PNNL-25162

Pacific Northwest National Laboratory's Climate Resilience Planning Process and Lessons Learned

February 2016

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U.S. DEPARTMENT OF ENERGY

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

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

Printed in the United States of America

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Abstract

In 2015, the Pacific Northwest National Laboratory (PNNL) developed its first Climate Resilience Plan for its Richland Campus. PNNL has performed Climate Resilience Planning for the Department of Defense, Nuclear Regulatory Commission, and Department of Energy (DOE) over the past 5 years. The assessment team included climate scientists, social scientists, engineers, and operations managers. A multi-disciplinary team was needed to understand the potential exposures to future changes at the site, the state of the science on future impacts, and the best process for "mainstreaming" new actions into existing activities. The team uncovered that the site's greatest vulnerabilities, and therefore priorities for climate resilience planning, are high temperature impacts on infrastructure and energy use, increased wildfire frequency, and intense precipitation impacts on stormwater conveyance systems. The planning method used by PNNL offers a science-based, objective, and practical approach to examining a site's vulnerabilities and risks in order to identify adaptation strategies that will be cost effective and minimize the impact of local/regional climate change. This method could easily be applied to other Federal sites.

PNNL Overview

PNNL is a DOE national laboratory managed by the DOE's Office of Science. PNNL's multidisciplinary scientific teams perform research to address problems focusing on fundamental science, energy, earth systems and national security.

The PNNL site is located in southeastern Washington State at an elevation of 371 feet.[1] The main campus has 89 buildings (2.4 million square feet) sitting on 620 acres of land (380 acres are undeveloped).[2] The PNNL campus sits south of the DOE Hanford Site in an area called the Columbia Plateau, which is a semiarid shrub-steppe environment. The area has hot dry summers, cold winters, and averages 7.1 inches of rain annually.[3] The Laboratory is located in Richland, but is frequently identified as being in the "Tri-Cities", which consist of Richland, Kennewick, and Pasco. The Tri-Cities, surrounded

[1] U.S. Climate Data. 2015. *Map of Richland – Washington*. http://www.usclimatedata.com/map.php?location=USWA0373

[2] PNNL. 2013. PNNL Facilities and Infrastructure: FY2013 Data-at-a-Glance. Pacific Northwest National Laboratory, Richland, Washington. https://collaborate.pnl.gov/projects/facilitiescontent/SiteAssets/Home_Page/DataAtaGlance.pdf

[3] Hanford.gov. 2015. *Monthly and Annual Precipitation*. http://www.hanford.gov/page.cfm/hms/products/totprcp

by the growing cities of West Richland, Benton City, and rural and farming communities in Benton and Franklin counties, has an estimated 2015 population of 275,740.[4]

Climate Resilience Planning Drivers

PNNL was compelled to prepare a Climate Resilience Plan for many reasons. PNNL's scientists have been on the forefront of climate change research for decades, including studying the impacts of regional climate change in the Pacific Northwest region where PNNL resides. Thus as a responsible steward of the Laboratory and community member, it was prudent to harness that knowledge to ensure the longevity of PNNL and our surrounding community. PNNL subject matter experts also sought an opportunity to demonstrate our climate resilience planning methods in a controlled environment. And there are also the following drivers:

- The President's Climate Action Plan, June 25, 2013[5]
- Executive Order 13653 - Preparing the United States for the Impacts of Climate Change, November 6, 2013[6]
- 2014 National Climate Assessment[7]
- DOE Climate Change Adaptation Policy Statement[8] and Adaptation Plan[9]
- Executive Order 13693 – Planning for Federal Sustainability in the Next Decade, March 25, 2015[10]

[4] Office of Financial Management. 2015. *State of Washington 2015 Population Trends: Table 4. Populations of Cities, Towns and Counties: April 1, 2010, to April 1, 2015*. Forecasting & Research Division, Office of Financial Management, Washington State. http://www.ofm.wa.gov/pop/april1/poptrends.pdf

[5] Executive Office of the President. June 2013. *The President's Climate Action Plan*. The White House, Washington, DC. https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

