DEPARTMENT OF ENERGY

COMMUNICATIONS REQUIREMENTS OF SMART GRID TECHNOLOGIES

October 5, 2010

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I. Introduction and Executive Summary

As Energy Secretary Steven Chu has noted, "America cannot build a 21st Century energy economy with a mid-20th Century electricity system."[1] Transforming the current grid into a dynamic, resilient, and adaptable Smart Grid will be one of the biggest technological challenges of our times. The rewards, however, may be dramatic, enabling consumers to better control their electricity use, integrating the next generation of plug-in electric vehicles, increasing efficiency, and better harnessing renewable energy. The Smart Grid will be able to revolutionize electricity generation, delivery, and use in this nation by combining the two-way flow of electricity with the two-way flow of information. It will leverage the benefits of modern computing capabilities to process information about electricity usage more dynamically and enable adjustments in electricity usage to make our use of electricity more efficient and reliable.[2] Key to achieving these potential benefits is ensuring that the foundational technological needs of the Smart Grid are in place. Because the Smart Grid relies on the increased use of communications and information technology, sufficient access to communications facilities is critically important.

This report sets forth the findings of the U.S. Department of Energy (DOE) on the communications requirements of electric utilities and proposes specific recommendations for next steps to support these requirements. In order to analyze these requirements properly, this report will review the projected requirements of various components of the Smart Grid. The template used in this report is built upon work by the Federal Energy Regulatory Commission (FERC), augmented by the National Institute of Standards and Technology (NIST), which

[1] *See* "Secretary Chu Presents Smart Grid Vision and Announces $144 Million in Recovery Act Funding to Transition to the Smart Grid," Sept. 21, 2009, http://www.energy.gov/8030.htm; *see also* "Investing in Our Energy Future," Secretary Steven Chu, U.S. Department of Energy, Sept. 21, 2009, *available at*: http://www.energy.gov/media/Secretary_Chu_Grid_Week.pdf.

[2] *See* "Report to NIST on the Smart Grid Interoperability Standards Roadmap," Electric Power Research Institute (EPRI), 6, June 17, 2009.

identified six key priority functionalities of the Smart Grid: (1) advanced metering infrastructure; (2) demand response; (3) electric vehicles; (4) wide-area situational awareness; (5) distributed energy resources and storage; and, (6) distribution grid management.[3] Recognizing the need for quantifying communications requirements in order to assess the performance of various communications technologies, NIST and the Smart Grid Interoperability Panel (SGIP) initiated an effort in the context of the Priority Action Plan on Wireless Communications[4] to collect communications requirements for various Smart Grid applications. This effort has been undertaken by the OpenSG SG Communications Task Group and to date has compiled over 1400 functional and volumetric requirements for 18 different use cases.[5] In addition, SGIP also established other Priority Action Plans and Working Groups to address networking, data modeling, and security issues. Because of the dynamic and continually evolving nature of Smart Grid applications and technologies, our review represents a snapshot of where the technologies and requirements stand today, informed by the responses to the DOE RFI. A summary of our findings is provided in Appendix A.

a. Overview of Smart Grid Benefits and Communications Needs

Understanding the evolving communications requirements of electric utilities and other entities involved in the generation, transmission, and distribution of electricity will inform the development of the nation's Smart Grid policies. The Smart Grid will have many new

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[3] *See* "Smart Grid Standards Adoption: Staff Update and Recommendations," FERC, July 15, 2010, *available at*: http://www.ferc.gov/legal/staff-reports/07-15-10-smart-grid.pdf (naming four key priority functionalities); *see also* "Report to NIST on the Smart Grid Interoperability Standards Roadmap," Electric Power Research Institute (EPRI), June 17, 2009, *available at*: http://www.nist.gov/smartgrid/upload/Report_to_NIST_August10_2.pdf (adding two key priority functionalities to FERC's original four: advanced metering infrastructure and distribution grid management). The report to NIST also identified two cross-cutting areas, cyber security and network communications.

[4] *See* "PAP02: Wireless Communications for the Smart Grid," NIST Smart Grid Collaboration Site, http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP02Wireless.

[5] *See* "OpenSG Users Group," Open Smart Grid – OpenSG, http://osgug.ucaiug.org/UtiliComm/Shared%20Documents/Latest_Release_Deliverables/.

applications for consumers, manufacturers, utilities, and others, and it will be composed of many vast, interrelated systems. One of the key technology areas of the Smart Grid is integrated two-way communications, which allows for dynamic monitoring of electricity use as well as the potential for automated electricity use scheduling. DOE's overarching objective was to gather input on how current communications needs are being met and what the anticipated network requirements would be with the adoption of more Smart Grid technologies and Smart Grid applications.

The potential promises of the Smart Grid are numerous, including: (1) improved reliability; (2) increased physical, operational, and cyber security and resilience against attack or natural disasters; (3) ease of repair, particularly remote repair; (4) increased information available to consumers regarding their energy use; (5) increased energy efficiency along with the environmental benefits gained by such efficiency; (6) the integration of a greater percentage of renewable energy sources, which can be inherently unpredictable in nature; (7) the integration of plug-in electric vehicles; and, (8) a reduction in peak demand.

Many communications and networking technologies can be used to support Smart Grid applications, including traditional twisted-copper phone lines, cable lines, fiber optic cable, cellular, satellite, microwave, WiMAX, power line carrier, and broadband over power line, as well as short-range in-home technologies such as WiFi and ZigBee. The Smart Grid applications that might be built on such communications technologies include home area networks (HAN), and networks for wide area situational awareness (WASA), enhanced substation supervisory control and data acquisition (SCADA) systems, distributed generation monitoring and control, demand response and pricing systems, and charging systems for plug-in electric vehicles.

Utilities have employed certain Smart Grid and demand response applications for many years,[6] and these applications have traditionally used private communications networks. Utilities cited higher rates of survivability following a natural disaster,[7] the ability to maintain service throughout a utility's service territory,[8] the avoidance of prioritization of other services when recovering from outages,[9] and the cost of service[10] as reasons why commercial services could not adequately replace private networks. In addition, some utilities suggested that dedicated wireless spectrum may be advantageous to certain Smart Grid services.[11] DOE has explored these issues in more detail in this report.

Commercial service providers are increasingly partnering with utilities to provide communications for Smart Grid applications. Indeed, in many cases, commercial carriers have encouraged technological changes, such as the general movement toward integrated platforms and open standards for utility communications functions that have historically been proprietary. Commercial providers have thus facilitated opportunities for qualitatively better communications systems, even where utilities have ultimately opted for private networks.

It is important to note that while entities now deploying the Smart Grid may be able to estimate the communications requirements of their near-term implementations, future

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[6] Federal Energy Regulatory Commission, *Assessment of Demand Response and Advanced Metering*, 8, 65 (Dec. 2008), *available at*: http://www.ferc.gov/legal/staff-reports/12-08-demand-response.pdf.
[7] United Telecom Council, *Hurricanes of 2005: Performance of Gulf Coast Critical Infrastructure Communications Networks*, 2, 24 (Nov. 2006), *available at*: http://www.utc.org/fileshare/files/34/Research/white_papers/2005_-_UTC_-_HURRICANES_OF_2005_PERFORMANCE_OF_GULF_COAST_CIC_NE.
[8] Southern Company Services, Inc., Comments - National Broadband Plan Public Notice #2, GN Docket No. 09-47, 09-51, and 09-137, 15,21 (Oct. 2, 2009).
[9] Utilities Telecom Council, Comments - National Broadband Plan Public Notice #2, GN Docket No. 09-47, 09-51, and 09-137, 11, 24 (Oct. 2, 2009).
[10] Sempra Energy Utilities, Comments regarding the Implementation of Smart Grid Technology, GN Docket No. 09-47, 09-51, and 09-137, 13, 22 (Oct. 2, 2009).
[11] Utilities Telecom Council, Comments in response to the National Broadband Plan Public Notice #2, GN Docket No. 09-47, 09-51, and 09-137, 3, 24 (Oct. 2, 2009); Nat'l Rural Elec. Coop. Ass'n, Comments in response to the National Broadband Plan Public Notice #2, GN Docket No. 09-47, 09-51, and 09-137, 12, 14 (Oct. 2, 2009).

communications needs may be difficult to quantify due to the pace of evolution in grid technologies. Smart Grid technologies continue to evolve, and future applications of Smart Grid technologies may lead to both an increase and a qualitative change in communications requirements. The purpose of this report is to identify any systematic impediments that could hinder utilities' flexibility to make their own decisions as to how to meet the communications needs of the Smart Grid. This report therefore makes recommendations based on projections of future communications needs, with the goal of identifying potential roadblocks to implementation, be they regulatory, technological, or otherwise, and proposing Smart Grid deployment strategies that will avoid them.

b. Summary of Recommendations

As stated above, the evolution toward a Smart Grid is a major technological change of national scope and communications systems are one of the critical technological foundations of this change. Indeed, even taken alone, the communications requirements of the Smart Grid promise to fundamentally change how the electricity network employs communications technologies. Thus, it is not surprising that technological changes of this scope would necessarily require reassessments of some of the federal processes related to the implementation of communications technologies, particularly those that are wireless, because of the relatively prominent role that wireless technologies are likely to play in the Smart Grid. As evident by the work of the OpenSG SG Communications Task Group and the record developed in this proceeding, the communications requirements for the Smart Grid continue to require careful consideration in internal federal government discussions related to spectrum management and emergency network operations support, and they should also be considered in federally sponsored committees (FACAs) made up of representatives from industry that address issues of spectrum management and communications network reliability.

Because wireless communications will play such a key role in the Smart Grid, within the auspices of the larger federal agency effort to identify additional spectrum for wireless broadband, DOE will seek to work with both the Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA) to review possibilities for spectrum access to accommodate Smart Grid needs, either through sharing frequencies with others users, leasing spectrum, or other alternatives.[12] We note that, in order to conduct such a study, DOE will need additional input from the utility and communications industries to determine the spectrum requirements, including gaining a better understanding of the particular uses (*e.g*., mobile or fixed) for such spectrum.[13]

Additionally, because the experience base with Smart Grid technologies and the particular communications applications for such technologies is still developing, DOE may consider establishing an online, interactive clearinghouse for Smart Grid communications technology applications, including leveraging the work already underway by the OpenSG SG Communications Task Group.[14] This online clearinghouse – which may augment already existing government websites – would serve as a resource for utilities to share "lessons learned" in the Smart Grid context. In addition, it could include substantive information about the technologies (*e.g*., technology primers), as well as pointers to and information on existing federal

[12] *See* "Presidential Memorandum: Unleashing the Wireless Broadband Revolution," President Barack Obama, June 28, 2010, *available at*: http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.

[13] The NIST/SGIP Priority Action Plan on Wireless Communications that is currently informing the development of guidelines for the use of wireless technologies in the context of the Smart Grid will also inform the discussion.

[14] *See* "OpenSG Users Group," "OpenSG Users Group," Open Smart Grid – OpenSG, http://osgug.ucaiug.org/UtiliComm/Shared%20Documents/Latest_Release_Deliverables/.

programs (*e.g.*, priority access) that may be helpful to utilities and their suppliers as they implement Smart Grid technologies.

DOE welcomes additional input on all of these recommendations, which are discussed more fully in Section VI of this report.

II. Federal Government Smart Grid Initiatives

a. DOE Request for Information

On May 11, 2010, DOE published a Request for Information (RFI) in the Federal Register, seeking comments and information from interested parties to assist DOE in developing recommendations to facilitate review of the communications requirements for the Smart Grid.[15] The RFI elicited responses on nine broad areas of inquiry, including the current communications requirements of utilities, the best use cases for the Smart Grid, the recommended communications technology options for seeing the Smart Grid to fruition, and the capability of commercial networks to provide the communications services for the Smart Grid.

Reflecting the high level of interest in these issues, DOE received comments and reply comments from nearly fifty stakeholders in response to the RFI.[16] These comments were submitted by parties representing a wide range of interests, including: rural electric cooperatives, investor-owned utilities, major communications services providers, wireless equipment manufacturers, utility and telecommunications industry trade groups, and consumer advocates.

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[15] In part, DOE's effort was spurred by issues identified by the Federal Communications Commission's National Broadband Plan, at Recommendation 12.6.
[16] A list of commenters is provided in Appendix B.

In addition to seeking written comments, DOE conducted outreach efforts to solicit additional input on these issues and, in particular, to facilitate an open dialogue on these issues among interested parties. Following on the publication of the RFI, DOE held a public meeting on June 17, 2010, in Washington, DC. The event, attended by approximately seventy-five members of the public, provided an opportunity for leading business, technology, and regulatory experts to share their knowledge, experiences, and views on the technological, economic, and regulatory factors that would affect the communications requirements of the Smart Grid. [17] Highlights of the discussion included the challenges of providing electricity in diverse geographic areas at a level of reliability far beyond most consumer services and the methods utilities have employed to do so, the emerging wired and wireless communications technologies being rolled out by leading telecommunications providers, and the next generation of applications and services already being tested by the nation's utilities.

