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Lessons Learned on Electricity and Information & Communication Technologies Convergence: Report from DOE Energy Policy and Systems Analysis Workshop on Electricity/ICT

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Over the past two decades, electricity and Information and Communications Technology (ICT) infrastructures have become more interdependent, driven by a combination of factors including initial advances in sensor, network and software technologies, the need to provide higher levels of both wide-area and deep situational awareness regarding grid conditions, and the promise of enhanced operational efficiencies. While this convergence presents new vulnerabilities, particularly to cyber threats, it is also providing opportunities for new grid-associated value streams, enhanced system performance, and more options for consumer interaction with electricity systems. Understanding these trends is critically important to developing forward looking policy recommendations, which is a fundamental goal of the Department of Energy's Office of Energy Policy and Systems Analysis.

The purpose of EPSA's technical workshop on electricity and information and communications technology was twofold. The first was to inform the completion of the PNNL white paper "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology". The second was to elicit additional electricity and ICT research and policy analysis topics for potential examination within DOE. A better understanding of the current state of electricity and ICT interdependence will help inform analysis needs for the next installment of the Department's Quadrennial Energy Review (QER).

The goal of this meeting was to leverage the inherent synergies between DOE's research and policy functions and gather expert input. Specifically, this workshop concerned the current status of deployment of electricity and ICT infrastructure, as well as trends and developments in market places, technologies, and regulations.

Disclaimer

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Presentation of the PNNL/DOE Framing Document

Jeffrey Taft, from the Pacific Northwest National Laboratory, presented his paper "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology" (the framing document for this workshop). He discussed the main topics of the report and started with setting the background for the paper and defining the key convergences within networking, computing and the electric grid. Next, he discussed the emerging trends in the US electric utility industry that are driving change, especially at the distribution level and the increasing complexities in operations and controls. The trends, discussed in detail in the paper, included: increasing data volumes from the grid, faster system dynamics, new hidden feedbacks and cross-coupling of grid systems, higher Variable Energy Resources (VER) penetration, bifurcation of the generation model, increasingly responsive loads, changing fuel mix, evolving industry/business models and structure, and evolving control system structure.

He then focused in on data-related considerations and highlighted the issue of the diversity of the time scales for which data can be useful and the necessity of data analytics development to

extract value. For example, the time scales involved in grid system operation and planning span 15 orders of magnitude. This ranges from high-frequency switching devices and inverters which operate at subsection timeframes, all the way to transmission planning and carbon emission goals which operate over decades. On top of temporal variation, the scale of the system in question varies as well, from ISOs, to NERC regions, distribution utilities and individual homeowners.

The convergence and growth of data generation have major implications for communications and networking, including potential for meters as computational platforms, cyber-security issues, and legacy communication infrastructure challenges. However, the biggest issue is still data quality assurance for processing, which, as Taft points out, is better addressed before applications expand further and the scale of the challenge increases. In order to process growing amounts of data into actionable information, analytic software development is needed. As the role of analytics grows, discussions should include specifics of how emerging trends in analytics interact with system structures. After highlighting details from sections of the report on analytics and visualization, and software for grid operations, Taft concluded with a discussion on potential Federal leadership opportunities. While a common vision will not completely encompass the complexity of the solutions required, convening industry stakeholders for the development of a reference architecture for control systems is an important step toward tackling the issues. For example, interoperability standards would be more useful if they had have a framework within which to exist. The organization that is put in charge of the architecture also needs to be carefully considered. Other opportunities include exploration of investment mechanisms and tools to determine sufficient investments in ICT networks, and acceleration of ongoing federal research and development efforts in grid management tools.

Comments and Questions from Audience

- One central issue is that of modeling, as different time scales make modeling very difficult. The purpose of data repositories and sharing data is to validate modeling. For example, there is a NASA model for sharing PMU data.
- Who should govern the reference architecture? Perhaps utilizing the convening power of DOE to figure it out would be beneficial.
    - The utilities should decide who is most appropriate within their respective organizations. However, before deciding upon governance, it is important to first determine a mutually agreed upon architecture. That should help inform the effort to determine the best-suited national governing body.
- When you have an electric utility that has the same territory as a water utility, how do you let the water utility ride on the electric utilities' field area network?

- This is a very important question. The water-energy nexus is another topic which warrants further exploration.[1]

Discussants Panel Summary

The panel discussion included views from experts working in Electricity, Network Infrastructure, and Policy. A summary of key points discussion are as follows:

Panelist 1:

- It is important to look at how systems are tied together and, to have a robust systems information model that supports accurate data. While the trend has been to have separate communication systems for SCADA, AMI, and mobile workforce, it is now possible to have strategic comprehensive communication systems, for example, the mobile workforce communication infrastructure needed to help restore the grid during an outage. Overall, communications systems of the grid need to be more reliable than the grid itself in order to report and respond rapidly to challenges and problems.
- As these systems become more interconnected and the scale of connected devices increases, having robust cyber security, both for detection and response to cyber-attacks is important.
- While new technology is becoming available, it is important to have the right architecture to support legacy systems as well as new sensors. This architecture will have to grapple with both long term infrastructure assets that will be in place for decades, and shorter term sensors which have a 3-5 year time frame.
- ICT infrastructure, as an enabling technology by definition, and AMI platforms open up opportunities to increase the participation of supply.
- Reliable and affordable coverage requires a balance of centralized and decentralized networks, and this is facilitated by utilities using integrated analytics, as well as continued efforts to improve data accuracy and quality.

Panelist 2:

- Consumers see the overarching value of increasing the tie between the grid and telecommunications, but the impacts delivered to them, in their home, are not as immediately visible to them. A sustained and clearly-communicated public education campaign is imperative.
  - For example, a Navigant research survey stated that less than ¼ of respondents were interested in demand response or combined energy programs, even when faced with savings on their bills.

