Department of Energy
Washington, DC 20585

September 24, 2015

**MEMORANDUM TO THE DEPARTMENT OF ENERGY
ELECTRICITY ADVISORY COMMITTEE**

From: **Patricia A. Hoffman** PH
Assistant Secretary
Office of Electricity Delivery and Energy Reliability

Subject: **DOE Response to EAC Work Product**

I want to thank all members of the Department of Energy's (DOE) Electricity Advisory Committee (EAC) for your hard work during 2015.

The work product delivered by the Committee during this period is listed below. The purpose of this memo and its attachment is to provide you with the Department's response to your analyses and recommendations in a systematic and inclusive form.

EAC March 2015 Work Product:

Smart Grid Research and Development Needs Recommendations, March 2015

The attachment that follows summarize DOE's actions and response to this March 2015 work product.

I continue to look forward to the future efforts of the EAC and am committed to ensuring a strong and fruitful working relationship between the Committee and DOE.

Electricity Advisory Committee (EAC) Recommendations
Smart Grid Research and Development Needs
March 27, 2015

In the Electricity Advisory Committee's (EAC) "Recommendations on Smart Grid Research and Development Needs," dated March 27, 2015, EAC suggested areas where the Department of Energy (DOE) can offer the most critical support of the smart grid through research, development and demonstration (RD&D) programs. DOE has prepared this coordinated response to broadly address the recommendations as found in the seven sections of the EAC report as follows: (1) overview; (2) transmission lines and substations; (3) distribution; (4) beyond the customer's meter; (5) cybersecurity; (6) communications; and (7) conclusion. In addition, many of EAC's identified RD&D needs and critical areas were considered during the composition of DOE's 2015 Quadrennial Technology Review (QTR) which examines the status of electric grid technologies and the research, development, demonstration and deployment opportunities to advance them. Focusing on technologies with commercialization potential in the mid-term and beyond, the QTR has a chapter that specifically addresses modernization of the electric power system. Please refer to chapter 3 of the recently released QTR and the associated technology assessments which can be found at: http://energy.gov/quadrennial-technology-review-2015 for a more in-depth discussion on specific technologies.

1. Overview:

DOE agrees with EAC's overall identified need to provide critical support through education, research, development and demonstrations to address power industry challenges. DOE's 2014 Strategic Plan established a key objective of supporting a more economically competitive, environmentally responsible, secure and resilient US energy infrastructure. In addition, the President directed a White House Task Force to develop the Quadrennial Energy Review (QER), a government-wide integrated energy policy document. One of the main objectives of the review was to assess the state of the energy landscape and provide policy recommendations, including funding levels for research, development, and demonstration programs to support key energy innovation goals. DOE's April 2015 publication of the QER on "Energy Transmission, Storage, and Distribution Infrastructure," recommended to the Administration and Congress to provide grid modernization R&D, analysis and institutional support. DOE is pursuing a multi-year, collaborative effort to accelerate grid modernization. This initiative is based on cost-shared research and development, analysis, and technical assistance for technology innovation that supports grid operations, security and management. Additionally, engagement with stakeholders through workshops and dialogues will highlight key opportunities and challenges for new technology in transforming the grid. DOE can serve as a resource and convener for the diverse and fragmented set of stakeholders across industry, the scientific community, and all levels of government.

DOE's launch of the Grid Modernization Laboratory Consortium (GMLC), a strategic partnership between DOE headquarters and our National Laboratories to bring together our leading experts and resources to collaborate on the goal of modernizing the nation's grid. The Consortium employs an integrated approach to ensure that DOE-funded studies and research and development are efficiently coordinated to reap the greatest return for the taxpayer dollar. The Grid Modernization Multi-Year Program Plan (MYPP) efforts underway draws on expertise within DOE program office and leverages the GMLC to ensure funds are well spent and leveraged for the next five years across the various program offices. Presently, 85% of the DOE Office of Electricity Delivery and Energy Reliability (OE) fiscal year (FY) 2015 program budget is dedicated toward research, development and demonstration projects. The QER, QTR, GLMC and associated programmatic efforts are expected to accelerate RD&D of beneficial new energy technologies in the future.

Recently, DOE launched phase II of the Future of the Grid Initiative. Phase I utilized a series of multi-stakeholder regional workshops to gather input to develop an industry-driven vision of the future electric grid and the changing operational, business and policy requirements needed in the electricity industry over the next 20 years. Phase II of the Initiative will develop a framework for decision makers around the issues associated with distributed energy resources as a driver for change. The framework can be used to facilitate public policy discussions at the state and local levels, and can be used by policy makers and regulators as they create their strategies (policy level) and roadmaps (regulatory level). The guide will provide a holistic view of the issues and frame them from multiple stakeholder perspectives to provide context around the decisions being evaluated. It will provide linkages between high level policy/regulatory decisions and the operational, regulatory and market consequences of those decisions. As part of this Initiative, DOE will leverage work being done to implement the QER recommendations as well as R&D work being done through the GMLC to provide input into the process and the development of decision support tools.

Education, including facilitation of peer-to-peer learning among utilities, is critical to stretching investment dollars and furthering modernization efforts. Continuing efforts to share understanding gained through the American Recovery and Reinvestment Act (Recovery Act or ARRA) projects as well as other grid modernization efforts across the country, DOE will investigate successful smart grid technology strategies and applications being implemented by utilities to integrate distributed energy resources (DER). DOE will document and disseminate the findings to assist utilities and other industry stakeholders as they evaluate possible approaches to increasing penetrations of DER as a Climate Readiness strategy.

