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National Association of Regulatory Utility Commissioners

The Smart Grid: An Annotated Bibliography of Essential Resources for State Commissions

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INTRODUCTION

The smart grid holds promise of transforming our current electricity delivery system into a more efficient and secure system that is able to better integrate variable supply resources while giving the end-user – the customer – greater autonomy in his/her energy consumption. Without a doubt, many of the technologies and management tools the smart grid may depend on have lead regulators, policy-makers, customers, companies, and stakeholders to consider many questions – what it is, what its benefits are, what value it brings to society as a whole as well as individual consumers, what its potential challenges are, and what kind of mistakes can be avoided when moving forward. The purpose of this literature review is to explore these questions and more in a fair and balanced, comprehensive overview of the smart Grid. The resources contained in this review are primarily derived from the internet and as such, many are available simply via the web links. For organizational purposes, the sources have been divided into six sections, respectively: (1) The Basics; (2) Supply Resources; (3) Transmission & Distribution Technologies; (4) End-Use Technologies & Rates; (5) Cybersecurity; and (6) Demonstration/Pilot Projects.

THE BASICS:

"Smart Grid: Enabler of the New Energy Economy." A Report by The Electricity Advisory Council. Produced by Energetics Incorporated, December 2008. (Accessed: March 6, 2009). Available at: <http://www.oe.energy.gov/eac.htm>

"The report substantiates the benefits of moving to a more intelligent grid, not only for utilities and grid operators, but also for consumers and society as a whole. Studies have shown that the potential economic and environmental payoffs of transforming the current electric power delivery system into a Smart Grid are numerous. From an economic perspective, Smart Grid can enable reduced overall energy consumption through consumer education and participation in energy efficiency and demand response/load management programs. Shifting electricity usage to less expensive off-peak hours can allow for better utilization of equipment and better use of capacity. From an environmental standpoint, a Smart Grid can reduce carbon emissions by maximizing demand response/load management, minimizing use of peak generation, and replacing traditional forms of generation with renewable sources of generation. A Smart Grid also holds the promise of enhanced reliability and security of the nation's power system." [Pages 1-2]

"The Smart Grid: An Introduction." Prepared for the U.S. Department of Energy by Litos Strategic Communication Under Contract No. DE-AC26-04NT, Subtask 560.01.04. (Accessed: March 6, 2009). Available at: <http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages.pdf>

"The electric industry is poised to make the transformation from a centralized, producer-controlled network to one that is less centralized and more consumer-interactive. The move to a smarter grid promises to change the industry's entire business model and its relationship with all stakeholders, involving and affecting utilities, regulators, energy service providers, technology and automation vendors and all consumers of electric power…People are often confused by the terms Smart Grid and smart meters. Are they not the same thing? Not exactly. Metering is just one of hundreds of possible applications that constitute the Smart Grid; a smart meter is a good example of an enabling technology that makes it possible to extract value from two-way communication in support of distributed technologies and consumer participation." [Pages 10, 14]

The Electric Power Research Institute, "Integrating New and Emerging Technologies into the California Smart Grid Infrastructure: A Report on a Smart Grid for California" December 2008. (Accessed: April 28, 2009). Available at: <http://my.epri.com/portal/server.pt?space=CommunityPage&cached=true&parentname=ObjMgr&parentid=2&control=SetCommunity&CommunityID=404&RaiseDocID=000000000001018191&RaiseDocType=Abstract_id>

"Achieving a smart grid for California will require the merging of two primary infrastructures: the electrical power system and a communications infrastructure, including information systems that incorporate common information models and interoperability guidelines. The intelligent applications and technologies made possible by the communications infrastructure will improve the performance of the system, allow integration of distributed resources, enable electric service innovations, and support the reliability and power quality needs of the system. This report develops a framework to show how the technological components—hardware, control algorithms, information technology, and communication networks—could be brought together to make a smart grid possible."

Butler, Frederick. "A Call to Order: A Regulatory Perspective on the Smart Grid." *IEEE Power & Energy Magazine,* March/April 2009, Pages 16-25, 93.

