



ECONOMIC IMPACT OF  
**Pacific Northwest  
National Laboratory on  
the State of Washington  
in Fiscal Year 2018**

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PACIFIC NORTHWEST NATIONAL LABORATORY  
*operated by*  
BATTELLE  
*for the*  
UNITED STATES DEPARTMENT OF ENERGY  
*under Contract DE-AC05-76RL01830*

Printed in the United States of America

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# **Economic Impact of Pacific Northwest National Laboratory on the State of Washington in Fiscal Year 2018**

August 2019

JM Niemeyer

Prepared for  
the U.S. Department of Energy  
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory  
Richland, Washington 99352

## Highlights

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**\$960M**

Annual Spending



**\$465M**

Total Payroll

**\$432M** in Washington State



**4,414**

Employees

**93% (4,096)** living  
in Washington State in 2018

**25%** growth  
in employment 2000-2018



**\$25.6M**

Estimated taxes paid by PNNL and its  
employees to Washington State  
and local governments

## Highlights

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**\$1.46B**

Total economic output supported by PNNL payroll and domestic purchased goods and services

**\$732M** in Washington State wage income

**7,180** total jobs generated in Washington State



**\$331M**

Domestic purchased goods and services

**\$88.9M** in Washington State



**193**

Companies established with PNNL roots since 1965

**18** started in the last 10 years and still in business in WA

**~\$30M** revenue in WA

**150+** employees in WA



**\$858K**

Value of Battelle, PNNL, and PNNL employee cash contributions to philanthropic and civic organizations, including **\$273K** corporate support for STEM education

## Acknowledgements

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Pacific Northwest National Laboratory's (PNNL's) fiscal year (FY) 2018 Economic Impact Analysis report was prepared by PNNL Economist Michelle Niemeyer, with editorial support from Jennifer Blake and Julie Fisher and key contributions throughout the report by Christopher Larmey.

Other PNNL and Battelle staff members who provided the data used in this report include Lori Avery, Jonathan Bates, Jim Blount, Peggy Braxton, Andrea Brown, Peter Christensen, Sean Clausen, Robin Conger, Danielle Deichman, Timothy Doyle, Jeff Enger, Mindy Frankenfield, Mark Hattrup, Jennifer Knotts, Greg Koller, Terry Law, Jeffrey London, Jim Mather, Marisela Linares-Mendoza, Carol MacInnis, Lauren McKinney, Vanessa Moore, Jason Nanni, David Oates, Stacy Petersen, Marc Podratz, Bruce Simanton, Tanya Smith, Christie Sylvester, Annette Schutzenhofer, Evangelina Shreeve, Shirah Thietje, and Brianna Yi.

# Executive Summary

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PNNL is a large economic entity with a total of 4,414 employees, \$1.04 billion (B) in total funding, and \$960 million (M) in total spending during FY 2018.<sup>1</sup> The 4,096 PNNL staff members who live in Washington State comprise 93 percent of the Laboratory staff.

The Laboratory directly and indirectly supported \$1.46B in economic output, 7,180 jobs, and \$732M in Washington State wage income from current operations. The state also gained \$255M in output, 1,633 jobs, and \$102M in income through closely related economic activities such as visitors, healthcare spending, spending by resident retirees, and companies with PNNL roots.<sup>2</sup>

PNNL affects Washington's economy through commonly recognized economic channels, including payrolls and the purchase of goods and services that support Laboratory operations. Less commonly recognized channels also have their own impacts and include company-supported spending on healthcare for its staff members and retirees, spending of its resident retirees, Laboratory visitor spending, and the economic activities in a growing constellation of companies founded on PNNL research, technology, and managerial expertise.

PNNL has a significant impact on science and technology (S&T) education and community not-for-profit organizations. PNNL is an active participant in the future scientific enterprise in Washington with the state's K–12 schools, colleges, and universities. The Laboratory sends staff members to the classroom and brings hundreds of students to the PNNL campus to help train the next generation of scientists, technicians, engineers, and mathematicians. This investment in human capital, though difficult to measure in terms of current dollars of economic output, is among the lasting legacies of PNNL and Battelle.

Finally, Battelle contributes to the local community with millions of dollars' worth of cash and in-kind corporate and staff contributions, all of which strengthen the economy.

The purpose of this report is to quantify these effects, providing detailed information on PNNL's revenues and expenditures, as well as the impacts of its activities on Washington State's economy.

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<sup>1</sup> The latest PNNL data available was for FY 2018, spanning October 1, 2017, through September 30, 2018.

<sup>2</sup> Economic impact of PNNL's operations on Washington State varies annually, as federal research programs are dynamic and affected by levels of federal funding. For a comparison with selected other major technology entities in Washington State and with other Department of Energy national laboratories, see Appendix B.

## Acronyms and Abbreviations

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<b>ANL</b>	Argonne National Laboratory
<b>ARM</b>	Atmospheric Radiation Measurement
<b>B</b>	billion
<b>BNL</b>	Brookhaven National Laboratory
<b>DCAT</b>	Dynamic Contingency Analysis Tool
<b>DOE</b>	U.S. Department of Energy
<b>EMSL</b>	Environmental Molecular Sciences Laboratory
<b>FLC</b>	Federal Laboratory Consortium
<b>FY</b>	fiscal year
<b>gsf</b>	gross square feet
<b>GSP</b>	gross state product
<b>IMPLAN®</b>	IMpact analysis for PLANning
<b>INL</b>	Idaho National Laboratory
<b>IP</b>	intellectual property
<b>K</b>	thousand
<b>LBNL</b>	Lawrence Berkeley National Laboratory
<b>M</b>	million
<b>MESA</b>	Mathematics, Engineering, and Science Achievement
<b>NAICS</b>	North American Industry Classification System
<b>NREL</b>	National Renewable Energy Laboratory
<b>OASI</b>	Social Security Old Age and Survivors' Insurance
<b>ORNL</b>	Oak Ridge National Laboratory
<b>PNNL</b>	Pacific Northwest National Laboratory
<b>R&amp;D</b>	research and development
<b>SC</b>	Office of Science
<b>S&amp;T</b>	science and technology
<b>STARS</b>	Solar Thermochemical Advanced Reactor System
<b>STEM</b>	science, technology, engineering, and mathematics
<b>U.S.</b>	United States
<b>WBL</b>	Work-Based Learning

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# Introduction

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PNNL is the nation’s premier laboratory for scientific discovery in chemistry, earth sciences, and data analytics, and for technology solutions to the nation’s toughest challenges in energy resiliency and national security. Based in Richland, Washington, PNNL is one of ten United States (U.S.) Department of Energy (DOE) Office of Science (SC) national laboratories. Operated by Battelle Memorial Institute, PNNL had 4,414 staff members and a total Laboratory cost of approximately \$960M during FY 2018.

PNNL has a global reputation for its work in climate and environmental science and for its many important contributions to the understanding of clouds and aerosols, two major sources of uncertainty in earth system science. PNNL is leading the community in efforts to gain deeper insights into the function of the integrated water cycle and biogeochemical processes that influence weather and environmental resilience. Also, recognized for its leadership in catalysis and chemical conversion, PNNL is on the leading edge of innovation in the development of new chemistries and materials for advanced energy storage to meet the nation’s growing needs for secure, resilient, and clean electric power. Building upon its strong base of discovery science, PNNL leads in the design, testing, and evaluation of technologies for power grid resiliency, visualization, and optimization, and in the development of grid cyber security defenses. PNNL is also a critical contributor to national security, developing technology solutions to transform the cyber security landscape. The Laboratory is providing the most advanced tools to strengthen the cyber defenses of the nation’s most critical infrastructure and web-connected systems, and to transfer strategic advantage from cyber attackers to cyber defenders.

