U.S. Department of Energy

Electricity Advisory Committee (EAC) Meeting

National Rural Electric Cooperative Association Conference Center

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Meeting Summary

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Welcome, Introductions, Developments since the February 2018 Meeting

Michael Heyeck, EAC Chair, started the meeting by thanking the National Rural Electric Cooperative Association for hosting. He noted that this is a public meeting and is being recorded. If members of the public are interested in making public comments, they should sign up at the registration desk.

Mr. Heyeck noted that the second EAC Meeting of the year is typically held in June, but was shifted to July for this year. July 1st also marked the beginning of the two-year term for a number of new EAC Members. He welcomed the new Members and asked everyone to introduce themselves.

Mr. Heyeck said that, on June 25th, the EAC Members approved five work products via a WebEx Meeting. They are: Regulatory Reform; A Review of Emerging Energy Storage Technologies; The Transmission-Distribution Interface; Securing the 21st Century Grid: The Potential Role of Storage in Providing Resilience, Reliability, and Security Services; and Enhancing Grid Resilience with Integrated Storage from Electric Vehicles.

Matthew Rosenbaum, EAC Designated Federal Officer (DFO), introduced himself and welcomed everyone in attendance.

Mr. Heyeck said that the Meeting will focus on resilience. Today's panel will be on the North American Grid Resilience Model and tomorrow's will be on Frequency Response and Grid Resilience. The EAC is asked to provide advice to the Department of Energy (DOE) on these topics and think about future panel and work product topics.

Update on the DOE Office of Electricity (OE) Programs and Initiatives

Deputy Assistant Secretary Katie Jereza provided the update on behalf of Assistant Secretary Bruce J. Walker.

Ms. Jereza started by welcoming returning EAC Members and soon-to-be new Members. She provided an update on Assistant Secretary Walker's top five priorities. DOE is working to finalize the scope of the North American Grid Resilience Model. One important part of developing this model is the issue with critical energy infrastructure information (CEII), which is sensitive to utilities and from a national security standpoint. A few years ago, DOE asked the Federal Energy Regulatory Commission (FERC) to define CEII. Now DOE needs to establish the procedures for handling CEII. The plan is to release these plans for public comment via the Federal Register. The handling of CEII is key for developing the model.

Under the Fixing America's Surface Transportation (FAST) Act, the Secretary of the Department of Energy has the authority to issue orders for emergency measures to protect or restore reliability of critical electricity infrastructure. Assistant Secretary Walker has run models when he was working at Con Edison and aims to develop a model that can be useful at the North American level. Existing models do not allow for contingency analysis. This model should help

inform where the vulnerabilities are and develop mitigation solutions. It will initially be a static model that examines the bulk electric system, but the end goal is to develop a real-time model that includes the distribution network. It will also look at interdependencies, including natural gas impacts and other critical infrastructures. One of the hindrances for developing such a model has been the lack of tools and computing power available, but now that technology has advanced, the development of this model becomes more feasible.

Ms. Jereza the discussed another OE priority, the Puerto Rico restoration and resiliency efforts, which is also a place to pilot the model. DOE is continuing to support the island in terms of governance structure and business models needed to support decision making on infrastructure development.

The third priority is to advance megawatt grid scale storage. The objective is to achieve $100 per kiloWatt, discharged for at least four hours, and have a lifetime of at least 20 years. In early May, DOE announced $30 million in funding for Advanced Research Project Agency – Energy (ARPA-E)'s Duration Addition to electricitY Storage (DAYS) program to pursue long-duration energy storage on the power grid, providing reliable electricity for 10 to approximately 100 hours.

The fourth priority is to revolutionize sensing technology utilization. The objective is to come up with measures for monitoring the health of a system. Michael Pesin, Deputy Assistant Secretary for Advanced Grid Research and Development at OE, provided an update and overview of this priority. This topic will be examined in two directions. One is high-resolution sensors deployed in several critical locations and providing capabilities that can predict or identify equipment failures. The other is ubiquitous low-cost sensors that can be deployed and provide good coverage for improving visibility.

The fifth priority is to develop an operational strategy for cyber/physical threats. DOE has organized a new office for Cybersecurity, Energy Security, and Emergency Response and has announced the nomination of a new Assistant Secretary, Karen Evans, who is awaiting confirmation. Earlier this spring, DOE announced a $25 million funding opportunity announcement (FOA) to support energy sector cybersecurity to conduct research, development, and demonstration to advance cyber resilient energy delivery systems, with some areas focused on the oil and natural gas subsector. The FOA just closed last week. Last month, DOE also announced a $7.5 million FOA to spur innovative design of large power transformers that will be more flexible and adaptable, increasing grid resilience.

Mr. Heyeck opened the floor to questions for DOE.

John Adams asked about natural gas being integrated into the model and how soon that first iteration will emerge. Mr. Pesin said it is part of the vision to identify the most critical interdependencies. The plan is to provide an iteration within 18 to 24 months, which will include natural gas.

Bob Cummings noted the industry has been conducting power flow and dynamic modeling for decades now, but it will be important to incorporate the interdependencies, particularly regarding

fuel and transportation for fuel. Ms. Jereza clarified that the goal is to leverage existing models and extend the contingency analysis. Mr. Heyeck concurred that the model will extend beyond existing criteria. Existing power flow tools are limited, so examining the intersection of gas and other components will be useful. Mr. Pesin added that it is simpler to develop a portfolio of tools that connect together than a single tool that integrates all components, which is the objective of this initiative.

Wanda Reder asked how these priorities are driving FOAs and investment strategies. Mr. Pesin said the focus is on coordination. Instead of looking at individual technologies, DOE will examine how these technologies are interconnected. They will also examine how current OE programs can align with the five priorities. Ms. Jereza said the Transmission Permitting and Technical Assistance (TPTA) office examines the groundwork that needs to be done, such as convening stakeholders, sharing information, etc.

Lola Infante asked about a time frame for the model and milestones that could potentially allow the model to be used by industry before final completion. Mr. Pesin said the first phase of the model is aimed for completion in 18 to 24 months. There was a question on how DOE is developing criteria for selecting the gas infrastructure that will be included in the model. Mr. Pesin said that is part of the development process. Mr. Adams raised a point about how they will coordinate the relationships and responsibilities between FERC, Independent Service Operators (ISOs), and the North American Electric Reliability Corporation (NERC).

