Metric #9: Grid-Responsive, Non-Generating Demand-Side Equipment

M.9.1.0 Introduction and Background

This metric measures the penetration of demand-side equipment that is responsive to the dynamic needs of the smart grid. The products that have emerged and continue to evolve in this category either directly monitor or receive communicated recommendations from the smart grid. This equipment then provides the useful dynamic responses to those needs either through automated responses or through the conveyance of useful information to consumers who then might appropriately respond. This metric includes only those grid-responsive features that are available on original equipment or by the simple retrofit of existing equipment without needing highly skilled labor. This metric intentionally excludes advanced meters (to be addressed in Metric 12), communications gateways (e.g., home management systems, building automation systems, etc.), equipment that generates or stores electrical energy, and equipment that requires unique engineering for its installation at an endpoint. This excludes much industrial and commercial equipment, except those examples having dynamic grid responses that are supplied on original equipment or by simple retrofit. The metric excludes many "smart" equipment features that target conservation (e.g., occupancy sensors, dirt sensors) or non-energy purposes (e.g., entertainment, security, health).

Examples of grid responsive equipment include communicating thermostats, responsive appliances, responsive space conditioning equipment, consumer energy monitors, responsive lighting controls, controllable wall switches, etc. This category of equipment also encompasses switches, controllable power outlets and various other controllers that could be used to retrofit or otherwise enable existing equipment to respond to smart-grid conditions. For example, a new "smart" refrigerator may be equipped with a device that coordinates with the facility's energy management system to adjust temperature controls, within user-specified limits, based on energy prices. Perhaps a new "smart" surge protector or power strip would communicate with the facility's energy-management system on behalf of the appliances plugged into it. An energy "orb" in a laundry room could advise owners of energy price penalties and opportunities. Consumers whose equipment connects to the internet might remotely receive equipment status updates, energy price updates, and be informed of maintenance issues by email or another message service. The examples are numerous and more will be invented.

The technology exists to implement such grid-responsive equipment; however, there is little standardized supporting infrastructure to communicate with the equipment, nor is there significant demand for it yet, since only approximately 8% of U.S. energy customers now have any form of time-based or incentive-based price structure.[1]

M.9.2.0 Description of Metric and Measurable Elements

This metric tracks the effectiveness and penetration of grid-responsive, non-generating demand-side equipment. The distinction with Metric 5 is that this metric focuses on the original equipment that is equipped to be load more responsive, while Metric 5 addresses benefits achieved from all controllable

[1]Federal Energy Regulatory Commission (FERC). 2008. *Assessment of Demand Response and Advanced Metering*. Staff report. Docket Number AD-06-2-000. Washington, D.C. Accessed November 6, 2008 at: http://www.ferc.gov/legal/staff-reports/demand-response.pdf

loads. The following two measurements have been identified as important to understanding and quantifying grid-responsive, non-generating demand-side equipment.

> *(Metric 9.a) Total U.S. load capacity in each consumer category (i.e., residential, commercial, and industrial) that is actually or potentially modified by behaviors of smart, grid-responsive equipment (MW):* Tracking the influence of new and enhanced "smart" consumer equipment differentiated between residential, commercial, and industrial types defines this metric.
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> *(Metric 9.b) Total yearly U.S. retail sales volume for purchases of smart, grid-responsive equipment ($)*: Establishing an overall market-share baseline for these devices will allow analysts to chart device penetration and commercialization success.

M.9.3.0 Deployment Trends and Projections

FERC's 2008 *Assessment of Demand Response and Advanced Metering*[2] estimated about 41 GW of available demand response in the U.S. Only about 8% of customers were on some form of rate- or incentive-based demand-response program. FERC's assessment further breaks this attribution out by region and by customer type. While useful, these numbers are not the same as to the numbers of those proposed for this metric. First, the smart equipment we wish to track could offer features other than traditional demand response. For example, a price-alert signal on a dryer would likely qualify the equipment as smart and responsive to the needs of the grid, but it does not necessarily bring about direct demand response. The FERC numbers also include scheduled voluntary responses (especially for industrial programs) that are communicated by phone or email and do not necessarily use or require any automation and smart equipment.

Programmable, communicating thermostats are a near-term success in this equipment category. Numerous installations of communicating thermostats have been conducted at pilot scale, and full-implementation installations are being launched. The California Energy Commission had planned to require programmable communicating thermostats as part of its 2008 Update to the Building Energy-Efficiency Standards, but had to revise this requirement.[3] It had been projected that the market for communicating thermostats in new California construction could contribute 100,000 new controllable points each year and that that number would be augmented by another 100,000–200,000 thermostats added yearly in existing buildings.[4]

Smart, grid-responsive appliances remain in their commercialization infancy. Trials have occurred in small pilot-scale installations only, where, in most cases, only limited integration of the grid-responsive features has been achieved. For example, the Department of Energy ran a smart-grid experiment on the Olympic Peninsula, Washington, where they tested retrofitted thermostats, water heaters, and clothes dryers fitted with communicating, grid-responsive equipment. The results were promising. The equipment reduced load fluctuations and decreased peak loads and consumer energy costs.[5] As of 2002,

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[2]FERC 2008.

