Statement of Carl Imhoff
Manager, Electricity Market Sector
Pacific Northwest National Laboratory
Before the
United States House of Representatives
Committee on Science, Space and Technology

October 3, 2017

Good morning. Thank you, Chairman Smith, Ranking Member Johnson, and Members of the committee. I appreciate the opportunity to appear before you today to discuss U.S. electric infrastructure resilience issues and opportunities.

My name is Carl Imhoff, and I lead the Grid Research Program at the 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, a team of national labs that, along with industry, industry groups such as the Gridwise Alliance and Electric Power Research Institute (EPRI), and university partners, supports the Department's Grid Modernization Initiative. The consortium members include PNNL, the National Renewable Energy National Laboratory, Sandia National Laboratories, Oak Ridge National Laboratory, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, Los Alamos National Laboratory, Idaho National Laboratory, Argonne National Laboratory, the National Energy Technology Laboratory, Savannah River National Laboratory, Lawrence Livermore National Laboratory and the National Accelerator Laboratory at Stanford.

Today I will address three main points:

1. Substantial opportunity exists to leverage fundamental science and applied research to enhance the nation's options for modernizing the grid in ways that enhance overall resilience.

2. The national laboratories have delivered important contributions in new approaches to enhance grid resilience. I will discuss the importance of research and development to ensuring a resilient, reliable and flexible grid, share recent accomplishments delivered in partnership with industry, and highlight emerging resilience research activities.

3. State and federal regulatory stakeholders need innovative tools and data sets to improve valuation of power system resilience so that they can better enable the investment required to deliver a modern grid that is resilient, reliable and flexible.

Background

For more than two decades, PNNL has supported power system reliability, resilience 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 unit networks are designed to enhance situational awareness of wide area systems. This new grid tool has demonstrated value by detecting impending system control and equipment faults for system operators, thus avoiding major outages. California estimates $360 million annual savings to customers due to avoided outages, plus $90 million annual savings in improved utilization of existing generation and delivery systems. In east Texas, phasor measurement units enabled Entergy to respond to major storm outages by synchronizing a temporary electrical island to reduce outages during the recovery. At the Columbia Generating Station, an 1100-megawatt nuclear reactor in Washington State, the Bonneville Power Administration has demonstrated savings of $400,000, on average, for testing generator controls settings without requiring a plant shutdown.

2. Led a public-private collaboration with utilities and vendors to develop and demonstrate transactive control concepts on the Olympic Peninsula in Washington and for the Pacific Northwest Smart Grid Demonstration project—the largest of its kind—to validate smart grid benefits and new control approaches that engage demand and distributed resources at scale. Example outcomes include Avista Corporation implementing distribution automation and smart metering pilots that delivered a 10-percent reduction in customer outages, reduced consumer outage durations by 21 percent, and resulted in 1.5 million avoided outage minutes between April 2015 and April 2016. Avista also saved 42,000 megawatt hours in 12 months. Idaho Falls Power implemented transactive control of end uses and utilized the concept to minimize customer outages during an extreme winter storm when the western system operators were calling for emergency reductions in load.

3. Delivered the first applications of high performance computing to 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 to open the door to the future world of predictive grid tools. 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, creating the potential to operate the system with much higher asset utilization.

These examples illustrate the high return on investment possible by utilities and national labs across the country when combining new electric infrastructure innovation with public-private validation and deployment.

The DOE Grid Modernization Initiative is an important source of innovation for national efforts to modernize the energy infrastructure. Improved grid resilience is a major objective of the overall effort. The Initiative is a DOE-wide effort across multiple program offices to accelerate the development of technology, modeling analysis, tools, and frameworks to enable grid modernization adoption. 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 will deliver new concepts, tools, platforms, and technologies to better measure, analyze, predict, and control the grid of the future to improve resilience, reliability and productivity. Public/private collaboration in field validation accelerates the development of lessons learned and data that support states and utilities to develop business cases for their grid modernization efforts. I respectfully request that the appended fact sheet on the Grid Modernization Laboratory Consortium be entered into the record along with my written testimony.

Emerging Science and Technology Opportunities to Enhance Power System Resilience

The definition of a resilient grid addresses both avoidance and resistance to outages before an incident, as well as to the ability to rapidly respond to an outage and achieve full recovery as quickly as possible. Science and technology provide substantial contributions to avoidance and resistance to outages, as well as to the post-event assessment and recovery. New digital sensing, measurement, and control concepts, often termed "smart grid", are enabling system operators to "see" and "control" the grid with exceptional precision and speed. These new concepts, combined with new distributed energy resources such as energy storage, local generation sources, or microgrids, are paving the way for enhanced grid performance that is more resilient, reliable and flexible. Selected examples of significant science and technology advances include:

1. **Enhanced real-time, predictive operational tools:** High-precision fast sensor networks linked to utility control centers enable operators to predict grid system behavior, anticipate dangerous oscillations, and optimally adjust power flows and power transfer limits. These tools leverage advanced computing and mathematical algorithms to deliver modeling and simulation tools that dramatically enhance resilience by helping avoid outages in the first place. They also help operators adapt to outages and recover system operations faster. These modeling and simulation tools are examples of the tools recommended in the National Academies report on grid resilience.

2. **Enhanced precision planning tools:** The nation invests substantial capital in grid infrastructure, and these investments typically have multi-decade lifetimes. Recent advances in computation and simulation tools promise to improve the accuracy and speed of system planning tools that can better assess complex risk scenarios and improve system designs that will improve resilience for future decades. DOE teamed with PNNL and ERCOT to develop a new dynamic contingency modeling tool that helps grid planners explore larger, more complex cascading failure scenarios. Successful testing with ERCOT has led to broader

industry use of this tool that promises to support the design of systems that are more resilient to increasingly complex “all hazards” threats to the system. This effort is consistent with the National Academies grid resilience recommendations for improved “visioning” of future resilient grid system outcomes and the modeling tools to validate cost effective system designs to deliver the desired resilience.