[1] The Department of Energy has issued a report on the water-energy nexus, and continues to work in this space. http://energy.gov/downloads/water-energy-nexus-challenges-and-opportunities.

  - Not that those consumers do not see value, but promoting the adoption of energy and telecommunication-connected systems requires public outreach. Less than one-quarter of individuals have knowledge of the full extent of the value smart grid can supply.
- It is unclear to what extent utilities or technology companies should develop the grid edge and manage communication systems.
  - Serious questions remain about whether to engage in utility owned systems or public carrier systems. Additionally, while there is a process for the development of data standards, the infrastructure and hardware standardization side has been moving at a slower pace.

Panelist 3:

- The convergence of electricity and ICT systems has created a lot of opportunities and challenges. There have been definite advances in improved reliability and response time. Increased information enables increased communication with customers, which is a major benefit for utilities. For example, initiatives like the Smart Grid Investment Grants (SGIG) program[2] have increased deployment and allowed for cost savings and better communication with customers.
- Five major categories of challenges include security, meeting customer expectations, shifting situational awareness, the need for better cross sector coordination and response, and working through state regulatory commissions to secure investments.
  - **Security**: the security issue is not bigger than it used to be – it is different. There has been an increase in cyber threats over physical ones. Processes for grid control are particularly vulnerable and the way in which standards evolve needs careful consideration. If utilities do not have access to information, problems can arise. For example, the intention to shed load could result in generation shedding if proper information about distributed generation is not available. The privacy aspect of security is also one for careful consideration.
  - **Meeting Customer expectations**: There is a need for public education programs to tell customers exactly what they will, and will not, be getting. In some cases, people have unrealistic expectations of smart meter technology.
  - **Shifting Situational Awareness**: The rate of change on the grid has increased, and it is expected to continue to change going forward. New information needs to keep up with this evolution, and utilities currently do not have access to real time information as it is being collected.
  - **Need for better cross sector coordination and response**: Some of our ability to control the system is not effective if communication systems are down. Specifically, the ability to organize and execute a response is not effective if the either the communication is down, or the mode of communication is faulty. Developing contingency plans around communication disruptions is important.

[2] Information about the SMIG program can be found at the following address: https://www.smartgrid.gov/recovery_act/overview/smart_grid_investment_grant_program.html

    - **All of these investments have to go through Commissions**: Public Utility Commissions (PUCs) need to be confident in system functionality before deployment, as is the case for utilities. Utilities need assistance with modeling distributed generation at high penetration levels as well as valuation and quantification metrics for distributed generation, demand response and other distributed energy resources. For example, having something like the ICE calculator for resilience would be helpful as it would allow commissions to understand the value of investments over time and expedite decision making and approval.
- **Jurisdictional challenges** also arise as utilities with service areas in multiple jurisdictions, having to deal with commissions in these different states, can make company-wide approaches challenging.
    - The federal government can help states step forward with investments by pointing to other locations (be it another state or region) as a success. This would be helpful in guiding PUC investment.

Panelist 4:

- The combination of AMS and smart grid systems at the distribution level are showing measurable benefits, specifically around higher reliability and increased understanding of grid dynamics.
- Customers need to be developed into prosumers. Deploying AMI will provide visibility on the distribution side, even at small penetrations. For example, 15% penetration of AMI is enough to detect faults and facilitate faster restoration. With increased levels of deployment, there are challenges with diminishing returns.
- The core goals of analytics in utilities are still reliability and customer service. However, as utilities build complicated systems, they need complicated processes to manage them. For example, as visibility and system interoperability increase, modeling across enterprises begins to be rolled together. Solutions and opportunities are found with common understanding across systems that result from integrated modeling.
- Universities are not teaching the skill set we need for new power systems engineers. While there is some development in the power systems area, by and large, electrical engineering classes do not teach the things needed, for example, by transmission companies like IT, cyber security, operational elements, and the intersection between new technologies and engineering; but, rather, such courses are teaching elements that support the status quo of power systems. There are problems finding qualified applicants.
- For security, low-frequency, high-impact events also need to be considered, especially around large hurricanes and EMP preparedness.

Comments and Questions from Audience

- What are customers going to do with the information to which they (potentially) have access? One of the problems is that the average customer does not want to take the time to be a prosumer.

  - There is still a subset of people who wants that information (it may only be 10%, but it still exists).The extent of this problem is unclear as most utilities are using rate structures for the old grid, which do not promote customer participation.
  - We cannot just look at today; we have to look at a system that will be present for years, and which will need to last. Can utilities really make these systems evolve? That should be the goal.
- What specific models/mechanisms are conducive to federal government support?
  - Pilot programs are incredibly useful, as well as grants.
- When a utility gives a value or quantifies success, you have to take it with a grain of salt, and commissions know this and tend not to trust us. The ICE calculator has helped in this respect, because it generates information into something that the federal government stands behind, making it an extremely helpful tool in getting commissions to understand what utilities need.
- One of the main problems with branching out into telecommunications is that we could not provide strong business benefits for the few projects that existed. The benefits are long term, so people cannot see them in the present. We need help to articulate these benefits so that people can make the investments.
- Another problem is interoperability. If it is streamlined, it is much easier for third parties to adapt, but it means all of us have the same security threats. If we cannot make the information we gather available, then we will never reach the customers. We have no future without sharing information between utilities and customers.
- We should look at what lessons were learned from the current communication system investments. We spent a lot of money installing systems that are expected to last 20 years, without first considering fully how reliable and resilient to make them. The current systems all have communications problems, so we should be looking at what we learned from that.

