2019 Standard for

Demand Response through Variable Capacity HVAC Systems in Residential and Small Commercial Applications

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Note:
This is a new standard.

Foreword

Since AHRI Standard 1380 is a performance standard, it does not address aspects pertaining to network security and data privacy. However, such aspects may be addressed by pertinent safety standards of products covered in the scope of AHRI Standard 1380.

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DEMAND RESPONSE THROUGH VARIABLE CAPACITY HVAC SYSTEMS IN RESIDENTIAL AND SMALL COMMERCIAL APPLICATIONS

Section 1. Purpose

1.1 *Purpose*. The purpose of this standard is to establish for Demand Response (DR) through variable capacity HVAC systems in residential and small commercial applications definitions; test requirements, operating and physical requirements, minimum data requirements for published ratings, marking and nameplate data and conformance conditions.

1.1.1 *Intent*. This standard is intended for the guidance of HVAC systems and electric utility industries, including manufacturers, designers, installers, contractors, users and demand side management program managers. By providing standardized requirements for DR-ready HVAC systems, DR program managers can be assured the equipment is enabled to communicate in standardized messages on OpenADR 2.0 standardized DR communication protocols.

1.1.2 *Review and Amendment*. This standard is subject to review and amendment as technology advances in both HVAC equipment and DR communication protocols.

1.1.3 *DR strategies*. DR strategies may include but are not limited to concepts such as direct load control and price response programs.

1.2 *Requirements*. This standard establishes requirements for variable capacity HVAC systems 65,000 Btu/hr and less that are capable of supporting DR strategies to benefit the electric grid in a predictable manner and to facilitate end users to participate in DR, price response or similar incentive programs offered by electric utilities or related entities. The requirements described in this standard include the following:

1.2.1 Specifications for standardized communication pathways and protocols to be utilized by DR-ready HVAC Systems to communicate with electric utilities or related entities operating DR programs.

1.2.2 Specifications for communication connections to DR-ready HVAC Systems.

1.2.3 Specifications for standardized communication signals between electric utilities or related entities and DR-ready HVAC Systems.

1.2.4 Specifications for DR actions to be taken by DR-ready HVAC Systems in response to signals from electric utilities or related entities, considering instructions pre-configured in the system during enrollment process or otherwise by the building occupant.

1.2.5 Specifications for transmittal to and from DR-ready HVAC Systems to facilitate enrollment in DR programs.

Section 2. Scope

2.1 *Scope*. This Standard applies to communication, infrastructure and system functionality as they relate to the implementation of energy management strategies for variable capacity DR-ready HVAC systems installed in residential and small commercial applications with capacities of 65,000 Btu/hr or less as defined in Section 3.

2.1.1 Standardized communication required to enable participation in DR programs of electric utilities and related entities.

2.1.2 Infrastructure or the minimum acceptable pathways, including the physical layer, to enable direct communication between HVAC systems and electric utilities and related entities throughout the U.S. and

Canada.

   2.1.3   HVAC system functionality including the control modes and how the system responds to signals to modulate or restore normal operation.

2.2   *Exclusions*. This standard does not apply to any AC or HP equipment with capacity greater than or equal to 65,000 Btu/h at Rated Load Conditions.

Section 3. Definitions

All terms in this document will follow the standard industry definitions in the *ASHRAE Terminology* website, https://www.ashrae.org/resources--publications/free-resources/ashrae-terminology unless otherwise defined in this section.

3.1   *Cloud Server*. A logical server that is built, hosted and delivered through a cloud computing platform over the Internet. Cloud Servers possess and exhibit similar capabilities and functionality to a typical server but are accessed remotely from a cloud service provider.

3.2   *Continuously-variable Capacity Equipment.* Equipment capable of varying its cooling and heating output continuously over a wide range. Typically, such equipment utilizes inverters (variable frequency drives) to raise and lower the speed and output of compressors, fans and blowers.

