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Enabling Demand-Response-Ready Appliances and Devices

Volume 2: Update and Air Conditioning Survey Results

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Technical Update, March 2011

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ABSTRACT

This Technical Update reports on the results of a 2010 Electric Power Research Institute (EPRI) survey of utilities that was performed as part of a multi-year effort to develop functional specifications for residential "demand-response- (DR-) ready" appliances and devices. This report also provides an update of industry trends and smart appliance development.

DR-ready appliances and devices are defined as those that are able to participate in demand-response programs out of the box. Such devices can receive utility signals and automatically modify their operation to reduce or shift demand.

The survey was conducted with 22 utility representatives at the EPRI Power Delivery and Utilization Advisory Meeting in September 2010 in Orlando, Florida. The purpose of the survey was to identify what utilities perceive as "must have" functions of air conditioners. Survey results will be used to inform a process to develop consensus on the functional capabilities for DR-ready air conditioners and other residential end-use devices by a broad group of stakeholders, including equipment and appliance manufacturers, government agencies, consumer groups, and utilities.

Industry trends covered here include the status of the EPRI-led development of specifications for a communication interface for residential devices, a snapshot of smart appliance concepts featured at the 2011 Consumer Electronics Show, and a summary of appliance manufacturer perspectives on how to advance smart-grid-enabled appliances for demand response.

Keywords

Air conditioning
Appliances
Demand-response ready
DR ready
Residential energy
Smart appliances

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1
INTRODUCTION

In 2009, EPRI began a multi-year collaborative effort with a broad group of public- and private-sector organizations to develop a set of functional specifications for residential "demand-response ready" (DR-ready) appliances and devices, and to create a roadmap for industry migration towards more automated and ubiquitous residential demand response.

To be considered demand response-ready (DR-ready), equipment must be able to participate in demand response programs out-of-the-box. To achieve this, devices must have the capability to receive signals from a utility, such as price information or an emergency event signal, and must have the capability to respond automatically to the signal by adjusting operation to reduce or shift demand in a manner consistent with both utility grid objectives and consumer expectations for comfort, convenience, and quality of service.

The organizations involved in this project include utilities, appliance and equipment manufacturers, consumer groups, and government agencies such as the U.S. Environmental Protection Agency and the Department of Energy.

The residential devices addressed in this project are major energy-consuming appliances and equipment, as well as controls such as thermostats and home energy management systems. Devices addressed to date include:

- Air conditioners
- Water heaters
- Pool pumps
- White goods, such as refrigerators, washers & dryers
- Programmable communication thermostats
- Home energy management systems.

This project was undertaken because of two primary factors. First, utilities had expressed interest in the advent and market adoption of end-use devices that do not require specialized utility-installed controls to participate in demand response programs. By avoiding the need for "truck rolls" to install load control infrastructure, utilities stand to reduce operating costs of demand response while simultaneously increasing the resource potential of demand response.

Secondly, appliance manufacturers in the process of incorporating smart grid-enabled features to differentiate their products expressed the importance of utility industry participation in navigating the uncertain waters of evolving functional and communications standards for home area networking and energy management. Since demand response is one of the most tangible applications of smart grid infrastructure, manufacturers sought out utility industry opinion on what functional features would best distinguish their products as suited to demand response.

Project Objectives

The emphasis of the project has been refined since its inception in 2009:

Development of Functional Capabilities, Versus Functional Specifications

The primary objective set out originally for the project was to develop *functional specifications*, a term which to some implies a prescription for device features or actions. Design prescriptions are not the intent of the project, but rather the development of recommended *functional capabilities* of devices. This includes a description of recommended device capabilities for communication, for load reduction, and for reporting of its capabilities. No specific features or actions will be prescribed; they will simply be identified as examples of what can enable automated demand response. Emphasis on capabilities, versus specifications or requirements, will enable device manufacturers to design their products or systems to be qualified to participate in demand response activities without fear of obsolescence, and with freedom to innovate device and system designs.

Develop a Set of Guidelines for Design of Residential Demand Response Programs that Involve DR-ready Devices

DR program designs that can garner support from manufacturers and consumers—and that can work well within the architecture of the smart grid—will be explored as part of this project to enable demand response ready devices. Guidelines will be developed for various scenarios of device capabilities and information exchange.

For example, one scenario would be in keeping with an EPRI design concept for the smart grid that enables advanced management of distributed energy resources, including the distributed resource represented by demand response devices. In this concept, the focus is on the energy provided by the resource rather than the device itself. Via the smart grid, the utility grid provides information on price or an event to a *Virtual End Node*–in this case the DR-ready device or group of devices—via a *Resource Energy Controller*, which may be operated by a utility or a third party. The Resource Energy Controller must know the capabilities and current availability of the resources in its domain, must be able to communicate with devices via a standard interface, and be able to perform demand response functions requested. The device or Virtual End Node only reports upstream to a single Resource Energy Controller, and not directly to the grid. In this way the controller can aggregate multiple devices and other end nodes to meet the situational needs of the utility grid, which can change dynamically. It would be unnecessary for the details of the demand response action, or what specific hardware was involved, to be communicated back to the grid.

In this smart grid concept:

> *A water heater is no longer defined by name as a "water heater." Rather it is an electricity consumer that consumes 4500 watts, can shed load within a few cycles, remain off for several hours, and could also be safely called upon to consume load if needed.*[1]

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[1] *Concepts to Enable Advancement of Distributed Energy Resources: White Paper on DER*. EPRI, Palo Alto, CA: 2010. 1020432.

DR program design options should also address the position of the Association of Home Appliance Manufacturers (AHAM)[2] on achieving a widely accepted smart grid. AHAM's view is that to protect consumer choice and privacy, DR-ready home devices should not share information with utilities on the type and state of appliance involved in demand response, or the actions they take. AHAM recommends that utilities obtain data from the smart meter only. Communication would be one way, with the utility providing only situational information (price, emergency), and the smart meter outside the home would be used to monitor whether load has been reduced in response to the situation. (For more information on the AHAM recommendations, see Chapter 3, Industry Trends and Smart Appliances.)

Project Approach

The development of functional capabilities is based largely on information sharing between the key stakeholders so they can reach consensus on capabilities that must be present in order for devices to be DR ready.

To date, emphasis has been on soliciting input via a workshop of a broad group of stakeholders and surveys of utility representatives. This material, including survey results presented in this report, are intended to help inform the process of identifying functional capabilities. These capabilities will be documented and provided to organizations that develop voluntary specifications and standards for equipment ratings, labels, or qualifying criteria for utility and government rebates. Such groups can use the information as the basis of any criteria they develop for what is considered DR ready.

