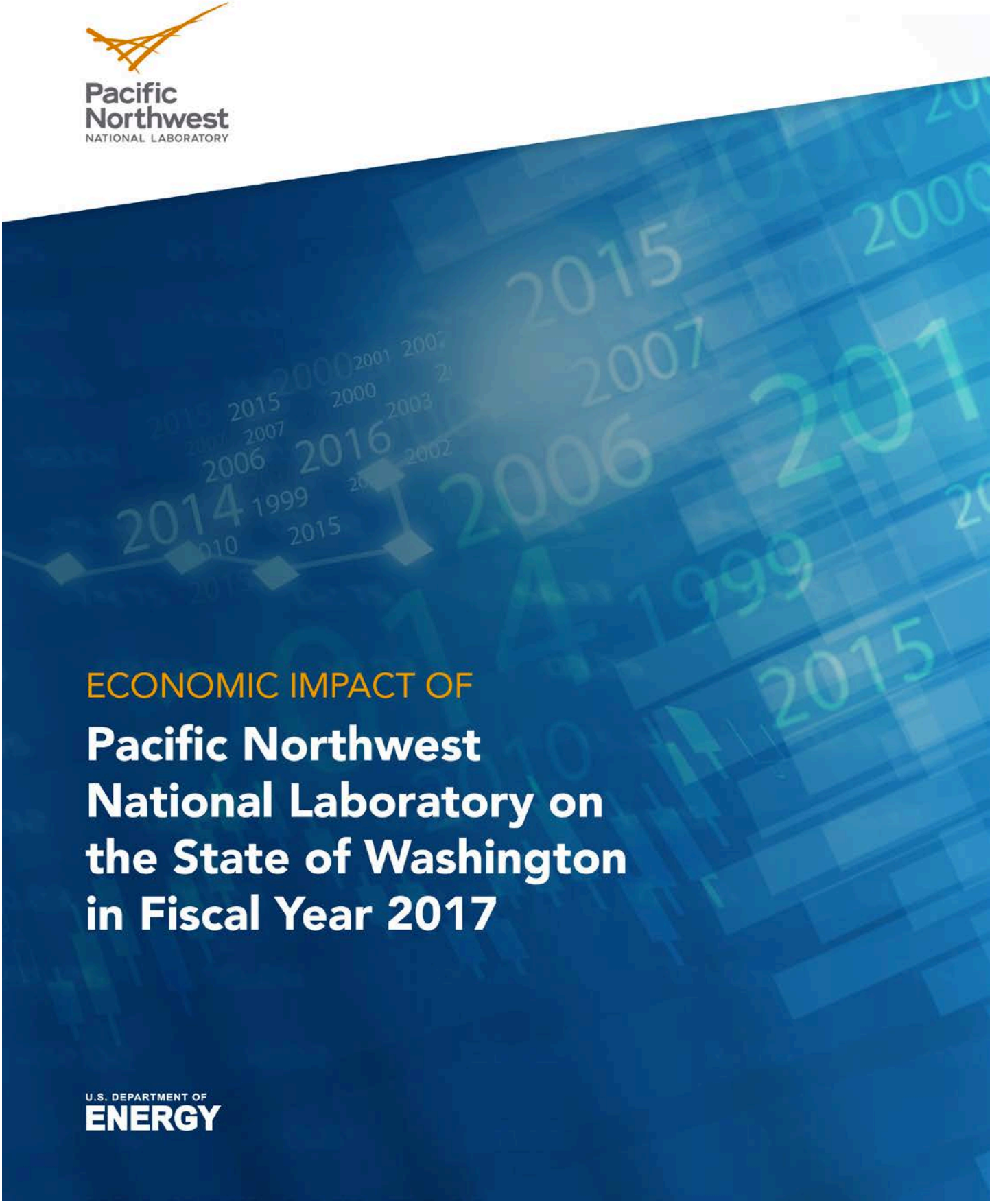
Pacific Northwest
NATIONAL LABORATORY



ECONOMIC IMPACT OF

Pacific Northwest National Laboratory on the State of Washington in Fiscal Year 2017

U.S. DEPARTMENT OF
ENERGY

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PNNL-27870

Economic Impact of Pacific Northwest National Laboratory on the State of Washington in Fiscal Year 2017

August 2018

JM Niemeyer

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

Pacific Northwest National Laboratory
Richland, Washington 99352

Highlights

$987M

Annual Spending

$456M

Total Payroll

$423M in Washington State

4,486

Employees

93% (4,190) living in Washington State in 2017

27% growth in employment 2000-2017

$26.2M

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

Highlights

$1.46B

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

$578M in Washington State wage income

7,100 total jobs generated in Washington State

$350M

Domestic purchased goods and services

$82.8M in Washington State

187

Companies established with PNNL roots since 1965

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

$27M revenue in WA

140 employees in WA

$820K

Value of Battelle, PNNL, and PNNL employee cash contributions to philanthropic and civic organizations, including **$245K** corporate support for STEM education

Acknowledgements

Pacific Northwest National Laboratory's (PNNL's) fiscal year (FY) 2017 Economic Impact Analysis report was prepared by PNNL Economist Michelle Niemeyer and Energy Analyst Eric Poehlman, 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 Kevin Adamson, Lori Avery, Jonathan Bates, Jim Blount, Lauren Brandon, Andrea Brown, Steve Cassidy, Peter Christensen, Wendy Chunn, Sean Clausen, Robin Conger, Danielle Deichman, Timothy Doyle, Mindy Frankenfield, Mark Hattrup, Pamela Hughes, Jennifer Knotts, Greg Koller, Terry Law, Jim Mather, Marisela Linares-Mendoza, Lauren McKinney, Vanessa Moore, Stacy Petersen, Marc Podratz, Bruce Simanton, Evangelina Shreeve, Tanya Smith, Gary Spanner, Christie Sylvester, Annette Schutzenhofer, Mary Ann Showalter, Evangelina Shreeve, Shirah Thietje, and Susan Turner.