3.3   *Demand Response (DR).* An umbrella term used to describe a range of methods through which systems respond to grid conditions or signals. These methods include various peak-shedding, such as direct load control, price-response methods, and curtailment of load. This definition is applicable for both noun and adjective usage of DR.

3.4   *Demand Response-ready (DR-ready) HVAC System*. A system manufactured ready to operate on standardized communication protocols designed for DR use, and configured to respond in defined ways to defined signals, including any field modifications (e.g. use of an accessory) authorized by a manufacturer's installation instructions.

3.5   *Demand Side Management (DSM).* A process used for the modification of consumer demand for energy through various methods such as financial incentives, direct load control, behavior change through education, etc. The goal of DSM is usually to encourage the consumer to use less energy during peak hours, or to move the time of energy use to off-peak times.

3.6   *Discretely-variable Capacity Equipment.* Equipment having the capability of varying its cooling and heating output capacity in two or more discrete steps. Typically, such system utilizes compressors with mechanical unloading capability, or utilizes two or more compressors operating in parallel. Such systems may also utilize various techniques to vary the output of fans and blowers.

3.7   *Peak Load Pricing Event.* An event in which the electric utility or related entity experiences severe peak loads and raises utility rates substantially to signal the need to reduce power (kW) use.

3.8   *Rated Load Conditions*. Ambient conditions defined by AHRI Standard 210/240 for the purpose of measuring cooling and heating output and energy efficiency of AC or HP equipment. For the purpose of this Standard, the primary rating conditions for cooling operations is the 95˚F cooling outdoor ambient rating point, A_{Full}; for heat pump heating operation, is the 47˚F heating outdoor ambient rating point as defined in AHRI Standard 210/240, at $H1_{Full}$ conditions for two-stage equipment as defined by AHRI Standard 210/240 and $H1_{Nom}$ for all other equipment.

3.9   *Rated Load Power.* The power (kW) consumed by AC or HP equipment at Rated Load Conditions defined by AHRI Standard 210/240. For the purpose of this Standard, the primary rating conditions for cooling operations is the 95˚F cooling outdoor ambient rating point A_{Full}; for heat pump heating operation, is the 47˚F heating outdoor ambient rating point as defined in AHRI Standard 210/240, at $H1_{Full}$ conditions for two-stage equipment as defined by AHRI Standard 210/240 and $H1_{Nom}$ for all other equipment.

3.10   *Run Normal.* No DR event is in effect and the AC or HP equipment is running under local control.

3.11 *"Shall" or "Should".* "Shall" or "should" shall be interpreted as follows:

    3.11.1 *Shall.* Where "shall" or "shall not" is used for a provision specified, that provision is mandatory if compliance with the standard is claimed.

    3.11.2 *Should.* "Should" is used to indicate provisions which are not mandatory but which are desirable as good practice.

3.12 *Test Tool.* A custom software application designed to connect to either CTA-2045-A or OpenADR 2.0 communication interfaces, which generates appropriate messages to assess the fulfillment of the requirements specified in Section 6 by the DR-ready HVAC system.

Section 4. Abbreviations and Symbols

4.1 Abbreviations used in this Standard:

    4.1.1   AC   Air Conditioner
    4.1.2   ACK   A communication response: acknowledged
    4.1.3   CTA   Consumer Technologies Association
    4.1.4   DHCP   Dynamic Host Configuration Protocol
    4.1.5   DR   Demand Response
    4.1.6   DSM   Demand Side Management
    4.1.7   HP   Heat Pump
    4.1.8   HVAC   Heating, Ventilation and Air Conditioning
    4.1.9   kW   Kilowatt
    4.1.10   NAK   A communication response: not acknowledged
    4.1.11   VEN   Virtual end node, refers to the HVAC system in OpenADR
    4.1.12   VTN   Virtual top node, refers the utility or other headend in OpenADR
    4.1.13   W   Watt

Section 5. Test Requirements

5.1 *Test Requirements*. Configuration requirements, communication requirements, and equipment performance requirements shall be verified by tests conducted in accordance with the test method described in Appendix C and utilizing the communication protocols in Section 6.