On behalf of DOE-SC’s Office of Biological and Environmental Research, PNNL operates the Environmental Molecular Sciences Laboratory (EMSL) and provides technical and operational leadership to the Atmospheric Radiation Measurement (ARM) Climate Research Facility. The Radiochemical Processing Laboratory, a Hazard Category II non-reactor nuclear facility, enables innovative radiological material processes and solutions for environmental, nuclear energy, and national security research. PNNL operates DOE’s only facility for marine sciences (the Marine Sciences Laboratory) in Sequim, Washington, building upon a rich history of research related to marine and coastal resources, environmental chemistry, water resources modeling, ecotoxicology, biotechnology, and national security. PNNL also has satellite offices in Seattle, Washington; Portland, Oregon; and College Park, Maryland.

## PNNL as an Economic Entity

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### PNNL Revenues and Expenses

During FY 2018, PNNL’s total funding was \$1.04B and total spending was \$960M (Figure 1 and Figure 2, respectively). The majority of the work that PNNL performs is for DOE (63 percent during FY 2018).

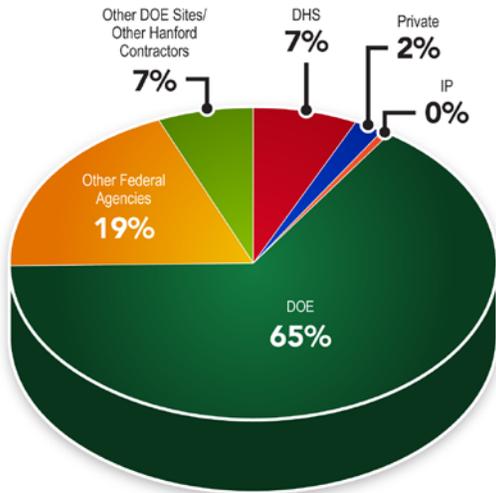
Work conducted for other federal agencies includes the U.S. Department of Defense, the Nuclear Regulatory Commission, the U.S. Department of Health and Human Services, and other federal agencies that collectively represent 20 percent of PNNL’s business volume. The U.S. Department of Homeland Security also plays a major role.

**\$1.04B**

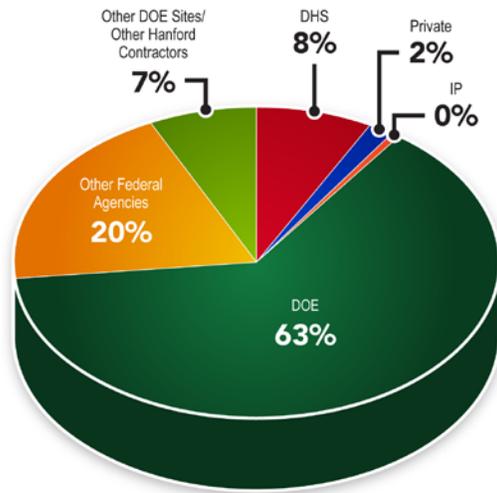
*FY18 funding*

**\$960M**

*FY18 spending*



**Figure 1.** PNNL's Total Funding in FY 2018



**Figure 2.** PNNL's Spending in FY 2018

## PNNL Employment

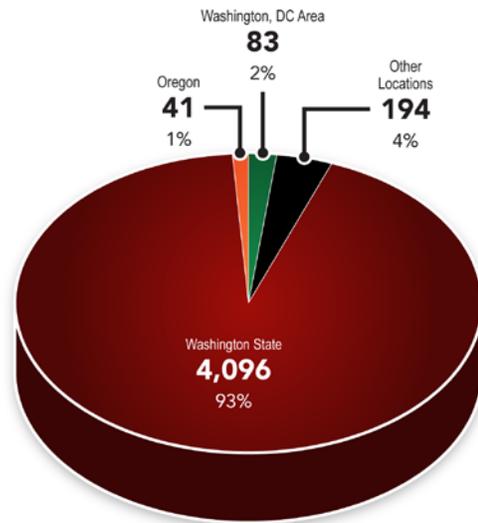
PNNL employed 4,414 people in FY 2018, 4,096 of whom were residents of Washington State and worked mainly in Richland, Seattle, and Sequim (see Figure 3).

**25%** employment growth FY00–FY18

**4,414** staff members

**93% (4,096)** employed & residing in Washington

Nearly 93 percent of the PNNL workforce resides in Washington State (81 percent in Benton County and 11 percent in Franklin County). Of the staff members residing in Benton and Franklin Counties, 52 percent reside in Richland, 20 percent in Kennewick, 12 percent each in Pasco and West Richland, and the remaining 4 percent reside elsewhere in the two counties.



**Figure 3.** Location of PNNL Employees

In addition, there were 83 staff members in the Washington, D.C., area; 41 staff members assigned to work in Corvallis and Portland, Oregon; and 194 staff members employed at other locations in the United States or in foreign countries.

## PNNL's Payroll and Benefits

PNNL's total payroll during FY 2018 was \$465M, of which \$432M went to staff members employed in Washington State. Because the Laboratory is a research and development (R&D) organization, PNNL has a large percentage of high-wage professions (see the average wages of other selected Washington R&D organizations and other DOE national laboratories in Appendix B).

The average annual wage for all Washington State PNNL employees at the end of FY 2018 was \$105,533.<sup>3</sup> In 2018, the state average occupational wage was \$64,588.<sup>4</sup> As such, the average PNNL worker likely spends at a higher level and, therefore, has an above-average impact on the state economy compared with the average worker in the state.

While not directly part of wages, benefits outlays contribute to PNNL's economic impact. PNNL provides a benefit package that costs \$90M per year. Included are an employer-provided health insurance package, employer matching of a portion of employee 401K contributions, a defined benefit pension plan, and other items (e.g., disability, tuition refunds, and group life insurance).

**\$465M** in  
payrolls

**\$432M** of  
payrolls going to  
Washington  
residents

**\$83.3M** for  
employer-provided  
benefits  
supporting  
Laboratory  
operations

## Purchased Goods, Services, and Investments

**\$88.9M** in  
purchases from  
Washington firms

During FY 2018, PNNL placed domestic procurements for \$331M in goods and services to support operations of the Laboratory. Table 1 shows that a wide variety of goods and services were purchased, including small scientific equipment and subcontracts with universities, consultants, and research firms. Of the total, 27 percent (or \$88.9M) of the purchases were made from Washington State firms.

**Table 1.** FY 2018 PNNL Purchased Goods and Services Spending (total U.S. domestic and in Washington State)

Type of Expenditure	Total (\$M)	In WA (\$M)
Construction	\$16.0	\$13
Finance, Insurance, Real Estate	\$26.0	\$13
Computers, Lab Equipment, Software, Services, Retail Trade	\$71.0	\$19
Utilities, Transportation, Publishing, Management, and Business Services	\$106.0	\$14
Technical and Scientific Subcontractors	\$74.0	\$23
Medical and Health Services	\$2.1	\$2.1
All Other	\$36.0	\$6
<b>Total*</b>	<b>\$331.07</b>	<b>\$88.9</b>

*\*Detail may not sum to total because of rounding.*

<sup>3</sup> \$105,533 includes student employees, which reduces the PNNL average. For comparable data on other Washington State R&D organizations and other DOE national laboratories, see Appendix B.

<sup>4</sup> Weighted average for all occupations that published both average annual wage and number of workers is \$64,588.

## Expenditures for New Construction and Renovations

PNNL is based in southeastern Washington State, with several off-site locations. The main campus, located at the north end of Richland, consists of land owned by DOE, Battelle, and third parties.

