

PNNL-26521



**Pacific Northwest**  
NATIONAL LABORATORY

*Proudly Operated by **Battelle** Since 1965*

**ECONOMIC IMPACT OF**  
**Pacific Northwest**  
**National Laboratory on**  
**the State of Washington**  
**in Fiscal Year 2016**

MAY 2017

U.S. DEPARTMENT OF  
**ENERGY**

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PACIFIC NORTHWEST NATIONAL LABORATORY  
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*for the*  
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# **Economic Impact of Pacific Northwest National Laboratory on the State of Washington in Fiscal Year 2016**

JM Niemeyer

May 2017

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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**\$920M**

Annual Spending



**\$435M**

Total payroll

**\$404M** in Washington State



**4,485**

Employees

**94% (4,203)** living  
in Washington State in 2016

**27%** growth  
in employment 2000-2016



**\$24.5M**

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

Highlights



**\$1.38B**

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

**\$550M** in Washington State wage income

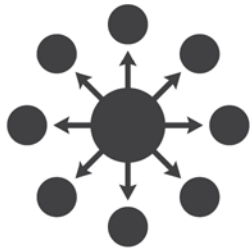
**7,008** total jobs generated in Washington State



**\$348M**

Domestic purchased goods and services

**\$83M** in Washington State



**103**

Companies with PNNL roots

**69** in Washington State

**\$586M** estimated revenue in Washington State

**3,097** total employees

**2,326** employees in Washington State



**\$842K**

Value of Battelle, PNNL, and PNNL employee cash contributions to philanthropic and civic organizations, including **\$320K** corporate support for STEM education

## Acknowledgments

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## Executive Summary

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PNNL is a large economic entity with a total of 4,485 employees, \$1.08 billion (B) in total funding, and \$920 million (M) in total spending during FY 2016.<sup>1</sup> The 4,203 PNNL employees that live in Washington State equal 94 percent of the Laboratory staff.

The Laboratory directly and indirectly supported \$1.38B in economic output, 7,008 jobs, and \$550M in Washington State wage income from current operations. The state also gained more than \$1.18B in output, 5,747 jobs, and \$437M in income through closely related economic activities such as visitors, health care spending, spending by resident retirees, and companies with PNNL roots.<sup>2</sup>

PNNL affects Washington's economy through commonly recognized economic channels, including spending on payrolls and other goods and services that support Laboratory operations. Less commonly recognized channels also have their own impacts and include company-supported spending on health care 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 also 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 important lasting legacies of the Laboratory. Finally, PNNL 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 the rest of Washington State's economy.

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<sup>1</sup> The latest PNNL data available was for FY 2016, spanning Oct. 1, 2015, through Sept. 30, 2016.

<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

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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>DOE</b>	U.S. Department of Energy
<b>EMSL</b>	Environmental Molecular Sciences Laboratory
<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>LASER</b>	Leadership and Assistance for Science Education Reform
<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>STEM</b>	science, technology, engineering, and mathematics
<b>TAP</b>	Technology Assistance Program
<b>U.S.</b>	United States
<b>WBL</b>	Work-Based Learning



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## Introduction

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Pacific Northwest National Laboratory (PNNL) is the United States (U.S.) Department of Energy's (DOE's) premier chemistry, earth science, and data analytics laboratory, delivering vital mission impacts in energy resiliency and national security. Located in Richland, Washington, PNNL is one of 10 DOE Office of Science (SC) national laboratories.

PNNL has world-leading capabilities in chemical catalysis, data analytics, and integrated earth system sciences. Building upon its strong base of discovery science, PNNL is a leader in energy storage and grid performance and is transforming the way the country operates and maintains its electricity and energy delivery systems. PNNL has developed advanced computing tools that analyze grid congestion faster and more accurately, saving utilities millions of dollars. In national security, PNNL possesses world-leading expertise in forensic signatures of plutonium production, large-scale data analytics, and cyber defense of high-consequence systems. The Laboratory provides critical capabilities to the United States and its international partners, making it possible to verify international treaties and implement security technologies around the globe.

Operated by Battelle Memorial Institute, PNNL has 4,485 staff members with total spending of \$920M during FY 2016. Several major research and development (R&D) facilities enable mission accomplishment. On behalf of the 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 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

### PNNL Revenues and Expenses

► In FY 2016, PNNL’s funding totaled \$1.08B and spending totaled \$920M.

During FY 2016, PNNL’s total funding was \$1.08B and total spending was \$920M (Figure 1 and Figure 2, respectively). The majority of the work that PNNL performs is for DOE (64 percent during FY 2016). Work that is 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 funding. The U.S. Department of Homeland Security also plays a major role.