    5.1.1 *HVAC System.* HVAC system shall be tested using all components as recommended by the manufacturer.

Section 6. Operating and Physical Requirements

6.1 *Summary of Operating and Physical Requirements*. DR-ready HVAC System shall meet the communication and equipment performance requirements as itemized below for either CTA-2045-A or OpenADR 2.0 or both communication protocols. Compliance with all requirements shall be verified by tests in accordance with Appendix C.

    6.1.1 *CTA-2045-A Communication Interface.*

        6.1.1.1 Table 1 outlines the communication and discovery functions and equipment responses to CTA-2045-A signals.

        6.1.1.2 Table 2 outlines the management functions and equipment responses to CTA-2045-A signals.

        6.1.1.3 The physical and electrical aspects of this interface are set forth in Section 6.2.2.

Table 1. Communication and Discovery with CTA-2045-A			
Function	**CTA-2045-A Message**	**CTA-2045-A Reference**	**Usage and Purpose**
Verifying Connectivity	Outside Comm Connection Status Message	Table 8-2	Outside Comm Connection Status Message is a CTA-2045-A mandatory message. This recurring signal, sent from the communication module to the HVAC system, with HVAC acknowledgment, allows: 1. the HVAC system to know that the attached communication module is successfully connected to a remote headend 2. the communication module to know that the HVAC system is present and connected
System Capabilities	Info Request – sent from the communication module to the HVAC system, with response	Section 9.1.1 Section 9.1.1.1 (request) and Section 9.1.1.2 (response)	Info request sent from the communication module enables the system type to be discovered. System responses shall include all mandatory CTA-2045-A fields noted by "M" in CTA-2045-A Section 9.1.1.2 plus: 1. Vendor ID (uniquely assigned to each manufacturer by the USNAP Alliance 2. Device type = 0x0004 for heat pumps Device type = 0x0007 for AC only 3. Model number (to support device characterization) 4. Capability bitmap = For Continuously-variable Capacity Equipment set Bit 4 and for Discretely-variable Capacity Equipment set Bit 5
Maximum Indoor Temperature Offset	Get/Set Temperature Offset Setting the temperature offset and reading the present temperature offset	Section 9.1.5 Section 9.1.5.3 and 9.1.5.4 for setting the temperature offset Section 9.1.5.1 and 9.1.5.2 for reading the present temperature offset	A non-zero temperature offset "Set" by this message shall be used as the "Maximum Indoor Temperature Offset" for HVAC system during a load control or price event unless locally modified by the consumer. This offset number is a decrease in set point when in heating mode and an increase when in cooling mode. There are no limits associated with the default value. Manufacturers may provide consumers with means to alter the default value. The present "Maximum Indoor Temperature Offset" value shall always be returned in response to a "Get" message.
Operational State Query and Response	Operational State Query and Response Messages	Table 8-2	Operational state query and response enables remote systems to monitor the present state of the HVAC system and to verify that curtailment events are acted upon and in effect.