In FY 2018, PNNL’s facility profile comprised 75 buildings and 44 other structures, including the following:

- 23 DOE-owned buildings and 21 other DOE structures and facilities (924,000 gross square feet [gsf]) on approximately 455 acres
- 21 Battelle-owned facilities (402,000 gsf) and 23 other structures and facilities on approximately 326 acres, including approximately 117 acres in Sequim, Washington
- 30 buildings from third-party leases and agreements (973,000 gsf).

**80** construction projects supported by **\$20.9M** in-state subcontractor construction spending

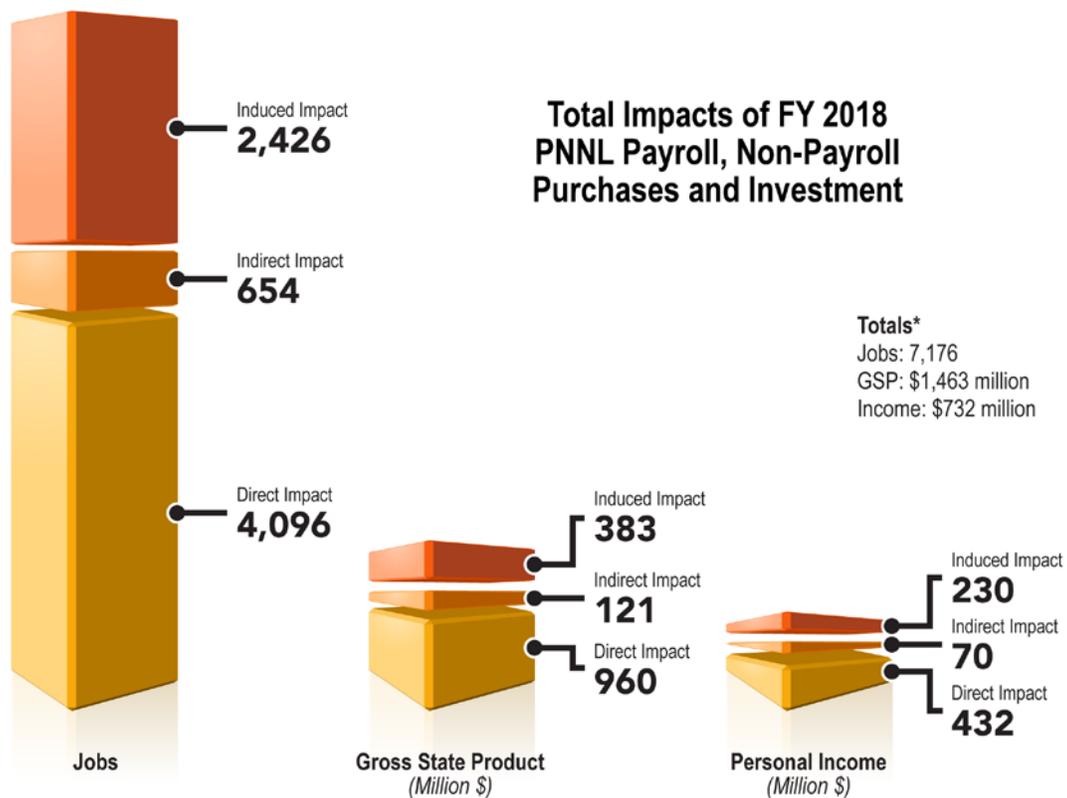
Large scientific enterprises like PNNL must periodically renovate their research facilities and procure major scientific equipment as their scope of work, scientific knowledge base, and responsibilities change. PNNL makes these investments through its Facilities and Infrastructure budgets.

FY 2018 was an active year for making Facilities and Infrastructure investments, with major renovations worth \$28M (see Table 2). All PNNL major renovations were performed on buildings located in Washington State. Of this total, 78 percent (\$22M) included reimbursements to subcontractors working on PNNL buildings, including out-of-state contractors working on in-state projects.<sup>5</sup> Washington State resident subcontractors earned \$20.9M of this \$21.5M, or 97 percent. Total costs other than PNNL labor related to these renovations are included in the \$331M non-payroll purchases listed in Table 1. An estimated 80 construction projects were supported by the \$20.9M in in-state subcontractor construction spending. These are included in the total impacts detailed in Table 2 and Figure 4.

**Table 2. PNNL Construction Spending in FY 2018**

FY 2018 Renovations	Total Spending (\$M)
PNNL Labor Costs	\$5.1
Miscellaneous Procurements	\$1.0
Disbursements to Subcontractors	\$21.5
<i>Item: Disbursements to Washington State Subcontractors = \$15.2M</i>	
<b>Total Renovation Spending</b>	<b>\$27.6</b>

<sup>5</sup> Renovations of PNNL building space or other construction activities conducted in other states (Oregon; the Washington, D.C. area; and other places where PNNL may be conducting research or other activities) are assumed not to affect the Washington State economy.



**Figure 4.** FY 2018 Economic Impact of Washington Payroll and Purchased Goods and Services Expenditures by PNNL

## PNNL State and Local Taxes Paid

**\$25.6M** paid  
 in local and  
 Washington taxes

PNNL and its employees paid a total of approximately \$25.6M in local and Washington State taxes, which includes sales and use taxes, property taxes, and a few others (e.g., motor fuel taxes).<sup>6</sup> Employee taxes were based on the total \$432M in wages of PNNL employees who work in Washington (and for the purpose of this analysis are assumed to live in WA) and the 2017 state and local governments' collection rates (for every dollar of personal income). The rates are an estimated \$0.026 in sales, use, and other production-related taxes by individuals; \$0.027 in state and local property tax collections; and \$0.002 in other taxes per dollar of personal income. The estimated tax payments by employees are shown in Table 3.

In total, PNNL paid \$1.68M in state and local taxes, and employees paid \$23.91M. In addition, the Laboratory paid \$3M into the state's unemployment and workers' compensation insurance systems during the fiscal year. This payment is not considered a tax and, therefore, is not included in the total.

<sup>6</sup> Washington State does not have a personal or corporate income tax.

**Table 3.** FY 2018 Washington State and Local Taxes Paid by PNNL and Its Employees

Washington Tax Category	<i>Paid by PNNL in FY 2018 (\$K*)</i>	<i>Estimated Paid by PNNL Employees in FY 2018 (\$K)**</i>
Sales and Use Taxes	\$231	\$11,378
Business and Occupation Taxes	\$372	\$0
Property Taxes	\$1,080	\$11,866
Other State and Local Taxes	Negligible	\$666
<b>Total*</b>	<b>\$1,680</b>	<b>\$23,911</b>

\* K = thousand  
 \*\* Detail does not sum to total because of rounding.

## Economic Impact of PNNL Operations



PNNL’s expenditures on operations (payrolls and non-payroll purchases) generate additional economic activity in Washington State. The dollar value of PNNL’s output, employment, and wages are measurements of PNNL’s *direct* economic activity. In turn, companies that supply goods and services to PNNL and its employees also buy goods and services. This is called *indirect* economic activity. Since many of the indirect purchases are made in Washington, much of the indirect economic activity also occurs in Washington State.

