Statement of Carl Imhoff
Manager, Electricity Market Sector
Pacific Northwest National Laboratory
Before the
United States Senate
Committee on Energy and Natural Resources

December 19, 2019

Good morning. Thank you, Chairman Murkowski, Ranking Member Manchin, and Members of the Committee. I appreciate the opportunity to appear before you today to discuss the impacts of wildfires on electric grid reliability and efforts to mitigate the wildfire risk and increase grid resiliency.

My name is Carl Imhoff, and I lead the Grid Research Program at Pacific Northwest National Laboratory (PNNL), a Department of Energy (DOE) national laboratory located in Richland, Washington. I also serve as the Chair of DOE's Grid Modernization Laboratory Consortium (GMLC), a team of national laboratories that works with industry, industry groups, and university partners to support DOE's Grid Modernization Initiative (GMI). The consortium members include PNNL, the National Renewable Energy National Laboratory (NREL), Sandia National Laboratories (SNL), Oak Ridge National Laboratory (ORNL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Los Alamos National Laboratory (LANL), Idaho National Laboratory (INL), Argonne National Laboratory (ANL), the National Energy Technology Laboratory (NETL), Savannah River National Laboratory (SRNL), Lawrence Livermore National Laboratory (LLNL), the Ames Laboratory and the National Accelerator Laboratory at Stanford University (SLAC).

For more than two decades, PNNL has supported power system reliability and innovation for the state of Washington, the Pacific Northwest, and the nation. Over this period, the laboratory has:

1. Led DOE-industry collaborations in developing and deploying synchrophasor technology to help avoid blackouts. Phasor measurement units in a network are designed to enhance situational awareness of wide-area power systems. This new grid tool has demonstrated value by detecting impending system control and equipment faults for system operators, enabling them to avoid major outages. California estimates $360M annual savings to customers due to avoided outages plus $90M annual savings in improved utilization of existing generation and delivery systems. In east Texas, this same technology enabled Entergy to respond to major storm outages by synchronizing a temporary electrical island to reduce outages during the recovery. The Bonneville Power Administration has demonstrated savings of $400,000 on average for testing generator controls settings on the Columbia Generating Station, an1,100-megawatt nuclear reactor in Washington State, while avoiding a plant shut down for maintenance. And PMU telemetry provides the

backbone of advanced wide-area sensing that is reducing the risk of fire from broken or downed power lines.

2. Delivered grid-scale energy storage concepts that are designed to deliver the system flexibility and resilience needed in a modern grid. PNNL has developed flow battery concepts that utilize earth-abundant materials to cross the interim cost target of $250/kWh (FY2019) and position us to meet the DOE goals of $120/kWh. And PNNL has advanced energy storage valuation efforts to help utilities identify opportunities to enhance resilience of their systems. For example, working with National Grid and DOE's Office of Electricity in 2019, PNNL analysts created a sophisticated distribution system network model for Nantucket Island to accurately assess a full portfolio of energy storage-enabled use cases, determining that the proposed energy storage and local generator could reduce the duration of outages experienced by Nantucket residents by nearly half.

3. Delivered the first applications using high-performance computing in grid tools such as interconnection-scale contingency analysis, reducing run times from days to under two minutes. PNNL also applied high performance computing and phasor measurement unit data to deliver the first real-time dynamic state estimation, opening the door predictive analytic tools for the grid. This parallelized state estimator tool enabled PNNL to meet an ARPA-E challenge to reduce dynamic line rating calculations from 24 hours to 10 minutes while creating the potential to operate the system with much higher asset utilization. High performance computing is core to the emerging class of extreme event planning tools like the dynamic contingency analysis tool developed by DOE in partnership with ERCOT. These new tools significantly enhance our ability to design future power systems that are resilient to the increasingly complex threat scenarios facing U.S. power grids.

These examples illustrate the high return on investment created by utilities and national laboratories working together on new electric infrastructure innovation, technology validation and field deployment to improve reliability and resilience.