Tom Weaver asked about the distinction between the types of sensor strategies to be applied on the transmission and generation system versus the distribution system. For example, if there are more phasor measurement units (PMUs) on the transmission system. Mr. Pesin said the effort will go beyond PMUs and modeling is needed to identify the best location for those sensors. Local sensors will need to be deployed everywhere, which includes three components: hardware, communications, and data analytics.

Ann Delenela asked about the multiyear plan that was released in March and whether that is part of the Office of Cybersecurity, Energy Security, and Emergency Response's (CESER's) operating strategy. Ms. Jereza said the multiyear plan is a long-term R&D strategy and will follow up on this question.

Mr. Pesin said new technologies have been developed since the emergence of PMUs and DOE is looking to adopt those new technologies for the grid. Mladen Kezunovic asked whether the model will look at only the physical model or the data model as well. Mr. Pesin said they will look at everything.

Mr. Heyeck concluded the discussion by remarking that the electric grid is becoming more just-in-time and more volatile with more variable and distributed generation. DOE is in the best position to examine issues, such as cybersecurity and electromagnetic pulse, that concern national security. Mr. Heyeck also encouraged Members to bring up issues of institutional gaps.

Panel: Development of a North American Grid Resilience Model

Mr. Adams introduced Dr. Ali Ghassemian, who is Program Manager for the North American Grid Resilience Model at the DOE-OE Advanced Grid Modeling (AGM) Research Program, for a background presentation. Dr. Ghassemian first noted that the presentation will be in two parts: the first is an overview of the Advanced Modeling Grid Research Program and the second will focus on the conceptual plan for the North American Grid Resilience Model.

The AGM Program supports the Nation's foundational capacity to analyze the electric power system using Big Data, advanced mathematical theory, and high-performance computing to assess the current state of the grid and understand future needs. Based on this information, the program develops prototypes for early stage research that can help utilities and grid operators improve their operations.

AGM is part of the Advanced Grid R&D Program, led by Deputy Assistant Secretary Michael Pesin. The program includes four parts: Resilient Distribution Systems, Transmission Reliability and Resilience, Transformer Resilience and Advanced Components, and Energy Storage Systems. AGM is part of the Transmission Reliability and Resilience program.

Dr. Ghassemian explained that deficiencies in how the power grid is operating today indicate the need for AGM. However, utilities and grid operators do not have easy access to traditional forms of financing for early stage R&D. The private sector has difficulty filling the gaps because they cannot afford it if there are not enough customers to recover their costs. Here is where OE provides support. The current AGM projects support the following objectives:

- Support the transformation of data to enable preventative actions rather than reactive responses to changes in grid conditions;
- Direct the research and development of advanced computational and control technologies to improve the reliability, resiliency, security, and flexibility of the Nation's electricity system;
- Help system operators and utilities prevent blackouts and improve reliability by expanding wide-area real-time visibility into the conditions of the grid;
- Help system operators and utilities minimize the effect of the extreme events and improve resilience through pre-impact operations and the recovery/restoration process;
- Support improvement of the performance of modeling tools and computations that are the basis of the grid operations and planning; and
- Support the tracking and expansion of the use of quantitative risk and uncertainty methods by federal and state level energy system decision makers regarding energy infrastructure investments.

AGM has three key research areas: Data management & Analytics, Mathematical Methods & Computation, and Models & Simulation. DOE has established strong partnerships with research centers across the country to fill R&D gaps. These concentrated efforts will bring together workers with advanced computing and mathematics technologies to develop the type of breakthrough that can make real impacts on behalf of industrial, business and residential customers.

DOE has built partnerships with National Labs, universities, and other government organizations, one of which is the National Science Foundation (NSF). Recently, AGM

collaborated with the Department of Mathematics and Computation at NSF to get math and statistics departments of universities to work on challenging power system problems and spurring interest in solving those problems. At the same time, DOE also developed internship programs with these universities, so that these students can go on to work at National Labs.

Dr. Ghassemian outlined a number of current modeling projects under AGM, which cover a variety of different topics. The timeline for each project is typically two to three years. Most of these projects are early stage research with little precedent, so the objective is to support commercialization. One of the projects is the North American Resilience Modeling Initiative.

Resiliency includes four main elements: robustness, which is the ability to absorb shocks and continue operating; adaptability, or the ability to quickly and effectively modify the system to manage and overcome the crisis as it unfolds; recovery, the ability to restore the system as quickly as possible; and adjustability, which is the ability to make adjustment based on lessons learned from past events. Therefore, the goal of the North American Resilience Modeling is to study robustness and adaptability; provide insight into recovery strategies; improve the attributes of resilience; and identify future investment to improve the resiliency of the system.

The Nation's critical infrastructure is critical to a modern way of life. Electricity is often central to ensuring efficient functionality of modern systems. Dr. Ghassemian examined four U.S. critical infrastructures that depend on electricity: communications and information technology, transportation, water, and energy, which includes all energy sources such as petroleum, natural gas, coal, solar, and wind. Each infrastructure has its own network, which is interconnected to others, so changes in one infrastructure will affect another. For example, natural gas and electricity are interconnected and failure in one can affect the other. Current analysis examines N-1 contingencies. However, if one gas pipeline fails, it could affect a number of generators. The analysis then becomes N-k. The North American Resilience Modeling Initiative aims to examine these interdependencies.

The Initiative will also gradually include a number of threats that could affect the electricity sector. Each threat has a number of associated elements. Models are intended to predict responses of the grid and to predict outages and disruptions. Modeling efforts primarily focus on natural hazards to inform utility synopsis. Utilities use models to balance their load and generators. System studies need to include the interdependencies among different infrastructure systems. Dr. Ghassemian provided an example of a scenario for modeling, which examines how a hurricane affects the production of electricity. The elements of a hurricane include high wind, rain and flooding, clouds, debris, etc. The impacts on electricity equipment include flooded substations and downed poles. The impact on energy can be an interruption in power generation. Impact on transportation can be difficulty in getting to the impacted areas for repair and the impact on natural gas can be disruptions in gas pipelines.

Dr. Ghassemian continued to outline the conceptual plan for the North American Resilience Model. He noted that there are many electricity dynamic models currently in use, but they are independent from energy, water, transportation, and telecommunication models. Modelers are now working to run co-simulations. For example, an energy model will examine impacts to electricity if a gas pipeline is disrupted. The next step is to use this analysis and the solutions in

running the subsequent electricity model to determine the full impact. Another example is to examine impacts when the flow of gas changes. Reduced flow likely will result in a reduction in generation, not a total outage. The initial plan is to do a static transmission model in a planning mode, where dynamic data and distribution will be added later. The ultimate goal is to run this model in real time, which means taking advantage of high-performance and probabilistic computing as well.