Executive Summary

PNNL is a large economic entity with a total of 4,486 employees, $972 million (M) in total funding, and $987 M in total spending during FY 2017.[1] The 4,190 PNNL employees who live in Washington State equal 93 percent of the Laboratory staff.

The Laboratory directly and indirectly supported $1.46 billion (B) in economic output, 7,100 jobs, and $578M in Washington State wage income from current operations. The state also gained $244M in output, 1,580 jobs, and $98M in income through closely related economic activities such as visitors, healthcare spending, spending by resident retirees, and companies with PNNL roots.[2]

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 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 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.

[1] The latest PNNL data available was for FY 2017, spanning October 1, 2016, through September 30, 2017.

[2] 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

ANL	Argonne National Laboratory
ARM	Atmospheric Radiation Measurement
B	billion
BNL	Brookhaven National Laboratory
DOE	U.S. Department of Energy
EMSL	Environmental Molecular Sciences Laboratory
FLC	Federal Laboratory Consortium
FY	fiscal year
gsf	gross square feet
GSP	gross state product
IMPLAN®	IMpact analysis for PLANning
INL	Idaho National Laboratory
IP	intellectual property
K	thousand
LASER	Leadership and Assistance for Science Education Reform
LBNL	Lawrence Berkeley National Laboratory
M	million
MESA	Mathematics, Engineering, and Science Achievement
NAICS	North American Industry Classification System
NREL	National Renewable Energy Laboratory
OASI	Social Security Old Age and Survivors' Insurance
ORNL	Oak Ridge National Laboratory
PACRAT	Physical and Cyber Risk Analysis Tool
PNNL	Pacific Northwest National Laboratory
R&D	research and development
SC	Office of Science
S&T	science and technology
SLIM	Structures for Lossless Ion Manipulation
STEM	science, technology, engineering, and mathematics
TAP	Technology Assistance Program
U.S.	United States
WBL	Work-Based Learning

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Introduction

Pacific Northwest National Laboratory (PNNL), as the nation's premier chemistry, earth science, and data analytics laboratory, conducts world-leading research and development (R&D) to address our most challenging problems in energy resiliency and national security. Located in Richland, Washington, PNNL is one of 10 United States (U.S.) Department of Energy (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 (Battelle), PNNL has 4,486 staff members with total spending of $987 million (M) during fiscal year (FY) 2017. Several major 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) user 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

During FY 2017, PNNL's total funding was $972M and total spending was $987M (Figure 1 and Figure 2, respectively). The majority of the work that PNNL performs is for DOE (64 percent during FY 2017).

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 19 percent of PNNL's business volume. The U.S. Department of Homeland Security also plays a major role.

$972M

FY17 funding

$987M

FY17 spending

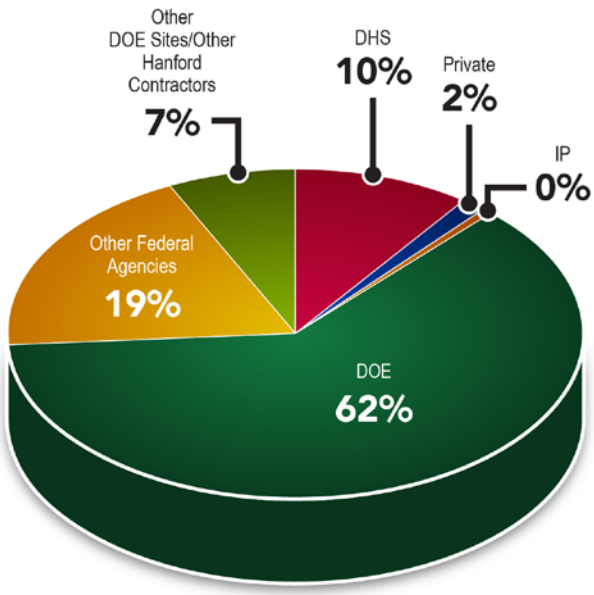

Figure 1. PNNL's Total Funding in FY 2017

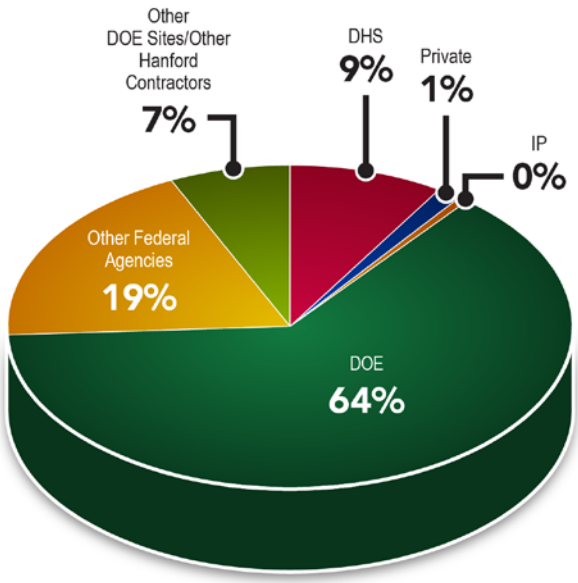

Figure 2. PNNL's Spending in FY 2017

PNNL Employment

27% *employment growth FY00–FY17*

4,486 *staff members*

93% (4,190) *employed & residing in Washington*

PNNL employed 4,486 people in FY 2017, 4,190 of whom were residents of Washington State and worked mainly in Richland, Seattle, and Sequim (Figure 3).

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, 53 percent reside in Richland, 20 percent in Kennewick, 12 percent each in Pasco and West Richland, and the remaining 3 percent reside elsewhere in the two counties.