Finally, when workers in the direct and indirect supplying firms spend their wages for goods and services, they *induce* additional output, employment, and wages in retail and services firms and their suppliers. The sum of direct, indirect, and induced impacts is usually called the *total impact* on output, employment, or income. The total value of output (value of goods and services) produced in the state is also called *GSP*. Finally, the ratio of total to direct impact is called the *multiplier effect*.<sup>7</sup>

Figure 4, above, shows estimates of direct, indirect, induced, and total impacts of PNNL payroll and non-payroll procurement spending in Washington State. The direct PNNL activity is shown as the lower bars: \$960M contribution to GSP in Washington, 4,096 Washington jobs, and \$432M in Washington wages. Together, with the indirect (middle bars) and induced (upper bars) impacts, the total impacts are \$1.46B in GSP, 7,175 jobs, and \$732M in total wages in Washington State.

<sup>7</sup> This study uses the IMPact analysis for PLANning (IMPLAN®) economic model (discussed in Appendix A) to estimate the indirect and induced impacts and total impact of PNNL direct payroll, benefits, in-state non-payroll purchases, and investment-related expenditures on Washington State GSP, employment, and personal income.

## Other Economic Influences

**\$41M** (approximate)

health-related services  
funded by health insurance

**\$26M** retired employees'

health insurance spending

**\$68M** FY18 total

estimated health insurance  
spending in Washington

This section of the report provides estimates of the total impact of economic activity that, while not strictly PNNL activity, would not exist in Washington State without the presence of the Laboratory. These activities include healthcare insurance expenditures on behalf of PNNL employee and retiree households, spending by PNNL retirees, spending by companies that have their “roots” at PNNL and likely would not be located in Washington State except for the presence of the Laboratory, and spending by visitors to the Laboratory who are paid by other institutions.

### Healthcare Expenditures

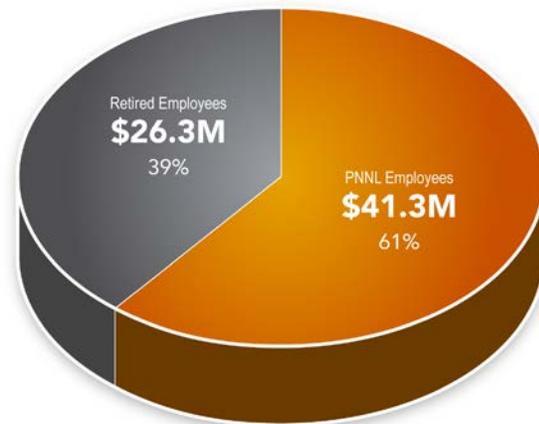
Health insurance expenditures for PNNL’s 4,096 Washington State employees, 2,101 retirees, and their households in the state of Washington totaled an estimated \$68M in FY 2018. PNNL’s direct medical and dental insurance expenditures on behalf of employee households in Washington were estimated at \$41M (see Figure 5).

Total costs of over \$26M for retired households were based on Kaiser Family Foundation estimates of per capita expenditures by type for healthcare in Washington State in 2014, adjusted to 2018 dollars. While not directly related to current Laboratory activity, because they are insurance payments, healthcare expenditures depend on the presence of Laboratory employees and have a substantial additional economic impact.

### PNNL Retirees

Although they are no longer paid by PNNL, many former employees have retired in Washington State and represent a significant additional source of consumer spending in the state’s economy. There are three principal sources of income that support this spending: pension benefits, federal Social Security Old Age and Survivors’ Insurance (OASI) benefits, and accumulated personal savings.

In FY 2018, the Battelle-defined benefit pension plan for PNNL employees paid out \$66M to 2,800 retirees and other beneficiaries. The PNNL pension benefit was an average of \$1,958 per month,



**Figure 5.** Estimated Spending for Washington PNNL Employee and Retiree Healthcare in FY 2018

per person, in Washington. For purposes of this report, 2,101 (75 percent) PNNL retirees were reported to live in Washington State.<sup>8</sup>

The estimated average monthly payment per OASI retired beneficiary in FY 2018 was \$1,405 in Washington. Because PNNL retirees have had salaries about 1.6 times the state average salary, Social Security calculator software shows that their average OASI payment would be 1.4 times the Washington State average. Information in Table 4 assumes that the 2,101 Washington PNNL retirees receive 1.4 times the OASI payment of the average retiree in the state, or about \$1,970 per month, for a total estimated \$49M. Pensions and Social Security together total \$132M, of which about \$99M is estimated to be spent in the state on goods and services. No estimate is available for spending of personal savings by PNNL retirees.

**Table 4.** Estimated Washington State PNNL Retiree Income in FY 2018

	<i>Estimated Average Retiree Monthly Income in FY 2018</i>	<i>Total Retiree Annual Income in FY 2018 Income (\$M)</i>
Pension	\$1,958	\$49
OASI (Social Security)	\$1,970	\$50
<b>Total</b>	<b>\$3,928</b>	<b>\$99</b>

## Technology Transfer

### Technology Commercialization: New Products and Companies with PNNL Roots

Many of PNNL’s research activities generate ideas and inventions (i.e., intellectual property [IP]) that have commercial value. PNNL prides itself on rapidly deploying this IP into the marketplace in cooperation with new or existing firms.

Since 1965, 193 companies were started that had technological or managerial roots at PNNL, and 100 of those are still in business. Forty-one (41) of those companies were started in the last 10 years, and Table 5 shows that 34 of them were still operating in FY 2018 and have more than 290 employees. Eighteen (18) of those companies are located in Washington State and have over 150 employees and estimated sales of \$30M.

**Table 5.** Companies with Ties to PNNL (established in last 10 years and still operating)

	<i>Total</i>	<i>In Washington State</i>
Number of Firms	34	18
Estimated Sales (\$M)		\$30
Employment	>290	>150

## Intellectual Property

While undoubtedly there is value in investing in the future or in Washington’s current quality of life, there are other aspects of PNNL’s presence in Washington State that are much more difficult to calculate in terms of the state’s GSP or employment. The first of these is IP created by PNNL R&D activities.

<sup>8</sup> Direct data from the pension administrator were available on PNNL retiree locations for FY 2018. Of 2,800 retirees, 2,101 had Washington addresses.

Often, federally funded research results in scientific and engineering solutions that have intellectual property value. Table 6 reflects the number of technologies or software that were disclosed, patented, or copyrighted in FY 2018, but it is much harder to put a dollar value on newly discovered fundamental principles in proteomics or calculate the future economic value associated with a new energy-saving approach, securing U.S. border crossings, or reducing greenhouse gases, let alone developing new ways to process terabytes of data or the discovery of a new organism. PNNL is transferring technologies—primarily through IP options and licenses—nearly once every 10 days, including 45 new license agreements during FY 2018.

**Table 6.** PNNL Statistics on Inventions, Patents, Technology Transfers, and License Income

	<i>New FY 2018</i>	<i>Cumulative 2000–2018</i>
Invention Disclosure	208	4,397
Patent Applications	67	1,348
Patents Received	41	935
Licenses and Options	45	635
<b>Total License Revenue Received</b>	<b>\$3.6M</b>	<b>\$66.3M</b>

PNNL continues to lead all other DOE laboratories in implementation of Agreements for Commercializing Technology, having 84 agreements with 71 different private organizations. In FY 2018, PNNL had 41 active Cooperative Research and Development Agreements and 237 non-federal Strategic Partnership Project agreements. Table 6 provides additional highlights of these efforts, including invention disclosures, patent applications, patents issued, commercial options and licenses issued, and license revenues earned. Licensing revenues totaled \$3.6M in FY 2018. A significant portion of these funds are reinvested at the Laboratory for additional commercialization-focused development work.

## Honors and Awards

In FY 2018, PNNL research was cited for two of the 100 most innovative scientific breakthroughs of the year, as announced by *R&D Magazine*. These two awards bring the cumulative total of PNNL’s R&D 100 Awards to 109.