Lunchtime Keynote Summary

Becky Harrison, CEO of the GridWise Alliance, presented on transitioning to the grid of the future. Some of the main themes included: the need for a balance between centralized and distributed generation and control; the challenges of the transition to two-way power flows; the need for smart inverters with rooftop solar; and expected non-uniformity among states and municipalities, resulting in challenges with standards and interoperability. She highlighted the importance of understanding the requirements and what they will be in the future and called attention to a report on the subject.[3] Some of the main points of her discussion are as follows:

- It does not seem to matter what the regulatory system is: generation is going to be both centralized and distributed, and system operators are learning to deal with increasing

[3] Gridwise Alliance has released a report on the Future of the Grid available at: https://www.smartgrid.gov/document/future_grid_evolving_meet_americas_needs_final_report_industry_driven_vision_2030_grid_and.html

levels of non-dispatchable generation, and while energy storage will be important for this, it will not replace the need for dispatchable generation.

- Along this theme, there will be both centralized and decentralized systems; microgrids are going to be complementary but will not replace the existing bulk system. There is a transition of the network from one-way power flow to two-way power flows. This is also true for distribution, which will need to more modular to facilitate isolation and reconnection. The distribution grid will look a lot more like a transmission grid – balancing and supply and demand.
- Proper investment in ICT infrastructure and markets is needed to allow efficient coordination between distrusted and centralized generation. For example, Hawaii has had a huge uptake in residential solar. Certain circuits are getting 125% of the local demand, and generation from residential solar has cascaded up into transmission, requiring the curtailment of grid scale renewables (such as wind) because of over-production.
- With smart inverters, solar can provide value back to the grid. Without smart inverters, rooftop solar presents resilience challenges to the grid. Investments in components as well as the development of markets are necessary to utilize the value of solar.
- We need stakeholders engaged in ways in which investments can be made. We need options, tools, and especially models. Specific analysis into large penetration of renewables is needed to help plan investments. There should be no expectation that retail markets, like wholesale markets, will be ubiquitous across all states. Third party, non-regulated players in this space need to understand their obligations, just as utilities and PUCs must understand what they need from the grid. While NY and CA are moving in this space, there are lots of states that are not taking action. Figuring out how to jump start the process across the United States is important. It is hard for vendors and suppliers to design products that work in all 50 states with their different PUCs, state and local rules, municipalities, co-ops, and IOUs.

Harrison concluded with a discussion of the Grid Modernization Index (GMI) report. [4] The Grid Modernization Index ranks the states according to the degree to which they are implementing grid-related policies and operations, as well as the degree of consumer engagement. Some specific examples she highlighted are California, Texas and Illinois: California, for their aggressive RPS goals and AMI deployment; Texas for its deregulated market, AMI deployment and resulting meter data repository, as well as its large deployment of wind; and, Illinois, which passed legislation and performance-based metrics to drive grid modernization which, two years later, led them to rise dramatically in the GMI. Each of these examples show how various policies can all have significant impacts on grid modernization investments.

[4] Grid Modernization Index: http://www.gridwise.org/resources_gmi.asp

Comments and Questions from Audience

- How are we going to invest in communications systems? What are your thoughts on this?
    - The bias toward investing in capital infrastructure is going to continue. When you make the business case internally, it is not going to go very far if there is not a capital component.
    - I had commercial and industrial meters with analog cellular technology. Then the cell service said they were going to stop the service. I had to go out and make the business case to upgrade all the AMI. This is a huge risk. How do I design systems such that if I am reliant on public resources, there is modularity to the upgrades?
- How should we approach the enormous challenge of building an interoperable architecture when the stakeholders are so varied?
    - The goal is first to find the common piece of the architecture on which people are going to agree. A large part of the architecture is understanding flexibility.
    - It starts to inform the discussion on how the markets link to the technical architecture and how business models link into the architecture. For example, if the wholesale market is the only one to "call on" resources, such that it bypasses the distribution grid, distribution system operators will not be able to understand why, or be able to prioritize with local resources. There is a very complex set of relationships defining the way(s) in which things fit together and how we think about the controls and who are we rewarding.

Breakout Sessions Summaries

Key findings from the PNNL White Paper are summarized at the beginning of each of the four topics followed by a short list of some of the key questions used to facilitate discussions during the Workshop. A summary of each breakout session then follows, along with a summary of some of the related challenges. At the end of each section is a list that summarizes potential research, federal involvement, and other opportunities discussed by the Workshop participants.

Discussion on Data Value, Latency, and Need for Data Collection and Analysis Tools

The influx of new information from grid modernization is increasingly being seen as an opportunity to improve performance through enhanced situational awareness. This data "tsunami", while large by utility standards, is not necessarily large by the standards of other sectors. The extraction of information via analytics, and the connection of that information to decision and control processes, is necessary to realize the potential benefits of the raw data. Thus, there is a growing interdependence involving data, analytics, and decision and control processes and systems occurring within the context of the physical grid and its associated systems and devices. Data latency for protection and control of grid applications is crucial, and this influences the requirements for the data transfer networks. The lack of contextual frameworks for utility industry interfaces is a major reason for the slow development of interoperability standards, as existing standards have been developed bottom-up. A reference architecture that focuses on grid control system structure that considers the regulatory and business context for stakeholders is needed to address the specific needs associated with the convergence of ICT and grid infrastructure. Data automation for meta-data management as well as to facilitate observability of distribution systems is needed to fully realize potential benefits of grid modernization and AMI infrastructure.[5]

The breakout session consisted of representatives from DOE, Verizon, American Council for an Energy Efficient Economy, Seattle City Light, Navigant Consulting, and Dominion Virginia Power.

Key Questions for Discussion:

- What are the major challenges, opportunities, and solutions for the massively increasing data volumes with increasing deployment of sensors and metering infrastructure?
- Centralized data management and analytics, distributed, or both?
- Where do Cloud approaches fit with real time infrastructure operation?

[5] PNNL, "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology." Draft, April 2015.

Participants began by framing the costs surrounding data collection and system integration. One participant noted that utilities do not always know how much data they need. Sometimes, the data they do collect does not integrate with the existing system, and thus only comes after the costs for developing interoperability. Another participant noted that the barrier is not so much interoperability, which can be managed, but trying to get business leadership to focus on a process they want to implement, and developing the capability to support that. This is in contrast to letting the capabilities drive the changes. With a plan, utilities can derive massive benefits from good system integration work and quickly recoup the costs that are invested.