To further assist and educate industry stakeholders as they develop and evaluate projects/technologies to integrate increasing amounts of DER on the electric grid, DOE funded Pacific Northwest National Laboratory to develop an Emissions Quantification tool (EQT) that uses a (new) standardized methodology for estimating the environmental impacts of a range of types of smart grid technologies. The EQT will allow stakeholders to quantify the impacts and articulate the benefits of a project thus providing an additional value streams that can be included when developing a smart grid business case. It will also give utilities a screening tool for comparing various projects. The tool uses quantitative inputs to describe the scope of a project, reflects regional differences regarding effects of displacing generation, and documents all input, assumptions, calculations, and results. It standardizes the methods to provide meaningful results for wider adoption. The current tool will characterize six widely used technologies:

1) Conservation Voltage Reduction (CVR) for Energy Conservation, 2) Photovoltaic solar, 3) Energy Storage for Peak Shaving, 4) Coordinated Electric Vehicle (EV) Charging, 5) Demand Response with Air Conditioning Units, 6) Advanced Metering Infrastructure (for reduced truck rolls). DOE will further expand the tool to include additional applications that can be evaluated. The EQT will be included as decision support tool for the Future of the Grid Initiative and in the report documenting successful approaches for DER integration.

As new technologies that collect increasing amounts of data are deployed throughout the electric grid, the continued protection of consumer privacy is critical and consumers will need assurances that their privacy is being protected. With this in mind, DOE facilitated the development of a voluntary code of conduct, and will launch the DataGuard program to provide utilities and third parties not only a framework for handling and protecting customer's data, but also a visible method (i.e., brand mark) for communicating their commitment to protecting customer privacy. The program will also help them to educate their customers on how they protect the access, use, and sharing of customers' data.

2. Transmission Lines and Substations:

Recommendation 2.1: Technologies ready for adoption and commercial use but not widely deployed

EAC identified technologies such as Dynamic Thermal Circuit Ratings (DTCRs), short circuit current limiters (SCCLs), Flexible Alternating Current Transmission (FACTS), Voltage Source Converters (VSCs), advanced analytics and visualization applications for Phasor Measurement Unit data, and intelligent electronic devices (IEDs) that are ready for adoption and commercial use but not widely deployed. In most cases, such technologies are limited in deployment due to cost/benefit analyses necessary to develop a more robust business case for U.S. utilities. Most of these technologies were specifically addressed in the QTR. DOE is working to secure future additional funds for next-generation components based on power electronic devices that will improve electric grid resilience and security, and for advanced modeling capabilities including dynamic operation, real-time analytics and predictive response. Moreover, DOE has been working with industry and utilities to further develop or use various design or valuation tools to develop economic use cases of smart grid technologies.

Recommendation 2.2: Technologies Requiring Additional Research, Development and Demonstration

2.2.1: Continue investment to promote advanced power electronics for transmission applications.

OE is coordinating with the Office of Energy Efficiency and Renewable Energy (EERE) and their Advanced Manufacturing Office (AMO) to leverage efforts with PowerAmerica, the manufacturing institute awarded to North Carolina State University, to make wide bandgap (WBG) semiconductor devices cost-competitive to silicon-based alternatives. DOE plans to continue to invest in advanced power electronic switches that can be utilized for transmission applications in alignment with findings in the 2015 QTR.

2.2.2: Continue and enhance research on new storage technologies, the development of early stage commercial technologies and the demonstration of various applications.

DOE plans to continue and enhance research, development, demonstration and deployment of new energy storage technologies across all technical/commercial readiness levels. Additional funding is being sought to provide technical assistance to states for locating, commissioning and optimizing energy storage assets through cost-shared demonstrations with diverse application profiles.

2.2.3: Investment in robotics and unmanned aerial vehicles can reduce inspection cost and increase safety.

DOE is supportive of the current investments and activities in robotics and unmanned aerial vehicles to reduce inspection cost and increase safety of transmission lines. DOE considers industry to be the main drivers of investment and adoption of these technologies. However, data integration to facilitate restoration and cost benefit analyses can provide further evidence of reduced inspection costs and increased safety.

2.2.4: Transmission operations requires advanced grid management tools

DOE recognizes that changing transmission operations from one based on traditionally off-line analysis to one based on real-time situational awareness (e.g., visibility) through measurements and fast control will require significant advancements in algorithms and computational approaches. OE's Advanced Modeling Grid Research Program leverages scientific advancements in mathematics and computation for application to power system models and software tools. In achieving this goal, the Program also fosters strategic, university-based power systems research capabilities. Based on a competitive solicitation issued in May 2012, OE selected five projects to develop a new class of decision support tools that will simulate dynamic events and help inform operators of real-time conditions to maintain stability. More recently, OE issued a National Laboratory call through the Grid Modernization Initiative which included development of an advanced grid planning and analytics platform that couple transmission, distribution and communication tools to enable timely evaluation of future grid alternatives. Another objective of the laboratory call is to create, maintain, and enhance a scalable math solver library for grid planning and operations tools that work for a variety of computational platforms to support advanced grid analytics, management and control capabilities.

2.2.5: Accelerate development of advanced sensors and other intelligent electronic devices which will allow for multiple applications including safety, reliability, outage response, condition based maintenance, asset management, increased asset utilization, forensic and diagnostic analysis and probabilistic risk assessment.

Through the Grid Modernization Initiative, the GMLC is focusing on high-level platform activities that cut across multiple program areas. There are five top priority platform activity areas that have been identified. One of those areas includes a sensing and measurement strategy which consists of developing, validating and documenting a new extended grid state framework and visibility strategy that encompasses power state, asset operational state, thermal states, and other important variables. The extended grid state framework will take into account sensing capabilities of new and existing devices. As part of this activity, the national labs will define a roadmap for developing complete visibility across the transmission, distribution, and building systems. This will also include environmental parameters for wind and solar forecasting. This activity will inform the programs on how to invest in a sensing and measurement strategy moving forward. In addition, the laboratory call requested proposals for developing advance applications of Phasor Measurement Units (i.e., synchrophasor) data. The focus of new projects under the Advanced Synchrophasor Technology Research program will be: (1) to use real-time synchrophasor data to improve electricity market operations, and (2) to use real-time synchrophasor data to actively control electricity system response so as to maintain reliability and/or system efficiency.