- Dynamic Contingency Analysis Tool (DCAT) – Researchers: Nader Samaan, Jeff Dagle, Yuri Makarov, Ruisheng Diao, Yousu Chen, Qiuhua Huang, Renke Huang, Xinya Li, Laurie Miller, Tony Nguyen, Frank Tuffner, Mallikarjuna Vallem, and Bharat Vyakaranam. Ever-increasing cyberattacks and natural disasters can wallop the nation’s electric grid, potentially causing cascading power outages that cost utilities and their customers billions of dollars. PNNL’s answer for minimizing the impact of extreme events on the power grid is DCAT. By simulating thousands of extreme events, DCAT automatically meshes the evaluation of steady-state operations with changing occurrences in the electric grid to find weak spots. Once a weakness is identified, DCAT determines the impacts that would result from a cascading power outage and provides the power operator with actions to stop the outage before it happens. With DCAT, utilities would gain at least 50 percent in efficiency for analyzing grid occurrences compared to today’s more manual processes.
- StreamWorks – Researchers: Sutanay Choudhury, Khushbu Agarwal, Sherman Beus, and George Chin. One hundred and forty-six days—that’s how long, on average, it takes to detect a cyberbreach

**2** FY18  
R&D 100 Awards

**109** R&D 100  
Awards total

from the time it begins. PNNL’s StreamWorks cuts that time significantly—to near real-time—by detecting emerging patterns of sophisticated cyberattacks in massive data streams. Combining several analytic approaches, never before seen together in a cybersecurity tool, the technology tells a cyber analyst when major suspicious patterns are occurring, along with a description of the potential threat and a rationale for why the threat was selected—so the analyst doesn’t have to guess, but instead can take action swiftly.

The Federal Laboratory Consortium (FLC), a nationwide network that encourages federal laboratories to transfer laboratory-developed, taxpayer-funded technologies to commercial markets, awarded PNNL with three Excellence in Technology Transfer Awards in FY 2018. These three awards bring PNNL’s total to 88, which is almost a quarter of the total FLC awards won by all DOE-SC laboratories.

**3** FY17 FLC  
Technology  
Transfer Awards

**88** FLC  
Awards total

- Suite of Cyber Tools: ABCD, MLSTONES, and SerialTap – PNNL: Glenn Fink, A. David McKinnon, Jereme Haack, Keith Star, Eric Choi, Thomas Edgar, Chris Oehmen, Elena Peterson, Aaron Phillips, and Kannan Krishnaswami; Cynash, Inc.: Richard Robinson; IP Group, Inc.: Scott Forbes; Former Department of Homeland Security: Michael Pozmantier; Department of Homeland Security: Nadia Carlsten. A trio of cybersecurity technologies—Ant-Based Cyber Defense, MLSTONES, and SerialTap—were developed by PNNL researchers independent of each other to address the need for scalable defense, identification of constantly changing malware, and to protect legacy systems, respectively. They were discovered in the Department of Homeland Security’s Transition to Practice Program, designed to present promising cyber technologies to entrepreneurs and potential investors. The result—an introduction and subsequent partnership of two entrepreneurs who formed a new startup company, Cynash, Inc., and licensed the cyber trio in August.
- Structures for Lossless Ion Manipulations – PNNL: Richard D. Smith, Yehia Ibrahim, and Bruce Harrer; MOBILion Systems, Inc.: Melissa Sherman and Ahmed Hamid; GAA Engineering: Gordon Anderson. Structures for Lossless Ion Manipulations—or SLIM—is expected to dramatically change how doctors analyze complex biological samples. It is 1,000 times faster than typical analysis methods, with unprecedented sensitivity that can identify trace amounts of molecules—potentially performing analyses never before thought possible. A startup company, MOBILion Systems, Inc., licensed the technology in January 2017. PNNL worked closely with MOBILion to tailor the technology to meet the company’s vision and sent a staff member to join MOBILion, part-time, to assist with the transfer.
- Solar Thermochemical Advanced Reactor System (STARS) – PNNL: Derek Maughan, Charlie Freeman, and Bruce Harrer; STARS Technology Corporation: Bob Wegeng, Peter Brehm, Chris Klasen, and Daryl Brown; Southern California Gas: Ron Kent. STARS converts 70 percent of solar energy run through the technology into chemical energy—such as transportation fuel or electricity. Use of this solar energy eliminates the need to burn fossil fuels to generate heat, reducing carbon emissions by as much as 40 percent. The spinoff company that licensed the technology, STARS Technology Corporation, is made up of three former PNNL employees who invented the technology, as well as their long-time industry mentor. The four STARS Technology Corporation principals were participants of DOE’s inaugural Energy I-Corps, a two-month business training program—graduating best in class and transferring the knowledge gained into formation of their company.

# STEM Education and Work-Based Learning

## The Office of STEM Education

The Office of Science, Technology, Engineering, and Mathematics (STEM) Education aligns the Laboratory's education efforts with national, state, and local initiatives to realize change in STEM education and to address workforce challenges. Through External Affairs, the Office of STEM Education connects PNNL resources with community, regional, and national STEM education stakeholders to help achieve the research, diversity, and education priorities of DOE; it focuses on building and expanding relationships with foundations, government sponsors, education institutions, and others to improve and accelerate the growth of STEM education and workforce preparation.

The Office of STEM Education led five signature STEM education outreach efforts in FY 2018. These included 1) the Washington State Mathematics, Engineering, and Science Achievement (MESA) program; 2) Teacher Scientist Partnerships; 3) STEM Ambassador Fellows Initiative; 4) DOE Regional Science Bowl; and 5) increased focus on the computing and cybersecurity workforce pipeline.

PNNL leads the Yakima Valley/Tri-Cities MESA program. The MESA initiative focuses on increasing the number of underrepresented students pursuing post-secondary education and entering the workforce in STEM fields by providing enriching, hands-on opportunities in mathematics, engineering, and science for students in grades 6–12. Teacher Scientist Partnerships pairs teachers and scientists to bring the world of scientific research conducted at PNNL together with the classroom experience, empowering both to have an impact on the next generation of highly skilled and diverse STEM workers. The STEM Ambassador Fellows Initiative provides professional development for researchers that allows them to channel their enthusiasm for science and helps them to effectively communicate and demonstrate their work with the general public.

The DOE Science Bowl is a regional and nationwide academic competition that tests students' knowledge in all areas of science and mathematics. PNNL's contributions include planning and implementing an annual regional event, as well as continually engaging students and teachers. While PNNL understands the importance of increasing the STEM workforce pipeline overall, the Laboratory is placing particular emphasis on computing sciences and cybersecurity, because the demand for skilled workers in those fields is growing rapidly. The multi-faceted effort includes career-focused learning experiences for students and content workshops and professional development for educators. It also includes leveraging PNNL's university partnerships to increase the opportunities for, and caliber of, computing education in local, state, and regional institutions.

PNNL also provided leadership for efforts related to the implementation of the Next Generation Science Standards in Washington State and was an active participant in the development of the computer science education standards that have been adopted by Washington State.

Through our Teacher Scientist Partnerships, we worked with the Cal Poly's Science Teachers and Researchers program and the Murdock Charitable Trust's Partners in Science Program to connect education and research in ways that better prepare pre-service and in-service STEM teachers for the classroom. Other 2018 outreach efforts included the Teacher Professional Development Programs, the DOE Cyber Defense Competition, CyberPatriots Camp, Pacific Science Center Curiosity Days, and Washington State Leadership and Assistance for Science Education Reform.