[3]California Energy Commission (CEC). 2008. *California's Energy Efficiency Standards for Residential and Nonresidential Buildings.* Accessed November 17, 2008 at http://www.energy.ca.gov/title24/. Last updated November 13, 2008.

[4]Rosenfeld A. 2005. *Memorandum to Demand Response Planning Meeting Attendees*. Accessed November 17, 2008 at http://www.title24dr.com/PDFs/Demand%20Response%20Memo.pdf

[5]Hammerstrom DJ, R Ambrosio, TA Carlon, DP Chassin, JG DeSteese, RT Guttromson, OM Jarvegren, R Kajfasz, S Katipamula, P Michie, T Oliver, and RG Pratt. 2007. *Pacific Northwest GridWise Testbed Projects: Part 1.*

through the use of gateway technology pioneered by Salton, Inc. and Microsoft, Westinghouse has manufactured appliances like bread machines and coffee makers that communicate with each other through an alarm-clock-like gateway which synchronizes its schedule and those of all its communication-enabled devices via the internet.[6] Conceivably, these communicating appliances could respond to energy objectives, although they are promoted for consumer convenience and other non-energy objectives. Other manufacturers are developing and testing responsive appliances, too.

Retrofit-able lighting controls have existed for years. Lighting can already be controlled at smart, communicating circuit panels.[7,8] Wirelessly addressable and dimmable fluorescent fixtures have become available for daylight adjustments and for commercial-building demand response.[9,10]

Autonomously responding equipment is also in its infancy. Some large commercial air handlers have been installed with under-frequency or under-voltage responses. Two hundred clothes dryers and water heaters were retrofitted with an autonomous under-frequency response during the Grid Friendly™ Appliance Demonstration.[11] Frequency responses have also been installed via load-control modules (not necessarily fitting our equipment category) and are being installed on refrigerators in the United Kingdom to provide dynamic demand.[12] By 2006, Hawaiian Electric Company, Inc. (HECO) had retrofitted 11,827 electric water heaters with Cooper Power System's Line Under-Frequency (LUF) controllers, representing 8.04 MW of under-frequency-responsive load.[13]

Many residential and commercial aggregators already incorporate web-page information services to utilities and customers as part of their system. Ambient Devices' wireless energy orb was demonstrated in conjunction with PG&E, where the orb color indicated to customers various dynamic electrical energy

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Olympic Peninsula Project. Technical Report PNNL-17167, Pacific Northwest National Laboratory, Richland, Washington, October 2007. Available at http://gridwise.pnl.gov

[6]Business Wire. April 22, 2002. *Salton, Inc. Introduces 'Smart' Home Appliances Under the Westinghouse Brand Powered by Microsoft*. Accessed November 18, 2008 at http://www.allbusiness.com/food-beverage/food-beverage-overview/5933350-1.html .

[7]Emerson Climate Technologies. 2003. *Square D Smart Panel Circuit Breaker Control Manual*. 026-1711 Rev 0 6-12-03. Computer Process Controls, Kenesaw GA. Accessed November 17, 2008 at http://www.emersonretailsolutions.com/library/manuals/0261711Rev0.pdf .

[8]Emerson Climate Technologies. 2003. *Cutler-Hammer Smart Breaker Panel Control Manual*. 026-1710 Rev 0 6-10-03. Computer Process Controls, Kenesaw GA. Accessed November 17, 2008 at http://www.emersonretailsolutions.com/library/manuals/0261710Rev0.pdf .

[9]Westinghouse. 2004. *RetroLUX™ T-5 Lighting System*. Westinghouse Lighting Corporation, Philadelphia, PA. Accessed November 17, 2008 at http://www.energysolve.com/Retrolux%20Sell%20Sheet.pdf .

[10]Piette MA and G Ghatikar. 2008. "Linking Continuous Energy Management and Open Automated Demand Response." In Proceedings of *Grid-Interop Forum 2008*, Atlanta, GA, November 11-13, 2008.

[11]Hammerstrom DJ et al. 2007. *Pacific Northwest GridWise™ Testbed Demonstration Projects: Part II. Grid Friendly™ Appliance Project.* Report PNNL-17079, prepared by PNNL for the U.S. DOE. Accessed November 18, 2008 at http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17079.pdf .

[12]Howe A. 2008. "Introducing Dynamic Demand." In proceedings of *Grid-Interop Forum 2008*, Atlanta, GA, November 11-13, 2008.