Table 2. Management with CTA-2045-A			
Function	**CTA-2045-A Message**	**CTA-2045-A Reference**	**Usage and Purpose**
General Curtailment	Shed (request) and Basic Application ACK (response) Messages	Table 8-2	General curtailment directs HVAC system (both heat pump and cooling-only types) to curtail energy consumption moderately, limiting input power to a maximum of 70% of the Rated Load Power. See section 3.1 definitions. HVAC system shall respond with an application "Acknowledge (ACK)", verifying receipt and support of the request. In the heating mode temperature drop shall be no more than 4˚F. Note: This curtailment is subject to indoor temperatures remaining within the "Maximum Indoor Temperature Offset", if set.
Critical Curtailment	Critical Peak Event (request) and Basic Application ACK (response) Messages	Table 8-2	Critical curtailment directs HVAC system (both heat pump and cooling-only types) to curtail energy consumption aggressively: 1. For Continuously-variable Capacity Equipment in cooling mode: limit input power to a maximum of 40% of the Rated Load Power. See Section 3.1 definitions. 2. For Discretely-variable Capacity Equipment in cooling mode: not-applicable, NAK response with reason code = 0x01 (Opcode not supported) and take no action. Note that the utility DR administrator system, upon receipt of a NAK from Discretely-variable Capacity Equipment may then automatically send a "General Curtailment" or "Turn off" signal depending on the agreement with the customer. Note: This curtailment is subject to indoor temperatures remaining within the "Maximum Indoor Temperature Offset", if set. Either Continuously-variable or Discretely-variable Capacity Equipment, if in the heating mode, shall turn off resistance heating elements unless indoor temperature is below 62˚F. HVAC system shall respond with an application "Acknowledge (ACK)", verifying receipt and support of the request.
Off Mode	Grid Emergency (request) and Basic Application ACK (response) Messages	Table 8-2	Grid emergency directs HVAC system to turn to off mode. Compressor crankcase heater, if any, and control power shall remain on. HVAC system shall respond with an application "Acknowledge (ACK)", verifying receipt and support of the request. Note: This curtailment is subject to indoor temperatures remaining within the "Maximum Indoor Temperature Offset", if set.

Function	CTA-2045-A Message	CTA-2045-A Reference	Usage and Purpose
			Table 2. Management with CTA-2045-A (continued)
End Active Events	End Shed/Run Normal Operation (request) and Basic Application ACK (response) Messages	Table 8-2	End shed/Run Normal operation informs HVAC system that any curtailment or price events that may be presently in effect are terminated. HVAC system shall respond with an application "Acknowledge (ACK)", verifying receipt and support of the request resuming Run Normal operation.
Advanced Notification	Pending Event Warning and Pending Event Type (notification) and Basic Application ACK (response) Messages	Table 8-2	Pending event warning and pending event type provides HVAC system with advanced notification of future events. Manufacturers may optionally use this information to take proactive action ahead of the event such as precooling or preheating.
Cancel Scheduled/ Future Events	Pending Event Type (notification) and Basic Application ACK (response) Messages	Table 8-2	Pending event type notifies HVAC system that any previously notified future event is canceled. HVAC system shall respond with an application "Acknowledge (ACK)", verifying receipt and support of the request. Usage: "Pending Event Type" 1. Opcode 1 = 0x19 2. Opcode 2 = 0x02 (future event cancelled)
Utility Peak Load Price Signal	Present Relative Price (notification) and Basic Application ACK (response) Messages	Table 8-2	Utility peak load price signal informs HVAC system that a peak price period is in effect and of the relative price value during this event. This function is differentiated from the "Curtailment" functions in that a response is not mandatory. Manufacturers may provide consumers with the ability to configure how they want the equipment to respond automatically to utility peak load price signals.
Customer Override	Customer Override Message (initiated by the HVAC system) and Basic Application ACK Messages	Table 8-2	Customer override is sent by the HVAC system to notify that a customer override has occurred. Note: in accordance with the CTA-2045-A standard, the HVAC system shall send this message when override is first initiated and following incoming energy management messages while override is in effect.

6.1.2   *OpenADR 2.0 Communication Interface.*

6.1.2.1   Table 3 outlines the communication and discovery functions and HVAC system responses to OpenADR 2.0 signals. The endpoints of an OpenADR message exchange are the server, called a "Virtual Top Node" or "VTN" and the client, called a "Virtual End Node" or "VEN". The HVAC system, manufacturer

cloud network or other methodology in communication with the system implements the VEN functionality, while the remote control system (utility, administrator or agent) acts as the VTN.

