2014

DOE Climate Change Adaptation Plan

U.S. Department of Energy

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Climate Change Adaptation Plan

"The threat from climate change is real and urgent. The science fully demands a prudent response."

- Secretary of Energy, Ernest Moniz

Changes in the global climate system are unmistakable, as is now evident from observations of increased global average air and ocean temperatures, decreased historical snow pack, rising global average sea level, and more frequent severe weather events.[1] The U.S. Department of Energy (DOE) recognizes that changes in the global climate system could have a profound impact on the Department's mission activities. DOE is committed to reducing greenhouse gas (GHG) emissions and mitigating climate change by developing clean energy and energy efficiency technologies for commercial deployment while providing leadership through its own sustainable operations. As effects of climate change are felt across the world, it is necessary to characterize potential impacts on the DOE mission, programs, and operations to foster adaptation and resilience. DOE will identify where to focus resources to develop greater resilience over time, minimize potential risks and maximize potential opportunities created by climate change. It is important to note that while longer term damages could be very substantial, we may have more modest, nearer term impacts (above and beyond those that we already have due to weather vulnerabilities). The 2014 DOE Climate Change Adaptation Plan (Adaptation Plan) outlines Departmental vulnerabilities and serves to guide our response to allow DOE to continue to achieve its mission.

The DOE vision for climate change adaptation is the integration of risk based resiliency to address identified climate change vulnerabilities across all DOE programs and policies wherever appropriate. Assessment of climate change vulnerabilities, informed by best available science, are seen as an integral part of the DOE's planning activities, risk assessment, and careful investment that define the DOE mission.

Climate change adaptation is not new to DOE; rather, climate change is an ongoing part of DOE research, modeling, and policy development. A strong culture of preparedness, integrated safety management, and operational excellence in potentially hazardous working environments already exists throughout DOE. Climate change resilience will build on this operational and capital planning, as well as provide information to the larger applied research body of climate change adaptation.

Impetus for Action

The Adaptation Plan serves as the second iteration of a living plan. This edition was modified in accordance with Executive Order (E.O.) 13653, *Preparing the United States for Climate Change*, the

[1] *State of the Climate in 2012*, NOAA
http://journals.ametsoc.org/doi/suppl/10.1175/2013BAMSStateoftheClimate.1/suppl_file/2013bamsstateoftheclimate.2.pdf

knowledge gained from our first Adaptation Plan (publicly released in 2012), and the experiences of the Department and other federal agencies in response to extreme events such as Hurricane Sandy. The Department's Adaptation Plan will also draw from E.O. 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, and the President's Climate Action Plan (June 2013) to provide a comprehensive planning document.

The Adaptation Plan addresses the national and international context of the DOE mission, as well as the local perspective of DOE facilities and community stakeholders. Increased understanding of climate change has enabled DOE to better forecast climate change impacts, quantify risk, and identify opportunities to improve resilience.

The Adaptation Plan will work in concert with DOE's ongoing mitigation activities outlined in DOE's annual Strategic Sustainability Performance Plan (SSPP)[2]. DOE maintains its commitment to reducing agency GHG emissions, utilizing renewable energy, and making operations more sustainable.

The DOE Mission and Climate Change Adaptation

DOE's mission is to "enhance U.S. security and economic growth through transformative science, technology innovation, and market solutions to meet our energy, nuclear security, and environmental challenges."[3] DOE achieves its mission through an operational and programmatic framework that supports the following goals outlined in the 2014-2018 DOE Strategic Plan:

- Advance foundational science, innovate energy technologies, and inform data driven policies that enhance U.S. economic growth and job creation, energy security, and environmental quality, with emphasis on implementation of the President's Climate Action Plan to mitigate the risks of and enhance resilience against climate change
- Strengthen national security by maintaining and modernizing the nuclear stockpile and nuclear security infrastructure, reducing global nuclear threats, providing for nuclear propulsion, improving physical and cybersecurity, and strengthening key science, technology, and engineering capabilities
- Position the Department of Energy to meet the challenges of the 21st century and the nation's Manhattan Project and Cold War legacy responsibilities by employing effective management and refining operational and support capabilities to pursue departmental missions.

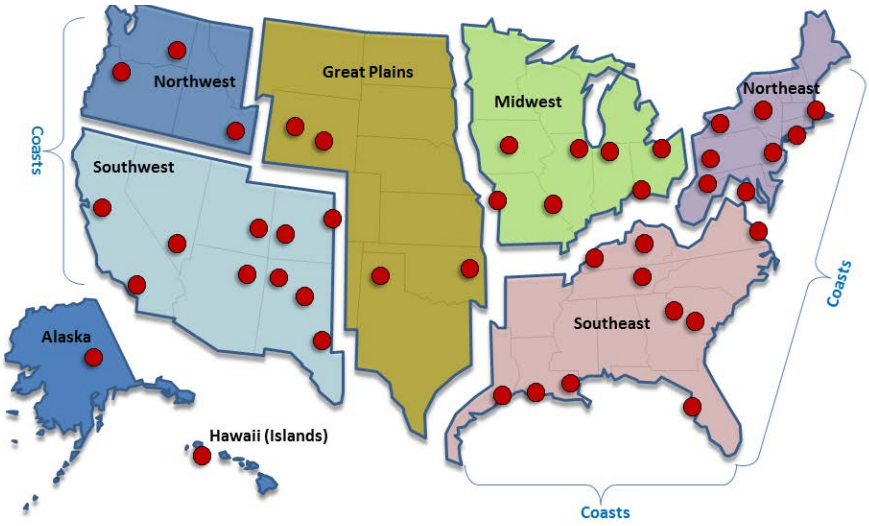
The DOE enterprise is comprised of approximately 15,000 federal employees and over 100,000 contractor employees at both the headquarters in Washington, DC and Germantown, Maryland and at over 47 facilities in 40 states (see Figure 1). DOE's facilities are located in all eight U.S. climate regions identified in the 2014 National Climate Assessment, as established by the U.S.