Project Activities

The focus of the project has been to identify the potential communication and energy load reduction and load shifting capabilities (framed as functional specifications) of selected devices. This has been accomplished through the following activities:

1. *2009 survey of utilities* regarding their demand response programs and priorities.
2. *October 2009 workshop with a broad set of stakeholders*, including manufacturers, utilities, government agencies and others to share information on the state of smart appliance an device development, and prepare a list of potential functional specifications for selected categories of devices.
3. September 2010 publication of *Enabling Demand Response-Ready Appliances: Volume 1: Functional Specifications.* EPRI, Palo Alto, CA: 2010. 1017878. This report documents the master list of potential functional requirements for residential end-use devices that were identified by stakeholders at the October 2009 workshop and in a 2009 survey of utility representatives. It also reports on industry trends and developments.
4. *September 2010 survey of utility advisors* for the EPRI Energy Efficiency and Demand Response Program (170) to refine the list of functional specifications for air conditioners—the residential load that has traditionally been the prime demand response resource. The survey was designed to garner information on what utilities consider to be

[2] Association of Home Appliance Manufacturers (AHAM), Smart Grid White Paper: *The Home Appliance Industry's Principles & Requirements for Achieving a Widely Accepted Smart Grid*, Washington, DC: December 2009.

"must have" functions of air conditioners for demand response including communication and reporting capabilities and load reduction capabilities.

Next Steps

Completion of the project is slated in 2011, and entails the following activities:

1. *Conduct surveys of all major stakeholders***.** Conduct online and in-person surveys of utility representatives, as well as devices manufacturers, and members of consumer and government organizations. This will be done to develop data that can inform the process of refining the potential functional capabilities of DR-ready residential equipment into a consolidated, consensus "must have" list.
2. *Identify consensus functional* capabilities of DR-ready devices. This may include identifying what has to happen to be able to move ahead with device communication interface specifications that are being developed through EPRI efforts with manufacturers, standard body organizations, and others. (See "EPRI Modular Interface Development Project" in Chapter 3 for more details on the communications interface.)
3. *Develop guidelines for demand response* programs that can garner manufacturer and consumer support, and help prepare for the advent of smart functionality of in-home devices and controls.
4. *Develop a roadmap* for achieving mass-market demand response. This will be done in association with project working groups.

This Report

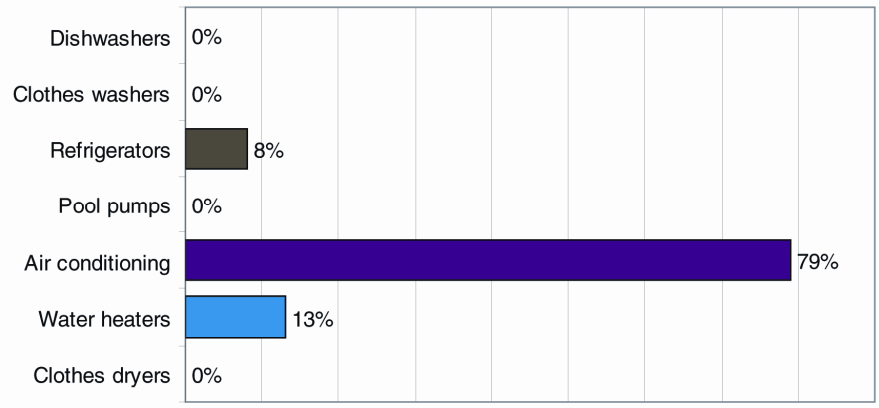
The results of the 2010 utility survey on air conditioners, item 4 under Project Activities above, are documented in this report. These results represent the utility view on what key features and functions of air conditioners would make them DR-ready. They do not represent a consensus view of stakeholders. Going forward, EPRI plans to conduct additional surveys with all stakeholders, so that potential functional specifications from the initial master list developed at the stakeholder workshop can be refined or revised into a consensus document on functional capabilities.

This report also provides an update on industry trends and smart appliances (see Chapter 3).

2
POTENTIAL AIR CONDITIONER FUNCTIONAL SPECIFICATIONS

In September 2010 advisors of the EPRI Energy Efficiency and Demand Response Program (170) attending the EPRI Power Delivery and Energy Utilization (PDU) Advisory Meeting in Orlando, Florida, were surveyed to gauge utility opinion on "must have" functions of DR-ready air conditioners.

Air conditioners are a category of residential end-use device deemed of highest priority for demand response by utilities according to an instant, electronic poll of utility representatives done at the PDU Advisors' meeting (see Figure 2-1).



Sample size = 24 utility respondents

Figure 2-1
What are the Highest Priority Devices for Demand Response?

Air conditioning load is the largest contributor to summer peak demand, exceeding 50% of total peak demand on hot summer days. For this reason, many utilities for decades have had load management programs focused on direct load control of central air conditioners.

In association with an instant, electronic poll of utility members on priorities, a written survey was conducted with EPRI utility advisors, in which respondents were asked to rate the key attributes and capabilities for DR-ready air conditioners, selecting from a list of potential functional specifications previously developed by stakeholders and presented as the initial master list below.

Initial Master List of Air Conditioner Functional Specifications

The following desired attributes of DR-ready air conditioners were gleaned from a combination of opinions expressed at the October 2009 stakeholder workshop and utility survey responses. This list was used as the basis of the written survey (see Appendix A, Survey Instrument) for utility representatives.

- Resident clock/timer with automatic daylight savings adjustment
- User-programmed specifications saved to memory in event of power loss (i.e. no need to reprogram)
- On/Off Compressor Cycling Control
  - Programmed for electricity price triggers (voluntary)
  - Programmed for time of day triggers (voluntary)
  - Programmed for response to utility event signals (voluntary)
  - Utility-controlled cycling – including full shut down under emergency conditions – with manual override
- Multi-speed compressors; Variable-speed control
- Defining temperature set-point range
  - Programmed for electricity price triggers (voluntary)
  - Programmed for time of day triggers (voluntary)
  - Programmed for response to utility event signals (voluntary)
  - Utility-controlled (DLC) cycling
  - User to set temperature within comfort range
  - Utility-controlled (DLC) temperature setback with manual override
- Fan Speed Modulation / Dehumidification Control
  - Variable speed operation
  - On/off
- Modes of Operation
  - Normal programmed routines (time of day; weekday and weekend)
  - Programmed DR modes
    - Ability to program off-peak "pre-cooling" by adjusting temperature set points as a function of time, utility retail price, emergency signal (day ahead?)
    - Time of day programs: Where fixed or day-ahead TOU rates exist, automatically receive and apply to adjust time of day operation
    - System-based programs (based on signals)
      - off-peak
      - mid-peak
      - peak
      - critical peak
    - Fan-only mode
- Remote controllability via home PCT/EMS/Gateway/other device
- Communication with utility to verify load reduction
- Display
    - What information to display

        - Temperature (current)
        - Temperature set-point
        - Program cycle
        - Event in progress
            - Utility event or high price initiated
            - Event/price duration
            - Actions being taken (confirmation)
        - Retail electricity price (if available)
        - Power draw (kW)
        - Energy consumption (kWh) over past hour/day/week/month
        - Cost savings from DR actions
    - Where to display
        - On the AC itself
        - On the thermostat (PCT)
        - Ability to communicate/transmit to central or dedicated display (dedicated home display, EMS) or PC/mobile device via e-mail, SMS

The Air Conditioning Survey Results

A survey of utility advisors to EPRI's Energy Efficiency and Demand Response Program (170) was administered on September 14, 2010. In this survey, 22 respondents rated the key attributes and capabilities for DR-ready air conditioners, based on a scale of:

1 = *Must Have* feature for DR-ready specification

2 = *Nice to Have* feature (not essential for DR-ready specification)

3 = *Don't Need* feature (unnecessary for DR-ready specification)

The intent of the survey was to identify crucial capabilities for a DR-ready air conditioner from a utility perspective, so that this information could be used in 2011 processes to refine the initial master list of air conditioner functional capabilities with a larger group of industry stakeholders.