## Work-Based Learning

Work-Based Learning (WBL) is a trusted and valued collaborator in DOE's Workforce Development for Teachers and Scientists program. WBL programs 1) establish a laboratory climate where developing students is recognized as a valued activity; 2) preserve, share, and pass on academics, research, professional protocol, knowledge, and skills; 3) provide opportunities for empowerment and self-determination that transcend age, ethnicity, gender, and race; 4) expose undergraduate students to other networking opportunities with STEM faculty, professionals, and students; and 5) advise students on academic courses to better prepare themselves for graduate school and, ultimately, for STEM careers.

The Office of STEM Education and WBL intersect in their goal to increase STEM opportunities for all students. Programs within STEM Education and WBL represent a long-term commitment and investment in the human capital of the nation's and state's future workforce. In FY 2018, DOE-SC provided project funding, and the Laboratory spent \$828,000 for post-secondary student and faculty programs. PNNL's Intern and Fellowship Management and Administration Pool was \$1,360,000. Finally, PNNL spent \$1,189,000 in overhead funds to support WBL (high school and post-secondary), STEM education, and outreach efforts (K-16).

In FY 2018, there were approximately 7,382 pre-college, undergraduate, graduate, post-graduate, and faculty researchers who participated in STEM education or WBL programs or used PNNL's Intern and Fellowship Service Center.

Employees are called either interns (students matriculating toward a degree) or research associates (post-graduates). Non-employees are called fellows, and they are undergraduates, graduate students, K-12 and university faculty, and visiting scientist appointments. Of these participants, 142 were fellows (non-PNNL employees) and 1,147 were interns or research associates. In FY 2018, 9 fellows and 334 interns/associates were from Washington State institutions.

In addition to the K-12 efforts led by Office of STEM Education, WBL had 65 high school students with academic year or summer research experiences at PNNL. In FY 2018, PNNL's K-12 efforts involved 2,147 students and 950 educators, almost all of whom were from Washington State institutions. Table 7 shows statistics on the Office of STEM Education and WBL programs.

## OTHER STEM EDUCATION PROGRAMS

*PNNL has strong post-graduate research programs at the post-bachelor, master, and PhD levels. These programs include the PNNL National Security Internship Program and the PNNL Post-Secondary and Post-Graduate Research Internship programs.*

*PNNL hosts several students each year in programs funded by outside sources or initiatives. These opportunities may require the student to apply to an outside program and request placement with PNNL. These include DOE-SC Community College Internships, Mickey Leland Energy Fellowships, Science Undergraduate Laboratory Internships and Visiting Faculty Program, and Department of Homeland Security Fellowship Program.*

*PNNL also hosts alternate-sponsored fellowship visitors and interns funded by home institutions and other sources.*

**Table 7. Statistics on the PNNL STEM Education Programs in FY 2018**

PNNL Programs in STEM Education	Participation in FY 2018
<b>Post-Secondary Programs</b>	
Four DOE-SC University Internship/Fellowship Programs	33 faculty, 89 students
Department of Homeland Security Fellowship	1 student
PNNL Post-Graduate and Post-Secondary Internships	1,147 students
PNNL National Security Internships	95 students
PNNL Alternate Sponsored Fellowships	195 students, faculty, and visiting scientists
PNNL K–12 STEM Teacher Programs	9 students (pre-service teachers)
<b>K–12 Student Programs</b>	
PNNL High School Interns	65 students
DOE Science Bowl	120 students
High School Shadow Program	8 students
Delta/Chiawana (STEM) High School Programs	24 faculty, 420 students
<b>K–12 Teacher Programs</b>	
Leadership and Assistance for Science Education Reform	578 educators

PNNL has 106 staff members serving as adjunct or joint appointment faculty at colleges and universities. Fifty-seven (57) of these staff members teach or have joint appointments in Washington State colleges and universities. Many staff members also act as PhD dissertation and master’s thesis committee members, guest lecturers, mentors, or volunteers for education programs at both the collegiate and K–12 level.

## PNNL Visitors

PNNL hosts thousands of business visitors each year, many of whom are from outside the state of Washington and contribute their spending to the state’s visitor economy. Direct impact of PNNL visitor spending was estimated from 2017 county-level per capita visitor spending statistics compiled by Dean Runyan Associates for Washington Tourism Alliance.<sup>9</sup>

Table 8 shows the statistics for out-of-town visitors to PNNL facilities in 2018, identified through PNNL visitor badges.<sup>10</sup> Visitor badges are issued for a specific period of time, and the total requested number of days was used as an estimate of visitor days. The estimate is intended to exclude local visitors, such as repair persons and vending machine operators, who are required to have visitor badges to access most PNNL facilities but are assumed not to contribute to tourism spending. Total costs of \$3.6M are based on statewide traveler spending averages, adjusted for Benton County’s lower-than-average accommodation costs as a proportion of total spending.

<sup>9</sup> Dean Runyan Associates. 2017. *Washington State Travel Impacts & Visitor Volume, 2000-2017p*.

<sup>10</sup> Several hundred individuals from DOE, other national laboratories, and subcontractors that visit PNNL each year have recognized credentials and do not require visitor badges. No count exists for visits by these individuals, but they also add to the economic impact. Badges are issued for a period of time that includes, but is not restricted to, the dates when visitors are actually at PNNL. This results in an overestimate of the number of days per visitor when visitors are present on-site. In the case of badges issued for site tours and on-site meetings, the raw numbers of days were adjusted downward to better reflect the number of days that visitors actually spend on-site. A similar adjustment was made for badges issued to visitors such as university researchers working at PNNL or needing access to laboratory space.

**Table 8.** Number of Out-of-Town Visitors and Visitor Days to PNNL Facilities

PNNL Visitor Statistics	
Number of out-of-town visitors	5,469
Estimated total visitor days	24,506
Estimated tourism expenditures	\$3.6M

## Community Investments and Assistance

Since 1965, Battelle has invested more than \$28M to improve science, education, and quality of life in Washington State. Over the past 10 years, staff members at PNNL have volunteered 335,000 hours to community projects, including 39,100 Team-Battelle-volunteered hours in FY 2018.

Staff members at PNNL serve on the boards of many community organizations, including the Association of Washington Business, Washington Roundtable, Washington State University Tri-Cities Advisory Committee, Tri-Cities Development Council, Tri-Cities Regional Chamber, The REACH Foundation, Washington Clean Tech Alliance, and the Washington State STEM Education Foundation.

The Makerspaces, Math is Cool, Tri-Cities Food Bank, For the Love of Giving, and Tumbleweed Music Festival are a few of the numerous Team Battelle projects from FY 2018.

Table 9 shows quantitative measures of PNNL and Battelle’s community assistance, including corporate and individual financial giving.

**Table 9.** PNNL and Battelle Community Assistance Statistics for FY 2018

Washington State Community Assistance	
Battelle cash donations to health, human services, and other philanthropic and civic organizations*	\$548,000
PNNL memberships in Washington civic organizations	\$101,000
Staff member contributions to United Way	\$209,000
<b>Total</b>	<b>\$858,000</b>

*\*Includes the \$273,000 donation to STEM education.*

## EMSL and ARM Users

PNNL operates EMSL and provides overall technical direction for the ARM user facility on behalf of the Office of Biological and Environmental Research. Both of these user facilities have a variety of users in the national and international science community. In the case of EMSL, the physical facility is located on the PNNL campus in Richland, Washington. Some users visit in person, while others access the facilities and their capabilities via remote portal. Many of EMSL’s users are Washington State companies or educational institutions (shown in Table 10). With remote access, the group of outside users is broader.

**Table 10.** FY 2018 EMSL Users

	Total EMSL Users	Washington State Users
EMSL total users	561	266
International (foreign) users	62	0
U.S. users	499	266
Non-PNNL U.S. users	276	42

The ARM user facility is a multi-platform scientific user facility designed to improve the understanding and representation in climate and earth system models, as well as clouds and aerosols, and their interactions and coupling with the earth's surface.