[2] 2013 DOE Strategic Sustainability Performance Plan http://www1.eere.energy.gov/sustainability/pdfs/doe_sspp_2013.pdf
[3] *2014 DOE Strategic Plan*

Global Change Research Program (USGCRP).[4] These facilities include a nationwide system of 17 national laboratories that provide world-class scientific, technological, and engineering capabilities that employ over 29,000 researchers. These laboratories include operate numerous scientific user facilities that allow researchers from other Federal agencies, universities and the private sector to use. DOE facilities also contain unique scientific equipment and processes and house advanced materials, including nuclear materials critical to U.S. national security.

DOE leads the nation in transformational research, development, demonstration, and deployment (RDD&D) of an extensive range of clean energy and efficiency technologies – supporting the President's Climate Action Plan and an all-of-the-above energy strategy. DOE also leads national efforts to develop technologies to modernize the electricity grid, enhance the security and resilience of energy infrastructure, and expedite recovery from energy supply disruptions. The Department conducts robust, integrated policy analysis and engagement in support of the nation's energy agenda.

Figure 1: DOE Sites Grouped in USGCRP Climate Regions



DOE enhances the security and safety of the nation through its national security endeavors: maintaining a safe, secure, and effective nuclear weapons stockpile in the absence of nuclear testing and managing the research, development, and production activities and associated infrastructure needed to meet national nuclear security requirements; accelerating and expanding efforts to reduce the global threat posed by nuclear weapons, nuclear proliferation and unsecured or excess nuclear materials; and, providing safe and effective nuclear propulsion for the U.S. Navy.

DOE leads one of the largest cleanup efforts in the world to remediate the environmental legacy of over six decades of nuclear weapons research, development, and production. As DOE carries out its mission, it employs effective and cost-efficient management, supports a highly skilled workforce, and provides a modern physical and information technology infrastructure. DOE remains committed to maintaining a safe and secure work environment for all personnel and to

[4] USGCRP. *Global Climate Change Impacts in the US*. 2009: http://globalchange.gov/publications/reports/scientific-assessments/us-impacts

ensuring that its operations preserve the health, safety, and security of the surrounding communities

The distribution of DOE facilities across all eight U.S climate regions gives DOE a unique opportunity to be a leader in climate change assessments and resiliency efforts. DOE's 2014-2018 Strategic Plan highlights the Department's leadership and commitment to bringing the extraordinary technical resources of the Department to bear in this effort. The DOE vision for climate change adaptation is the integration of climate change resiliency across the Department wherever appropriate. DOE will look to incorporate the risks and impacts posed by climate change in DOE plans, programs and policies, and mission.

Risks to Operations, Missions and People

Findings of the DOE High-Level Vulnerability Assessment

DOE completed a high level vulnerability assessment in 2012 to determine departmental risks to climate change[5]. Locations where the DOE mission is conducted were found to be likely to encounter a combination of climate change effects, both in the form of direct acute events (e.g., severe weather) and long-term changes (e.g., average annual precipitation). Additional indirect impacts, particularly those related to social systems and human health, were also recognized. These were found to possibly manifest as both acute (e.g., economic and political instability) and long-term (e.g., changes in population and social demographics) vulnerabilities. DOE identified the following high level critical vulnerabilities:

- DOE could potentially be exposed to global, national, regional and location-specific effects of climate change;
- DOE's mission, site operations and programs have varying degrees of sensitivity, depending on location and type of work. This diversity must be accounted for in the planning process in order to prevent maladaptation.
- Given the nature of its mission and in-house expertise, DOE possesses considerable adaptive capacity within existing policy, planning, and operational frameworks. Greater and more consistent integration can develop resilience to future climate change effects.

DOE has the opportunity to enhance its own operations and programs through increased climate change resiliency, while also contributing technical expertise and climate change resilient energy technology solutions. The Department can therefore both provide continuity for its own operations and help the nation and its international partners to adapt to a changing climate.

Physical Assets and Real Property

DOE physical assets and real property are diverse and vary in complexity. The Department's assets include typical office buildings, laboratory buildings, warehouses and shops, as well as unique one-of-a-kind research facilities such as light sources, research reactors, semi-conductor

[5] DOE High Level Analysis of Vulnerability to Climate Change, April 2012

fabrication facilities, particle accelerators, and nuclear material production and processing facilities. This diversity of facilities results in a multitude of vulnerabilities, risks and impacts.

The Energy-Water Nexus

The energy-water nexus poses a significant risk to DOE sites and operations. Extreme climate events such as increased temperature and associated drought have important impacts on the energy-water interface. Climate impacts will manifest as changes in land use and resource demand. These changes tend to reinforce and intensify individual impacts on land and water resources (e.g., reduced cropping due to water shortages raises feed prices, which changes grazing patterns, which in turn affects vegetation density and thus potentially increases wild fire vulnerability). To an extent, these changes feedback through water and land use to impact energy demand and production[6].

In FY 2013, DOE facilities used 4.947 million megawatt hours (MWh) of electricity. Much of this electricity is procured by DOE from off-site providers that utilize hydropower or steam electric power generation requiring significant volumes of water. Interruption of electricity for any extended period of time will greatly impact DOE mission activities. Examples of how this could occur are discussed below.

Warmer temperatures and changes in the hydrologic cycle, including precipitation type, frequency, and intensity are expected with climate change – putting generating capacity at risk. Temporally, this impact may cause concern with short term, seasonal fluctuations as well as longer term disruptions in service capacity. The Power Marketing Administrations within DOE operate federal hydropower facilities and may be subject to additional vulnerabilities as well. The potential for changes in reservoir operations to meet new, non-power uses, and the aging of federal hydropower assets, could lead to lower reliability and a reduction in operating capacity[7].