3. **Advanced grid architecture, coordination and control:** Technology and business model evolution are driving substantial change to power systems and related critical infrastructures such as communications, fuel supply, markets and control. DOE is working with states and industry to envision how the new aspects of a modern grid will change and fit together in the future. This effort will then frame where changes in coordination and control of utility systems and consumer systems must occur to ensure a resilient and reliable grid. Success will lead to new control concepts that ensure modern, distributed power systems will be more resilient and secure. These new paradigms of grid structures and control will be a fundamental element in the National Academies recommended “visioning” processes to chart new approaches for grid resilience.

4. **Advanced data and visual analytic tools:** Trends in e-commerce, digital grid technologies, and consumer devices and services are creating a dramatic increase in data on the power system, much of which flows at very high speed. GE Digital Energy testified earlier this year that the grid has approximately two billion “edge devices” today, estimated to grow to more than 20 billion in 2025. Substantial opportunities exist for “big data” management, advanced data analytics, machine learning, network science, and research to ensure security of the grid and effective use of the data generated by the grid. Fundamental advances will be required in high performance computation, mathematics, statistics, and communications networks to deliver on the potential for full system observability and control. PNNL, in partnership with Argonne National Laboratory and the National Renewable Laboratory, has launched the first grid application of exascale computing for the grid as part of the DOE Exascale Computing program.

5. **Energy storage at an affordable price point to provide a new grid element:** Large complex systems typically require the flexibility to decouple supply and demand to maintain reliability. Examples include warehouses for logistics and storage tanks for water systems. The equivalent for power systems is energy storage. The power system of the future will greatly benefit from increased use of energy storage to serve this “shock absorber” role as loads become more complex and generation becomes more variable. Energy storage systems will reduce the risk of outage, enhance emergency operations of local microgrids during emergencies, and improve the recovery of failed systems. Early GMLC research indicates that affordable grid-scale storage, linked with smart power electronics and new control theory, offers significant potential to improve grid resilience to all hazards. Materials science is vital to driving the grid-scale price points down, and advanced theory for coordination and control linked with storage is important to delivering increased grid flexibility and resilience.

With regard to the Hearing objective of improved cyber resilience, advanced data analytics (item 4 above) and new grid architecture and controls (item 5 above) would substantially improve situational awareness of cyber threats and provide more resilient control options to mitigate the impact from attacks. And the advanced predictive, real-time operational tools (item 1 above) would give operators precise tools to limit the spread of a cyber-induced outage and speed recovery. Energy storage (item 5 above) would provide more flexibility in how operators mitigate any cyber outage and speed recovery. In addition to technology innovations, small and mid-sized utilities could substantially improve their cyber readiness through implementation of existing cyber security maturity self-assessment tools and vulnerability assessments. The challenge small utilities face is limited engineering staff and financial resources to systematically conduct cyber vulnerability assessments and cyber maturity self-assessments.

For the Hearing objective of physical resilience, an important emerging tool is the development of "design basis threat" assessments to frame the physical threat scenarios of highest priority to individual utilities. PNNL recently developed the first design basis threat assessment for NERC targeting physical resilience. This approach is consistent with the National Academies grid resilience report recommendation to systematically "vision" the emerging threat profiles and define priorities for improved resilience. With a prioritized plan for reducing physical security risk, the predictive real-time operation tools (item 1 above), enhanced planning tools to mitigate the risk of cascading outages triggered by physical attack (item 2 above), and sources of flexibility to cushion the system and speed recovery (e.g., energy storage in item 5 above or adaptive controls in item 3 above) would provide a path to improving physical attack resilience.

In summary, advances in science and technology concepts, conducted and validated in the field with public-private partnerships, offer substantial potential to improve grid resilience to cyber threat, physical attack and other sources of threat to the grid.

National Laboratory Collaborative Efforts To Improve Power System Resilience

DOE convened a consortium of 13 national laboratories—the Grid Modernization Laboratory Consortium (GMLC)–in 2014 to support its Grid Modernization Initiative in a coordinated, collaborative manner. A foundational element of this effort has been to frame metrics to support government and industry efforts in grid modernization. Grid resilience is one of the six metrics; it is closely related to the traditional metric of grid reliability, as well as an emerging metric called grid flexibility.

The National Academies grid resilience definition is similar to the definition in the GMLC Metrics effort. The challenge, however, is that metrics for resilience depend upon the type of threat or risk being addressed. And the attribute of "grid flexibility" is an emerging grid attribute that will be important to providing improved grid resilience in the future grid. Definitions and perspectives for these three metrics are described below.