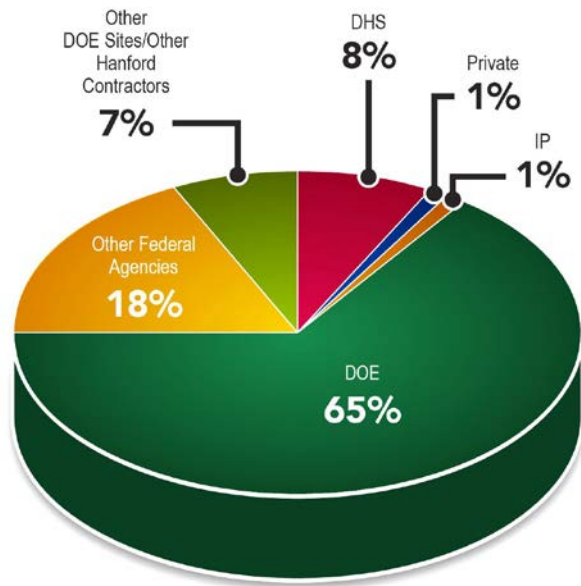


Figure 1. PNNL’s Total Funding in FY 2016

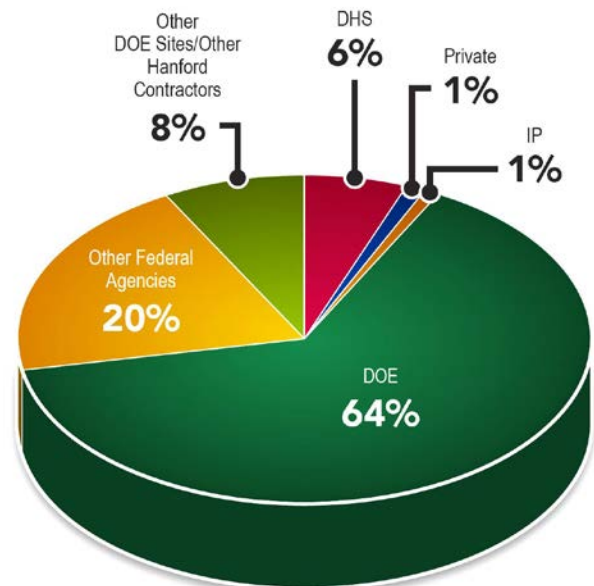


Figure 2. PNNL’s Spending in FY 2016

### PNNL Employment

- Employment at PNNL grew 27% between FY 2000 and FY 2016.
- As of September 30, 2016, PNNL employed 4,485 staff members, with 94% (4,203) employed and residing in Washington State.

PNNL employed 4,485 people in FY 2016, 4,203 of whom were residents of Washington State and worked mainly in Richland, Seattle, and Sequim (Figure 3).

Nearly 94 percent of the PNNL workforce resides in Washington State (82 percent in Benton County and 11 percent in Franklin County). Of the staff residing in Benton and Franklin Counties, 53 percent reside in Richland, 20 percent in Kennewick, 11 percent each in Pasco and West Richland, and the remaining 5 percent reside elsewhere in the two counties.

In addition, there were 95 staff members in the Washington, D.C. area; 36 staff members assigned to work in Corvallis and Portland, Oregon; and 151 staff members employed at other locations in the United States or in foreign countries.

### PNNL's Payroll and Benefits

- ▶ **PNNL spent a total of \$435M on payrolls, with \$404M going to Washington State residents.**
- ▶ **PNNL provides \$109M for employer-provided benefits to support Laboratory operations.**

PNNL's total payroll during FY 2016 was \$435M, of which \$404M went to Washington State residents. Because the Lab is an 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 2016 was \$96,155.<sup>1</sup> In 2016, the state average occupational wage was \$60,188.<sup>2</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 \$109M 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).

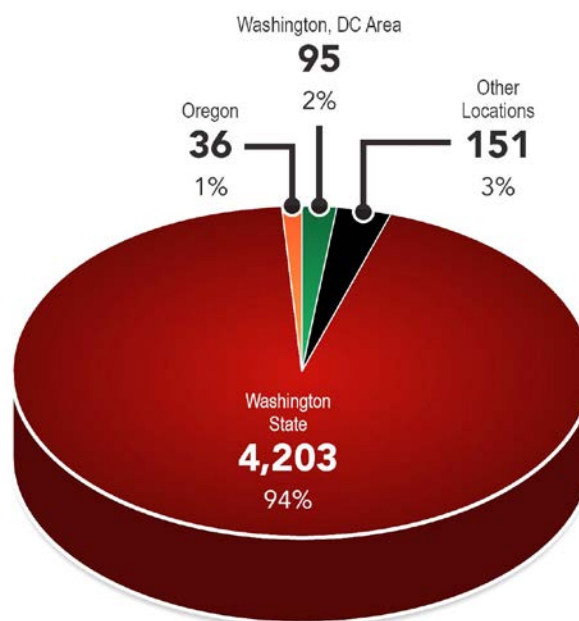


Figure 3. Location of PNNL Employees

<sup>1</sup> \$96,155 includes student employees, which reduce the PNNL average. For comparable data on other Washington State R&D organizations and other DOE national laboratories, see Appendix B.

