EPA Clean Energy-Environment Technical Forum
Motivating Energy Efficiency with Metering Technologies
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I. Introduction

Advanced Metering Infrastructure (AMI) initiatives are gaining popularity in the states as an important tool to **modernize the electricity grid, reduce peak demand and reach energy efficiency goals**. Often called Smart Metering, AMI is part of the foundation for utilities to implement a new "smart grid"[1] that can **minimize the need for additional power generation facilities and transmission lines**. AMI uses technology to capture and transmit energy use information on an hourly, and sometimes sub-hourly, basis to a central collection point (DPSC 2006). In contrast, standard meters provide a daily electricity usage total and a cumulative monthly billed amount that is determined by multiplying total usage by a fixed, non-time sensitive price (DRAM 2004). The new advanced metering systems currently account for about 6% of all meters in the U.S. (FERC 2006).

II. Benefits

There are many economic and environmental benefits to utilities and consumers from adopting advanced metering technology.

Utility Benefits

Utilities pay much more for the power used by consumers during peak demand periods than during non-peak demand periods. **Most current electricity rate systems do not reflect these cost differences and consumers have little incentive to change their electricity use patterns**. With AMI systems, utilities can manage their electricity supply in response to real-time information, and are able to provide consumers with more detailed use data and improved price signals. Utilities use the data from the advanced systems to perform more accurate load forecasting, reduce spot market purchases (or sell more power to the wholesale grid), minimize energy imbalances, reduce energy waste, and improve system reliability. Utilities can also shave peak use, reducing their costs and the need for new power plants and transmission lines (SCE 2007).

Installation of AMI can **support demand response programs**[2] that reflect market pricing and reduce peak energy use to improve system reliability. In the U.S., about five percent of electric customers

1. Called an "internet for the electric grid" by the U.S. Department of Energy's (DOE) Modern Grid Initiative, the Smart Grid encompasses digital communication devices, enables connection and disconnection of generators, enables distributed generation dispatch, and provides for computer-based monitoring of the grid. In "Grid 2030- A National Vision for Electricity's Second 100 Years," the DOE sets forth its goal of 100% of power flowing through smart grids by 2030 (Grid 2030). Southern California Edison, a consortium of utilities in the Pacific Northwest and TXU Electric Delivery Company have pilot projects that hope to test the commercial applicability and develop standards and protocols for these technologies. DOE's Modern Grid initiative is funding research and development and working to develop standards.

2. According to the U.S. Department of Energy, demand response is defined as "changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."

participate in demand response programs (FERC 2006). The most common demand response programs are interruptible/curtailment, direct load control and time-of-use (TOU) pricing. There is growing interest in demand response programs including other types of time-based rates beyond TOU, such as critical peak pricing (CPP) and real time pricing (RTP) (FERC 2006).

AMI can also reduce labor costs associated with manual meter reading and provide instant information on power quality and outage detection, allowing for faster response and restoration of service.

Customer Benefits

With advanced meters, consumers **can see their energy use and energy costs in real time**, allowing them to **make more informed decisions about their overall energy use**, and potentially diagnose solutions to equipment problems. Consumers are able to use the data to **benchmark their energy use** before, during, and after the installation of energy-efficient appliances and lighting technologies. An advanced metering pilot project in Europe showed that consumers used 5% to 15% less electricity as a result of direct feedback about their electricity consumption (Darby 2006). Another pilot conducted by Hydro One, an Ontario utility, found that average energy consumption dropped by 6.5% when customers had access to real time monitoring (Hydro One). AMI also encompasses net metering, where a customer's onsite meter runs backward if the electricity the customer generates is more than they consume.

III. Technology Deployment

Utility-Owned AMI

Utilities typically use AMI for demand response programs. Advanced metering technology is readily available and declining costs are making AMI more attractive to utilities. For example, the cost to a utility per AMI meter has dropped from $99 in the late 1990s to $76 in 2005-2006. The cost to install meters is often **passed to customers by way of base rate increases or a separate surcharge, and is ultimately decided by a state public utility commission** (FERC, 2006). Advanced metering infrastructure consists of various components, including new meters equipped with the ability to collect data and communicate with a network. These networks provide infrastructure that establishes a real-time link between the consumers' meters and the utility's centralized control facilities. The AMI host then uses a data management system to analyze and interpret the data collected from the consumers' meters through the network.