ARM provides the international research community with unparalleled infrastructure for obtaining precise observations of key atmospheric phenomena needed to advance scientific understanding of atmospheric processes and climate models.

In FY 2018, there were 1,173 unique ARM scientific users: 507 from universities, 31 from industry, 213 from DOE laboratories, 94 from other federal agencies, and 328 foreign. Three hundred and seventy-seven (377) users used ARM's facilities' on-site assets, 86 used off-site services, and 710 used data services. The vast majority of ARM users do not visit PNNL but interact with the facility by downloading data or by visiting one of the remote ARM field sites. ARM has approximately 60 employees at PNNL, not all of whom are full-time.

## **Economic Impact of Closely Related Activity**

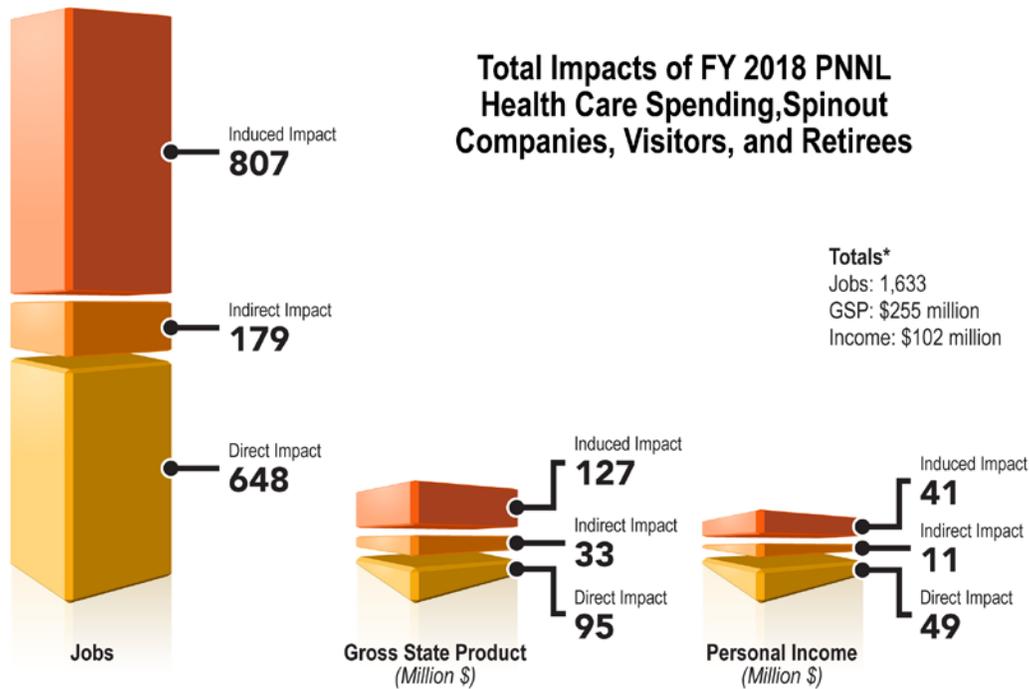
Spending by the four closely related economic activities (spending on health-related services, spending by companies with PNNL roots, and spending by PNNL visitors and retirees) also creates significant additional economic activity in the state. Taken together, these activities directly employ 648 people and generate a GSP of \$95M. The IMPLAN model calculates that, when the indirect and induced economic impacts are taken into account, a total of \$255M in GSP, 1,633 jobs, and \$102M in labor income depend on these activities (see Figure 6).

## **ENVIRONMENTAL MOLECULAR SCIENCES LABORATORY**

*Through EMSL, scientists gain a predictive understanding of biological and environmental systems across temporal and spatial scales—a necessary step in the development of sustainable solutions to the nation's energy and environmental challenges.*

*Research focuses on understanding the mechanisms that drive the flow and stabilization of nutrients and contaminants through the plant-microbe-soil-atmosphere system and the interplay with biogeochemical and hydrologic processes in natural ecosystems and managed bioenergy crops, as well as enzymatic and metabolic processes involved in the production of lignocellulosic biofuels and bioproducts.*

*EMSL provides a collaborative team research environment that includes high-performance computational capabilities linked directly to suites of state-of-the-art experimental instruments. By shortening the time required to gather, analyze, store, process, and disseminate experimental and computational data, EMSL users can accelerate their time to scientific innovation.*



**Figure 6.** Total Impact of Healthcare Spending, Companies with PNNL Roots, Visitor Spending, and Retirees on the Washington State Economy in FY 2018

The impacts of the individual activities are estimated by the IMPLAN model, as follows:

- PNNL and its retirees' health insurance spent an estimated \$68M on healthcare in FY 2018, which produces an estimated statewide total impact of 807 jobs, \$121M in GSP, and \$59M in labor income.
- The companies with PNNL roots had an estimated in-state employment of 150+ and estimated revenue of \$30M. The companies with PNNL roots, as a group, generated a statewide total economic impact of \$50M in GSP, 268 jobs, and \$25M in labor income.
- The estimated in-state visitor spending of \$3.6M per year generated a total economic impact of \$5M in GSP, 54 jobs, and \$2M in labor income.
- Finally, the retirees received an estimated \$99M in pension and Social Security income in FY 2018, the spending from which generated a total economic impact of \$80M in GSP, 506 jobs, and \$26M in labor income.

## Conclusion

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PNNL is an economic asset to the nation and the state of Washington. Its scientists, engineers, and support professionals regularly contribute ideas, inventions, technologies, and processes to the nation's and state's body of scientific and technological knowledge that will build the economy of tomorrow. PNNL takes seriously its role in making this knowledge practical, actionable, and commercially viable, and has won numerous awards for interagency collaboration, technology transfer, and technology commercialization. The growing number of commercial companies in Washington State that were formed based on PNNL ideas and assistance has added more than 150 employees and an estimated \$30M in funding as proof of the success of the PNNL model.

PNNL's current operations constitute a large source of economic activity in Washington State, with \$960M in total spending, 4,096 resident employees, in-state payrolls of \$432M, and purchases from Washington businesses of approximately \$88.9M. This economic activity supports a total of \$1.46B total economic output, total in-state payrolls of \$732M, and 7,175 jobs through Laboratory operations in the state. An additional \$255M in output, in-state payrolls of \$102M, and 1,633 jobs are supported through closely related activities such as companies with PNNL roots, Laboratory retirees, visitors to PNNL, and healthcare spending. Lastly, PNNL and its employees have contributed millions of dollars and thousands of volunteer hours to education and community services, helping secure the future and making Washington a better place to live.

## **Appendix A**

### **The IMPLAN Model**

# Appendix A

## The IMPLAN Model

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To calculate the economic impact of PNNL on the state of Washington, PNNL used IMPLAN® (Impact analysis for PLANning),<sup>1</sup> a widely accepted economic input-output model, to estimate funding, employment, and labor income impacts. IMPLAN, a product of IMPLAN Group LLC, Inc., contains highly disaggregated data on regional economic indicators based on data from a variety of sources, such as the U.S. Bureau of Economic Analysis, and then aggregates the entire economy into 526 sectors. It is based on social accounting between industries and within the distribution chain and contains numerous economic multipliers to quantify direct, indirect, and induced output; employment; and labor income impacts. Output from IMPLAN is in the form of direct, indirect, and induced economic output (gross funding); jobs; and labor income created or supported, as well as their associated multipliers.

