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Standardized Communications for Demand Response

An Overview of the CTA-2045 Standard and Early Field Demonstrations

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NRECA
America's Electric Cooperatives

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Standardized Communications for Demand Response:

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Challenges of Load Control Communications

Electric cooperatives and other electricity providers face a multitude of challenges when it comes to controllable loads, at a time when flexible loads are becoming an increasingly important asset. Co-ops are facing decisions about how to replace aging demand response (DR) equipment with new technology to ensure their DR programs will continue to provide value, while also expanding load control programs as an added service to members and to help manage the variability of increasing distributed energy resources (DERs) on their grids.

The growing penetration of "smart" devices—those that can communicate over a network—is a promising step toward being able to control loads. Many co-ops use Nest or ecobee smart thermostats, for example, to facilitate DR programs on cooling loads. But broad adoption of smart devices for DR or other control scenarios is challenging for a variety of reasons:

- **Differences Between Products Across Manufacturers.** Manufacturers design products to respond to and relay information over a network connection, often the Internet. The available commands and data vary from product to product and manufacturer to manufacturer. In addition, the manufacturer chooses the product's communications technology(s), such as Ethernet, Wi-Fi, or Zigbee, forcing the utility to manage multiple technologies rather than choose a single solution that makes sense for the program in question. The issue is compounded if the utility wants to add additional products to its program, as it may have to integrate multiple communications methods.
- **Communication Methods Evolve and Change Quickly.** Over the relatively long life of a controllable load like a water heater or a pool pump, many new or revised methods may be introduced.
- **Purchase and Installation Costs.** Often, the purchase price of a smart appliance is much more than its unconnected counterparts. Based on online retail prices, connected water heaters can cost an additional $150 or more than traditional models. If the installation of the smart product is not straightforward, installation costs are borne by either the consumer or the utility. Current DR equipment presents a similar problem: installation is performed by the utility, requiring labor and truck rolls.
- **Data Streams Involve Third Parties.** In many of today's smart appliances, data is collected by the manufacturer. To control and receive information from Nest thermostats, for example, the co-op needs to collaborate with Nest. This can require significant additional resources for integration with the utility's systems.

To address these issues, the Consumer Technology Association (CTA) (formerly the Consumer Electronics Association, CEA) developed the ANSI/CTA-2045 (formerly CEA-2045) Modular Communications Interface for Energy Management standard. First published in 2013, the standard allows electricity providers to communicate with end uses over a standard interface that is compatible with any current or future communications technology.

Following the publication of the CTA-2045 standard, the Electric Power Research Institute (EPRI), NRECA, electric utilities and co-ops, and manufacturers collaborated to develop CTA-2045-enabled prototypes of products that are likely to be the first to incorporate CTA-2045 (see Table 1), which were then deployed at utilities and co-ops around the country for field testing. This paper gives an overview of the standard, discusses the prototype development and field demonstration findings to date, and highlights potential benefits that CTA-2045-enabled end uses can bring to co-ops.

Table 1: Products Likely to First Incorporate CTA-2045.

Heat Pump Water Heaters
Electric Resistance Water Heaters
Thermostats
Electric Vehicle Supply Equipment
Variable-Speed Pool Pumps

CTA-2045: A Universal Port for Smart Products

The ANSI/CTA-2045 Modular Communications Interface Standard was designed to meet several goals, addressing the challenges faced by DR programs. These included:

- A modular design, so that communications methods may be updated during a product's lifetime by replacing a standard format module from any manufacturer or vendor.
- Two-way communications to enable the device to report its state, energy usage, and other key information, as well as receive commands. It also allows for firmware updates to be delivered to both the module and the end product.
- The ability to accommodate any current or future communications method.
- Minimal additional cost to the consumer for the implementing hardware and software.
- An easy-to-install communications module that can be connected by the consumer, minimizing truck rolls and staff time dedicated to installing DR-enabling hardware.
- A set of control commands that deliver consistent responses from products.