On top of the interdependencies are the elements of threats. For example, how would a hurricane affect any of these models? The idea is to make the changes in these models, run them, then determine the impacts on electricity. Afterwards, plans are developed to:

- Identify and protect critical asset(s) important for national security;
- Identify the potential impact of the interdependencies between different infrastructure systems;
- Minimize the impact of the threat and reduce risks;
- Provide corrective actions to get the system to the stable condition and continue the operation;
- Identify viable plan(s) for outage management and system recovery; and
- Identify the future investment needs to prevent/minimize the impact of the event of the same nature as well as improve reliability, resiliency, and security. The future investment could be: building new generator(s); deploying microgrid; utilizing energy storage; diversifying the fuel and generation mix; developing new operational procedure; etc.;

Possible plans to deal with hurricanes can include hardening substations to withstand high wind and flooding, islanding the system, utilizing energy storage and microgrid, and utilizing diversification in fuel and generation mix to help with islanding.

Dr. Ghassemian discussed a Southwest cold weather event in February 2011, which resulted in loss of power for 4.4 million customers. After the event, NERC convened a group of analysts to examine the lessons learned and one of the main findings was the interdependency of natural gas and electricity. The goal of OE is to take these efforts to the next level. The AGM Program has been active in the area of modeling and simulations for several years, and a considerable amount of research and development has been done. There have also been similar efforts throughout federal government. Building a model is only the first step; analyzing data is another key component. While there is a good understanding of the technical aspects of this initiative, OE is seeking guidance from the EAC on four key issues: data handling, industry involvement, model validation, and information sharing. These issues include collecting and storing data, encouraging utilities to share data, determining how to get industry engaged in these efforts, identifying the right partners to validate the model, and sharing information with industry.

Key issues require EAC guidance in terms of data handling (encourage utilities to share), industry involvement (how to get industry engaged in this process), model validation (who would be the right partner, making sense of it, the simulation), and information sharing (come up with critical assets, classification).

Mr. Adams proceeded to introduce the panelists: Anda Ray, Senior Vice President of External Relations and Technical Resources, Electric Power Research Institute; Peter Brandien, Vice

President of System Operations, ISO New England; and John Moura, Director of Reliability Assessment and System Analysis, NERC.

The first panelist, Ms. Ray, began by describing the role of the Electric Power Research Institute (EPRI) as a non-profit that provides thought leadership, industry expertise, and collaborative value to help the electricity sector identify issues, technology gaps, and broader needs with an independent advisory board to help the organization stay on that mission. When EPRI considers resilience, the organization looks at not just the economic issues, but the quality of life impacts as well as, in some cases, life itself. A Harvard study was recently released that showed that a significant number of deaths from Hurricane Maria came from the disruption of access to health care. Ms. Ray said that sometimes industry stakeholders get caught up in the models and forget why the underlying impacts of the work is so important. She mentioned the concept of an Integrated Energy Network, which includes other interdependent, if not directly connected, systems. She said there are 10 building blocks of resilience. First, there is the scope of the issue, and once you identify the scope, you can look at the gaps and interdependency. After the scope and interdependency, identify the threats, and determine if you may be vulnerable. As other speakers mentioned, consider the possibility of using the N-K assessment.

Ms. Ray continued identifying the buildings blocks of resilience on identifying the potential impacts. Some people say that resiliency is a subset of reliability, however there has been a big focus on Blue Sky reliability. There has also been great improvement in reliability, but it is unclear if that helps the industry from a resilience perspective. Improving reliability numbers does not relate to events like Hurricane Harvey. As an example, after that storm, American Electric Power (AEP) in Texas came up with resiliency-based solutions at a much lower cost using energy storage, but the public utility commission (PUC) had to deny their proposal because it could not be assured that AEP would not use the batteries for generation, which is illegal in Texas. The PUC had to ask AEP to come back with that solution at a later date so they could potentially update their resiliency policy planning.

Ms. Ray went on to discuss the potential mitigation options and assessing the current situation. She identified things like hardening/prevention, response/recovery, and customer/community adaptability. Further research in this area at EPRI includes AI for unmanned aerial vehicles (UAVs), comparing old images to the current images to assess potential issues like the status of transformers or poles over time. It includes looking at the customer survivability from their lens. For instance, Ms. Ray suggested the EAC can look at the sharing economy and an integrated grid that can be used to support the grid during a resilience event. For example, a fire station's microgrid can be leveraged during an event. The same thing can happen with solar leveraging smart inverters. Energy storage is a great example because it provides so many grid services. A shared, integrated grid can use systems like energy storage or microgrids that can provide multiple services to multiple portions of the systems at different times and under different conditions. Once those mitigation options are established, you can move to maturity models – essentially a report card. If resiliency

is built in to the rate base, you can have more guardrails to make sure the new system is not going to be gold plated. These models help you understand how your system works from a resilience perspective and the kind of coverage you need.

Ms. Ray concluded by highlighting some barriers to answer some of EPRI's policy goals about the need to identify who implements these new systems. There are many organizations involved and we need them all due to the overlapping jurisdiction. There ultimately needs to be a determination of who pays: existing utility customers, all taxpayers in a state, regional electricity customers, or federal budgets.

Mr. Adams then introduced the second panelist, Peter Brandien, ISO New England, for his opening statement. Mr. Brandien said that, when he thinks about resilience, he looks at resource adequacy and all-around security of the system. His team uses market signals to address these issues, which are happening a lot quicker today for resource planning than in the past – whether it's wind, solar, or combined-cycle natural gas. The industry has to be a lot more flexible to understanding the reliability of the system, particularly when it comes to cyber.

In New England, grid operators are challenged with fuel. Every year the system is losing more stored fuel – such as a coal plant, a nuclear plant, or an oil plant with 20-day storage. So, ISO New England has been running models to understand the impact of gas loss. New England is not a big area, so natural gas runs through the pipelines a couple of times in a day. The region needs to be constantly assessing the state of the system to understand a variety of things like how much liquefied natural gas there is in the tanks, where they are located, and what exposure the system has based on certain issues. ISO New England examines dual fuels, their tankage, how much storage they have, and how quickly they can be refilled by the variety of their delivery systems.

