).

Estimating how much of the total value generated by these drug discoveries is attributable to Argonne's facilities and scientists is not an easy task, since there is no record of commercial transactions that would reflect the market value provided to private companies by their use of APS facility. In the absence of such data, a second-best estimate can be obtained by calculating the market value of APS, as if it were built and owned by a publicly traded firm. The total construction budget for the APS facility, which was completed in 1995, was $812 million (1995 dollars), which equates to $1.4 billion in 2021 dollars.[22] Using the price-to-book method discussed in Appendix A3, we estimate that the current market value of the APS facility is around $7.9 billion in 2021 dollars. APS therefore represents a very fruitful investment on the part of the U.S. taxpayer.



RESEARCH HIGHLIGHT

APS PHARMACEUTICAL WORK

Some of the pharmaceuticals derived from research at the APS are:

- Kaletra®, from Abbott Laboratories, now AbbVie (North Chicago, IL), used to stop the progression of the human immunodeficiency virus into AIDS
- Zelboraf®, from Plexxikon, Inc., and Genentech (both South San Francisco, CA), halts the progression of malignant and inoperable skin cancer
- Januvia®, from Merck & Co. (Rahway, NJ), a type 2 diabetes medication
- Votrient®, from GlaxoSmithKline (Brentford, UK) for fighting advanced kidney cancer
- Venetoclax™, from AbbVie (North Chicago, IL), a small-molecule drug that treats chronic lymphocytic leukemia in those with a specific chromosomal abnormality
- Paxlovid, from Pfizer (New York, NY), an antiviral medication that treats the effects of COVID-19

22 See fred.stlouisfed.org. Adjustment made using the Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, Index 1982-1984=100, Monthly, Seasonally Adjusted, by comparing 2021 average (index = 271) to 1995 average (152), we obtain 1.78 multiplier. We then multiply $812 million by 1.78 to reach $1.4 billion.

4.3.2 Argonne Leadership Computing Facility

Likewise, ALCF facilitates computational science and engineering by offering supercomputing and artificial intelligence resources to its users. In a similar manner to APS, Argonne researchers collaborate with academia, industry, and other national labs to design, develop, and execute impactful research for useful real-world applications, several examples of which are shown in Table 4.2.

Table 4.2: Selected impactful research conducted at ALCF.

ADVANCING FUSION ENERGY RESEARCH

Researchers from TAE Technologies performed simulations on Argonne's Theta supercomputer to accelerate their experimental research program aimed at developing a clean, commercially viable, fusion-based electricity generator.

IMPROVING THE ENERGY EFFICIENCY OF JET ENGINES

Argonne is partnering with Raytheon Technologies Research Center to use machine learning to improve the performance, design, and energy efficiency of gas turbine engines.

REDUCING ENERGY CONSUMPTION IN FIBER MANUFACTURING

Working with 3M Co., Argonne is using high performance computing, fluid-dynamics simulations, and machine learning to minimize the energy used in the melt-blown fiber manufacturing process, which can reduce the energy consumed by 20%. This would save the industry nearly 50 gigawatt hours per year.

CREATING FULL-SCALE MODERN AUTOMOTIVE ENGINE SIMULATIONS

Researchers from Argonne performed numerical simulations of modern automotive engines to develop improved wall heat transfer models, which will help optimize engine designs to improve efficiency and reduce emissions.

4.4 INDUSTRY PARTNERSHIPS—SPPS AND CRADAS

Argonne provides private industry, universities, and government entities with access to its world-class expertise and unique research facilities to conduct research and technology development. Argonne provides several collaborative mechanisms tailored to its partners' needs, two of those being SPPs and CRADAs.[23] SPPs are contracts under which outside entities pay Argonne to perform a defined scope of work with tasks that draw upon the unique facilities, equipment, and personnel of the laboratory. With certain DOE approvals, the sponsor may obtain ownership of both inventions and data generated under an SPP. CRADAs are cost-shared research and development agreements that allow outside entities to work collaboratively with Argonne to share technical expertise, develop novel technologies and solutions, and obtain access to intellectual property emerging from the effort.

Argonne collaborated with 1,871 and 453 institutional partners worldwide under SPP and CRADA partnerships, respectively, from 2017 to 2021. The breakdown of these partnerships by partner types over time is shown in Figure 4.4. The SPP is a more common type of partnership across all partner types, with the exception of other DOE national labs. CRADAs are popular among large and small businesses because they allow partners to access the intellectual property that emerges from the joint agreement.

Argonne's SPP and CRADA partnerships provide value for partners across the United States, as illustrated in Figure 4.5. Argonne's U.S.–based SPP partnerships led to contracts valued at $498 million over the period from 2017 to 2021. Partners based in Washington, DC (mostly federal agencies) contributed the most ($184 million), followed by Maryland ($96.3 million), Virginia ($85.2 million), and Illinois ($38.2 million). During the same time interval, Argonne's CRADA partnerships led to contracts valued at $32 million, with the highest amount of research performed in conjunction with organizations based in California ($18.3 million), followed by Virginia ($3.4 million), and Illinois ($2.5 million).

Through CRADAs and SPPs, Argonne and its industry partners have co-developed major impactful projects year after year. Selected projects are highlighted in Figure 4.6. Projects of this nature show how Argonne is leading the development of technologies that will be critical to the future U.S. economy.

23 See www.anl.gov/partnerships/private-industry.

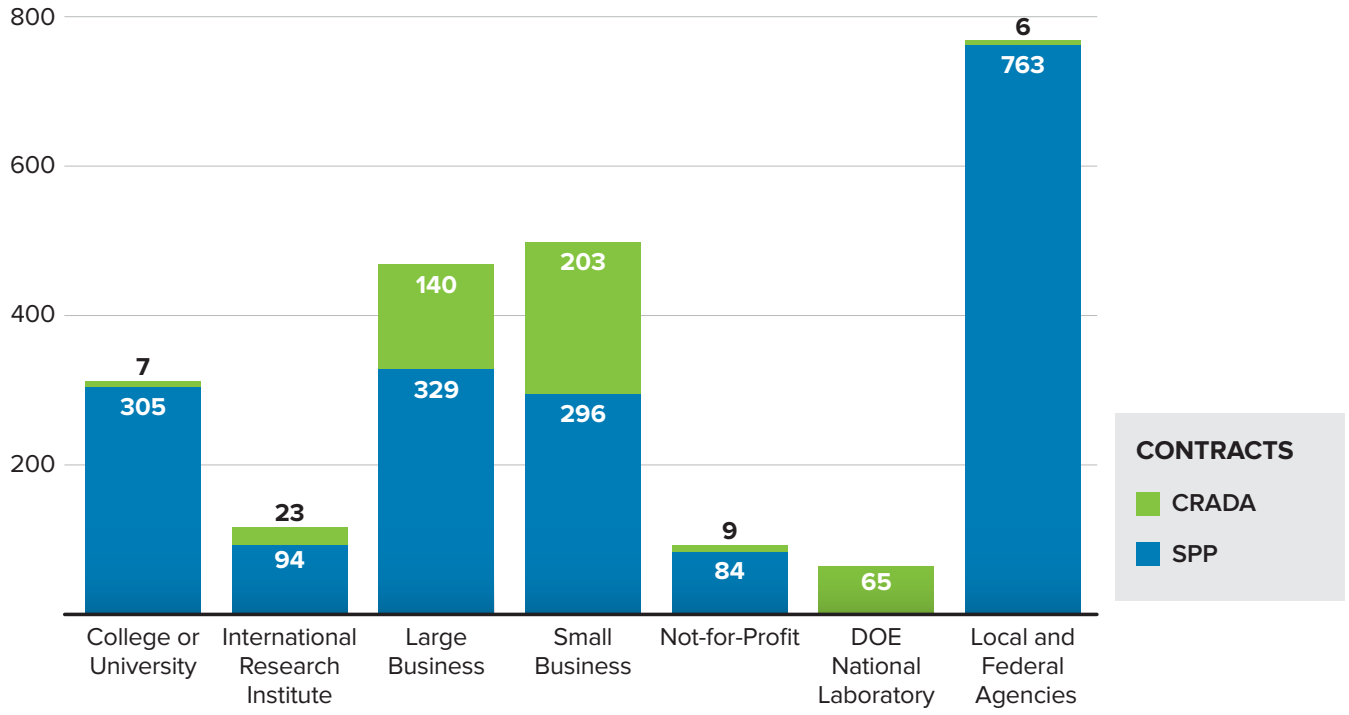


Figure 4.4: Number of SPPs and CRADAs by partner type, 2017–2021.