<sup>2</sup> The weighted average for all occupations for which the average annual wage and the number of workers both were published was \$60,188.

## Purchased Goods and Services and Investments

► **\$83M was spent on purchases made from Washington State firms.**

During FY 2016, PNNL placed domestic procurements<sup>1</sup> for \$348M 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, 24 percent (or \$83M) of the purchases were made from Washington State firms.

**Table 1.** FY 2016 PNNL Purchased Goods and Services Spending (total U.S. domestic and in Washington State)

Type of Expenditure	Total (\$M)	In WA (\$M)
Construction	\$28.0	\$26
Finance, Insurance, Real Estate	\$32.0	\$14
Computers, Lab Equipment, Software, Services, Retail Trade	\$74.0	\$13
Utilities, Transportation, Publishing, Management, and Business Services	\$104.0	\$14
Technical and Scientific Subcontractors	\$67.0	\$11
Medical and Health Services	\$0.1	\$0
All Other	\$41.0	\$5
<b>Total*</b>	<b>\$348.0</b>	<b>\$83</b>

\*Detail may not add to total due to rounding.

## Expenditures for New Construction and Renovations

► **Ninety-five (95) construction jobs were supported by the \$17.7M in in-state subcontractor construction spending.**



**Figure 4.** PNNL 3820 Systems Engineering Building in Richland, Washington

PNNL is based in southeastern Washington State, with several off-site locations. The main campus (shown in Figure 4), located at the north end of Richland, consists of land owned by DOE, Battelle, and third parties.

<sup>1</sup> Excludes purchases outside of the United States.



In FY 2016, PNNL's facility profile comprised a total of 77 buildings and 42 other structures, including the following:

- 21 DOE-owned buildings and 19 other DOE structures and facilities (874,346 gross square feet [gsf]) on 379 acres
- 29 Battelle-owned facilities (473,088 gsf) and 23 other structures and facilities on 203 acres, including 39 acres in Sequim, Washington
- 27 buildings from third-party leases and agreements (962,119 gsf).

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.

Fiscal year 2016 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, 68 percent (\$18.8M) included reimbursements to subcontractors working on PNNL buildings, including out-of-state contractors working on in-state projects.<sup>1</sup> Washington State resident subcontractors earned \$17.7M of this \$18.8M, or 94 percent. Total costs other than PNNL labor related to these renovations are included in the \$348M non-payroll purchases listed in Table 1. An estimated 95 construction jobs were supported by the \$17.7M in in-state subcontractor construction spending. These are included in the total impacts detailed in Table 2 and Figure 5 (located in the Economic Impact of PNNL Operations section below).

**Table 2. PNNL Construction Spending in FY 2016**

FY 2016 Renovations	Total Spending (\$M)
PNNL Labor Costs	\$7
Miscellaneous Procurements	\$2
Disbursements to Subcontractors	\$19
<i>Item: Disbursements to Washington State Subcontractors = \$17.7M</i>	
<b>Total Renovation Spending</b>	<b>\$28</b>

## PNNL State and Local Taxes Paid

### ► PNNL and its employees paid a total of approximately \$24.5M in local and Washington State taxes.

PNNL and its employees paid a total of approximately \$24.5M in local and Washington State taxes, which includes sales and use taxes, property taxes, and a few others (e.g., motor fuel taxes).<sup>2</sup> Employee taxes were based on the total \$404M in wages of PNNL employees who are residents of Washington and the 2015 state and local governments' collection rates (for every dollar of personal income): an estimated \$0.028 in sales, use, and other production-related taxes by individuals; \$0.029 in state and local property tax collections; and \$0.003 in other taxes per dollar of personal income. The estimated tax payments by employees are shown in Table 3.

<sup>1</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.

<sup>2</sup> Washington State does not have a personal or corporate income tax.

In total, PNNL paid \$1.7M in state and local taxes, and employees paid \$22.9M. In addition, the Laboratory paid \$4M 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.

**Table 3.** FY 2016 Washington State and Local Taxes Paid by PNNL and its Employees

Washington Tax Category	Paid by PNNL in FY 2016 (\$K)	Estimated Paid by PNNL Employees in FY 2016 (\$K) <sup>(*)</sup>
Sales and Use Taxes	\$351	\$10,488
Business and Occupation Taxes	\$387	\$0
Leasehold Taxes	\$9	\$0
Property Taxes	\$910	\$10,511
Other State and Local Taxes	Negligible	\$951
<b>Total</b>	<b>\$1,657</b>	<b>\$22,853</b>