The New England states want to decarbonize and build out more renewables, so they need to understand that transition and the vulnerabilities. ISO New England does a lot with modeling the system, organizing the system, and understanding the state of the gas pipelines, so ISO New England understands what the vulnerabilities are. They have great insight into the natural gas system, the varying states of pressure in the system, and what would happen if it lost a piece outside of New York City.

Mr. Brandien concluded his remarks by recognizing that it will be difficult to build out a whole North American model. Dangers include getting lost in the data, and being sure they can provide the planner with the useful information they need. The model will need to identify the current vulnerabilities, and the options to alleviate those issues. Operators need to be able to take action to protect the system. If you go back to the 2003 blackout, it took us 4 hours to get the useful actionable information we needed in the 90 seconds it took to take down the system. Therefore, these models need to provide useful, actionable information.

Mr. Adams introduce the third panelist, John Moura, NERC, for his opening

statement. Mr. Moura began his remarks describing that a lot of his time is spent looking at the uniqueness of systems around the world because these are conversations that are going on throughout the world. Mr. Moura believes that we are transitioning to a just-in-time system and that complexity is the enemy of reliability. While Mr. Moura is cautious, the gas-electric system models are important to bring together. Since these are mathematical models, the systems need to at least avoid some of the issues around assumptions. The extent to which these assumptions are important depends on the how these models will be used. If it's operational decisions, then there is concern because these decisions need to be very carefully considered in a short amount of time. On the other hand, Mr. Moura states, there is real opportunity with planning decisions. In this case, the data has to be translated to useful information for policy makers to act on that model. The models need to be sure that the information is good enough to use as an operator to protect critical systems and make real-world decisions. We can show the risk and provide the data, but there is another element of what we're going to do with the data.

Mr. Moura continued by outlining the importance of understanding the generation mix change with retirements and the new launch of gas combustion to be a much more just-in-time system. The North American grid is really the only system with this much reliance on natural gas. There are two major buckets around retirements: near and long term. For near term, what will happen in the immediate, one to ten-year timeframe, after the retirements (i.e., maintaining NERC standards, does the system need more transmission, add storage, etc.)? Then, there are the longer-term issues, over 10 years, e.g., when we have a system with large amounts of natural gas, what do we do with that? Florida is an interesting example of this, which has just about the highest percentage of natural gas (75% – 80%), but they have highly reliable natural gas generation because of the regulatory process that was structured around generators. They have had almost zero forced outages due to a lack of fuel. The reason they are able to do this is that the system was built for the generators and not the heating customers, since there is not much heating load in Florida. Mr. Moura concluded that it's really up to regulators to use the right tools to meet particular objectives.

Mr. Adams proceeded to questions and discussion with EAC Members.
Mladen Kezunovic said that modeling the grid at different scales and times has been an issue for years, but on the customer side there is very little, so asked how the panel views model integration to incorporate the behavioral role of the customer? Ms. Ray responded that the first thing is determining what the consumer actually wants. They want communications, so you have to think about the interface of the electric grid with telecommunications, and determining if we can prioritize that around things like health care. Mr. Brandien continued that there are two sides to this with infrastructure and markets. On the markets side in New England, energy efficiency can be bid into the wholesale markets with the ability to dispatch load off just like you could dispatch generation on. We are attempting through the markets to incent customers based on impact of the grid. Mr. Moura said that you need to look at the performance of generation of the customer side; for example, in Puerto Rico

there were pictures of solar panels scattered across a field and some solar plants will not operate without a supply of electricity. Therefore, a planner may want to just consider that those resources will not be available at all during a resiliency event. Dr. Ghassemian added that DOE will be incorporating a place for customer behavior models into the modeling system; it may not be in the first phase, but it is something DOE is looking to include.

Another EAC Member asked whether there is a disconnect in the industry when it comes to Demand Response. Does the model get ahead of the empirical reality, and what do big blocks of demand response look like? Ms. Ray asked to clarify how the question addressed resilience. The original questioner replied that perhaps this is reliability, but there is some overlap, and the questioner thought the empirical reality is an important consideration for these models. Ms. Ray agreed, and continued that it goes back to the important point of looking at this issue from the customers' perspective and what they really want and/or need. Mr. Moura added that NERC has models where demand response events are recorded and there are basically 2 types. One is the smaller price-based events that occur about every day. Now NERC uses probabilistic models from an adequacy planning perspective, and NERC gives generation a certain probabilistic generation output and then tests the area under the curve for reserve margin.

Ms. Reder asked a question on the importance of usability. The topic is both local and broad, and it is very important to have something that is useful in the end. She asked the panel if they have some preconceived notion of what is in and out of scope for the model. What would be necessary for it to be useful? Mr. Moura responded that, first of all, combining the natural gas and electricity models makes a lot of sense. The gas system in particular has areas that are not being looked at today, but should be. From the operations side, it is essential to work with the actual operators pushing buttons. Ms. Ray added that there are some people that say we do not need a national model considering that we are doing these models in the Eastern or Western Interconnect. However, the national perspective really helps identify the right considerations that the electricity modelers need. There is more than just electricity as it relates to maintaining essential services to customers. This will help us give the priorities. Mr. Moura acknowledged that the planning commissioners did a lot of work modeling the Eastern Interconnect to help New England understand its exposure. He said they also look day-to-day to understand impacts of potential losses, and there is communication back and forth every day to share planning. There is experience available from modeling the impact of gas and electricity systems. Dr. Ghassemian added that Puerto Rico was an eye-opening exposure to the interconnected nature of these systems and how problems can affect your planning where certain strategies are not available. He continued that it is important to focus on the role of critical assets to identify what systems are essential for the grid.

Richard Mroz asked what the planners do with the product that comes from the model, and what structures might be helpful to better plan for those investments in the future. Mr. Brandien responded that ISO New England does studies to educate its

stakeholders, federal representatives, and state policymakers to help people understand the exposure that we could close down risks through markets. The discussions in New England have led ISO New England to invest in energy efficiency, rooftop solar, and connections with Quebec. Working with them, the organization can match the strategies to the policy while addressing the risks. For example, off-shore wind has the issue of performing at 100% until it hits high wind and has to be shut all the way down. Mr. Moura continued that, on the regulatory side, there are few forums that have a way to analyze building a transmission line or a gas pipeline. Dr. Ghassemian added that the first phase of this work will only be transmission, and FERC is involved in this process; as DOE gets further along in the process, DOE will bring in these other necessary stakeholders.