		Table 3. Communication and Discovery with OpenADR 2.0	
Function	**Message**	**OpenADR 2.0 Reference**	**Usage and Purpose**
Verifying Connectivity	oadrPoll - sent from the VEN to the VTN, with VTN acknowledgement (oadrResponse or other pending messages)	Section 8.6, OpenADR Poll Figures 19 to 22, Interaction Diagrams: oadrPoll (various responses)	Verifying connectivity is an OpenADR message that is used for "pull" mode VENs. This signal and its acknowledgement allow: 1. The VEN to know that it is successfully connected to a remote headend (VTN). 2. The VTN to know that the VEN is present and connected. 3. The VEN to retrieve any pending messages the VTN has queued up for it.
Utility Setup	oadrCreatePartyRegistration – sent from the VEN to the VTN, with response	Section 8.4.1, Service Operations Figure 14, Interaction Diagram: Create Registration	Utility Setup informs the VTN of information about the VEN. The equipment shall respond with the following values indicated: 1. VEN ID, only if this is a re-registration request 2. profile = 2.0b 3. transport = HTTP 4. XML signature use = N 5. VEN name = ASCII string (optional) 6. pull mode = Y The VTN's response to a successful registration contains: 1. registration ID (for reregistration or cancellation) 2. VEN ID 3. VTN ID 4. profiles (and associated transports) 5. polling interval 6. service or extension data
Registration	oadrRegisterReport – sent from VEN, with VTN response (oadrRegisteredReport containing an oadrReportRequest), followed by subsequent oadrCreatedReport from the VEN	Section 8.3.2.1, Register Reporting Capabilities Figure 9, Interaction Diagram, Register Reporting Capabilities	Registration is used by the VEN to inform the VTN about its characteristics and capabilities, which are specified in the "METADATA" report. The metadata report includes special identifiers, the amount of time for which data can be collected (or has been collected thus far); maximum and minimum sampling frequencies, and whether the data is sampled as it changes (Y or N). The VEN shall register an "x-AHRI_STATUS" report. The VTN acknowledges this request by sending an oadrRegsiteredReport message. In response to an immediate or subsequent oadrReportRequest for this report, the VEN responds with a report containing the requested data.

Table 3. Communication and Discovery with OpenADR 2.0 (continued)			
Function	**Message**	**OpenADR 2.0 Reference**	**Usage and Purpose**
Cancel Registration	oadrCancelPartyReg istration/oadrCancel edPartyRegsitration	Section 8.4.1, Service Operations Figure 16, Interaction Diagram: Cancel Registration	Cancel Registration allows either the VTN or VEN to cancel an active registration.
Re-Registration	oadrRequestReregist ration/oadrResponse	Section 8.4.1, Service Operations Figure 15, Interaction Diagram: Request Re-registration	Re-registration allows VENs to re-register (for instance, if its capabilities change) by issuing another oadrCreatePartyRegistration message. VTNs can request that a VEN reregister by issuing an oadrRequestReregistration message. The VEN shall acknowledge receipt of this request using an oadrRespose, and shall also issue a new oadrCreatePartyRegistration message.

6.1.2.2 *Description and use of status data fields.*

    6.1.2.2.1 *Operational State.*

0 = "Idle Normal" Indicates that no DR event is in effect and the HVAC system has no/insignificant energy consumption.

1 = "Running Normal" Indicates that no DR event is in effect and the HVAC system is running normal under local control.

2 = "Running Curtailed" Indicates that a curtailment type DR event is in effect and system is running in General Curtailment mode

3 = "Running Heightened" Indicates that a heightened-operation type of DR event is in effect and system is running in Critical Curtailment mode

4 = "Idle Curtailed" Indicates that a curtailment type DR event is in effect and the HVAC system is in off mode.

5 = "SGD Error Condition" Indicates that the HVAC system is not operating or is in some way disabled (for example, no response to the grid).

6 = "Idle Heightened" Indicates that a heightened-operation type of DR event is in effect and the HVAC system is in off mode.

7 =   Unused code.

8 =   Unused code.

9 =   Unused code.

10 =   Unused code.

11 = "Idle, Opted Out" Indicates that the HVAC system is presently opted out of any DR events and the system is in off mode.