GMLC Grid Modernization Metrics Research Related to Resilience		
GMLC Definition	**Current Status**	**Next Steps**
Resilience: The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions, deliberate attacks, accidents, or naturally occurring threats or incidents.	Widely-accepted metrics for resilience do not exist currently. Existing metrics do not focus on impacts resulting from individual events or on individual critical sectors, especially resilience events, which are generally infrequent yet have large consequences.	With key stakeholders, GMLC is piloting new metrics through case studies: • Electrical service • Critical electrical service • Restoration cost and time • Monetary impacts
Reliability: Maintain the delivery of electric services to customers in the face of routine uncertainty in operating conditions. For distribution systems, focus is on interruptions in the delivery of electricity in sufficient quantities and quality. For bulk power system reliability, metrics focus on near-term operations and longer term planning.	Existing metrics are mature but focus on distribution networks. They gauge the frequency and duration of outages averaged over all customers within a service territory over a specific time period. This approach masks the wide variance among outages in terms of size, duration and economic impact on customers.	For distribution, the GMLC is developing more granular, value-based metrics that enable utilities to estimate the likely costs to customers in specific locations so that investment dollars can be allocated to reduce the likelihood of the most costly interruptions. These are being developed and demonstrated through a partnership with the American Public Power Association. Bulk power efforts include working with the North American Electric Reliability Corporation new transmission metrics to gauge overall reliability of the three North American interconnections.
Flexibility: The ability to respond to future uncertainties that stress the system in the short term and may require the system to adapt over the long term. For near-term operations, flexibility refers to the agility of electrical networks to adjust to known or unforeseen short-term changes, such as abrupt changes in load conditions or sharp ramps due to errors in renewable generation forecasts. For longer-term investment perspectives, flexibility refers to the ability to respond to major regulatory and policy changes and technological breakthroughs without incurring stranded assets.	Widely accepted metrics for flexibility do not exist.	Industry feedback indicates the highest priority for flexibility metrics pertain to coping with short-term fluctuations in the availability of generation from wind and utility-scale solar facilities. The GMLC is evaluating more than 20 separate metrics that could quickly identify the nature of a given fluctuation or estimate the likely effectiveness of alternative options for dealing with that fluctuation. The GMLC will also examine how to build more flexibility into long-term system planning.

The GMLC research portfolio includes projects focused on improved power system resilience. Some highlights of recent results include the following (fact sheets attached):

- **Transactive Campus Testbeds for Local and Regional Grid Resilience and Flexibility:** Corporate, university, and government campuses represent a substantial resource for microgrid and load coordination to support emergency response and deliver power system flexibility at local and regional levels. In Washington State, three campuses (PNNL, the University of Washington, and Washington State University) are establishing transactive controls of responsive distributed energy resources, major loads and energy storage to coordinate at the local campus and to collectively deliver resilience and flexibility to the regional grid. These testbeds will deliver design and operational strategies and lessons learned to support wider adoption across the nation.

- **Grid Analysis and Design for Energy and Infrastructure Resiliency for New Orleans:** Coastal cities like New Orleans, Louisiana, often experience extended disruption of electric grid operations, resulting in impacts to other energy intensive infrastructures vital to recovery, including flood control operations, water supply and treatment, transportation, emergency response, and banking. A recently completed GMLC project developed strategies with stakeholders to effectively use local distributed generation, microgrids, and renewable energy resources as well as cost-effective grid resilience enhancements to reduce the severity of power outage impacts and enhance community resilience for U.S. coastal communities. It delivered an integrated strategy engaging city emergency response officials, utility representatives and others to deliver a more robust city response that supported flooding management and emergency services in addition to power restoration to city neighborhoods.

- **Microgrid Enhancements for Grid Resilience in Kentucky and Alaska:** Two projects addressed how to enhance resiliency of power grids supporting critical loads and remote communities, respectively, through advanced microgrid controls, as well as informing investment decisions to reduce risks to extreme storms and other threats. These projects have delivered enhanced microgrid toolsets available to industry microgrid designs, and strategies for system planning and financing to expand the availability of microgrids to support improved grid resilience.

- **Threat Detection and Response with Data Analytics:** The nation's power grid faces dynamic and complex threats from cyber-attacks, physical attacks, and storms. This research brings together six laboratories to develop an all-hazards approach to protect the grid through advancements in three key areas of technology development: sensors, data analytics, and a response/mitigation framework. Industry partners are advising the research and will ultimately be candidates for field validation of these emerging analytic concepts.

- **Southeast Regional Consortium for Improving Distribution Resiliency through Advanced Sensors and Controls:** GMLC labs have teamed with multiple utilities in the Southeast to deploy and test advanced sensor platforms and analytic tools to enhance power system monitoring and recovery in the face of increasing extreme events (e.g., hurricanes). Through the development of an advanced sensing, communication, and control ecosystem, increased situational awareness technologies have been deployed for field validation that will improve overall storm resilience and response.

Finally, DOE recently awarded seven new resilient distribution systems projects in September. These public-private efforts will validate emerging GMLC resilience concepts in utility and community environments.

Innovation in Valuation Tools and Data Sets to Advance State and Federal Regulatory Consideration of Investment for Power System Resilience

Science and technology efforts are critical to modernize the grid for resilience, reliability and flexibility, but alone cannot achieve the end state goal. Utilities at all levels—consumer-owned, investor-owned, municipalities—must have the capacity to understand the value of alternatives to improve their system resilience and performance. State regulators need the same tools and data sets with which to evaluate modernization plans and provide the regulatory incentives to achieve prudent modernization that delivers affordable resilience improvements to product offerings that enable modernization at scale. Finally, vendors must be able to define market opportunities to ensure rapid innovation in their product offerings.

The GMLC portfolio includes research projects to develop a framework for valuation of the new grid technologies and concepts so that government and industry stakeholders can work together to assess the benefits and costs of resilience improvement strategies. This partnership between DOE, states, and industry is an important collaboration in charting a timely path to a more resilient U.S. power system.

Conclusion

In conclusion, science and technology innovation offer the capacity to deliver a resilient and modernized grid that we can "see and control and protect" like never before. Big data management, new data analytics and fundamental advances in machine learning, and exascale computing will be central to delivering this modern grid and maintaining U.S. leadership. Grid resilience is intricately linked to other grid attributes such as reliability and flexibility. And new tools to value and simulate grid resilience concepts, in concert with public/private field validation, will accelerate national grid modernization efforts.