"There's a worn-out cliché that goes something like this: Don't put the cart before the horse…The benefits of the smart grid are obvious, but we must be sure that we move deliberately and in stages so that the costs of rolling out the necessary infrastructure are borne by those who will benefit. If we expect the horse – i.e., the consumers – to pull the cart before it is ready, we may never get the smart grid off the ground. This means that we should not focus immediately on the end-user and demand response; rather, we must start with the backbone – the transmission and distribution systems – before going inside consumers' homes…Many utilities, engineers, and vendors have extolled how an updated, modernized transmission system will give grid operators a much better view of their transmission and distribution network. If we start with the backbone, if we update and improve the delivery system first, we will see the benefits of the smart grid on the utility company side." [Pages 16-22]

Koerner, Brendan I. "Power to the People: 7 Ways to Fix the Grid, Now." *Wired Magazine,* March 23, 2009. (Accessed: April 6, 2009). Available at: <http://www.wired.com/print/science/discoveries/magazine/17-04/gp_intro>

"We must fix the grid – reinvent it to be reliable, efficient, responsive, and smart…But technology alone won't solve this mess, because fixing the grid is not a technology problem – it's a system problem on the broadest scale. Political gridlock, broken markets, and shortsighted planning have created a slew of bottlenecks that can't be solved with a bunch of smart meters and fancy routers. Here, we show how utilities and businesses have begun to tackle those obstacles – from installing new transmission lines to empowering consumers. If we're serious about remaking our energy infrastructure, we'll need to encourage these kinds of fixes and replace our current system of misplaced incentives. Right now, that system encourages everyone involved – customers, utilities, and private industry – to neglect the grid. We have to give those stakeholders new reasons to turn on, engage, and transform…To fix the grid, then, we don't need another layer of oversight. We need to tweak the system so that companies are rewarded – not punished – for investing in the grid. [Pages 1-3]

SUPPLY RESOURCES:

"Accommodating High Levels of Variable Generation (A Special Report)." North American Electric Reliability Corporation. April 16, 2009. (Accessed April 21, 2009). Available at: <http://www.nerc.com/files/IVGTF_Report_041609.pdf>

"Reliably integrating high levels of variable resources – wind, solar, ocean, and some forms of hydro – into the North American bulk power system will require significant changes to traditional methods used for system planning and operation. This report builds on current experience with variable resources to recommend enhanced practices, study and coordination efforts needed to lay the foundation for this important integration effort." [Page i]

Kempton, W., Tomić, Jasna. "Vehicle-to-Grid Power Implementation: From Stabilizing the Grid to Supporting Large-Scale Renewable Energy." ***Journal of Power Sources,*** **December 8, 2004. (Accessed: April 23, 2009). Available at:** <http://www.udel.edu/V2G/KempTom-V2G-Implementation05.PDF>

Vehicle-to-grid power (V2G) uses electric-drive vehicles (battery, fuel cell, or hybrid) to provide power for specific electric markets. This article examines the systems and processes needed to tap energy in vehicles and implement V2G. It quantitatively compares today's light vehicle fleet with the electric power system. The vehicle fleet has 20 times the power capacity, less than one-tenth the utilization, and one-tenth the capital cost per prime mover kW. Conversely, utility generators have 10-50 times longer operating life and lower operating costs per kWh. To tap V2G is to synergistically use these complementary strengths and to reconcile the complementary needs of the driver and grid manager. This article suggests strategies and business models for doing so, and the steps necessary for the implementation of V2G. After the initial high-value, V2G markets saturate and productions costs drop, V2G can provide storage for renewable energy generation. Our calculations suggest that V2G could stabilize large-scale (one-half of US electricity) wind power with 3% of the fleet dedicated to regulation for wind, plus 8-38% of the fleet providing operating reserves or storage for wind. Jurisdictions more likely to take the lead in adopting V2G are identified. [Page 1]

Smith, Charles J. (Utility Wind Integration Group). "Wind Integration Issues and Smart Grid." 4th Smart Grid E-Forum, February 24, 2009. (Accessed April 16, 2009). Available at: <http://www.eei.org/meetings/Meeting%20Documents/2009-02SMITH_EForumEEId1.pdf>