Climate change impacts to water availability may impact energy availability at other DOE facilities as well. Water accessibility for commercial offsite electricity production may impact electricity production and energy costs. The increased incidence of droughts and water constraints could result in water-related electricity shortages and disruption of DOE facility operations.

Water Vulnerabilities

Declines in the quantity and quality of water associated with climate change may directly affect site operations and research efforts. In FY 2013, DOE used 6.464 billion gallons of potable water, and an additional 1.171 billion gallons of non-potable water. Facility and industrial uses account

[6]U.S. Department of Energy, Climate and Energy-Water-Land System Interactions: Technical Report to the U.S. Department of Energy in Support of the NCA, March 2012 http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21185.pdf

[7] U.S. Department of Energy, Effects of Climate Change on Federal Hydropower, August 2013 http://www1.eere.energy.gov/water/pdfs/hydro_climate_change_report.pdf

for the majority of DOE's potable and non-potable water use. The availability of significant volumes of water will remain essential to critical facility operations.

Prolonged droughts coupled with warmer weather may also contribute to increased wildfires. Particularly in western regions of the country wild fire risk can pose a serious threat to facilities and local infrastructure supporting DOE operations. Wildfire damage has already proven a risk to DOE facilities (see Case Study 1) and may increase with climate change.

The amount of rain falling in extreme precipitation events has increased in the U.S. by approximately 20 percent in the past century, and this trend is projected to continue. A national upward trend in the number of extreme precipitation events is statistically significant with the greatest frequencies occurring in recent years[8]. More intense precipitation or storm events could result in flooding. DOE sites already experience floods under existing climate conditions (see Case Study 2) along with record breaking rainfalls, resulting in millions of dollars in damages.

DOE Case Study 2: 2010 Extreme Flooding at Pantex

DOE's Pantex Plant is the nation's only nuclear weapons assembly and disassembly facility. Work performed at Pantex is critical to national security. The plant is located in flat terrain in the Texas Panhandle, with shallow and gentle slopes for drainage.

In July, 2010, the region experienced record breaking rainfall and severe flash flooding. Pantex received 11.04 inches of rain in a single day, 8.76 inches of which fell during a single hour. Natural and man-made drainage systems on the site were overwhelmed. Since this incident, Pantex has constructed improved drainage ditches on the site, and also response plans, procedures and equipment to better prepare for flash flooding events. As this example shows DOE is already experiencing increased frequency and intensity of climate related impacts. This adds increased urgency to adaptation efforts.

Temperature Extremes

Increased average temperatures will result in decreased heating needs during winter months; they will also result in increased summer cooling needs for DOE buildings. In addition, DOE sites could face operationally disruptive electricity shortages during peak summer demand periods due to increased DOE and non-DOE electricity demand. Other regions of the country may face more extreme climate events (extreme heat and cold) and more variable temperatures throughout the year. Results could include increased energy and heating/cooling costs and the need for additional capacity. Increased incidence of heat and climate related workforce health issues

[8] USCGCRP, 2013 NCA Regional Climate Scenarios Summaries Parts 1-9 http://scenarios.globalchange.gov/node/1155

related to heat stress, potential increases in pestilent species or epidemics, and outdoor human operational constraints may affect day to day operations.

Sea Level Rise and Extreme Events

Climate change projections include sea level rise and a greater likelihood of severe weather events (e.g., hurricanes, storm surge, etc.). The effects of sea-level rise on coasts will vary considerably from region-to-region and over a range of spatial and temporal scales. Land subsidence in certain locations causes relative sea-level rise to exceed global mean sea-level rise. The effects will be greatest and most immediate on low-relief, low-elevation parts of the U.S. coast along the Gulf of Mexico, Mid-Atlantic States, northern Alaska, Hawaii, and island territories and especially on coasts containing deltas, coastal plains, tidal wetlands, bays, and estuaries. [9]

Even though a majority of DOE facilities are located inland, sea level rise and extreme events could impact those facilities located in coastal regions through inundation, especially during storm events, and salt water intrusion affecting freshwater availability and quality. In the longer term, coastal erosion could also increase vulnerability at some locations. Additionally, in a more regional context, inland DOE sites are staffed and supported by resources located in coastal locations.

Sea level rise may also affect external facilities that provide DOE with electricity. Most saltwater consumption in U.S. coastal counties occurs during thermoelectric power generation. Changes in water temperature, density and level may impact the effectiveness of water as a cooling medium. Additionally the coasts are areas of exploration for energy sources including traditional sources, such as the extraction and transportation of offshore fossil fuels to inland areas, and alternative sources, such as tidal, wave, and wind energy. DOE facilities that rely on external power sources will need to account for these vulnerabilities.

Appendix 1, *Summary of Forecasted Climate Effects for Major US Climate Regions*, illustrates examples of the effects of climate change in each major climate region. This table includes general regional effects summarized by the USGCRP with a focus on those most likely to impact DOE. Identifying the likelihood, timing, frequency, and magnitude of climate change impacts including secondary risks for specific DOE sites and their surrounding communities requires further analysis, outreach, research and modeling.

Programmatic Risks

Given that much of DOE's work is tied to critical specialized infrastructure, it is impossible to completely separate DOE's programs from location-specific facility operations. However, it is important to consider climate change not just in terms of infrastructure integrity and facility operations, but also in terms of broader programs and mission. DOE is working in its current programmatic structure to account for vulnerabilities and impacts are at more than just the

[9] Burkett, Virginia and Margaret Davidson, "Coastal Impacts, Adaptation and Vulnerabilities: A Technical Input to the 2013 National Climate Assessment" NOAA, 2013 http://cakex.org/sites/default/files/documents/Coastal-NCA-1.13-web.form__0.pdf

facility level. The high level view allows DOE to engage decision makers and informs mission continuity.