2.2.6: Continued development of advanced high voltage direct current technologies

The Department recognizes the role that high voltage direct current (HVDC) technologies can play in the future grid. While OE does not currently have the funding to support the development of advanced HVDC systems, activities in power electronic devices (see response to 2.2.1) can be leveraged. Additionally, as part of the national laboratory call, proposals have been solicited to improve the models and methods for assessing HVDC and medium voltage direct current (MVDC) technologies. This activity will improve understanding of control capabilities offered by HVDC and MVDC and explore scenarios and use cases, such as accelerated siting from undergrounding and the provision of virtual inertia.

2.2.7: Imperative to anticipate the significant transformation the nation's grid faces in supply, demand, consumer expectations and market through development of a next generation grid operating system or energy management system (EMS). Development of the EMS would contain enhanced state estimation and visualization technologies while considering leveraging evolving high performance computing (HPC), analytics and power system analysis algorithms to take advantage of HPC capabilities.

Foundational research in the Transmission Reliability and Advanced Modeling Grid Research programs support development of a next generation grid operating system or EMS. These critical areas are further described in the Grid Modernization Multi-Year Program Plan. Specific projects include developing integrated dynamic modeling and simulation tools across transmission, distribution and communications to support the evaluation and design for system stability. In addition, these projects will create and distribute new scalable libraries of algorithms, solvers, statistical modules, and analytic applications to take advantage of new technologies such a cloud computing, high performance computers (HPC), multi-core and graphics processing units (GPU), and data analytics architectures. Future projects will develop and validate open standards to ensure interoperability and coordinate and integrate currently separated energy management systems for the bulk power system, distribution systems and buildings.

2.2.8: Consider lower cost, practical superconducting cables.

The Department recognizes the value that low cost superconducting cables can have for the grid. OE had a high temperature superconductor (HTS) research program but does not currently have the budget to continue the development of lower cost superconducting cables. Under the Smart Grid Regional Demonstration Projects, SuperPower Inc. and its partners were funded to build and demonstrate critical components of a superconducting fault current limiting (FCL) transformer and test for AC losses and FCL functionality. Results and findings from this project will be useful to for the development of cables and other fault current limiter projects. The Advanced Research Projects Agency- Energy (ARPA-E) is presently funding projects in superconducting technologies. Grid Logic is developing a new generation high-temperature superconducting composite conductor that could significantly improve the performance and lower the cost of generation, transmission, and distribution assets. If successful, Grid Logic would create superconductors for high-power electric utility applications that are more energy efficient at 10% of the cost of today's conductors.

2.2.9: Ongoing need for materials advances promoting a smarter responding, more resilient grid.

The 2015 QTR highlighted the role that material advances can play in promoting a smarter responding and more resilient grid. The Grid Modernization MYPP and GMLC laboratory call includes research in power electronics for vehicle to grid applications and other intelligent devices interfacing with the electric grid. Additionally, OE plans to establish a new program in FY16 called the Transformer Resilience and Advanced Components (TRAC) program focused on improving the resilience of transformers and accelerating the development of next-generation grid components, including associated materials and devices. Recently, OE held a workshop titled Materials Innovation for Next-Generation Grid Transmission and Distribution Components in Oak Ridge, Tennessee to further inform directions of TRAC.

3. Distribution:

Recommendation 3.1: Status of Technologies Ready for Adoption

EAC identified distribution automation, Advanced Metering Infrastructure (AMI), advanced smart inverters with grid supportive functionality, conservation voltage reduction (CVR) and Volt-VAR optimization as technologies that are ready for adoption. However, deployment by US utilities has been limited due in part by the business case for these investments that include the cost/benefit analysis. Most of these technologies were specifically highlighted in the QTR. DOE is currently planning to evaluate projects and disseminate lessons learned from the ARRA Smart Grid Investment Grants that helped to deploy and demonstrate many of the technologies identified. Moreover, DOE has been working with industry and utilities to use various design or valuation tools to develop economic use cases of smart grid technologies.

Recommendation 3.2: Technologies Requiring Additional Research, Development and Demonstration

3.2.1: Computer models for new technologies need to be developed and incorporated into planning tools. As new technologies evolve, there is the opportunity to develop robust data sets on the performance of those technologies under an array of conditions.

DOE is continuing activities to expand modeling efforts to accelerate new software development through the Advanced Grid Modeling research program. As part of the FY16 GMLC laboratory call, proposals were solicited for the development of advanced load models and improved models for protection. Additionally, under the Grid Modernization Initiative MYPP, testing and characterization of new technologies has been identified as a critical research activity.

3.2.2: Develop alternative microgrid architectures. Determine impact of expanding the use of microgrids and what their preferred architectures be to enable functionality and integration into the grid during normal and emergency operation.

The DOE Smart Grid R&D Program issued a laboratory research call in FY15 to develop decision support tools to evaluate direct current (DC), alternating current (AC), and hybrid AC/DC microgrids design for applications in remote communities. The tools will be implemented in FY17 to evaluate various architectures for optimal performance in meeting individual community-defined objectives. Looking ahead, the tools will be enhanced with capabilities in transient analysis to ensure that any chosen architecture will meet the microgrid survivability requirements during both normal and emergency operations when integrated with the grid.

3.2.3: Sophisticated distribution management systems are needed <u>to leverage the increased volumes of data available from new grid technologies that will enhance the observability and controllability that will be required for the next generation grid.</u> Development of such systems will require significant, multi-year RD&D investments.

One of the largest challenges that utilities face when deploying an Advanced Distribution Management System (ADMS) is the interconnections and interoperability with peripheral systems such as Geographic Information System (GIS), Outage Management System (OMS), Computer Information System (CIS), Advanced Metering Infrastructure/Automatic Meter Reading (AMI/AMR), and Supervisory Control and Data Acquisition (SCADA). For utilities that span multiple states, it is not uncommon to have multiple systems provided by different vendors. This integration can be expensive and time consuming to implement making it difficult for most utilities to justify the costs. DOE has requested funding to develop a next generation Open Source Platform for ADMS which will provide a vendor agnostic interconnection layer. This interconnection layer will allow various systems and applications to be more effectively integrated. An initial version of this software platform will support the full suite of distribution management applications (such as voltage and reactive power optimization; fault location, isolation, and service restoration; economic dispatch; and optimization routines), other advanced applications (such as integration of microgrids, building management systems (BMS), and electric vehicles), and emerging applications (such as transactive control and connectivity with transmission level energy management systems). These new applications will greatly enhance observability and controllability required to integrate large amounts of renewables in a safe and effective manner, utilize assets more efficiently during restorations, enable much wider range of choices for consumers, and maintain affordable electricity rates.