This presentation discusses ways in which smart grid technologies can help integrate variable energy sources such as wind. The author contends that "a number of recent events have highlighted the need for good wind plant output forecasts." These events include: (1) the Danish high wind event of Jan '05; (2) the European system breakup of Nov '06; and (3) the Texas high wind event of Feb '08. "Wind plant output forecasting [is] increasingly recognized as an important tool in minimizing operating impacts and delivering critical information to operators." Furthermore, "forecasting [is] critical to minimizing wind integration cost and increasing wind value." Through demonstrations mentioned in the presentation, employing smart grid technologies and system management tools such as individual turbine data acquisition, line loading and curtailment monitoring, demand side management, price responsive load markets, and plug-in hybrid electric vehicles(PHEVs) can provide an opportunity for improved forecasting and increased flexibility. [Slides 11, 15, 16]

TRANSMISSION & DISTRIBUTION TECHNOLOGIES:

"Overview of the Smart Grid: Policies, Initiatives, and Needs: ISO New England Report." (Accessed April 6, 2009). Available at: <http://www.iso-ne.com/pubs/whtpprs/smart_grid_report_021709_final.pdf>

"This research paper is a technical overview of Smart Grid technologies and how these technologies are being implemented around the country and in New England to improve the efficiency of the power grid. It presents a range of views about Smart Grid; describes the mix of technologies Smart Grid comprises; and summarizes various federal, State, and other programs aimed at bringing these technologies into more widespread use." [Page 1]

"U.S. Energy Infrastructure Investment: Large-Scale Integrated Smart Grid Solutions with High Penetration of Renewable Resources, Dispersed Generation, and Customer Participation (A White Paper)." Power Systems Engineering Research Center. PSERC Publication 09-01, March 2009. (Accessed April 6, 2009). Available at: <http://www.pserc.org/ecow/get/publicatio/2009public/pserc_smart_grid_white_paper_march_2009_adobe7.pdf>

"The four tasks described are crucial to smart grid research and development, demonstration, and eventual deployment. As learning and innovation occurs during the course of a demonstration, changes may be needed in the architecture, the components, and how they are integrated operationally. The goal is to acquire the best information possible for the eventual decisions on whether and how an integrated smart grid solution should be

implemented, so adjusting demonstrations as needed to provide that information could be very appropriate. It is also important that demonstrations be designed and implemented to gain the knowledge needed for a system-wide deployment of a smart grid. The bulk transmission system should be included in the design. There are a great number of unknowns in moving toward a national goal of a low-carbon economy. That uncertainty can be reduced by effectively designed large-scale demonstrations drawing on results of research and development work." [Page 11]

END-USE TECHNOLOGIES & RATES:

Brockway, Nancy. "Advanced Metering Infrastructure: What Regulators Need to Know About Its Value to Residential Customers." National Regulatory Research Institute. February 13, 2008. (Accessed April 21, 2009). Available at: <http://nrri.org/pubs/multiutility/advanced_metering_08-03.pdf>

"This report began as an effort to understand who has the better argument: those opposed to "advanced metering infrastructure" (AMI) as a demand response tool, and those supporting AMI for the same reason…We provide regulators with a general framework for evaluating an electric utility's request for recovery of the costs of implementing an advanced metering infrastructure. We do return to, and examine in depth, the disputes between consumer advocates who oppose AMI and environmentalists, and utilities who support AMI. We place these disagreements in the context of a model for analyzing the overall costs and benefits of AMI…We introduce a recurring theme: AMI is one way, but only one way, for a utility to offer time-varying utility prices and induce demand response. Proponents and opponents of AMI agree on this point." [Pages vii-viii]

"Quantifying the Benefits of Dynamic Pricing in the Mass Market." Prepared by: The Brattle Group. Prepared for: Edison Electric Institute, January 2008. (Accessed April 27, 2009). Available at: <http://www.eei.org/ourissues/electricitydistribution/Documents/quantifying_benefits_final.pdf>