Mr. Heyeck asked if there are some things that we do to protect the system that aren't in the standards or in the models, and if there is something simpler we can do to affect the standards to improve resilience. On the information side, DOE helped get synchrophasors out there, but so much of this data is just sitting on servers for forensics. There is a point where the customer will say that they don't want their bill to go higher. How do we manage resilience while dealing with bill fatigue? Mr. Brandien responded that we need to be smart about the investment we make; it can't be done in isolation. It needs to go back to the planning process. In New England, they have invested about a billion dollars in hardening, from new transformers to transitioning from wood pole to steel pole, which is closing down a number of risks. Ms. Ray added that there is certainly low-hanging fruit on vulnerabilities, but from the who-pays perspective, it is important to consider that resiliency efforts can pay for themselves. Mr. Moura said that we can already do the work to identify the issues on our system on our gas systems, and the electricity systems which can further identify the highly critical assets. When that information is incorporated into the planning process, we can begin to take risk out of the system.

Lisa Grow remarked to the panel that out in Idaho they have some particular issues that are heightened in the spring when the water comes through their hydro plants, and is combined with low demand. When managing this system, Idaho Power does its best given certain regulatory issues that make the job much more difficult. She asked what is the best way to get the bad bureaucracy out of the way to make their lives easier today. How are we supposed to take something away from the work being done in Puerto Rico? Dr. Ghassemian responded that, first of all, DOE recognizes that all regions are different. Solutions for Florida will not work in New England. On Puerto Rico, the solutions the federal agencies worked on to get the power back were short term. Mr. Moura said that he's not a compliance guy, but he can say that there were many NERC compliance issues in Puerto Rico and they didn't have to follow our standards because they fall outside our system. He added that when it comes to resilience, it is hard to ascribe certain prescriptions to all systems. For example, you hear so much about fuel diversity but places like Hydro Quebec, which is 98% hydro, have a lot of flexibility into the system. Mr. Brandien added that different parts of the country are facing different issues, and these issues are coming faster in some places versus others.

Clay Koplin brought up his outlook from a small islanded community in Alaska. He is trying to work out how their organization falls into this fascinating discussion. As an example, Mr. Koplin's system is built out with new technologies and they almost always have to configure the equipment to actually work together and get the benefits in a way that can accommodated their small customer base. His organization has had to tackle resilience issues on a small scale, and he wonders if there is an opportunity to build this out from a smaller local level to ultimately get it accomplished at a large national scale. Ultimately, he asked, when looking at the whole picture, is there an opportunity to break this into smaller pieces from technology or communications perspectives. Dr. Ghassemian responded that the North American Resiliency Model will first start on the transmission level before taking on the distribution solutions that Mr. Koplin is taking about.

Flora Flygt asked what is the line between resiliency and restoration. She said they don't want to gold plate the system, but is asking if it is a resilience model or restoration model. Ms. Ray responded that she would like to go back to the three aspects of resilience – start with hardening, then recovery, and mitigation – and look at the value of certain investments. Dr. Ghassemian added that it is a combination of all at once, and what makes sense at what point. Mr. Moura said that sometimes we confuse a couple things with reliability – such as resource adequacy – but there are also risks associated with issues with potential cascading failures; i.e., ideas like what we would need to do with frequency regulation versus capacity. Mr. Brandien suggested grounding this discussion a bit to focus on the interdependency of different industries to identify risks to national security so they can mitigate or plan their way out of those scenarios. This is not a system that is intended to take the place of local planning efforts. Ms. Flygt replied that she thinks that's an excellent point and appreciates the response as a way to get that scope understood.

Bryan Olnick remarked that, in Florida, his organization Florida Power & Light set out in 2006 to harden all our poles, and they are 90% done and should be completed by 2021. He said this is just one aspect of resilience. Florida Power & Light still has had major storms and major outages; however, there are clear signs that this works, but it takes time. When the North American Resiliency Model comes out in a couple years, it is important to understand that these issues won't be resolved for many more years. This work is very important, particularly from a national security perspective, but we also have to understand how good is good when it comes to the model. Mr. Moura replied that if regulators have a complete picture from a planning perspective, from either a molecule or electron perspective, so regulators know their options and the full picture, that would be a big win. Ms. Ray responded that, as a Florida customer, she thanked Florida Power & Light for all these efforts, and said there was a lot of work done on sequencing these investments.

Mladen Kezunovic asked where is the scope that we can understand. Beyond that, who will own or run these models – e.g., PUCs, Homeland Security, etc.? Who verifies them, and stands behind the results? Dr. Ghassemian replied that it is above

his pay-grade, but that these are things that need to be addressed. Over time, we will be able to understand these issues. Katie Jereza interjected that the model is really for DOE, and that it is going to start out with a very limited use within DOE and, as it matures, DOE can begin to expand its availability. The model is going to start out with a very limited use within DOE and, as it matures, we can begin to expand its availability. Ms. Ray added that it could be helpful for DOE to develop some more information about expectations for what will be delivered at the end of 18-24 months.

Delia Patterson asked what is the definition of resilience. Is it a subset of reliability? Mr. Brandien responded that the work that NERC has done on reliability shows that people believe that resilience is being covered in the way that NERC is defining our reliability standards. That aside, there is discussion around fuel adequacy that NERC has shone a light on during this rapid change in generation mix and the issue of our just-in-time generation system. Mr. Moura added that there are resilience components that are outside of the NERC purview around some of the distribution system events. Darlene Philips said that, at PJM, the organization agrees that there is lots of resiliency built into the NERC standards, but it is a spectrum from reliability to resiliency. PJM finds that it is hard to identify just where one of those attributes begins and the other ends.

Mr. Adams concluded the panel saying that it is important to begin to plan out the project so EAC can anticipate what can be expected at the first milestone and begin early to set a project management plan to get there. Mr. Adams sees a very wide scope and bringing all these models together from weather to gas and the potential for something that couldn't be achieved in 18 months – so framing what will be developed is an important issue. On the national security side, the challenge to consider a coordinated attack with a wide geographic scope is something totally different, and he recognized that is not something that DOE usually considers.