The extensive public input received by DOE on Smart Grid communications requirements has provided the basis for this report. The findings in this report provide a baseline for review of these critical communications issues and identify potential recommendations to remove possible impediments to the successful implementation of Smart Grid technologies. DOE fully anticipates that the interaction between DOE and the various Smart Grid stakeholders will continue upon the publication of this report, through seminars, public-private working groups, and other outreach and collaboration efforts.

[17] A list of panelists is provided in Appendix B.

b. Other Federal Government Smart Grid Initiatives

Congress set in motion the federal government's efforts to modernize the electricity grid in Title XIII of the Energy Independence and Security Act of 2007 (EISA).[18] Title XIII stated that it is the policy of the United States "to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth," and to achieve a variety of specific goals, including the development and deployment of real-time metering and "smart" devices, the integration of distributed energy resources such as renewable energy, and improved management of both energy supply and demand.[19] Congress gave DOE primary responsibility for coordinating and funding Smart Grid efforts, along with reporting back to Congress on the progress of Smart Grid Development.[20]

DOE has made significant progress to date in supporting development of the Smart Grid. DOE has issued 100 awards totaling $3.4 billion to stimulate the development of the Smart Grid,[21] as part of the American Recovery and Reinvestment Act of 2009.[22] This funding has led to tangible results, such as the installation of two million smart meters across the nation.[23] DOE published a Smart Grid primer in 2008, which explored the need for Smart Grid implementation, as well as its challenges and opportunities.[24] In addition, as directed by EISA, DOE's Assistant Secretary of the Office of Electricity Delivery and Energy Reliability established the Smart Grid

[18] Pub. L. No. 110-140, 121 Stat. 1492.
[19] EISA § 1301.
[20] *See* EISA §§ 1302-1304, 1306.
[21] *See* "Recovery Act Smart Grid Investment Grant Awards," U.S. Department of Energy, http://www.oe.energy.gov/recovery/1249.htm .
[22] Pub. L. No. 111-5, 123 Stat. 115.
[23] Liz Meckes, "2 Million Smart Meters and Counting," *EnergyBlog*, Aug. 31, 2010, *available at*: http://blog.energy.gov/blog/2010/08/31/2-million-smart-meters-and-counting.
[24] "Smart Grid," Federal Energy Regulatory Commission, http://www.ferc.gov/industries/electric/indus-act/smart-grid.asp. Subsequent reports can be retrieved from the following website: "The Smart Grid: An Introduction," U.S. Department of Energy, http://www.oe.energy.gov/SmartGridIntroduction.htm.

Task Force, the mission of which is to insure awareness, coordination and integration of the diverse activities within DOE and elsewhere in the Federal Government related to Smart Grid technologies, practices, and services.[25] Also chaired by DOE's Assistant Secretary of the Office of Electricity Delivery and Energy Reliability is a Subcommittee on Smart Grid policy, established by the National Science and Technology Council's Committee on Technology.

It is important to note that Smart Grid initiatives extend far beyond DOE. A number of other federal agencies are contributing significant efforts to the development of the Smart Grid. Specifically, under EISA, the Federal Energy Regulatory Commission (FERC), an independent regulatory agency, has the responsibility to institute rulemaking proceedings to adopt standards necessary to insure "functionality and interoperability in interstate transmission of electric power, and regional and wholesale electricity markets."[26] FERC has historically had authority over the rates, terms and conditions of transmission and wholesale sales in interstate commerce, as well as reliability standards for the bulk power system in the United States, and EISA built upon these duties in the context of the Smart Grid.[27] DOE is also working with NIST, which has primary responsibility to coordinate development of protocols and model standards for information management within the Smart Grid,[28] in order to achieve interoperability of Smart Grid devices and systems. NIST and the Smart Grid Interoperability Panel (SGIP) established several Priority Action Plans, namely the Priority Action Plan on Wireless Communications,[29] in

[25] EISA § 1303(b).
[26] EISA § 1305(d). EISA directs FERC to initiate rulemakings for adoption of Smart Grid standards when it determines that the standards identified in the NIST framework development efforts have sufficient consensus. On July 16, 2009, FERC issued a Policy Statement on Smart Grid Policy that acknowledged that EISA does not make any such standards mandatory and gave FERC no new authority to enforce such standards. Smart Grid Policy Statement, 128 F.E.R.C. ¶61,337, at 61,060–359 (Jul. 16, 2009).
[27] "Smart Grid," Federal Energy Regulatory Commission, http://www.ferc.gov/industries/electric/indus-act/smart-grid.asp.
[28] *See* EISA § 1305(a).
[29] The priority action plan is *available at*: http://www.nist.gov/smartgrid/upload/2-Guidelines_for_Wireless.pdf.

order to investigate communications technologies and how well they support the various Smart Grid communications requirements. DOE is also working with NIST, the Department of Homeland Security, and state, local, tribal, and commercial sector cyber security officials to ensure the implementation of secure communications systems.[30] In addition, the FCC examined the communications needs of various sectors of the economy in the recently released National Broadband Plan (NBP),[31] and the ongoing work resulting from the NBP's recommendations will inform the communications technology choices made as the Smart Grid is built out. Finally, although beyond the scope of this review, it should be noted that the states have a vital role to play in the development of Smart Grid policy, and many state public utility commissions (PUCs) have been actively examining issues related to the Smart Grid, such as securing appropriate investments from utilities in Smart Grid technology and ensuring that consumers benefit from such investments.[32]

III. Communications Requirements of Smart Grid Applications

The Smart Grid will likely employ a variety of communications technologies, many of which will have multiple applications. A particular technology's characteristics can best be reviewed in the context of where it may be used within the Smart Grid. Based on work previously completed by both NIST and FERC, as well as the comments received from stakeholders, DOE has determined that there are six functional categories into which most, if not all, Smart Grid applications fall: advanced metering infrastructure, demand response, wide-area situational awareness, distributed energy resources and storage, electric transportation, and

[30] While cyber security is outside the scope of this report, there are extensive resources available on the topic. *See, e.g.*, "Guidelines for Smart Grid Cyber Security (NISTIR 7628)," Smart Grid Interoperability Panel – Cyber Security Working Group, *available at*: http://csrc.nist.gov/publications/PubsNISTIRs.html#NIST-IR-7628.
[31] "The National Broadband Plan: Connecting America," Federal Communications Commission, http://www.broadband.gov.
[32] *See* EISA § 1307 for specific requirements of PUCs in regard to Smart Grid development.

distribution grid management. The following sections analyze the communications requirements of each of these application categories and highlight the relative merits of various technologies in meeting these requirements.[33] Note that multiple applications may in some cases be able to function on the same network, and accurately estimating the requirements for a given communications technology as applied to the Smart Grid would require the various requirements of component uses to be considered together.[34]

a. Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) allows utilities to collect, measure, and analyze energy consumption data for grid management, outage notification, and billing purposes via two-way communications.[35] While a predecessor technology called Automatic Meter Reading (AMR), still prevalent and in use today, uses one-way communications to accomplish meter readings primarily for monthly billing purposes, AMI can be leveraged to provide consumers with historical energy consumption data, comparisons of energy use in similar households, dynamic pricing information, and suggested approaches to reducing peak load via in-home displays.[36] For certain applications, such as near-real-time data feedback and full energy management analysis, AMI will likely be required. AMI networks, however, still require a significant investment to build out fully, and are not required to enable most consumer-facing

[33] Additionally, much work in this area is underway, and a more detailed technical review of the functional and volumetric communications requirements has been catalogued by the OpenSG SG Communications Task Group. *See* "OpenSG Users Group," Open Smart Grid – OpenSG, http://osgug.ucaiug.org/UtiliComm/Shared%20Documents/Latest_Release_Deliverables/

[34] The development of synchrophasors for wide-area situational awareness and transmission monitoring, for instance, may have among the most stringent requirements of any of the functionalities discussed in this report, and may therefore be a main driver of Smart Grid communications requirements.

[35] DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).

[36] Note that dynamic pricing includes a variety of data points, including time of use (TOU), critical peak pricing (CPP), peak time rebates (PTR), and real-time pricing (RTP), among others.

applications.[37] Several alternatives to AMI are therefore discussed below in the context of home and office applications.

i. Technologies for on-premises networking

The vision for Home Area Networks (HANs) is to connect the smart meter, smart appliances, electric vehicles, and on-site electricity generation or storage, both for in-home displays, controls, and data uploads, and to allow for automated modulation of energy loads during peak demand periods.[38] For most in-home applications, communications needs are modest. The amount of data being transferred at any one moment will likely consist only of the instantaneous electricity use of each device, measured in watts, and thus commenters state that the bandwidth needs to accomplish this will likely fall between 10 and 100 kbps per node/device.[39] This requirement could scale up quickly, however, for large homes or office buildings, so the networking technology selected should be suitably scalable as well.[40] Because in-home applications are primarily intended to inform consumers of their energy use, such applications are not likely to be considered "mission critical," and the required level of reliability may fall into the 99 percent to 99.99 percent range, with the possible exception of demand response and distributed generation, discussed later in this paper.[41] Likewise, latency, in this

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[37] The National Association of State Utility Consumer Advocates asserts that, "[r]atepayers will be expected to shoulder much of the investment expense, as they will be the arguable beneficiaries . . . . infrastructure investments should be demonstrably effective, widely adopted, with benefits inuring to the consumers, as a general principle, not just to the utilities and other corporate entities seeking to leverage the technology." National Association of State Utility Consumer Advocates, Comments - Request for Information on Smart Grid Communications Requirements, 2-3 (July 12, 2010).

[38] Baltimore Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).

[39] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 19 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[40] Tropos Networks, Comments - Request for Information on Smart Grid Communications Requirements, 13 (July 12, 2010).

[41] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 19 (July 12, 2010).

case the delay between the moment instantaneous energy use is measured and the moment at which that information is reported on the display, is not critical. UTC and Verizon assert that the ideal latency for in-home applications should be between 2 and 15 seconds.[42] Voluntary reduction in energy use, one of the anticipated outcomes of in-home displays, does not depend on instantaneous information, so clearly much higher latencies might be reasonable. Reasonable timeliness of information is still important, however, if consumers are expected to change behaviors based on the information. Furthermore, such delays may affect the value of information for upstream applications that depend on the information, such as demand response.

The communications needs of on-premises applications can be handled by low-power, short-distance technologies designed with consumer uses in mind. Technologies currently being used or considered for on-premises communications include 2.4 GHz WiFi, the common 802.11 wireless networking protocol, ZigBee, which is based on the wireless IEEE 802.15.4 standard and is a close technological cousin of the ubiquitous Bluetooth protocol, and HomePlug, a form of powerline networking that carries data over the existing electrical wiring in the home.[43] While the industry has not yet converged on a standard, the predominant technology used in installations today is ZigBee, followed by HomePlug.[44] ZigBee offers the advantage of being wireless while requiring very little power, and both technologies, despite being relatively low-bandwidth, are cost-effective and flexible, although each is accompanied by their individual

[42] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 19 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7(July 12, 2010).

[43] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 16 (July 12, 2010).

[44] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 31-32 (July 12, 2010). For examples of utilities currently using these technologies, *see, e.g.*, Pepco Holdings, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010) (noting the use of ZigBee); Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010) (noting that its Smart Meters support ZigBee communications to enable future connectivity to in-home devices, but that this functionality is not active and will require additional investment).

challenges.[45] These characteristics will be critical if the HAN is to communicate with myriad smart appliances, large and small, in the home,[46] which will in turn allow various consumer applications, such as remote monitoring and control of a home's thermostat or appliances via smart phone.[47]

Ultimately, a key goal for in-home networking communications may be interoperability between Smart Grid communications technologies.[48] While a thorough analysis of the various benefits and drawbacks of network technologies is beyond the scope of this report, it is worth noting that a number of stakeholders have recommended standardizing on the use of the internet protocol (IP) for Smart Grid communications.[49]

As noted above, in-home applications can leverage AMI networks, but can also exist separately from such utility-driven systems.[50] For instance, both traditional meters and AMR meters can be connected to the HAN via bolt-on technologies. For example, products may leverage a website working in concert with a WiFi-enabled sensor that reads traditional meters to

[45] Worthy of mention is another short-range networking standard under development by the IEEE, the IEEE 802.15.4g Smart Utility Networks (SUN) standard. The standard will be for outdoor low data rate, wireless, smart metering utility networks and is targeted for use in the 902-928 MHz band.

[46] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 33 (July 12, 2010).

[47] Note that while the focus of this discussion is on in-home applications, users of commercial buildings will also benefit from similar applications. In many commercial buildings, BACnet is the communications protocol used for building automation and control networks. BACnet was developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Although traditionally a wired technology, BACnet is now available using short-range wireless networks (*e.g.*, ZigBee). The use of a wireless platform allows for more flexibility in the placement of the BACnet sensors and controls.

[48] *See* Comments of Roy Perry, Director of Strategic Assessment at Cable Labs, Transcript of Public Meeting at 123-124, *available at*: http://www.gc.energy.gov/documents/PublicMeetingTranscript_June17.pdf.

[49] *See, e.g.*, Honeywell, Comments – Request for Information on Smart Grid Communications Requirements, 7-8 (Undated); Hughes Network Systems, LLC and Inmarsat Inc., Comments – Request for Information on Smart Grid Communications Requirements, 4-5 (July 12, 2010); Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 17 (July 12, 2010); Silver Spring Networks, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010); Telecommunications Industry Association, Comments - Request for Information on Smart Grid Communications Requirements, 4 (July 26, 2010).