DOE's research, development, demonstration, and deployment (RDD&D) mission requires specialized facilities, many of which are located in drought-prone regions. RDD&D equipment, such as particle accelerators, bio-refinery pilot plants, and High Performance Computers can require significant water and energy resources. Thus, these activities could be subject to disruptions or delays due to infrastructure impacts attributable largely to a changing climate. Increased energy and water costs could impact RDD&D budgets and the development and deployment of clean energy technologies due to diminished DOE research capacity. For example, the large scale development and deployment of biofuels and new thermoelectric generation technologies could be impacted by energy and water scarcity, possibly reducing technical and economic viability.

At the same time, DOE's scientific mission includes addressing the challenges of climate change for our energy sector. Climate change effects could result in the need for expanded or accelerated development and deployment of clean energy generation, resilient transmission, and energy efficient technologies which also mitigate climate change – particularly those that are less vulnerable to climate change and extreme weather. DOE's scientific and analytical capabilities will continue to serve a critical role in understanding, projecting, developing and implementing sound policies for adapting to climate change effects.

The DOE nuclear security mission, which is critical to our national security, is also largely conducted at DOE sites faced with potentially disruptive infrastructure impacts caused by extreme weather conditions and climate events. DOE will look to increase its resilience to climate change. DOE must account and prepare for potential climate change impacts on its missions, to include its nuclear security mission, and will look to manage risk through its emergency and site planning processes.

DOE's environmental mission could also experience negative impacts as well as opportunities. Groundwater remediation systems in some regions may experience decreased operational efficiency due to drought, while other areas may experience improved operational efficiencies due to increased recharge and/or flow. Accelerated deterioration of inactive excess facilities due to increased precipitation and rainwater infiltration may also occur. Remedial action construction may suffer from reduced efficiency due to change in behavior patterns or migration of protected and threatened species, including the nesting of migratory birds.

As previously discussed, increased ambient temperatures and potential for drought may also affect the DOE Power Marketing Administrations (PMAs) through impact to operations at federal hydroelectric facilities. Together, the PMAs stretch from coast to coast and each may encounter unique challenges that could disrupt stream flows and generation output, potentially affecting millions of electricity customers.

Climate change may also affect DOE's ongoing role in preserving historic and cultural resources on its federal lands, partnerships with Tribal governments, and environmental justice responsibilities. DOE-managed historical and cultural resources will be exposed to the same climate change effects as adjacent DOE facilities which could present new challenges in protecting, preserving, curating, and mitigating impacts to these resources. In particular, the long-term integrity of DOE landfills and waste-storage sites containing hazardous materials could be affected by climate change, resulting in secondary impacts in adjacent or downstream culturally or environmentally sensitive areas, including Tribal lands. DOE is committed to implementing its Environmental Justice Strategy which reflects a commitment to the fair treatment and meaningful involvement of all people in agency programs. Moreover, the Memorandum of Understanding concerning E.O. 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,* to which DOE is a party, specifically cites climate change as an area of focus when considering environmental justice[10].

Human Health and Safety

DOE sites are likely to encounter new climate change-related workforce challenges in the future, regardless of region. DOE sites may experience increased incidence of worker illness due to changing environmental conditions. Shifts in climate can change disease vectors that increase infectious disease exposures and may exacerbate existing health problems[11]. Other facilities may experience human welfare and quality of life issues caused by frequent or prolonged heat waves and heat stress. Heat related issues may result in vulnerabilities for employees both on and off the DOE complex. Potential local climate change impacts on workforce health and quality of life may affect the operational capacity of DOE's facilities. In all instances DOE sites will have to adapt operations to accommodate changes in workforce needs and safety concerns.

Another key aspect to consider is transportation infrastructure connecting DOE facilities with each other, the supply chain, and the DOE workforce. Roadways and mass transit infrastructure may be damaged or obstructed by extreme weather events, disrupting operations and endangering employees. Additionally, stress on public transportation infrastructure by climate change may impact operations. DOE will need to coordinate with neighboring communities to address effective adaptation and mitigation responses.

[10] Federal Memorandum of Understanding Executive Order 12898 *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*
http://energy.gov/lm/services/environmental-justice
[11] National Climate Assessment – Health Sector Workshop: Southeast Region Report, 2012

Building Resilience

Current Activities

DOE has an array of programs, policies and plans currently in place that are beginning to address climate vulnerabilities across the enterprise. These activities detail a strong commitment by all facets of DOE, ensuring the Department and the nation is more resilient to climate change effects.

Site Sustainability Planning includes Climate Change Resilience Goal

DOE sites engage the Department's sustainability process and requirements through annual site specific reporting. Site Sustainability Plans (SSPs), driven primarily by E.O. 13514 and the Department's SSPP[12], have been leveraged to include adaptation activities. These efforts address facility, programmatic and human health vulnerabilities. DOE, through the Sustainability Performance Office, tracks site performance with respect to the goals outlined in the 2012 Adaptation Plan as well as the strategies outlined in the climate change resilience goal in the SSPP. These actions will continue to be measured on an annual basis through this process. Some of the strategies and corresponding activities include:

- Review DOE Orders, Guides and Technical Standards to determine which require updates, and prioritize updates on a multi-year schedule.
  - DOE identified DOE Guide 413.3-6A, *High Performance Sustainable Buildings,* as a planning guide that requires an update to include climate change resiliency language. The guide provides implementing instructions for implementing the HPSB requirements of DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets.* The update will also contribute to the agency's ongoing effort to consider climate adaptation and resilience into procurement, real property and leasing decisions. Additional opportunities to further this priority are under consideration.
  - DOE also identified DOE Order 150.1A, *Continuity Programs,* as an ideal opportunity to integrate climate change adaptation. This order outlines the requirements for DOE sites when completing continuity planning. Working with the Office of Emergency Management, DOE was able to include climate change in the list of potential risks and as a part of the All Hazard Risk assessment process. Finally E.O. 13653 was added as a reference for this process. This update and future similar orders will help DOE sites to retain operational abilities in the face of emergencies associated with climate change.
- Identify DOE program and site specific planning documents and guidance that should be developed or updated to improve climate change resiliency. For example:

[12] US Dept. of Energy, 2013 DOE Strategic Sustainability Performance Plan
http://www1.eere.energy.gov/sustainability/pdfs/doe_sspp_2013.pdf

    - The Pacific Northwest National Laboratory's (PNNL) Sustainability Program identified and reviewed site plans that either currently address or present an opportunity to address climate change adaption including the Building Emergency Plan, Business Continuity Plan, and Campus Master Plan. The Campus Master Plan was determined to present the most important opportunity to address climate adaptation planning. The current plan does not specifically address climate change adaptation but does include commitments to climate change mitigation through sustainable campus design. The Plan is scheduled for revision in FY 2014, and the campus planning team is now committed to working with the Sustainability Program to understand and address the greatest vulnerabilities. PNNL will look to focus particularly on facility energy shortages and reduced water supply. These efforts address multiple departmental vulnerabilities including facility and programmatic risks.
- Strengthen and broaden the internal DOE Adaptation Working Group to involve sites, share experiences (e.g., Hurricane Sandy – see below), best practices, case studies and innovation across programs and sites, identify corporate and other federal resources to support site vulnerability assessment, and provide communication tools (e.g., web sites, video and teleconferences, newsletters such as the DOE Sustainability SPOtlight).
    - In October 2012, Brookhaven National Laboratory (BNL) in Upton, New York experienced the effects of a record storm event, Hurricane Sandy, which impacted most of the northeast. Significant upfront planning was initiated for this storm to understand building vulnerabilities and potential effects on the science mission. Directly after the storm, Preliminary Damage Assessment (PDA) Teams were directed by the Office of Emergency Management to assess the site and restore services. As a direct result of planning and coordination, the overall impact to BNL was minimal and ongoing projects were not significantly impacted. After the storm, BNL re-opened for business earlier than planned, which provided a significant cost savings to BNL and DOE, and enabled researchers to continue their experiments. BNL"s planning and response serve as best practice for DOE sites preparing for extreme weather events.
- Continue group participation at DOE and inter-agency level, to ensure awareness of current and best available climate science and associated technologies with dissemination via the DOE Adaptation Working Group.

Activities to meet these objectives are occurring throughout the Department. Sustainability planning and reporting will continue to be leveraged to encourage further action in support of this plan. The sharing of best practices and success stories will enable DOE to meet the vision of agency wide resilience to climate change.

Regional Collaboration and Interagency Cooperation

The 2012 Adaptation Plan prioritized site-level regional coordination efforts and interagency cooperation to advance climate preparedness at DOE facilities. DOE looks to incorporate local and

regional collaboration at all levels of climate change planning in recognition of the fact that vulnerabilities impacting our facilities also threaten their neighboring communities. Likewise, DOE will learn from local and regional efforts. DOE has incorporated regional collaboration into annual sustainability reporting collected by the Sustainability Performance Office. Examples of collaboration include:

- Oak Ridge National Laboratory, in collaboration with Sustainable Tennessee, produced the report "The State of the Future for a Sustainable Tennessee: Grand Challenges and Grand Opportunities Under Changing Climate" in August 2012[13]. The goal of the report was to outline vulnerabilities and pathways for the state moving forward.
- PNNL operated the Joint Global Change Research Institute (JGCRI) along with the University of Maryland. The institute houses an interdisciplinary team dedicated to understanding the problems of global climate change and their potential solutions. Research areas include carbon cycle science, climate change assessment modeling, energy technology, and adaptation and mitigation programs.
- Idaho National Laboratory (INL) serves as coordinating partner for the Mountain West Water Institute (MWWI) as part of the US Climate Change Technology Program, a multi-agency research program. INL has worked closely with NASA, the Pacific Northwest Collaboratory and the North Olympic Peninsula to develop decision support tools. The goal of MWWI's climate change work is to collaborate with state, regional and federal agencies, universities, and other researchers and stakeholders to develop a better understanding of the probabilities, vulnerabilities and potential impacts of projected climate changes. It will also develop strategies to avoid, adapt to or mitigate negative impacts or to take advantage of positive impacts relative to water resources. Furthermore, it is MWWI's goal to conduct such evaluations in a systematic and interdisciplinary manner, and to develop a holistic understanding and comprehensive response to potential vulnerabilities and impacts on the region's water resources.
- Thomas Jefferson National Accelerator Facility is a partner in the development of a Hampton Roads Energy Corridor. Hampton Roads is unique in its vast array of distributed Federal facilities and on site expertise in various forms of alternative energy and renewable resources. The Energy Corridor serves to draw on this expertise to create a more resilient region. Climate change vulnerabilities and adaptation are key planning components of this effort.

These examples and others are shared and discussed via the DOE Adaptation Working Group.

In addition to initiatives occurring at the Department's National Laboratories and facilities, DOE is also building resilience in communities impacted by Hurricane Sandy. The Office of Electricity and Energy Reliability is supporting the Sandia National Laboratories (SNL) to aid the city of Hoboken,

[13] The State of the Future for a Sustainable Tennessee: Grand Challenges and Grand Opportunities Under a Changing Climate (http://sustainabletennessee.org/wp-content/uploads/2012/09/Sustainable_TN.pdf)

NJ in boosting the resiliency of its electric grid[14]. This critical partnership brings the deep expertise of the national laboratories to address the critical needs of our nation's electric grid. SNL will bring its Energy Surety Design Methodology to partner with the City of Hoboken, New Jersey Board of Public Utilities, Public Service Electric and Gas Company (PSE&G), Greener by Design and other stakeholders to develop a comprehensive plan to meet the critical needs of Hoboken in future events such as storms and other disruptions to the electric grid. The design methodology uses advanced, smart grid technologies and distributed and renewable generation and storage resources as a way to improve the reliability, security, and resiliency of the electric grid. Activities such as this allow DOE to engage local communities on improving the resilience of the energy sector in support of the DOE mission.