Presentation: Advanced Grid Research and Development Portfolio

Michael Pesin, Deputy Assistant Secretary of Advanced Grid R&D in DOE's Office of Electricity, provided a high-level description about OE's portfolio projects and emphasized that they have been trying to make sure all programs are well-coordinated. He began by sharing OE's mission, which is that OE provides national leadership to ensure that the Nation's energy delivery system is secure, resilient and reliable. He said OE works to develop new technologies to improve the infrastructure that brings electricity into our homes, offices, and factories, and the federal and state electricity policies and programs that shape electricity system planning and market operations.

OE is responsible for the electric power grid, with electric generation on one side and load on the other. Mr. Pesin emphasized that they need to make sure loads can be sold by generation and continue to make this work in the future. He pointed out that one of the challenges they have been facing is high penetration of renewables and distributed energy resources (DERs). There is a lot more participation from consumers and local demand from industry for higher reliability and better resilience. The tools in their portfolio address these challenges. He gave some

examples, which included wide area sensors, measurements, and monitoring on the transmission side, distribution automation and management efforts on the distribution side, and equipment, materials, transformer protection, and power control devices at the substations. OE works with multiple stakeholders, such as independent system operators (ISOs)/regional transmission organizations (RTOs), electric utilities, state/territories and communities. He mentioned that energy storage is the holy grail of the industry that makes everything better. Mr. Pesin then transitioned into a discussion of the Advanced Grid R&D programs.

The Advanced Grid R&D division is divided into two groups: hardware (grid controls and communications) and software (grid systems and components). Mr. Pesin went over the programs.

1. Transmission Reliability and Resilience, which includes Synchrophasors and AGM, which Ali Ghassemian is leading.
2. Resilient Distribution Systems, which includes Advanced Distribution Systems, Advanced Microgrids, Dynamic Controls and Communications, High-fidelity and low-cost sensors.
3. Transformer Resilience and Advanced Components (TRAC), which includes Advanced Power Grid Components.
4. Energy Storage Systems, which focuses on energy storage.

Mr. Pesin then went over the five priorities for OE moving forward:

1. North American Energy Resiliency Model
2. Operational Strategy for Cyber and Physical Threats
3. Megawatt-Scale Grid Storage
4. Revolutionize Sensing Technology Utilization
5. Puerto Rico and US Virgin Islands Resiliency Efforts

Mr. Pesin pointed out that all of their programs align in a way that they can support one or several of the priorities mentioned above, as well as align with the Grid Modernization Initiative, which he noted would be discussed by Gil Bindewald the following day. He identified the following integrated technical thrusts:

1. Design and Planning
2. System Operations, Power Flow, and Control
3. Sensing and Measurements
4. Devices and Integrated Systems
5. Security and Resilience
6. Institutional Support

Mr. Pesin moved on to explain about technology adoption and how there needs to be an interaction between policy, markets, and technology to have a successful outcome. For technology to exist, there needs to be a market that can support adoption of these technologies, and for markets to exist, policies that enables those markets need to be present. This connection works both ways and the intersection of these three aspects is important for technology to succeed. He then transitioned to the discussion of Transmission Reliability and Resilience Program, which consists of two internal programs: Synchrophasors and AGM.

Mr. Pesin pointed out that one of the biggest successes that DOE has had in the last several years is with its Transmission Reliability and Resilience Program. There has been successful deployment of about 2,000 measurement units that allowed DOE to have significantly better visibility to the system. This is particularly significant to avoid power outages like the one in 2003, when 50 million people were without power due to cascading failures on the electric grid across 8 states. He mentioned that reliable electricity cannot be provided without synchrophasors and the applications that use the data from those sensors.

Mr. Pesin said Dr. Ghassemian covered his planned discussion on AGM in his presentation, and moved to the discussion on the advanced synchrophasors program, which consists of four parts. The first is the North American Synchrophasor Initiative, which focuses on deployment of synchrophasors. There have been significant impacts due to improved visibility and improved reliability and resiliency, but there is room for more work. The second one is Advanced Application Development, which deals with automatic switchable networks for reliable early warning for informed remedial reaction, reliability monitoring and NERC compliance tools, and oscillation behavior. The third is Reliability and Models, which includes research, development, and implementation of electricity infrastructure and market simulations by using this data. And finally, the last one is Equipment Standards, which focuses on data quality and device calibration in partnership with the National Institute of Standards and Technology.

Mr. Pesin moved on to talking about Resilient Distribution Systems. He pointed out that this program is on the distribution side and consists of four internal programs: Advanced Distribution Systems, Microgrids, Dynamic Controls & Communications, and High Fidelity, Low-Cost Sensors.

The Advanced Microgrid Program consists of two parts: core activities and crosscut activities. Core activities include off-grid microgrids, grid connected microgrids, and network microgrids. In remote, off-grid microgrids, there is active control of electrical and thermal energy, which enables synergistic systems to exist that complement each other and enable control in optimal conditions in absence of electric grid. It also includes developing standardized methods for system designs and performance monitoring and integration of local energy sources. Mr. Pesin explained that technically there is not much difference between off-grid microgrids and grid-connected microgrids. Grid-connected Microgrid deals with development of planning/design tools and operations/controls tools. It is integrated with distribution systems. Moreover, it includes developing standardized cost/performance data to have the ability to justify those microgrids. He mentioned that initially, when microgrids first started to appear, their main purpose was resilience. He said that they had customers who required adjustment resiliency and it was not easy to build business cases exclusively on resilience alone. It becomes very expensive and not everyone who wants to deploy a micro grid can afford this, but there are multiple ways to take advantage of this. He went back to his discussion of having the right markets that enable successful adoption of this technology along with regulations to support this. He emphasized that when there is a link between monetized value stream and investment, success is possible. He noted that network microgrids are the next step in the evolution of microgrids. When there is more than one micro grid in the same system or even the same distribution feeder, synergistic value can be created by optimizing and coordinating performance of those microgrids. He pointed out that they develop tools for planning and evaluation with new

modeling/simulation/optimization capabilities and are enabling implementation in cities and regionally coordinating microgrids.

Mr. Pesin then moved on to discuss the crosscut activities, which consist of resiliency tools and standards and testing. Resiliency tools consist of pre-event preparation, during-event detection and mitigation, along with post-event response, recovery, and remediation. Standards and testing are comprised of new and revised microgrid standards, standardized test methods and testing. He mentioned that a lot of companies offer microgrid solutions. However, it is okay to stick to the same vendor in case of having a proprietary unique system, but it is an advantage to have the ability to keep other options open. There need to be standards that drive innovation, even if standards take a very long time to develop.