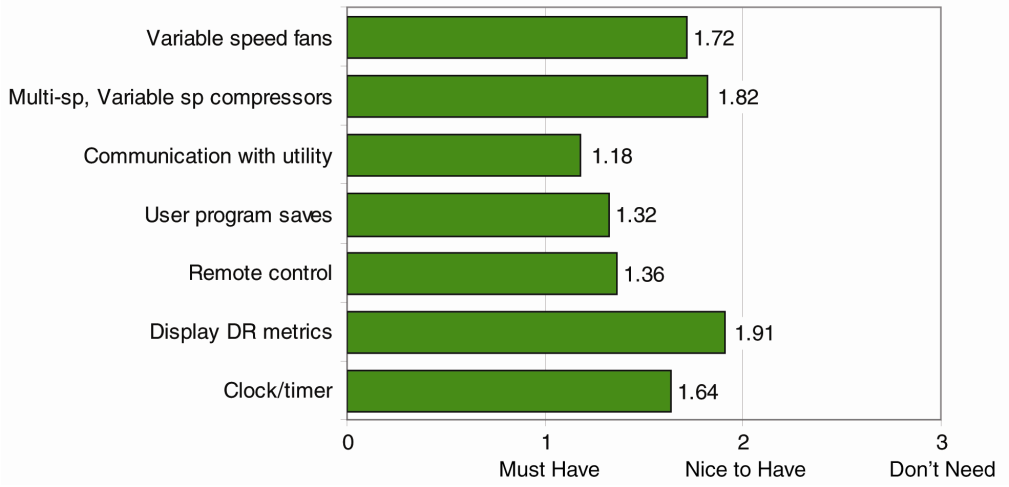
The highest priority features according to respondents were the ability of the air conditioner to communicate with the utility, and the ability to modify load with fan-only operation, on/off cycling and temperature set back.

Among metrics considered most important to display to consumers were whether a DR event is in progress, the temperature reading, and the temperature set point. Displaying a confirmation that a DR action was taken was also considered important. As to where such information could be displayed, consumer devices such as personal computers and smart phones were the most popular choices, as well as dedicated displays.

Details on survey responses are provided below.

Resident Features

The rankings of the built-in features of an air conditioner that would make it capable of being demand responsive are presented in Figure 2-2. The scale used ranges from 1 to 3, with 1 representing "must have," 2 as "nice to have," and 3 as "don't need." The lower the average score, the more important the feature was considered by the group of utility representatives surveyed.



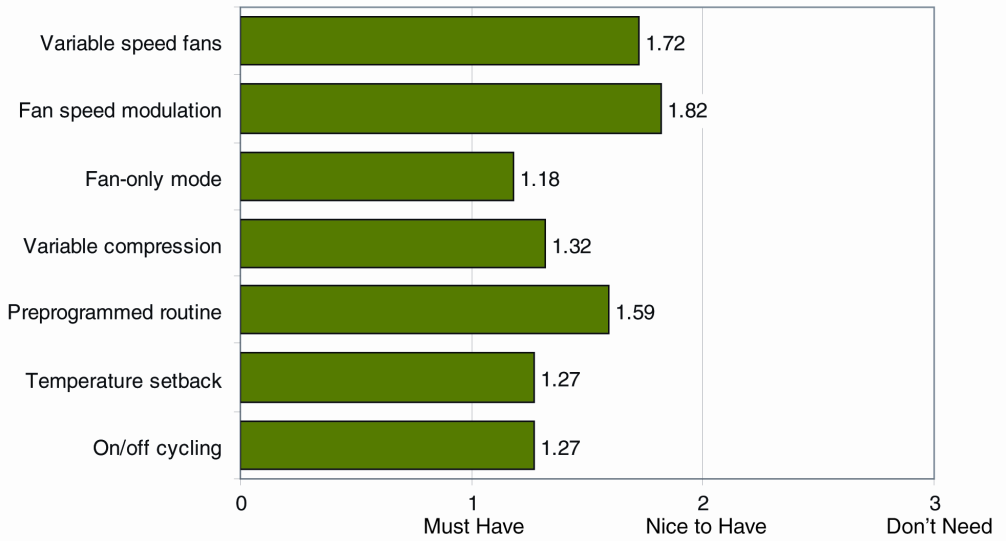
Note: Those items closest to 1, the "must have," are the capabilities/features considered most important.

Figure 2-2
Resident Features of an Air Conditioner, 2010

The built-in features of an air conditioner ranked closest to 1, or "must have," are communication with the utility at 1.18, the ability of the consumer to have user-programmed responses that are saved into memory at 1.32, and the capability for remote control at 1.36. Note that the description of the communication with the utility did not specify whether the communication was two-way (to and from utility and appliance) or one way (a signal received from the utility by the appliance). This is an issue for further discussion as consensus functional specifications are developed, since appliance manufacturers have established a position that they do not want appliances to communicate back to utilities (See Chapter 3, Industry Trends and Smart Appliances, for more information on manufacturer views.)

Types of Response

What response capabilities are essential for an air conditioner to reduce or shift load? Figure 2-3 presents utility respondent answers to this question. Fan-only operation is the most crucial and closest to "must have" at 1.18, and both on/off cycling and temperature set-back at 1.27.



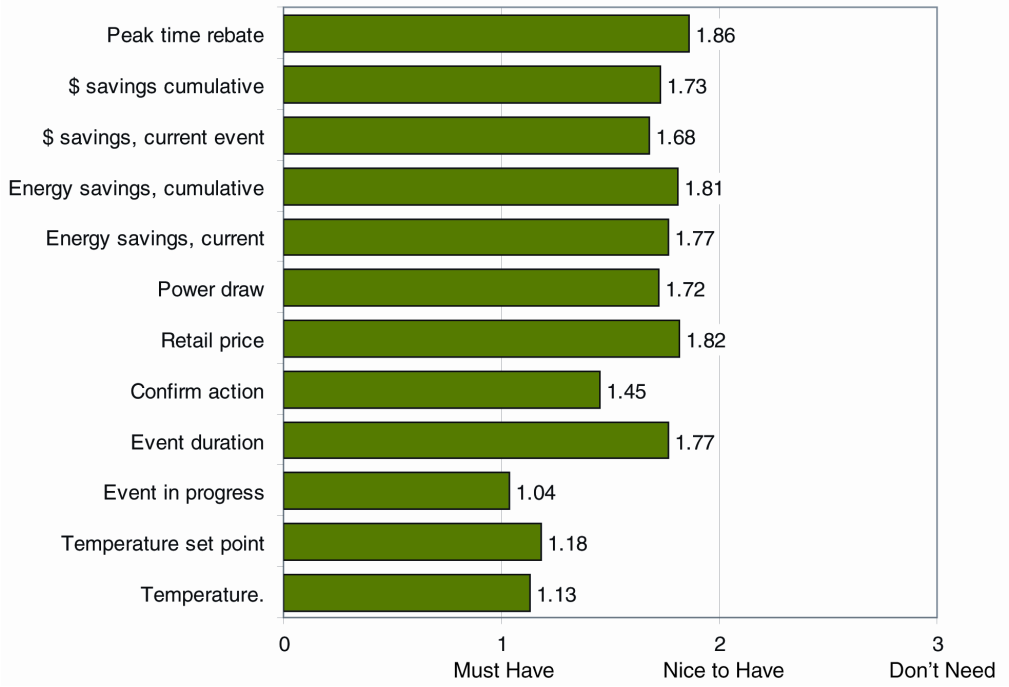
Note: Those items closest to 1, the "must have," are the capabilities/features considered most important.