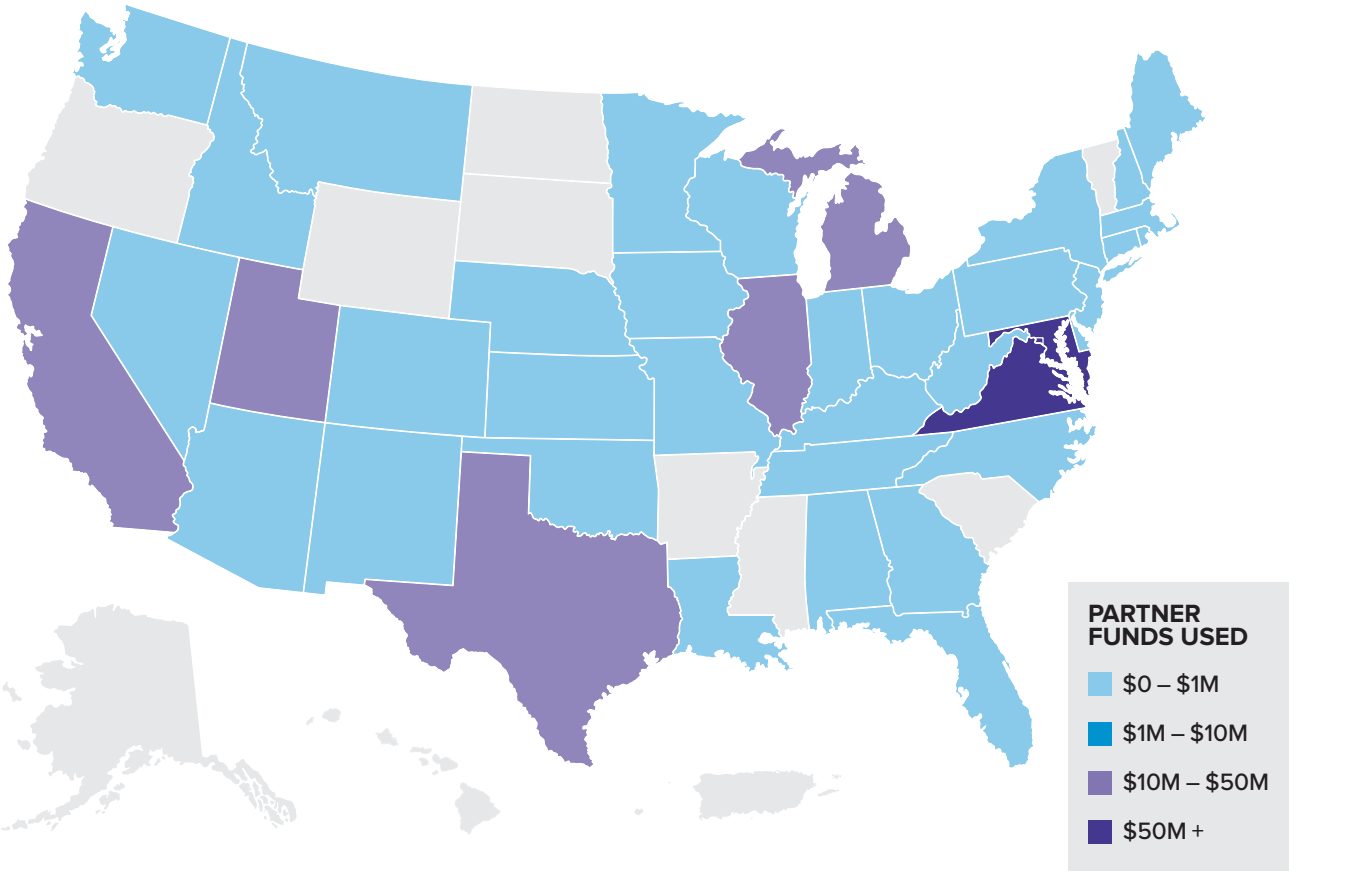
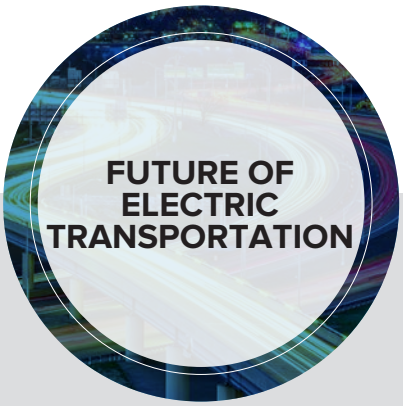
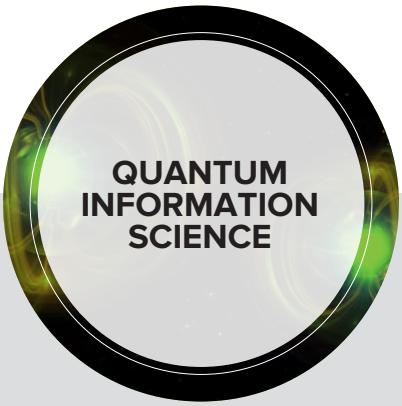


Figure 4.5: Partner funds used by state, 2017–2021.



Argonne and Exelon co-developed an Agent-based Transportation Energy Analysis Model (ATEAM), to study how electric vehicle adoption and the development of charging infrastructure would co-evolve spatially over a three- to ten-year timeframe.



Argonne and the University of Chicago recently received two awards from the Defense Advanced Research Projects Agency (DARPA) to develop novel quantum algorithms and quantum systems that can scale to hundreds or thousands of qubits with high performance and reliability, which will help to secure the nation's leadership in the field of quantum information science.

Researchers from Plexxikon, Inc., (Berkeley, CA) and Genentech (San Francisco, CA) collaborated with Argonne researchers to use APS to study the structure of a cancer-causing mutated protein, and developed Zelboraf, a medication that has been used to disrupt melanoma in hundreds of thousands of patients worldwide in more than 50 countries.

Figure 4.6: Selected joint research projects developed with SPPs and CRADAs.

Figure 4.7: Summary of CRI impact measures as of August 2022.

4.5 CRI: AN ARGONNE-BASED INCUBATOR

Argonne creates additional long-term value by making its facilities and expertise available to entrepreneurs through CRI, its embedded entrepreneurship program.