Home Area Networks

Installed in a consumer's home behind the utility meter, home area networks may be used for demand response programs, but also can help consumers save energy and money by becoming more energy efficient. Readily available technologies for these networks include usage monitoring devices, load control devices, and payment systems. *Usage monitoring devices* include in-home displays, which can display current energy usage in kWh, dollars per kWh, and CO_2 emissions. One example of a *load control device* is a programmable communicating thermostat (PCT). These thermostats provide real-time electricity price signals and a daily running total of the consumers' bills and can automatically control the use of air conditioners or central heating systems based on periods of peak pricing. A USB device is installed to connect the meters and appliances to the consumer's and the utility's network. Consumers can

make payments to the utility via the network, or make changes to their payment frequency or pricing programs. With such a network in place, consumers can control their electricity use by programming their appliances and heating and cooling systems to adjust to changes in energy prices.

Customer Information Feeds

Home area networks can be enhanced with new communication technologies that are currently on the market. Technological advances have reduced the costs of customer information feeds installed inside the home to **improve communication among meters and appliances**. These "gateways" are the size of thermostats, and are mounted on the wall where they can be coordinated with phone or cable lines, as well as any wireless technology consumers may be using. They enable consumers and utilities to **remotely access the meters and electricity systems**. These technologies are designed so that consumers can monitor their electricity use from anywhere inside the house or outside the home via an internet connection or personal digital assistant (PDA), making changes when energy prices change.

IV. Initiatives

Federal policies

Both the 2005 and 2007 comprehensive energy bills passed by the U.S. Congress support the advanced metering industry.

The Energy Policy Act of 2005. EPAct 2005 requires establishment of a National Metering Standard, where utilities offer customers time-based rates, or in the case of large customers, capacity credits. EPAct also requires that utilities and state utility commissions study the potential for demand response as a quantifiable, reliable resource for regional planning purposes and requires that demand resources be treated equitably relative to conventional resources. The legislation directed states to commence consideration by August 2006, and to complete consideration within a year. In addition, EPAct 2005 required FERC to prepare reports assessing electric demand response resources from all consumer classes. The 2006 and 2007 reports, *Assessment of Demand Response and Advanced Metering,* include an analysis of the saturation and penetration rate of advanced meters and communications technologies, devices, and systems.

Energy Independence and Security Act of 2007. This act encourages the deployment of ''smart'' technologies (i.e., real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation, and directs the integration of ''smart'' appliances and consumer devices. In addition, the Act directs the Secretary of the U.S. Department of Energy to work with other agencies, electric utilities, and states to develop advanced techniques for measuring peak load reductions and energy efficiency savings from smart metering, demand response, distributed generation, and electricity storage systems. The legislation also establishes a Federal Matching Fund for Smart Grid Investment Costs, dedicated to supporting metering devices, sensors, control devices, and other devices integrated with and attached to an electric utility system or retail distributor or marketer of electricity that is capable of engaging in Smart Grid functions. Funding for such programs is available until 2012, while a Smart Grid Advisory Committee and Smart Grid Task Force established by the legislation are funded through 2020.

Other federal and regional efforts

FERC-NARUC. The Demand Response Collaborative between FERC and the National Association of Regulatory Utility Commissioners (NARUC) addresses the coordination of federal and state demand

response policies, such as regulatory barriers to increased customer participation in demand response programs identified in the FERC *Assessment of Demand Response and Advanced Metering*.

National Action Plan for Energy Efficiency - Vision for 2025. The Action Plan encourages implementation of state of the art utility billing, information sharing, and delivery systems. The Plan also encourages:

- Utilities to work with large customers to develop methods of supplying consistent energy use and cost information across states, service territories, and the nation.
- Utilities and other program administrators to:
    - Explore the development and implementation of state-of-the-art energy delivery information, including smart grid infrastructures, data analysis, and two-way communication programs.
    - Explore methods of integrating advanced technologies to help curb demand peaks and monitor efficiency upgrades to prevent equipment degradation.
    - Coordinate demand response and energy efficiency programs to maximize value to customers.

Independent System Operators (ISOs). PJM Interconnection has identified the lack of widespread use of hourly and sub-hourly metering as an obstacle to including demand response into PJM transmission planning and operations. Consequently, PJM has pledged to work with state regulatory agencies to support their efforts to advance AMI technology and deployment (FERC 2006).