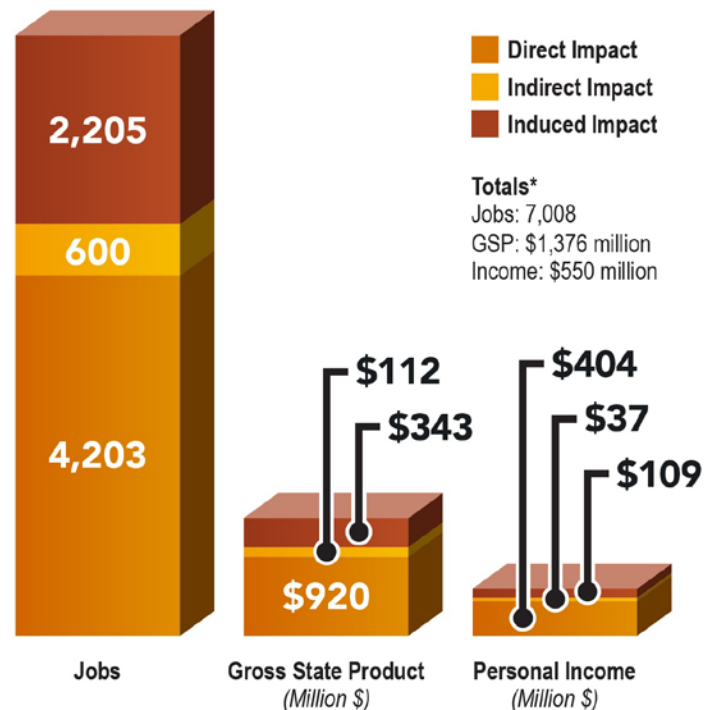
<sup>\*</sup>Detail does not sum to total because of rounding.

### Economic Impact of PNNL Operations

► **Total impacts of FY 2016 PNNL payroll and non-payroll purchases are \$1.38B in gross state product, 7,008 jobs, and \$550M in total wages in Washington State.**

PNNL’s expenditures on operations (payrolls and non-payroll purchases) generate additional economic activity in Washington State. The dollar value of PNNL’s output, its employment, and its 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)



<sup>\*</sup>Detail may not add to total due to rounding

**Figure 5.** FY 2016 Economic Impact of Washington Payroll and Purchased Goods and Services Expenditures by PNNL

produced in the state is also called *gross state product* (GSP). Finally, the ratio of total to direct impact is called the *multiplier effect*.<sup>1</sup>

Figure 5 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: \$920M contribution to GSP in Washington, 4,203 Washington jobs, and \$404M in Washington wages. Together, with the indirect (middle bars) and induced (upper bars) impacts, the total impacts are \$1.38B in GSP, 7,008 jobs, and \$550M in total wages in Washington State.

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<sup>1</sup> This study uses the 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

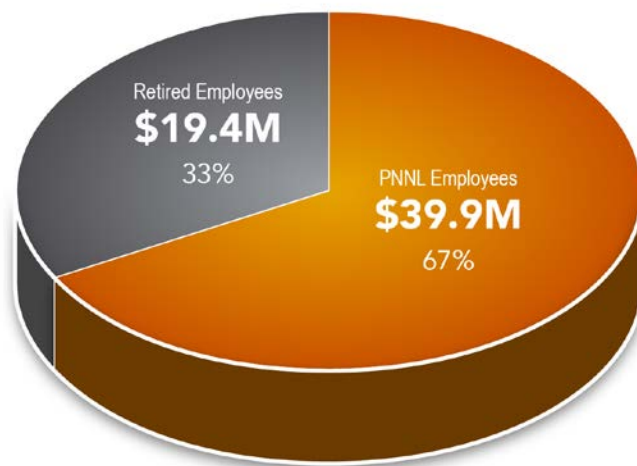
This section of the report provides estimates of the total impact of economic activity that, while not strictly PNNL activity, would not exist in Washington State without the presence of the Laboratory. These activities include health care insurance expenditures on behalf of PNNL employee and retiree households, spending by PNNL retirees, spending by companies that have their “roots” in 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.

### Health Care Expenditures

- ▶ **PNNL employees and their households spent approximately \$40M in health-related services funded by PNNL health insurance (not personal income).**
- ▶ **Retired employees’ health insurance (e.g., Medicare) spent over \$19M.**
- ▶ **These two sources together spent an estimated \$59M in FY 2016 in Washington State.**

Health insurance expenditures for PNNL’s 4,203 Washington State employees, 1,714 retirees, and their households in the state of Washington totaled an estimated \$59M in FY 2016. PNNL’s direct medical and dental insurance expenditures on behalf of employee households in Washington were estimated at \$40M (see Figure 6).

Total costs of over \$19M for retired households were based on Kaiser Family Foundation estimates of per capita expenditures by type for health care in Washington State in 2009, adjusted to 2016 dollars. While not directly related to current Laboratory activity because they are insurance payments, health care expenditures depend on the presence of Laboratory employees and have a substantial additional economic impact.