CTA-2045 defines a standard interface between a product and a communications module that enables communications between utilities and residential and commercial end uses. It defines the physical port, as well as electrical and logical properties of the interface, allowing any enabled product and communications module to connect to and communicate with each other. CTA-2045 standardizes two physical connections: an AC form factor, used on large appliances such as water heaters (**Figure 1** and **Figure 2**), and a smaller DC form factor for small products such as thermostats (**Figure 3** and **Figure 4**). In both cases, power to the communications module is supplied from the end product.

CTA-2045 not only standardizes the hardware interface between a communications module and a smart appliance, but also specifies the "language" that the two devices speak to each other. The standard defines a limited set of basic commands to guarantee a minimum functionality and easy initial vendor implementation to foster competition. In the basic messages, "shed" and "end shed" are mandatory for all CTA-2045-enabled products, as these enable basic DR functionality. Advanced, nonmandatory messages allow for more complex interaction.

Figure 1: Illustration of CTA-2045 Port on a Water Heater, and a CTA-2045 AC Form Factor Communications Module. *Figure modified from EPRI*

Figure 2: Photo of SkyCentrics AC Communications Module Connected to an A.O. Smith Water Heater. *Photo courtesy of SkyCentrics*

Figure 3: DC Form Factor Communications Module. *Photo courtesy of SkyCentrics*

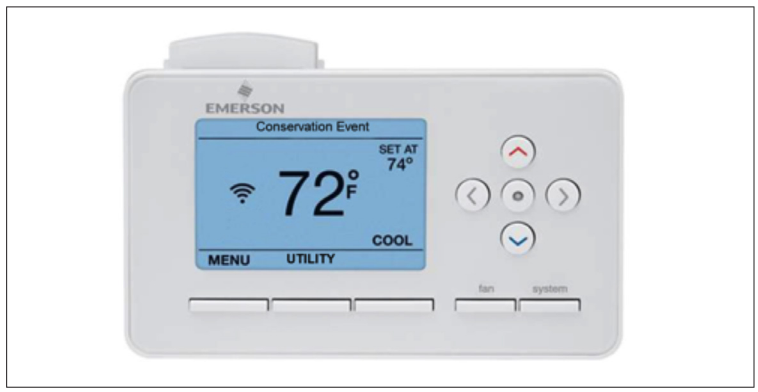

Figure 4: DC Communications Module Plugged into the Upper Left Corner of an Emerson Smart Thermostat. *Photo courtesy of EPRI*

The standard hardware interface means modules can be installed "plug & play" into a port built into a device, simplifying the installation process. The communications module enables a connection to the utility's DR systems and allows for the use of a variety of popular technologies. Co-ops are free to select those that fit their unique circumstances. For example, technologies such as Ethernet, Wi-Fi, and Zigbee rely on the consumer's Internet connection, while cellular and power-line-carrier communications do not. Any necessary communications module and end product software updates can be made remotely from the utility, vendor, or manufacturer head-end. When a type of communications hardware becomes obsolete, the communications module can be swapped out, avoiding obsolescence of the entire product.

Developing CTA-2045-Enabled Products

To facilitate the development and deployment of CTA-2045-enabled end uses, as well as provide a first evaluation of the new standard, EPRI led a multiyear research study that involved both electricity providers—including three distribution co-ops—and manufacturers. NRECA contributed funding to support co-op field demonstrations. The project's ultimate goal was to work with manufacturers to incorporate a CTA-2045 interface into five different products—electric-resistance water heaters, heat-pump water heaters, electric vehicle supply equipment, variable-speed pool pumps, and thermostats—that could be installed for field testing at participating utilities.

The first step in the process was to develop a set of functional requirements for each of the five product types. These documents were designed to specify the minimum set of CTA-2045 messages that each device must support, along with guidance on how devices should respond to these messages. Since one of the goals of the project was to deploy the same product across different service territories, utilities collaboratively developed the functional requirements to help ensure that the devices include the functions required to support their own DR programs. Chuck Thomas, Technical Leader at EPRI, said that products built to meet the functional requirements were interoperable and included embedded functions that supported each utility's DR programs.