The DOE Grid Modernization Initiative is an important source of innovation for the national efforts to modernize our energy infrastructure. The initiative is a DOE-wide effort across multiple program offices to accelerate the development of technology, modeling analysis, tools, and frameworks to enable and accelerate grid modernization. As a key component of this initiative, the Grid Modernization Laboratory Consortium is working closely with partners in industry, academia, and cities and states to deliver on the objectives outlined in DOE's Grid Modernization Multiyear Program Plan. These integrated efforts are delivering new concepts, tools, platforms, and technologies to better measure, analyze, predict, and control the grid of the future. The federal role is to invest in high-risk research and then collaborate with vendors, utilities, and state and regional regulatory entities to provide the tools, data, and demonstration support. This accelerates the development of lessons learned and provides valuable data that support states and utilities in their development of business cases for their grid modernization.

The projects are peer reviewed annually for quality assurance and to maximize awareness by stakeholders in industry, academia, and with policymakers across the country. The research progress has been shared with this Committee and others; and we appreciate your support for GMLC since its inception. I respectfully request that the appended fact sheet on the Grid Modernization Laboratory Consortium be entered into the record along with my written testimony.

Today I will address three main points:

1. **DOE FOCUS IS ON R&D FOR "ALL HAZARDS" RESILIENCE:** The DOE Grid Modernization Initiative and its derivative R&D portfolio are focused on grid reliability and grid/energy system resilience. These resilience efforts adopt an "all-hazards" framework that enables power system owners and operators, federal land managers, states, communities, and consumers to address wildfire risks.

2. **IDENTIFYING DOE RESULTS THAT CAN SUPPORT THE 2020 FIRE SEASON:** While most of the DOE investments are in R&D, there are some DOE and national laboratory capabilities and tools that are well positioned to support industry in the 2020 wildfire season. Industry, through the Edison Electric Institute (EEI), has begun a systemic engagement of DOE to this end. In addition, the recent Electricity Subsector Coordinating Council (ESCC) endorsement of wildfire response as a focus will further advance industry coordination.

3. **ENHANCING WILDFIRE USE CASES AND PLANNING SCENARIOS:** The extreme challenges faced in recent wildfires present the opportunity to sharpen the focus of specific use cases and extreme event planning scenarios in the ongoing DOE grid modernization efforts.

Electric Power System is Vital to U.S. Economy and Security

The electric grid and its infrastructure span the nation, providing essential services to the U.S. economy. It comprises 640,000 miles of transmission lines and 6.3 million miles of distribution lines and serves over 19,000 electric generators over 1 megawatt in size, ultimately engaging virtually all Americans via more than 3,500 utilities. The electric grid infrastructure also includes small, remote communities that must provide their own electric services, predominantly through local diesel generation and microgrids. The digital revolution is increasing the role that electricity plays in our gross domestic product, and the emergence of smart grid concepts and new advanced generation technologies is creating new opportunities for consumer products, services and choice.

The DOE Grid Modernization Initiative recognizes the rapid technology change and increasing complexity facing the nation's power industry and policy makers responsible for providing affordable, clean, and reliable power. Increased frequency of extreme weather events; growing risk of cyberattack; increasing interdependence between grid operations with other critical

infrastructures, such as communications and natural gas pipelines; and grid management challenges driven by the emergence of digital technologies at the "grid edge" have led DOE to increase emphasis on grid and energy system resilience in its research portfolios.

The GMI strategy takes an "all-hazards" (e.g. cyber risk, natural disaster risk, physical attack, etc.) approach to developing new fundamental knowledge, analytic tools, and technologies that support improved grid resilience. Though these DOE programs do not focus specifically on wildfires, the GMLC R&D portfolios and DOE R&D programs offer tools and concepts that can directly mitigate wildfire risk and support industry and other agencies in emergency wildfire response. Examples include:

- advanced sensing and data analytics
- extreme event planning tools to enhance grid resilience design
- real-time grid operational and emergency response tools to support wildfire challenges.

DOE Engagement with Industry on Wildfire Risk

There are 17 DOE national laboratories across the country. These laboratories serve multiple DOE missions through the development and maintenance of core capabilities needed by DOE and other federal agencies. In most cases, these national capability assets are put to work in one of the following three ways:

1. Direct engagement with industry, states, or other federal agencies
2. Utilization of DOE program results delivered by one or more laboratories through traditional programs funded by Congress
3. Commercialization and adoption of the GMLC portfolio of research delivered by the 14 labs in partnership with more 100 partners from across industry, academia, and states. The GMLC is a cross-cut effort to help implement the DOE GMI, again funded by Congress.