**Figure 6.** Estimated Spending for Washington State PNNL Employee and Retiree Health Care in FY 2016

### 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 2016, the Battelle-defined benefit pension plan for PNNL employees paid out \$58M to 2,282 retirees and other beneficiaries. The PNNL pension benefit was an average of \$2,133 per month,

per person, in Washington. For purposes of this report, 1,714 (75 percent) of all PNNL retirees were reported to live in Washington State.<sup>1</sup>

The estimated average monthly payment per OASI retired beneficiary in FY 2016 was \$1,293 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 1,714 Washington PNNL retirees receive 1.4 times the OASI payment of the average retiree in the state, or about \$1,925 per month, for a total estimated \$44M. Pensions and Social Security together total \$111M, of which about \$83M 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 2016

	Estimated Average Retiree Monthly Income in FY 2016	Total Retiree Annual Income in FY 2016 Income (\$M)
Pension	\$2,133	\$43
OASI (Social Security)	\$1,925	\$40
<b>Total</b>	<b>\$4,057</b>	<b>\$83</b>

## Technology Transfer

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

Many of PNNL's research activities generate ideas and inventions (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. In the case of new start-up firms, PNNL also takes an active role in helping new businesses succeed.

Table 5 shows that 103 companies operating in FY 2016 had technological or managerial roots at PNNL, and they had estimated sales of \$838M and 3,097 employees. The 69 companies located in Washington State have an estimated sales of \$586M and 2,326 employees in Washington State.

**Table 5.** Companies with Ties to PNNL—Number, Estimated FY 2016 Funding, and Number of Employees

	Total	In Washington State
Number of Firms	103	69
Estimated Sales (\$M)	\$838	\$586
Employment	3,097	2,326

PNNL's Economic Development Office's Technology Assistance Program (TAP) provides funding for researchers to work with a small business for up to a staff-week per project. Small businesses that use PNNL's free TAP are eligible to receive a royalty-free license for IP generated in the course of the project.

<sup>1</sup> Direct data from the pension administrator were available on PNNL retiree locations for FY 2016. Of 2,282 retirees, 1,714 had Washington addresses.

Table 6 shows that PNNL conducted 58 TAP projects during FY 2016. Fifty-two (52) percent of these were conducted for Washington-State-based companies.

**Table 6. Technology Assistance Program Statistics**

	Total	In Washington State
Number of Projects in FY 2016	58	52%
Cumulative Projects Since 1994	1,315	68%

These projects involved 2,397 hours of assistance at no cost to the small business. Since 1994, PNNL has completed 1,315 assistance projects—68 percent of them for Washington-State-based companies. Many fledgling companies in Washington State either directly receive in-kind assistance from PNNL or become partners with PNNL in identifying potential start-up funding or markets for their products and services. In many cases, the funding that they receive from others likely would not occur if PNNL was not providing this assistance.

### Intellectual Property

While undoubtedly valuable as investments 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.

The discoveries and outcomes resulting from the research enterprise are the Laboratory’s most important product. Table 7 shows results that are easily countable, but it is much harder to put a dollar value on a 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 39 new license agreements during FY 2016.

**Table 7. PNNL Statistics on Inventions, Patents, Technology Transfers, and License Income**

	New FY 2016	Cumulative 2000-2016
Invention Disclosures	204	3,917
Patent Applications	60	1,098
Patents Received	63	753
Commercial and Research Licenses	39	583
<b>Total License Revenue Received</b>	<b>\$5.7M</b>	<b>\$61.3M</b>

PNNL leads all other DOE laboratories in implementation of Agreements for Commercializing Technology, having 60 agreements with 54 different sponsors. In FY 2016, PNNL had 21 active Cooperative Research and Development Agreements and 197 non-federal Strategic Partnership Project agreements. Table 7 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 \$5.7M in FY 2016. A significant portion of these funds are reinvested at the Laboratory for additional commercialization-focused development work.



## Honors and Awards

In FY 2016, 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 brings the cumulative total of PNNL's R&D 100 Awards to 100.

- PNNL researchers, with the support of DOE-SC's Office of Environmental Management, developed and are applying **Real-time Four-Dimensional Subsurface Imaging Software** to determine the extent of contamination and what is driving its migration. No other commercial subsurface modeling software constructs three-dimensional, time-lapse images of how the subsurface environment changes over time, in real time.
- PNNL is one of five national laboratories involved in the **Carbon Capture Simulation Initiative Toolset**—a suite of computational tools and models that accelerates the development, scale-up, and commercialization of various post-combustion carbon-capture technologies. As carbon-capture technologies are being scaled up, the Carbon Capture Simulation Initiative Toolset toolset can reduce the time needed to commercialize these technologies and provide greater confidence for those investing in carbon capture. The technology was sponsored by DOE's Office of Fossil Energy and led by DOE's National Energy Technology Laboratory.

The Federal Laboratory Consortium, a nationwide network that encourages federal laboratories to transfer laboratory-developed, taxpayer-funded technologies to commercial markets, awarded PNNL with two Excellence in Technology Transfer Awards in FY 2016. These two awards bring PNNL's total to 83, which is almost a quarter of the total FLC awards won by all DOE-SC laboratories.