[50] *See* CTIA Wireless Association, Comments – Request for Information on Smart Grid Communications Requirements, 3-4 (July 12, 2010).

allow consumers to monitor their energy use, compare their energy consumption with neighboring homes, and learn how to improve energy efficiency.[51] Other approaches will involve a more extensive suite of hardware and software products to enable additional Smart Grid consumer applications. For example, consumers might view their home energy consumption and electricity pricing in real-time via a wall-mounted device, control certain appliances and thermostats remotely via smartphone, and shut off conventional appliances through the use of ZigBee-connected outlets.[52] As the National Cable & Telecommunications Association notes, these applications, whether they use an existing meter or a smart meter, allow consumer-facing functions without the need for any communications technologies beyond those already installed in an Internet-connected home.[53]

ii. Technologies for hand off of information from the premises

The utility network would have four tiers in the Smart Grid architecture: (1) the core backbone – the primary path to the utility data center; (2) backhaul distribution – the aggregation point for neighborhood data; (3) the access point – typically the smart meter; and, (4) the HAN – the home network.[54] Communications between the smart meter and the other devices on the HAN was discussed in the previous section. The next step in the network is to carry this information away from the premises to an aggregation point, which will often be a substation, a utility pole-mounted device, or a communications tower.[55] Bandwidth requirements will be

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[51] *See, e.g.*, Microsoft Hohm, http://www.microsoft-hohm.com.

[52] *See*, Comments of Adrian Tuck, CEO of Tendril, Inc., Transcript of Public Meeting at 22-25, *available at*: http://www.gc.energy.gov/documents/PublicMeetingTranscript_June29.pdf (describing Tendril's Smart Grid technology); *see also* Tendril – Smart Grid Products, Tendril, http://www.tendrilinc.com/products/.

[53] National Cable & Telecommunications Association, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

[54] *See* Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 30-31 (July 12, 2010).

[55] The aggregation point may also be at a transformer. *See* "Echelon, T-Mobile Team on Smart Meter Contracts" Press Release, April 22, 2009, *available at*:

similar to those for in-home networking, in the 10-100 kbps range per device in the home or office, although this will scale up quickly if appliance-level data points as opposed to whole-home data are transmitted to the aggregation point.[56] As with on-premises communications, UTC and Verizon suggest that the required latency will be in the range of 2 to 15 seconds for some types of data traffic, and reliability requirements will be in the 99 percent to 99.99 percent range.[57] The availability of emergency power backup at the meter will not be critical because in-home metering services are not needed during outages, although backup power at aggregation points in varying sizes is used depending on specific needs.

Determining the appropriate communications technologies for AMI applications will depend on the level of AMI functionality desired. Early AMI installations traditionally had been serviced by power line carrier (PLC) technology,[58] which is used for relaying meter data and other internal communications over a utility's power lines.[59] PLC is still the most common conduit for AMI functions in rural, low-density areas, where wireless coverage is less available.[60] While PLC is low cost and can reach all utility customers in a territory, it has very

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http://www.pmbventures.net/index.php?option=com_content&view=article&id=1073:echelon-t-mobile-team-on-smart-meter-contracts-&catid=34:grid&Itemid=54.

[56] For an analysis of bandwidth requirements by neighborhood density, *see* Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 9 (July 12, 2010).

[57] *See, e.g.*, Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 16 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[58] *See, e.g.*, Meeker Cooperative Light and Power – Minnesota, Comments – Request for Information on Smart Grid Communications Requirements, 3 (June 28, 2010); Mille Lacs Energy Cooperative, Comments - Request for Information on Smart Grid Communications Requirements, 3 (June 30, 2010).

[59] Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 3 (Undated).

[60] Lower Colorado River Authority, Comments - Request for Information on Smart Grid Communications Requirements, 2 (July 12, 2010) ("In many parts of LCRA's rural service territory, LCRA telecommunication systems are the only service available."); *see also* National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010); Baltimore Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 36 (July 12, 2010). As noted by UTC in a recent report, "[i]n many cases, a utility's service area may be only fully covered by multiple mobile communications carriers. If the utility cannot find a provider willing to perform the role of 'general contractor' or integrator, it has to contract with multiple entities in order to leverage

low bandwidth (often below 20 kbps) and requires hopping of the PLC signal around transformers by using a bridge, for instance via a wireless connection, that bypasses this grid element that would normally scramble the PLC signal.[61] The bandwidth provided by PLC may not be adequate to meet the requirements of real-time AMI at the per-device level (up to 100 kbps per device). Many AMI deployments, particularly in urban areas, use 900 MHz wireless mesh networks.[62] In a mesh network, each endpoint has the ability to function as a router, and connectivity between meters and collection points is typically achieved via a dedicated network using unlicensed radio spectrum, run either by the utility or a subcontractor.[63] Fixed point-to-multipoint radio frequency networks, also known as star, radial, or spoke networks, are also common in current installations, using licensed spectrum and communications towers or other sources of elevation.[64] Commenters note that it is quite possible that greater demands for bandwidth will emerge over time,[65] meaning that new technologies may be required to connect homes and businesses to aggregation points. Some industry representatives contend that traditional PLC and wireless mesh may well be replaced by broadband communications such as

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commercial services, making efficient operations of service work difficult." Utilities Telecom Council, "Utility Communications Needs: Key Factors That Impact Utility Communications Networks," Sept. 2010. As noted by several commercial carriers, one option is to fill in network holes with other technologies, such as fixed wireless or wireless mesh. Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010); AT&T Inc., Comments – Request for Information on Smart Grid Communications Requirements, 14 (July 12, 2010).

[61] Silver Spring Networks, Comments – Request for Information on Smart Grid Communications Requirements, 3-4 (July 12, 2010).

[62] San Diego Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 9 (July 12, 2010); Baltimore Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

[63] Silver Spring Networks, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010); AT&T Inc., Comments – Request for Information on Smart Grid Communications Requirements, 5-6 (July 12, 2010).

[64] On-Ramp Wireless notes that for various reasons, star networks may be preferable to mesh networks for Smart Grid applications. *See* On-Ramp Wireless, Inc., Comments - Request for Information on Smart Grid Communications Requirements, 14-18 (July 12, 2010).

[65] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010); Ambient Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 2 (Undated) ("Many utilities operate radio systems, which have been selected as a compromise between coverage, reliability scale and their lower cost. These systems in operation today meet many of the current AMI requirements, but will not be able to handle the flood of data expected of a true smart grid.").

the IEEE 802.16e mobile WiMAX standard, broadband PLC,[66] or next-generation cellular technologies.[67]

The backhaul of information from aggregation points to the utility typically functions over private networks. Backhaul can be accomplished using a variety of technologies, such as fiber, T1, or microwave networks.[68] Star networks may also be used for backhaul of data from the hub to the utility,[69] often utilizing commercial wireless connectivity.[70]

To enable more advanced applications such as real-time pricing, which would bill for electricity at the current rate, a two-way communications system is required, and lower latency may be necessary as well.[71] The backhaul of aggregated data from an aggregation point to a utility is likely to have bandwidth requirements in the 500 kbps range.[72] Current AMI networks may be strained by such applications.[73] In fact, many AMI networks only have intermittent connectivity to the utility, as data is aggregated at a neighborhood node and only sent to the utility periodically.[74] An open question remains, however, whether such two-way

[66] *See*, the ITU-T G.9960/9961, G.9972, or IEEE P1901 standards. Notably, these are broadband standards for PLC, which has historically been a low-bandwidth communications medium.

[67] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 15 (July 12, 2010).

[68] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010). *See also* East Central Energy-Minnesota, Comments – Request for Information on Smart Grid Communications Requirements, 2 (July 12, 2010) (noting the use of 700 MHz radio for backhaul).

[69] Silver Spring Networks, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

[70] *See, e.g.*, Comments of AT&T Inc. at 5-6; Comments of Pepco Holdings, Inc. at 2, 10 (indicating its trial of EVDO services for its AMI network, as well as its current unlicensed mesh network used for AMI); Comments of Southern California Edison at 6 (indicating that commercial networks will be leveraged for backhaul from its 5.3 million AMI meters); Comments of Southern Company Services, Inc. at 3-4 (indicating that the utility has deployed narrow band communications infrastructures in the 900 MHz band, and has also utilized commercial services with some success).

[71] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).

[72] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).

[73] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 15, 17 (July 12, 2010).

[74] Honeywell, Comments – Request for Information on Smart Grid Communications Requirements, 4 (Undated).

communications must be truly "real-time"; such consumption data may be of more use if limited to the HAN, which can act locally to manage energy consuming devices and appliances,[75] with only aggregated data being backhauled to the utility, perhaps on an hourly or less frequent basis. Indeed, in the opinion of many experts, backhauling real-time or near-real-time data from the billions of devices that may eventually be connected to the Smart Grid would require not only tremendous bandwidth, but also data storage capacities well beyond the current installed base, making the undertaking economically infeasible.[76]

b. Demand Response

One of the most common steps taken by utilities toward creating a smarter power grid has been the increasing implementation of demand response (DR). Demand response is the reduction of the consumption of electric energy by customers in response to an increase in the price of electricity or heavy burdens on the system. Demand response can significantly reduce peak loads.[77] Demand response programs can be implemented at both the wholesale and retail levels. Wholesale demand response programs are typically operated by independent service operators (ISO) and regional transmission organizations (RTO),[78] while retail programs are run by utilities.

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[75] Honeywell, Comments – Request for Information on Smart Grid Communications Requirements, 3 (Undated).

[76] *See* Comments of Lynne Ellyn, Senior VP and CIO of DTE Energy, Transcript of Public Meeting at 105, *available at*: http://www.gc.energy.gov/documents/PublicMeetingTranscript_June17.pdf; Comments of Roy Perry, Director of Strategic Assessment at Cable Labs, Transcript of Public Meeting at 51-52, *available at*: http://www.gc.energy.gov/documents/PublicMeetingTranscript_June17.pdf.

[77] For example, Lake Region Electric Cooperative-Minnesota, estimates that its demand response program reduces peak demand by 10 to 15 percent, depending on the season. Comments of Lake Region Electric Cooperative-Minnesota at 2.

[78] *See, e.g.*, San Diego Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 17-18 (July 12, 2010).

Demand response programs have been implemented across the country, but FERC estimates that such programs tap only 25 percent of the market for such services.[79] At current rates, demand response would reduce U.S. peak demand by 38,000 megawatts (MW) in the year 2019; if the existing mix of programs were to expand, however, to include regions that do not currently have DR programs, and participation reached levels representing today's best industry practices, the potential impact of demand response programs would be significantly higher, reaching 82,000 MW, or 9 percent of U.S. peak demand.[80]

Retail demand response can take various forms. With direct load control (DLC), customers agree to have their consumption of electricity automatically curtailed at times of peak load, via the powering down of appliances.[81] A more advanced version of DR is automated DR, which allows on-premises equipment to respond to dynamic conditions on the grid, shifting load consumption in near-real-time. The DR device can be an energy management system or a smart appliance, the latter referred to as "prices to devices" because it sends pricing information directly to the appliance, which responds accordingly without an explicit control command. Another variation of DR would have the electricity usage at the premises offloaded to distributed generation sources at the customer's location. A fourth variation of demand response is the delivery of dynamic pricing to the customer. With such pricing, the customer has the option to curtail electricity use manually.

[79] *See* "National Action Plan on Demand Response," Federal Energy Regulatory Commission, June 17, 2010, at 1, *available at*: http://www.ferc.gov/legal/staff-reports/06-17-10-demand-response.pdf.
[80] "A National Assessment of Demand Response Potential," Federal Energy Regulatory Commission, June 2009, at 27, *available at*: http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf (National Assessment).
[81] *See, e.g.*, Steele-Waseca Cooperative, Comments - Request for Information on Smart Grid Communications Requirements, 3 (June 28, 2010) (noting that it has "an extensive demand response system that directly controls end use devices such as water heaters, AC, heat and irrigation. The system is capable of reducing peak demands between 10-15% depending on season of year.").

The communications requirements of DR applications may vary depending on the sophistication of the system desired; at its most basic (for example, DLC), DR simply sends a shut-off command to an appliance, such as an air conditioner or hot water heater, and bandwidth requirements for this type of application are quite low and are easily handled by today's infrastructure. Some experts have estimated future bandwidth requirements to range from 14 kbps to 100 kbps per node/device, [82] similar to AMI, or perhaps even higher.[83] Other experts have estimated bandwidth requirements to be lower than AMI, on the order of 120 bytes per message.[84] If next-generation DR systems work in tandem with AMI, however, the total bandwidth requirements of DR would likely be at least as high as AMI. At least as important as bandwidth for DR purposes is consistent latency.[85] Estimates of the latency requirements of DR fall into a wide range, from as little as 500ms,[86] to 2 seconds,[87] up to several minutes.[88] The difference in perspective of various experts on this issue is likely due to the various potential applications of DR. Certain iterations of DR may be considered "mission critical," in that failure to reduce energy use will lead to a system overload situation.[89] If DR is truly intended to avert imminent emergencies such as an overload, relatively lower latencies may be necessary. If DR

[82] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 16 (July 12, 2010); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010).