[6] Executive Office of the President. November 2013. *Preparing the United States for the Impacts of Climate Change*. The White House, Washington, DC. https://www.whitehouse.gov/the-press-office/2013/11/01/executive-order-preparing-united-states-impacts-climate-change

[7] Melillo, Jerry M, Terese (T.C.) Richmond, and Gary W. Yohe, Eds. 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. ISBN: 9780160924026. U.S. Global Change Research Program, Washington, DC. http://nca2014.globalchange.gov/report

[8] U.S. DOE. June 2011. *Climate Change Adaptation Policy Statement*. U.S. Department of Energy, Washington, DC. http://energy.gov/sites/prod/files/2014/03/f11/doestatement_ccadaptationpolicy.pdf

[9] U.S. DOE. June 2014. *DOE Climate Change Adaptation Plan*. U.S. Department of Energy, Washington, DC. http://energy.gov/sites/prod/files/2014/10/f18/doe_ccap_2014.pdf

[10] Executive Office of the President. March 2015. *Planning for Federal Sustainability in the Next Decade*. The White House, Washington, DC. https://www.whitehouse.gov/the-press-office/2015/03/19/executive-order-planning-federal-sustainability-next-decade

Method

The method used to prepare PNNL's Climate Resilience Plan was developed from multiple resources that were adapted to meet a DOE site's needs.[11] This method is currently being used to develop a plan for the entire Hanford Site, and is applicable to other DOE sites. The planning process has the following five steps Figure 1:

1. Determine who will be involved in the process by establishing a core assessment team, identifying stakeholders, and defining roles and commitments.
2. Conduct an initial exposure assessment using the core team and targeted engagements with stakeholders.
3. Assess the existing plans and processes that could be adapted to enhance the ability of the site to adapt.
4. Draft the priority site vulnerabilities and engage stakeholders to seek consensus and/or identify gaps.
5. Develop specific actions for each program/department that includes frequency of re-assessment.

Figure 1. Climate Resilience Planning Steps

Forming Core Assessment and Stakeholder Teams—the Most Important Step

The most important step when initiating the climate resilience planning effort is forming the *core assessment team and the stakeholder team* so that the expertise includes regional scientific expertise in climate change impacts, sustainability program managers, and leadership in relevant operations programs. It is critical to establish the right composition of both of these teams (Table 1).

The core assessment team will be responsible for the development of the plan and likely large portions of its implementation. Ideally, this team's membership would include individuals with intimate knowledge of site operations/mission requirements, an understanding of regional climate impacts, and facilitation expertise. The core assessment team will outline the scope of the planning effort, identify key stakeholders to engage at different points in the process, and secure their commitment to participate. The most important role of the core assessment team is ensuring the right composition of the internal stakeholder group – that is, who are the internal decision-makers with direct responsibility for plans and infrastructure that are potentially vulnerable to climate impact?

[11] Moss, R.H., et al. (2015). *Vulnerability Assessments and Resilience Planning at Federal Facilities: Preliminary Synthesis of Project Results*. Pacific Northwest National Laboratory PNWD-4451. 48 pp.

External stakeholders, such as local utilities, can be critical to a site's ability to implement aspects of its plan and may be involved on an *ad hoc* basis or as a member of the planning team. The degree of external stakeholder engagement can vary with their direct relevance to the process. For example, if damage to information technology infrastructure from extreme weather events is determined to be a critical vulnerability, it may make sense to engage the internet service providers selectively to clarify how their plans (e.g. undergrounding cables) could help reduce the site's vulnerability. Additional resources for how to effectively engage stakeholders can be found in the literature.[12]

Table 1 Key Expertise in the Core and/or Stakeholder Team

Sustainability Program	Worker Safety & Health
Energy Operations	IT Services
Facilities Strategic Planning	Water Resource Management
Facilities Engineering	Critical Regional Stakeholders
Facilities & Operations Strategic Projects	Research subject matter experts such as
Facilities & Grounds Maintenance	- Earth Systems/Climate Science
Environmental Health & Safety	- Sustainable Building Performance