- Analytical software called Columnar Hierarchical Auto-associative Memory Processing in Ontological Networks—or **CHAMPION**—was developed at PNNL and licensed to Champion Technology Company, Inc. This new software has the knowledge to sort through data using descriptive logic to reason whether activity is suspicious and, if so, alert analysts of the suspicious activity in time to potentially thwart attacks.
- Many microbe-caused ailments, ranging from staph infections to Ebola, can now be prevented with the **Micro Aerosol Disinfecting System**, which was developed at PNNL. Watertech Equipment and Sales, LLC, which licensed the system from PNNL, has adapted the system into an easy-to-deploy product to be sold for various uses, including hospital and clinical disinfection, mold remediation, and supporting the agricultural and food processing industries.

## STEM Education and Work-Based Learning

### The Office of STEM Education

The Office of Science, Technology, Engineering, and Mathematics (STEM) Education function serves to align 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's goal is to impact the K–20 STEM education ecosystem. The Office informs state and federal policies that advance STEM education; designs and deploys exemplary programs that foster best practices in STEM education; leads efforts to develop, study, test, and implement STEM education approaches for

educators, students, and the community; and identifies and develops critical collaborators inside and outside PNNL with whom to advance STEM education locally, regionally, and nationally.

External Affairs stewards PNNL's STEM education mission, linking the human, financial, and technical resources of the Laboratory with elementary and secondary schools, colleges and universities, and other education-oriented organizations in ways that support the education, diversity, and research objectives of the nation, DOE, PNNL, Battelle, and our education partners.

## 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 goals 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 2016, the DOE-SC provided project funding, and the Laboratory spent \$818,400 for post-secondary student and faculty programs. PNNL's Intern and Fellowship Management and Administration Pool was \$986,600. Finally, PNNL spent \$1,319,000 in overhead funds to support WBL (high school and post-secondary), STEM education, and outreach efforts (K-16).

In FY 2016, there were approximately 9,370 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, 216 were fellows (non-PNNL employees) and 1,113 were interns or research associates. In FY 2016, 21 fellows and 334 interns/associates were from Washington State institutions.

### 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 fellows and interns funded by home institutions and other sources.

At the K–12 level, four signature STEM education outreach efforts were conducted in FY 2016. These included 1) Delta High School; 2) Washington State Leadership and Assistance for Science Education Reform (LASER); 3) Washington State Mathematics, Engineering, and Science Achievement (MESA); and 4) the Mid-Columbia STEM Education Collaboratory.

Delta High School is a small, public institution in the Tri-Cities (i.e., Richland, Pasco, and Kennewick), Washington, focused on integrated STEM. LASER is a public/private partnership whose vision is to make science an essential part of the education of today’s students for tomorrow’s world. MESA efforts are designed to increase the number of underrepresented students acquiring STEM degrees and working in STEM careers. The Mid-Columbia STEM Education Collaboratory is a collaboration between Battelle, PNNL, Delta, LASER, MESA, and other like-minded organizations to design, implement, and mature a local STEM education collaboration zone that realizes changes in the STEM education system that collaborators cannot accomplish individually.

PNNL provided leadership for efforts related to the implementation of the Next Generation Science Standards in Washington State. PNNL was also an active participant in the development of computer science education standards, which are expected to be adopted by Washington State in December 2016. Through its Educator STEMLab@PNNL, 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 2016 outreach efforts included the PNNL Student Job Shadow Program, DOE Science Bowl, Pasco School District STEM Teacher Professional Development Program, the DOE Office of Economic Impact and Diversity’s My Brother’s Keeper Outreach Event, and the Whitman College Summer Institute for Educators.

In addition, 47 high school students had academic year or summer research experiences at PNNL. In FY 2016, these programs involved nearly 2,600 students and more than 1,100 educators, almost all of whom were from Washington State institutions. Table 8 shows statistics on the Office of STEM Education and WBL programs.

**Table 8. Statistics on the PNNL STEM Education Programs in FY 2016**

PNNL Programs in STEM Education	Participation in FY 2016
<b>Post-Secondary Programs</b>	
Four DOE-SC University Internship/Fellowship Programs	11 faculty, 69 students
Department of Homeland Security Fellowship	4 students
PNNL Post-Graduate and Post-Secondary Internships	1,113 students
PNNL National Security Internships	57 students
PNNL Alternate Sponsored Fellowships	216 students, faculty, and visiting scientists
PNNL K-12 STEM Teacher Programs	17 students (pre-service teachers)
<b>K-12 Student Programs</b>	
PNNL High School Research Intern and Apprentice Programs	47 students
DOE Science Bowl	154 students
High School Shadow Program	2 students
Delta/Chiawana (STEM) High School Programs	30 faculty, 560 students
<b>K-12 Teacher Programs</b>	
LASER	645 educators
<b>K-12 Collective Impact Project</b>	
Mid-Columbia STEM Education Collaboratory (Phase 3: Collaboratory Implementation)	920 students and 380 educators

PNNL has 91 staff members serving as adjunct or joint appointment faculty at colleges and universities. Fifty-five (55) of these staff members teach 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 2015 state-level per capita visitor spending statistics compiled by Dean Runyan Associates for Washington Tourism Alliance.<sup>1</sup>

Table 9 shows the statistics for out-of-town visitors to PNNL facilities in 2016, identified through PNNL visitor badges.<sup>2</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 \$6M are based on statewide traveler spending averages, adjusted for Benton County’s lower-than-average accommodation costs as a proportion of total spending.