[83] GE Digital Energy, Comments - Request for Information on Smart Grid Communications Requirements, 5 (Undated) (noting that message size may range from 50 bytes to several thousand bytes).

[84] Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[85] GE Digital Energy, Comments - Request for Information on Smart Grid Communications Requirements, 5 (Undated) ("While high bandwidth may be necessary the driving need is high reliability low latency messages that enable real time control.").

[86] Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[87] Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 1010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 16 (July 12, 2010).

[88] Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

[89] East Central Energy-Minnesota, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).

is used as a load balancing tool, however, the responsiveness of the system may not be critical, and thus latency could be higher. Either way, because utilities using DR will likely depend on it as a grid management tool, reliability will be important, and experts have provided estimates of reliability ranging from 99 percent to 99.99 percent level.[90] The delay of a significant number of DR commands due to high latency would greatly impact effectiveness of the system. Several commenters note that unlike AMI and certain other Smart Grid functions, DR is likely to be implemented only on the order of 30 to 35 days per year, corresponding with periods of peak energy usage.[91] As with AMI, demand response systems typically do not need back up power, as the load management functions of demand response are not necessary if the electrical system is not operational.[92]

Communications technologies capable of providing these services include standard paging systems or PLC, sometimes not connected to AMI systems at all. Communications would be passed along to the in-home network, which could utilize the ZigBee networking protocol or others to distribute commands to appliances and devices.[93] Other implementations of DR may use more modern communications technologies, such as broadband (via cable, DSL, fiber, etc.), next-generation cellular such as LTE, WiFi, or WiMAX.[94] Using such higher

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[90] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 16 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010); Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010).

[91] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[92] *See* Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 10 (Undated).

[93] Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

[94] Honeywell, Comments – Request for Information on Smart Grid Communications Requirements, 4 (Undated).

bandwidth systems will allow for two-way communications and the implementation of more time-sensitive applications.

c. Wide-Area Situational Awareness

With increasing demand on the power supply system, as well as the need for improved reliability, prevention of power supply disruption is one of the key goals of the Smart Grid. Because of the inherently interconnected and interdependent nature of the grid, improving wide area monitoring and situational awareness is necessary to achieve this objective.[95] A disturbance in the power supply in one area can quickly translate into a widespread problem, with cascading and deleterious consequences.[96] Additionally, information about the power supply in neighboring areas can help utilities optimize the economic operation of the grid. Wide area situational awareness (WASA) refers to the implementation of a set of technologies designed to improve the monitoring of the power system across large geographic areas – effectively providing grid operators with a broad and dynamic picture of the functioning of the grid.

Synchrophasors are one of the major new wide area measurement technologies being deployed. Although synchrophasor technology is being incorporated into other Smart Grid technologies,[97] the chief kind of synchrophasor deployment uses phasor measurement units (PMUs).[98] PMUs provide precise voltage and current phasor measurements – sampling as

[95] *See* North American SynchroPhasor Initiative, www.naspi.org.
[96] *See* "Smart Generation and Transmission with Coherent, Real-Time Data," by Bakken, Bose, Hauser, Schweitzerr, Whetehead, and Zweigle, *available at*: http://gridstat.net/publications/TR-GS-015.pdf.
[97] *See* "Smart Generation and Transmission with Coherent, Real-Time Data," by Bakken, Bose, Hauser, Schweitzerr, Whetehead, and Zweigle, at 8. *available at:* http://gridstat.net/publications/TR-GS-015.pdf. (noting that while stand alone PMUs were, until recently, the only devices that used synchrophasor technology, "[t]oday, synchrophasor technology is also found in meters, protective relays, and fault recorders, which dramatically lowers the cost of implementing synchrophasor-based control and protection strategies").
[98] Through the use of Recovery Act funds, DOE is funding the installation of over 800 PMUs, which once installed will cover most of the country. *See* "2010 Strategic Plan," Office of Electricity Delivery & Energy Reliability, 17-18, June 2010, *available at*: http://www.oe.energy.gov/DocumentsandMedia/OE_StrategicPlan_061010_web.pdf.

frequently as 60 times per second – with time stamps synchronized to a common clock.[99] The frequency of the readings, coupled most importantly with the fact that readings from disparate locations can be time-tagged and compared to form an aggregate snapshot of the state of the power supply at any one time, enable real-time wide area monitoring of the power system. Data from synchrophasors are sent to phasor data concentrators, and then subsequently distributed to end users for various power monitoring applications.

According to the commenters – many of whom have begun implementing synchrophasor technology – synchrophasors have a long list of specific benefits, including, among others, obviating the need for construction of additional transmission lines,[100] facilitating integration of intermittent and renewable resources, and improving system modeling and planning.[101] Synchrophasors also assist with contingency analysis, which analyzes security through simulating the effect of removing equipment, and post-event analysis of power disturbances. Notably, synchrophasors will not supplant SCADA systems.[102] The focus of synchrophasors is widespread grid situational awareness, whereas SCADA systems will continue to be used for local monitoring and control, and synchrophasors may be used as a backup mechanism in the event that local control and management technologies fail.

The North American Synchro-Phasor Initiative (NASPI) is a coordinated effort by the electric power industry, with support from DOE and other government agencies, to create a

[99] *See* "Smart Generation and Transmission with Coherent, Real-Time Data," by Bakken, Bose, Hauser, Schweitzerr, Whetehead, and Zweigle, at 8. *available at*: http://gridstat.net/publications/TR-GS-015.pdf; Alcatel, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010); Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 7 (Undated).
[100] DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).
[101] Bonneville Power Administration, Comments – Request for Information on Smart Grid Communications Requirements, 3 (Undated).
[102] "Design Aspects for Wide-Area Monitoring and Control Systems," by Zima, Marek *et. al.*, Proceedings of the IEEE, 1, May 2005; "EIPP Real-Time Dynamics Monitoring System," by Parashar, Manu *et. al.*, 1, Consortium for Electric Reliability Technology Solutions, November 21, 2005.

nationwide network of synchrophasor deployments and, as a result, deployments are proceeding apace. For example, GRE estimates that within five years all of its substations will have synchrophasors, and Bonneville Power Authority states that it will have them at "many substations."[103] Additionally, Florida Power & Light notes that, as distributed generation becomes more ubiquitous, synchrophasor deployments will also increase.[104] Alcatel adds that PMUs may also be deployed at "a few transmission towers in the future."[105]

The communications requirements of synchrophasors vary depending on the nature of data being transmitted.[106] For real-time monitoring and control, latency requirements are very low. Alcatel suggests that the maximum latency for these applications is 20 milliseconds,[107] although UTC and Avista states that it is below 200 milliseconds.[108] For post-event, historical data, low latency is less imperative.

In terms of data requirements, Florida Power & Light notes that phasor measurement data will be continuous, rather than variable.[109] UTC and Avista estimate that synchrophasors will

[103] Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 6 (Undated); Bonneville Power Administration, Comments – Request for Information on Smart Grid Communications Requirements, 3 (Undated).
[104] Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).
[105] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).
[106] For a detailed explanation of the types of synchrophasor data characterized according to latency, accuracy, and other technical quality of service requirements, *see* "Data Bus Technical Specifications for the North American Synchro-Phasor Initiative Network (NASPInet)," (2009) Department of Energy at 3.1.2.
[107] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).
[108] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 25 (July 12, 2010); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 1020).
[109] Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

require between 600 kbps and 1500 kbps.[110] GRE characterizes synchrophasors as requiring "high speed, high throughput communications," pointing specifically to the IEC standard 61850, which is applicable for these types of communications.[111] Over time, with the proliferation of devices, the increased use of distributed generation, and the introduction of new applications for phasor data, the aggregate bandwidth demands will increase.[112]

Reliability requirements for synchrophasors are stringent. Bonneville Power Authority puts PMUs in its highest service class, which "requires circuit availability of 99.93 percent and a functional availability of 99.98 percent."[113] To achieve this level of reliability, Bonneville Power Authority states that its "most critical microwave paths must meet a one-way availability of 99.99995 percent which equates to being out of service for 16 seconds a year."[114] Bonneville Power Authority notes further that it achieves these requirements through "the use of frequency-diversity microwave radios."[115] It also notes that it uses its own fiber SONET network for PMU usage, although it "see[s] good potential for the use of the modified Ethernet system."[116] In

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[110] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 25 (July 12, 2010); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010).

[111] Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 7 (Undated); Bonneville Power Authority, Comments – Request for Information on Smart Grid Communications Requirements, 6-7 (Undated) (noting that PMUs will be moving from the current requirement of 128 kbps to 256 kbps per circuit).

[112] Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[113] Bonneville Power Authority, Comments – Request for Information on Smart Grid Communications Requirements, 4 (Undated); *see also* Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 25 (July 12, 2010); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 1020) (stating that the reliability for synchrophasors is 99.999-99.9999 percent).

[114] Bonneville Power Authority, Comments – Request for Information on Smart Grid Communications Requirements, 4 (Undated).

[115] Bonneville Power Authority, Comments – Request for Information on Smart Grid Communications Requirements, 4 (Undated).

[116] Bonneville Power Authority, Comments – Request for Information on Smart Grid Communications Requirements, 3 (Undated).

terms of backup power, UTC and Avista note that synchrophasors should have a 24-hour supply.[117]

There are several communications network technologies for networking synchrophasors. They include: fiber optics, microwave, and even broadband over powerline (BPL).[118] The NASPInet architecture envisions a private Wide Area Network, consisting of Local Area Networks, using open network architecture "to allow the addition of future functionality and the replacement of hardware without disruption" to normal operation.[119]

There is abundant information in the relevant technical literature on standards and quality of service requirements for synchrophasors. While these technical issues are beyond the scope of this report, it is clear that these parameters are still evolving. Given the stringent technical requirements for these types of communications, however, the issue relevant for our inquiry is how supporting the stringent communications needs for these devices will impact the way in which utilities meet the communications requirements for other Smart Grid devices. That is, to the extent that the increasingly ubiquitous implementation of synchrophasors is driving the utilities to ramp up and invest in low latency communications platforms, the communications needs for synchrophasors might be coupled with, or drive, the communications choices for other Smart Grid technologies. At this time, the implementation of synchrophasors is still in the relatively nascent stage and it is therefore not possible to do a more detailed analysis. This issue, however, is one worthy of continued exploration and review.

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[117] Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010).

[118] *See* "The Future of Power Transmission," Horowitz, Phadke, and Renz, IEEE Power & Energy (Mar./Apr. 2010) at 35.

[119] "Data Bus Technical Specifications for North American Synchro-Phasor Initiative Network (NASPInet) (2009) at 6-2.

d. Distributed Energy Resources and Storage

One of the promises of the Smart Grid is better and more uniform integration of distributed energy resources (DER) into the grid, most notably on-grid renewable energy sources.[120] In some markets, distributed renewables are already experiencing tremendous growth.[121] As DER becomes a more significant percentage of the energy supply, for instance under state renewable portfolio standards (RPS),[122] reliable communications will be required to monitor and effectively used these resources. DER, however, extends beyond renewable energy, and may include electric vehicle batteries, combined heat and power (CHP), uninterruptible power supplies (UPS), utility-scale energy storage (USES) and community energy storage (CES).[123] While the focus is often on these smaller-scale applications, the control of larger distributed generation sites, for instance commercial-scale wind turbine farms, will also require new communications to tie them into existing communications systems, as they are often located in remote locations, far from existing utility infrastructure.[124]

These new energy technologies will require a grid very different from today's uni-directional system. The energy flow will be multi-directional, from utility to home, home to utility, or even home to home, and there will inevitably be greater variability in the energy

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[120] Examples of DER renewable energy sources include photovoltaic (PV) cells at residences, or PV cells and wind turbines at commercial and industrial locations. *See* Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).

[121] *See* San Diego Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010). (noting that SDG&E experienced a 68 percent increase in its residential net energy metering program in 2009).

[122] For more information on state RPS, *see* "States with Renewable Portfolio Standards," U.S. Department of Energy, http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm.

[123] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010); Grid Net, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 8 (July 12, 2010).

[124] Bonneville Power Administration, Comments – Request for Information on Smart Grid Communications Requirements, 3 (Undated).

supply.[125] Renewable electricity generation is variable by nature, and is likely to be even more unpredictable when operated on a small scale. Due to this more complex control situation, effective communications technologies will be critical in DER applications. One required technology will be real-time net metering, which will precisely measure the electricity drawn from the grid minus the energy provided to a home or office by energy sources on the premises. Perhaps even more significantly, when excess on-site energy production flows back into the grid, utilities will need to effectively allocate that energy using communications technologies that provide information on instantaneous electricity generation at points around the grid. Utilities may even build into their systems the capacity to do short-term DER generation projections based on weather and the time of day. Additionally, more sophisticated applications of DER may incorporate the "microgrid" concept, in which the Smart Grid will allow the "islanding" and balancing of distributed resources with local energy loads.[126] Such systems will likely require additional communications capabilities, as they will require point-to-point communications with a patch into the utility's central communications system.