Data/Analysis Challenges:

- Big data and analytics bring the promise of making real time decisions and feedback. Three issues emerge from this: latency, sampling, and integration of data into one stream of information.
- Integration of electricity infrastructure and ICT is the responsibility of the utility, since optimal configurations are often specific to a given system; however knowledge generation and help from third parties are needed, especially at higher levels.
- Challenges arise when utilities do not have access to real time information as it is being collected by third parties.

Utilities have data with volume, variety and velocity that result from advanced metering infrastructure (AMI). For example, the data collected can range from structured scalar information being collected by deployed units at microsecond intervals, video feeds of lines and poles, to phone messages from customers. At least one participant argued that the reason utilities have not gravitated towards ICT is because they are reluctant to come forward with a new business case. Utilities want nothing more than business as usual, so it falls on the vendors to put forth new business plans, which is not something they are particularly inclined to do.

Participants noted that one major challenge often overlooked by policymakers is the organizational culture within utility companies. There is a value to making sure that individual and organizational experiences inform policy. Culturally, there are two potential communications-related barriers to change. First, vertically, there can be a lack communication from the top down in terms of direction and a lack of trust from the bottom up in terms of best practices and understanding the day-to-day operations of the systems as well as nuances of the data. Second, horizontally, different departments carve out their own systems and best practices. Different groups within the company can be resistant to working together based on biases and stereotypes (e.g. the “workers” (engineers and linemen) vs. the “techies” (software engineers and data scientists).

A key topic that emerged from the discussion was that vision in governance is critical. Participants proposed the need for a roadmap to guide the transition from the current market to a more data-centric or data-driven end state. This roadmap must contain step functions or successions of architectures to guide the transition, and leadership must drive the movement from one step to the next. The roadmap could prove a way to improve current information

"disconnects" within companies, as well as highlight best practices and opportunities for web services which do not require hardware. Participants emphasized that utility leadership must know their destination before making changes. Each decision must be informed by a vision, and the technology strategy must be business-driven. Finally, independent and honest evaluation of which parts of the legacy systems are of critical value must be part of the plan.

With regard to the process of integration of electricity and ICT infrastructure, participants discussed how, until recently, the strategy has been to buy platform services, relying on a provider to have proven solutions. However, these providers often do not fully understand utility system operations, or it is not their major concern. Ultimately, integration is the responsibility of the utility, because optimal configurations are often system-specific. One reason why governance is important is that, within a given company, a different division may operate each legacy system, and the data each generates is not necessarily interoperable or easily reconciled. As a result, the knowledge and help from third parties is needed, especially at higher levels.

Another topic consisted of the ways in which big data and analytics bring the promise of facilitating real-time decisions. Sampling data in real-time creates the possibility for generating instructions for immediate action. Three issues emerged from this discussion: latency, sampling, and integration of data into one stream of digestible information; all of which have a strong impact on analytics. Of particular note was how to correlate information where data sources record time differently (with the variety of methods to time-stamp data), making data integration especially difficult from disparate sources, if time is of critical value.

An overarching architecture is imperative to making the data systems share information effectively, so that the operator in the control room has access. Several participants discussed the cloud as another important opportunity in this area. Specifically, allowing cloud services to be included in capital costs could be beneficial to data management. It provides a great deal of opportunity to smaller municipalities and co-ops that do not have the resources for their own data centers.

Discussion on Hardware and Network Infrastructure

An increasing number of devices are being connected to the electric grid. The increasing connectivity demands on the network should be considered when making long term investment decisions to prevent stranded investments. This is true not just for physical infrastructure, but for the standards that support ICT. For example, while internet protocol networking was one of the key reasons for the success of the internet, electricity industry adoption of internet protocol is uneven and lacks depth. Instead, capabilities inherent within the internet protocol network are duplicated in less effective ways resulting in sub-optimal performance and additional costs. Adoption of newer versions of internet protocol (IPv6), can provide additional advantages to utilities and their customers, including increased flexibility, security and interoperability.

Another example pertains to challenges with wireless mesh networking. Last mile Field Area Networks (FANs) for advanced metering infrastructure, especially those that use wireless mesh networking, are sufficient for reading meter data. However, latency and bandwidth issues make supporting advanced distribution automation challenging as existing networks are not all adequate for advanced functions. These legacy systems can require asset replacements/upgrades before the useful life of the asset has expired, which has both financial and regulatory hurdles, and can delay the implementation of advanced distribution automation and its benefits.[6]

The Hardware and Infrastructure group included representatives from EPRI, FCC, NRECA, UTC, Accenture, Machfu, Inc., Alstom Grid, COG, and Ameren services.

Key Questions for Discussion:

- Should utilities continue to own communication infrastructure? Where do performance priorities and security outweigh shared infrastructure cost benefits?
- What are the major challenges, opportunities, and solutions for the design and sizing of communications networks to connect with electricity infrastructure?
- As the needs and opportunities driven by deployment of AMI and distribution automation (DA) become clearer, what are the best means for addressing concerns about stranded investments in legacy systems? What incentives might be most effective, for purposes of ensuring "right-sized" investment in utility communications networks—to support the evolving nature of operations, particularly at the distribution level?

The group discussion was focused around the innovation of utilities. For example, some participants brought up the need for a modular network platform that will allow for innovation. In addition, there was a push to set standards to support this platform and other aspects of the hardware and networks. Standards were raised again when discussing Advanced Metering Infrastructure (AMI). Specifically, standardizing hardware ports and interfaces for AMI would help create competition between vendors, and prevent technological lock-in to certain vendors,

[6] PNNL, "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology." Draft, April 2015.Pg 5.1 – 5.7

which would inhibit innovation. Another issue discussed was disconnecting the public from the electricity system, and how this acts as a barrier to innovation investments.