12 = "Running, Opted Out" Indicates that the SGD is presently opted out of any DR events and the SGD is operating normal under local control.

    6.1.2.2.2 *Override State.*

        6.1.2.2.2.1   Set to "1" if in override
        6.1.2.2.2.2   Set to "0" if not overridden

6.1.2.3   Table 4 outlines the management functions and equipment responses to OpenADR 2.0 protocol.

			Table 4. Management with OpenADR 2.0
Function	**Message**	**OpenADR 2.0 Reference**	**Usage and Purpose**
Maximum Indoor Temperature Offset	oadrDistribute Event – sent from VTN to VEN, with response (oadrCreatedE vent)	Section 8.1, OpenADR 2.0b EiEvent Service Figures 4 & 5, EiEvent Patterns Section 8.2.2, OpenADR 2.0b Signal Definitions Table 1, Signals	The VTN shall send an oadrDistributeEvent carrying an oadrEvent element with a signalName:signalType of "LOAD_CONTROL:x-LoadCon-trolLevel-Offset" to specify the Maximum indoor temperature offset that the HVAC system must use when processing any curtailment or price signals. Note 1: If the oadrCreatedEvent includes two signals, one being the LOAD_CONTROL:x-LoadCon-trolLevel-Offset then the HVAC system must use the payload value of this signal to control the max temperature offset over the duration of the event. Note 2: This event message also informs the HVAC system of the timing and status of future DR events. The VTN's oadrDistributeEvent includes a start time, an event duration, as well as an eventStatus element that is set to "NEAR" or "FAR" (the transition from FAR to NEAR occurs at the start of the ramp period for an event). Name: LOAD_CONTROL Type: x-LoadCon-trolLevel-Offset Units: Degree Fahrenheit Payload: Integer
General Curtailment (includes advanced notification)	oadrDistribute Event – sent from VTN to VEN, with response (oadrCreatedE vent)	Section 8.1, OpenADR 2.0b EiEvent Service Figures 4 & 5, EiEvent Patterns Section 8.2.2, OpenADR 2.0b Signal Definitions Table 1, Signals	General curtailment directs HVAC system (both cooling-only and heat-pump) to curtail power consumption to a maximum of 70% of the Rated Load Power. The VTN shall send an oadrDistributeEvent carrying an oadrEvent element with a signalName:signalType of "SIMPLE:level" set to "1" to indicate the nominal shed level for "General Curtailment." Note: This event message also informs the HVAC system of the timing and status of future DR events. The VTN's oadrDistributeEvent includes a start time, an event duration, as well as an eventStatus element that is set to "NEAR" or "FAR" (the transition from FAR to NEAR occurs at the start of the ramp period for an event). Name: SIMPLE Type: level Units: None Payload: 1

Table 4. Management with OpenADR 2.0 (continued)			
Function	**Message**	**OpenADR 2.0 Reference**	**Usage and Purpose**
Critical Curtailment (includes advanced notification)	oadrDistribute Event – sent from VTN to VEN, with response (oadrCreatedE vent)	Section 8.1, OpenADR 2.0b EiEvent Service Figures 4 & 5, EiEvent Patterns Section 8.2.2, OpenADR 2.0b Signal Definitions Table 1, Signals	Critical curtailment directs HVAC system in cooling mode to curtail power consumption to a maximum of 40% of the Rated Load Power. See Section 3.2 definitions. In either Continuously-variable or Discretely-variable Capacity Equipment in heating mode, resistance heating elements shall be turned off unless indoor ambient temperature is below 62˚F. The VTN shall send an oadrDistributeEvent carrying an oadrEvent element with a signalName:signalType of "SIMPLE:level" set to "2" to indicate the nominal shed level for "Infrequent Critical Curtailment." Note: This event message also informs the HVAC system of the timing and status of future DR events. The VTN's oadrDistributeEvent includes a start time, an event duration, as well as an eventStatus element that is set to "NEAR" or "FAR" (the transition from FAR to NEAR occurs at the start of the ramp period for an event). Name: SIMPLE Type: level Units: None Payload: 2
Off Mode (includes advanced notification)	oadrDistribute Event – sent from VTN to VEN, with response (oadrCreatedE vent)	Section 8.1, OpenADR 2.0b EiEvent Service Figures 4 & 5, EiEvent Patterns Section 8.2.2, OpenADR 2.0b Signal Definitions Table 1, Signals	Off mode directs HVAC system (both cooling-only and heat-pump) to turn to off mode, without turning off the compressor crankcase heater and system controls. The VTN shall send an oadrDistributeEvent carrying an oadrEvent element with a signalName:signalType of "SIMPLE:level" set to "3" to indicate the nominal shed level for "Grid Emergency Curtailment." Note: This event message also informs the HVAC system of the timing and status of future DR events. The VTN's oadrDistributeEvent includes a start time, an event duration, as well as an eventStatus element that is set to "NEAR" or "FAR" (the transition from FAR to NEAR occurs at the start of the ramp period for an event). Name: SIMPLE Type: level Units: None Payload: 3