Table 2: Communications Requirements for CTA-2045-Enabled Water Heaters.

Control Requirements: Data/Requests to End Use	Monitoring Requirements: Data from End Use
Shed load: avoid operation to allow the present stored energy level of the tank to decrease	**Customer override status:** reports when the override state is changed
End shed: return to normal operations	**Operational state**
Critical peak: avoid operation and aggressively allow the present stored energy level of the tank to decrease	**Instantaneous power**
Load up: operate now and load up if possible	**Cumulative energy**
Emergency shutdown: avoid operation until emergency ends	**Total energy storage capacity**
Operate at a specific duty cycle	**Present energy storage level**
* **Cost of electricity:** allows water heater to respond to price signals, loading up when prices are low or avoiding operation when prices are high	
* Optional command, not used in this project	

For water heaters in particular, the requirements were developed to ensure that water heater control and monitoring requests met or exceeded the needs of all participating utility DR programs (Table 2). In addition, the functional requirements aim to allow the water heater to meet customer needs by ensuring hot water is available during all control events except grid emergency shutdown. During normal operations, the water heater utilizes a relatively narrow band range of its stored energy capacity (grey band in **Figure 5**). During control events, the water heater takes advantage of a wider range, allowing additional load reduction during shed load events (blue band in **Figure 5**). The limits on the control range are related to consumer comfort and safety: the water heater should provide hot water when the consumer needs it, even during control events. If the stored energy capacity dips below the control minimum during a control event, the water heater will draw power to heat a volume of water to acceptable levels to reduce the risk of a cold water event.

Next, EPRI worked with manufacturers to develop the CTA-2045-enabled products and communications modules for field deployment. During this iterative process, each manufacturer would send a prototype to EPRI for testing in its lab. Using a CTA-2045 simulator, developed in-house, EPRI put each prototype through a series of tests to determine if it met the functional specifications and to predict how it would behave in the field. During this process, issues with the CTA-2045 standard were identified and recommended changes to the standard were made to the CTA-2045 Working Group. If the prototype did not pass all tests, the findings were reported to the manufacturer so they could make modifications to address the issues.

Each product type went through an average of 6 rounds of testing. Once a prototype passed the tests, the manufacturer produced models for field deployment at 13 participating electricity providers, including 3 distribution cooperatives. All