The New York ISO (NYISO) recently initiated a Comprehensive Reliability Planning Process which identifies reliability concerns and transmission needs. This process involves extensive modeling, considering expected loads, generation resources, transmission limitations, and demand response resources. NYISO is considering allowing demand response to apply to net metering provisions (FERC 2006).

Mid-Atlantic Distributed Resources Initiative (MADRI). The MADRI Toolbox was developed to provide Mid-Atlantic public utility commissions with additional resources for learning more about advanced metering infrastructure. The AMI Toolbox represents a compilation of reports, studies and other Web-based resources.

State policies

California. The California Public Utilities Commission (CPUC) and the California Energy Commission are promoting demand response and advanced metering through the Statewide Pricing Pilot, Advanced Metering Initiative, and Energy Action Plan II. The Statewide Pricing Pilot was conducted to investigate the effect of different time-based pricing strategies on consumer behavior. The study included 2,500 customers, involved all three investor-owned utilities (IOUs), and ran from July 2003 to December 2004. The Advanced Metering Initiative is a plan by Southern California Edison to replace five million standard meters in residential and commercial buildings with AMI systems. The Energy Action Plan II creates a "loading order" where utilities must prioritize their resource procurements as follows: (1) energy efficiency and demand response, (2) renewable energy (including renewable DG), and (3) clean fossil-fueled DG and clean fossil-fueled central-station generation. The CPUC requires investor-owned utilities to meet 5% of their load requirements with demand response (FERC 2006).

Kansas. Kansas City Power and Light (KCP&L) offers a free programmable thermostat, worth $300, to qualifying customers to manage their energy usage (KCP&L 2007). The consumer can remotely program the thermostat for air conditioning units through the internet. Kansas does not have a consumer net

metering incentive, but does have a renewable metering incentive on the wholesale level that provides the sale of renewable energy at 150% of the avoided cost (KCP&L 2007).

New York. New York's system benefits charge (SBC) supports advanced metering activities through NYSERDA's Residential Comprehensive Energy Management Services Program (CEM). This program provides incentives for consumers to help fund a portion of the cost of installing advanced metering and energy management systems in single-family dwellings and multifamily buildings. NYSERDA offers a variety of programs, including Peak-Load Reduction and Technical Assistance (for load control and energy efficiency), to facilitate participation in demand-reduction initiatives and other conservation programs. It offers incentives for the installation of smart meters and for systems and software to read them through the Internet (NYSERDA 2007). The New York Public Service Commission has authority over approval of meters used in customer billing, commonly called "revenue-grade" meters, and accredits firms that offer advanced electric metering services (NYSERDA 2003).

Ohio. On March 28, 2007, the Public Utilities Commission of Ohio approved a set of recommendations that address advanced metering infrastructure and demand response, interconnection, stand-by rates, net metering, and renewable energy portfolio standards. The approved recommendations require Ohio's electric distribution utility companies to file a comprehensive list of AMI technologies and costs, and identify types of customers and their related load shapes. The state will also eliminate rules that place limits on net metering and streamline the interconnection rules that would allow for simplified applications and fee schedules (DOE 2007).

Ontario, Canada. The government of Ontario is facilitating a number of key initiatives to become a leader in energy efficiency, including a commitment to install smart meters in 800,000 homes and businesses by 2007 and throughout all of Ontario by 2010. The government also plans to introduce time of use pricing, legislation to implement the government's smart metering and conservation targets, facilitation of installation of smart meters in condominiums, and a requirement that commercial submetering entities providing condominiums with smart meters be licensed by the Ontario Energy Board (Ontario 2007).

V. Additional Resources

Information Resources for Advanced Metering Technologies	
Title/Description	**Web Site**
Advanced Metering Programs and Initiatives	
ACEEE Emerging Technologies in Energy Efficiency Summit. The American Council for an Energy-Efficient Economy is dedicated to advancing energy efficiency as a means of promoting economic prosperity and environmental protection. The organization sponsors a biennial summit to facilitate discussion on innovations in energy-efficient technologies and practices such as demand response. Their October 2006 summit, for example, included a working session on Demand Response: Utility-Side Technologies (Meter to Grid).	http://www.aceee.org
Association of Energy Services Professionals (AESP). AESP is a member-based association dedicated to improving the delivery and implementation of energy efficiency, energy management, and distributed renewable resources that can provide numerous information resources on the energy services industry.	http://www.aesp.org/displaycommon.cfm?an=1&subarticlenbr=118