In addition, there were 104 staff members in the Washington, D.C., area; 38 staff members assigned to work in Corvallis and Portland, Oregon; and 154 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 2017 was $456M, of which $423M went to staff members employed in Washington State. 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 2017 was $100,931.[3] In 2017, the state average occupational wage was $62,706.[4] 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).

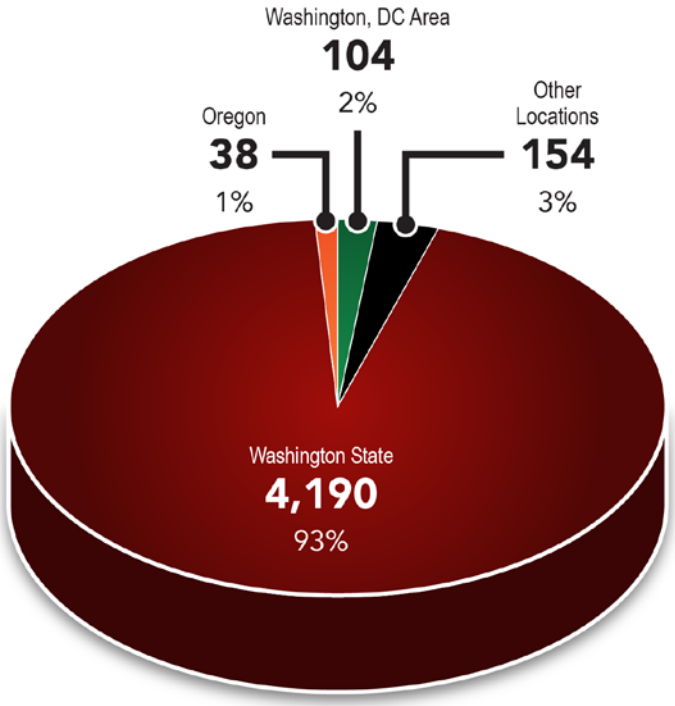

Figure 3. Location of PNNL Employees

$456M *in payrolls*

$423M *of payrolls going to Washington residents*

$89.7M *for employer-provided benefits supporting Laboratory operations*

[3] $100,931 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.

[4] The weighted average for all occupations that published both the average annual wage and the number of workers was $62,706.

Purchased Goods and Services and Investments

$82.8M

in purchases from Washington firms

During FY 2017, PNNL placed domestic procurements for $350M 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 $82.8M) of the purchases were made from Washington State firms.

Table 1. FY 2017 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	$49.0	$19
Computers, Lab Equipment, Software, Services, Retail Trade	$64.0	$17
Utilities, Transportation, Publishing, Management, and Business Services	$141.0	$12
Technical and Scientific Subcontractors	$51.0	$16
Medical and Health Services	$1.6	$1.4
All Other	$26.0	$4
Total*	**$349.9**	**$82.8**

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

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.

90 *construction jobs, supported by*

$15.2M

in-state subcontractor construction spending

In FY 2017, PNNL's facility profile comprised 71 buildings and 40 other structures, including the following:

- 22 DOE-owned buildings and 18 other DOE structures and facilities (901,000 gross square feet [gsf]) on approximately 465 acres
- 20 Battelle-owned facilities (402,00 gsf) and 23 other structures and facilities on approximately 347 acres, including approximately 117 acres in Sequim, Washington
- 28 buildings from third-party leases and agreements (958,000 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.

FY 2017 was an active year for making Facilities and Infrastructure investments, with major renovations worth $31M (see Table 2). All PNNL major renovations were performed on buildings located in Washington State. Of this total, 54 percent ($16.5M) included reimbursements to subcontractors working on PNNL buildings, including out-of-state contractors working on in-state projects.[5] Washington State resident subcontractors earned $15.2M of this $16.5M, or 92 percent. Total costs other than PNNL labor related to these renovations are included in the $350M non-payroll purchases listed in Table 1. An estimated 90 construction jobs were supported by the $15.2M 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 2017

FY 2017 Renovations	*Total Spending ($M)*
PNNL Labor Costs	$7.7
Miscellaneous Procurements	$6.5
Disbursements to Subcontractors	$16.5
Item: Disbursements to Washington State Subcontractors = $15.2M	
Total Renovation Spending	**$30.7**

Construction on PNNL's new Discovery Hall Building (see Figure 4 below) was just recently completed, which will enable researchers to convene large scientific meetings and other mission-driven events within walking distance of PNNL's world-class research facilities.

Figure 4. PNNL's New Discovery Hall Building in Richland, Washington

[5] 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.

PNNL State and Local Taxes Paid

$26.2M

paid in local and Washington taxes

PNNL and its employees paid a total of approximately $26.2M in local and Washington State taxes, which includes sales and use taxes, property taxes, and a few others (e.g., motor fuel taxes).[6] Employee taxes were based on the total $423M in wages of PNNL employees who work in Washington (and for the purpose of this analysis are assumed to live in WA) and the 2016 state and local governments' collection rates (for every dollar of personal income). The rates are an estimated $0.028 in sales, use, and other production-related taxes by individuals; $0.028 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 $1.47M in state and local taxes, and employees paid $24.75M. 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.

Table 3. FY 2017 Washington State and Local Taxes Paid by PNNL and its Employees

Washington Tax Category	*Paid by PNNL in FY 2017 ($K*)*	*Estimated Paid by PNNL Employees in FY 2017 ($K)(**)*
Sales and Use Taxes	$227	$11,999
Business and Occupation Taxes	$393	$0
Leasehold Taxes	Negligible	$0
Property Taxes	$853	$11,800
Other State and Local Taxes	Negligible	$980
Total*	**$1,470**	**$24,750**

* *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, 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

[6] Washington State does not have a personal or corporate income tax.