DOE recognizes this is a high priority area and ADMS is a key pillar of the Smart Grid R&D program. Recently, a laboratory call was issued seeking the development of the integrated software platform described above and the establishment of a test-bed to enable the testing and evaluation of existing ADMS products in a realistic, complex environment.

3.2.4: Demonstrate and deploy power electronics enhanced transformers

DOE believes that power electronics enhanced transformers will play an important role in the future grid to serve as an interface point for distributed resources, including storage and plug-in hybrid electric vehicles. A new program called the Transformer Resilience and Advanced Components (TRAC) will consider the R&D opportunities for this technology (see response in section 2.2.9).

3.2.5: Develop Phasor Measurement Units for Distribution Systems. Research needed around the applications and modeling required for real time applications.

DOE believes that phasor measurement units (PMU) for the distribution system will have a role in the future grid. DOE will leverage the project on micro-PMU funded by ARPA-E as well as the broader sensing and measurement strategy being developed under the GMLC (see response in section 2.2.5) to identify future R&D opportunities.

4. Beyond the Customer Meter:

Recommendation 4.1: Market and rate design needs further investigation as changes in utility rate design may be needed particularly for customers who take advantage of distributed energy technologies and intelligent energy using devices.

DOE recognizes the impact that rapid deployment of end-use efficiency and distributed energy resources can have on the utility business environment. DOE's Office for Energy Policy and Systems Analysis is working closely with OE to better understand the issues and identify potential solutions.

As part of the Grid Modernization Initiative, valuation is a top priority area, and proposals through the National Laboratory call are sought for further research and development. Efficient characterization and valuation of services provided to the grid by existing and new technologies, as well as the value the grid provides to distributed technologies, is important for maintaining reliability and affordability of the rapidly evolving electricity system and providing clear price signals to consumers. Methods for establishing rates and policies should appropriately compensate new and existing technologies for the value streams they provide. The National Laboratories are in the process of developing a framework to identify values provided by grid services and technologies, and determine which are monetized in regional markets and which are not. Based on the QER and the Grid Modernization MYPP, development of a comprehensive strategy for valuation that encompasses generation, transmission, distribution, storage, and distributed energy resources (including energy efficiency) will be important to ensure all efforts at the labs and the Department is coordinated. DOE has also been investigating time-based rate programs in conjunction with advanced metering infrastructure and customers systems (as described in the following sections) that can be leveraged for market and rate designs.

Additionally, DOE's Market Based Control effort has begun to assemble a plan of research around what most of the industry calls Transactive Energy. Transactive Energy seeks to increase the temporal and locational precision of market signals such that price-responsive behavior contributes more effectively to both load and control constraints. Central to this body of research is to identify ways to tap into the flexibility of distributed generation and other customer-owned assets, and to establish a theoretical, modeling and simulation basis to ensure it results in a stable, reliable and efficient system.

Recommendation 4.2: Industry needs a comprehensive and accurate evaluation of consumer perspectives toward Smart Grid technologies in order to further the understanding of motivators for consumer adoption. Research needs include motivation, understanding, education, incentives and program designs, and competitive market development of smart grid technologies.

DOE has been working to help industry develop an enhanced understanding of customer behavior regarding electric technologies through various means.

In September 2014, DOE published a report entitled “Experiences from the Consumer Behavior Studies on Engaging Customers” that provide lessons learned by utilities through consumer behavior studies (CBS) conducted as part of the Department of Energy’s (DOE) Smart Grid Investment Grant (SGIG) program. In June 2015, DOE published a report entitled “Interim Report on Customer Acceptance, Retention, and Response to Time-Based Rates from the Consumer Behavior Studies” that provide a synthesis of measured impacts contained in the CBS utilities’ evaluation reports in the areas identified in the report title. DOE is also planning to publish a series of reports over the next 12 months on the results of analysis on the SGIG CBS data and utility evaluations. Upcoming reports include: final analysis report on SGIG CBS program impacts including energy savings, peak demand reductions, bill impacts, and customer acceptance/retention; an analysis that seeks to identify and explain differential customer acceptance, retention and response to time-based rates under voluntary vs. default enrollment approaches; an analysis of energy and peak demand impacts at times not anticipated due to the rate design (e.g., non-emergency day load reductions); an analysis of impacts on vulnerable populations such as low-income and elderly customers; and an analysis of the relative merits of alternative experimental designs for studies of time-based rate programs.

DOE is also publishing shorter and more accessible material derived from the SGIG CBS experience. As an example of a case study, in April of 2010, DTE Energy and the U.S. Department of Energy (DOE) signed an agreement finalizing a nearly $84 million grant that enabled DTE Energy to accelerate deployment of "Smart Grid" technology in Michigan through the SmartCurrents initiative. The program serves as a platform to eliminate manual meter reading and provide remote monitoring of the electric distribution system, which will enable faster and more reliable power outage detection and restoration. DTE Energy also has the ability to connect meters remotely. The program also enables customers to manage their bills by tracking their consumption and demand via the DTE Energy Web site. The SmartCurrents program, besides advanced metering technology, includes technologies that address improved electric distribution service and electric rates that incentivize off-peak electrical usage, web-based customer energy usage presentation and customer outage notification. In addition, certain "smart" appliances can communicate with DTE Energy to provide optimum energy savings. In general, pilot customers were satisfied with the rate, and it is estimated that customers saved 10 to 15 percent in 2013. Results further indicated that given the right combination of equipment, education, and pricing structure, significant influence can be exerted on how and when energy is consumed.