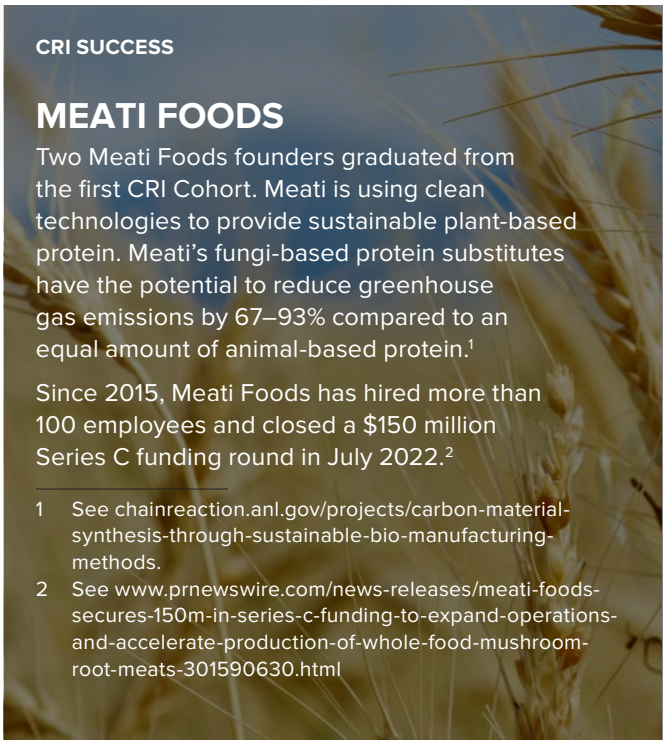
Founded in 2016, CRI is a 2-year fellowship for early-stage startups focusing on clean energy and climate technologies. Through an annual call, four to six individuals or teams are selected to join each CRI cohort.

The goal of CRI is to provide guidance and mentorship to the nation's brightest energy and science innovators to enable startups to reach their true potential and commercialize their technology. CRI provides its innovators with the laboratory tools, seed capital, and collaborators needed to grow their early-stage technologies so they can attract the long-term capital and commercial partners needed to scale and launch into the marketplace.

The program's mission is to accelerate the de-risking of innovations that can solve national energy, security, and advanced manufacturing challenges; to instill the spirit of entrepreneurship at Argonne; to strengthen the regional innovation ecosystem; and to educate entrepreneurs to increase the probability of successful startups.[24]

The CRI program has incubated six cohorts to date, through which 31 startups successfully launched and seven are currently selling products commercially. The 35 CRI innovators have created 585 jobs over the past 6 years, and it is estimated that they will eliminate ~2.5 billion tons of CO_2 emissions by 2030. Moreover, 50% of founders were from underrepresented demographic groups and 31% of entrepreneurs were women. Selected impact data as of August 2022 are shown in Figure 4.7.

Besides hosting an in-depth program of business mentorship at CRI, Argonne also participates in DOE's Energy I-Corps program and the University of Chicago's Polsky Center for Entrepreneurship and Innovation. The Energy I-Corps program pairs teams of researchers with industry mentors for an intensive 2-month training where the researchers develop go-to-market strategies by preparing value propositions via customer interviews. The Polsky Center focuses on technology commercialization in the Chicago area and supports entrepreneurial activity.



CRI SUCCESS

MEATI FOODS

Two Meati Foods founders graduated from the first CRI Cohort. Meati is using clean technologies to provide sustainable plant-based protein. Meati's fungi-based protein substitutes have the potential to reduce greenhouse gas emissions by 67–93% compared to an equal amount of animal-based protein.[1]

Since 2015, Meati Foods has hired more than 100 employees and closed a $150 million Series C funding round in July 2022.[2]

1 See chainreaction.anl.gov/projects/carbon-material-synthesis-through-sustainable-bio-manufacturing-methods.
2 See www.prnewswire.com/news-releases/meati-foods-secures-150m-in-series-c-funding-to-expand-operations-and-accelerate-production-of-whole-food-mushroom-root-meats-301590630.html

24 See www.energy.gov/sites/prod/files/2019/07/f64/025-Poster19-11 - Chain Reaction Innovations_ANL.pdf.

5. COMMUNITY OUTREACH

Argonne generates impact over the longer term through its influence on the community. The lab makes substantial economic contributions to education at all levels: developing future researchers through its STEM outreach and offerings in its learning center, as well as programs for undergraduate- and graduate-level students. Argonne researchers also give back to the community by volunteering their time and talents to local service clubs, school boards, and other community organizations. Argonne performs a convening role by assembling groups, such as the Community Leaders Roundtable. An often-overlooked subject, Argonne's social media and online editorial presence, highlights areas in which Argonne amplifies the impact of discoveries to the general public, which ultimately helps the public become aware of recent scientific achievements, their benefits to society, and what happens to taxpayers' money in the world of science. Lastly, Argonne "alumni" also generate impact as they pursue their careers across the nation and the world and utilize the skills they acquired at Argonne.

5.1 ARGONNE IN CHICAGO

In 2020 Argonne opened a second location in Chicago's Hyde Park neighborhood, a community located on the city's south side. Known as Argonne in Chicago, its mission is to drive inclusive innovation that will help advance economic and societal impacts for underserved and under-represented communities. Opened with the support of DOE and in partnership with the University of Chicago, Argonne in Chicago is a collaboration space that is shared with Fermi National Accelerator Laboratory, the University of Illinois at Urbana-Champaign, and the Chicago Quantum Exchange. Argonne in Chicago aims at delivering four strategic goals:

- **Community:** Extend the benefits of Argonne's capabilities and resources to disadvantaged and under-represented communities
- **Science:** Advance science and technology through expanded collaborations
- **Partnerships:** Accelerate the transfer and adoption of technology by industry for U.S. economic prosperity
- **Education:** Build a diverse workforce of the future to maintain U.S. competitiveness

Argonne in Chicago has been working with local community members, advocates and local officials to gain insights into community needs and address issues that are particularly important to these communities. These collaborative efforts have already helped to launch several programs and initiatives to study climate change, advance environmental justice and broaden STEM education and career opportunities.

5.2 CONTRIBUTION TO EDUCATION

Argonne's educational programs provide an open and engaging environment for K-12, high school, undergraduate, and graduate students. These programs are designed to inspire students to learn about science and become tomorrow's STEM problem solvers. Figure 5.1 summarizes Argonne's educational programs and resources.

STEM Outreach: Argonne builds STEM awareness in the community by organizing competitions, connecting scientists with students through lectures, and showcasing Argonne research at local STEM events. For example, Argonne has connected with more than 30,000 youth and families through its outreach programs. In 2019 (the last pre pandemic year), Argonne reached over 29,000 people across seven counties in Illinois through its K–12 outreach. Its STEM outreach programs in 2019 were represented at 97 events and 92 schools, and Argonne hosted 65 school visits to the lab. More than 200 individuals in the Educational Volunteer Program contributed over 3,500 hours (an increase of 35% from 2017) to judge local science competitions, mentor students, and/or speak at regional institutions.

Learning Center: The Learning Center contains four research laboratories, three classrooms, and a computer lab that provide students with immersive educational experiences. The center organizes summer camps and high school research programs where students learn STEM skills such as coding, building batteries, designing a magnetic linear accelerator, and others. Through its middle school to graduate programming, Argonne has hosted more than 4,400 middle and high school students at the Learning Center.

Undergraduate and Graduate Programs: More than 100 undergraduate students participate in internships which help them explore various research areas of the lab and develop areas of interest for further study. Argonne also provides opportunities to graduate students by offering master's students and Ph.D. candidates the opportunity to pursue internships, temporary employment, and training programs. For example, in FY 2019, Argonne supported and employed 224 graduate students and 297 undergraduate students.