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*.[7]

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: $987M contribution to GSP in Washington, 4,190 Washington jobs, and $423M in Washington wages. Together, with the indirect (middle bars) and induced (upper bars) impacts, the total impacts are $1.46B in GSP, 7,100 jobs, and $578M in total wages in Washington State.

$1.46 billion (B)
gross state product (GSP)
FY17 payroll & non-payroll purchases

7,100 *jobs*

$578M *in Washington wages*

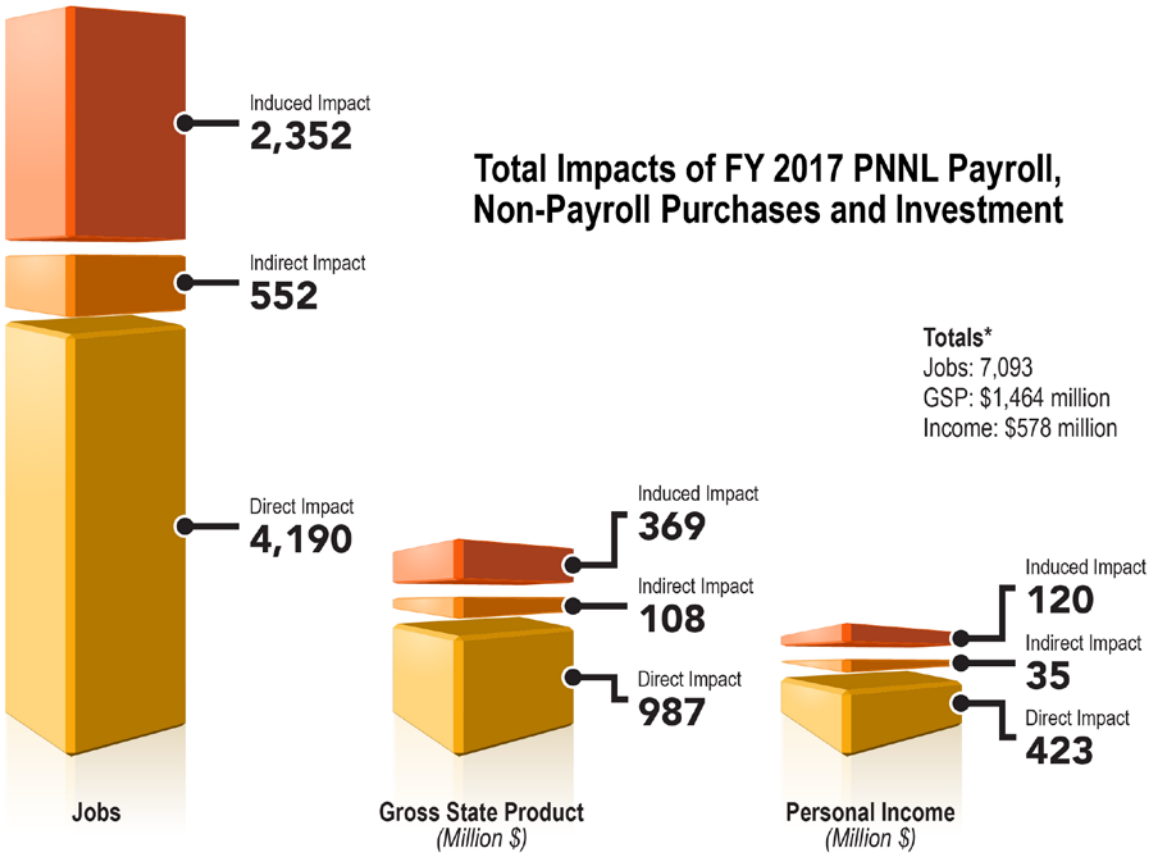

Figure 5. FY 2017 Economic Impact of Washington Payroll and Purchased Goods and Services Expenditures by PNNL

[7] 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

$45M

(approximate) health-related services funded by health insurance

$23M

retired employees' health insurance spending

$68M

FY17 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" 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.

Healthcare Expenditures

Health insurance expenditures for PNNL's 4,190 Washington State employees, 1,990 retirees, and their households in the state of Washington totaled an estimated $68M in FY 2017. PNNL's direct medical and dental insurance expenditures on behalf of employee households in Washington were estimated at $45M (see Figure 6).

Total costs of over $23M for retired households were based on Kaiser Family Foundation estimates of per capita expenditures by type for healthcare in Washington State in 2009, adjusted to 2017 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,

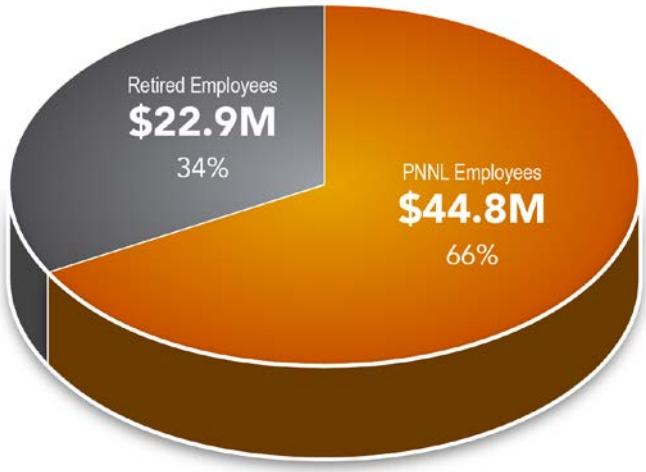

Figure 6. Estimated Spending for Washington State PNNL Employee and Retiree Healthcare in FY 2017

federal Social Security Old Age and Survivors' Insurance (OASI) benefits, and accumulated personal savings.