Table 4. Management with OpenADR 2.0 (continued)			
Function	**Message**	**OpenADR 2.0 Reference**	**Usage and Purpose**
End Active Events And Cancel Scheduled/ Future Events	oadrDistribute Event – sent from VTN to VEN, with response (oadrCreatedE vent)	Section 8.1, OpenADR 2.0b EiEvent Service Figures 4 & 5, EiEvent Patterns	End active events informs the HVAC system that a specified curtailment or price event that may be presently in effect, or scheduled in the future, is terminated. The VTN shall send an oadrDistributeEvent with an eventStatus element set to "CANCELLED".
Utility Peak Load Price Signal	oadrDistribute Event – sent from VTN to VEN, with response (oadrCreatedE vent)	Section 8.1, OpenADR 2.0b EiEvent Service Figures 4 & 5, EiEvent Patterns Section 8.2.2, OpenADR 2.0b Signal Definitions Table 1, Signals	Utility peak load price signal informs the HVAC system that a peak price period is in effect and of the relative price value during the event. The VTN shall send an oadrDistributeEvent with a signalName of "ELECTRICITY_PRICE" and with signalType: "priceMultiplier". This message format expresses price as a unit-less multiplier to be applied to the existing cost of electricity. Equipment manufacturer may provide user with the means to configure system to automatically respond to peak load price signals.
Customer Override	oadrCreateOpt – Sent from VEN to VTN, with response (oadrCreatedO pt)	Section 8.5, OpenADR 2.0b EiOpt Service Figure 17, Interaction Diagram: Create Opt	Customer override is sent by the HVAC system to notify that a customer override has occurred. The VEN shall send an oadrCreateOpt message.

6.1.3 *Additional performance requirement for Continuously-variable Capacity Equipment*.

6.1.3.1 *Five-Second Ramp.* At all times when decreasing or increasing electric power (kW), pursuant to only DR operation, Continuously-variable Capacity Equipment shall ramp the electric power change approximately linearly over an interval of five seconds or more to reduce transients on the utility's distribution circuits.

6.2 *Summary of Physical Requirements*. DR-ready HVAC system shall be capable of connecting to either CTA-2045-A or OpenADR 2.0 or both communication interfaces.

6.2.1 *Requirements for connecting to CTA-2045-A.* DR-ready HVAC System using the CTA-2045-A option shall include the CTA-2045-A AC form factor or DC form factor physical interface as described in Appendix B of the CTA-2045-A standard.

6.2.2 *Requirements for connecting to OpenADR 2.0.* DR-ready HVAC System using the OpenADR 2.0 option shall include one or more of the following interfaces. Location of the interface can reside within any of the required system architecture.