The Edison Electric Institute (EEI), which represents the nation's investor-owned electric utilities, engaged DOE's Office of Electricity (OE) this past August to better understand how to link EEI membership efforts in wildfire issues with the DOE R&D agenda. This engagement was triggered by the EEI CEO's Wildfire Initiative, in which EEI expressed an interest in ways the DOE could help address the following challenges in wildfire risk mitigation:

1. Electric Grid Technologies
    - Better/faster "downed line" technology
    - Better/more accurate line fault detection
    - Near real-time auto shutdown and distribution controls

2. Enhanced Data Sources and Methods
    - Satellite imagery and remote sensing data to determine, for example, "heat spots," vegetation conditions on slopes, and forest health.

- Drones and related technology to support electric infrastructure inspections and assessment of forest health conditions.

3. Advanced Data Analytics and Modeling
    - More accurate modeling and predictive capabilities for weather, fuel sources, fire spread, with consistency across the country versus state by state.
    - Near real-time identification of fire starts (e.g., machine learning for high-resolution camera feeds to identify smoke plumes).
    - Improvements in LIDAR data-processing speeds and analysis results.

EEI members are primarily interested in innovations that can deliver benefits quickly to impact the 2020 fire season. This is consistent with the recent decision by the Electricity Subsector Coordinating Council (ESCC) to add wildfire topics to its agenda, ensuring a full industry focus on the wildfire challenge that spans public and private power entities.

The DOE and the GMLC leadership team met with the EEI task force in September to present an initial mapping of DOE research that could address the issues posed by EEI members. The DOE portfolio focuses primarily on "all-hazards" resilience approaches for grid modernization, offering analytics, technologies and models that can be applied to wildfire risk along with other grid risks. In some cases, the national laboratories had experience and tools that had been applied directly to wildfire issues. The majority of the relevant topics were R&D activities not yet commercially available. There were several examples of tools, either being tested or likely to be able to provide near-term support, to industry for the 2020 fire season. These discussions between EEI and the DOE Office of Electricity (OE) are ongoing. Selected examples under discussion are highlighted below:

Sensing and Measurement: The GMLC has developed advanced high-speed optical sensors that reflect grid status (e.g., voltage and phase angle) at ultra-high speed to help detect impending grid faults. Advanced data analytics platforms that use machine-learning algorithms to detect system faults and other risks to the grid have also been developed. Examples applicable to wildfire management include the following:

1. DOE/GMLC efforts in advanced sensors and machine-leaning analytics (Oak Ridge National Laboratory and Lawrence Livermore National Laboratory) recently led to a DOE project with PG&E to detect arcing faults – downed power lines -- on distribution systems.
2. San Diego Gas and Electric (SDG&E) is working with a commercial vendor to test a concept that detects falling lines and de-energizes those lines prior to ground contact. This tool needs to operate in just over 1 second, and the approach is dependent on the emerging use of phasor measurement devices, which have been the focus of the DOE-led North American Synchrophasor Initiative. Successful demonstrations have led to SDG&E beginning implementation of these concepts on high-risk distribution circuits.
3. The U.S. Department of Homeland Security's (DHS's) and DOE's Office of Cybersecurity, Energy Security, and Emergency Response (CESER's) investments at PNNL in satellite imagery platforms that use LIDAR imaging have been developed and deployed to support national response to extreme weather events and natural disasters.

These tools can conduct damage assessments to infrastructure and map water inundation. These platforms can be adapted to wildfires to provide damage assessments caused by fire, correlate this analysis with electrical infrastructure, and inform responders regarding risk and response strategy.

4. The DOE Office of Energy Efficiency & Renewable Energy's (EERE's) Biomass Program and the U.S. Forest Service have funded PNNL to develop tools to use aerial imagery to map biomass for fuel load, vegetation type, and moisture content to support land managers, utilities, and emergency responders in identifying wildfire risk profiles in anticipation of events. This tool is under evaluation on two watersheds in Washington State and could be extended to other high-risk National Forest areas in the West.