In FY 2017, the Battelle-defined benefit pension plan for PNNL employees paid out $61M to 2,690 retirees and other beneficiaries. The PNNL pension benefit was an average of $1,900 per month, per person, in Washington. For purposes of this report, 1,990 (74 percent) of all PNNL retirees were reported to live in Washington State.[8]

The estimated average monthly payment per OASI retired beneficiary in FY 2017 was $1,380 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 1,990 Washington PNNL retirees receive 1.4 times the OASI payment of the average retiree in the state, or about $1,940 per month, for a total estimated $45M. Pensions and Social Security together total $124M, of which about $92M 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 2017

	Estimated Average Retiree Monthly Income in FY 2017	*Total Retiree Annual Income in FY 2017 Income ($M)*
Pension	$1,900	$45
OASI (Social Security)	$1,940	$46
Total	**$3,830**	**$92**

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. In the case of new startup firms, PNNL also takes an active role in helping new businesses succeed.

Since 1965, 187 companies were started that had technological or managerial roots at PNNL and 96 of those are still in business. Forty (40) of those companies were started in the last 10 years, and Table 5 shows that 33 of them were still operating in FY 2017 and have more than 280 employees. Eighteen (18) of those companies are located in Washington State and have over 140 employees and estimated sales of $27M.

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

	Total	*In Washington State*
Number of Firms	33	18
Estimated Sales ($M)		$27
Employment	>280	>140

[8] Direct data from the pension administrator were available on PNNL retiree locations for FY 2017. Of 2,692 retirees, 1,990 had Washington addresses.

PNNL's Technology Assistance Program (TAP) provides funding for researchers to work with a small business to solve technical challenges. Table 6 shows that PNNL conducted 35 TAP projects during FY 2017. Sixty (60) percent of these were conducted for Washington-State-based companies. Since 1994, PNNL has completed 1,340 assistance projects—68 percent of them for Washington-State-based companies.

Table 6. Technology Assistance Program Statistics

	Total	*In Washington State*
Number of Projects in FY 2017	35	60%
Cumulative Projects Since 1994	1,340	68%

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 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 37 new license agreements during FY 2017.

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

	New FY 2017	*Cumulative 2000–2017*
Invention Disclosure	221	4,190
Patent Applications	48	1,280
Patents Received	33	894
Commercial and Research Licenses	37	582
Total License Revenue Received	**$3.8M**	**$62.7M**

PNNL leads all other DOE laboratories in implementation of Agreements for Commercializing Technology, having 78 agreements with 65 different sponsors. In FY 2017, PNNL had 34 active Cooperative Research and Development Agreements and 223 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 $3.8M in FY 2017. A significant portion of these funds are reinvested at the Laboratory for additional commercialization-focused development work.

Honors and Awards

In FY 2017, PNNL research was cited for seven of the 100 most innovative scientific breakthroughs of the year, as announced by R&D Magazine. These seven awards brings the cumulative total of PNNL's R&D 100 Awards to 107.

- **Acoustic Gunshot Detection System** – Jim Skorpik, Eric Gonzalez, and Michael S. Hughes (PNNL). Researchers at PNNL have created a gunshot detector specifically for indoor environments, such as schools and public buildings. SecurityUSA Services has licensed the Acoustic Gunshot Detector for integration into its lockdown and reporting systems. With SecurityUSA's version of the sensor, once a shot is detected, its system can activate a building lockdown and notify authorities.

7 *FY17 R&D 100 Awards*

107 *R&D 100 Awards total*

- **Multibed Adsorption Recuperating Cooling** – Pete McGrail, Radha Kishan Motkuri, and Jeromy Jenks (PNNL); Brett Van Horn (Arkema, Inc.). PNNL has incorporated a proprietary nanomaterial into a new cooling system, which uses heat to drive the cooling process instead of electricity. MARCool, which stands for Multibed Adsorption Recuperative Cooling, was developed by PNNL and Arkema.

- **Friction Stir Scribe Process for Joining Dissimilar Materials** – Piyush Upadhyay, Glenn Grant, Karl Mattlin, Saumyadeep Jana, Scott Whalen (PNNL); Yuri Hovanski and Rich Davies (former PNNL staff members). PNNL's Friction Stir Scribe Process is the first technology that makes it possible to join materials with drastically different melting points in a continuous, linear, or curved manner, without needing additional adhesives, bolts, and rivets. Using this tool, manufacturers can now incorporate new and different materials into a variety of strong, lightweight parts, such as sub-frames for the engine chassis, without sacrificing strength or durability.

- **Ircell** – Markus Geiser, Markus Mangold, and Andreas Hugi (IRsweep); Bruce Bernacki (PNNL). Scientists need to rapidly identify trace gases when detecting toxic industrial chemicals, identifying disease indicators, or monitoring for possible proliferation of nuclear or chemical weapons. PNNL's compact, patented IRcell technology is a dramatic improvement to traditional detection methods IRcell has been licensed to IRsweep, a provider of high-performance mid-infrared sensing solutions.

- **SerialTap** – Thomas Edgar, Sean Zabriskie, and Eric Choi (PNNL). SerialTap, created by PNNL, is an inexpensive, non-intrusive add-on that can monitor and verify the cyber activity in older serial communication systems. A startup company, Cynash, licensed the technology and is commercializing it.

- **Structures for Lossless Ion Manipulations (SLIM)** – Richard D. Smith, Ian Webb, Sandilya Garimella, Yehia Ibrahim, Erin Baker, Randolph Norheim, Spencer Prost, and Raymond Dunn (PNNL); Liulin Deng, Ahmed Hamid, and Gordon Anderson (former PNNL). PNNL's SLIM technology is 1,000 times faster than current methods and can identify trace differences in samples as small as a single cell. A startup, MOBILion, is commercializing SLIM, with the goal of creating a compact version that doctors could use to provide biomarker-based disease results to patients.