**Table 9. Number of Out-of-Town Visitors and Visitor Days to PNNL Facilities**

PNNL Visitor Statistics	
Number of out-of-town visitors	5,656
Estimated total visitor days	38,545
Estimated tourism expenditures	\$6M

## Community Investments and Assistance

Since 1965, Battelle has invested more than \$26M to improve science, education, and quality of life in Washington State. Over the past 10 years, staff members at PNNL have volunteered more than 279,626 hours to community projects, including 45,741 Team-Battelle-volunteered hours in FY 2016. Staff members at PNNL serve on the boards of many community organizations, including: Washington State University Tri-Cities, the Tri-Cities Development Council, Tri-City Regional Chamber of Commerce, the REACH Foundation, Association of Washington Business, Washington Roundtable, Washington Clean Tech Alliance, and United Way of Benton and Franklin Counties.

The Makerspaces, Delta Electric Vehicle Engineering Club, Tri-Cities Food Bank, For the Love of Giving, and Tumbleweed Music Festival are a few of the numerous Team Battelle projects from FY 2016.

<sup>1</sup> Dean Runyan Associates. 2015. *Washington State Travel Impacts & Visitor Volume, Compiled for Washington Tourism Alliance, 1991-2013p.*

<sup>2</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 10 shows quantitative measures of PNNL and Battelle’s community assistance, including corporate and individual financial giving.

**Table 10.** PNNL and Battelle Community Assistance Statistics for FY 2016

Washington State Community Assistance	
Battelle cash donations to health, human services, and other philanthropic and civic organizations*	\$520,307
PNNL memberships in Washington civic organizations	\$104,807
Staff member contributions to United Way	\$216,422

\*Includes the \$319,750 donation to STEM education discussed above.

### EMSL and ARM Climate Research Facility Users

PNNL operates EMSL and provides the overall technical direction for the ARM Program Climate Research 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 11). With remote access, the group of outside users is broader.

The ARM Climate Research 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.

#### Environmental Molecular Sciences Laboratory

Through EMSL, scientists gain a predictive understanding of the molecular-to-mesoscale processes that affect biological, environmental, and energy systems—a necessary step in the development of sustainable solutions to the nation’s energy and environmental challenges.

Research focuses on understanding how soil organic carbon formation, cycling, and sequestration occur via microbial and plant interactions and geochemical and physical processes in terrestrial and subsurface ecosystems; how the formation and aging of aerosols alters atmospheric radiative forcing; how the physical and chemical properties at critical interfaces in energy materials affect their efficiency; and how to predict and control dynamic inter- and intracellular processes for the design of biorenewable chemicals.

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.

In FY 2016, there were 1,170 unique ARM scientific users: 242 from universities, 10 from industry, 128 from DOE laboratories, 51 from other federal agencies, 89 foreign, and 650 “other.” Ninety-six (96) users used ARM’s facilities’ on-site assets, 148 used off-site services, and 926 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 53 employees at PNNL, not all of whom are full-time.

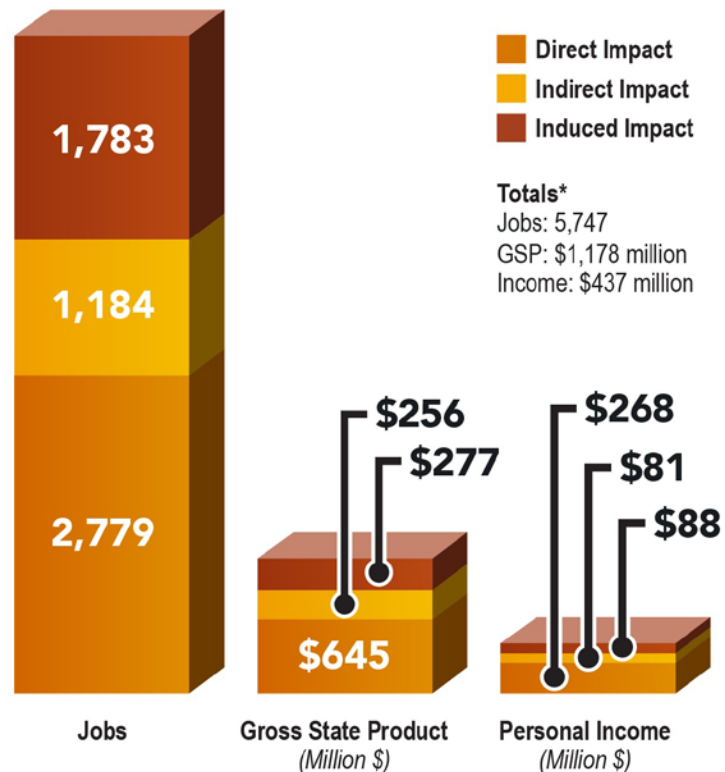
**Table 11. FY 2016 EMSL Users**

	Total EMSL Users	Washington State Users
EMSL total users	644	298
Number of international (foreign) users	74	0
U.S. users	570	298
Non-PNNL U.S. users	322	50

### Economic Impact of Closely Related Activity

The 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 2,779 people and generate a GSP of \$645M. The IMPLAN (Impact analysis for PLANning) model calculates that, when the indirect and induced economic impacts are taken into account, a total of \$1.18B in GSP, 5,747 jobs, and \$437M in labor income depend on these activities (see Figure 7).