The SGIG CBS program funded SMUD to run a comprehensive study of several different time-based rate designs under alternative enrollment approaches (i.e., voluntary vs. default). Based on their experience and results of the study, SMUD has committed to making the default rate for all residential customers starting in 2018 one that is time-based, charging customers more for on-peak electricity and less for off-peak electricity. In June of 2015, the California Public Utility

Commission followed suit, citing substantial influence from the SMUD experience and decision, by ordering all of the state's investor-owned utilities to likewise transition their default residential rates to be similarly time-based. This is a stark example of DOE helping to catalyze change in the retail electric industry by providing a more detailed and rigorous understanding of customer behavior and preferences related to time-based rate designs enabled by smart grid investments.

Other examples of DOE helping industry to understand customer behavior include efforts in the Power Over Energy Initiative, an energy literacy campaign created by a coalition of energy and environmental groups to educate, motivate and empower customers to make smart decisions about how they use electricity. DOE joined the coalition in April 2013, and other members include leading organizations from across the energy industry. Reaching 82 million consumers through social networking sites such as Facebook, Twitter, Pinterest and YouTube, the website is an important credibility channel and its research results indicate that 92% of respondents believe it is extremely or very important to modernize the electricity grid to help conserve energy. 91% of respondents have changed behaviors to conserve energy and 83% are extremely or very concerned about the impact of their electricity usage on our environment. Further research is underway to better understand consumer sentiment on energy and conservation.

Finally, the SmartGrid.gov website is another means to motivate, promote understanding, education, and incentives to industry and consumers on the smart grid. Posted final reports from the SGIG and the Smart Grid Demonstration Program (SGDP) inform both public and private sectors on grid impacts, lessons learned and benefits to further promote investments in smart grid technologies, tools, and techniques that increase flexibility, functionality, interoperability, cybersecurity, situational awareness, and operational efficiency.

Recommendation 4.3: Additional research and development may be warranted in PV inverters.

DOE is presently investing in research and development of PV inverters through various program offices. OE sponsored work through Sandia National Laboratories to collaborate with the Korea Electrotechnology Research Institute (KERI) on testing PV inverters and developing inverter functions for distributed energy resource (DER) interoperability. Currently, there is no standardized protocol for verifying the communications or electrical behavior functionality of PV inverters or other DER. Sandia and KERI are developing the pre-certification protocol by building test-beds in the US and Korea, and investigating inverter behavior with advanced functionality. By comparing experiences and results from the laboratories, test procedures and parameters will be refined and submitted to international and national code-making organizations.

Through the Office of Energy Efficiency and Renewable Energy (EERE)'s SunShot Initiative, DOE is funding the Electric Power Research Institute (EPRI) to develop, implement, and demonstrate smart-grid ready inverters with grid support functionality with required utility communication and control links to capture the full value of distributed PV. ARPA-E also funded various projects including an award to Transphorm for developing power switches in inverters that improve the efficiency and reliability of the system.

Recommendation 4.4: Additional research and development may be warranted in Residential Energy Management Systems (REMS), energy usage portals, in-home displays, access to energy information, and in grid-ready appliances and devices with demand-response capabilities already built in.

DOE has been conducting research on customer-sited technologies and will continue to do so to explore the opportunities afforded. Through the Smart Grid Investment Grant Program, over $5 billion was spent on deploying Advanced Metering Infrastructure (AMI) and Customer Systems. AMI is an integrated system comprising of smart meters, two-way communications networks, and data management systems to enable metering and other information exchange between utilities and their customers. Customer systems include in-home displays, home area networks, energy management systems, and other customer-side-of-the-meter equipment that enable smart grid functions in homes, offices, and factories. More than 16 million smart meters were installed and put into operation through ARRA from 2010-2015, and were used in conjunction with deployed customer systems such as Web portals, in-home displays (IHD), direct load control devices, programmable communicating thermostats (PCTs) and smart appliances. Initial lessons learned reported from two utilities indicate that deployed commercial devices lacked appropriate product testing and quality control (missing components, unclear instructions, and incorrectly labeled parts). Such deficiencies would be the responsibility of industry to correct.

Oklahoma Gas and Electric Company (OG&E)'s final report indicated that customers with IHDs appeared to have the largest overall electricity conservation effect in the first year of the study, regardless of the rate design, but in the second year the effect was no greater than those with web portals alone. This observation warrants further study but suggests that IHDs may, in the short run, enable customers to identify and change behaviors that reduce wasteful energy use. However, over the longer term, the IHDs may not be any better than web portals at achieving and maintaining electricity conservation effects. OG&E's results suggest that customer systems such as PCTs, IHDs, and web portals can help customers respond to time-based rates. These systems are in the early stages of development and OG&E reports that there are challenges to address, including installations inside customer premises and integrating the devices with AMI, communications, and back-office systems.

Moreover, the final evaluation of Marblehead (Massachusetts) Municipal Light Department's (MMLD's) two-year Critical Peak Pricing (CPP) pilot program revealed that the technologies deployed were not always compatible and installation was not always intuitive to contractors who had not been exposed to the specific brands deployed. As an example, several of the first orders of the Wi-Fi enabled hot water switches had to be sent back to the manufacturer as they lacked necessary components (missing an amp meter for example) or were impossible to install (directions mentioned wires by color, all wires on the device were black). Once the correct units were received, other issues arose such as an inflexible and rare connector, a lack of easy ways to secure the box, and quick-fixes resulting in less than safe wiring. All these problems led local electricians to begin refusing to attempt installations and resulted in very low installation success rates. Any future use of these enabling technologies should include a more thorough pre-testing period and should involve a heavier focus on training a smaller subset of qualified technicians.

Finally, results of DTE's Energy Smart Currents Dynamic Peak Pricing pilot project indicated that the availability of a PCT device made a significant impact on demand response and energy conservation on event and non-event days, while the additional presence of IHD did not appear to make much of a difference. Results were slightly surprisingly since surveys conducted during the study indicated customers preferred the IHD and had some difficulties with the PCT operation. However, these results were consistent with other SGIG CBS projects and prior studies funded from other sources.

Recommendation 4.5: Research and development may be warranted in plug-in electric vehicle charging infrastructure and on-vehicle smart grid communications technologies.