- **National Risk Assessment Partnership Toolset** – Nomination led by National Energy Technology Laboratory; PNNL team members Christopher Brown, Amanda Lawter, Catherine Yonkofski, Chris

Murray, Diana Bacon, Jason Gastelum, Kirk Cantrell, Nik Qafoku, and Luke Rodriguez (PNNL); Ellen Porter and George Last (former PNNL). Deep underground geologic formations offer promising places to safely and effectively store large volumes of carbon dioxide generated from burning coal, oil, and natural gas. The National Risk Assessment Partnership Toolset is the first complete suite of computer software that models possible environmental risks from potential storage sites, such as fluid leakage and earthquakes. The toolset draws on the expertise of five DOE national laboratories, including PNNL, and is being used by over 250 stakeholders from academia, regulatory agencies, and industry.

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 two Excellence in Technology Transfer Awards in FY 2017. These two awards bring PNNL's total to 85, which is almost a quarter of the total FLC awards won by all DOE-SC laboratories.

2 *FY17 FLC Technology Transfer Awards*

85 *FLC Awards total*

- **Physical and Cyber Risk Analysis Tool (PACRAT)** – PNNL: Doug MacDonald, Kannan Krishnaswami, Casey Perkins, Samuel Clements, and William Hutton; RhinoCorps, Ltd. Co.: Anthony Contri and Dan McCorquodale. PACRAT discovers potential vulnerabilities by analyzing how cyber and physical systems affect each other, identifying vulnerabilities not found by looking at the systems independently. The software was licensed to Albuquerque-based RhinoCorps in March 2016, after being demonstrated to potential industry and government licensees through the Department of Homeland Security's Transition to Practice Program. RhinoCorps is integrating the tool into a platform for federal and commercial customers to evaluate cyber and physical security risks.
- **Smartphone Microscope** – PNNL: Rebecca Erikson, Janine Hutchison, Josef Christ, Ron Thomas, Derek Maughan, and Gary Spanner; former PNNL staff members: Cameron Hohimer; Plastic Inspection Molding: Ken Williams. PNNL's smartphone microscope is a sleek, simple, and inexpensive way to turn a smartphone into a cost-effective, portable, and powerful microscope—allowing anyone with a smartphone to explore the world's tiniest objects. Originally part of an effort to develop a tool to quickly identify biological materials in the field, a unique decision by the inventors and PNNL's commercialization staff made the microscope available at no cost to the general public via a free, downloadable 3D printer design.

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.

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 2017, the DOE-SC provided project funding, and the Laboratory spent $832,000 for post-secondary student and faculty programs. PNNL's Intern and Fellowship Management and Administration Pool was $1,254,000. Finally, PNNL spent $1,140,000 in overhead funds to support WBL (high school and post-secondary), STEM education, and outreach efforts (K–16).

In FY 2017, there were approximately 9,369 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.

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.

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, 192 were fellows (non-PNNL employees) and 1,137 were interns or research associates. In FY 2017, 15 fellows and 339 interns/associates were from Washington State institutions.

At the K–12 level, four signature STEM education outreach efforts were conducted in FY 2017. These included 1) the Washington State Mathematics, Engineering, and Science Achievement (MESA) program; 2) Teacher Scientist Partnerships; 3) DOE Regional Science Bowl; and 4) 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 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 2017 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 (LASER).

In addition, 32 high school students had academic year or summer research experiences at PNNL. In FY 2017, these programs involved nearly 3,400 students and more than 1,200 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 2017

PNNL Programs in STEM Education	Participation in FY 2017
Post-Secondary Programs	
Four DOE-SC University Internship/Fellowship Programs	42 faculty, 65 students
Department of Homeland Security Fellowship	4 students
PNNL Post-Graduate and Post-Secondary Internships	1,140 students
PNNL National Security Internships	106 students
PNNL Alternate Sponsored Fellowships	192 students, faculty, and visiting scientists
PNNL K-12 STEM Teacher Programs	17 students (pre-service teachers)

PNNL Programs in STEM Education	Participation in FY 2017
K-12 Student Programs	
PNNL High School Interns	32 students
DOE Science Bowl	110 students
High School Shadow Program	4 students
Delta/Chiawana (STEM) High School Programs	33 faculty, 530 students
K-12 Teacher Programs	
LASER	816 educators
K-12 Collective Impact Project	
Mid-Columbia STEM Education Collaboratory (Phase 3: Collaboratory Implementation)	623 students and 224 educators

PNNL has 91 staff members serving as adjunct or joint appointment faculty at colleges and universities. Fifty-four (54) 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 2015 state-level per capita visitor spending statistics compiled by Dean Runyan Associates for Washington Tourism Alliance.[9]

Table 9 shows the statistics for out-of-town visitors to PNNL facilities in 2017, identified through PNNL visitor badges.[10] 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 $4.6M 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	5,234
Estimated total visitor days	30,500
Estimated tourism expenditures	$4.6M

[9] Dean Runyan Associates. 2015. *Washington State Travel Impacts & Visitor Volume, Compiled for Washington Tourism Alliance,* 1991-2013p.

[10] 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.

Community Investments and Assistance

Since 1965, Battelle has invested more than $27M to improve science, education, and quality of life in Washington State. Over the past 10 years, staff members at PNNL have volunteered more than 312,000 hours to community projects, including almost 42,000 Team-Battelle-volunteered hours in FY 2017. Staff members at PNNL serve on the boards of many community organizations, including: Association of Washington Business, Washington Roundtable, Washington State University Tri-Cities Advisory Committee, the 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 2017.

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 2017

Washington State Community Assistance	
Battelle cash donations to health, human services, and other philanthropic and civic organizations*	$535,000
PNNL memberships in Washington civic organizations	$108,000
Staff member contributions to United Way	$177,000
Total	**$820,000**

**Includes the $245,000 donation to STEM education.*

EMSL and ARM Users

PNNL operates EMSL and provides the 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 11). With remote access, the group of outside users is broader.