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

GRID
MODERNIZATION
LABORATORY
CONSORTIUM
U.S. Department of Energy

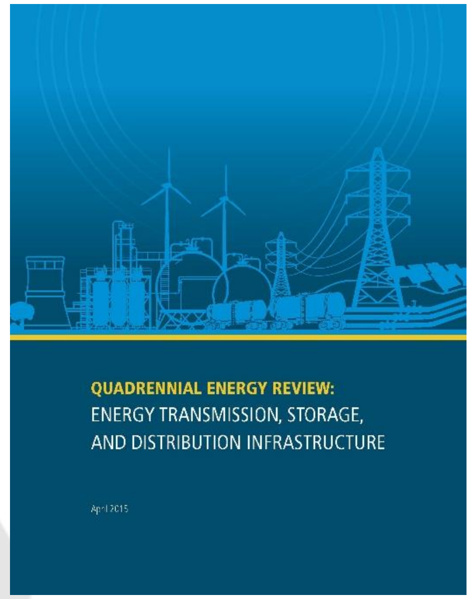
Delivering a Power Grid for the 21st Century

The United States power system is a strategic investment for our nation, and new paradigms for designing, operating and securing our grid are critical for our national economic and security goals. To meet this challenge, the U.S. Department of Energy established the Grid Modernization Initiative. Through this Initiative, DOE is working with public and private stakeholders to develop the concepts, tools, and technologies needed to measure, analyze, predict, protect, and control the grid of the future.

In support of this Initiative, the DOE launched the **Grid Modernization Laboratory Consortium** to engage the national laboratories working on DOE grid programs to frame a new integrated approach for planning and delivering innovations and thought leadership in support of grid modernization. This new, crosscutting approach ensures that DOE research and development investments and capabilities are fully coordinated to enable a modern U.S. power system.

Comprised of 65 leading scientists and engineers from across the DOE national labs, the technical teams are aligned with **six technical thrust areas**:

- **sensing and measurements**
- **devices and integrated systems**
- **system operations, power flow, and control**
- **design and planning tools**
- **security and resilience**
- **institutional support.**



Released in April 2015, the Quadrennial Energy Review (QER) highlighted fundamental challenges and new opportunities for transforming the grid to meet new demands of U.S. energy and economic priorities of the 21st century. The QER recommended focused investment in Grid Modernization research and development as a national imperative.

IMPACT

By 2025, grid modernization is expected to help industry substantially improve the performance and security of the U.S. electric system by delivering the following grid qualities:

- Improved reliability for customers
- Enhanced resilience against all hazards
- Continued affordability in the face of change
- Enhanced environmental performance delivering a clean supply of electricity
- Fundamental security of the delivery of the nation's electricity needs

THE CHALLENGE

For the next several decades, the Grid Modernization Laboratory Consortium will coordinate grid modernization activities to address the following challenges:

- increasing the grid's digital capacity
- enabling two-way power flow for distributed generation (renewables)
- improving security and resilience to all hazards—cyber, physical and other risks
- developing tools and control paradigms that leverage the capabilities of new digital grid technologies to deliver improved reliability and economic productivity.

STAKEHOLDER INVOLVEMENT AND OUTREACH

Modernization of the U.S. electric grid entails dramatic transformations, with close collaboration required across industry, states, federal agencies, regulators and numerous other stakeholders. In addition to leading the lab-to-lab technical teams to best leverage intellectual and scientific assets, the labs also play a key role in engaging regional stakeholders in new concepts.

For example, the labs are providing institutional support to states, local communities, tribes, and others to develop new regulations needed to unleash the potential of the modern grid. The labs will also engage in the development and implementation of regional and local demonstrations, co-funded by industry, to accelerate the rate of impact of the new innovations emerging from the DOE Grid Modernization efforts.

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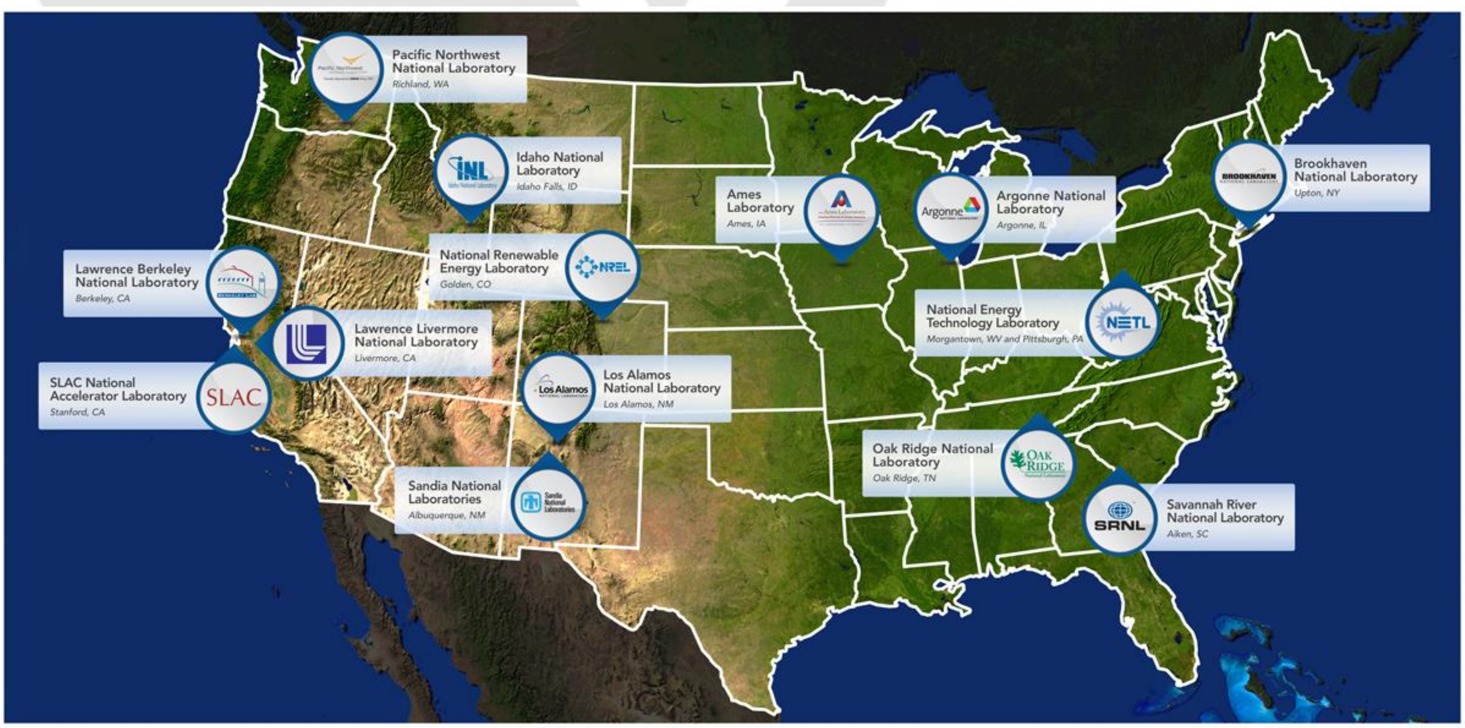
MULTI-YEAR PROGRAM PLAN