Each sector that produces goods and services generates demand for goods and services in other sectors. This iterative process is the multiplier effect. Multipliers can be described through the following definitions:

- Direct effects are the initial change to the industry or institution in question.
- Indirect effects are the changes in inter-industry purchases as they respond to the new demands of the directly affected industries. The direct change creates increases in economic activity for downstream businesses that support these direct industries.
- Induced effects are the increases in household income expenditures generated by the direct and indirect effects.

The Washington State data file for 2016 was used in this analysis, with gross domestic product deflators within the model used to convert impacts to 2018 dollars. PNNL data on purchases of goods and services, associated companies output, employee payroll, retiree income, visitor spending, and healthcare purchases were compiled and translated into IMPLAN inputs. Table A.1 characterizes the IMPLAN inputs.

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<sup>1</sup> IMPLAN. Version 3.0. Davidson, NC: IMPLAN Group LLC, Inc. [www.implan.com](http://www.implan.com).

**Table A.1. IMPLAN Input Characterization**

<i>Expenditures</i>	<i>Input Characterization</i>
Purchases on goods and services	Expenditures were assigned a NAICS code and then translated to their respective IMPLAN sector using the IMPLAN NAICS bridge. Expenditures were calculated as an industry change and retail margins used where needed. Purchases are dominated by the construction, real estate, engineering services, medical and diagnostic laboratories, computer systems design services, and university sectors.
Companies with PNNL roots	Each company was assigned an IMPLAN sector. IMPLAN data were used to derive an output per employee and each company's output was subsequently calculated in IMPLAN. The dominant sector was battery storage manufacturing.
Employee salaries	Payroll data are calculated in IMPLAN as a change in employee compensation. IMPLAN derives the impact from the model's income expenditure patterns.
Healthcare spending	Healthcare expenditures from employees and retirees were assigned a NAICS code and translated to one of the five primary medical IMPLAN sectors and one retail sector supplying medical-related items and then calculated as an industry change. Margins were used for the retail sector.
Retiree income	Retiree income was calculated in IMPLAN as a change in employee compensation. IMPLAN derives the impact from the model's income expenditure patterns.
Visitor spending	Visitor spending was aggregated into day-visitor and overnight-visitor spending and calculated in IMPLAN as a change in sectors typically affected by visitor spending, such as accommodation, food establishments, and retail gasoline sectors.

IMPLAN = IMpact Analysis for PLANning  
NAICS = North American Industry Classification System

## **Appendix B**

### **Benchmarking the Results**

# Appendix B

## Benchmarking the Results

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Many regions' private and public stakeholders care about the economic impact of major industries and industry clusters. This Appendix reports on benchmarking reviews of economic impact analyses of a peer group that includes other large industries and companies ("peer entities") within the state of Washington and other national laboratories to show where PNNL "fits" on a number of economic dimensions assessed in this study.

It is important to note that the main report used the IMPLAN economic model to calculate the effects of several types of PNNL operations expenditures (and, separately, expenditures for closely related economic activities) on overall economic activity in Washington. Due to lack of certain data on peer entities and study resource constraints, it was not possible to perform the same analysis for the peer entities. Rather, this Appendix compares key economic input data and results from published reports of previously completed economic impact studies on the peer entities to similar economic input data and results from the main report for PNNL operations (most of the other studies did not look at closely related activities). A list of the studies on the peer entities appears at the end of this Appendix. Where an input or output is different from the similar concept in this study, this has been noted in the following tables. Where no comparable data was available in the peer entity study, an "NA" appears.

The other studies are all reasonably recent (within the last 10 years), but the studies were done at different times, for different scopes of activity, and some used different impact assessment methods and variables than in this study; therefore, comparisons with and between peer entities are only an approximation.

PNNL is a medium-large economic entity that consistently delivers at or above its weight compared to its peers. The dimensions that are compared across peer entities are

1. Scale of the peers' direct economic activity, as measured by total spending or funding, resident employment, purchases of other goods and services, average annual wage rates, and total payroll.
2. Impact on total state economic activity, as measured by GSP, employment, and wage income.

Because the other studies did not look at all of the dimensions examined in this study, the comparison is limited to the dimensions discussed above.

PNNL's Washington State science and technology (S&T) peer group includes Boeing, Microsoft, the University of Washington, and Washington State University. Although they are not S&T companies, comparisons were also done on the first two dimensions for three other large, high-profile employers in the state, for which economic impact information is available: the military, life sciences, and wine sectors.

PNNL's national laboratory peer group includes: Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), Brookhaven National Laboratory (BNL), National Renewable Energy Laboratory (NREL), and Idaho National Laboratory (INL). An economic benefit study was done in 2008 of all of DOE activities in Tennessee, including Oak Ridge National Laboratory (ORNL), but it was not possible to isolate the effects of ORNL alone.

**Table B.1.** Washington State Peer Economic Comparisons

Company/Sector & Year of Data	Sales (\$B)	Employment (WA)	Average Wages per Worker (\$K)	Total WA Payroll (\$B)	Other Purchased Goods and Services In- State (\$B)	Impact on GSP (\$B)	Impact on Employment	Impact on Total Wage Income (\$B)
<b>PNNL</b> (FY 2018)	\$1.0	4,100	\$105.5	\$0.4	\$0.1	\$1.5	7,200	\$0.7
<b>Boeing Commercial</b> (2014)	\$55.4	67,600	\$113.9	\$9.7 (including benefits)	NA	\$77.3 (sales)	206,100	\$17.0
<b>Microsoft</b> (2011)	\$72.1 (global)	40,300	\$184.8	\$7.5	\$2.5	\$34.3	243,000	\$19.4
<b>University of Washington</b> (FY 2014)	\$5.7 (spending)	34,700	NA	NA	NA	\$12.5	79,300	NA
<b>Washington State University</b> (2014) (Operations)	\$1.0	11,900	\$50.2	\$0.6	NA	\$2.3	20,600	\$1.0
<b>Military</b> (2009)	\$8.7 (output)	103,400	\$49.5	\$5.1	\$2.8	\$12.2	191,600	\$10.5
<b>Life Sciences</b> (2015)	NA	36,200	\$86.0	\$3.1	NA	\$12.5	98,100	\$7.8
<b>Wine Industry</b> (2009)	\$3.6	14,200	\$30.1	\$0.4	NA	\$7.4	29,100	\$1.2

**Table B.2.** National Laboratory Peer Economic Comparisons

Laboratory & Year of Data	Funding (\$B)	Employment	Average Wages per Worker (\$K)	Total Payroll In-State (\$M)	Other Purchased Goods & Services In- State (\$M)	Impact on GSP (\$B)	Impact on Employment In-State	Impact on State Total Wage Income (\$B)
<b>PNNL</b> (FY 2018)	\$0.96 (total spending)	4,100 (WA State)	\$105.1	\$432	\$89	\$1.46	7,200	\$0.73
<b>ANL</b> (FY 2017)	\$0.82	3,200 (FTE)	\$101.3	\$324	\$97	NA	NA	NA
<b>LBNL</b> (FY 2009)	\$0.70 (total cost)	3,200	\$80.4	\$259	\$227	\$0.80	6,900	\$0.49
<b>BNL</b> (FY 2009)	\$0.57	2,900	\$86.4	\$250	\$120	\$0.70	5,300	\$0.48
<b>NREL</b> (FY 2014)	\$0.38 (total cost)	1,600 (FY 2012)	\$117.5 (FY 2012)	\$208	\$85	\$0.70	4,100	\$0.32
<b>INL</b> (FY 2018)	\$1.09 (in Idaho)	4,300	\$97.9	\$426	\$148	\$2.06	11,800	\$1.03

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PNNL-28969