Table 11. FY 2017 EMSL Users

	Total EMSL Users	*Washington State Users*
EMSL total users	615	297
International (foreign) users	67	0
U.S. users	548	297
Non-PNNL U.S. users	303	52

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 2017, there were 1,109 unique ARM scientific users: 525 from universities, 29 from industry, 172 from DOE laboratories, 74 from other federal agencies, and 309 foreign. 218 users used ARM's facilities' on-site assets, 204 used off-site services, and 686 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 57 employees at PNNL, not all of whom are full-time.

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 637 people and generate a GSP of $92M. The IMPLAN model calculates that, when the indirect and induced economic impacts are taken into account, a total of $244M in GSP, 1,580 jobs, and $98M in labor income depend on these activities (see Figure 7).

ENVIRONMENTAL MOLECULAR SCIENCES LABORATORY

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

Research focuses on understanding the molecular mechanisms that drive 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 molecular processes involved in 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.

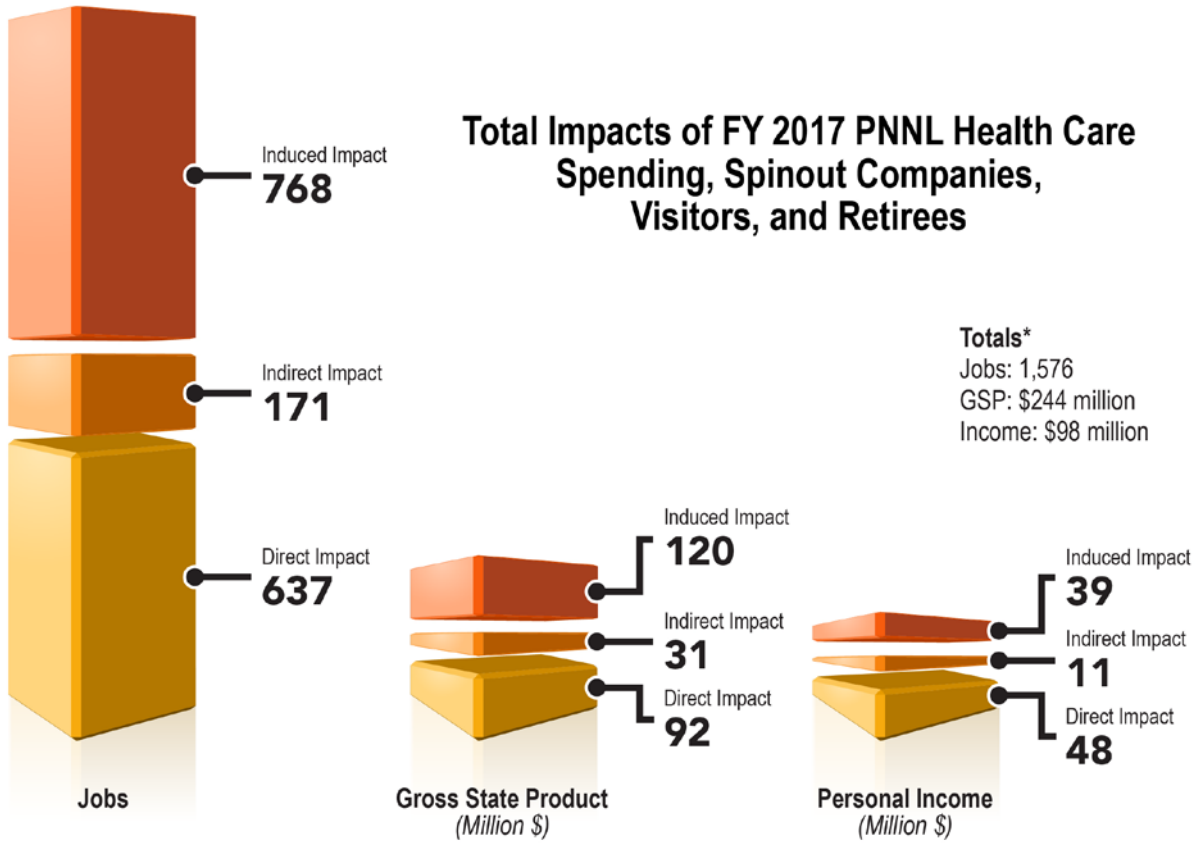

Figure 7. Total Impact of Healthcare Spending, Companies with PNNL Roots, Visitor Spending, and Retirees on the Washington State Economy in FY 2017

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 2017, which produces an estimated statewide total impact of 798 jobs, $119M in GSP, and $58M in labor income. The companies with PNNL roots had an estimated in-state employment of 145 and estimated revenue of $27M. The companies with PNNL roots, as a group, generated a statewide total economic impact of $45M in GSP, 246 jobs, and $21M in labor income. The estimated in-state visitor spending of $4.6M per year generated a total economic impact of $6M in GSP, 64 jobs, and $2M in labor income. Finally, the retirees received an estimated $92M in pension and Social Security income in FY 2017, the spending from which generated a total economic impact of $73M in GSP, 468 jobs, and $24M in labor income.

Conclusion

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 140 employees and an estimated $27M 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 $987M in total spending, 4,190 resident employees, in-state payrolls of $423M, and purchases from Washington businesses of approximately $82.8M. This economic activity supports a total of $1.46B total economic output, total in-state payrolls of $578M, and 7,100 jobs through Laboratory operations in the state. An additional $244M in output, in-state payrolls of $98M, and 1,580 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

To calculate the economic impact of PNNL on the state of Washington, PNNL used IMPLAN® (IMpact analysis for PLANning),[1] 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 2017 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.