"The purpose of this report is to lay out a methodology for quantifying the benefits to customers and utilities of dynamic pricing programs. We illustrate the methodology with specific examples using a suite of models called the Pricing Impact Simulation Model (PRISM) Suite. This suite extends a model that was derived from the experimental data collected in the 2003-2005 California Statewide Pricing Pilot (SPP). Such benefits are critical inputs for evaluating the cost-effectiveness of potential advanced metering infrastructure (AMI) deployments. Although PRISM was developed in California, the basic model can be adapted to conditions in other parts of North America after adjustments have been made for climatic, socio-demographic, rate and load shape characteristics. The PRISM Suite includes a model for estimating demand response impacts and a model for estimating financial benefits to customers and utilities." [Page xi]

"Retail Electricity Pricing and Rate Design in Evolving Markets." Prepared by: Christensen Associates Energy Consulting, LLC. Prepared for: Edison Electric Institute, July 2007. (Accessed April 27, 2009). Available at: <http://www.eei.org/ourissues/electricitydistribution/Documents/Retail_Electricity_Pricing.pdf>

"Industry experts increasingly recognize the importance of improving the link between wholesale and retail power markets. Efficient pricing that better links the two markets has the potential for improving the efficiency of electric power system operations and the industry's resources investments. Currently the two sides of the electricity market are largely disjointed, with varying wholesale prices on the supply side and fixed "one-size-fits-all" retail rates for all customers in a rate class on the demand side. An efficient pricing outcome would have energy providers offer a range of price structures that are based on wholesale market prices but reflect different degrees of risk premiums and price guarantees, and have customers choose the price structure that best balances their relative preference for low prices and low risk management." [Page 33]

"The Green Grid: Energy Savings and Carbon Emissions Reductions Enabled by a Smart Grid." June 2008 EPRI Report 1016905. (Accessed April 6, 2009). Available for download at: <http://my.epri.com/>

"While the establishment of innovative rates, regulations, and markets and the development of smart and efficient end-use devices are all key pillars of energy efficiency, the development of a Smart Grid communications infrastructure has the potential to compound energy savings beyond what is achievable through conventional piecemeal deployments of energy efficiency and demand response measures. A Smart Grid, in essence, can make the energy efficiency benefits of the whole greater than the sum of its parts. This paper describes and quantifies how the enhanced communications and control functionality of a Smart Grid can unleash the following mechanisms to facilitate greater levels of energy savings, and therefore reductions in carbon dioxide emissions: (1) Continuous commissioning of buildings; (2) Reduced transmission and distribution (T&D) line losses; (3) Direct feedback to customers; (4) More effective and reliable demand response and load control; and (5) Enhanced measurement & verification (M&V) capabilities." [Page 1-3]

CYBERSECURITY:

"AMI System Security Requirements V1.01." The Advanced Meter Infrastructure Security Task Force. December 17, 2008. (Accessed April 6, 2009). Available at: <http://osgug.ucaiug.org/utilisec/amisec/Shared%20Documents/1.%20System%20Security%20Requirements/AMI%20System%20Security%20Requirements%20-%20v1_01.doc>

"This document provides the utility industry and vendors with a set of security requirements for Advanced Metering Infrastructure (AMI). These requirements are intended to be used in the procurement process, and represent a superset of requirements gathered from current cross-industry accepted security standards and best practice guidance documents. This document provides substantial supporting information for the use of these requirements including scope, context, constraints, objectives, user characteristics, assumptions, and dependencies. This document also introduces the concept of requirements for security states and modes, with requirements delineated for security states. These requirements are categorized into three areas: (1) Primary Security Services; (2) Supporting Security Services; and (3) Assurance Services. The requirements will change over time corresponding with current security threats and countermeasures they represent. The AMI-SEC Task Force presents the current set as a benchmark, and the authors expect utilities and vendors to tailor the set to individual environments and deployments." [Page i]

"Smart Electric Grid of the Future: A National 'Distributed Store-Gen' Test Bed." The Earth Institute at Columbia University, *et al.*, Summer 2003. (Accessed April 23, 2009). Available at: <http://www.ldeo.columbia.edu/res/pi/4d4/testbeds/Smart-Grid-White-Paper.pdf>