The impacts of the individual activities are estimated by the IMPLAN model, as follows. PNNL and its retirees' health insurance spent an estimated \$59M on health care in FY 2016, which produces an estimated statewide total impact of 689 jobs, \$102M in GSP, and \$49M in labor income. The companies with PNNL roots had an estimated in-state employment of 2,326 and estimated revenue of \$586M. The companies with PNNL roots, as a group, generated a statewide total economic impact of \$1.0B in GSP, 4,557 jobs, and \$597M in labor income. The estimated in-state visitor spending of \$6M per year generated a total economic impact of \$8M in GSP, 84 jobs, and \$3M in labor income. Finally, the retirees received an estimated \$83M in pension and Social Security income in FY 2016, the spending from which generated a total economic impact of \$65M in GSP, 417 jobs, and \$21M in labor income.



\*Detail may not add to total due to rounding

**Figure 7. Total Impact of Health Care Spending, Companies with PNNL Roots, Visitor Spending, and Retirees on the Washington State Economy in FY 2016**



## 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 have added 2,326 resident employees and an estimated \$586M 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 \$920M in total spending, 4,203 resident employees, in-state payrolls of \$404M, and purchases from Washington businesses of approximately \$83M. This economic activity supports a total of \$1.38B total economic output, total in-state payrolls of \$550M, and 7,008 jobs through Laboratory operations in the state. An additional \$1.18B in output, in-state payrolls of \$437M, and 5,747 jobs are supported through closely related activities such as companies with PNNL roots, Laboratory retirees, visitors to PNNL, and health care spending. Lastly, PNNL and its employees annually contribute millions of dollars and thousands of hours to education and community services, helping secure the future and making Washington a better place to live.

## Appendix A

### The IMPLAN Model

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 2014 was used in this analysis, with gross domestic product deflators within the model used to convert impacts to 2016 dollars. PNNL data on purchases of goods and services, associated companies output, employee payroll, retiree income, visitor spending, and health care 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

Expenditures	Input Characterization
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 sectors were inorganic chemical manufacturing and environmental and technical consulting services sectors.
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.
Health care spending	Health care 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

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, so 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 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 (FY 2016)</b>	\$1.1	4,200	\$96.2	\$0.4	\$0.1	\$1.4	7,000	\$0.6
<b>Boeing Commercial (2014)</b>	\$55.4	67,600	\$113.9	\$9.7 (including benefits)	NA	\$77.3 (sales)	206,100	\$17.0
<b>Microsoft (2011)</b>	\$72.1 (global)	40,300	\$184.8	\$7.5	\$2.5	\$34.3	243,000	\$19.4
<b>University of Washington (FY 2014)</b>	\$5.7 (spending)	34,700	NA	NA	NA	\$12.5	79,300	NA
<b>Washington State University (2014) (Operations)</b>	\$1.0	11,900	\$50.2	\$0.6	NA	\$2.3	20,600	\$1.0
<b>Military (2009)</b>	\$8.7 (output)	103,400	\$49.5	\$5.1	\$2.8	\$12.2	191,600	\$10.5
<b>Life Sciences (2015)</b>	NA	36,200	\$86.0	\$3.1	NA	\$12.5	98,100	\$7.8
<b>Wine Industry (2009)</b>	\$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 (FY 2016)</b>	\$0.92 (total spending)	4,200 (WA State)	\$96.2	\$404	\$83	\$1.38	7,000	\$0.55
<b>ANL (FY 2010)</b>	\$0.67	2,700 (FTE)	\$72.3	\$165	\$195	\$0.70	4,900	\$0.21
<b>LBNL (FY 2009)</b>	\$0.70 (total cost)	3,200	\$80.4	\$259	\$227	\$0.80	6,900	\$0.49
<b>BNL (FY 2009)</b>	\$0.57	2,900	\$86.4	\$250	\$120	\$0.70	5,300	\$0.48
<b>NREL (FY 2014)</b>	\$0.38 (total cost)	1,600 (FY 2012)	\$117.5 (FY 2012)	\$208	\$85	\$0.70	4,100	\$0.32
<b>INL (FY 2016)</b>	\$1.03 (in Idaho)	4,100	\$92.6	\$397	\$136	\$1.91	11,300	\$0.80

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