Consortium members developed a draft multi-year program plan (MYPP) that outlines an integrated approach to grid research funding, stewarded primarily across three DOE offices:

- Electricity Delivery and Energy Reliability (DOE-OE)
- Energy Efficiency and Renewable Energy (DOE-EERE)
- Energy Policy and Systems Analysis (DOE-EPSA).

Other DOE grid programs, such as Fossil Energy, Advanced Research Projects Agency-Energy and the Office of Science, are also engaged. The MYPP defines an agenda to accelerate the impact of the DOE innovations on the nation's infrastructure, including partnerships with industry and states to launch emerging concepts.



Clean Energy & Transactive Campus

CHALLENGE

Vast opportunities for improved reliability, consumer benefits, and energy efficiency exist at the buildings-to-grid nexus. Realizing those benefits, however, requires research, development, and testing of transactive controls for energy management. Greater understanding and implementation of transactive controls at the single building, single campus, multi-campus, and community microgrid scale will help lead to a more reliable, resilient grid.

On PNNL's campus, the Building Operations Control Center tracks building energy use and serves as the "nerve center" for the multi-campus project.

APPROACH

Pacific Northwest National Laboratory (PNNL) is leading a three-site project with Washington State University (WSU) and the University of Washington (UW). This is the first time researchers will test the use of demand-side transactive controls ("behind the meter") at this scale, involving multiple buildings and devices. Primary activities at each campus include the following:

- PNNL – multi-campus network operations; transactive campus/building response applications; transactive/advanced buildings controls testbed
- WSU – microgrids as a resilience resource/smart city; solar and battery in microgrid operations; flexible loads; thermal storage
- UW – energy efficiency applications, leveraging transactive network; smart solar inverter integration with distribution; transactive grid controls.

Another key objective is the establishment of a transactive energy system testbed. The partners will examine how the testbed can be operated as both a flexibility resource to help manage electricity loads and bring intermittent renewable energy onto the power grid, and as a platform for future research and development in the emerging buildings-grid discipline. A second phase of this project expands to new partners Case Western Reserve University and the University of Toledo in 2017.

At-A-Glance

PROJECT LEAD

- **Srinivas Katipamula**
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PARTNERS

- Washington State University
- University of Washington
- Case Western Reserve University
- University of Toledo

TECHNOLOGY

- VOLTTRON™
- Transactive Controls
- Microgrids
- Smart Solar Inverter
- Energy Storage

BUDGET

$4.5 million

- $2.25 million
  (U.S. Department of Energy)
- $2.25 million
  (Washington State Clean Energy Fund)

DURATION

October 2015 – October 2017

TECHNICAL AREA

Systems Operations and Control

Lead: Jeff Dagle

Pacific Northwest National Laboratory

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EXPECTED OUTCOMES

Using transactive controls to manage devices, data, and decision making, buildings will automatically adjust energy loads based on pre-determined criteria such as cost, essential services, and comfort levels.

Knowledge gained from this activity informs responsive load management, energy conservation, and future grid modernization decision making, regionally and nationally. This is a key step forward in achieving a more modern, efficient, and reliable power grid.

LAB TEAM

Pacific Northwest NATIONAL LABORATORY

Alaska Microgrid Partnership

CHALLENGE

Alaska—perhaps more than any other region in the country—faces unprecedented challenges in modernizing its rural energy infrastructure. Across the state, approximately 200 isolated microgrid systems are not connected to larger grids, and most of these systems rely almost exclusively on imported fuel (primarily diesel) to meet electrical, space/water heating, and transportation requirements. These communities have populations ranging from 50 to 6,000 people, are composed primarily of native Alaskans, and have some of the highest energy costs in the nation (up to ~10 times the national average).

Two of three wind turbines can be seen over the bulk fuel tanks of the Kasigluk Power Station, a vision of what could be possible in the future.