The way utilities innovate is different than the typical consumer household product. Utilities are not as competitive, due to their status as regulated monopolies. The large growth in demand and increasingly stricter environmental regulations are bringing an immediate need to innovate both for short term and long term systems. The challenge is to convey the importance of ICT investment to PUCs, despite a general lack of understanding often by commissions and by consumers of the ICT infrastructure behind electricity. Participants expressed the need to educate stakeholders on ICT and help them understand why investments could open up opportunities for greater benefits.

Infrastructure modularity that facilitates and plans for system upgrades can allow for smooth adaptation to new planning needs as the grid evolves. This type of investment need is difficult to convey to PUCs, as it is hard to quantify the benefits of this added flexibility.

Hardware/Network Challenges:

- Concern over competition with vendors of AMI due to a lack of interoperability standards was discussed among participants.
- Participants brought up the issues of the need for investments in hardware and network infrastructure, the lack of incentives to invest in new technologies, as well as regulatory requirements making upgrades and continued development cumbersome.

One of the major challenges is creating a modular network platform that would support communication and allow for innovation upgrades to easily be added to the system is the development of standards. The proper standards would facilitate modularity, flexibility, and innovation. For example, by having the hardware producers all creating their products with the same connection ports, this would allow for interchangeability. It would also allow the utilities to switch producer companies without having to update their whole platform. While a variety of standards are already being developed, no single standard is emerging. Participants discussed the need for clear leadership in standard development, evaluation, and adoption.

The challenges and opportunities for the hardware and network are specific to certain utilities both domestically and internationally. Knowing the major challenges and opportunities would be greatly facilitated by performing a gap analysis study on the industry as a whole. Continued convening of utility industry representatives and regulators is critical to setting standards and overcoming challenges. A full scale gap analysis will determine the major challenges and also determine what solutions have risen to the top.

Discussion on Software Needs and Development Challenges

The recent interdependencies of E-ITC are a result of advances in sensor, network and software technologies. New software is needed to meet the changing operational grid; however, software developers face a "chicken and egg" situation. The market for software is very thin and software developers are hesitant to invest in new technologies if the market demand does not exist. In addition, software developers are hesitant to invest in new products for control systems that may also replace existing product lines.[7]

Software tools are enabling the collection and use of grid and end use related data. Major software issues include the following: how should the utility invest in software systems to create cleaner metrics that will increase the understanding of the value of data, and the shift away from basic assumptions of existing grid planning and the limitations of traditional software for power grids. Finally, as the market for software is narrow, it is not attractive to invest in new software developments because the demand for new software is unclear. Due to the need for systems to undergo extensive trial and testing, it will take system operators some time to adopt new software technologies. [8]

Breakout Session C consisted of representatives from DOE, National Rural Electric Cooperative Associate, National Association of State Energy Officials, Edison Electric Institute, and Alstom Grid.

Key Questions for Discussion:

- What are the major gaps and challenges hindering the deployment of analysis methodologies, software tools, and metric for power grids to realize opportunities posed by the ICT-electricity convergence?
- Will the emergence of market-based or market-like methods such as Transactive Energy change the essential nature of utility software or just add new applications? What is the impact of customer-owned Distributed Energy Resources (DER) – should DER management be treated as a siloed application or be integrated with grid control?

Participants discussed how challenges in software technologies are a result of the increased interdependency between electricity and ICT infrastructure. For example, there can be challenges with funding to move software programs forward, though creating tools for vendors and utilities would facilitate project development. Another challenge is educating consumers about new technologies as consumer buy-in is essential for program adoption. On the distribution side, participants expressed concern about unbalanced production and demand of electricity, and the growing software needs for balancing on distribution networks. More efficient energy storage

[7] PNNL, "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology." Draft, April 2015. Pg. iii-iv

[8] PNNL, "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology." Draft, April 2015.

was mentioned as a potential solution. Finally, participants discussed challenges with pushing new technologies to the device level with current low bandwidth systems.

ICT is necessary for planning, as the grid is in transition, as it helps provide much-needed data and tools for resource planning. Participants expressed that ICT can facilitate interactions with customers to better consider what customers want before new energy systems and grids are planned. As these systems are heterogeneous and customer expectations vary, managing the system transition becomes difficult. One participant mentioned that pre-pay systems might have a high level of buy-in from customers as it would allow for more customer options and increased efficiency. The customer would pay the utility up front for the amount of electricity they are going to use. However, for this system to work, automation and interoperability are necessary.

Software/development Challenges:

- The discussion was focused around the different types of software, including market, operational and consumer software. Participants mentioned that operational software works best when two way communications are implemented as it allows for increased system awareness.
- Participants noted that interoperability challenges among software systems inhibit automation, as the software for each market is slightly different. At least one participant stated that developing software at the distribution level will require customer field conditioning.
- Participants discussed difficulties with adopting new technologies at the device level due to low bandwidth systems for operation technology and information technology.
- The utility industry expressed the need to understand what electricity customers want in order to create programs to focus on energy system planning. Without customer data availability, this becomes challenging.

Throughout the discussion, market, operational and consumer software systems were mentioned. The two main software systems discussed were operational and market software. One participant observed that the biggest impact for operational software was in implementing a two-way communications system to track outage information. The additional data, voltage thresholds, and changes in operational centers resulting from the upgrade greatly improved the ability of dispatchers to obtain information on power quality. Different software management systems have different levels of development when it comes to stakeholder engagement and infrastructure support. For example, one participant mentioned how market software is affected by each market's specific rules.