Determining Vulnerabilities of Core Systems

An *exposure assessment* involves understanding regional climate change trends, future projections (e.g. higher temperatures) and the site's exposure to secondary impacts (e.g. increased wildfire risk, loss of water availability). Resources such as the National Climate Assessment[13] and its regional supplements, and local weather station data can help inform this assessment. Vulnerabilities can be exacerbated by characteristics of infrastructure, such as their design, condition and placement, that are ill-suited to the acute regional effects of climate change. When an extreme event or change in climate occurs, it can exploit system vulnerabilities to produce impacts that affect mission attainment (Figure 2). The site core systems, such as energy services and buildings, are then considered in relationship to the climate trends. The outcome of this step is a first draft assessment of relevant climate changes and at-risk core systems.

[12] Hund, G., J.A. Engel-Cox, K.M. Fowler. 2004. *A Communication Guide for Sustainable Development: How Interested Parties Become Partners*. ISBN: 1-57477-140-X. Battelle Press, Columbus, Ohio.
[13] Melillo, Jerry M, Terese (T.C.) Richmond, and Gary W. Yohe, Eds. 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. ISBN: 9780160924026. U.S. Global Change Research Program, Washington, DC. http://nca2014.globalchange.gov/report

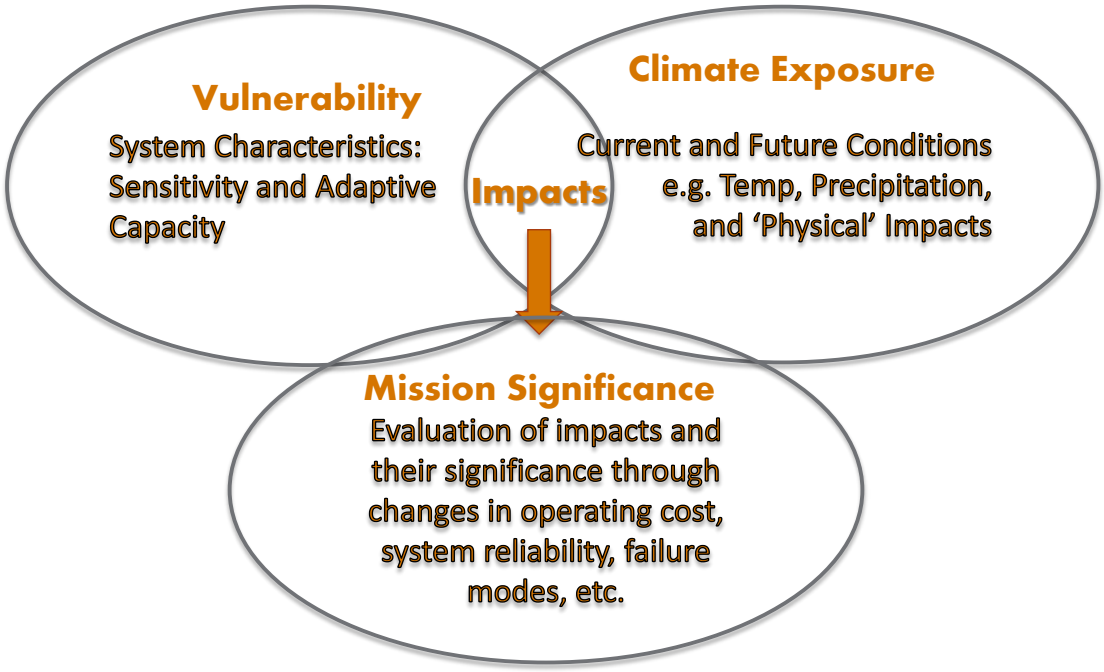

Figure 2. Elements of Vulnerability Assessment.[14]

Review and Adapt Existing Stie Plans Relevant to Vulnerability of Core Systems

Step 3 involves *understanding the current plans* to manage the site's core systems. Many organizations have existing plans addressing the operation of their core systems that cover major aspects of a climate resilience plan. Some examples of useful plans to look for include emergency preparedness plans, master construction plans, and building design standards. Reviewing these existing plans is a key step in understanding how the core systems are valued and how prepared the site is to protect and restore those assets under different scenarios. The review of these plans, and conversations with the plan authors can elucidate the ease for modifications to enhance site adaptation. In addition to site plans, look for assessments and plans from key external stakeholders, such as state natural resource agencies or utilities, to better understand if and how others are planning to address regional climate impacts. The failure of external organizations to plan for climate change can represent a vulnerability to the site if they provide critical services. To facilitate documentation of the information collected, a framework such as that presented in Figure 3 may be used.