Figure 2-3
Types of Response of an Air Conditioner, 2010

The features nearest to 1, or "must have," are fan-only mode at 1.18, and on/off cycling and temperature setback, both at 1.27.

Metrics to Display

DR-ready devices could provide information to consumers about a number of metrics related to energy use and demand response. Most information was considered closer to "nice to have" than "must have" per Figure 2-4 above. However, conveying that an event is in progress was considered essential at 1.04, and current temperature readings and temperature set points were also key metrics to display, at rankings of 1.13 and 1.18 respectively. Confirming that a DR action had taken place was also relatively important, at 1.45.

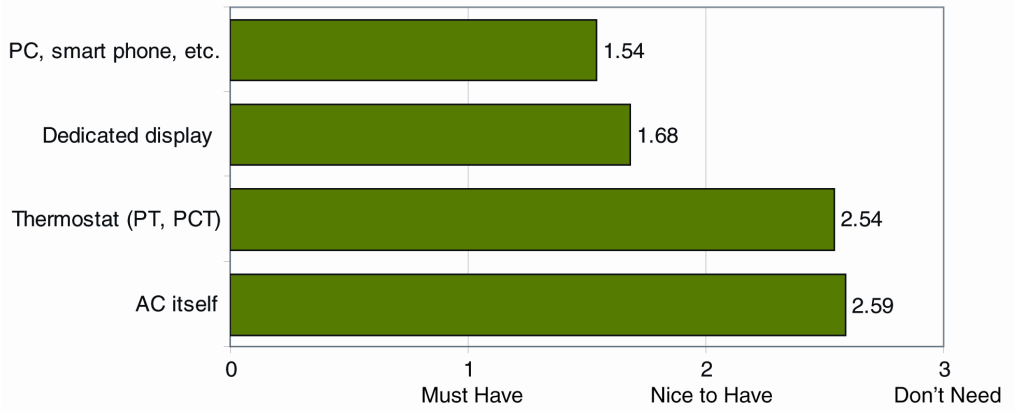


Note: Those items closest to 1, the "must have," are the capabilities considered most important.

Figure 2-4
Metrics on Air Conditioner to Display, 2010

Where to Display Metrics

Where to display information on the status of air conditioner demand response was asked of respondents. Not surprisingly, on the air conditioning unit itself was considered close to "don't need." Information should be where people are most likely to see the metrics, according to utilities, which is on personal devices such as a PCs or smart phones, or on a dedicated display. However, none of the displays listed ranked as close to 1 as some other capabilities.



Note: Those items closest to 1, the "must have," are the capabilities considered most important.

Figure 2-5
Where to Display AC Demand Response Metrics, 2010

Overarching Issues

There are several overarching issues related to the category of DR-ready air conditioners, per the first volume report of this project (EPRI report number 1017878).

Capabilities of Central vs. Room/Window Units

Air conditioners can be broadly segmented into central units that serve an entire home and room or window units that condition a specific room or zone within a home. Central air conditioning is typically the focus of most demand response discussion – utility direct load control programs that involve cycling residential air conditioners are exclusively applied to the central units rather than room/window units.

However, the general functional capabilities and specifications defined by utility surveys and included in the master list developed at the 2009 stakeholder workshop may also be applicable to room/window air conditioners as well, despite their lack of meaningful representation in current demand response programs. Workshop participants, in particular, expressed the importance of not restricting DR-ready to just central air conditioners at the expense of room/window units. Certain regions of the country have a relatively high penetration of room/window air conditioners compared to central air conditioners, such as the dense urban areas of the Northeast with high concentrations of multi-family dwellings, to more tropical climates such as Hawaii. The advent of DR-ready room/window air conditioners would particularly address the demand response needs of these parts of the country.

EPRI Energy Efficiency and Demand Response program advisors are split on this topic according to 2010 polling, however, with roughly even numbers for and against a focus on both central and room air conditioners. This is an issue that will need to be resolved in deriving final, consensus functional capabilities for air conditioners in 2011.

Point of Control: Programmable Communicating Thermostat or Air Conditioner

Another overarching issue is whether the thermostat or the unit itself is the appropriate point of control for a DR-ready air conditioner. Direct load control programs today typically feature a communications and control device located at the AC condensing unit, and many utility respondents to our 2009 survey favor this approach, which relegates the thermostat as a sensor and point of user interface.

Programmable thermostats represent an alternate, and some would argue more convenient, point of control for air conditioners. Programmable thermostats allow occupants to control a heating, ventilation, and air conditioning (HVAC) system by scheduling different set-point temperatures at various times throughout the day. According to the U.S. Environmental Protection Agency (EPA), 25 million households currently have programmable thermostats in the U.S.[3] A recent development in programmable thermostats is the introduction of **programmable *communicating* thermostats (PCTs)**, which have the capability to receive information and adjust HVAC operation accordingly. PCTs are commercially available but have typically only been deployed in homes as part of utility DR pilots or programs. The utility can transmit information such as a price signal or explicit temperature setting instruction to the PCT, whether

[3] U.S. EPA. "Summary of Research Findings from the Programmable Thermostat Market".

through wireless communication from a smart meter or directly broadcast via FM radio or paging frequencies.

The concept of DR-ready is based on DR capabilities being incorporated into a device itself without the need to install any additional equipment. On that basis, the air conditioner itself would seem the logical point of control. However, in our survey of utilities in 2009, 83% favored the PCT as the primary point of DR-ready control for an air conditioner, rather than the air conditioner itself. On September 14, 2010, 96% of the EPRI advisors selected the PCT as point of control in an instant polling session in Orlando, Florida.

Table 2-1
Point of DR-ready Control: AC Unit vs. PCT

Point of DR-ready Control for Air Conditioner	Advantages	Challenges
Air Conditioner Unit	Lends itself to direct load control (on/off cycling) Not dependent on utility installing any other device into the home, such as PCT Only option for room/window ACs	Limited consumer visibility Manual override of utility-controlled cycling could require customer to change setting at outdoor unit, which some would consider inconvenient
Programmable Communicating Thermostat (PCT)	Convenient for temperature set-back settings in central AC units	PCT market share is small; only meaningful deployments are in conjunction with utility DR pilots/programs, so utility would still bear cost to incentivize and install PCTs.