DOE has been conducting research with electric vehicle charging infrastructure and will continue to do so to explore the opportunities afforded. Through the Smart Grid Investment Grant Program, 492 electric vehicle (EV) charging stations were installed and operationalized, and an additional 852 were installed and operationalized through the Smart Grid Demonstration Program. In total, $12.4 M has been invested to date on EV charging stations alone through the Recovery Act. A report issued in December 2014 (https://www.smartgrid.gov/document/evaluating_electric_vehicle_charging_impacts_and_customer_charging_behaviors_experiences.html) summarizes the efforts of six utilities funded under the SGIG program. Since there are relatively few plug-in electric vehicles on the road today, the six projects had a relatively low number of stations deployed and evaluated a small number of participating vehicles. As expected, project results showed negligible grid impacts from electric vehicle charging, but gave utilities important insights into the demand growth and peak-period charging habits they can anticipate if electric vehicle adoption rises as expected over the next decade.

The Smart Grid Regional Demonstration projects involve assessments of the integration of advanced technologies including plug-in electric vehicles, renewable and distributed energy systems, and demand response program with the grid. The technical and economic performance is being evaluated and final reports are still pending. In one example, AEP Ohio found that initial adoption of PEVs *did not* appear to have significant impact on residential transformer loading. However, a thorough analysis was recommended to be completed before public chargers are sited, as PEV usage tends to be location-specific. Other SGDP projects that assess

EV charging stations include work with Consolidated Edison of New York, Los Angeles Department of Water and Power, Pecan Street, Southern California Edison, and Detroit Edison.

Additionally, the DOE Smart Grid R&D Program invested in the development of smart grid capable electric vehicle supply equipment (EVSE) for residential and commercial applications. Four projects were awarded through the FY11 Funding Opportunity Announcement, which resulted in commercial ready EVSE products that have been independently verified and/or certified to be capable of implementing smart charging of EVs while conforming to applicable standards of communications, interoperability, and cybersecurity. As an example, Siemens provided the first Underwriters Laboratories (UL) approved residential EVSE that can reduce up to 60 percent of homeowners' charging costs by automatically charging during low energy rate periods, where such programs are available. Smart charging also benefits utilities, as it can help shift EV loads to off peak periods to avoid the need for new capacity investments.

EERE's EV Everywhere Grand Challenge also established a 10-year vision to enable the U.S. to be the first nation in the world to produce plug-in electric vehicles that are as affordable for the average American family as today's gasoline powered vehicles by 2022. This Challenge is bringing together scientists, engineers, and businesses to work collaboratively to make plug-in electric vehicles less expensive and more convenient to own and drive, including considerations for the electric vehicle charging infrastructure as it impacts the total cost of ownership.

Recommendation 4.6: Research and development may be warranted in communication upgrades for building automation.

DOE believes there is an opportunity for communication upgrades in buildings and building automation to support the grid. Through the Smart Grid Investment Grant and Regional Demonstration Program, projects have been funded to assess communication upgrades for building automation including critical organizations such as Wall Street, the Federal Reserve, major medical facilities, and hubs for national and global communications. As seen in the Consolidated Edison Secure Interoperable Open Smart Grid Demonstration project, coupling real-time information and insight into the electricity market with advanced communication protocols, operators were able to make informed decisions about customer curtailment and deployment of energy storage. Through the VPower system, a web-based software platform with customer-facing portal, customers can optimize building system operations while giving system operators access to curtailable load. Customers gain greater visibility of their energy needs, consumption, and costs, which they can use to develop strategies to improve efficiency. This project illustrated the value of improved communications and load management to individual participating customers, the local utility, and the system as a whole.

The recently issued June 2015 final report on the Pacific Northwest Smart Grid Demonstration Project indicated that research and development is needed to further develop and deploy distributed, automated systems, both within the utility infrastructure and in customer premises. The performance of the automated systems must be demonstrated to be at a high enough level such that utilities and their customers are comfortable with the results. Otherwise, there will continue to be significant use of person-in-the-loop approaches that limit the effectiveness of the deployed technologies in delivering their full value to the asset owner and the electric power system.

Other examples of projects involving communication upgrades for building automation include the Pecan Street Project Energy Internet Demonstration and the Southern California Edison Irvine Smart Grid Demonstration. Analyzed data, final reports and lessons learned are still pending on these projects and may lead to further identified opportunities for future research or partnership.

5. Cybersecurity:

Recommendation 5.1: Cyber security in the Smart Grid must include a balance of both power and cyber system technologies and processes in IT and power system operations and governance. A great deal of research is needed to enhance IT technologies to enable them to withstand attacks and intrusions.

Cybersecurity for the smart grid has been a priority in the department and activities are led by OE's Cybersecurity for Energy Delivery Systems (CEDS) program. The smart grid uses computers and networks to manage, monitor, protect and control the physical process of energy delivery. These computers and networks are referred to as operational technology (OT), and must satisfy stringent operational requirements, making their purpose and architecture different from that of IT enterprise business systems. The 2011 Roadmap to Achieve Energy Delivery Systems Cybersecurity is a strategic framework to improve cybersecurity of the energy sector for the next decade. While the Roadmap vision is "by 2020, resilient energy delivery systems are designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions," the CEDS program remains agile to address the evolving technology and dynamic threat landscape, including those present through OT technologies. However, as communication and information technologies advance, the interactions between IT and OT will become more significant and will be considered as well. The recent GLMC lab call requested proposals for innovative cybersecurity technologies or techniques that address next generation cybersecurity needs. CEDS supports research to advance the energy sector's cyber-resilience, working toward the Roadmap's vision of a smart grid able to survive a cyber-incident. Finally, the Electricity Sector Cybersecurity Capability Maturity Model (ES-C2M2) lets electric utilities and grid operators to assess the maturity levels for their cybersecurity capabilities allowing them to prioritize their actions and investments to improve cybersecurity. This model also combines elements from existing cybersecurity efforts into a common tool that can be used consistently across the industry.