Alaska has extensive renewable energy resources, access to advanced diesel and load control technologies, and significant opportunities to improve energy efficiency. Despite this potential, relatively few energy projects have been completed with most of these projects being funded by grants. Rural Alaska likely has the lowest reliability and least resilient power systems in the country.

APPROACH

This project involves creating a development pathway for islanded microgrids that emphasizes leading by example, then testing the pathway using two pilot projects, and making the pathway data and other useful information available for other communities to follow. Key project activities include the following:

- developing a consistent assessment pathway to reduce total imported energy usage in a holistic way, working to address electrical, heating, and transportation energy needs;
- pulling together largely existing analytical tools to coordinate technical and financial methods that support full development assessments, allowing expanded public and private sector engagement;
- integrating more robust financial pro-forma assessment into the analysis of energy options, facilitating private sector investment in energy system improvements;
- implementing the pathway with two pilot communities, providing a workable example for other, non-pilot communities; and

At-A-Glance

PROJECT LEADS

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PARTNERS

- Renewable Energy Alaska Project
- University of Alaska Center for Energy and Power
- Intelligent Energy Systems
- University of Alaska Institute of Social and Economic Research

BUDGET

$1.18 million

DURATION

March 2016 – September 2017

TECHNICAL AREA

Design and Planning

Lead: John Grosh

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Rev. 2, June 2017

- developing new data sources and sharing information with project developers—via the Alaska Energy Data Gateway—that details the human, financial, and technical capacity of communities across Alaska to undertake new energy infrastructure projects.

EXPECTED OUTCOMES

The over-arching goal of the Alaska Microgrid Partnership is to significantly reduce the use of imported energy sources in Alaska's remote microgrids without increasing system lifecycle costs, while improving overall system reliability, security, and resilience. Expected outcomes from this project include the following:

- documenting the full techno-economic development process for reducing imported energy consumption by at least 50% in remote microgrids in Alaska, using a combination of energy efficiency, building energy improvements, power system upgrades, and transportation options analysis;
- identifying investment opportunities (i.e., the business case) to attract the funding needed to implement these types of projects on a wide scale;
- creating an implementation methodology for other communities to follow by documenting and publicizing the community assessment, data collection, project analysis, and development process; and
- implementing the methodology in two pilot communities to serve as models to position the communities to seek private and public funding to implement project recommendations.
- making Alaska Mircrogrid Partnership project and community information and data more readily available through an expansion of the Alaska Energy Data Gateway: https://akenergygateway.alaska.edu/

The potential worldwide market and impact are significant: 400 diesel microgrids in Canada, 70 in Greenland, and more than 1,000 in Indonesia. The International Energy Agency estimates that more than 700 million people currently without electricity access could be most cost-effectively served by mini-grids or microgrids.

Pathway for Holistic Community Microgrid Development

LAB TEAM

BERKELEY LAB | NREL NATIONAL RENEWABLE ENERGY LABORATORY | Pacific Northwest NATIONAL LABORATORY | Sandia National Laboratories

Launched in November 2014 under the U.S. Department of Energy's Grid Modernization Initiative, the GMLC is a strategic partnership between DOE Headquarters and the national laboratories, bringing together leading experts and resources to collaborate on national grid modernization goals. The GMLC's work is focused in **six technical areas** viewed as essential to modernization efforts:

Devices and Testing | Sensing and Measurements | Systems Operations and Control
Design and Planning | Security and Resilience | Institutional Support

Industrial Microgrid Analysis and Design for Energy Security and Resiliency

CHALLENGE

Industrial utility customers have a unique opportunity to support a modern energy economy and a stronger, more reliable grid. They typically need reliable, secure power in high quantities, and many facilities have their own backup generators and redundant electrical feeds to bolster their reliability. However, many of the generators are only used for routine testing and for their intended purpose only a few hours a year. If these backup assets could be used as a microgrid for both blue-sky and contingency cases, then the microgrid could provide both reliability to the customer and services to the grid. Some utilities are not familiar with some of the emerging grid technologies and how they can be incorporated into their operations to increase grid resilience for their customers. The perceived risk associated with new technology adoption can present a significant barrier to modernizing the grid.

Addressing utility hesitation head-on by involving utilities in the entire development of grid modernization technologies and providing hard evidence of benefit to both customers and utilities could be the key to unlocking utility modernization efforts across the country.

APPROACH

Advanced microgrid control schemes are one way to increase the reliability and strength of the grid. Oak Ridge National Laboratory (ORNL), in partnership with Sandia National Laboratories (SNL) and Fortune 10 company United Parcel Service (UPS), is investigating, developing, and analyzing the risks, costs, and benefits of a microgrid at the UPS World Port and Centennial Hub facilities in Louisville, Kentucky. This processing hub, the crown jewel of UPS's company, is the most technically advanced facility of its kind in the world, and UPS is very interested in the development of an industrial microgrid to serve its 50-megawatt power needs.

This partnership will keep the utility engaged in the project and aware of how industry customers want to use microgrids, and how microgrids will affect the larger electric grid.

At-A-Glance

PROJECT LEADS

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PARTNERS

- United Parcel Service
- Waste Management
- Burns & McDonnell
- Harshaw Trane
- Louisville Gas & Electric
- State of Kentucky

BUDGET

$1 million

DURATION

April 2016 – September 2017

TECHNICAL AREA

Security and Resilience
Lead: Juan Torres
National Renewable Energy Laboratory
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EXPECTED OUTCOMES

Technical documents developed from this project will provide a roadmap and set of open-source tools for UPS and other industries interested in microgrid technologies. The institutional and regulatory challenges associated with development of an industrial microgrid will be spelled out. The methods and open-source tools used in this project can be directly applied to other interested industries. The project will also highlight the interaction between an industrial customer interested in pursuing a microgrid and a utility that may be unfamiliar with adopting such a technology—a scenario that industries across the country are highly likely to face.