A **home energy management system** that includes temperature controls and displays as well as control for other functions and devices also needs to be addressed, within the context of how suites of devices are signaled and controlled.

3
INDUSTRY UPDATE AND SMART APPLIANCES

A number of projects, white papers, and product announcements occurred in 2010 and January 2011 that are moving forward the development and market readiness of smart "demand-response-ready" devices. These activities create the context in which EPRI is coordinating efforts to identify the functional capabilities needed for DR-ready devices. They include:

- AHAM and efficiency organizations' petition to ENERGY STAR to incorporate a 5% credit to the energy performance level of smart appliances.
- Specifications for a communication interface of residential devices published for EPRI's Modular Interface Development, a supplemental project.
- AHAM recommendations for achieving a widely accepted smart grid that features demand-response ready appliances.
- A summary of the smart grid-enabled appliances and concepts presented by appliance manufacturers in late 2010 and at the Consumer Electronics Show in January 2011.
- General findings of retailer Best Buy's market research on consumer attitudes about energy management technology.

Petition for ENERGY STAR Peak Demand Reduction Credit

The Association of Home Appliance Manufacturers (AHAM) and efficiency organizations including the American Council for an Energy-Efficient Economy (ACEEE), submitted a petition to the ENERGY STAR program in January 2011 to urge that the ENERGY STAR program incorporate a 5% credit to the energy performance level required to achieve ENERGY STAR ratings for smart grid enabled appliances as soon as possible.

These groups entered the petition to increase the deployment of smart-grid-enabled appliances, citing the profound impact they can have on reducing expensive peak demand.

Besides AHAM and ACEEE, petitioners included the Alliance for Water Efficiency, Alliance to Save Energy, Appliance Standards Awareness Project, Consumer Federation of America, National Consumer Law Center, Natural Resources Defense Council, Northeast Energy Efficiency Partnerships, and Northwest Power and Conservation Council.

Per the press release regarding the petition,[4] a newly released cost/benefit analysis by the Pacific Northwest National Laboratory (PNNL) for the U.S. Department of Energy (DOE) accompanied the petition, and determined that the annual benefits from having smart grid capabilities in an

[4] ACEEE, "AHAM and Efficiency Organizations Seek Recognition of Benefits of Smart Appliances from ENERGY STAR," Press release. January 2011. See www.aceee.org/

appliance are greater than the costs of an equivalent five percent increase in operational machine efficiencies.[5]

The petition to ENERGY STAR is one of three aspects of an agreement between appliance manufacturers and energy efficiency advocates signed in 2010. The other parts of the agreement relate to new, more stringent minimum energy efficiency standards for appliances and tax credits for very high-efficiency tax incentives. The appliance standard proposal is pending as of February 2011 before DOE. The first year of the tax credit proposal was enacted into law in December 2010.

EPRI Modular Interface Development Project

Besides EPRI's Energy Efficiency and Demand Response Program (P170) project to define the functional capabilities for DR-ready appliances and devices, EPRI is also engaged in a separate, supplemental project related to demand response and residential devices. This is development of a communication interface for residential appliances and devices.

The Modular Communication Interface Development project began in 2009, with EPRI coordinating a group of utilities, residential device manufacturers, and communication providers to study the idea of a modular interface that would allow end devices to work with any communication system or protocol. The project began by compiling use cases and requirements, and then allowed the participants to develop a common vision as they understood one another's perspectives. More than 150 individuals from diverse stakeholder groups contributed to the work. A large percentage of the industry of residential end device manufacturers (HVAC, water heaters, appliances, etc) was represented.

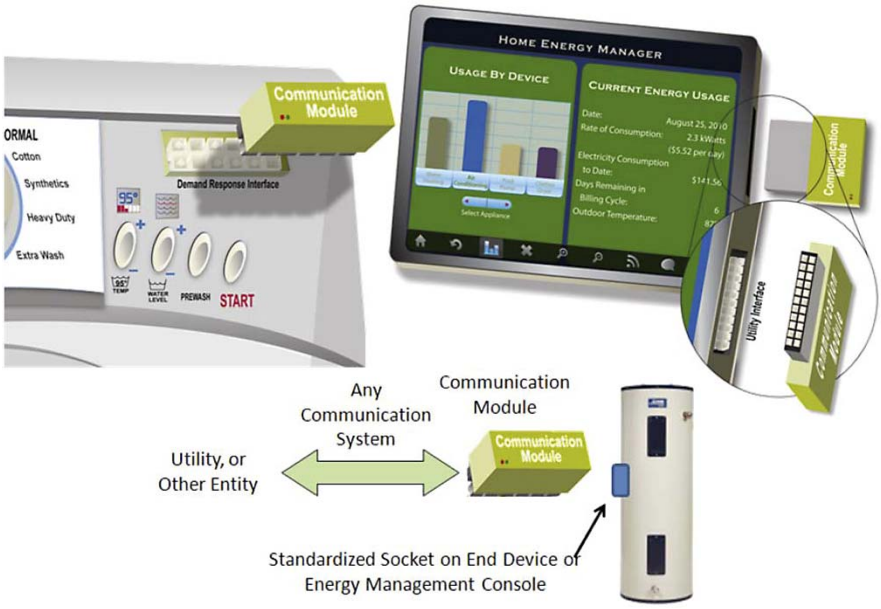


Figure 3-1
Illustration of Standard Communications Interface Module

[5] Visit www.aham.org/smartgrid to download the petition to the ENERGY STAR program, and for a link to the DOE cost/ benefit analysis on smart grid-enabled appliances.

The project has resulted in a technical specification for such an interface. The specification is equally supportive of architectures that use long-range communication, direct to end-use device communication, and communication involving local home area networks (HANs). It is designed to work equally well for systems either with or without energy management consoles, and is supportive of all kinds of communication systems, including wireless and power-line, one-way and two-way, high and low bandwidth, public and private.

The resulting interface specification and other findings of EPRI's research for this project were presented to the NIST[6] Home to Grid Domain Expert Working Group (H2G DEWG) along with a similar interface specification managed by an organization called the U-SNAP Alliance.[7] Following these presentations, the H2G DEWG requested that EPRI and the U-SNAP Alliance work together to merge the two bodies of work into a single specification that keeps the best characteristics of each.

This merging process is underway in 2011. All parties are recognizing strengths in both specifications and a single merged result is taking shape. The final result will be presented back the H2G DEWG for standardization.

Presently, three standards development organizations (SDOs) have expressed an interest in being the keeper of this work and making it into a standard: IEEE, NEMA, and CEA.[8] There are good arguments for each of these to own a standard of this nature and NIST is the appropriate organization for making a final SDO selection. These standards organizations have estimated a process of approximately 9-15 months from initial receipt of the contribution to final release of a standard.

A prototype of an interface using the technical specification is being developed and evaluated on a limited scale as a final phase of the initial project in 2011. In addition, EPRI is launching a new supplemental project in 2011 in which participating utilities may identify and enlist specific communication and end device providers to produce prototypes and to participate in a series of industry-wide interoperability workshops.[9]

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[6] NIST is the National Institute of Standards and Technology – an agency of the U.S Department of Commerce. See www.nist.gov/

[7] The U-Snap Alliance stands for Utility Smart Network Access Port Alliance. This group is developing a specification for a physical interface – via a serial port – intended to enable communications between any smart meter and home area network. U-SNAP membership consists of vendors, service providers, and utilities. See www.usnap.org/.