The next program Mr. Pesin talked about was the Dynamic Controls and Communication Program. He asked the audience to see how many of them were familiar with transactive energy. He explained that the idea of transactive energy is to create a market-based control (spatial and temporal control), so that every single customer in the system at any given moment of time has a unique cost/value for the utility. If the price is created in real time, correct actions from the customers can be encouraged without making customers do what utilities want them to do. This price structure makes customers the participants in the market. He used Uber as an analogy. Every customer has a vehicle (load) and any customer can participate any way they want to. He pointed out that this is the ultimate vision of microgrids but in the meantime, there is a lot of complexity that is yet to be solved. He then went over the internal programs within the dynamic controls and communication program:

1. Policy and Market Design, which focuses on continued reliability, understanding volatility of generation and demand, and varying timescales and cost effectiveness.
2. Business Models and Value Realization, which focuses on understanding of customer value streams and understanding DER transactions.
3. Conceptual Architecture Guidelines, which focuses on establishing traditional and distributed interfaces for market participants.
4. Strong Interfaces and Partners to enhance intra-grid information and value flows from one part of the grid to another, along with ensuring “docking” with critical partners at the grid edge.

Mr. Pesin mentioned that DOE is interested in getting feedback from the EAC on how they can apply block chain technologies for these transactions and other applications. He said that block chain has been around for a long time and many people associate it with Bitcoin. Bitcoin uses this same technology, but Mr. Pesin wanted to make clear they are not getting into the finance market, and instead are trying to analyze the capabilities and dangers of block chain. The main question was how to use block chain to an advantage and how to prevent something bad from happening because of the hype. He pointed out that dozens of companies would jump into using block chain for energy but they want to take advantage of the opportunities, conduct peer-to-peer energy exchange, and ensure security by documenting transactions.

The next program Mr. Pesin discussed was the High-fidelity, Low-cost Sensor Program. He said that there are two thrusts in this program. One is high fidelity with extremely high-resolution sensors that can enable signature recognition for certain events, such as equipment failure modes.

The other is low-cost sensors that can be distributed all over the electrical network and create a high level of visibility. Mr. Pesin then moved on to describing the three internal projects.

1. Fault Detection, which includes novel, low-cost sensors for deployment directly at/on the asset to be monitored along with data analytics for asset health monitoring and anomaly detection and identification.
2. Distribution System Resilience deals with the low cost for integrating multiple sensors that are self-powered and capable of spatially distributed measurements of multiple parameters. It focuses on high-fidelity data, ingestion, visualization, analytics, and standardization to rapidly detect low-probability, high-consequence events to protect critical distribution grid equipment.
3. Accurate DER Forecasting, which deals with low-cost platform technologies, including wireless, self-powered, self-calibrating sensors for large-scale deployment with capability for auto self-configuration and commissioning. It focuses on validating forecast models of load, variable renewable, net-load power, and ramps.

Mr. Pesin transitioned to discussing the advanced distribution system program that has been going on for several years. It is open platform, similar to Android or Apple iOS, and allows third parties to develop applications. He said that there is number of efforts to develop applications that can be used by utilities without necessarily making large investments, since affordability is very important. These applications can be deployed at a very low cost and can become revolutionary. Applications should be tested to make sure they work well in the environments they are supposed to work within in the utility world. He pointed out that this is not for DOE's benefit, but for industry's benefit.

The next program Mr. Pesin discussed was Advanced Grid R&D. To ensure the electric grid remains reliable and resilient, next-generation transmission and distribution hardware will need to better withstand physical and cyber threats, facilitate rapid recovery and restoration, and provide new capabilities that meet future grid requirements. The focus is on the following areas:

1. Increased energy efficiency.
2. Improved operations and new architectural paradigms.
3. Enhanced asset utilization and management.
4. Increased system resilience.
5. More domestic manufacturing and jobs.

Mr. Pesin described the organization of the OE's Advanced Grid R&D Division. The first part is market and system impact analysis, which includes understanding system impacts of new technologies and functions along with techno-economic analysis for costs and benefits of advances. The second part is component design and development, which deals with design and prototype components with enhanced features and functions, and field validations to demonstrate and evaluate new capabilities. Mr. Pesin said that they involve different types of efforts and are looking at the materials, devices and components (used interchangeably), and transformer designs. He commented that several years ago DOE was asked to look at the feasibility of creating a strategic transformer reserve and whether it would make sense since large power transformers are unique. He mentioned that one way to address this issue is to be able to create a more standard transformer design and to replace every single transformer in the system. The second choice is to create flexible transformer design. He noted that a configurable transformer

would be a great solution. He pointed out that there could be just a few transformers that can be configured in a way so that they can meet unique specifications and can be deployed where needed. He mentioned that there are a number of ways to address this. One way is to have modular transformer design and another is a hybrid transformer. He added that a big part of this is still traditional, but it has been powered with augmented power electronics that allows configuration by changing the parameters of the transformer. The third part is monitoring, modeling and testing. This includes developing embedded sensors and intelligence to improve reliability, along with testing and model validation to understand limits and performance. The last part is applied materials R&D for which applied materials need to be considered. This includes evaluating and developing new materials and devices that underpin advanced components and figuring out a way to use these materials in the new grid components.

Mr. Pesin pointed out that the goal of the energy storage program is to lower system costs while simultaneously defining and articulating the value and benefits storage can provide across the grid infrastructure. The goals are to have $150/kWh total installed system cost by 2022 (for a flow battery), two long-duration cycles per day (with deep discharge for each cycle) by 2028, six hours output duration per cycle, and 10,000 cycles lifetime (about 20 years). The four specific areas of this project are:

1. Cost Competitive Technology, which deals with materials and chemistry, systems and manufacturing, cost reduction, and expanded applications for energy storage.
2. Reliability and Safety, which consists of lab testing, codes and standards, guidebooks, and R&D improvements.
3. Regulatory Environment, which is comprised of policy analysis, valuation methods, and resolution of benefits.
4. Industry Acceptance through Demonstrations, which looks at stakeholder engagement, proving success, seamless integration, and consumer benefits.