Site-Level Climate Vulnerability Assessments

In 2013, DOE began work on a series of pilot site-level climate vulnerability assessments to develop tools and templates that would be useful to other DOE sites. These assessments engage sites on climate change risk at a level of detail useful for site planning and decision making. The projects are designed to address a broad range of climate-related risks at DOE facilities. This work is intended to be a platform for further assessment for other sites and will attempt to standardize climate change risk assessment approaches and processes across missions and operations. The results will be used to engage decision makers and support preparation of future site planning documents. Initial stages of the project will be completed by the end of 2014.

The first pilot site chosen was the Thomas Jefferson National Accelerator Facility (TJNAF) due to its coastal location in Newport News, Virginia. This area is particularly vulnerable to coastal storms and sea level rise. The assessment and corresponding work will provide DOE with an opportunity to not only engage our own facilities but also the larger federal community collocated in the Hampton Roads area. DOE will look to partner with other agencies and local communities, where possible, to develop stronger planning and increase resiliency.

The second pilot site chosen was the National Renewable Energy Laboratory (NREL) in Golden, Colorado. NREL is situated in an inland climate and will provide DOE an additional perspective on the vulnerability assessment process. NREL also has close ties to its local community and surrounding federal facilities and will look to develop partnerships to increase adaptive capacity and resilience.

Energy Sector Vulnerabilities to Climate Change and Extreme Weather

In 2014, DOE released an assessment of climate change impacts on the United States energy sector. The assessment included a review of key vulnerabilities – including power plant

[14] Dept. of Energy Press Release June 13, 2013 http://energy.gov/articles/energy-department-partners-state-city-and-industry-stakeholders-help-hoboken-region-improve

disruptions due to drought and disruption of fuel supplies during severe storms – as well as a discussion of potential opportunities to make our energy infrastructure more resilient to climate risks. The DOE report, *US Energy Sector Vulnerabilities to Climate Change and Extreme Weather,* covers all aspects of the energy system, including supply, distribution and end use, and provides a comprehensive, high-level examination of impacts related to increasing temperatures, decreasing water availability, and increasing intensity of storms, flooding, and sea level rise.

The release of the DOE report provided a timely platform for launching actions that DOE will take in response to energy system vulnerabilities. Next steps include work to better characterize response measures that might be taken to enhance climate preparedness and resilience of the energy system, and assess barriers in resilience investment decisions in the energy sector. DOE's efforts will help to coordinate other activities designed to enhance information, improve stakeholder coordination and inform on policies and other actions that could enhance deployment of climate-resilient energy technologies. This information will be helpful to DOE sites in conducting their vulnerability assessments and developing plans to address their vulnerabilities.

Grid Resilience

In 2013, DOE's Office of Electricity Delivery and Energy Reliability and the President's Council of Economic Advisers, with assistance from the White House Office of Science and Technology, released a report examining the economic impact of increasing the resilience of the U.S. electric grid[15]. The report estimates the annual cost of power outages caused by severe weather between 2003 and 2012 and describes various strategies for modernizing the grid and increasing grid resilience. Over this period, weather-related outages are estimated to have cost the U.S. economy an inflation-adjusted annual average of $18 billion to $33 billion. Grid resilience is increasingly important as climate change increases the frequency and intensity of severe weather.

Preparing for the challenges posed to the grid by climate change requires investment in 21st century technology. A multi-dimensional strategy will prepare the United States for climate change and the increasing incidence of severe weather. Developing a smarter, more resilient electric grid is one step that can be taken in the short term to develop energy stability that drives our economy into the future. DOE recognizes that it has an important role to play in this effort.

Increasing the Scientific Understanding of Climate Change

DOE's core mission to advance scientific understanding, as established in the *2014-2018 DOE Strategic Plan*, confirms the Department's commitment to the development of useful and timely decision-support tools for climate change preparedness. These efforts serve to meet the Department's contribution to the President's Climate Action Plan as well the goals outlined in the first installment of this plan. The Climate and Environmental Sciences Division (CESD), in the Office of Science's Office of Biological and Environmental Research, focuses on advancing a robust,

[15] Economic Benefits of Increasing Electric Grid Resilience to Weather Outages, Executive Office of the President, August 2013 http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf

predictive understanding of the Earth's climate and environmental systems that informs the development of sustainable solutions to the nation's energy and environmental challenges[16].

The division has three research activities, each of which directly informs climate science. The Climate and Earth System Modeling group's research seeks to develop high fidelity community models representing the coupled physical-human system, with a significant focus on understanding dynamical variability and system response to natural and anthropogenic forcing. Atmospheric System Research strives to understand the physics, chemistry, and dynamics governing clouds, aerosols, and precipitation interactions, with a goal to advance the predictive understanding of the climate system. The third research activity, Environmental System Science, focuses on advancing ecological and subsurface terrestrial science, with a goal to understand the full dynamics of the carbon cycle and how it influences climate change.