According to UTC and Avista, the bandwidth required for DER will be along the same lines as that required for AMI, *i.e.* 9.6 kbps to 56 kbps,[127] with this bandwidth requirement allocated per individual distributed source.[128] The increasing use of DER will mean that there will be multiple energy sources feeding the distribution grid at multiple locations, complicating

[125] Motorola, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 12 (Undated).
[126] *See* San Diego Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).
[127] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 17 (July 12, 2010); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010).
[128] Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

service restoration efforts.[129] The opinions on required latency differ, however, starting as high as 15 seconds.[130] Other estimates suggest that latency will need to be in the 300 milliseconds to 2 second range,[131] although at least one commenter noted that a latency of 20 milliseconds would be needed during faults when protection devices are switching.[132] To effectively and safely use DER, reliability will need to be in the 99 percent to 99.99 percent range and security should be high, according to commenters.[133] Several commenters also mentioned the need for backup power in the range of one hour.[134] Backup power during an outage, however, is arguably less critical during for DER applications, as DER sites with sufficient energy generation to assist in the restoration of power could likely power themselves.

Some experts have suggested that AMI systems currently in development will be able to support the integration of DER into the grid, for instance through the use of ZigBee or other HAN technologies, as discussed in the AMI section above.[135] For large-scale operations, greater capabilities will be required, and the Bonneville Power Administration has suggested that it will

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[129] Motorola, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (Undated).

[130] Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[131] Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 17 (July 12, 2010).

[132] Motorola, Inc. Comments – Request for Information on Smart Grid Communications Requirements, 11 (Undated).

[133] Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010); *see also* Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[134] Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 2, 2010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 17 (July 12, 2010).

[135] *See, e.g.*, Baltimore Gas & Electric Co., Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010).

need significant incremental point to point microwave capacity.[136] Southern California Edison noted that satellite technology may also be appropriate.[137]

e. Electric Transportation

The mass-marketing of electric vehicles (EVs) holds much promise in regard to emissions reductions and energy independence, but it also poses a significant management challenge to utilities across the country. The ability to provide sufficient electricity supply for such vehicles will depend in large part on the ability to effectively manage supply and demand, a core benefit of the Smart Grid. It is unlikely that many utilities, for instance, could currently provide the peak capacity required to charge a significant number of EVs at the same time of day (*e.g.*, the after work hours of 5 p.m. to 7 p.m.).[138] EVs present new opportunities as well, however, in that they offer the potential to function as an energy storage device, thus playing a unique role in balancing demands on the Smart Grid. EVs can absorb excess supply during periods of low demand and feed that energy back into the grid when necessary. Selecting the appropriate communications technologies to allow for the effective integration of EVs into the grid will be critical.

i. Specific challenges and opportunities presented by Electric Vehicles

As noted above, one of the significant concerns related to EV use is the potential for large increases in peak demand. In addition, however, the charging of EVs will need to be coordinated so as not to overload single transformers in a neighborhood. A high current EV charger could

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[136] Bonneville Power Administration, Comments – Request for Information on Smart Grid Communications Requirements, 7 (Undated).

[137] Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

[138] *See* Comments of Becky Blalock, Senior VP and CIO of the Southern Company, Transcript of Public Meeting at 22-23, *available at*: http://www.gc.energy.gov/documents/PublicMeetingTranscript_June17.pdf.

represent the equivalent of one or two additional homes drawing on a transformer.[139] Likewise, plugging numerous EVs into multi-car public charging facilities will require appropriate load distribution. As with in-home charging, public charging will need to match supply and demand, potentially with even more speed and accuracy than in-home charging, as vehicle owners will likely wish to avoid a long delay in the initiation of the EV charging cycle. Having effective communications technologies will be critical to achieve the optimal result.

Communications technologies will also be useful for billing purposes. In one model, "electric usage roaming" will allow electricity use to be billed back to a customer's utility bill, much like roaming on cellular phones works today.[140] Billing of such electricity use, however, might also be accomplished via the use of a credit card, and utilities may need to agree on their preferred method.

While meeting the energy needs of a large fleet of EVs will no doubt be a challenge, EVs may also play a role in accommodating the peaks and valleys in electricity demand. The high-capacity battery packs of EVs can be used as a buffer for the grid, mitigating generation variability associated with intermittent resources, such as wind and solar, and absorbing "excess" generation during certain periods of the day, such as the middle of the night, or at key locations on the distribution system.[141]

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[139] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 17 (July 12, 2010).

[140] *See* Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).

[141] San Diego Gas & Electric, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).

ii. Communications needs presented by Electric Vehicles

The successful rollout of EVs will demand reliable, two-way communications networks.[142] In addition to certain levels of bandwidth, latency, reliability, and security, EVs present an additional requirement not required in most Smart Grid applications, namely mobility. Because most EVs will likely charge at a variety of locations, including their home premises, office parking lots, and other public or private locations during long-distance travel, it will be important to maintain compatibility of communications technologies. The requirements for EV communications will not be all that different from other home applications, however, and many of the same communications technologies will likely be used. It is estimated that the bandwidth required for both load balancing and billing purposes will be between 9.6 kbps and 56 kbps,[143] although for effective demand response system integration, the 100 kbps bandwidth noted previously for DR applications may be a good target. Estimates of latency requirements provided by commenters ranged from 2 seconds to five minutes,[144] and the discrepancy is likely due to whether billing was viewed as the main purpose or whether DR applications were factored into the estimate. Experts believe that the security of EV communications, for instance to avoid disclosure of a vehicle's location to or unauthorized discharging by third parties, should be

[142] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 17-18 (July 12, 2010).
[143] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).
[144] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010); Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

relatively high.[145] Experts noted that reliability should be moderately high, in the 99 percent to 99.99 percent range, as with other demand response applications.[146]

At the EVs home charging location, many of the same communications technologies used for AMI and DR, as discussed above, can be used. ZigBee or another low-bandwidth in-home networking method such as power line carrier could connect the EV and/or charger to the home network, and information could be sent to and from the neighborhood concentrator or utility via a mesh network, cellular, or other technology.[147] Of note, backup power likely will not be critical, as charging will not take place during an outage. In fact, as noted above, the EV itself may serve as backup power not only for its own communications equipment but also the premises and potentially critical applications on the Smart Grid.

Charging at public locations will pose additional communications considerations, due to the added elements of remote billing and charging outside the footprint of a utility's service area. For billing purposes at public locations, commercial wireless providers, which have good penetration in transit corridors and offer more than sufficient capabilities to communicate billing information, may be a good match.[148] Furthermore, because EV charging may take place outside of an EV owner's home utility area, interoperability is a prime concern, and as such, private networks may be at a disadvantage.[149] One possible scenario for public charging may be to layer

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145 Grid Net, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).
146 Grid Net, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010); Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).
147 *See* DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 12 (July 12, 2010).
148 Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 18 (July 12, 2010).
149 AT&T Inc. Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010).

commercial cellular services on top of whichever communications services are selected to assist in the balancing of electricity loads. To enable charging from a standard 120-volt socket rather than just specially-designed high-voltage charging stations, the communications technology for EV applications will likely need to be on-board the vehicle. For this reason, the use of a standard traditionally used for home networking, such as Zigbee, should be scrutinized carefully to ensure it is a viable option for all charging scenarios.[150] There may well be a need for multiple on-board communications systems, but having an industry-wide standard for all vehicles would likely be preferable.

f. Distribution Grid Management

i. Distribution automation

Historically, there has been little "intelligence" in the distribution side of the electric grid.[151] Distribution automation (DA) allows utilities to remotely monitor and control assets in its distribution network through automated decision-making, providing more effective fault detection and power restoration.[152] As explained by the National Rural Electric Cooperative Association, "DA includes control center-based control and monitoring systems, such as distribution SCADA or distribution management systems, and distribution automation field equipment, ranging from remote terminal units to intelligent electronic devices such as circuit

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[150] Qualcomm notes that cellular connectivity, which is already embedded in many vehicles, may allow for rapid proliferation of EVs. Qualcomm Incorporated, Comments - Request for Information on Smart Grid Communications Requirements, 13 (July 12, 2010).
[151] *See, e.g.,* American Public Power Association, Comments – Request for Information on Smart Grid Communications Requirements, 15 (Undated). (noting that "[t]he transmission system is monitored more closely than most distribution systems through SCADA systems and the modern generation of solid-state relays being deployed.")
[152] Baltimore Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 2 (July 12, 2010).

breakers, reclosers, switches, capacitors and transformers that can be remotely monitored, if not also remotely controlled or operated."[153]

The primary function of distribution substations is to reduce voltage levels to consumer levels. They also, however, act to isolate potential faults, so that they do not adversely affect other portions of the grid. DA will offer new functionality, incorporate alarming and automated feeder switching, which will enable improved fault detection, isolation, and restoration (FDIR), which in turn will help reduce the frequency and duration of customer outages.[154] DA achieves these goals first by providing notification of the whereabouts of circuit trouble to repair crews with much greater accuracy than previously possible, and then by sectionalizing faulted circuits so that fewer customers are impacted by circuit trouble.[155] Finally, DA allows utilities to employ autorestoration to provide power through an alternate circuit.[156] Other benefits of DA include improved capacitor bank and voltage regulator control, which helps maintain circuit voltage and reduces energy waste, as well as the communication of fault oscillography data, which helps system operators find and clear faults and electrical system planners design improvements.[157]

In most, if not all, cases, distribution automation represents one of the least latency-tolerant smart grid applications, with requirements for less than 1 second of latency for alarms and alert communications and sub-100 milliseconds for messaging between peer-to-peer nodes

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[153] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 4, fn. 6 (July 12, 2010).
[154] Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).
[155] DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010). *See also* Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 13 (Undated).
[156] Verizon, Comments – Request for Information on Smart Grid Communications Requirements, 5-6 (July 12, 2010).
[157] DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010). *See also* Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 13 (July 12, 2010).

inside RF mesh configurations.[158] The maximum latency for certain more latency-tolerant DA applications will not exceed two seconds.[159] Bandwidth requirements will be in the range of 9.6 kbps – 100 kbps, and the required level of reliability will be 99 percent to 99.999 percent.[160] As these functions are only required when there is electricity available, backup power is not required.[161]

Utilities have or will use a variety of communications technologies to provide DA functionality, and many utilities provided specific examples of their implementations of DA in our record. For instance, Florida Power & Light will leverage its AMI network for DA.[162] Pepco is in the process of building an unlicensed wireless mesh for both AMI and DA communications.[163] Southern has used its proprietary SouthernLINC Wireless for DA.[164] According to the National Rural Electric Cooperative Association, the most common backhaul communications media being used for DA is cellular, followed by unlicensed 900 MHz spread spectrum, but it notes that most cooperatives would prefer to use licensed radio frequencies for

[158] Silver Spring Networks, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010).
[159] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).
[160] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 20-21 (July 12, 2010).
[161] *See* Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 20-21 (July 12, 2010).
[162] Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).
[163] Pepco Holdings, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 10 (Undated).
[164] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).

DA if it were not for the lack of spectrum availability in the 150 to 750 MHz range.[165] Another potential option for DA applications is satellite technology.[166]

ii. Substation automation

In order to monitor and control the function of the grid, utilities install Supervisory Control and Data Acquisition (SCADA) equipment at each switching station and substation. SCADA provides voltage and current measurements at critical grid nodes every two to four seconds.[167] SCADA systems require minimal latency. As Southern notes in its comments, latency must be low "to optimize polling performance and prevent communications 'front ends' from timing out."[168] Southern asserts that its operating companies require latency levels of less than 100 milliseconds for command and control applications like SCADA.[169] Florida Power and Light noted that latency can have differing impacts depending on the particular SCADA application. For instance, while delays during normal operations reduce momentary "situational awareness and control, delays during a life-critical situation involving high-voltage lines" are more deleterious.[170] While bandwidth requirements for SCADA-like operations may grow with Smart Grid deployments, traditional SCADA systems are not bandwidth-intensive.[171] The

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[165] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 10-11 (June 28, 2010).
[166] Hughes Network Systems, LLC and Inmarsat Inc., Comments – Request for Information on Smart Grid Communications Requirements, 8 (July 12, 2010).
[167] Comments of Great River Energy at 6; Comments of National Rural Electric Cooperative Association at 6.
[168] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).
[169] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).
[170] Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 21 (July 12, 2010).
[171] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010).

reliability requirements of SCADA are high.[172] As SCADA equipment is at all substations, its coverage requirements are coextensive with the utility footprint.[173]

Currently, some SCADA systems use licensed spectrum exclusively, while others use combinations of licensed and unlicensed spectrum. For example, Great River Energy developed a private network using leased licensed spectrum. Its network is IP to the transmission substation using a wireless DOCSIS modem operating on 700 MHz spectrum, supplementing this configuration, and extending its coverage in particularly rural areas, with unlicensed 900 MHz spectrum. GRE notes that it uses the unlicensed network because it is more economic than the leased spectrum alternative, while rural deployments minimize the likelihood of problems due to interference from other spectrum users.