Information Resources for Advanced Metering Technologies	
Title/Description	**Web Site**
Demand Response and Advanced Metering Coalition (DRAM). DRAM is a non-profit organization that includes the leading providers of demand response technologies and services, including advanced metering.	http://www.dramcoalition.org
Electric Power Research Institute (EPRI) Dynamic Energy Management Initiative. This initiative supports research on improving energy efficiency in end-use equipment and developing advanced communications and control devices as strategies for demand response.	http://my.epri.com/portal/server.pt?open=512&objID=300&PageID=534&cached=true&mode=2&userID=2
The Environmental Change Institute. An interdisciplinary unit administered within the Oxford University Centre for the Environment that has conducted research on electric metering technologies.	http://www.eci.ox.ac.uk/research/energy/electric-metering.php
Lawrence Berkeley National Laboratory Demand Response Research Center (LBNL). LBNL operates a Demand Response Research Center that conducts research across a wide range of demand response disciplines.	http://drrc.lbl.gov/drrc.html
National Energy Technology Laboratory (NETL) Modern Grid Strategy. Through this NETL program, DOE seeks to accelerate the modernization of the U.S. electric grid by fostering collaboration between stakeholders nationwide.	http://www.netl.doe.gov/moderngrid
Ontario Ministry of Energy. The Ontario Ministry of Energy Web site provides information on the province's smart metering initiatives, which include an AMI program.	http://www.energy.gov.on.ca/index.cfm?fuseaction=electricity.smartmeters
Pacific Gas & Electric (PGE) SmartMeter Program. PGE began upgrading gas and electric meters in its distribution area in 2006. By 2012, the utility expects to extend its SmartMeter program to all of its customers.	http://www.pge.com/smartmeter/
Southern California Edison (SCE) SmartConnect Program. Through its SmartConnect program, SCE plans to install five million advanced meters in residential and commercial buildings. The program is expected to reduce peak demand by approximately 1,000 MW.	http://www.sce.com/PowerandEnvironment/ami
U.S. Department of Energy GridWise Program. The GridWise program and its associated GridWise Alliance support development of advanced sensor, communication, control, and information technologies to enable seamless integration for all distribution systems.	http://gridwise.pnl.gov
Additional Information Materials on Advanced Metering	
Deciding on "Smart" Meters: The Technology Implications of Section 1252 of the Energy Policy Act of 2005. This report by Edison Electric Institute provides information for utilities and members of the regulatory community on the implications of the 2005 EPAct with respect to advanced metering.	http://www.eei.org/industry_issues/electricity_policy/federal_legislation/deciding_on_smart_meters.pdf
Directive on Energy End-Use Efficiency and Energy Services. This directive from the European Parliament is intended to assist European Union member states in enhancing the cost-effectiveness and efficiency of energy use.	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0032:EN:NOT
How Can We Manage What We Cannot Measure? This white paper by the Delaware Public Service Commission provides an overview of advanced metering technologies and discusses how these technologies can be cost effective strategies for reducing customer electricity costs.	http://depsc.delaware.gov/electric/advmtr_whitepaper.pdf