[1] IMPLAN. Version 3.0. Davidson, NC: IMPLAN Group LLC, Inc. 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 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

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)
PNNL (FY 2017)	$1.0	4,200	$100.1	$0.4	$0.1	$1.5	7,100	$0.6
Boeing Commercial (2014)	$55.4	67,600	$113.9	$9.7 (including benefits)	NA	$77.3 (sales)	206,100	$17.0
Microsoft (2011)	$72.1 (global)	40,300	$184.8	$7.5	$2.5	$34.3	243,000	$19.4
University of Washington (FY 2014)	$5.7 (spending)	34,700	NA	NA	NA	$12.5	79,300	NA
Washington State University (2014) (Operations)	$1.0	11,900	$50.2	$0.6	NA	$2.3	20,600	$1.0
Military (2009)	$8.7 (output)	103,400	$49.5	$5.1	$2.8	$12.2	191,600	$10.5
Life Sciences (2015)	NA	36,200	$86.0	$3.1	NA	$12.5	98,100	$7.8
Wine Industry (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)
PNNL (FY 2017)	$0.99 (total spending)	4,200 (WA State)	$100.1	$423	$83	$1.46	7,100	$0.58
ANL (FY 2010)	$0.67	2,700 (FTE)	$72.3	$165	$195	$0.70	4,900	$0.21
LBNL (FY 2009)	$0.70 (total cost)	3,200	$80.4	$259	$227	$0.80	6,900	$0.49
BNL (FY 2009)	$0.57	2,900	$86.4	$250	$120	$0.70	5,300	$0.48
NREL (FY 2014)	$0.38 (total cost)	1,600 (FY 2012)	$117.5 (FY 2012)	$208	$85	$0.70	4,100	$0.32
INL (FY 2017)	$1.00 (in Idaho)	4,300	$95.8	$445	$139	$1.94	12,000	$0.86

Other Studies Reviewed

Appleseed. 2010. Brookhaven National Laboratory Economic Impact Report: Meeting National Needs, Creating Opportunities for Growth. Appleseed, New York., 60 pp. http://www.appleseedinc.com/wp-content/uploads/2014/12/Meeting-National-Needs-Creating-Opportunities-for-Growth.pdf. Last accessed 9-25-2014.

Berk and Associates. 2010. Washington State's Defense Economy: Measuring and Growing its Impact. Washington Economic Development Commission, Washington Department of Commerce, Seattle, Washington, 29pp.

Black G, D Holley, and J Church. 2010. INL Impacts: An Analysis of the Effects of Idaho National Laboratory Site Operations on Idaho's Economy. Boise State University, Boise, Idaho, 16 pp. http://www.inl.gov/portal-files/impacts_brochure.pdf. Last accessed 9-25-2014.

CBRE Consulting. 2010. Berkeley Lab Economic Impact Study. CBRE Consulting, San Francisco, California, 51 pp. https://www.lbl.gov/wp-content/uploads/2014/06/CBRE-LBNL-Economic-Impact-Study-FINAL.pdf. Last accessed 9-25-2014.

Community Attributes, Inc. 2015a. Washington State Aerospace Industry Economic Impact Study: 2015 Addendum, Washington State Aerospace Partnership, 7 pp. http://www.governor.wa.gov/sites/default/files/documents/AerospaceImpacts2015.pdf. Last accessed 4-20-2015.

Community Attributes, Inc. 2015b. Washington State University Economic Reach and Impact, 16 pp. https://economicdevelopment.wsu.edu/documents/2015/06/wsu-economic-impact.pdf. Last accessed 4-20-15.

Eicher TS. 2014. The 2011 Microsoft Economic Impact Study. Prepared for Microsoft Corporation, 31pp. http://www.one-report.com/download.html/2014/shared/library/0259-00010864.pdf. Last accessed 9-25-2014.

Sallee CM, SD Watkins, and AL Rosaen. 2011. The Economic Impact of Argonne National Laboratory. Anderson Economic Group, LLC, Chicago, Illinois, 42 pp. http://uchicagoargonnellc.org/pdf/AEG_Argonne_June_2011.pdf. Last accessed 9-25-14.

Stoel Rives, LLP. 2012. 2011 Washington Patent Report. https://www.stoel.com/getattachment/People/O/Alex-Oh/WA_PatentReport_2011.xls. Last accessed 4-20-2015.

Stonebridge Research Group, LLC. 2012. The Economic Impact of Washington State Wine and Grapes. Prepared for the Washington State Wine Commission. Stonebridge Research Group, LLC, St. Helena, California, 53pp. http://www.wawgg.org/files/documents/2012_Economic_Impact_WA_Wine-Grapes.pdf. Last accessed 9-25-2014.

Tripp Umbach. 2014. 2014 Economic and Community Impact Report of the University of Washington. Executive Report (FY 08-09). University of Washington, Seattle, Washington, 33 pp. http://www.washington.edu/externalaffairs/files/2015/01/14-Economic-Impact-Report.pdf. Last accessed 4-20-14.

Washington Biotechnology and Biomedical Association. 2014. Trends in Washington's Life Sciences Industry 2015 Summary. http://www.washbio.org/?page=Economic_Development. 1p.
Last Accessed 4-20-2015.

Washington Research Council. 2011. Trends in Washington's Life Sciences Industry. Washington Research Council, Tukwila, Washington, 24 pp.
https://researchcouncil.files.wordpress.com/2013/08/2011lifesciencesimpactreportfinal111711.pdf.
Last accessed 4-2-14.

Wobbekind R and B Lewandowski. 2015. National Renewable Energy Laboratory: Economic Contribution of Operations and Capital Investments on the Region, the State of Colorado, and the Nation, FY 2012-FY 2014. Leeds School of Business, University of Colorado, Boulder, Colorado, 37pp.
https://www.nrel.gov/about/assets/pdfs/nrel-economic-impact-report-may2015.pdf.
Last Accessed 6-25-2015.

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