Additionally, satellite services are also used to meet the communications needs of SCADA systems in remote or rural locations. As Hughes Network Systems and Inmarsat note in their comments, one way that has been used to buttress the reliability of satellite services for SCADA applications is to back up a primary Ku- or Ka- band service, which is vulnerable to rain fade, with L-band service, which is not subject to rain fade.[174] While satellite service is limited in its bandwidth capabilities, its advantage over other wireless services is that it has universal coverage. As a result, one of the major concerns expressed by utilities about the mismatch in

[172] Southern California Edison, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 12, 2010).
[173] Exelon, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).
[174] Hughes Network Systems, LLC, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

coverage areas between utilities and commercial providers for supporting Smart Grid deployments, is alleviated. That said, latency can be an issue with satellite technology.[175]

In terms of communications requirements, one of the factors that favors wireless technologies is that substations are inherently hazardous electrical environments. Because of the possibility of ground potential rise (GPR), which creates problematic currents in the ground with the potential to damage conductive materials in the vicinity, wireline technologies need often expensive and complex protection at substations.[176] Fiber optic communications are used for this reason as well. As with other Smart Grid applications, the SCADA equipment industry is moving towards IP-enabled networks.[177]

iii. Fleet management by Automatic Vehicle Location

Another management application that may allow for significantly enhanced functionality is Automatic Vehicle Location (AVL). The ability to track and direct vehicles in the field to locations needing repair is a critical need, but one which does not necessarily require next generation telecommunications services. Current commercial carrier services have provided adequate mobile data services for mobile applications, which include complementary mobile voice communications to improve "dispatch to vehicle" and "vehicle to vehicle"

[175] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 19 (July 12, 2010); *see also* American Petroleum Comments, Comments – Request for Information on Smart Grid Communications Requirements, 12 (July 12, 2010). (noting that "[i]n many instances, latency is simply too high for pipeline leak detection and other applications that require frequent polling for optimal performance.")
[176] Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 2 (Undated); Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 9 (July 12, 2010).
[177] Southern Company Services, Inc. Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).

communications.[178] Because the efficient routing of vehicles is critical to restoration of services, AVL generally requires relatively low latency and high reliability, as well as broad coverage and high security.[179] While data intensive, AVL only requires a minimum of information to actually be sent to any given vehicle: only 50 bytes of data is typically sent in each AVL message.[180] To provide for communications in large service areas, utilities may consider equipping vehicles with routers with the capability to route both voice and data to the currently available communications technology, such as cellular, private radio, or satellite.[181]

iv. Video surveillance

With the implementation of Smart Grid technologies, and the increasing number of assets deemed critical by NERC, utilities anticipate that their needs for video surveillance will increase.[182] Many of the utility commenters cite video surveillance capability as a core communications requirement.[183] For example, GRE anticipates that each substation will have video surveillance capabilities. This represents a significant investment – over 700 substations for GRE. Other parties add that video surveillance capabilities will also be at all offices and

[178] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 7, 12 (July 12, 2010); Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).
[179] Southern Company Services, Inc, Comments – Request for Information on Smart Grid Communications Requirements, 22 (July 12, 2010).
[180] *See* National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).
[181] Hughes Network Systems, LLC and Inmarsat Inc., Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010).
[182] Over the past several years, the security requirements for utility facilities have increased significantly. *See* NERC Critical Infrastructure Protection requirements.
[183] Exelon Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010); Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 5(Undated); Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010); *see* American Public Power Association, Comments – Request for Information on Smart Grid Communications Requirements, 15 (Undated).

storage locations.[184] Indeed, video is just one of the communications tools used for required security systems.

As with other video applications, the bandwidth requirements for video surveillance are high.[185] Additionally, given that video surveillance is used for security applications, reliability is an important requirement as well.[186] Commercial service providers routinely provide video surveillance capabilities.[187]

IV. Key Concerns of Utilities

Based on our review of the record, there are several issues that cut across different functions of the Smart Grid that are of critical importance in determining how utilities will meet the communications needs of the Smart Grid. These include: (1) maintaining the reliability of Smart Grid communications networks through measures that ensure continuity of service; and, (2) the adequacy of access to radio spectrum for wireless services to support Smart Grid technologies. Each of these topics is discussed below.

a. Reliability

As has been noted throughout, one of the most significant benefits of Smart Grid technologies is to increase the reliability of the electric power grid. As a result, and quite understandably, in selecting among alternatives for the Smart Grid communications needs, utilities do not want to introduce any elements that could potentially compromise reliability. The

[184] Exelon Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).
[185] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010).
[186] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 10 (July 12, 2010).
[187] Honeywell, Comments – Request for Information on Smart Grid Communications Requirements, 9 (Undated).

most-discussed issues in the comments regarding reliability were back up power for communications services, priority of service in the event of either an outage or congestion, and overall communications network design and management. These issues will be discussed in turn.

i. Backup power

Lack of sufficient backup power is one of the most significant reservations voiced by utilities as a basis for their preference for using their own communications networks rather than commercial networks to support Smart Grid technologies. APPA reports that many utility facilities, in addition to being able to withstand extreme weather conditions, have backup power for 72 hours.[188] Southern states that "[a]ll sites must have batteries with an absolute minimum capacity of eight hours and a generator with on-site fuel capable of powering the site for several days."[189] And, notably, the back-up power needs of utilities can be even more substantial depending on site and application. As UTC explains, "[s]ome remote utility sites have propane tanks with enough fuel to power the site for weeks."[190] These stringent back-up power needs lead many utilities to come to the view that commercial networks do not have the capabilities needed for Smart Grid technologies. Some utilities offered data to support this view. For

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[188] American Public Power Association, Comments – Request for Information on Smart Grid Communications Requirements, 17 (Undated); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 2, 2010). (noting in its experience, that "much of the carrier infrastructure is not sufficiently hardened to withstand typical utility operating environments, extreme weather conditions, and independence from AC power."); Great River Energy, Comments – Request for Information on Smart Grid Communications Requirements, 8 (Undated). (noting that its "communications systems have a minimum of 72 hour generator backup in order to allow for black start capabilities"); *see also* Edison Electric Institute, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).
[189] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 26 (July 12, 2010); *see* Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010) (noting that "utilities have extensive emergency situation requirements which necessitate power back-up capabilities that might not be found in many carrier options.").
[190] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 12 (July 12, 2010).

example, Northeast Utilities System conducted a study across all of the different communications platforms it uses and it found that, in one year, "[p]rivate services were down 3 times fewer hours than leased services."[191]

Many of these utilities' concerns center particularly on wireless networks. In its comments, NRECA sets forth a short list of proposed improvements to commercial services, which, if implemented, would significantly increase the likelihood of commercial carriers to meet utilities' communications needs. Included among NRECA's list is the requirement that "back-up power at all cell sites [be] maintained for several days if power is interrupted due to a major event."[192] At the same time, commercial carriers insist that they have sufficient backup power. For example, AT&T asserts that "over 99% of [its] wireless sites are engineered with reserve batteries and/or permanent generators. [I]ts switching centers are typically equipped with redundant permanent generators with local fuel supply to allow greater than 4 days of run time. With regular refueling, these generators can maintain power at a location virtually indefinitely until commercial power is restored."[193] Verizon explains the great lengths it has gone to in order to ensure that its communications networks are reliable. It notes, among other preventative measures, that its "network personnel have the ability to re-route traffic dynamically . . . to address outages at a specific location to make the networks more resistant to the impact of

[191] Northeast Utilities System, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010).
[192] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 13 (July 12, 2010).
[193] AT&T Inc., Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).

a local weather emergency or disaster" and that it maintains portable cell sites, powered by generators, "that can replace or enhance network coverage and capacity . . . ."[194]

In addition to the other challenges related to provisioning increased backup power, there may be some logistic or regulatory issues related to backup power at the local level as well. For example, Alcatel Lucent notes that "[t]here may also be local regulations, such as the storage of fuel for a back-up generator on the roof of a building where a carrier base station is located, that make it difficult for the carrier to comply with extended off-grid operations requirements."[195]

These back-up power issues warrant further study. As the record in this proceeding demonstrates, there is generally a gap between the utilities' and commercial service provider industries' relative assessments of the sufficiency of the back-up power capabilities in commercial networks. It may be that discussions over back-up power sufficiency are best negotiated at the commercial level. As noted earlier in this report, the concept of one-size-fits-all does not work when determining the appropriate communications technologies for Smart Grid applications. This is likely true for back-up power as well – what is sufficient for one type of deployment may be unacceptable for another deployment. At the same time, perhaps there is some systematic way to address this issue. For example, commercial providers could submit to some type of outside certification process that would provide the necessary assurances to utilities. Even so, there may be some situations in which the level of back-up power required means that it may not be economic for commercial providers to provide particular

[194] Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 12 (July 12, 2010).
[195] Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 19 (July 12, 2010).

communications services.[196] To the extent that parties have suggestions for next steps on these issues, we welcome further input.

ii. Priority of service

Another concern that utilities noted nearly universally as a basis for their reluctance to use commercial services for Smart Grid communications applications was the need – particularly during an emergency – to have priority access over consumers.[197] Priority access can be achieved through several means. In the commercial world, Service Level Agreements (SLAs) are often used to commit a communications service provider contractually to a certain level of service. As Avista noted, particularly for critical core communications, service "should be highly redundant and tied to enforceable SLAs that ensure high availability and prioritization of critical applications traffic."[198] Utility commenters also voiced concerns about the inherent limitations to commercial contracts for priority of service.[199] BGE noted particularly that SLAs are not sufficient because, according to BGE, "[t]he current business model for commercial

[196] *See* Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 28 (July 12, 2010).

[197] *See*, *e.g.*, Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010) (noting that utilities "need communications systems that do not become unavailable due to traffic congestion, particularly during emergency scenarios when utilities need reliable communications the most"); Florida Power & Light Company, Comments – Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010) ("[f]ollowing hurricanes and natural disasters, utilities require a core foundation of voice dispatch to begin initial restoration work; this demands priority service comparable to first responders."); Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 2, 2010); DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 8 (July 12, 2010). (citing the provision of priority access as among "the most valuable improvements commercial network operators could make"); Great River Energy, Comments at 10 (noting that, "[i]f a utility chooses to use a commercial network, then prioritization of that traffic to allow the utility priority above the general public is required.").

[198] Avista Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 4 (July 2, 2010).

[199] *See* DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 8 (July 12, 2010) ("Service level agreements (SLAs) and private contracts are simply not enough guarantees when public safety is at risk.").

network providers creates incentives to oversubscribe the network."[200] This leads to problems particularly during times of emergency. Utilities noted numerous instances in which their proprietary systems were most resilient in the face of disaster. DTE Energy cited the example of the blackout in 2003, in which "[s]ubstations connected by [its] private networks stayed in communications with system operators for hours or days longer than those connected by telephone company leased lines,"[201] Cleco noted that "[w]ithin 24 hours of Katrina's passing, Cleco's radio system was operational, serving as the only communication method in the St. Tammany Parish area,"[202] and Tacoma Public Utilities noted that there was "absolutely no interruption of service" on its network during the 2001 Nisqually earthquake, even as commercial carriers experienced outages and congested networks.[203] Also, as Southern points out, the typical recourse for the violation of an SLA is monetary damages, which may be inappropriate redress for a utility's loss of control of the grid or consumers' loss of electricity service.[204] Further developments in communications technologies may help to alleviate some of these concerns by providing additional priority access capabilities (*e.g.*, LTE wireless).

In addition to commercial agreements for service priority, government programs exist to ensure priority service for certain communications, particularly in case of emergency. The National Communications Service (NSC) operates the Telecommunications Service Priority (TSP) system that enables certain telecommunications users to receive priority treatment for

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[200] Baltimore Gas & Electric Company, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).
[201] DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 8 (July 12, 2010).
[202] Cleco Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 9 (July 12, 2010).
[203] Tacoma Public Utilities, Comments - Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).
[204] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 26-27 (July 12, 2010).

replacement and restoration activities. Both data and voice services are covered.[205] Electric utilities, however, have not yet fully availed themselves of this program.[206] Also, for voice calls, NCS administers a Wireless Priority Service program, that enables qualified emergency personnel to make phone calls during periods of high network congestion resulting from emergency disruptions.[207] A possible explanation for the lack of utility participation in these programs could be one of lack of awareness. Another potential avenue worth exploring is to review the current contours of the Wireless Priority Service program and extend it, as Verizon suggests, to include critical infrastructure communications.[208] To address these priority-of-service issues, we suggest undertaking a review of both the TSP and Wireless Priority Service programs to determine whether – particularly in light of the deployment of Smart Grid technologies – there are any needed changes in the programs. Additionally, in the section on

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[205] AT&T in its comments alludes to the fact that "it is encouraging the FCC to work with the appropriate government agencies to establish a similar system for prioritizing IP-based communications." AT&T Inc., Comments – Request for Information on Smart Grid Communications Requirements, 16 (July 12, 2010).

[206] *People and Processes: Current State of Telecommunications and Electric Power Interdependencies*, The Telecommunications and Electric Power Interdependency Task Force (TEPITF), 2006, p. 3-2 (noting that electric utilities "ha[d] not significantly participated in the TSP program, having made very few applications for priority restoration").