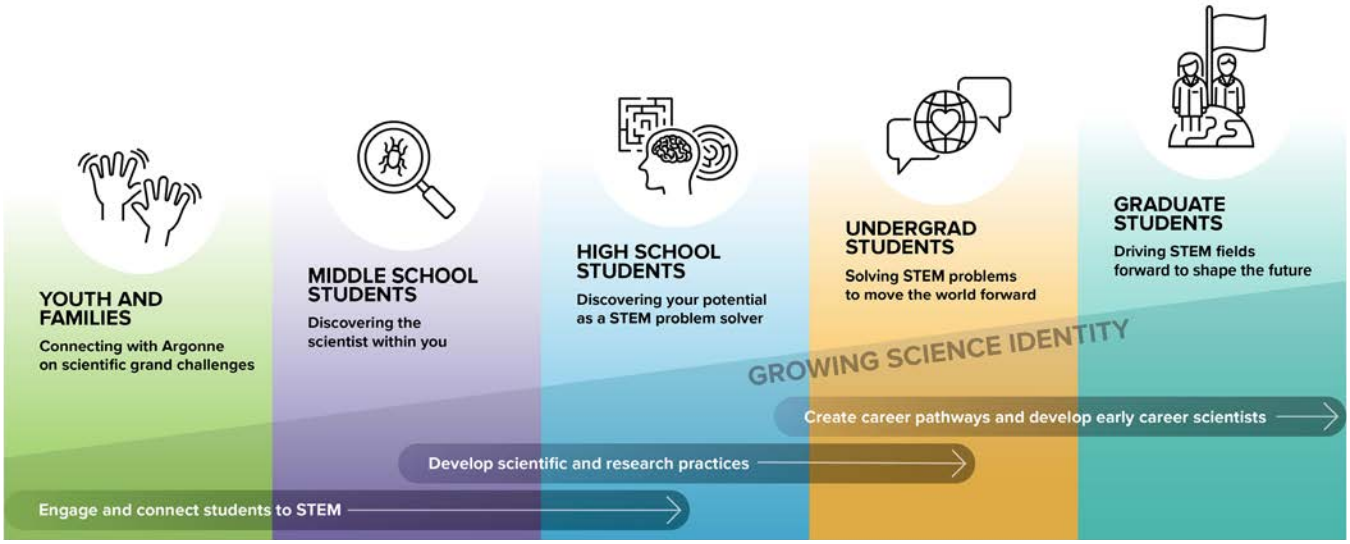


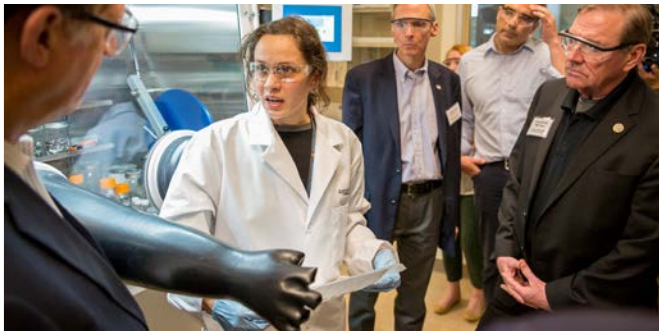
Figure 5.1: Argonne educational outreach.

5.3 COMMUNITY INTERACTION

Argonne researchers give back to the community by volunteering their time and talents to local service clubs, school boards, and other community organizations. One such event is the Community Leaders Roundtable, where Argonne researchers discuss projects and the latest scientific and technological discoveries with elected officials at the village, city, township, county, and state levels.

Below are some impact statistics about Argonne's community events:

- **Community Leaders Round Table.** In 2019, four on-site meetings were held. Thirty-two attendees heard presentations on a variety of topics including an update on the APS upgrade.
- **Public lectures**. Four on-site lectures were hosted on soil science, extreme weather, innovation, and the evolving economy attracting a total of 1,100 people in 2019.
- **Laboratory tours**. In 2018, the lab led 322 tours for approximately 5,000 members of the public.



5.4 ARGONNE ALUMNI

Argonne has been a melting pot for innovators, researchers, engineers, and technologists, attracting talented and driven professionals from across the nation and world to the Midwest region of the United States. Argonne's valuable human capital not only contributes to the economy and society while at Argonne, but continues to do so after the researchers leave the institution with the knowledge and connections built

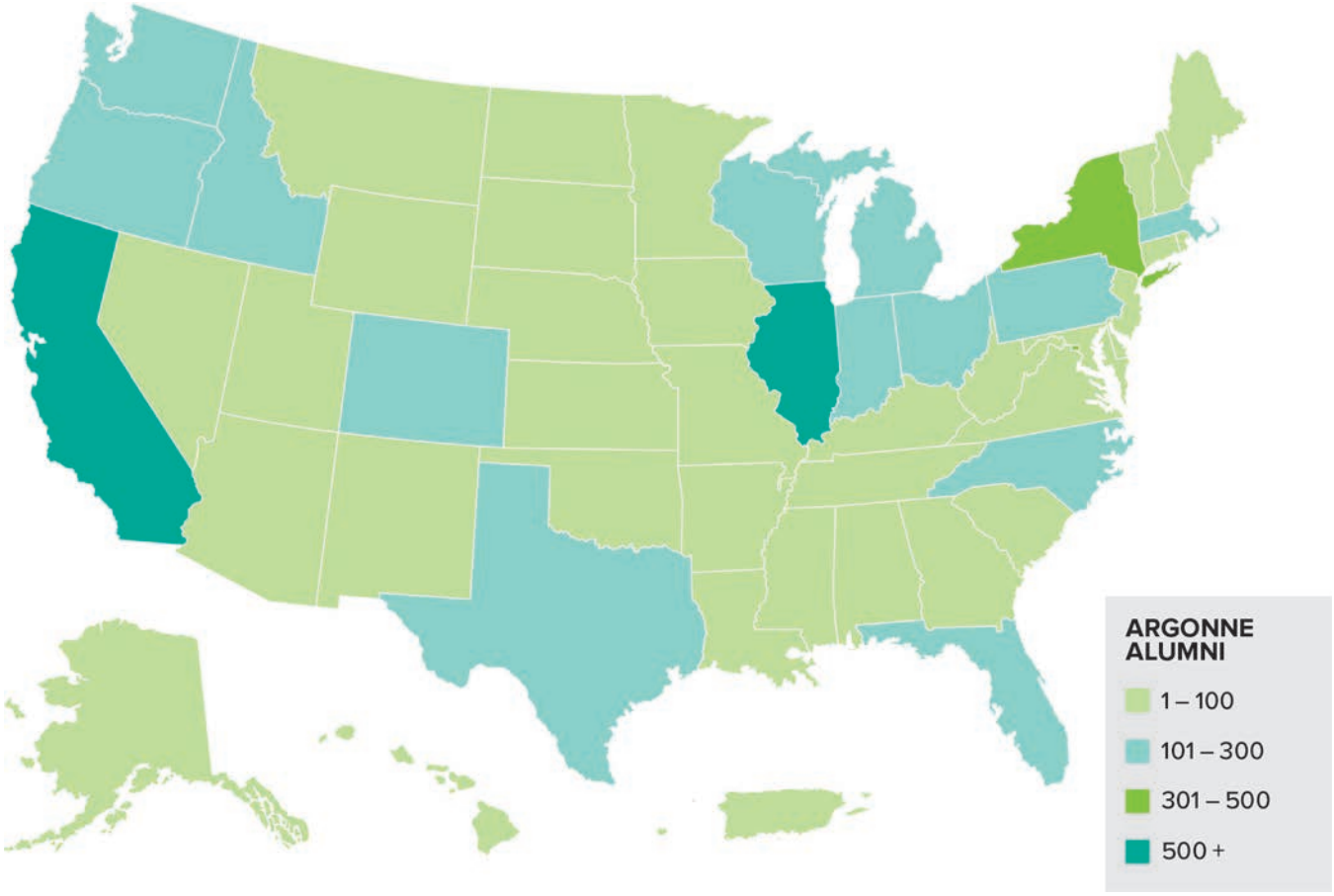


Figure 5.2: Number of Argonne alumni by state as of December 2022.

during their time at Argonne. Notable alumni from Argonne include three Nobel laureates, Enrico Fermi, Maria Goeppert Mayer, Alexei Abrikosov, and others who have transformed science through their discoveries in energy, climate, health, computing, cosmology, and more.[25]

The impact of Argonne's recent alumni is summarized using LinkedIn data. LinkedIn profiles that mention "Argonne" as a past employer are used to identify a broadly defined class of alumni, including not only full-time employees but also interns and students. A total of 8,325 profiles are collected, where 7,600 are based in the United States and 725 are based internationally. The map in Figure 5.2 shows the location of known U.S.–based Argonne alumni. The majority stayed in Illinois, while many moved to other states, principally California and New York.