The connection between hardware and software often came up, especially in regards to the limitations that insufficient hardware and network infrastructure impose on software development. For example, Market Management Systems (MMS) have stakeholder processes to engage the needs of the system, while Distribution Management Systems (DMS) have less-developed processes, and often have less time to respond to requirements. Specifically, one participant noted that costs associated with ICT are likely to decrease for large scale systems and

MMS, however, costs will likely remain high for DMS. Along these lines, a second participant noted that smaller utilities are especially affected by prohibitive costs. The participants viewed the cloud as a reliable solution for smaller utilities who could not afford to store the data otherwise. Meter Data Management Systems (MDMS) that move data into the cloud were discussed as ways in which to facilitate the development of disaster recovery plans and information backup during outages. While the management of the data would exist within the utility, the cloud would allow data storage outside of the utility to reduce costs.

Discussion on Privacy & Security

As grid modernization efforts continue, cybersecurity risks associated with ICT must be mitigated. The market continues to develop cybersecurity solutions, but both cyber and physical security continue to be of concern. Connectivity to the internet on the one hand can exacerbate the problem, because the internet was not necessarily designed for the high level of security desired; and, yet, there is increasing pressure on utilities to make use of the internet for various purposes. On the other hand, technology can help isolate and resolve threats in a timely manner and minimize the extent of damage. Security requires multiple layers of defenses, and extensive processes and training.[9]

The Privacy and Security Breakout Session included representatives from DOE, Idaho National Laboratory, University of Pittsburgh, NextEra Energy, and the Utilities Telecom Council.

Key Questions for Discussion:

- How do we understand data confidentiality, privacy and security as distinct or overlapping in the realm of ICT? Are there varying burdens of responsibility, consumer engagement and jurisdictional involvement depending on those definitions?
- Is there anything new we are putting on the grid today that is not secure and if so, how do we deal with the security gaps in these and legacy devices and systems?

There are two major areas of focus for this discussion. The first involves data security problems that can result in privacy breaches, and the second is cybersecurity breaches on systems, which lead to operational impacts. In general, privacy is a legal compact about personal information, while security is concerned with system integrity. One participant mentioned that while both of these concerns are distinct, in practice, they are related. The electric utility industry has a handle on customer data privacy with policies in place to address this issue. It was also noted that there is a clear business case with privacy, as it is a well-known issue across information and communication technologies. However, there are still tensions between data privacy and data access. For example, one participant mentioned that, because markets do not have customer data until customers sign on with them, it is difficult to design technologies or systems in advance to meet their potential needs.

Utilities are far more concerned with cybersecurity breaches which could compromise the integrity of the grid. Business cases for cyber security are harder to develop and understand. One participant argued that having a completely "air-gapped" system (where there is no connectivity to an outward facing system) and being fully compliant with NERC's Critical Infrastructure Protection (CIP) standards are implausible extremes that do not necessarily bring the desired level of security. While the NERC CIP standards have brought awareness to the industry, one participant argued that cybersecurity is still an issue for distribution systems. Participants

[9] PNNL, "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology." Draft, April 2015. Pg. 5.8

discussed the need for best practices to be communication-specific, rather than just general security best practices.

Privacy/Security Challenges:

- There are two major types of data security challenges: 1) data security problems that can result in privacy breaches and 2) cybersecurity breaches on actual systems.
- Because industry is already fairly experienced with privacy concerns, the business case is easier to make in this regard, and detecting and solving the issues are easier. Cyber security was identified as more challenging to anticipate and/or fully understand in terms of the nature of a threat or attack.
- Participants recognized that compliance with NERC CIP (Critical Infrastructure Protection) is not the same as security, but it does help raise awareness about this issue.
- The introduction of more products with two-way communications was seen as a manageable challenge. Participants discussed the importance of both technological and procedural solutions.

Part of the discussion focused on vendors in the electricity ICT space. There is a benefit to having a diversity of vendors and suppliers who do encryption on their own, however it is important to check the robustness of encryption to make sure it is sufficient. At times, procurement personnel assume that devices from vendors are already protected, when this is not necessarily the case in all instances. Keeping an inventory of components was mentioned as an important step in managing cybersecurity threats and assuring compliance.

One participant noted that it can be difficult to determine whether a system disturbance is the result of a device failure or an actual attack. Encouraging more granular visibility over the system can also help with cyber security. There was concern over the ability of utilities to collect threat intelligence. Participants mentioned that programs and tools such as PNNL's Cybersecurity Risk Information Sharing Program (CRISP) can help with this challenge.

Conclusion

In brief, the Workshop was designed to inform the QER, which is an outward-facing document. It began with a presentation from PNNL on the framing document, which informed the topics for discussion during the expert panel. After a lunchtime keynote which discussed the importance of grid modernization and highlighted key ongoing state efforts, the participants were divided into groups. The four breakouts discussed data value, latency, and the need for data collection and analysis tools; hardware and network infrastructure; software needs and development challenges; and privacy & security. The Workshop concluded with a summary of the breakout sessions. The following research areas were highlighted.

Potential Research Opportunities

- The development of a robust architecture for electricity and ICT systems would facilitate grid modernization and data system interoperability and accessibility.
    - Due to the heterogeneity of electricity systems, interoperability needs to be considered among the various electricity system topologies and regulatory regimes.
    - Developing a roadmap for grid modernization with ICT systems, with honest evaluation and information transparency, could spur development.
- A robust systems information model that maps data collection, quality, modeling and analytics could advance grid analytics in order to help manage grid data needs for operations. An increase in quality and frequency of grid planning can facilitate increased certainty in order to ease the transition to a more diverse energy system.
    - The development and possible certification of test data sets can facilitate the validation and development of operational software for energy system and grid planning.
- Studying existing ICT investments in the electricity sector should provide valuable lessons learned for reliability and resilience over time.
    - When choosing among technologies, it is difficult to move past the issue of stranded assets. There is interest in a national gap analysis to assess which needs are not being met with existing network infrastructure and to probe utilities about their communications and networking issues.
- Development of tools for cybersecurity risk assessment and information dissemination could be useful for system planners. Quantifying measurable resilience, reliability, and safety metrics should include industry "buy in."