By way of background, the principal objective of the TSP Program "is to ensure priority treatment for our nation's most important NS/EP telecommunications services The TSP Program is the regulatory, administrative, and operational framework for the priority restoration and provisioning of any qualified NS/EP telecommunications service. NS/EP services are those services used to maintain a state of readiness or to respond to and manage any event or crisis (local, national, or international) that causes or could cause injury or harm to the population, damage to or loss of property, or degrades or threatens the NS/EP posture of the United States." Utilities fall within the category of Public Health, Safety, & Maintenance of Law & Order (Levels 3-5). This category covers the minimum number of telecommunication services necessary for giving civil alert to the U.S. population and maintaining law and order and the health and safety of the U.S. population in times of any national, regional, or serious local emergency. These services are those for which a service interruption ranging from a few minutes to one day would have serious adverse impact on the supported NS/EP functions. *See* "Telecommunications Service Priority," U.S. Department of Homeland Security, http://tsp.ncs.gov/eligibility.html.

[207] Establishment of Rules and Requirements for Priority Access Service, WT Docket No. 96-86, *Second Report and Order*, 15 FCC Record 16720 (2000); *see also* National Communications System, U.S. Department of Homeland Security, http://www.ncs.gov.

[208] *See* Verizon and Verizon Wireless, Comments – Request for Information on Smart Grid Communications Requirements, 12 (July 12, 2010). Another noteworthy program that relates to priority of service is CTIA's voluntary certification program, the CTIA Business Continuity/Disaster Recovery Program, in which carriers certify that they have met a host of criteria related to planning for prioritized service continuity and disaster recovery. *See* CTIA Wireless Association, Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).

recommended next steps, we set forth some concrete suggestions for outreach to the utility community to increase awareness of these programs as well.

iii. Network design and management

In addition to voicing concern about the current level of back-up capabilities in commercial networks, utilities assert other reliability problems as well. For example, Southern points to findings expressing concerns about creating additional interdependencies between different parts of the nation's critical infrastructure – that is, between the electric power industry and the commercial communications industry.[209] In general, utilities are focused on maintaining a certain level of communications service that is unaffected by routine or intermittent congestion in broadband networks, particularly in the case of emergencies.[210] Some commenters suggest that priority access for utilities should be reviewed on a large scale.[211] As has been noted, in the event of an emergency, both industries require priority access to fuel, facilities, and other resources to restore services.[212] And indeed some utilities point to the joint imperative need for communications during emergencies as a reason that they should opt for their own networks, over commercial networks.[213] That is, they assert that priority of service does not address the issue of both utilities and communications services providers needing and competing for access

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[209] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 28 (July 12, 2010). (citing the Communications Dependency on Electric Power Working Group Report, "Long-Term Outage Study," National Communications System Committee of Principals (Feb. 17, 2009)).
[210] Oncor Electric Delivery, Comments – Request for Information on Smart Grid Communications Requirements, 5 (July 12, 2010).
[211] Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 26 (July 12, 2010). (noting particularly that "some type of priority must be given to utility traffic with negligible latency and zero probability of blocking in order to provide real-time communications"); *see* Exelon Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 9 (July 12, 2010).
[212] "People and Processes: Current State of Telecommunications and Electric Power Interdependencies," National Security Telecommunications Advisory Committee, 3-5 January 31, 2006.
[213] DTE Energy, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010). (noting that in their "own experience, cellular networks experience crippling congestion and failed equipment during severe weather events, just the time when [they] need field communications the most."); American Public Power Association, Comments – Request for Information on Smart Grid Communications Requirements, 18 (Undated).

to the same, limited resources in emergencies. Commenters also expressed concern over federal regulatory requirements (including those of NERC and FERC) that direct utilities to meet certain reliability and physical and cyber security standards.[214]

b. Availability of Spectrum

As discussed, wireless communications technologies may offer advantages over other technologies for certain Smart Grid applications and deployments.[215] Moreover, the implementation of Smart Grid technologies is likely to increase utilities' demand for wireless services, either employing their own networks or using those of commercial service providers. A threshold issue to consider is access to radio spectrum. For wireless services, spectrum translates into capacity. Without sufficient capacity, projected increases in demand for wireless services may not be able to be met. As a result, it is important to review current options for spectrum access and identify any issues that could create roadblocks or that warrant further action.

One of the ways utilities use wireless spectrum is for voice communications, including communications regarding facilities maintenance or troubleshooting. Currently, some utilities access 512 MHz spectrum for push-to-talk voice communications. They share this spectrum with other critical infrastructure users. Many utilities noted that this spectrum is of limited utility and that, even for voice communications, they would like access to additional spectrum.[216]

While voice communications drive some spectrum usage, the bulk of current and anticipated spectrum needs associated with the Smart Grid relate to data communications.

[214] Comments of the American Public Power Association at 5; Comments of Edison Electric Institute at 7. *See, e.g.*, NERC Reliability Standards at http://www.nerc.com/page.php?cid=2%7C20.
[215] Utilities Telecom Council notes wireless' relatively low capital and investment cost as compared with wireline technologies. Additionally, wireless technologies do not create the safety issues associated with ground fault currents that wireless technologies do. Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).
[216] Comments of Utilities Telecom Council at 4; Comments of Edison Electric Institute at 16.

There are different spectrum access models and different spectrum bands that may be used for data communications – each with its own advantages and disadvantages. The remainder of this section will discuss the principal access models and their implications for Smart Grid technologies.

i. Spectrum for unlicensed devices

The FCC permits the operation of unlicensed devices in many bands. While spectrum access using unlicensed devices is free, the device operations do not have any rights to protection from interference, and must operate with whatever interference they receive from other devices. That is, once the FCC has authorized the approval for the devices to the manufacturer, they can be installed by anyone without any additional regulatory approvals. The limited barriers to entry – as a result of both free access to spectrum and the availability of off-the-shelf equipment – may make using these wireless devices an attractive alternative for certain Smart Grid applications.

For the purposes of Smart Grid applications, the principal bands in which unlicensed devices operate include 902-928 MHz, 2.4 GHz, 3.65 GHz, and 5 GHz.[217] Each of these bands has relative advantages and disadvantages. The 900 MHz band provides better building and foliage penetration; whereas there is more bandwidth available at 5 GHz but radio signals do not travel as far. Currently, many wireless meter readers use the 900 MHz band. This is not without complications, however. While meter reading is not an always-on application (that is communications are not happening constantly, and, as a result, tying up the channel), other unlicensed devices that operate in this band may indeed transmit constantly and, at the same time, may utilize all of the available bandwidth in a particular location. This may introduce

[217] The FCC recently made additional spectrum – the TV white spaces – available for unlicensed devices. This spectrum holds promise for Smart Grid communications technologies.

issues, such as increased latency, with the meter transmitter waiting for an open channel before transmitting.[218] Some of these operational challenges have been well documented and may, particularly in urban and suburban environments, limit the utility of unlicensed devices for more critical grid control.[219] With more ubiquitous smart meter deployments, the limitations of using unlicensed devices for non-critical operations may become more problematic. This is an issue to monitor going forward.

Unlicensed devices are also used in certain circumstances for SCADA applications. Due to the potential for interference, however, the use of unlicensed devices for SCADA applications is likely limited to rural areas, where there are few competing – and potentially interfering – uses for the designated spectrum. While there are potentially other Smart Grid applications that may be appropriate for unlicensed devices (*e.g.*, video surveillance), given the need for high reliability of Smart Grid communications, many of the Smart Grid applications may warrant the used of licensed spectrum, which offers interference protections.

ii. Licensed spectrum

While a detailed discussion of the licensed spectrum model is beyond the scope of this report, the following are some of the important characteristics that inform the debate about spectrum in the Smart Grid context. As mentioned earlier, the key distinction between using licensed spectrum and using unlicensed devices is that licensed spectrum users are entitled to protection from interference from other users and therefore this type of access is generally more suitable for communications that require low latency and high reliability. Additionally, there are

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[218] *See* Alcatel-Lucent, Comments – Request for Information on Smart Grid Communications Requirements, 17 (July 12, 2010). (noting that, "as more systems use these frequencies, the [interference] problem is compounded and results in a growing problem with latency")
[219] *See* "Modification of Parts 2 and 15 of the Commission's Rules for unlicensed devices and equipments approval," Federal Communications Commission. ET Docket No. 03-201 (June 22, 2010).

some circumstances in which spectrum can be shared and users can lease spectrum from licensees. As noted briefly above, not all spectrum is created equal. Lower spectrum bands offer greater signal penetration, and this is among the reasons industry uses spectrum at or below 3 GHz for mobile operations. As a result, the spectrum region below 3 GHz is often referred to as the beachfront property of radio spectrum. Finally, all of the radio spectrum through 300 GHz has been allocated, yet remains lightly used above 40 GHz. Reallocation of bands where incumbents must be moved requires significant groundwork to justify. Taken together, these parameters set the backdrop for the discussion of spectrum with regard to Smart Grid communications needs.

Many utilities assert that they require additional spectrum to meet Smart Grid communications requirements, either on an exclusive basis or shared with other users, for example public safety entities. Indeed, many argue that, even with today's wireless needs, they do not have access to sufficient spectrum.[220] Numerous commenters argue specifically that utilities should receive an allocation for an exclusive 30 MHz from 1800 - 1830 MHz.[221] UTC asserts that this amount of spectrum is needed "based on the estimated throughput requirements for each Smart Grid application, extrapolated by the number of devices/nodes and the average

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[220] *See* Southern Company Services, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010); Cleco Corporation, Comments – Request for Information on Smart Grid Communications Requirements, 9 (July 12, 2010); Crow Wing Power, Comments - Request for Information on Smart Grid Communications Requirements, 2 (June 29, 2010); Dakota Electric Association, Comments - Request for Information on Smart Grid Communications Requirements, 3 (July 12, 2010); Space Data Corporation, Comments - Request for Information on Smart Grid Communications Requirements, 1 (July 12, 2010).

[221] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 2; *see also* Edison Electric Institute, Comments – Request for Information on Smart Grid Communications Requirements, 16; DTE Energy Company, Comments – Request for Information on Smart Grid Communications Requirements, 10; GE Digital Energy, Comments – Request for Information on Smart Grid Communications Requirements, 6; Pepco Holdings, Inc., Comments – Request for Information on Smart Grid Communications Requirements, 5. *But see* T-Mobile USA, Inc., Reply Comments – Request for Information on Smart Grid Communications Requirements, 8 (noting drawbacks of this proposal).

number of collectors per branch of the network."[222] UTC states that these lower frequencies are required "in order to provide optimal propagation characteristics, which in turn plays into the overall cost effectiveness of the network."[223] And, finally, utility commenters note that the 1800 - 1830 MHz band has been allocated to Smart Grid communications in Canada. We note that allocating spectrum for specific applications or industries, however, raises issues regarding the efficient use of spectrum. Additionally, the 1800-1830 MHz band (1755-1780 MHz) is already part of a broader band currently under review for wireless broadband.

The specific request for reallocation is beyond the scope of this proceeding, given that the FCC and NTIA are charged with allocations decisions. It is clear, however, that Smart Grid technologies will introduce incremental demand for wireless services. Indeed, because of the more general upward trend in the demand for wireless services, the FCC has already committed to making additional spectrum available for wireless broadband, and perhaps any Smart Grid needs can be accommodated by the FCC's initiative already underway. Moreover, much additional discussion is required to assess potential spectrum needs associated with the Smart Grid and more needs to be learned about the specific uses for which the spectrum is to be used. For example, to the extent that the communications utilities need are between fixed points – like substations and transformers – it may be possible for them to use frequencies above 3 GHz for these networks. Additionally, as every band has already been allocated, in determining potential spectrum needs, it is important to conduct a thorough review of the needs of the incumbents and the cost of relocation to determine whether any proposed changes and attendant benefits would be sufficient to offset the existing public interest benefits of the current allocations. Notably, the

[222] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 7 (July 12, 2010).

[223] Utilities Telecom Council, Comments – Request for Information on Smart Grid Communications Requirements, 6 (July 12, 2010).

band currently suggested by utilities for their use is already allocated for federal use and is used by existing Department of Defense systems, federal law enforcement, and other systems. As stated above, DOE makes no independent spectrum needs assessment here. Rather, DOE is presenting the comments in the record and identifying key issues that would need to be considered and evaluated going forward. Based on our review of the record, it will be important to take into account these evolving needs for spectrum to support Smart Grid services. Consequently, it will be necessary to review the various federal forums for decision making to ensure that utilities have the appropriate representation. In the main, we believe that there are opportunities for an increased role for utilities' Smart Grid interests and we discuss them in greater detail in our next-steps recommendation section.

V. Recommendations for Next Steps

Federal and state initiatives have been crucial for laying a foundation for continued development and deployment of Smart Grid technologies. As communications systems are an integral part of grid evolution, it is important to identify and act upon additional opportunities to support this continued growth. To that end, DOE's recommendations for next steps are set forth here. Commenting parties in this proceeding, participants in the public meeting, and the DOE's outreach efforts helped guide these recommendations.

a. Increasing representation and consideration of Smart Grid communications interests in federal spectrum management and emergency operations support programs

<u>Strengthen representation of utilities' Smart Grid communications needs, particularly in intragovernmental forums.</u> Like the public safety industry, the electric utility industry is made up of many diverse entities with disparate communications challenges and needs, some of whom

have full-time staffs and many resources to address communications challenges and others who do not have extensive resources. Moreover, the electric power that utilities provide as part of the critical infrastructure of this country is crucial to the successful operation of many other services and businesses. Going forward, it is quite likely that both wireless and wired communications – either through private or commercial networks – will be increasingly important. These attributes, coupled with the fact that creating the Smart Grid is a major technological change, suggest that there should be strengthened advocacy for Smart Grid interests within the federal spectrum management arena. Consequently, there is a role that DOE can play in terms of evaluating the needs for Smart Grid in terms of access to communications infrastructure, in coordination with the NIST/SGIP Priority Action Plan on Wireless Communications.