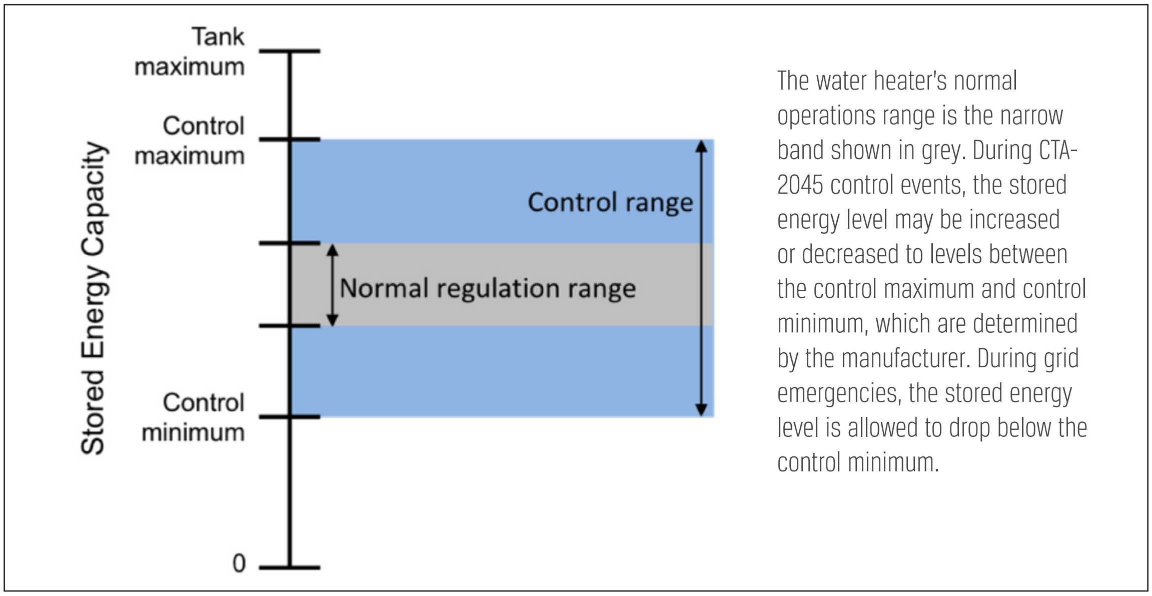

Figure 5: Stored Energy Levels for CTA-2045-Enabled Water Heaters. *Figure adapted from EPRI*

end-use devices tested under this project received UL certification, which added an additional 12 weeks to the development time.

Field Deployment at the Co-ops

Three electric distribution cooperatives are participating in the pilot, each deploying 10 electric resistance water heaters. Of these, two co-ops are local power companies associated with the Tennessee Valley Authority (TVA): North Georgia Electric Membership Corporation (EMC, Dalton, Ga.), and Duck River EMC (Columbia, Tenn.).

According to Sam Delay, Senior Program Manager of Technology Innovation at TVA, pilots at both co-ops are still in the deployment phase because of challenges associated with developing a UL-approved communications module. North Georgia EMC worked with a smart meter manufacturer to develop a UL-certified module, but ultimately decided to use a UL-approved SkyCentrics communications module. Duck River EMC is in the process of installing communications modules, said Delay. Initially, Delay said, the co-ops are interested in testing the commands allowed by CTA-2045 and the response of the water heaters.

Jackson EMC (Jefferson, Ga.) deployed its water heaters and communications modules in 2016, and now has more than a year of experience with utilizing the new technology. The co-op was interested in piloting CTA-2045-enabled water heaters for several reasons, noted Amy Bryan, Director of Residential Marketing. First, their current load management technology is outdated; the one-way communication equipment is based on radio signals to control air conditioning and water heating appliances and, in most cases, repair and replacement parts are unavailable. In addition, the co-op wanted to reduce the cost of installing control devices. If members were able to install CTA-2045 communication modules themselves, eliminating in-home visits and truck rolls, costs would decrease. Jackson EMC was also interested in testing the benefits of enhanced two-way communications strategies between the co-op and the homeowner, including increased member engagement.

Finally, Jackson's service territory is located in a high-growth corridor northeast of metropolitan Atlanta, with significant single and multifamily home construction. Grid-enabled smart water heaters allow Jackson EMC to maintain and gain electric heat and water heating load fofr the co-op. CTA-2045-enabled water heaters seemed conducive to providing smart technologies that benefit the homebuyer by providing both hot water when needed and convenience, like the ability to put their water heaters on vacation or energy-efficiency modes. In addition, the co-op could benefit through load control strategies that lower costs and increase environmental benefits.

Instrumentation and Installation

Jackson EMC installed A.O. Smith water heaters in nine employee homes and one at its corporate campus. To help characterize water heater behavior during CTA-2045 control tests, Jackson EMC outfitted each water heater with inlet and outlet temperature and water flow sensors. It also monitored voltage and current to calculate water heater energy use.

Once the water heaters were installed in the field, each participating employee was given a SkyCentrics Wi-Fi communications module for self-installation. Six homeowners successfully installed the module and connected it to their Wi-Fi network without help, and one homeowner did so with help over the phone. The remaining two installations required a co-op technician's help setting up the Wi-Fi. Although the sample size is small, these results suggest that a substantial proportion of co-op members can perform the installation of the communications module.

Jackson EMC used the SkyCentrics scheduling and analytics platform to schedule control events and to retrieve data collected from the water heaters, which is stored in the SkyCentrics cloud.