[13]Block K, J Layer, and R Rognli. 2007. "Cooper Power Systems Cannon Demand Response Goes Hawaiian. Cooper Power Systems, *The Line*, August 2007. Accessed November 19, 2008 at http://www.cooperpower.com/Library/TheLine/pdf/07_08/Line_HECO.pdf .

price conditions.[14] Whirlpool Corporation demonstrated in its Woodridge Study that appliance consumption could be reduced and deferred by appliance panel indicators and customer feedback.[15]

According to recent interviews conducted for this report (Annex B),

- 45% of responding utilities presently have no automated responses for signals sent to major energy-using equipment
- 45% have some in development
- 10% have a little.

Due to their recent addition to the market, estimates of current smart and web-enabled equipment, as well as forecasts, are hard to obtain. However, due to the convenience, as well as the energy and cost-savings potential of these devices, demand for such devices is expected to increase as the supporting infrastructure becomes available.

M.9.3.1 Associated Stakeholders

Associated stakeholders include:

- End users: incentives to reduce electricity bills as peak-demand electricity prices rise;
- Balancing authorities and reliability coordinators: frequency-responsive devices can greatly benefit the grid during stressed conditions and prevent blackouts;
- Product and service providers: they are interested if there is a market. Appliance manufacturers will have an obvious role to play in providing the market with competitive and high-quality "smart" solutions and should welcome an opportunity to compete by providing better grid services than do their competitors;
- Policymakers: incentives to create a more reliable grid.

M.9.3.2 Regional Influences

These devices will be expected to meet the same standards that non-smart devices are required to meet in terms of energy use, safety, and other regional parameters.

The evolution of smart-grid devices will be heavily influenced by the way energy programs are offered and enacted. Energy programs tend to be localized and regional; however, smart-grid devices will be most economically manufactured for a larger national, or even global, customer set. Cost-effective application of smart-grid devices will be difficult to attain without much standardization.

[14] Ambient Devices. 2008. *PG&E Demand-Response Orb*. Accessed November 17, 2008 at http://www.ambientdevices.com/cat/orb/PGE.html

[15] Horst GR. 2006. *Whirlpool Corporation Woodridge Energy Study and Monitoring Pilot.* Whirlpool Corporation. Accessed November 17, 2008 at http://www.ucop.edu/ciee/dretd/documents/Woodridge%20Final%20Report.pdf

M.9.4.0 Challenges to Deployment

Smart, grid-responsive equipment faces significant implementation challenges. As was succinctly stated by Arthur Rosenfeld, Commissioner, CEC, in a 2005 memorandum concerning programmable, communicating thermostat programs in California, "We perceive that the barriers to increased market penetration include relatively high costs of hardware installation, no plug-and-play capabilities, lack of a universal communication protocol to send price or emergency signals, and a lack of product availability at big box retailers."[16]

M.9.4.1 Technical Challenges

Among the biggest challenges facing these devices are technical considerations. Implementing communication interfaces in modern appliances requires significant investments into hard-, soft-, and firm-ware design.[17] Memory considerations such as the amount of data storage and networking options are an important concern. Other hardware considerations include accommodating diverse operating environments such as temperature and water exposure. Further decisions will have to be made regarding communications options. "Wired" networking options have costs and performance characteristics different from those of "wireless" networking options.

M.9.4.2 Business and Financial Challenges

Currently there is significant interest in this field. Businesses such as LG Electronics and Westinghouse are designing and producing more "web-enabled" household appliances. Research and development in these fields will poise producers to easily transition into "smart" devices. However, incorporating electronics into increasing numbers of appliances, as well as developing and maintaining software for these appliances, will require a new look at the products' life-cycle costs. Manufacturers and grid entities have not yet settled on standards that would give manufacturers the confidence necessary to fully integrate and launch grid-responsive equipment. Perhaps this is because the business case for integration of these features has not yet been fully proven.

M.9.5.0 Metric Recommendations

The smart equipment discussed in this metric remains in its infancy. New examples continue to emerge. Consequently, the definition of which equipment should and should not be counted in this metric should also be expected to evolve in the next few years. An issue in defining this metric is the emphasis on residential appliances. Commercial building and industrial equipment with embedded, grid-responsive capability deserves to be more closely scrutinized in future investigations.

Today, the numbers of responsive equipment of other types are overwhelmed by the relative commercial success of communicating thermostats. This metric may be more meaningful if it were separated from the rest, leaving a catch-all category for other grid-responsive equipment that is in a much less mature state of commercialization.

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[16]Rosenfeld. 2005.

[17]Eckel C, G Gaderer, and T Sauter. 2003. "Implementation Requirements for Web-Enabled Appliances – a Case Study." In *2003 IEEE Conference on Emerging Technologies and Factory Automation Proceedings (ETFA 2003).* Vol 2, pp. 636-642. Institute of Electrical and Electronics Engineers, Piscataway, New Jersey. Accessed November 18, 2008 at http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1248758&isnumber=27958

Secondary information sources were not readily found for estimating penetration of responsive equipment. More effort is required to accurately quantify the penetration of responsive equipment. In two years, pilot installations of responsive-equipment examples should be more readily compiled.