Mr. Pesin brought up a discussion he had with Assistant Secretary Walker on how to create a focus on the program. One way is to focus on a few technologies. Mr. Pesin noted that one of the successes of the program was the development of the flow battery that has seen a reduction in costs from $600/kWh down to $275/kWh, but the reduction was further limited by the cost of the commodity material. He pointed out that other materials that are significantly lower in cost may be used to reduce costs even further. Manganese oxide has the same chemistry used in traditional batteries. It uses a second electron to double the density and efficiency, as well as the potential to make it rechargeable.

Mr. Pesin stressed that it is important to remember when people talk about cost of energy storage, they are talking about the cost of the whole system. The cost of a storage system depends on the storage device (25-50%), power electronics (20-25%), and the balance of the plant (20-25%). The value of a storage system depends on multiple benefit streams, both monetized and unmonetized. To be able to monetize values, the right regulations need to be in place. The key is to reduce the cost and increase the value, and have a golden point in the evolution of energy storage.

Mr. Pesin opened the floor for questions. Mr. Mroz asked about the on-going work and coordination with the industry, EPRI and the Edison Electric Institute since he believes that

EPRI is doing similar research and hopes there is some coordination to avoid duplication. Mr. Pesin noted that they go to as many events as they can afford to present their work and solicit feedback. Moreover, they invite people to their program reviews because they understand the importance of avoiding duplication. Mr. Mroz asked another question regarding microgrids and the standards for equipment. He pointed out that a lot of work is being done regarding DER, particularly equipment that is being integrated on the retail side, and there is work on the standards in the operation devices. He asked if there is an effort being taken on standards around the production or manufacturing of devices for security purposes, specifically for cyber security. Mr. Pesin commented that there is close coordination on the cyber security element, but DOE is not a standards body though their partnership comes with it. Mr. Mroz recommended that Mr. Pesin present this work to make people aware of it.

Ramteen Sioshansi asked how market design and monetization of value streams produced by energy storage is coordinated with FERC, ISOs, RTOs, and State regulators. Ms. Jereza commented that they have not been doing a lot with the RTO conferences but there are associations and stakeholders that they engage with, including the National Association of State Energy Officials, legislator/governor associations, the states). She said they are in the second year of their cooperative agreement. She added that they look at their priorities and give them money as they get about 6-7 million dollars to work with them. She mentioned that this is a fluid program and they conduct basic training since there will be a lot of turn over with the election.

Dr. Kezunovic asked if this work will eventually be integrated into some kind of systems solution and if they are looking at the interoperability issues beyond what the Smart Grid panel talked about. Mr. Pesin replied that integration happens on multiple levels. For example, they have a new architecture design effort for electric grid distribution systems. On that level, from an architectural perspective, there is an effort underway. Eventually everything is integrated because electrons leave generators and come to the lightbulb. If the software integration is considered, the software standards need to be considered along with how they can be integrated. Hardware integration is a completely different topic. Mr. Pesin noted that he cannot say everything is integrated but it is integrated in a way of effort, and all the effort is driven by common goals towards five common objectives. Dr. Kezunovic mentioned that interoperability is defined at least in one framework published by Gridwise Architecture that has all of these different levels, from physical level, to syntax and semantics, to organizational levels, to regulatory levels). He asked Mr. Pesin if they are relying on that definition or if they have conducted additional work. Mr. Pesin responded that there has been additional work, but he does not have a good answer for this question and will keep this question in mind moving forward.

A participant mentioned that they were impressed by the efforts to monetize more of the value streams that are associated with energy storage since it is key to be able to make good decisions on where to go next. She asked if there is information available where they could track the progress. Mr. Pesin commented that there is an energy storage database maintained by Sandia National Lab, which captures every energy storage project in the world, including the business cases for the projects. He pointed out that in some places, such as Puerto Rico, there are tremendous changes but also a lot of opportunities. There are tasks for developing new interconnection policies for microgrids and there are ways to develop new interconnection

utilities, but DOE cannot guide regulations or policies. At the same time, if they let people know what is available, they can make the right decisions.

Mr. Adams expressed that he was tremendously impressed by the intersection graph of markets, policy, and technology, and he asked how EAC can help. Mr. Jereza said that EAC could make their challenges and most urgent needs known to them. She noted that they could do an open competition and the public can be creative on developing the solutions. She added that it is important to know the parameters and be able to characterize the problem in a way that would be most useful for EAC to help them.

Tom Weaver brought up the discussion about values and cost and pointed out that the business cases are really difficult, whether for an investor, a third party or a utility. He said the most complicated part is that the person who does the investments also needs to claim all the benefits to make their business case work and making those match up is challenging. Mr. Weaver asked if there has been work to make this better. Mr. Pesin used block chain as an example as one of the potential solutions. One way companies try to do this is to completely disaggregate the physical transaction from the financial transactions. One can transact with anyone they want, regardless of their electric flow, as a result of which they can sell their energy to someone within the same utility. If electrons can be sold from a solar panel to someone on the adjacent distribution, then energy credits can be sold to a company that is interested in buying them. Thus, on the consumer side, one can take advantage of multiple benefits. On the utility side, it is more of a regulatory issue and he said that he does not want to get into a regulatory discussion. Ms. Jereza added that this is an excellent question because value can be so personal and can vary. She noted that she would like to have more conversation around this because her team is trying to help facilitate the programs.

Mr. Heyeck mentioned that the market is good at the low end of energy storage. He encouraged Mr. Pesin to look at the utility scale of things because the market has fewer players. He noted that he is not sure about the risks of the technology choices and encouraged looking out for other options and being able to displace existing focuses. Mr. Pesin responded that they are trying to make sure to do that and keeping a look out for something interesting for them to take in.

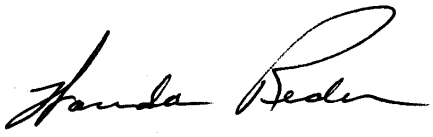
Wrap-up and Adjourn Day One of July 2018 Meeting of the EAC

Mr. Heyeck thanked everyone for participating. He mentioned that there is a Dutch dinner at restaurant Pinzimini in the Westin Hotel for EAC members. The meeting will resume the next day at 8:00 AM at the same location, and end at noon. After the conclusion of the EAC Meeting tomorrow, the Energy Storage Subcommittee also will be meeting starting at 1:00 PM. There were no closing comments. The meeting was adjourned.

Respectfully Submitted and Certified as Accurate,

Michael Heyeck
The Grid Group, LLC
Chair
DOE Electricity Advisory Committee

02/20/2019
Date



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