Argonne alumni work across 139 industries based on LinkedIn industry categorization. As shown in Figure 5.3, research, computer software, and higher education are the top three industries, and the top 10 industries attract more than 50% of the alumni.

Figure 5.4 shows the 10 institutions with the largest number of employees who are Argonne alumni. The top employers are mainly research institutes, technology giants, and federal agencies like DOE, the Department of Defense, and the Census Bureau.

25 See www.anl.gov/article/people-of-argonnes-history-a-look-at-leaders-who-made-argonne-what-it-is-today.

Figure 5.3: Top 10 industries employing Argonne alumni as of December 2022.

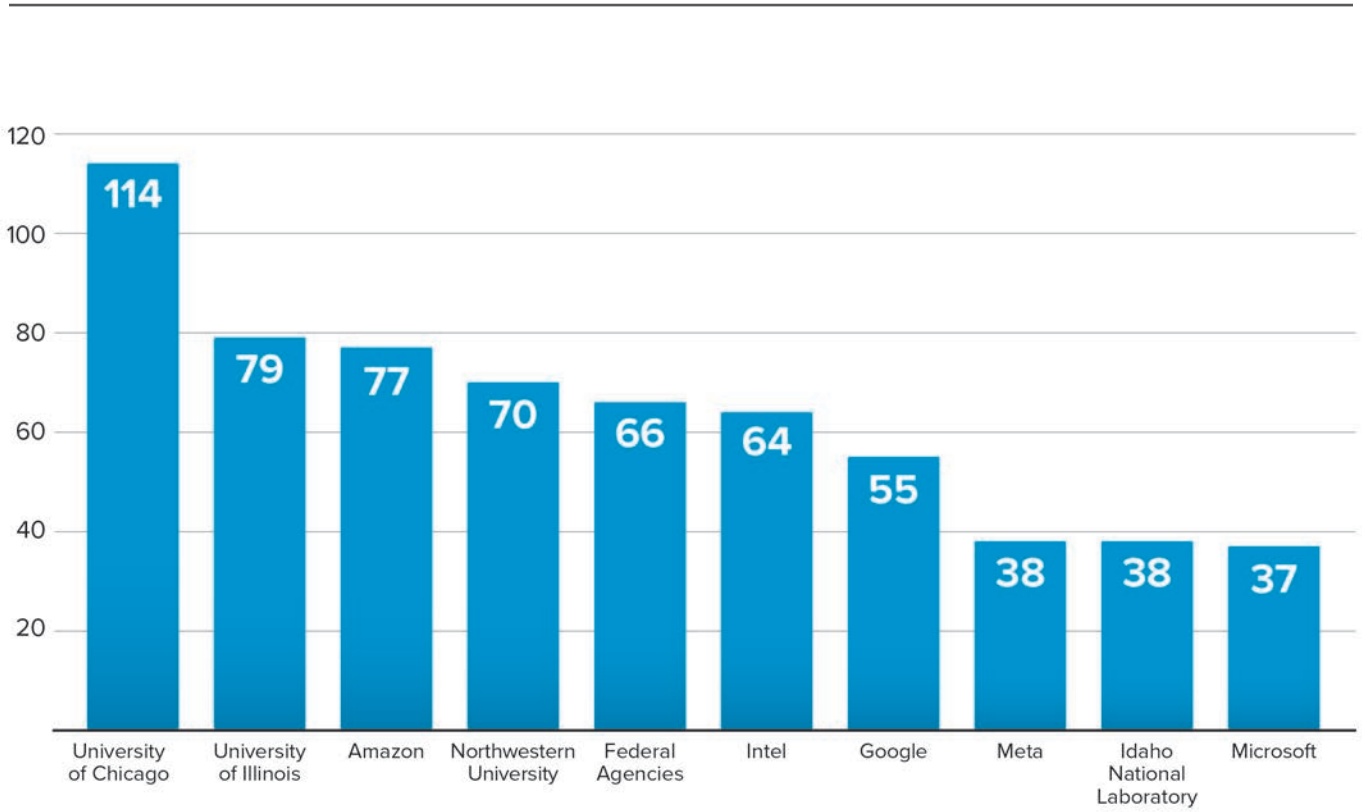


Figure 5.4: Top 10 institutions employing Argonne alumni as of December 2022.

6. GLOSSARY

6.1 ACRONYMS AND INITIALISMS

AHCI
Arts and Humanities Citation Index

ALCF
Argonne Leadership Computing Facility

APS
Advanced Photon Source

Argonne
Argonne National Laboratory

ARM
Atmospheric Radiation Measurement User Facility

ATLAS
Argonne Tandem Linac Accelerator System

CNM
Center for Nanoscale Materials

CRADA
Cooperative Research and Development Agreement

CRI
Chain Reaction Innovations

DOE
Department of Energy

ESCI
Emerging Sources Citation Index

EV
Electric Vehicle

FY
Fiscal Year

GREET
Greenhouse gases, Regulated Emissions, and Energy use in Technologies model

IAMECON
Intelligent Analytics and Modeling

IVEM
Intermediate Voltage Electron Microscope

JCESR
Joint Center on Energy Storage Research

NE
Office of Nuclear Energy

SC
Office of Science

SCI
Science Citation Index

SCIE
Science Citation Index Expanded

SPP
Strategic Partnership Project

SSCI
Social Sciences Citation Index

STEM
Science, Technology, Engineering, and Mathematics

UNCD
Ultrananocrystalline diamond

6.2 DEFINITIONS

Capital funding
Includes construction and capital improvements expenses.

Direct impact
Initial economic activity (sales, expenditures, employment, production, etc.) by a company or industry.

Fiscal year
Argonne's fiscal year runs from October 1 to September 30.

Indirect impact
The upstream (backward) economic activity impacted by purchases along a company or industry supply chain.

Induced impact
Economic activity derived from workers spending their earnings on goods and services in the economy.

Midwest
For the purposes of this report, the region comprised of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.

Operational funding
Includes salaries and benefits, along with procurement expenses.

7. APPENDICIES

A. METHODOLOGY

A.1 Economic Impact of Argonne Spending

Economic impact figures associated with Argonne's budgetary activities (i.e., salaries, wages, and contractor payments; procurement of goods and services; capital improvement and construction projects) are estimated using the industry standard input-output software IMPLAN.[26]

The primary data set was detailed spending data provided by Argonne, including an itemized breakdown by location, by industry, and by supplier characteristics.[27] Information regarding location and industry is crucial for estimating economic impact accurately, since it allows the IAMECON analyst to trace the flow of funds, and ultimately to measure how much of Argonne's spending took place close to the laboratory and how much "leaked" away from the area and took place elsewhere in Illinois, the Midwest, or the rest of the United States. The "leakage" percentage captures Argonne spending on non-local vendors. With respect to any base location (e.g., county, state, or country), the higher the leakage is, the lower the economic impact of spending on that local region. Knowledge of spending broken out by industry segment informs the analyst of, in essence, a second degree of leakage, since standard economic input and output tables inform us where suppliers of goods and services to Argonne spend their revenue. In other words, Argonne's spending is revenue to its suppliers; these suppliers spend this revenue, which creates economic impact elsewhere in the country.