[8] IEEE is a professional association of those in the engineering, computing, and technology professions. See www.ieee.org/. NEMA is the National Electrical Manufacturers Association. See www.nema.org/. The CEA is the Consumer Electronics Association. See www.ce.org/.

[9] The EPRI technical contact for the Modular Interface Development Project is Brian Seal, (bseal@epri.com).

AHAM Requirements for Achieving a Widely Accepted Smart Grid (with DR-Ready Appliances)

According to the Smart Grid White Paper[10] published by the Association of Home Appliance Manufacturers (AHAM), appliance manufacturers believe that in order for the smart grid to be successful, and for the smart appliances that enable demand response to be marketable, there are three essential requirements:

1. Pricing must provide incentives to manage energy use more efficiently and enable consumers to save money.
2. Communication standards must be open, flexible, secure, and limited in number.
3. Consumer choice and privacy must be respected; the consumer is the decision maker.

AHAM's Definition of Smart Appliances

AHAM defines a *smart appliance* as having the following features:

- Dynamic electricity pricing information is delivered to the user, providing the ability to adjust demand of electrical energy use.
- It can respond to utility signals, contributing to efforts to improve the peak management capability of the Smart Grid and save energy by:
  1. providing reminders to the consumer to move usage to a to a time of day when electricity prices are lower, or
  2. automatically "shed" or reduce usage based on the consumer's previously established guidelines or manual overrides.
- Integrity of its operation is maintained while automatically adjusting its operation to respond to emergency power situations and help prevent brown or blackouts.
- The consumer can override all previously programmed selections or instructions from the Smart Grid, while insuring the appliance's safety functions remain active.
- When connected through a home area network and/or controlled via a home energy management system, smart appliances allow for a "total home energy usage" approach. This enables the consumer to develop their own energy usage profile and use the data according to how it best benefits them.
- It can leverage features to use renewable energy by shifting power usage to an optimal time for renewable energy generation; i.e., when the wind is blowing or the sun is shining.

Key Elements of AHAM's Smart Grid and DR-Ready Vision

AHAM published key principles and requirements for advancing the smart-grid-ready (and demand response ready) appliances in its white paper:

Consumer vs. utility control: "Projects should emphasize the consumer as the decision maker as opposed to the scenarios where the utility possesses absolute control over the consumer's appliances and devices."

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[10] Association of Home Appliance Manufacturers (AHAM), *Smart Grid White Paper: The Home Appliance Industry's Principles & Requirements for Achieving a Widely Accepted Smart Grid*, Washington, DC: December 2009.

Communication with home energy management systems and multiple devices: "The most pressing area of AHAM's interest is the communication from the smart meter into the home. The electric utility industry has been conducting smart meter pilots for some time, and many of the pilots include communication to a programmable communicating thermostat. However, any protocol also must provide capability for communication with other devices, smart appliances, or to an energy management system."

Customer choice and privacy: "In all cases, the smart appliance will retain control of the appliance response to a signal from the utility company. Utilities do not have the expertise in the use and operation of appliances. A utility does not need to have control of appliances in someone's home nor do they need to monitor how someone is using their appliance. . . Smart appliances would likely always allow the customer the option to override a demand response request."

On enabling demand response: "AHAM's objective is to make this interaction as simple and effective as possible for the consumer."

Utility reach: "The boundary of the utility's reach should end at the smart meter. Communication or interaction inside the home should be under the control of the consumer. "

Recommended actions for utilities related to smart grid and demand response:

"a) Participate in selecting one national standard for smart meter communication to the residence.

b) Strive to leverage existing communication technologies in the home, such as the Internet.

c) Begin steering smart meter pilot projects towards standards and architectures that are expandable for the future.

d) Remove absolute control of in-home appliance scenarios from use cases, requirements, and standards.

e) Participate in developing a national uniform standard for pricing and usage information. Work with state public utility commissions to adopt tariffs that will properly incentivize consumers to engage in the Smart Grid and encourage innovation in the appliances and devices industries. Such tariffs should look at the flexibility smart appliances provide to the total grid system."

Smart Appliance Developments

The connected home was a major theme at the Consumer Electronics Show in Las Vegas the first week of January 2011, and smart appliances from manufacturers including LG, General Electric Whirlpool, Samsung and others were featured in a new section of the show, The Connected Home Appliances TechZone. Demonstrating smart appliance products at the CES, the largest consumer electronics show, was one of the first concerted efforts by manufacturers to market the concept of new "smart-grid ready" appliances that can respond to the utility price signals to help consumers reduce electricity bills.

In addition to the ability to automatically respond to price signals, the appliances shown offered a number of other functions that appliance makers hope will make smart appliances more attractive to buyers. These include remote diagnostics, control and status display via smart

phones, and a variety of services ranging from display of recipes on stove screens to preparation of shopping lists based on refrigerator inventory.

Most of the appliances shown at CES are not yet available on the market, although some manufacturers will have models available for purchase sometime late in 2011. Since the ability to interact with the smart grid and receive price signals is the main selling point of these appliances, the appliances will be rolled out in association with smart grid.

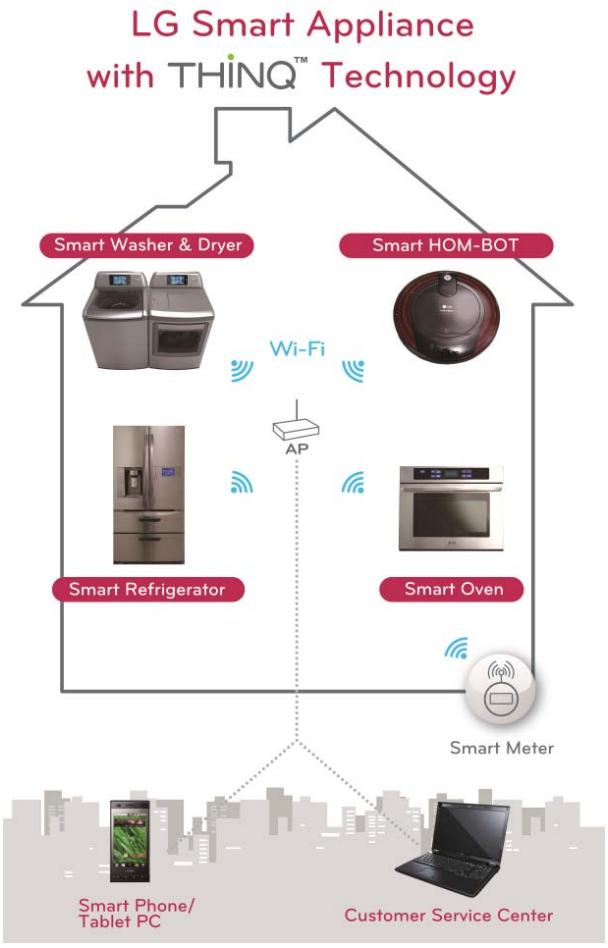
Selected product concepts being touted by manufacturers are summarized below.