Numerous national laboratories within the Department are also involved in basic climate change science, climate modeling, and support tools. A number of these research facilities contributed to the International Panel on Climate Change (IPCC) Fifth Assessment Report and the Third National Climate Assessment. Examples of current research include:

- Pacific Northwest National Laboratory (PNNL) plays a leadership role in the multi-laboratory Atmospheric Radiation Measurement (ARM) Research Facility program, that in turn provides critical data necessary to reduce climate prediction uncertainty associated with the earth's radiation balance, with particular focus on clouds, aerosols, and precipitation systems.
- At the Lawrence Berkeley National Laboratory (LBNL), research is dedicated to understand the physical and stochastic nature of extreme events within the climate system, with a special focus to project how anthropogenic forcing of the climate leads to a redistribution of extremes, in both space and time.
- At the Oak Ridge National Laboratory (ORNL), significant research on decadal scale ecological field experiments, at both midlatitude and arctic sites. The ORNL activities in the Arctic, involve in particular a network of numerous national laboratory and academic institutions, to understand the dynamics governing permafrost ecology and the future risks of abrupt climate change.

Future Activities

DOE is committed to its vision of mainstreaming and integrating climate change resiliency considerations across all DOE programs, wherever appropriate. To accomplish this goal, DOE will engage in a variety of activities in addition to those already ongoing.

Continuity of Operations Planning and Policy

[16] Climate and Environmental Sciences Division 2012 Strategic Plan http://science.energy.gov/~/media/ber/pdf/CESD-StratPlan-2012.pdf

DOE plans to update its Departmental Continuity of Operations (COOP) Plan in 2014 and will also look to consider climate change resilience. The COOP Plan is used to outline the actions taken to provide the capability to continue mission-essential processing and restore normal operations after a disaster or disruption. The inclusion of climatic risks into the COOP will enable DOE to increase resilience across multiple identified vulnerabilities. The update will be a joint-effort and supported by numerous offices throughout the Department, including the Office of Emergency Management located in the National Nuclear Security Administration (NNSA).

Infrastructure Resilience Working Group -Council on Climate Preparedness and Resilience

President Obama established the Council on Climate Preparedness and Resilience with Executive Order 13653, *Preparing the United States for the Impacts of Climate Change*. The Council will identify priority federal government actions related to climate change preparedness and resilience and coordinate agency and interagency efforts to implement those actions, including those described in the President's Climate Action Plan. Four working groups have been established to support the Council, including the Infrastructure Resilience Working Group, co- chaired by DOE and the Department of Homeland Security (DHS), with the focus of realizing innovative infrastructure resilience solutions to climate change. In addition to a high level assessment across critical infrastructure, the working group will pursue a "deep dive" on energy that includes: characterizing and prioritizing energy sector vulnerabilities and interdependencies to other sectors; identifying existing resilience activities, barriers, and key research and policy opportunities for enhancing resilience; and identifying metrics for measuring success. It will forge new interagency partnerships where appropriate, and undertake immediate action on multi-sector climate change preparedness and resilience efforts.

While this effort will look broadly across infrastructure, it will also target specific sectors such as the energy infrastructure. DOE and other agencies will leverage activities underway for the Quadrennial Energy Review (QER) and focus on vulnerabilities and climate change preparedness and resilience strategies for the energy sector. This work acknowledges the critical role energy will play, but will also identify interdependencies between energy and other sectors (e.g., communication, water, transportation, health, etc.). Specific tasks targeting energy infrastructure will include identifying federal energy technology R&D activities and policies/programs focused on climate resilience such as the update to the Quadrennial Technology Review, and identifying key gaps. In addition, the effort will identify relevant information, data, tools, best practices, and lessons learned for climate change preparedness and resilience for energy systems, as well as desired outcomes and measures for measuring progress towards energy sector preparedness and resilience to climate change. This information will be helpful as well to DOE sites in conducting their vulnerability assessments and developing plans to address their vulnerabilities.

Agency Procurement, Acquisition, and Real Property Decisions

DOE will consider the need to improve the integration of climate adaptation and resilience into procurement and real property decisions. The ability to address DOE physical asset and programmatic vulnerabilities facilitates the need for the Department to begin to contemplate such issues. DOE has already made climate adaptation planning a tenet of the Site Sustainability Plans and can leverage that mechanism to begin the discussion. DOE's pilot vulnerability assessments will look to transfer approaches and templates to other DOE sites. Further action requires widespread involvement of DOE procurement and facilities management offices.

DOE identified the Asset Management Plan as a possible conduit for incorporating resiliency into personal and real property planning. The Asset Management Plan is scheduled to be updated in FY 2014. The plan, combined with proper action, identification of climatic risk could allow DOE sites to more effectively manage assets in the short and long term. Another potential opportunity is DOE Order 430.1B, *Real Property Asset Management*, which includes requirements for preparing Ten Year Site Plans. The process of updating this order has not yet begun.

The DOE Acquisition Guide serves to supplement the Federal Acquisition Regulation (FAR) and the Department of Energy Acquisition Regulation (DEAR) by identifying relevant internal standard operating procedures to be followed by both procurement and program personnel who are involved in various aspects of the acquisition process. The guide is also intended to be a repository of best practices found throughout the Department. DOE will consider the inclusion of climate change resiliency to the guide as a way to ensure that challenges to procurement of critical inputs are addressed. DOE recognizes the threat climate change poses to acquisition activities due to supply chain disruption and will work to address this vulnerability.

Modernizing Federal Programs to Support Resilience Investments

E.O. 13653 calls for efforts to modernize federal programs and policies to support collaboration at local and regional levels. Departmental efforts to develop collaboration are largely addressed in actions to engage local and regional stakeholders on resiliency. The "Regional Collaboration and Interagency Cooperation" section of this Plan details current activities in support of this goal. DOE is in the process of evaluating appropriate policies, programs and plans. During these evaluations and potential updates DOE will look to identify barriers discouraging actions, reform programs inhibiting resilience, and identify opportunities to support smarter actions and investments. A particular focus will be paid to DOE's grants, loans and other financing programs but the effort will encompass DOE's entire mission.

DOE recognizes that its unique scientific and technologic innovation mission provides an opportunity to foster local and regional collaboration as well as encourage investment in resilience.