IAMECON analysts then compared the itemized spending data to aggregate spending data as provided in Argonne's financial documents. Salary and wage payments, which constitute the bulk of Argonne's spending, were aggregated by zip code, which allowed the analyst to determine the locality of spending. For remaining spending categories (capital and operating expenses), itemized details were available for only 68% of expenditures; these itemized expenses were analyzed by location and industry, and the analyst assumed that the breakdown of location and industry applied to all operating and capital expenses.

Once industry and location information were assigned to expense figures, the IAMECON analyst used IMPLAN bridges that map NAICS codes to IMPLAN sector codes and used these expenditures as an input to IMPLAN.

We also adjusted expenses from 2021 dollars to 2019 dollars (deflated using consumer price indices from Bureau of Economic Analysis), since the most recent and reliable (pre-COVID) economic data available in the latest version of the IMPLAN software was prepared using 2019 economic data.

A.2 Economic Impact of Technology Developed at Argonne

Quantifying the economic impact of technology is not always straightforward. Once a specific technology is integrated into society, the impact it generates is difficult to distinguish from impact provided by other sources. Likewise, it is sometimes difficult to assign a definite value to the technology development effort at Argonne: in many cases, Argonne is not the only organization whose research and development activities enable a technology breakthrough. In such cases, it is clear that Argonne has created economic value, but it is difficult to say exactly how much.

Nevertheless, we can estimate the market value of Argonne's licenses using historical royalty payments as a starting point. Royalty payments alone typically represent the economic value of the marginal contribution of the licensed technology to a specific vendor for a specific set of products. The payments are revenues to Argonne, and expenses for the books of licensees. According to financial literature, book value and market value differ significantly, and this difference is captured by "price-to-book" ratio (or "market-to-book" ratio, equivalently).[28] The estimated market value of the technology is the price-to-book ratio multiplied by the total royalty payments. Note that for each industry, a separate price-to-book ratio is appropriate; and those rates are available publicly for each industry.[29] Broader measure of societal impact can be obtained by analyzing the total volume of sales in commercial markets. Although we do not know the exact sales volume of products covered by Argonne's licensed technologies, we can estimate this using the quantity of royalty payments and average royalty rates for similar technology. Using publicly available information, we estimate that average industry royalty rates for car battery technologies (which accounts for over 50% of all licensing revenues as shown in Table 4.1) ranges

26 See implan.com.
27 For industry classification, we used the North American Industry Classification System (NAICS).
28 Use of price-to-book ratio for valuation of intellectual property is standard in the literature. See, for example, DeSouza, G. (1997). Royalty methods for intellectual property. *Business Economics*, pp. 46–52.
29 See pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/pbvdata.html.

from 2% to 6%, whereas all other licensed technologies (we used "software models" as a common descriptor for the rest of technologies) are assumed to be licensed using a royalty rate between 1% and 10% of revenues.[30]

For licensing revenues, we have received a detailed list covering revenues from 2017 to 2021. For licensing revenues covering from 2012 to 2016, we have been provided an aggregate estimate by Argonne personnel. See Table 4.1 for details.

A.3 Economic Value of Argonne's APS Facility

To estimate the market value of APS, we use the "price-to-book" ratio approach discussed previously. The book value of the APS facility is calculated as $1.4 billion (in 2021 dollars), by converting the $812 million (in 1995 dollars) construction costs to 2021 dollars, using consumer price indices from 1995 to 2021.[31]

In order to properly compute the appropriate price-to-book ratio to be used, we first analyzed revenues collected by APS users, and grouped them by two-digit NAICS codes, as shown in Table 7.1.

Using an average of price-to-book ratios (weighted by how much revenues were generated), we estimate that the appropriate industry price-to-book ratio is 5.46, implying that $1 spent on construction of a facility like APS would result in $5.46 of market value, all else being equal. Using this multiplier, we estimate that the $1.4 billion construction cost implies $7.9 billion of market value (7.9 = 1.4 × 5.46).

Table 7.1: Two-digit NAICS codes applicable to APS users.

NAICS TWO-DIGIT CODE	NAICS TITLE	PRICE-TO-BOOK RATIO	REVENUE TO ARGONNE
32	Manufacturing	**5.72**	**$ 1,371,480**
33	Manufacturing	**5.76**	**$ 8,129**
44	Retail Trade	**5.89**	**$ 2,975**
54	Professional, Scientific, and Technical Services	**4.86**	**$ 615,453**
62	Health Care and Social Assistance	**5.92**	**$ 33,446**

30 We used the following sources to estimate the ranges of royalty rates:
- dost.hochiminhcity.gov.vn/documents/594/royalty-rates-for-technology-4th-edition-sample-report.pdf.
- www.sec.gov/Archives/edgar/data/1453420/000106299312004126/exhibit10-1.htm.
- techtransfercentral.com/wp-content/uploads/2018/03/Royalty-Rates-for-Technology-7th-Edition-TOC.pdf.
- www.wsj.com/articles/SB987474784770167306.

31 See fred.stlouisfed.org. Adjustment made using the Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, Index 1982-1984=100, Monthly, Seasonally Adjusted, by comparing 2021 average (index = 271) to 1995 average (152), we obtain 1.78 multiplier. We then multiply $812 million by 1.78 to obtain $1.4 billion.

A.4 Economic Impact of Visitors to Argonne

Visitors to Argonne facilities also generate economic impact through their spending on local vendors during their stay. Note that this spending is independent of Argonne spending. These impacts originate mostly from visitor spending on lodging, transportation, and dining. For visitor impact estimation, it is very important to identify a base location (or "home") such that visitors can be defined to be visiting from outside of the base location. In other words, economic impact is only created if the visitors are coming from outside the base location.

A total of 5,995 visitors used Argonne facilities in 2021. Among them, 4,386 came from outside Illinois. Visitor data only tracks the origin of visitors at the state level, and their affiliation for visitors coming from in-state institutions.[32] Therefore, we are able to identify whether they are visiting from outside of DuPage County (and the Chicago area), and we can generate impact figures for five different "base" locations: DuPage County, Chicago area, Illinois, Midwest, and the United States. By definition, there is no impact on Cook County (because it does not include the region being visited). For nationwide economic impact, only foreign visitors generate impact, so only 651 visitors are included on this part of the estimation.

Using user facility visit duration data, we find that out-of-state visitors stayed an average of 9.2 nights. Assuming that all of them used air transportation to Chicago O'Hare International Airport (average roundtrip cost of $284.93),[33] and a taxi ride from the airport (roundtrip cost of $170),[34] a total of almost $2 million was spent for transportation. The Argonne Guest House charges an average of $101.50 + 6% tax per person per night; we use this amount to calculate lodging spending per night because it is very similar to other hotel rates in the area. In addition, for every dollar spent on lodging in the area, consumers pay 68 cents for food and beverages while traveling.[35]

Using the itemized spending information, we utilized the IMPLAN software to estimate the total economic impact of Argonne user facility visitors on the local economy with respect to each of our four base locations.

A.5 Argonne Alumni

The database of Argonne alumni was created by extracting data from LinkedIn of users who have Argonne listed as a past employer. This data collection was performed between April 4 and 6, 2022. We acknowledge that this data collection process does not account for Argonne alumni who do not have LinkedIn profiles. In addition, the data extraction process was not limited to previous full-time employees but also includes interns and students.

32 Visitors from University of Illinois Urbana-Champaign and Northern Illinois University are classified as visitors for both the Chicago area and DuPage County, whereas visitors from University of Chicago, Illinois Institute of Technology, and Northwestern University are treated as part of the Chicago area, and hence only count as visitors for DuPage County.

33 Bureau of Transportation Statistics: www.transtats.bts.gov/averagefare. Conservatively, we assumed that even foreign visitors' transportation impact (airfare) is identical to that of domestic visitors.