Review existing representation in spectrum- and communications-related federal government committees to ensure sufficient representation of the Smart Grid interests. Notably, the two federal government agencies tasked with managing all radio spectrum – the FCC and NTIA – have longstanding, coordinated processes for addressing policy issues related to spectrum allocations.[224] As an outgrowth of earlier spectrum reform efforts, NTIA established a Policy and Plans Steering Group (PPSG) comprised of Assistant Secretaries of federal government agencies that use spectrum, along with the FCC.[225] DOE already participates in this effort and we will endeavor to have our representative receive input from the utility community and help to ensure that Smart Grid communications needs are taken into consideration in the

[224] NTIA's Interdepartment Radio Advisory Committee (IRAC) is the principal mechanism for addressing spectrum assignment and allocation issues.
[225] *See*, "Spectrum Policy for the 21st Century – The President's Spectrum Policy Initiative: Report 1, Recommendations of the Federal Government Spectrum Task Force," Department of Commerce, June 2004, *available at*: http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm ("Task Force Report 1"); "Spectrum Policy for the 21st Century – The President's Spectrum Policy: Report 2, Recommendations from State and Local Governments and Private Sector Responders," Department of Commerce, June 2004, *available at*: http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report2_06242004.htm ("Task Force Report 2").

meetings of the PPSG and related working groups. Another next step to consider is having a representative from the utility community participate in the Commerce Spectrum Management Advisory Committee (CSMAC), a federal advisory committee (known as a FACA), made up of non-federal spectrum users tasked with providing NTIA with input on spectrum policy.[226]

In addition to purely spectrum-related federal government activities, utilities should have representation on key FACAs that address communications- and network-related security and reliability issues. One such example is the President's National Security Telecommunications Advisory Committee (NSTAC), which is an advisory committee made up of industry representatives from the communications industry, as well as a cross-section of other industries. NSTAC provides advice and recommendations on issues related to telecommunications systems continuity in the event of an emergency or crisis.[227] In addition, the FCC's Communications Security and Reliability Council addresses issues of security and reliability in communications networks and it would be helpful for utilities to have representation on this committee as well.

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[226] *See* CSMAC Charter, *available at*: http://www.ntia.doc.gov/advisory/spectrum/csmac_charter.html

[227] An excerpt from NSTAC's website describes its mission and scope as follows: "Beyond the industry collaboration alone, the NSTAC serves as a prominent model for trusted public/private partnerships, resulting in mutually beneficial information sharing mechanisms and the implementation of several programs to reinforce that partnership. One of the NSTAC's first efforts recommended the creation of the National Coordinating Center as an operational arm of the NSTAC, and later, as the Information Sharing and Analysis Center for the communications sector, where information relevant to the protection and operation of the communications infrastructure is shared between industry and Government. Subsequently, the NSTAC also helped to establish the industry and Government Network Security Information Exchanges, allowing representatives from the public and private sectors to share sensitive information on threats to operations, administration, maintenance, and provisioning systems supporting the telecommunications infrastructure. The NSTAC recognized that information sharing is a key component to the industry and Government relationship, tying together all facets of the NSTAC agenda to provide resilient national telecommunications services.

Since its inception, the NSTAC has addressed a wide range of policy and technical issues regarding communications, information systems, information assurance, critical infrastructure protection, and other NS/EP communications concerns. In recent years, the Government, with the support of the NSTAC, addressed new NS/EP challenges caused by several primary factors: the convergence of traditional and broadband networks; the changing global threat environment; and the continuing global expansion of both provider and user communities. In the face of this ever-increasing complexity of the domestic and global network environment, the NSTAC's work, more so than ever, is of vital national importance, and the committee remains vigilant in aggressively addressing our Nation's highest priority NS/EP communications needs." National Communications System, www.ncs.gov.

These are just a few examples of relevant federal industry working groups. The Department of Energy welcomes input on additional groups in the communications- and network-related areas that might benefit from increased utilities' representation.

Review existing federal programs that address priority of service and emergency restoration to determine whether there are ways that utilities could better utilize such programs. In addition to increasing utilities' participation in federal government committees related to spectrum management and communications network security and reliability, it is also important to review federal programs related to providing priority for both service and restoration activities. Ensuring that key communications related to Smart Grid functions operate generally without impediments and are restored quickly in the event of an emergency hinders both utilities' own operations and additionally limits their ability to rely on commercial communications service providers. To address this issue, it would be helpful to review the Telecommunications Service Priority program run by the National Communications Service (NCS) with the communications requirements of the Smart Grid in mind, in order to determine whether there are any gaps that should be addressed. For example, like public safety, utilities can already use these programs, and it is important to review the extent to which utilities are availing themselves of the program and, to the extent they are not, identify the impediments and work to resolve them. Additionally, the NCS' existing Wireless Priority Service program should be reviewed in this light as well.

Review opportunities for increased spectrum access for Smart Grid communications needs, including spectrum sharing and/or leasing. There are currently efforts underway to inventory spectrum use for both federal and non-federal users, to determine whether any spectrum is underutilized.[228] Additionally, the President directed NTIA, in collaboration with the FCC, to make available 500 MHz of Federal and non-federal spectrum for wireless broadband over the next decade.[229] Given that the Smart Grid will create additional demand for spectrum-based services, its communications requirements should be considered in these efforts going forward. Toward that end, DOE will work with the FCC and NTIA to review potential Smart Grid spectrum needs. As part of these efforts, new spectrum may be made available that would be suitable for utilities to share with other uses (involving leasing arrangements, for example), with public safety, federal government, or other users. At the same time, electric utilities should also be creative in exploring different opportunities, ranging from spectrum leases from licensees holding spectrum that they are not using, to new spectrum access made available under the FCC's TV White Spaces decision. Indeed, it is possible that a multi-mode architecture may emerge as utilities experiment with different alternatives. As such, DOE is not endorsing any particular communications technology or encouraging utilities to provide the service itself or contract with others to provide it. Rather, the goal is to continue to do the necessary homework to identify and remove any obstacles and facilitate as many options as possible, so that the optimal choice can be made for a particular Smart Grid deployment.

b. Improve utilities' ability to get information on communications applications for Smart Grid applications in a straightforward and turnkey manner and to ensure, through educational efforts, that utilities are aware of existing programs and applications

Develop a national online clearinghouse to serve as a forum for utilities engaged in Smart Grid applications. With the continued implementation of Smart Grid technologies, more and

[228] *See, e.g.*, "Radio Spectrum Inventory Act," *Bill*, Sens. John Kerry and Olympia Snowe, July 2009.
[229] "Presidential Memorandum: Unleashing the Wireless Broadband Revolution," President Barack Obama, *available at*: http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.

more utilities will be assessing their communications needs in the context of particular Smart Grid applications or deployments. Commenters have suggested that it would be helpful to have some forum to share "lessons learned" for Smart Grid communications requirements.[230] To that end, the Department can consider establishing – or augmenting an existing – interactive online clearinghouse to catalog and coordinate utilities' and commercial providers' experiences with various Smart Grid deployments, coordinating with the existing NIST/SGIP Open SG effort.[231] Utilities, and any other parties with field experience implementing Smart Grid communications technologies, could access the clearinghouse to learn more about existing projects. For example, a utility located in a rural, mountainous area could consult the clearinghouse to learn more about wireless communications technologies that worked for similarly situated utilities deploying Smart Grid technologies.

One important use of the online clearinghouse would be to provide substantive information on communications alternatives, model commercial agreements, and general information on federal programs. Particularly for smaller or rural utilities, the online clearinghouse could provide substantive information designed to facilitate awareness of communications technologies alternatives for Smart Grid deployments. For example, the online clearinghouse could include "how to" resources on technology options for Smart Grid communications.[232] The online clearinghouse could also be a way to provide utilities information on the existing federal programs, like TSP and Wireless Priority Service.

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[230] National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 15 (July 12, 2010).

[231] Other clearinghouses currently available include, for example, the Smart Grid Information Clearinghouse funded by DOE and run by Virginia Tech, *available at*: http://www.sgiclearinghouse.org/, and the NIST/SGIP Smart Grid Collaboration Site, *available at*: http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/InteroperabilityKnowledgeBase.

[232] *See, e.g.*, "Understanding Wireless Communications in Public Safety – A Guidebook to Technology, Issues, Planning, and Management." www.fcc.gov.

Additionally, utilities noted that one of the difficulties with using commercial services for Smart Grid communications needs is that a particular utility's footprint might span the coverage area of several commercial services providers. Having to negotiate full service agreements with multiple service providers significantly increases the transaction time and costs and deters interest in doing so.[233] To address this issue, the Department, or clearinghouse users themselves, could develop model Service Level Agreements (SLAs) that would include stock terms and conditions for the communications needs associated with particular Smart Grid applications or technologies.

[233] *See* National Rural Electric Cooperative Association, Comments – Request for Information on Smart Grid Communications Requirements, 11 (July 12, 2010).

Appendix A

Smart Grid Functionalities and Communications Needs

Note: The information presented in this table summarizes the input of commenters, and does not reflect a technical assessment by DOE.

Application	Network Requirements				
	Bandwidth	**Latency**	**Reliability**	**Security**	**Backup Power**
AMI	10-100 kbps/node, 500 kbps for backhaul	2-15 sec	99-99.99%	High	Not necessary
Demand Response	14kbps- 100 kbps per node/device	500 ms-several minutes	99-99.99%	High	Not necessary
Wide Area Situational Awareness	600-1500 kbps	20 ms-200 ms	99.999-99.9999%	High	24 hour supply
Distribution Energy Resources and Storage	9.6-56 kbps	20 ms-15 sec	99-99.99%	High	1 hour
Electric Transportation	9.6-56 kbps, 100 kbps is a good target	2 sec-5 min	99-99.99%	Relatively high	Not necessary
Distribution Grid Management	9.6-100 kbps	100 ms-2 sec	99-99.999%	High	24-72 hours

Appendix B

The following organizations submitted comments in response to DOE's RFI:[234]

- Alcatel-Lucent
- Ambient Corporation
- American Petroleum Institute
- American Public Power Association (APPA)
- AT&T
- Avista Corporation
- Baltimore Gas & Electric Company (BGE)
- Bonneville Power Administration
- Booz Allen Hamilton
- Cleco Corporation
- Crow Wing Power
- Dakota Electric Association
- DTE Energy Company
- East Central Energy
- Edison Electric Institute (EEI)
- Exelon Corporation
- Florida Power & Light Company
- GE Digital Energy
- Great River Energy
- Grid Net
- Honeywell International, Inc.
- Hughes Network Systems, LLC
- Lake Region Electric Cooperative
- Lower Colorado River Authority (LCRA)
- Meeker Cooperative Light and Power
- Mille Lacs Energy Cooperative Electric
- Motorola, Inc.
- National Association of State Utility Consumer Advocates (NASUCA)
- National Cable & Telecommunications Association (NCTA)
- National Rural Electric Cooperative Association (NRECA)
- Northeast Utilities System
- Oncor Electric Delivery

[234] Copies of the comments are *available at*: http://www.gc.energy.gov/1592.htm.

- On-Ramp Wireless, Inc.
- Pepco Holdings, Inc.
- Qualcomm Incorporated
- San Diego Gas & Electric (SDG&E)
- Silver Spring Networks
- Southern California Edison
- Southern Company Services, Inc.
- Space Data Corporation
- Steele-Waseca Cooperative
- Tacoma Public Utilities
- Telecommunications Industry Association (TIA)
- Tropos Networks
- Utilities Telecom Council
- Verizon/Verizon Wireless
- The Wireless Association (CTIA)

The following organizations submitted reply comments in response to comments to the RFI:[235]

- AT&T
- Diversified Energy Partners, Inc.
- Edison Electric Institute
- Motorola, Inc.
- National Rural Electric Cooperative Association (NRECA)
- Southern Company Services, Inc.
- T-Mobile
- Utilities Telecom Council
- Verizon/Verizon Wireless

The following panelists presented at the public meeting held at DOE on June 17, 2010:[236]

- Becky Blalock, Senior VP and CIO of the Southern Company
- Sherman Elliott, Commissioner of the Illinois Commerce Commission
- Lynne Ellyn, Senior VP and CIO of DTE Energy
- Jim Ingraham, Vice President of Strategic Research for the Electric Power Board of Chattanooga
- Jim Jones, CIO of Great River Energy
- Mike Lanman, President for Enterprise and Government Markets at Verizon Wireless

[235] Copies of the reply comments are *available at*: http://www.gc.energy.gov/1592.htm.
[236] A copy of the transcript for the meeting is *available at*: http://www.gc.energy.gov/documents/PublicMeetingTranscript_June17.pdf.

- Kyle McSlarrow, President and the CEO of the National Cable and Telecommunications Association
- Roy Perry, Director of Strategic Assessment at Cable Labs.