Extreme Event Planning Tools: The growing complexity of the power grid, combined with the increasing risks from natural and human threats have driven efforts to improve the fidelity and capacity of planning tools needed to design resilient, reliable, and affordable modern grids. Both the GMLC and the North American Energy System Resilience Modeling program (NAERM) are developing advanced tool sets to improve the design of resilient power and energy systems. Use cases reflecting wildfire risks can be readily developed within these analytic frameworks. Examples applicable to wildfire management include:

1. The DOE/Advanced Grid Modeling program invested in the development of the Dynamic Contingency Analysis Tool (DCAT) in partnership with ERCOT, EPRI, and PNNL. This tool reflects the emerging system dynamics driven by increased variable generation, the performance of the protection system in preventing cascading blackouts, and advanced computing to enable planners to examine larger, more challenging system threats. This tool is part of the NAERM project being developed by DOE.
2. The GMLC Extreme Event Modeling project developed new solutions targeted to deliver 500x performance improvement in modeling cascading grid events. Eight national laboratories (LANL, PNNL, LLNL, ANL, BNL, NREL, ORNL and SNL) collaborated with industry partners (i.e., the North American Reliability Corporation (NERC), the PJM Interconnection, LLC., (PJM), the Electric Reliability Corporation of Texas (ERCOT), and Dominion Energy) to develop these tools.
3. NAERM modeling efforts are examining interdependencies between power, communications, fuel supply, and other critical infrastructures. Wildfire threats can often threaten multiple critical infrastructures, thus requiring interdependency analysis. Involved national laboratories include ANL, LANL, PNNL, and ORNL.
4. The GMLC developed advanced co-simulation tools (i.e., HELICS) to integrate multiple modeling efforts to support interdependency assessments and provide a connection between, for example, Earth systems models (used by land managers), power system models, and emergency response models (used by the Federal Emergency Management Agency (FEMA) and state and local emergency responders). This effort includes contributions from PNNL, LLNL, NREL, ANL, and INL.

Real-time Grid Operational and Emergency Support Tools: Power system operators utilize a portfolio of tools to operate the grid under normal (blue sky) and unusual (dark sky) conditions.

As the power system becomes more variable, more connected across transmission and distribution, and more interdependent with other critical infrastructures, new tools to monitor and control the system are required.

1. Sandia National Laboratories has deployed its Standard Unified Modeling, Mapping, and Integration Toolkit for use by the California Fire and Rescue Training Authority to help agencies in their response to emergency scenarios, including wildfires and other public emergency events.
2. DOE's Infrastructure Security and Energy Restoration (ISER) division has funded the development (at ORNL) of a power system situational awareness tool to support industry and emergency responders at the national and local level. This tool integrates energy-sector data with modeling tools and data from other critical infrastructures and agencies. It is already used for extreme weather events and can be extended to support wildfire operations as well.
3. The DOE OE Advanced Grid Modeling program funded at PNNL the development of high-performance contingency analysis tools that use parallel computing to provide near real-time (under 1-minute) power system risk profiles for multiple contingencies (e.g., what can happen in the western interconnection under extreme fire conditions).

The items above reflect examples of DOE-derived assets that are being considered by industry for managing the wildfire threat in the near term. These and other topics are candidates for further R&D and use in improving grid reliability and resilience in the face of the wildfire threat.

Closing Comments

DOE's Grid Modernization Initiative strategy and the R&D investments across the GMLC, NAERM, and other DOE programs offer tools and concepts that contribute to grid reliability and resilience to "all hazards," including the specific challenges of recent wildfire events. Some specific projects involving the national laboratories and industry are under way, and EEI is facilitating deeper collaboration that will be linked to the ESCC to ensure dialogue that spans the entire power industry. These conversations have strong potential to deliver innovations to support the upcoming 2020 fire season and to identify additional mid-term R&D to support the subsequent fire seasons.

In addition, the lessons learned along with feedback from industry, land management agencies, and emergency responders can inform DOE national laboratories and industry planners with improved understanding of extreme event scenarios. With this knowledge, we can develop the use cases for these technologies that can improve the resilience of the nation's power system in the face of wildfires and other threats to our energy infrastructure.

I appreciate the opportunity to discuss this important issue with you today, and I am happy to answer your questions. Thank you.