LAB TEAM

Oak Ridge National Laboratory

Sandia National Laboratories

Grid Analysis and Design for Energy and Infrastructure Resiliency for New Orleans

CHALLENGE

The heightened risk coastal cities like New Orleans, Lousiana (NOLA) encounter from hurricanes, floods, and other natural disasters is never farther than the memory of Hurricane Katrina. During such events, extended disruption of electric grid operations exacerbate interruption of energy intensive infrastructures vital to recovery, including flood control operations, water supply and treatment, transportation, emergency response, and banking. The resilience of communities is dependent on grid resilience.

This color-coded schematic of New Orleans indicates where critical infrastructure in the area does not exist (red); exists but is less than required by users (yellow); or exists and meets user-defined requirements (green).

APPROACH

Identifying approaches to effectively use local distributed generation and renewable energy resources as well as cost-effective grid resilience enhancements can help reduce the severity of power outage impacts and enhance community resilience for many U.S. coastal communities subject to similar threats and risks. This project will support the development of priority electrical distribution system upgrades and advanced microgrid pilot projects that can help bolster community-level resilience for NOLA and other coastal U.S. cities. This project will provide detailed information and conceptual models that can help NOLA and other coastal cities prepare for, prioritize, and execute grid resilience projects. Data will be available to stakeholders from the following efforts:

- Infrastructure Impact Modeling and Analysis
- Resilient Power Distribution Modeling and Analysis
- Integration of Distributed, Renewable, Energy Storage, and Energy Efficiency Options
- Cost/Benefit Analysis.

At-A-Glance

PROJECT LEADS

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PARTNERS

- City of New Orleans
- Rockefeller Institute
- Entergy New Orleans
- US Army Corps of Engineers

TECHNOLOGY

- Infrastructure modeling
- Energy systems resilience
- Power system modeling
- Renewable energy
- Microgrids
- Energy and water infrastructure

BUDGET

$1 million

DURATION

June 2016 – March 2017

TECHNICAL AREA

Security and Resilience
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EXPECTED OUTCOMES

NOLA, the local electric utility Entergy, and relevant stakeholders will have a set of risk-informed, cost-effective recommendations for grid resilience enhancement. NOLA, Entergy, and state and federal agencies can use these recommendations to rank energy infrastructure improvement options and set improvement implementation and funding priorities. This effort will produce a template for other communities to use for increasing grid and community resilience.

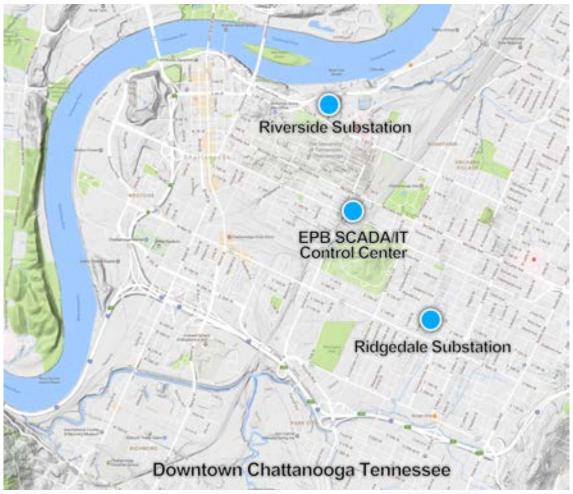
LAB TEAM

Los Alamos NATIONAL LABORATORY

Sandia National Laboratories

Southeast Regional Consortium

CHALLENGE



Time-sensitive network testing locations.

Different geographical regions across the United States face specific electric grid challenges, such as recurring weather extremes, integration of distributed energy resources (DERs), and an aging electricity infrastructure. On the hurricane-prone Southeast Coast of the United States, damage to electrical infrastructure is not merely inconvenient—it can cause loss of life and millions to billions of dollars in economic losses. Advancing the state of the grid in the Southeast to improve overall system resiliency will reduce the impact of these weather events. Engaging regional stakeholders is crucial to effectively developing new technologies to address the unique regional challenges they face. This involvement will help overcome barriers in transitioning modern, new grid technologies to industry.

APPROACH

The Southeast Regional Consortium is conducting collaborative research to enhance responsiveness, enable faster restoration of power, and increase the concentration of DERs for overall system resiliency. Led by Oak Ridge National Laboratory (ORNL), Savannah River National Laboratory, the University of Tennessee, the Center for Advanced Power Energy Research, and the Clemson 20 MVA Electrical Grid Laboratory—along with critical industry partners, such as Duke Energy, Tennessee Valley Authority, Southern Company, Chattanooga Electric Power Board (EPB), and Santee Cooper—this effort includes four technical projects:

1. Development and testing of distributed control technologies and algorithms for the future EPB distribution center microgrid through hardware-in-the-loop testing at ORNL. ORNL's distributed control framework—Complete System-Level Efficient and Interoperable Solution for Microgrid Integrated Controls—will be applied to a detailed model of the future EPB microgrid that includes photovoltaics, inverters, communications, storage, and loads to accurately simulate

At-A-Glance

PROJECT LEADS

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PARTNERS

- Electric Power Board
- University of North Carolina–Charlotte
- Santee Cooper
- Duke University
- Clemson University
- Southern Company
- Tennessee Valley Authority