Early Findings

Early findings at Jackson EMC have been positive. During the first phase of the pilot, during fall and early winter 2016–2017, the water heaters were able to meet calls for load control 94% of the time. This indicates that the members' Wi-Fi was usually a reliable way to communicate with the water heaters.

The ability to communicate is one prerequisite for a water heater to respond to the co-op's request. In addition, the water heater must also have capacity to carry out the request. In the case of the "Load Up" command, the water heater must be able to consume energy to heat water. Testing the Load Up command, Jackson found that water heaters responded by using energy 49% of the time. Staff noted that 22% of the time, the water heaters had operated in the hour before the request. It appears that the remaining water heaters had not operated in the hour prior to the event, but were still at full capacity and could not add load.

As discussed above, CTA-2045 allows end uses to communicate their status and current ability to shed or add load. Using this information, co-ops can forecast the response from a request by understanding the status of the loads. To have better response to a Load Up request, the co-op can test different strategies, like requesting Shed Load for the hours prior.

Jackson EMC also tested the Shed Load capability of the water heaters. During DR periods, Jackson achieved an average 25% reduction in water heater electricity use, most of which was shifted to subsequent "snapback" periods after the event. This indicates that Jackson's shed events were able to effectively shift load without a significant reduction in overall load or sales.

Results from a 10-day period in November and December 2016 are shown in **Figure 6**. The first five days demonstrate baseline conditions, when no control events took place. During the last five days, Jackson EMC called multiple Shed Load events per day, preceded by Add Load events. During Shed Load periods, energy use was limited, but generally non-zero, indicating that some water heaters still needed to heat water to meet hot water demands during the control event.