6. Communications:

Recommendation 6.1: New infrastructure will be needed capable of supporting the higher level of information monitoring, analysis, and control required for Smart Grid operations as well as the communication infrastructure to support full integration of upstream and downstream operations. At the same time, it is necessary to ensure the privacy and security of individual customer information.

DOE is aware of the communication needs and research opportunities posed by a modernizing grid. As evidenced in the ARRA smart grid demonstration projects, the emergence of interconnected electricity information and control systems provide daunting challenges. The IT and communications overlay of our electric grid is changing all aspects of grid planning and operations including new requirements for interoperability, cybersecurity, and the management of massive quantities of data from new meters and sensors.

One outcome of the SGIG experiences is that DOE, through work at Idaho National Laboratory, has undertaken analysis efforts to build a quantitative basis for assessing the communications needs of a modern electricity system. Part of that effort will result in a data driven analysis tool that allows users to accumulate data transport needs through the selection of Smart Grid applications. This work builds on public domain contributions to both the OpenSmartGrid (OpenSG) group within the Utility Communication Association International users group (UCAIug) and the Priority Action Plan 02 within the Smart Grid Interoperability Panel. Additional analysis and industry stakeholder meetings may reveal gaps in research and development suitable to the role of federally funded initiatives.

DOE is planning to continue pursuing research in Advanced Distribution Management Systems (ADMS), Market-Based Control Signals (transactive energy), and demonstration projects that may lead to further progress in overcoming many of the identified challenges and lessons learned of current projects to advance the distribution grid of the future and big data management.

In addition, DOE has sponsored work to address the need to ensure the privacy and security of individual customer information as seen in the development of the Voluntary Code of Conduct (VCC) for Smart Grid Data Privacy. The VCC is an industry-led initiative to establish a code of common practices that protect the access, use and sharing of customers' electricity usage and related data. Released on January 12, 2015, the VCC will be applicable to and voluntarily adopted by utilities and third parties. DOE is stewarding the VCC, which has been branded as the DataGuard Energy Data Privacy Program (DataGuard), for the first two years and will plan to transition to an industry group or non-profit in the long-term.

Recommendation 6.2: Interoperability remains one of the most critical success factors for Smart Grid communications.

DOE agrees that interoperability is a critical success factor for effective Smart Grid communications. Interoperability standards define technical requirements for the capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively. DOE has funded both past and present projects in addressing interoperability challenges, including the foundational GridWise Architecture Council, and plans to fund relevant interoperability projects into the future. Many of the ARRA SGIG/SGDP awardees were required to describe how the projects would support the NIST Interoperability Framework to facilitate interoperability.

While there were some challenges in implementation, DTE Energy is a successful interoperability case study that provided cost savings, reduced delivery times, and reduced the total cost of ownership. The success realized by DTE Energy is built on the adoption of Service Oriented Architecture using and Enterprise Service Bus, development and use of standard names for standard things, and use of the Common Information Model (CIM). The CIM is an open standard for representing power system components originally developed by the Electric Power Research Institute (EPRI) in North America and now is a series of standards under the auspices of the International Electrotechnical Commission (IEC). CIM for power systems currently have three primary uses: to facilitate the exchange of power system network data between organizations; to allow the exchange of data between applications within an organization; and to exchange market data between organizations. The CIM has become an industry standard for electric utilities and is growing to accommodate more parts of the business. This adds value to DTE Energy by facilitating interoperability, if needed, with outside partners who have also adopted the CIM and will continue to interoperate in the future as each partner evolves and improves their systems using the same common messaging format that the CIM offers. The CIM has facilitated the standardization of business terms and makes these terms common across business areas.

Many of the participating utilities in the Pacific Northwest Smart Grid Demonstration Project reported among their lessons learned that the communications capabilities of various system components were not interoperable. The source of the incompatibility was different versions of rapidly evolving communication standards, but even system components that were said to use the same standard were not easily integrated. Utilities observed that the communications of the systems were not especially interoperable out of the box and additional engineering integration was required. Many loads are still made controllable in a smart grid by appending the control system to existing electric loads. The devices are not yet smart enough to cleverly manage the tradeoffs between customer comfort and the grid’s needs. The controllability is usually limited to switching the load off and very few assets can *increase* load or smoothly transition throughout a continuum of available responses. Finally, the largest controllable loads maintain human control which limits the availability and reliability of the assets’ responses.

While some of these interoperability issues are appropriate for industry to address through routine system integration efforts, other challenges can only be overcome through standards development, reconciliation between competing standards, standardized testing, or collaboration in international efforts as noted in 4.3. One of the most appropriate forums for improving interoperability, especially where the equipment and systems are designed and built to multiple Standards Development Organizations specifications, is the Smart Grid Interoperability Panel (SGIP). The SGIP, a public-private partnership initially funded by both the DOE and NIST and now a stand-alone organization, is one of the principal forums for addressing difficult interoperability issues - between devices, systems, and organizations. DOE has maintained its presence in the SGIP, as a member of the Board of Directors and participant in both Technical and Cybersecurity Committees. As highlighted in the Grid Modernization MYPP and GMLC laboratory call, DOE plans for National Laboratories to consider consensus interoperability standards for the building, distribution, and bulk power systems, and will coordinate with the respective industry sectors responsibly. In addition, National Laboratories, in direct consultation with the SGIP Testing and Conformance efforts and other industry partners, will assist in developing testing procedures for interoperability standards, especially where none exist.

7. Conclusions:

Recommendation 7.1: DOE's most important and fundamental role is to accelerate research, development, and demonstration of beneficial new energy technologies that might otherwise not go forward in the absence of this assistance.

DOE agrees that the agency plays a crucial role in accelerating research, development and demonstration of beneficial new energy technologies. The North American Synchrophasor Initiative (NASPI) is an excellent example of DOE sponsoring research to improve power system reliability and visibility through wide area measurement and control, by fostering the use and capabilities of synchrophasor technology. Through DOE sponsored research in leveraging data streams and models to achieve wide-area situational awareness, DOE played a vital role in the world's first demonstrations of sub-second state estimation of the current health of the grid. DOE plans to continue to invest in research, development and demonstration of a variety of tools and technologies that will improve system monitoring, visualization, control, operations, planning, security, and market structure of the future grid.