"We saw on August 14, 2003, that the country's economic and political well-being depends upon the energy infrastructure that we have taken so long for granted…It is of vital national security interest that [the grid] be modernized and brought into the 21st century if we are to have any hope of preventing future disruptions of the electricity supply to the country. And next time, it may be far worse than that on August 14, 2003. The failure detection and remediation system showed major flaws and weaknesses. The system was designed 50 years ago to automatically shut down at any sign of such a power surge…Modern computer sensing, planning and control software could have prevented the shut down in the first place by diverting power from the wave front using what are called Smart Power Controllers…Widespread use of those and far more advanced technologies will be required to create a Smart Grid of the Future." [Page 2]

DEMONSTRATION/PILOT PROJECTS:

Du Bois, Dennis. "Time of Use Electricity Billing: How Puget Sound Energy Reduced Peak Power Demands (Case Study)." *Energy Priorities Magazine,* February 14, 2006. (Accessed April 21, 2009). Available at: <http://energypriorities.com/entries/2006/02/pse_tou_amr_case.php>

"When power prices are volatile or supplies are short, reducing peak loads becomes a top priority for utilities. Billing customers for energy based on the time of day has proved to be a viable means for reducing peak loads. This case study examines one of the first field trials of time-of-use [TOU] tariffs and automated meter reading technologies, how they worked, the results, and why the program ended abruptly." [Page 1]

Hammerstrom, D.J., *et al.* "Olympic Peninsula GridWise Study." Pacific Northwest National Laboratory, October 2007. (Accessed March 6, 2009). Available at: <http://gridwise.pnl.gov/docs/op_project_final_report_pnnl17167.pdf>

"This report describes the implementation and results of a field of demonstration wherein residential electric water heaters and thermostats, commercial building space conditioning, municipal water pump loads, and several distributed generators were coordinated to manage constrained feeder electrical distribution through the two-way communication of load status and electric price signals. The field demonstration took place in Washington and Oregon and was paid for by the U.S. Department of Energy and several northwest utilities. Price is found to be an effective control signal for managing transmission or distribution congestion. Real-time signals at 5-minute intervals are shown to shift controlled load in time. The behaviors of customers and their responses under fixed, time-of-use, and real-time price contracts are compared. Peak loads are effectively reduced on the experimental feeder. A novel application of portfolio theory is applied to the selection of an optimal mix of customer contract types." [Page iii]

"San Diego Smart Grid Study Final Report." Prepared for: The Energy Policy Initiatives Center, University of San Diego School of Law. Prepared by: The SAIC Smart Grid Team, October 2006. (Accessed April 23, 2009). Available at: <http://www.sandiego.edu/epic/publications/documents/061017_SDSmartGridStudyFINAL>

"This San Diego Smart Grid Study is one of the first in the nation to apply the Smart Grid concepts developed by the U.S. Department of Energy's Modern Grid Initiative to a specific region. It provides preliminary analysis to determine the technical feasibility and cost effectiveness of implementing Smart Grid technologies and strategies in the San Diego Region. The objectives of the study are to (1) determine whether the future economic and regulatory climate in the San Diego region could accommodate or necessitate a Smart Grid, (2) determine the portfolio of technologies that could implement a Smart Grid, and (3) conduct a cost-benefit analysis to determine whether implementing a Smart Grid would be cost effective for the region." [Page 1]

"Xcel Energy Smart Grid: A White Paper." (Accessed April 6, 2009). Available at: <http://smartgridcity.xcelenergy.com/media/pdf/SmartGridWhitePaper.pdf>

"One of the objectives of our Smart Grid City initiative is to demonstrate the possibilities that smart grid technologies have for the enhancement of the grid of the future as well as its impact on the environment. We are also anticipating significant involvement in the effort from regulators and legislators as well to help educate them on those possibilities. The goal will not be to request specific recovery on the dollars we invest in the Smart Grid City effort but rather set the stage and work with the regulators on how recovery should be sought in the future. Because of the potential for rate return degradation and uncompensated demand destruction that the smart grid will result in, we believe that regulatory structures will need to be significantly different in the future than they are today. Our hope is to use Smart Grid City to help bring awareness to these issues and enable regulators an opportunity to see the value of smart grid and be open to making changes; perhaps even provide that test ground to experiment with different regulatory scenarios." [Page 12]

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