Policy Levers

- When determining policies that govern the electricity and ICT sectors, it is important to consider organizational dynamics, the flow of information, and best practices; continued discussions can facilitate an increased understanding between system operators and technology vendors.
- DOE could demonstrate leadership in promoting interoperability standards, by developing and/or facilitating the adoption of a standard, as a possible way to help focus efforts among the industry.
- There was interest in supporting a sustained and clearly-communicated public education campaign in order to help inform the public on the importance of investment in, and usefulness of, ICT in energy systems.

Technology Development Opportunities

- There are opportunities for demonstrations of ICT infrastructure and software systems that would be of critical value to utilities.

- The development of a modular network platform that allows for innovation could be facilitated with interoperability standards.
    - Standardized hardware ports and interfaces for AMI would be beneficial to promote technological advantages and/or prevent preferences for specific vendors.
- Research into the practicality, reliability, and costs of implementing cloud based storage systems could be beneficial.
    - Participants discussed the opportunities to use cloud based systems to store utility data, and mentioned that "cloud" computing and storage provides a great deal of opportunity to smaller municipalities and co-ops that do not have the resources to build those services in house.
- As products increasingly communicate with each other, one way to manage risk is for utilities to set and meet cybersecurity standards for each product they buy.
    - Participants noted that modifications to utility procurement guides would be particularly helpful, especially if focused on specific standards and suggestions for ensuring cybersecurity and privacy of distributed energy systems.

Appendix A: Meeting Agenda

Technical Workshop on Electricity and Information & Communication Technologies Convergence

Over the past two decades, electricity, Information and Communications Technology (ICT) infrastructures have become more interdependent, driven by a combination of factors including initial advances in sensor, network and software technologies, the need to provide higher levels of both wide-area and deep situational awareness regarding grid conditions, and the promise of enhanced operational efficiencies. While this convergence presents new vulnerabilities, particularly to cyber threats, it also is providing opportunities for new grid-associated value streams, enhanced system performance, and more options for consumer interaction with electricity systems. A better understanding of the current state of electricity and ICT interdependence will help inform analysis needs for the next installment of the Quadrennial Energy Review (QER).

The Office of Energy Policy and Systems Analysis at the U.S. Department of Energy will hold a technical workshop on electricity/ICT convergence, in order to elicit perspectives on the nature and scale of the challenges and opportunities it presents. This workshop will be held on **June 15, 2015** at the Metropolitan Washington Council of Governments at 777 North Capitol St NE, Washington, DC 20002. The purpose of the workshop will be twofold. First, the workshop will inform the completion of a PNNL white paper commissioned for the QER called "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology". Second, the workshop will elicit additional electricity and ICT research and policy analysis topics for potential examination within DOE, to be summarized in a report made publically available on the DOE website.

Even as new hardware and software tools are enabling the collection and use of ever more grid and end use energy related data, the landscape of electricity supply and demand is changing and posing more challenges to the grid (e.g., voltage stability problems associated with distributed PV at scale), and more work is needed to harness ICT capabilities in order to solve the rising challenges. Issues that need to be addressed include:

- Utility investments in hardware-connected ICT networks, software systems, data acquisition and management, and the associated processing architectures vary widely across the country; creating clearer and universally-accepted metrics that will increase the understanding of data value, latency requirements, and the high-value characteristics of analytic tools and network structures would pay dividends.

- Although advanced metering infrastructure (AMI) deployment continues to increase, and is projected to reach one-third of electric customers by 2015, many meter communication networks have often been designed to support energy usage reporting—but were not designed and built with sufficient bandwidth and latency capabilities to support other data gathering and usage requirements that could leverage the same infrastructure to support advanced distribution automation. Moreover, characteristics of the wireless mesh networks built to support metering functions may face resilience challenges and, therefore, have limited capabilities to be used in power restoration scenarios.
- To date, attempts to create interoperability standards, while extensive and needed to facilitate data representation and interchange, have not achieved sufficient traction in the US utility industry. A major reason for this is the lack of a contextual framework to define the interfaces at which these standards might be most usefully applied. The scope of data includes consumer behavior (and related social networking interactions) and market data for emerging distributed energy resource markets, data on quantifying end use equipment's (e.g. PV, EV, HVAC) ability to provide grid-relevant responses, in addition to grid operational and asset monitoring data.
- The use of traditional software for power grids is becoming problematic because the way the grid is evolving is moving away from the basic assumptions built into existing grid planning, management, and control tools. The emerging interdependence between natural gas and electric infrastructure and markets adds yet another dimension to this challenge. Software providers face a "chicken-and-egg" problem: the market for their products is relatively thin (confined to U.S. utilities), making them reluctant to invest heavily in developing new software until the demand is clear, while utilities want to wait until new solutions are tested and demonstrated before committing to buy them. This also applies to consumers who will make choices on purchasing equipment with enhanced ability to interact with the grid if the value proposition is clear for all participants.
- States and the Federal government could play a number of roles in addressing these challenges, including facilitating the standardization of business processes across the industry and supporting industry best practices. This would also enable the development of a reference architecture for grid-connected IT. Governments also could work with industry to invest in tools and technologies to harness the opportunities presented by the convergence of IT and electricity systems.
- Deployment of these new technologies across the grid is only enabled through a robust communications infrastructure to enable real-time situational awareness and control. This communications infrastructure will most likely be a mixture of private and public components and must be designed so it can be leveraged by multiple systems (e.g., AMI and advanced distribution automation) and modes of communication (e.g. RF, Wi-Fi, and PLC). This also highlights an additional interdependency that is emerging between communication networks and the electric power network that must be planned for and managed going forward.
- Within this fast-changing electricity/IT context, cybersecurity risks must be mitigated. The market continues to develop cybersecurity solutions, but assuring security of physical control systems on the grid continues to be of concern.