Recommendation 7.2: DOE can verify the effectiveness and reliability of new technologies; demonstrate the effectiveness of such technologies through demonstration/pilot projects; and promote utility and regulatory awareness of the benefits of such technologies that deliver value to customers and meet customer expectations for cyber-security, resilience, reliability and other needs.

Working within current budget constraints, OE will continue to verify the effectiveness and reliability of new technologies, demonstrate effectiveness through pilot projects, and promote utility and regulatory awareness of the benefits of those new technologies that deliver value to customers and meet customer expectations for cyber-security, resilience, reliability and other needs. As an example, the Smart Grid R&D Program made seven awards to advance microgrid system designs (less than 10 MW), and plans for field demonstrations of these designs coupled with advanced control functionalities to support achievement of program targets and community-defined resilience objectives. As mentioned in the examples in previous sections, DOE has invested in numerous demonstration/pilot projects. Lessons learned from these projects will be compiled and disseminated to promote utility and regulatory awareness. Moreover, the Grid Modernization Multi-Year Program Plan promotes these activities in an integrated fashion across DOE program offices and national laboratories.

Recommendation 7.3: DOE has a role in helping facilitate the development and deployment of innovative technologies by collaborating with the private financial sectors [whom are spending money on advancing smart grid technologies such as electrical apparatus manufacturers, EPRI, venture capitalists and others] to develop the instruments that minimize risk to the ultimate electric customer. ***Note: EAC clarification received post-issuance of report and noted in brackets***

DOE has collaborated with private industry in facilitating the development and deployment of innovative technologies through past and ongoing solicitations. Past examples include the numerous private partnerships developed through the SGIG and SGDP programs as highlighted in previous sections. Through the Advanced Microgrid Design and Controller Funding Opportunity Announcement, General Electric, ComEd, EPRI, Alstom, TDX Power, and the Microgrid Institute are some of the most recent private sector entities engaged in cost-shared projects. DOE will continue to partner with private industry in the future through similar announcements or through collaborations with our National Laboratories.

Recommendation 7.4: DOE plays an important function when it: (a) helps utilities and regulators understand the disruptive nature of technological change combined with increasing customer demands/opportunities; (b) help utilities and regulators develop evolutionary business/regulatory models to accommodate these changes in ways that encourage utilities to develop new or different ways to serve their customers and regulators to develop new models that permit customers to choose their own path, while still meeting shareholder expectations.

DOE has been working with utilities and regulators to help them: (1) understand the disruptive nature of technological change combined with increasing customer demands and (2) develop evolutionary business/regulatory models to accommodate those changes through conducting workshops, sharing reports, and lessons learned from DOE sponsored work. As an example, the results of the SGDP allowed Con Edison to more effectively and efficiently respond to regulatory directives and initiatives such as the proceeding announced by the New York Public Service Commission (NYPSC) in April 2014, known as "Reforming the Energy

Vision" (REV). REV references numerous DOE Smart Grid reports and aims to reform New York State's energy industry and regulatory practices to meet future challenges related to more efficient use of energy, deeper penetration of renewable energy resources (e.g., wind and solar), and wider deployment of DERs (e.g., micro-grids, on-site power supplies, and storage).

Another example of DOE helping utilities to understand and develop evolutionary models is the series of multi-stakeholder regional workshops and National Summit entitled "Future of the Grid: Evolving to Meet America's Needs" facilitated by OE and the GridWise Alliance (GWA). Workshop breakout groups addressed subjects such as new technologies and financial models required for investment, and the policy and regulatory barriers to realizing the vision. One key finding of the published report indicate that increasing interdependencies of transmission and distribution operations will create jurisdictional uncertainty that will need to be refined and clarified, and better coordination between federal and state regulatory entities will be needed. New roles and responsibilities of both federal and state regulators will need to be defined. DOE is working to implement some of the recommendations of the GWA final report.

Recommendation 7.5: DOE should convene interactive sessions involving utility executives, regulatory leaders, consumers, other policy-making leaders, technological innovators/researchers, national laboratory staff, and financial community leaders and discuss the disruptive change that are and will occur. The Department should allow the proverbial marketplace work out which options are correct for each utility/regulatory/customer, but engage the relevant sectors in discussions about options, paths and collaborative programs.

DOE regularly engages utility executives, regulatory leaders, consumers, policy making leaders, technological innovators, national laboratory staff and financial community leaders through various fora and will continue to do so in the future. One example is the four regional workshops (Western, Central, Southeast and Northeast) and National Summit held by OE and GWA to engage industry stakeholders in helping to formulate the future grid's requirements and identifying any possible regional variations. Attended by thought leaders from all stakeholder groups including utilities, regulators, state government officials, renewable energy providers, vendors, consumer advocates, academia and third-party innovators, the workshops provided an open discussion on compelling issues on the future state of the grid. Efforts are underway to implement two key recommendations that are planned for completion by March and December 2016 respectively:

1. Establish clear and comprehensive guiding principles, along with a unifying architecture that can be applied at a regional, state, and local level to guide modernization of the electric grid;
2. Create a framework for guiding investments to transition from today's grid to the future grid.

In addition, DOE plans to partner with the private sector to convene regional workshops to address common challenges faced by industry, leveraging private or public partnerships when appropriate.

More recently, DOE convened and briefed numerous utility executives in meetings of the Partnership for Energy Sector Climate Resilience in April 2015, sponsored by the Office of Energy Policy and Systems Analysis. The Partnership for Energy Sector Climate Resilience is an initiative to enhance U.S. energy security by improving the resilience of energy infrastructure to extreme weather and climate change impacts. The goal is to accelerate investment in technologies, practices, and policies that will enable a resilient 21st century energy system. Under this Partnership, owners and operators of energy assets will develop and pursue strategies to reduce climate and weather-related vulnerabilities. Collectively, these Partners and the DOE will develop resources to facilitate risk-based decision making and pursue cost-effective strategies for a more climate-resilient U.S. energy infrastructure.