BUDGET

$1 million

DURATION

April 2016 – March 2017

TECHNICAL AREA

System Operations and Control

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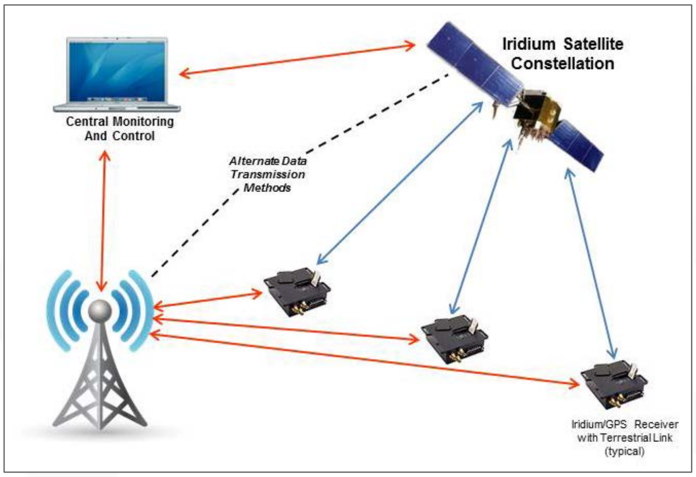
the EPB microgrid from bits to electrons. This will be done using ORNL's Distributed Energy Communications and Controls laboratory low-voltage hardware-based microgrid simulator and Real-time Digital Simulator.

2. Development and validation of a cyber-resilient dual-mode, terrestrial and satellite-based wireless sensor/control network—applicable not only to the Southeast, but any region in the United States due to the use of satellite networks.
3. Testing of new time-sensitive network technologies using dark fibers on the EPB fiber-optic data network.
4. Development of step distance protection for distribution systems using passive optical sensors.

   Step distance protection is currently only applied at the transmission level.

In addition, the consortium is convening a workshop to connect regional stakeholders, foster shared understanding of the technical challenges facing utilities in the Southeast, and discuss the new technologies emerging from DOE grid modernization efforts.



EXPECTED OUTCOMES

Distributed control technologies will improve distribution system resiliency while increasing the concentration of DERs, and dual-mode wireless networks will allow rapid detection of cyber-attacks. Time-sensitive networks will provide the information needed for fast digital control over networks and transient monitoring in distribution systems.

The increased resolution of optical sensors will provide increased visibility, opportunities for new more resilient protection schemes at the distribution level, improved fault localization, and bi-directional power flow. Dual wireless sensing/control will create weather-independent information networks that will help restore power to critical loads more quickly during storms.

Building on existing collaborations, the consortium will foster new engagements with the University of Tennessee, Clemson, Duke University, The University of North Carolina, EPB, Santee Cooper, Southern Company, Dominion, SRNL, and ORNL to assure that these and other emerging technology developments to create a modern resilient grid are more rapidly moved from laboratories to industry implementation.

LAB TEAM

Oak Ridge National Laboratory
SRNL Savannah River National Laboratory

Threat Detection and Response with Data Analytics

CHALLENGE

Large amounts of data related to regional outages, cyber health, distribution sensors, and advanced metering infrastructure (AMI) are gathered from the electrical grid. However, it is difficult to identify cyber-attacks and differentiate them from non-cyber incidents. Furthermore, degradation of the grid can come in many forms, including failure of materials, equipment, and information infrastructure resulting from natural or malicious events. Consequences from any of these scenarios can affect the reliability, maintainability, and availability of data required for decision making at numerous levels.

APPROACH

This project will develop advanced analytics using operational technology (OT) cyber data to detect complex cyber threats. Analytics will be developed that can assist in differentiating between cyber and non-cyber-caused incidents using available cyber data. To this end, the project team will conduct the following activities:

- Evaluate which sensor data are most valuable and could provide the biggest positive impact (in terms of grid resiliency/security) if an event is successfully detected. Possible data sources are phasor measurement units (PMUs) in electrical distribution systems, renewable generation and distributed energy resources (photovoltaics/inverters), demand response data for energy dispatch on the bulk electric system or electric vehicles on the consumer side, AMI data, and building automation data.
- Develop analytics to identify emerging cyber incidents on the electric grid using OT data identified in the previous objective.
- Attempt to differentiate cyber grid incidents from other grid hazard incidents, such as physical attacks, natural hazards, etc.
- Test analytics with industry and asset owner partners.

At-A-Glance

PROJECT LEADS

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PARTNERS

- Electric Power Board
- Johnson Controls
- Schweitzer Engineering Laboratories

BUDGET

$3 million

DURATION

April 2016 – March 2019

TECHNICAL AREA

Security and Resilience
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EXPECTED OUTCOMES

The project will identify “cyber-physical” signatures that will allow us to quickly differentiate between cyber events and non-cyber events on the grid. By differentiating between cyber-related and non-cyber-related/operational events, determinations can be made about the type of incident and its root cause. We will partner with a U.S. utility to obtain sensor data and validate prototype analytics against the data.

Research results will lead to development of commercial tools that will improve a utility’s ability to differentiate between cyber and non-cyber incidents so that they can make the most appropriate response during an event.

LAB TEAM

Berkeley Lab | Idaho National Laboratory | Lawrence Livermore National Laboratory | Oak Ridge National Laboratory | Pacific Northwest National Laboratory | Sandia National Laboratories

Launched in November 2014 under the U.S. Department of Energy’s Grid Modernization Initiative, the GMLC is a strategic partnership between DOE Headquarters and the national laboratories, bringing together leading experts and resources to collaborate on national grid modernization goals. The GMLC’s work is focused in **six technical areas** viewed as essential to modernization efforts:

Devices and Testing | Sensing and Measurements | Systems Operations and Control
Design and Planning | Security and Resilience | Institutional Support