WORKSHOP DOCUMENTS

This workshop will inform the completion of the PNNL white paper "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology".

A separate document summarizing workshop discussions will follow.

AGENDA

9:30am – 9:45am: Welcome and framing of workshop goals, process, and outcomes.
Carol Battershell and Karen Wayland from the Office of Energy Policy and Systems Analysis

9:45am – 10:30am: Presentation on "The Emerging Interdependence of the Electric Power Grid & Information and Communication Technology" with audience Q&A.

10:30am – 10:45am: Break

10:45am – 12:00 am: Discussion Panel

Moderator: Dan Correa, OSTP Technology & Innovation Division, Senior Advisor

Steve Crout, VP, Government Affairs at Qualcomm

Matt Wakefield, EPRI, Director of Information and Communication Technologies (ICT) research.

Valentine A. Emesih, CenterPoint Energy, Vice President, Grid & Market Operations.

Susan Mora, Pepco Holdings, Federal Affairs Director.

12:00pm – 1:00pm: Lunch Keynote: Becky Harrison, GridWise Alliance CEO

1:00am – 2:30pm: BREAKOUT SESSIONS

Group A: Discussion on data value, latency, and need for data collection and analysis tools

Group B: Discussion on hardware and network infrastructure

Group C: Discussion on software needs and development challenges

Group D: Privacy & security

2:30pm – 2:45pm: Break

2:45pm – 4:00pm: Summary of Breakout Findings

4:00pm – 4:30pm: Open discussion of findings and research and policy needs and wrap-up

Appendix B: Summary of Questions Mapped to Panel and Breakout Sessions

Discussion Panel:

- How should policymakers, regulators, utilities, and ICT providers handle current and future investments as new opportunities arise and grid conditions and requirements change?
- What additional opportunities for new value streams and enhanced grid performance lay on the horizon as ICT capabilities are increasingly harnessed within electricity systems? What are potential unintended consequences?
- What kind of opportunities or emerging requirements are there for coordination across sectors (natural gas, water, etc.), with the growing ICT interdependence with electricity?
- What are key challenges - technological, regulatory or otherwise - that are restraining the development of these new ICT-driven applications and where is Federal action needed?

Breakout Session A: Discussion on data value, latency, and need for data collection and analysis tools

- What are the major challenges, opportunities, and solutions for the massively increasing data volumes with increasing deployment of sensors and metering infrastructure?
- Centralized data management and analytics, distributed, or both?
- Where do Cloud approaches fit with real time infrastructure operation?

Breakout Session B: Discussion on hardware and network infrastructure

- Should utilities continue to own communication infrastructure? Where do performance priorities and security outweigh shared infrastructure cost benefits?
- What are the major challenges, opportunities, and solutions for the design and sizing of communications networks to connect with electricity infrastructure?
- As the needs and opportunities driven by deployment of AMI and distribution automation (DA) become clearer, what are the best means for addressing concerns about stranded investments in legacy systems? What incentives might be most effective, for purposes of ensuring "right-sized" investment in utility communications networks—to support the evolving nature of operations, particularly at the distribution level?

Breakout Session C: Discussion on software needs and development challenges

- What are the major gaps and challenges hindering the deployment of analysis methodologies, software tools, and metric for power grids to realize opportunities posed by the ICT-electricity convergence?
- Will the emergence of market-based or market-like methods such as Transactive Energy change the essential nature of utility software or just add new applications? What is the impact of customer-owned Distributed Energy Resources (DER) – should DER management be treated as a siloed application or be integrated with grid control?

Breakout Session D: Privacy & security

- How do we understand data confidentiality, *privacy* and *security* as distinct or overlapping in the realm of ICT? Are there varying burdens of responsibility, consumer engagement and jurisdictional involvement depending on those definitions?
- Is there anything new we are putting on the grid today that *is not* secure and if so, how do we deal with the security gaps in these and legacy devices and systems?

Appendix C: Attendees

First Name	Last Name	Organization
Ethan	Rogers	ACEEE
But-Chung	Chiu	Alstom Grid
Lawrence	Jones	Alstom Grid
John	Hughes	Ameren Services
Valentine	Emesih	CenterPoint
Steve	Bieber	MWCOG
Kevin	Lynn	DOE
David	Meyer	DOE
Madeline	Press	DOE
Karen	Wayland	DOE
Jonathan	Cohen	DOE/EERE
Christin	Badylak-Reals	DOE/EPSA
Carol	Battershell	DOE/EPSA
Patrick	Brown	DOE/EPSA
Alice	Chao	DOE/EPSA
Christina	Cody	DOE/EPSA
Sandra	Jenkins	DOE/EPSA
Matt	McGovern	DOE/EPSA
Lara	Pierpoint	DOE/EPSA
Kelly	LeFler	DOE/EPSA
Andy	Bochman	DOE/INL
Jeff	Taft	DOE/Labs
Christopher	Irwin	DOE/OE
Alice	Lippert	DOE/OE
David	Ortiz	DOE/OE
Tao	Xia	Dominion
Aryeh	Fishman	EEI
Deana	Dennis	EPRI
Matt	Wakefield	EPRI
Walter	Johnson	FCC
Ladeene	Freimuth	Gridwise Alliance
Becky	Harrison	Gridwise Alliance
Joseph	Andersen	Information Technology Industry Council

Prakash	Chakravarthi	Machfu Inc.
Jeff	King	MWCOG
Stephen	Goss	NASEO
Joel	De Granda	Next Era Energy
Doug	Lambert	NRECA
Tony	Thomas	NRECA
Keith	Dennis	NRECA
Dan	Correa	OSTP Technology & Innovation Division
Susan	Mora	Pepco
Steve	Crout	Qualcomm
Dirk	Mahling	Seattle City Light
Luke	Bassett	U.S. Department of Energy
David	Tipper	University of Pittsburgh
Mike	Oldak	Utilities Telecom Council
Ernie	Lewis	Verizon