Conclusion

The 2014 Adaptation Plan is the second installment of an ongoing effort to build resilience across the Department. The plan serves as a foundation from which future updates will build. Future plans must account for advancement in scientific understanding and continued evaluation, made in accordance with E.O. 13653.

The 2014 Adaptation Plan will be incorporated into DOE's internal planning processes described above and through its integration with the goals of the annual SSPP, implemented by DOE's Senior Sustainability Officer, Sustainability Performance Office, and Senior Sustainability Steering Committee and their component DOE programs and sites.

Further, DOE will engage in and share best practices within the Department and with other federal agencies as appropriate through the Council on Climate Resilience, interagency working groups, and also by forging new collaborations with other agencies and stakeholders as appropriate. DOE will continue to leverage its unique modeling, climate science expertise, and engineering capabilities in collaboration with other agencies and institutions, to continuously improve understanding of the effects of climate change and identify appropriate adaptation strategies.

DOE will continue to include climate change adaptation as part of its planning and operations. A more resilient DOE enables the Department to maintain mission specific operations and minimize disruption to critical functions. A steadfast commitment to climate resilience strengthens Departmental operations by creating a more adaptive agency, and helps to create a resilient energy sector, and stronger, better prepared communities.

Appendices

Appendix 1

Table 1. Summary of Forecasted Climate Effects for Major US Climate Regions[17,18,19,20]

Region	Potential Effects of Greatest Concern to DOE
Alaska	• Longer summers and higher temperatures are causing drier conditions, even in the absence of strong trends in precipitation • Insect outbreaks and wildfires are increasing with warming • Lakes are declining in area • Thawing permafrost damages infrastructure (roads, runways, water and sewer systems, transmission lines, oil and gas pipelines, etc.) and increases the potential for the release of GHG gases (e.g., methane) from thawing permafrost • Coastal storms increase risks to coastal oil and gas facilities and operations
Great Plains	• Projected increases in temperature, evaporation, and drought frequency add to concerns about the region's declining water resources (impacts on steam electric power generation) • Agriculture (e.g., biofuels), and natural lands, already under pressure due to an increasingly limited water supply, are very likely to also be stressed by rising temperatures • Ongoing shifts in the region's population from rural areas to urban centers will interact with a changing climate, resulting in a variety of consequences to energy sector infrastructure and demand
Midwest	• During the summer, public health and quality of life, especially in cities, will be negatively affected by increasing heat waves and potential electricity shortages or brownouts, reduced air quality, and increasing insect and waterborne diseases. In the winter, warming will have mixed impacts • The likely increase in precipitation in winter and spring, more heavy downpours, and greater evaporation in summer would lead to more periods of both floods and water deficits affecting both hydropower, and steam electric power generation • While the longer growing season provides the potential for increased crop yields, increases in heat waves, floods, droughts, insects, and weeds will present increasing challenges to managing crops (e.g., for biofuels)
Northeast	• Extreme variability in heat and declining air quality are likely to pose increasing problems for human health, especially in urban areas • Agricultural production is likely to be adversely affected as favorable climates shift • Severe flooding due to sea-level rise and heavy downpours associated with more intense precipitation events is likely to occur more frequently • Significant sea-level rise and storm surge will adversely affect coastal cities, ecosystems, and

[17] USGCRP. *Global Climate Change Impacts in the US*. 2009. http://globalchange.gov/publications/reports/scientific-assessments/us-impacts

[18] USCGCRP 2013 NCA Regional Climate Scenarios Summaries Parts 1-9 http://scenarios.globalchange.gov/node/1155

[19] U.S. Climate Change Science Program. *Climate Change on Energy Production and Use in the United States*. (Synthesis and Assessment Product 4.5). 2007. http://globalchange.gov/publications/reports/scientific-assessments/saps/sap4-5

[20] A. Anthony Bloom, Paul I. Palmer, Annemarie Fraser, David S. Reay and Christian Frankenberg. "Large-Scale Controls of Methanogenesis Inferred from Methane and Gravity Space Borne Data". *Science* Vol. 327. No. 5963. January 15, 2010: pp. 322-325. http://www.sciencemag.org/content/327/5963/322.full.pdf

	energy infrastructure; low-lying and subsiding areas are most vulnerable
Northwest	• Declining springtime snowpack leads to reduced summer stream flows, straining water supplies, and potentially reducing hydro-electric power generation • Increased insect outbreaks, wildfires, and changing species composition in forests will pose challenges for ecosystems and the forest products industry • Ecosystems will experience additional stresses as a result of rising water temperatures and declining summer stream flows
Pacific Islands	• The availability of freshwater is likely to be reduced, with significant implications for island communities, economies, and resources • Island communities, infrastructure, and ecosystems are vulnerable to coastal inundation due to sea-level rise and coastal storms
Southeast	• Projected increases in air and water temperatures will cause heat-related stresses for people, plants, and animals • Decreased water availability is very likely to affect the region's economy, natural systems, and steam electric power generation • Sea-level rise and the likely increase in hurricane intensity and associated storm surge will impact energy infrastructure (e.g., oil and gas production and storage facilities) • Ecological thresholds are likely to be crossed throughout the region, causing major disruptions to ecosystems and to the benefits they provide to people • Quality of life will be affected by increasing heat stress, water scarcity, severe weather events, and reduced availability of insurance for at-risk properties
Southwest	• Water supplies will become increasingly scarce, calling for trade-offs among competing uses, (e.g., energy, agriculture, industry, domestic use, etc.) and potentially leading to conflict • Increasing temperature, drought, wildfire, and invasive species will accelerate transformation of the landscape • Increased frequency and altered timing of flooding will increase risks to people, ecosystems, and infrastructure • Cities and human health systems face increasing risks from shifting disease vectors, temperature increases and health care system infrastructure from a changing climate