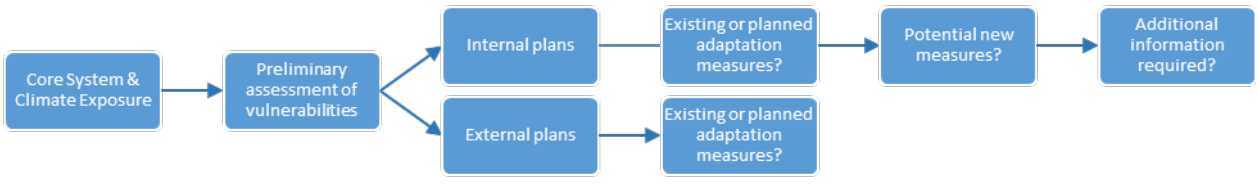

Figure 3. Documentation Review Framework

[14] Adapted from Moss et al, 2015. http://www.osti.gov/scitech/servlets/purl/1211559

Prioritize Core Systems According to Vulnerability and Adequacy of Existing Risk Management Plans

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes".[15] Vulnerability includes an understanding of an asset's potential for exposure, its sensitivity to exposure, and its adaptive capacity. *Identifying and prioritizing the site vulnerabilities* includes working with internal stakeholders to define the nature of potential vulnerabilities for each of core system and exposure. For example, high temperatures (climate exposure) have the potential to increasing the degradation rate of the building exterior (vulnerability). The prioritization of each core system and vulnerability will depend on whether existing and planned adaptation measures are adequate to manage the vulnerability, or whether additional measures are needed to build resilience. This will be an iterative process of engaging system operators and external stakeholders to fill the information gaps. Ultimately the internal stakeholder team should review the final information and collectively decide on the priority vulnerabilities. A matrix may be used to illustrate the relative priorities and help the stakeholder team focus action planning on the most vulnerable areas. An example matrix is shown in Table 2.

Table 2. Example Vulnerability Matrix

Climate Exposure / Core System	High Temperatures	Intense Precipitation	Wildfire	Drought
Buildings				
Energy				
Water Resources				
Worker Health & Safety				
Transportation				

Establish the Action Plan with a Goal to Mainstream Into Standard Operational Practice

The final step is to *establish the action plan.* This step involves final engagement with the internal stakeholders, and external stakeholders as needed, to confirm the prioritization of vulnerabilities, confirm existing plans and processes that could be adapted, finalize the recommended actions, and establish an approach for integrating the recommendations into everyday operations. One key component of the action plan is to schedule a time to evaluate progress on the assigned actions (e.g., quarterly core team meeting). The Climate Resilience Plan is the written product of the effort, but an understanding of how the plan will be integrated into existing operational practices, where appropriate, and implemented across the site is the final outcome.

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[15] IPCC. 2007. *IPCC Fourth Assessment Report: Climate Change 2007: Section: 19.1.2.1 Meaning of 'key vulnerability'*. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch19s19-1-2.html

PNNL Climate Resilience Plan

PNNL's Sustainability Program personnel enlisted PNNL's climate change research scientists to assist with the development of the site's first Climate Resilience Plan. For PNNL the internal stakeholder team was comprised of program managers and some technical personnel with responsibility for employee safety, environmental management, energy and water resource management, information technology systems, emergency planning, facility engineering and design, and campus master planning. External stakeholders were consulted as needed to fill information gaps.