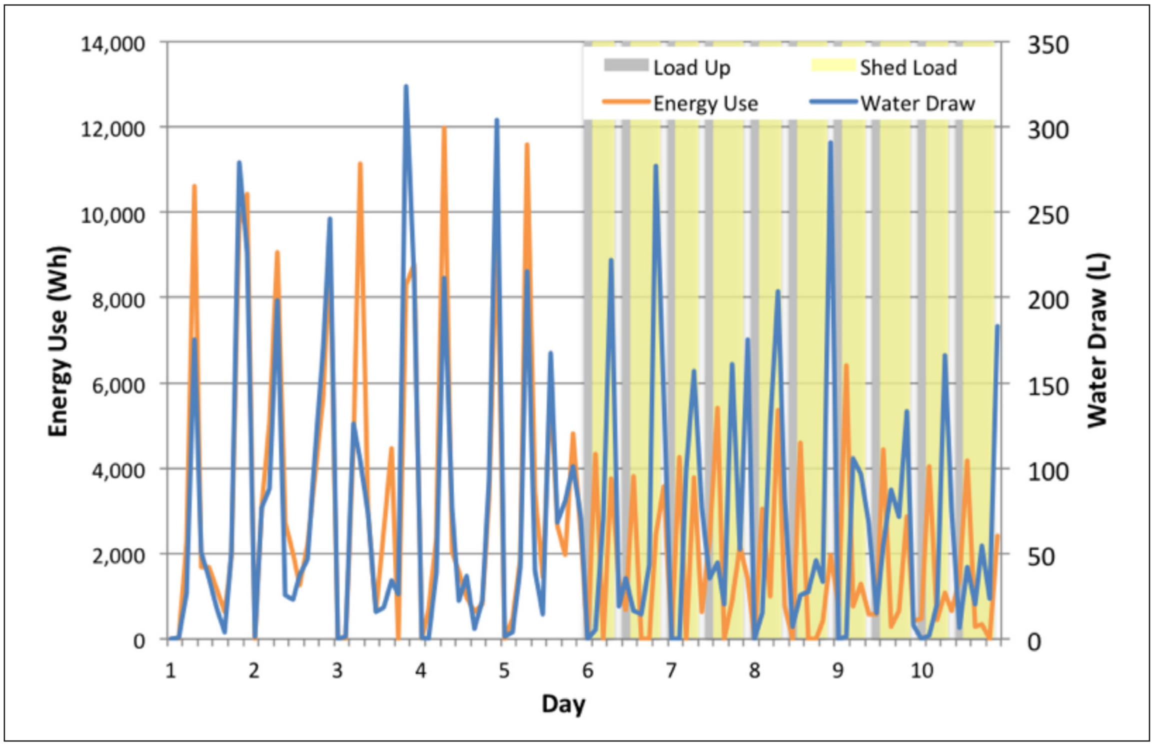

Figure 6: Total Energy Consumption and Water Usage for All Water Heaters in the Jackson EMC Pilot During a 10-Day Period in November and December 2016.
Modified from a figure provided by Jackson EMC

Challenges

Although Jackson EMC's initial tests of CTA-2045-enabled water heaters succeeded, the co-op also experienced a few challenges during the pilot. EMC collected a great deal of data (temperature, water flow, voltage, and current) from the additional instrumentation used to confirm that the water heaters were performing as expected. Bryan noted that they collected about 90,000 data points per water heater per month and, in retrospect, should have set up a database to handle the data. The data from the communications modules, however, was stored and analyzed in the SkyCentrics Amazon Web Services-based cloud. Once the data from the communications modules is proven accurate and complete, the expectation is that co-ops and utilities will not need additional instrumentation and associated data storage and analytics capacity.

As with any connected and data collecting technology, data security and privacy concerns may arise from members. In this case, concerns about how and where the data collected by CTA-2045 products is stored are most relevant. The current major player in CTA-2045 communications, SkyCentrics, uses industry standard practices when it comes to protecting privacy and data. According to Tristan de Frondeville, CEO at SkyCentrics, the data is secured with end-to-end encryption from the product to the app; a customizable permission structure within the platform limits who has access to, and control over, the products. Additional information on cybersecurity for co-ops is available from NRECA Business and Technology Strategies (BTS).

Another issue Jackson EMC identified is the need to identify communications problems early, so that few data and control opportunities are lost. If members' Internet service is used, ensuring connectivity may mean checking and upgrading member network equipment. Because Jackson EMC's communications strategy relied on members' Internet service, each member's modem and Wi-Fi router needed to be operational. For one member, Jackson EMC needed to repair—or have the member replace—equipment during the pilot. To improve uptime, SkyCentrics has since added email, text, and mobile app notifications to the customer when his or her device is offline.

Jackson EMC is still assessing customer comfort and whether control events lead to insufficient hot water. Although they received several complaints regarding insufficient hot water, many of these did not occur during a control event. The degree to which a control event impacts customer comfort is still an admittedly challenging area of investigation, given their small sample size. Bryan hypothesized, however, that the 50-gallon tanks installed in the pilot were insufficiently sized for some of the participating households. To reduce the potential of customer complaints, Jackson EMC will be using 80-gallon tanks in the next phase of its work and any upcoming programs.

Understanding the incremental costs of nascent technology can be challenging. The CTA-2045 standard was designed to keep incremental costs low. EPRI's Thomas estimates that it should cost less than one dollar to add the CTA-2045 connector to appliances (not including nonrecurring engineering and retooling costs), minimizing cost to the consumer.

Bill Hosken, National Utility Program Manager at A.O. Smith, notes that economies of scale cannot be realized without larger production volumes. As a start, however, A.O. Smith now offers CTA-2045-capable heat pump water heaters in various capacities and a CTA-2045, 80-gallon, electric resistance water heater priced at or below comparable grid-connected models with standard electromechanical thermostats. Additional 40- and 50-gallon resistive electric CTA-2045 capable models are in the works for release in 2018, says Hosken.