LG

LG introduced appliances based on THINQ™ ("think-you") technology. These appliances use a home WiFi network and a smart meter to offer smart functions such as demand response. The appliances also have a "Smart Access" system, which allows remote control of the appliances via a smart phone or tablet PC.

The LG Thinq appliances include a washing machine, oven, and refrigerator—as well as a robot vacuum cleaner. The washer, oven, and refrigerator will be enabled to obtain dynamic prices. The appliances will allow customers to select "Recommend Time" so that, for example, the time selected automatically for the washing is "at the nearest, most cost-effective time or immediately if no there are no off-peak electricity options available soon."[11] Users can also opt for "Lowest Rate" settings or select the wash time themselves. If the time selected happens to be at a high, on-peak rate, the machine will recommend the most energy efficient cycles to use.

[11] *LG Unveils Total Home Appliance Solution Empowering Consumers to Smartly Manage Their Homes*, Press release, LG, Seoul, Korea: January 3, 2011.

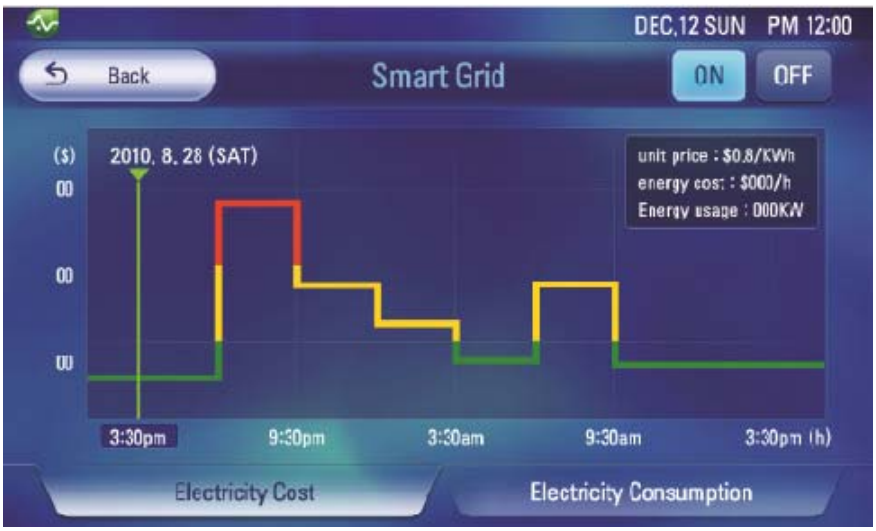


Source: LG

Figure 3-2
LG THINQ™ Appliance Concept

Ovens will also offer cost options—labeled as high, medium and low—that consider the cooking duration and varying costs of electricity. The refrigerators, which are always on, can adjust operation automatically using an algorithm to time various functions, such as the defrost cycle, to allow for savings during peak periods.

Displays are a feature of the Thinq appliances, and they can show energy consumption and costs by day, week or month. This data is also accessible via a smart phone or tablet PC, as part of the "Smart Access" functions of the appliance suite. Alerts such as ice maker off, or door left open can also be displayed on the built-in screens. LG reports that in the future models, alerts will also be able to be sent to phones or PCs.



Source: LG

Figure 3-3
Example Display for LG Thinq Appliance

Remote control via smart devices is also possible as part of Smart Access, so that from outside the home, the washing machine cycles can be controlled or temperatures set on the refrigerator.

"Smart Diagnosis" services are another feature touted by LG as a consumer benefit. The appliance can be activated when a customer calls a service technician. An example given by LG representatives at the CES 2011 is having the customer call a technician for a washing machine problem, and the technician can have the customer push a series of buttons on the washer that trigger tones the technician can obtain over the phone. This provides data on the nature of the problem and how to correct it. A downloadable application for the smart phone can also be used by the consumer to diagnose washer problems.

LG has not yet revealed pricing or availability of Thinq appliances at the time of this update's publication.

Whirlpool

Whirlpool Corporation has stated a goal to make all its electronically controlled appliances capable of receiving and responding to signals from the smart grid by 2015.[12] The first appliances will be available in 2011. This includes an Energy Smart water heater, with an external hook up for connection to a smart meter.

The 2015 date for an entire suite of appliances has been set by Whirlpool as the company estimates that this amount of time is needed to design and make market ready the "smart" hardware that communicates with the smart meter.[13] An industry-wide standard for appliances to

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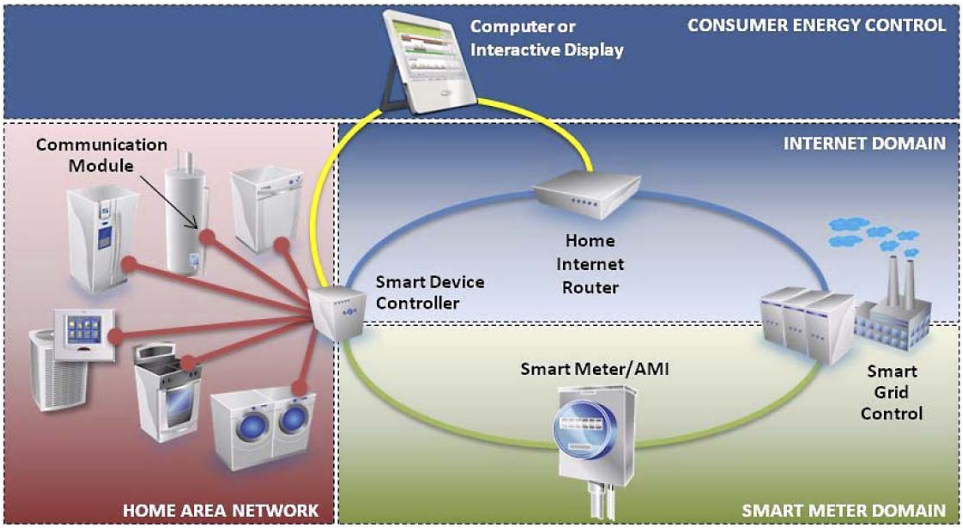
[12] Whirlpool Corporation. "EPRI DR Appliance Workshop." Quotation by Bracken Darrell, President of Whirlpool Europe, and EVP of Whirlpool Corporation. October 28, 2009.

[13] Steven Castle, *Whirlpool Aims for Smart Appliances in 2011*, Electronic House, May 12, 2010.

communicate with one another is needed as well, since "many customers aren't often in a position to buy a whole suite of appliances from the same manufacturer."[14]

As noted in Volume 1 of this Update, in public forums, Whirlpool has presented a vision of a home appliance controller that interfaces with: (a) the gateway for the utility signal to the home – whether a smart meter or other device; (b) all controllable, communicating major appliances; and (c) a display device for consumers to monitor power usage, whether a stand-alone console or rendered for display on a computer, tablet, or smart phone platform.