PNNL identified its core systems as:

- Buildings
- Energy
- Water resources
- Information technology
- Transportation
- Worker safety and health

PNNL's areas of potential or existing climate exposure included:

- Intense precipitation
- Drought
- Wildfire
- High temperatures
- Storms and winds
- Ice storms

Because the internal stakeholder team was designed to be multi-disciplinary and included responsibility for the breadth of systems affected by potential climate impacts, the team was well equipped to explain the existing or planned adaptation measures, share ideas on new adaptation measures, identify and close information gaps, and commit to taking future actions. For example, even though PNNL is located in an arid climate, water scarcity was not prioritized as one of the highest potential exposures because the large volume of the Columbia River that is maintained by multiple dams along the entire expanse of the river. The variability of the snowpack in the Cascade Mountains will not have a significant impact on the overall water availability to this region over time. However, water temperature was identified as a potential risk because higher temperatures reduce the cooling capacity at PNNL, in addition to increasing energy use and the rate of infrastructure degradation.

The final resilience plan was shared with external stakeholders, including federal site managers at the nearby Hanford Site, to enable them to use the information to support their own resilience efforts. An example vulnerability assessment and action plan for the high temperature climate exposure related to PNNL buildings is shown in Figure 4.

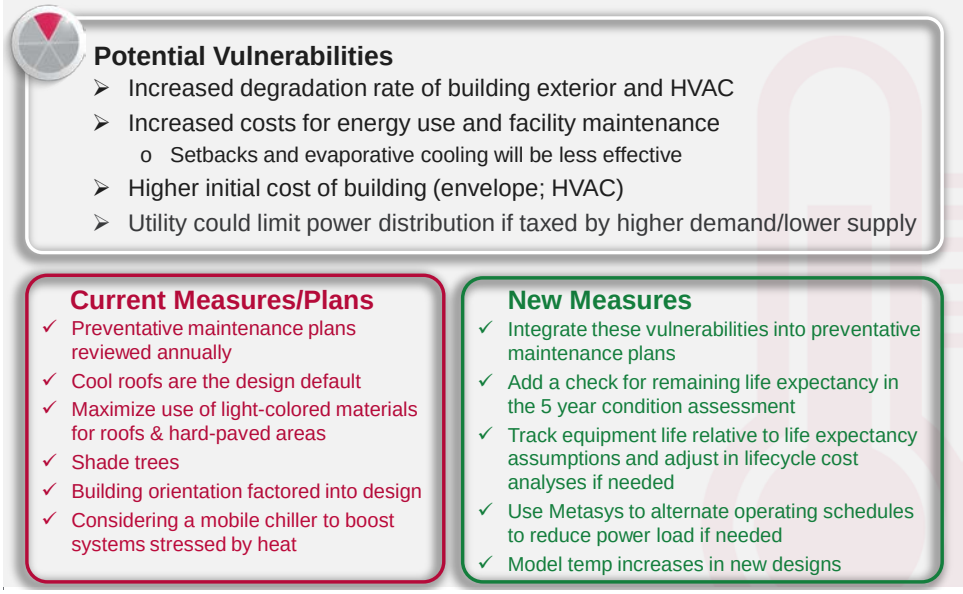

Figure 4. Example Action Plan for Buildings

Because vulnerability can change over time, a critical outcome of PNNL's climate resilience planning process was the definition of metrics that the internal stakeholder team agreed to track and review annually. The following metrics will be tracked annually to gauge changes in risk over time:

- High temperature risk – calculated as the number of consecutive days per year over 100 degrees Fahrenheit (data source: Hanford weather station)
- High temperature impact – calculated with 3 metrics including premature heating, ventilation, and air conditioning (HVAC) equipment failure rates for envelope degradation rate (data source: 5-year condition assessments comparing planned HVAC unit life to estimated remaining life); change in cooling season utility costs (data source: EnergyCap utility management system); and the rate of water use for cooling (data source: PNNL's Building Operations Control Center)
- Wildfire risk – calculated with 3 metrics including the change in the number of regional fire events per year (data source: Hanford Off-Normal Occurrence Center); the change in air filter loading rate (data source: PNNL's Building Operations Control Center); and the cost of responding to wildfire events (data source: PNNL's Facility Reliability Index)
- Intense precipitation risk – calculated with 4 metrics including the number of rainfall events per year that exceed 1 inch within 24 hours, which is the design standard for PNNL's drainage systems (data source: Hanford weather station); the number of flood incidents per year that affect facilities and infrastructure such as vaults (data source: PNNL Facilities Engineering records and service requests); the cost to respond to flood events (data source: PNNL's Facility Reliability Index); and the number of times per year catch-basins are clogged and require maintenance (data source: PNNL service request system)