34 See www.rome2rio.com.

35 Bureau of Labor Statistics: www.bls.gov/opub/ted/2022/consumer-expenditures-on-travel-declined-sharply-from-2019-to-2020.htm.

B. IMPACT TABLES

Table 7.2: Economic impact of Argonne's operational funding by geography.

OPERATIONAL FUNDING IMPACT

TYPE OF IMPACT	EMPLOYMENT	EMPLOYEE COMPENSATION	VALUE ADDED	ECONOMIC OUTPUT
DUPAGE COUNTY				
Direct	1,163	$ 176,556,238	$ 15,071,981	$ 191,628,219
Indirect	102	9,307,376	12,493,524	21,351,034
Induced	387	23,127,525	41,597,901	66,483,677
TOTAL IMPACT	**1,652**	**$ 208,991,139**	**$ 69,163,406**	**$ 279,462,930**
COOK COUNTY				
Direct	967	$ 125,556,780	$ 49,148,136	$ 174,704,916
Indirect	358	31,432,844	43,386,505	67,188,336
Induced	549	34,665,935	61,927,045	96,796,760
TOTAL IMPACT	**1,874**	**$ 191,655,559**	**$ 154,461,686**	**$ 338,690,012**
CHICAGO AREA				
Direct	3,210	$ 445,015,511	$ 71,813,293	$ 516,828,804
Indirect	544	46,250,912	63,940,199	101,947,344
Induced	2,418	150,105,872	268,296,859	432,005,859
TOTAL IMPACT	**6,172**	**$ 641,372,296**	**$ 404,050,351**	**$ 1,050,782,008**
ILLINOIS				
Direct	3,313	$ 455,336,779	$ 79,961,437	$ 535,298,216
Indirect	645	49,390,121	68,421,625	111,345,579
Induced	2,575	149,075,966	270,237,748	447,116,909
TOTAL IMPACT	**6,533**	**$ 653,802,865**	**$ 418,620,810**	**$ 1,093,760,704**
MIDWEST REGION				
Direct	3,398	$ 466,990,241	$ 129,098,537	$ 596,088,779
Indirect	1,014	65,520,903	92,495,056	158,892,712
Induced	3,274	174,806,620	310,274,540	549,476,949
TOTAL IMPACT	**7,686**	**$ 707,317,764**	**$ 531,868,133**	**$ 1,304,458,440**
UNITED STATES				
Direct	3,574	$ 495,915,761	$ 312,895,275	$ 808,811,037
Indirect	2,481	189,039,438	269,643,848	457,333,745
Induced	5,273	309,896,712	550,281,193	981,849,949
TOTAL IMPACT	**11,328**	**$ 994,851,911**	**$ 1,132,820,315**	**$ 2,247,994,731**

Table 7.3: Economic impact of Argonne's capital funding by geography.

CAPITAL FUNDING IMPACT

TYPE OF IMPACT	EMPLOYMENT	EMPLOYEE COMPENSATION	VALUE ADDED	ECONOMIC OUTPUT
DUPAGE COUNTY				
Direct	258	$ 23,355,850	$ 24,440,642	$ 39,188,764
Indirect	35	3,002,723	4,711,279	7,823,152
Induced	67	4,013,519	7,196,636	11,514,378
TOTAL IMPACT	**360**	**$ 30,372,092**	**$ 36,348,557**	**$ 58,526,294**
COOK COUNTY				
Direct	187	$ 14,108,112	$ 16,227,913	$ 31,850,835
Indirect	37	3,383,036	5,350,210	8,868,481
Induced	66	4,181,802	7,453,057	11,651,636
TOTAL IMPACT	**290**	**$ 21,672,950**	**$ 29,031,181**	**$ 52,370,952**
CHICAGO AREA				
Direct	583	$ 44,907,725	$ 48,769,029	$ 87,814,233
Indirect	123	10,715,322	17,186,284	30,348,559
Induced	287	17,807,302	31,765,975	51,158,498
TOTAL IMPACT	**993**	**$ 73,430,349**	**$ 97,721,288**	**$ 169,321,290**
ILLINOIS				
Direct	613	$ 44,970,940	$ 49,094,958	$ 91,143,847
Indirect	134	10,904,905	17,684,290	32,618,639
Induced	298	17,276,320	31,262,662	51,733,222
TOTAL IMPACT	**1,045**	**$ 73,152,165**	**$ 98,041,909**	**$ 175,495,708**
MIDWEST REGION				
Direct	660	$ 45,232,916	$ 49,360,589	$ 97,240,783
Indirect	206	15,157,609	24,176,072	50,029,028
Induced	388	20,698,668	36,698,764	64,989,663
TOTAL IMPACT	**1,254**	**$ 81,089,193**	**$ 110,235,424**	**$ 212,259,473**
UNITED STATES				
Direct	805	$ 60,277,789	$ 71,840,650	$ 147,640,464
Indirect	460	36,697,289	59,078,100	125,367,980
Induced	772	45,383,160	80,523,614	143,650,894
TOTAL IMPACT	**2,037**	**$ 142,358,238**	**$ 211,442,364**	**$ 416,659,338**

Table 7.4: Economic impact of Argonne's user facility visitors by geography.

USER FACILITY VISITOR IMPACT

TYPE OF IMPACT	EMPLOYMENT	EMPLOYEE COMPENSATION	VALUE ADDED	ECONOMIC OUTPUT
DUPAGE COUNTY				
Direct	99	$ 4,146,383	$ 6,736,992	$ 10,712,932
Indirect	19	1,373,761	2,040,038	3,471,223
Induced	13	793,217	1,424,166	2,278,331
TOTAL IMPACT	**132**	**$ 6,313,360**	**$ 10,201,197**	**$ 16,462,486**
COOK COUNTY				
Direct	0	$ 0	$ 0	$ 0
Indirect	0	0	0	0
Induced	0	0	0	0
TOTAL IMPACT	**0**	**$ 0**	**$ 0**	**$ 0**
CHICAGO AREA				
Direct	89	$ 3,889,435	$ 6,221,330	$ 9,667,923
Indirect	19	1,326,929	2,057,311	3,717,175
Induced	29	1,622,684	2,938,344	4,862,177
TOTAL IMPACT	**136**	**$ 6,839,048**	**$ 11,216,985**	**$ 18,247,275**
ILLINOIS				
Direct	84	$ 3,680,488	$ 5,887,110	$ 9,148,546
Indirect	18	1,255,644	1,946,789	3,517,482
Induced	27	1,535,511	2,780,491	4,600,973
TOTAL IMPACT	**128**	**$ 6,471,644**	**$ 10,614,390**	**$ 17,267,001**
MIDWEST REGION				
Direct	79	$ 2,770,103	$ 4,667,455	$ 7,746,853
Indirect	19	1,186,714	1,840,755	3,592,955
Induced	26	1,362,382	2,416,715	4,279,489
TOTAL IMPACT	**124**	**$ 5,319,199**	**$ 8,924,926**	**$ 15,619,297**
UNITED STATES				
Direct	13	$ 495,665	$ 851,945	$ 1,357,888
Indirect	4	268,036	429,955	841,560
Induced	6	358,181	635,712	1,133,769
TOTAL IMPACT	**23**	**$ 1,121,881**	**$ 1,917,612**	**$ 3,333,217**

C. TOTAL IMPACT (OPERATIONAL FUNDING, CAPITAL FUNDING, AND VISITOR IMPACT)

Table 7.5: Argonne's total impact by geography.