To run a program using CTA-2045, co-ops and utilities must consider costs associated with the communications modules, as well as a platform to schedule control events and manage data. Communications modules from SkyCentrics currently retail for $80 (DC form factor) and $180 (AC form factor) for a single unit, although de Frondeville notes the price to utilities buying in volume is significantly lower and has the potential to decrease further with economies of scale as adoption of CTA-2045 accelerates. SkyCentrics charges—on a per-unit basis for access to its DR platform, apps, and analytics—about one dollar per month per product.

Benefits Beyond DR

Benefits of CTA-2045-enabled end uses reach beyond improving DR program results through low-cost, two-way communications that can allow fine-tuned control and accurate prediction of the results of event commands. In an age of increasing DERs, co-ops and other utilities are examining economically beneficial solutions to store energy for later use, rather than produce power on demand.

Community storage is one tool that co-ops are implementing to address this challenge; it leverages member energy storage resources like water heaters, HVAC, electric vehicle batteries, and home storage batteries to store excess generation. A key component of any community storage program is the communications link between those who manage demand and the end uses. The universality of CTA-2045 is particularly appealing because a wide variety of end uses and manufacturers could be included in these efforts.

Co-ops also face stagnant or declining load and sales. Electrification of appliances that burn fossil fuels may help reduce these impacts. Jackson EMC, for example, is focusing on ensuring that new water heater loads are electric, in part through its RightChoice program that promotes efficient new homes.

Another strategy—beneficial or strategic electrification—emphasizes electrification opportunities that also reduce emissions, lower bills, increase grid flexibility, and improve energy efficiency. Many appliances that could be electrified—such as water heaters, space heaters, and vehicles—are flexible loads. They present opportunity for storing excess renewable generation and may result in lower net carbon emissions if carefully implemented.

Orchestrating this storage or load shifting demands the two-way, reliable, and universal communications that CTA-2045 can provide. By monitoring end-use status in real time, co-ops can understand how much capacity they have to either add or shed load in response to excess generation or peak demand. This allows them to better prepare for these events and anticipate the result of an add or shed load period.

Benefits that manufacturers may realize from CTA-2045 may positively impact co-ops and their members as well. Open standards like CTA-2045 often encourage innovation, especially from smaller manufacturers, and can result in more choices to the consumer.

In addition, the modular approach of CTA-2045 may benefit end-product manufacturers by simplifying their product design and manufacturing. Rather than having to design the communications components into their products, they can rely on the expertise of the communications module manufacturer.

Next Steps

Pilots conducted to date have shown that co-ops and other electricity providers can reliably control CTA-2045-enabled end uses. But are CTA-2045-enabled products ready for broad market adoption and use in control programs? For most devices, there still exists a chicken-and-egg problem common to many market transformation efforts. Manufacturers won't invest in creating a new product line if demand for it doesn't exist, but demand depends, in part, on consumers who are familiar enough with the product to see value in it. Chuck Thomas of EPRI thinks that larger pilots of CTA-2045-enabled products will help accelerate awareness and demand, while reducing risk for manufacturers. Bonneville Power Authority has announced it will conduct a large field demonstration of up to 600 CTA-2045-enabled heat pump and electric resistance water heaters.

For it's part, EPRI and its members want the CTA-2045 technology to continue to advance. Their recent efforts have focused on helping to establish testing of CTA-2045 at an independent agency, such as the Universal Smart Network Access Port (USNAP) Alliance. NRECA is a member of USNAP. EPRI is also publicizing its findings and updating the functional requirements. A new version of the standard will be published soon.

One water heater manufacturer, A.O. Smith, has leaped across the chasm by releasing the first commercially available CTA-2045 electric resistance water heater model. And Jackson EMC has ordered a first truckload of them to deploy in new homes as an essential element of its RightChoice home program, guaranteeing that the co-op will have reliably controllable loads for the lifetime of these water heaters and, potentially, beyond.

Co-ops that have current load control programs, or want to start new ones, should keep an eye on CTA-2045. Ultimately, it could prove to be a reliable and standard way to control end uses from a wide variety of manufacturers using whatever communications technology works best for the co-op. As more results from field demonstrations become available, NRECA will update its members on the findings and potential benefits.

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