Information Resources for Advanced Metering Technologies	
Title/Description	**Web Site**
Learning from European Advanced Metering Deployments. This article discusses benefits to North American utilities of building on the experiences and best practices of European deployment of advanced metering initiatives.	http://uaelp.pennnet.com/display_article/295749/22/ARTCL/none/none/Learning-from-European-Advanced-Metering-Deployments/
Overview of Advanced Metering Technologies and Costs. This DRAM white paper provides information on the costs and benefits of advanced metering and communications technologies.	http://www.dramcoalition.org/white_paper_overview_of_am_technologies_and_costs.htm
The Real Story on AMI: From Conception to Completion, Learning from Those that Have Lived It. This presentation provides an overview of AMI principles and examples of AMI programs in action. The presentation also discusses implications for AMI under the 2005 EPAct.	http://www.state.ar.us/psc/presentations/Clark%20Pierce/AMI%20101%20AKPSC.pdf
Smart Grid Newsletter. This newsletter, sponsored by the GridWise Architecture Council and Pacific Northwest National Laboratory, covers modernization and automation of the electric power delivery industry.	http://wwwsmartgridnews.com
Smart Metering. This paper discusses the benefits of advanced metering infrastructure and identifies issues that need to be resolved for advanced metering to be fully deployed in the U.S.	http://www.leonardo-energy.org/drupal/files/SmartMetering.pdf?download
Smart Metering Could Throttle Carbon. This article discusses the United Kingdom's smart metering initiative, which involves soliciting consultation from experts on a variety of energy efficiency proposals published in a government white paper published in May 2007, including smart metering.	http://www.businessweek.com/globalbiz/content/aug2007/gb2007086_356928.htm?chan=globalbiz_europe+index+page_top+stories
Smart Meters, Demand Response, and "Real Time" Pricing: Too Many Questions and Not Many Answers. This presentation from the National Association of Regulatory Utility Commissioners provides information on state experiences with smart meters, demand response, and real-time pricing, and presents several key questions associated with the deployment of these technologies and services.	http://www.narucmeetings.org/Presentations/Dynamic%20Pricing%20NARUC%202007.ppt
The View from Europe: Smart Grid Efforts Share Common Goal with U.S. This article discusses the differences and similarities of advanced metering activities and interests between Europe and the United States. The article discusses the benefits of global collaboration as a means of advancing smart grid technology.	http://uaelp.pennnet.com/display_article/295759/22/ARTCL/none/none/The-View-from-Europe:-Smart-Grid-Efforts-Share-Common-Goal-with-US/

References

American Public Power Association (APPA). Nov-Dec 2007. AMR or AMI? Available: http://www.appanet.org/newsletters/ppmagazinedetail.cfm?ItemNumber=20460&sn.ItemNumber=2108

Darby, Sarah. The Effectiveness of Feedback on Energy Consumption: A Review for DEFRA of the Literature on Metering, Billing and Direct Displays. The Environmental Change Institute, University of Oxford, April 2006.

Darby, Sarah. Making it Obvious: Designing Feedback into Energy Consumption. The Environmental Change Institute, University of Oxford, 2001

Demand Response and Advanced Metering Coalition (DRAM). April, 2004. Overview of Advanced Metering Technologies. Available: http://www.dramcoalition.org/white_paper_overview_of_am_technologies_and_costs.htm

Delaware Public Service Commission (DPSC). 2006. Whitepaper on Advanced Metering. Available: http://depsc.delaware.gov/electric.shtml

Department of Energy, Energy Efficiency and Renewable Energy. EERE State Activities and Partnerships Web Site. April 2, 2007. http://www.eere.energy.gov/states/state_news_detail.cfm/news_id=10694/state=OH

Environmental Protection Agency. 2006. National Action Plan for Energy Efficiency. Available: http://www.epa.gov/cleanenergy/documents/napee/napee_report.pdf

Federal Energy Regulatory Commission (FERC). August 2006. Assessment of Demand Response and Advanced Metering. Available: http://www.ferc.gov/legal/staff-reports/demand-response.pdf

Hydro One, The Impact of Real Time Feedback on Residential Electricity Consumption: The Hydro One Pilot, March 2006.

Kansas City Power and Light (KCP&L). 2007. Energy Optimizer. Available: http://www.kcpl.com/residential/acc.html

Leonardo Energy. July 2006. Smart Metering. Available: http://www.leonardo-energy.org/drupal/node/769

New York State Energy Research and Development Authority (NYSERDA). Fall 2003. A Primer on Smart Metering. Available: www.energetics.com/MADRI/toolbox/pdfs/background/primer.pdf

NYSERDA. 2007. Available: http://www.nyserda.org/programs/pdfs/102502technology.pdf

U.S. Department of Energy Modern Grid Initiative. Available: http://www.netl.doe.gov/moderngrid

Ontario Ministry of Energy. August 15, 2007. Smart Meters. Available: http://www.energy.gov.on.ca/index.cfm?fuseaction=electricity.smartmeters

PSE&G. 2007. Testing Advanced Metering Technologies as Additional Way to Combat Climate Change. Available: http://www.pseg.com/media_center/pressreleases/articles/2007/ 2007-12-12.jsp

Southern California Edison (SCE). 2007. Building a Smarter, Cleaner Energy Future with Our Customers. Available: http://www.sce.com/PowerandEnvironment/ami/

Texas Public Utilities Commission (TPUC). May 25, 2007. Advanced Meters. Available: www.puc.state.tx.us/rules/subrules/electric/25.130/25.130ei.cfm