Tracking these metrics will provide the internal stakeholder team with an objective and tangible means of tracking trends and determining when further adaptation actions are warranted. The status of PNNL's risk assessment will be updated each year as part of the Site Sustainability Plan.

Lessons Learned

PNNL operations reported that the assessment planning effort was useful. They found that the process enabled them to examine Laboratory operations from a new point of view and identify previously unknown vulnerabilities. The core assessment team has committed to share lessons learned to help other Federal sites in their Climate Resilience Planning efforts.

Out of the many climate vulnerability assessments performed by PNNL, participants reported that the internal assessment was the most successful. Participants concluded that its success was driven by the multi-disciplinary composition of both the core and stakeholder teams; the fact that data was collected and analyzed to the first full stakeholder meeting; assessment experts facilitated all meetings, and PNNL quickly institutionalized the action plan into “every-day” operations.

Site- and Topic-Specfic Stakeholder Engagement

Stakeholder engagement strategies are most effective when they are site- and topic- specific. Stakeholder engagement can make or break a process with cross-cutting dependencies like climate resilience planning. We often hear the adage “engage stakeholders early and often”, but all stakeholders may not need to be at the table at the outset. The need for, and timing of, engagement will vary with the stakeholders’ knowledge of climate change impacts and decision-making influence each stakeholder has over core systems with potential vulnerabilities.

Initially, the core assessment team must work with key stakeholders to develop a summary of climate exposures, current processes that already support adaptation, and some draft ideas of changes to processes. The number of stakeholders and the depth of their involvement can expand as required for future planning efforts. The core assessment team’s ability to facilitate the process and perform data collection and analysis will help ensure productive engagements with stakeholders.

Preparation is Key to Effective Stakeholder Engagement

When the facilitators of the planning efforts show they are prepared, the stakeholders are more willing to engage. PNNL’s core assessment team prepared by examining climate impacts research and narrowing the field of climate exposures to bring to the stakeholder team. Internal and external stakeholder review of all relevant plans and meeting with individuals to clarify key information needs required significant effort but led to a far more efficient first engagement with the stakeholders. PNNL found that meetings with stakeholders could then focus on two items: 1) validating the initial assessments of vulnerabilities and current adaptation measures and 2) brainstorming new measures. Full engagement by the stakeholders during the assessment process can result in greater implementation success because the stakeholders will have ownership of the activities outlined in the plan.

Vulnerability Thresholds are Crucial, May Require an Iterative Process to Establish

Effective vulnerability assessment frameworks include establishing vulnerability “thresholds” that indicate when a system has become high risk and requires action. This can be difficult, particularly for a site new to resilience planning. To get a better handle on changes to the site’s vulnerability over time, an

assessment team should start by defining metrics that will be tracked, and commit to revisit them periodically and set thresholds when they are better understood. Vulnerability thresholds that are developed deliberately support a more comprehensible resilience plan. Clarity on vulnerability thresholds can result in quicker tracking of repair cost changes and modifications to other operational programs. This is important because these costs will be the basis for current or future vulnerability calculations to the site operations.

The number of plans that exist for Federal sites make it hard to initiate a new planning effort. However, in the case of the PNNL Climate Resilience Plan, the effort resulted in cost effective new processes that were “main-streamed” into existing processes. PNNL expects that the cross-functional nature of the plan will improve existing, more traditional planning efforts and identify key vulnerabilities that might otherwise appear during a crisis. PNNL found that, of all the high-value lessons learned during the climate resilience planning process the criticality of the composition of the core and stakeholder teams stood out the most.

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