TOTAL IMPACT: OPERATIONAL, CAPITAL, AND VISITOR

TYPE OF IMPACT	EMPLOYMENT	EMPLOYEE COMPENSATION	VALUE ADDED	ECONOMIC OUTPUT
DUPAGE COUNTY				
Direct	1,520	$ 204,058,471	$ 46,249,615	$ 241,529,915
Indirect	156	13,683,860	19,244,840	32,645,409
Induced	467	27,934,261	50,218,703	80,276,386
TOTAL IMPACT	**2,144**	**$ 245,676,591**	**$ 115,713,159**	**$ 354,451,710**
COOK COUNTY				
Direct	1,154	$ 139,664,892	$ 65,376,049	$ 206,555,751
Indirect	395	34,815,880	48,736,714	76,056,817
Induced	615	38,847,738	69,380,102	108,448,396
TOTAL IMPACT	**2,164**	**$ 213,328,509**	**$ 183,492,866**	**$ 391,060,964**
CHICAGO AREA				
Direct	3,882	$ 493,812,671	$ 126,803,652	$ 614,310,960
Indirect	686	58,293,164	83,183,794	136,013,078
Induced	2,733	169,535,858	303,001,178	488,026,535
TOTAL IMPACT	**7,301**	**$ 721,641,693**	**$ 512,988,624**	**$ 1,238,350,573**
ILLINOIS				
Direct	4,010	$ 503,988,207	$ 134,943,505	$ 635,590,609
Indirect	798	61,550,670	88,052,704	147,481,700
Induced	2,900	167,887,796	304,280,901	503,451,104
TOTAL IMPACT	**7,706**	**$ 733,426,674**	**$ 527,277,109**	**$ 1,286,523,414**
MIDWEST REGION				
Direct	4,137	$ 514,993,260	$ 183,126,581	$ 701,076,415
Indirect	1,240	81,865,226	118,511,882	212,514,695
Induced	3,688	196,867,671	349,390,019	618,746,101
TOTAL IMPACT	**9,064**	**$ 793,726,156**	**$ 651,028,483**	**$ 1,532,337,210**
UNITED STATES				
Direct	4,392	$ 556,689,215	$ 385,587,870	$ 957,809,389
Indirect	2,945	226,004,763	329,151,902	583,543,285
Induced	6,051	355,638,053	631,440,519	1,126,634,612
TOTAL IMPACT	**13,388**	**$ 1,138,332,030**	**$ 1,346,180,291**	**$ 2,667,987,286**

Table 7.6: Argonne's total impact by geography, by funding type.

TOTAL IMPACT BY TYPE

	TOTAL		OPERATIONAL FUNDING	
TYPE OF IMPACT	**EMPLOYMENT**	**ECONOMIC OUTPUT**	**EMPLOYMENT**	**ECONOMIC OUTPUT**
DUPAGE COUNTY				
Direct	1,520	$ 204,058,471	1,163	$ 191,628,219
Indirect	156	13,683,860	102	21,351,034
Induced	467	27,934,261	387	66,483,677
TOTAL IMPACT	**2,144**	**$ 245,676,591**	**1,652**	**$ 279,462,930**
COOK COUNTY				
Direct	1,154	$ 139,664,892	967	$ 174,704,916
Indirect	395	34,815,880	358	67,188,336
Induced	615	38,847,738	549	96,796,760
TOTAL IMPACT	**2,164**	**$ 213,328,509**	**1,874**	**$ 338,690,012**
CHICAGO AREA				
Direct	3,882	$ 493,812,671	3,210	$ 516,828,804
Indirect	686	58,293,164	544	101,947,344
Induced	2,733	169,535,858	2,418	432,005,859
TOTAL IMPACT	**7,301**	**$ 721,641,693**	**6,172**	**$ 1,050,782,007**
ILLINOIS				
Direct	4,010	$ 503,988,207	3,313	$ 535,298,216
Indirect	798	61,550,670	645	111,345,579
Induced	2,900	167,887,796	2,575	447,116,909
TOTAL IMPACT	**7,706**	**$ 733,426,674**	**6,533**	**$ 1,093,760,704**
MIDWEST REGION				
Direct	4,137	$ 514,993,260	3,398	$ 596,088,779
Indirect	1,240	81,865,226	1,014	158,892,712
Induced	3,688	196,867,671	3,274	549,476,949
TOTAL IMPACT	**9,064**	**$ 793,726,156**	**7,686**	**$ 1,304,458,440**
UNITED STATES				
Direct	4,392	$ 556,689,215	3,574	$ 808,811,037
Indirect	2,945	226,004,763	2,481	457,333,745
Induced	6,051	355,638,053	5,273	981,849,949
TOTAL IMPACT	**13,388**	**$ 2,667,987,286**	**11,328**	**$ 2,247,994,731**

TOTAL IMPACT BY TYPE CONTINUED

	CAPITAL FUNDING		VISITOR IMPACT	
TYPE OF IMPACT	EMPLOYMENT	ECONOMIC OUTPUT	EMPLOYMENT	ECONOMIC OUTPUT
DUPAGE COUNTY				
Direct	258	$ 39,188,764	99	$ 10,712,932
Indirect	35	7,823,152	19	3,471,223
Induced	67	11,514,378	13	2,278,331
TOTAL IMPACT	**360**	**$ 58,526,294**	**131**	**$ 16,462,486**
COOK COUNTY				
Direct	187	$ 31,850,835	0	$ 0
Indirect	37	8,868,481	0	0
Induced	66	11,651,636	0	0
TOTAL IMPACT	**290**	**$ 52,370,952**	**0**	**$ 0**
CHICAGO AREA				
Direct	583	$ 87,814,233	89	$ 9,667,923
Indirect	123	30,348,559	19	3,717,175
Induced	287	51,158,498	29	4,862,177
TOTAL IMPACT	**993**	**$ 169,321,290**	**137**	**$ 18,247,275**
ILLINOIS				
Direct	613	$ 91,143,847	84	$ 9,148,546
Indirect	134	32,618,639	18	3,517,482
Induced	298	51,733,222	27	4,600,973
TOTAL IMPACT	**1,045**	**$ 175,495,708**	**129**	**$ 17,267,001**
MIDWEST REGION				
Direct	660	$ 97,240,783	79	$ 7,746,853
Indirect	206	50,029,028	19	3,592,955
Induced	388	64,989,663	26	4,279,489
TOTAL IMPACT	**1,254**	**$ 212,259,474**	**124**	**$ 15,619,297**
UNITED STATES				
Direct	805	$ 147,640,464	13	$ 1,357,888
Indirect	460	125,367,980	4	841,560
Induced	772	143,650,894	6	1,133,769
TOTAL IMPACT	**2,037**	**$ 416,659,338**	**23**	**$ 3,333,217**

Table 7.7: Argonne's total tax impact by government level, by funding type.

TOTAL IMPACT BY GEOGRAPHY

TYPE OF IMPACT	SUB-COUNTY *GENERAL*	SUB-COUNTY *SPECIAL DISTRICTS*	COUNTY	STATE	FEDERAL	TOTAL
Direct	$ 1.5 M	$ 1.3 M	$ 0.9 M	$ 7.6 M	$ 39.2 M	$ 50.5 M
Indirect	1.8 M	1.7 M	1.1 M	6.4 M	21.5 M	32.5 M
Induced	10.5 M	10.3 M	7.0 M	32.6 M	79.5 M	139.9 M
TOTAL IMPACT	**$ 13.8 M**	**$ 13.4 M**	**$ 9.0 M**	**$ 46.6 M**	**$ 140.2 M**	**$ 222.9 M**

D. PATENTS

Table 7.8: Number of Argonne patents by technology category, 2011–2022.

TECHNOLOGY CATEGORY	NUMBER OF PATENTS
Metal oxide	104
Layer	103
Non-aqueous	99
Transition metal	93
Lithium ion	78
Redox	31
Electrode material	28
Metal ion	22
Active material	21
Graphene	21
Ion exchange	20
Base material	10
Intermetallic	7
Reaction zone	6
Porous material	6
Microwave plasma source	5
Other	53

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