Source: Whirlpool Corporation

Figure 3-4
Whirlpool Smart Appliance Architecture

Whirlpool Corporation received $19 million in funding in federal stimulus funds as part of the American Recovery and Reinvestment Act of 2009 to support the manufacturing of smart appliances and to accelerate the commercialization of residential appliances capable of communicating over a home network with other smart technologies. Whirlpool is spending $20 million in matching funds for the effort, for a total development cost of $39 million.[15]

General Electric

General Electric has been developing a suite of smart appliances and a home energy management system since 2009, and it displayed its suite of products at CES 2011. It includes Brillion™ smart appliances, a line that includes washer, dryer, refrigerator and dishwasher. It also displayed the GeoSpring heat pump water heater.

Home devices can be controlled by the GE Nucleus Energy Manager™, which enables communication with a smart phone or personal computer. Consumers can remotely program operation schedules and temperature settings for multiple devices in the home, including heating

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[14] Mark W. Smith, 2011 Consumer: Smart appliances keep users connected to home, *Detroit Free Press* January 6, 2011. See http://www.freep.com/fdcp/?1298327074245

[15] www.smartgrid.gov, Investment Grant Program, Whirlpool Corporation Smart Grid Project

and cooling. Because the system is connected to a PC or smart phone, Mike Beyerle, Marketing Manager for Innovation at GE, points out, "You can program the thermostat on a PC rather than using the small buttons on the thermostat."[16] The Nucleus Energy Manager allows customers to monitor the amount of electricity being used as well as pricing, cost in terms of dollars per hour, and historical energy use graphs.

Source: GE

Figure 3-5
GE Nucleus Energy Manager Communicates with PC or Smart Phone

GE's Nucleus, shown in the top photo above, is about the size of a wall thermostat, and collects information from smart meters; storing it for up to three years. This data can be sent to a PC or smart phone.

A pilot test of the GE Nucleus system is underway in Martha's Vineyard,[17] and Department of Energy funded tests that are a collaborative effort of General Electric, the Sacramento Municipal Utility District, Salt River Project, and San Diego Gas & Electric are planned.[18]

Samsung

Like LG, which got its start in electronic consumer products, Samsung is leveraging its experience with connected electronic devices and is planning to introduce smart appliances. It displayed connected appliances at CES 2011, including a WiFi connected refrigerator featuring an in-door touchscreen that consumers can use to manage smart grid functions (demand response), and set temperatures without opening the refrigerator door.

Remote control of household devices via smart phone is an important application featured by Samsung.

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[16] Video from Smart Grid News of CES show demonstration, http://www.smartgridnews.com/artman/publish/Videos-Products-and-Technologies/GE-appliances-at-CES-2011-3429.html

[17] *Martha's Vineyard: Making changes for a better energy future*, http://www.geappliances.com/home-energy-manager/marthas-vineyard-pilot/

[18] *GE Unveils Energy Efficiency Plan for American Homes*, www.getsolar.com/blog/ge-unveils-energy-efficiency-plan-for-american-homes/11148/. August 24, 2010.

Best Buy's Market Research on Energy Management

Citing its significant role in introducing new technologies, the consumer electronics and appliance retailer Best Buy conducted a market research study to assess energy management solutions for the home: the Smart Energy Program Study to Understand Consumer Lifestyle Drivers and Energy Attitudes as Motivation for Smart Energy Program Participation.[19] The research was performed via an online survey with a sample of 2000 consumers. EPRI has not seen or evaluated detailed findings; however, the general findings released by Best Buy are of interest:

Consumers are frustrated with complexity: Citing frustration with growing complexity and fragmentation of product solutions, Best Buy concludes that it currently takes a "sheer force of will" to adopt some technologies for lifestyle benefits.

Integration with other home functions is needed: Best Buy believes energy management needs to be incorporated with other functions in the home such as entertainment and security to be saleable. "These solutions must become integrated and work alongside everything else in home, not an independent and unrelated addition to the home technology dynamic. Ignoring these expectations relative to energy management dooms any solution's full integration into the consumer's day to day life.

Geography and the local utility relationship are important drivers: The price of electricity, the perception of the local utility, and the how "green" the local market is help shape perceptions of energy management.

Energy management perceptions differ according to generation: Younger generations are more comfortable with technology. "This group's optimism about the role of technology, and their willingness to incorporate more technology into already device-filled homes, drives an increased likelihood of adoption for new energy management solutions."

The bottom line: Best Buy recommends that energy management technologies such as DR-ready or smart devices should be easy to use, convenient, and provide a return on investment. The return is defined in terms of both money and as a return on investment of time; e.g., will the product streamline a task and add comfort or convenience?

[19] Best Buy, *Energy Management: A Mass Market Consumer Opportunity*, 2010. Available at http://ase.org/resources/best-buy-report-residential-energy-management

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APPENDIX: SURVEY INSTRUMENT

EPRI End-Use Energy Efficiency and Demand Response Program
DR-Ready Appliances and Devices

Survey of Program Advisors: Air Conditioning Functional Requirements

Orlando, Florida
September 14, 2010

The following desired attributes of DR-ready air conditioners were gleaned from a combination of previous utility survey responses and opinions expressed at the 2009 stakeholder workshop. Going forward, EPRI plans to work with an expanded set of stakeholders to refine this initial master list of functional specifications into a consolidated set of specifications appropriate for a formal designation by a voluntary standards-setting body, such as the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE).

Please rate the following attributes on a scale of:

1 = **Must Have** feature DR-ready specification

2 = **Nice to Have** feature (not essential for DR-ready specification)

3 = **Don't Need** feature (unnecessary for DR-ready specification)

Resident Feature

- ☐ Clock/timer with automatic daylight savings adjustment
- ☐ Display of DR-related metrics
- ☐ Remote controllability
- ☐ User-programmed specifications saved to memory (i.e. no need to reprogram)
- ☐ Communication with utility to verify action taken or overridden
- ☐ Multi-speed compressors; Variable–speed control
- ☐ Variable-speed fans

Types of Response

- ☐ On/Off compressor cycling
- ☐ Temperature setback
- ☐ Pre-programmed routine
- ☐ Variable compression
- ☐ Fan-only mode
- ☐ Fan speed modulation

DR Event Triggers

- ☐ Electricity price (e.g., RTP, TOU, day ahead, hour ahead, etc.)
- ☐ Time of day
- ☐ Utility event signal (e.g., emergency, peak, critical peak)

Pre-Programmable Routines

- ☐ Pre-cooling (shift compressor usage to off-peak morning and ride-through peak)
- ☐ Set temperature comfort range (bounds of acceptable low and high temperatures

Metrics to Display

- ☐ Temperature (current)
- ☐ Temperature set point
- ☐ Event initiated; in progress
- ☐ Event duration
- ☐ Confirmation of action taken or overridden

☐ Retail electricity price (if available)

☐ Power draw (Watts)

☐ Energy savings (kWh) per current event

☐ Energy savings (kWh) cumulative

☐ Cost savings from current DR event

☐ Cost savings from demand response, cumulative

☐ Utility peak time rebate (if applicable)

Where to Display

☐ On the AC itself

☐ On the thermostat (PT or PCT)

☐ Ability to communicate metrics to dedicated display

☐ Ability to communicate metrics to a consumer device (e.g., PC, mobile device)

Thank you for completing this survey!

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