6.2.2.1 IEEE/ISO/IEC 8802-2 (Ethernet).
6.2.2.2 IEEE 802.11 (Wi-Fi) with the option of access to a Cloud Server.

Note: In the case that Wi-Fi is utilized, the manufacturer shall provide a means by which the consumer can commission the HVAC system to their Wi-Fi LAN, including SSID and security settings. Manufacturer can also provide consumer means to terminate VEN signals at manufacturer Cloud Server to enable that other service capabilities can be reliably and correctly provisioned.

Section 7. Minimum Data Requirements for Published Ratings

7.1 *Minimum Data Requirements for Published Ratings*. As a minimum, manufacturers shall provide the following data for each set of DR-ready HVAC system.

    7.1.1 *General.* All data required under AHRI Standard 210/240, including model numbers for all relevant components of the equipment, whether a self-contained system, or split system including outdoor unit, indoor coil and air-handling unit, system controls or other components required for the operation of the system.

    7.1.2 *Type of capacity modulation.*

        7.1.2.1 Continuously-variable capacity (inverter driven compressor), or
        7.1.2.2 Discretely-variable capacity (such as a step-modulated compressor or dual compressor).

    7.1.3 *DR communication protocol(s) supported by the equipment.*

        7.1.3.1 CTA-2045-A,
        7.1.3.2 OpenADR 2.0, or
        7.1.3.3 Both CTA-2045-A and OpenADR 2.0.

    7.1.4 *All systems.* Rated Load Power in Watts at the conditions defined by AHRI Standard 210/240 for cooling (outdoor 95°F and indoor 80°F dry bulb/67°F wet bulb), A_{Full}.

    7.1.5 *Heat pump systems.* Rated Load Power in Watts at the conditions defined by AHRI Standard 210/240 for light-load heating (outdoor 47°F and indoor 70°F dry bulb/60°F wet bulb), $H1_N$.

    7.1.6 *If the CTA-2045-A communication format is utilized:* Record which one of the following form factors is utilized.

        7.1.6.1 AC Form Factor, or
        7.1.6.2 DC Form Factor.

Section 8. Marking and Nameplate Data

8.1 Manufacturers' descriptive and technical literature for DR-ready HVAC System shall reference this Standard number and designate which DR communication protocol(s) the system is capable of supporting, using the following designations depending upon the system capability:

    8.1.1 DR-ready: CTA-2045-A
    8.1.2 DR-ready: OpenADR 2.0
    8.1.3 DR-ready: Both CTA-2045-A and OpenADR 2.0

8.2 In the event the system utilizes CTA-2045-A, either alone or together with OpenADR 2.0, manufacturers' descriptive and technical literature shall also designate the CTA Form Factor utilized:

    8.2.1 AC form factor, or
    8.2.2 DC form factor.

Section 9. Conformance Conditions

9.1   *Conformance.* While conformance with this standard is voluntary, conformance shall not be claimed or implied for products or equipment within the standard's *Purpose* (Section 1) and *Scope* (Section 2) unless such product claims meet all of the requirements of the standard and all of the testing and rating requirements are measured and reported in complete compliance with the standard. Any product that has not met all the requirements of the standard shall not reference, state, or acknowledge the standard in any written, oral, or electronic communication.

APPENDIX A. REFERENCES – NORMATIVE

A1 Listed here are all standards, handbooks and other publications essential to the formation and implementation of the standard. All references in this appendix are considered as part of the standard.

A1.1 AHRI Standard 210/240-2017, *Unitary Air-Conditioning and Air-Source Heat Pump Equipment*, 2017**,** Air-Conditioning Heating and Refrigeration Institute, 2311 Wilson Blvd., Suite 400, Arlington, VA 22201, U.S.A.

A1.2 CTA-2045-A Standard, *Modular Communications Interface for Energy Management,* September 2017, Consumer Technology Association, 1919 S Eads St, Arlington, VA 22202, U.S.A.

A1.3 *IEEE 802.11-2016: Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, 14 December 2016, IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-4141, U.S.A.

A1.4 *IEEE/ISO/IEC 8802-2-1998: IEEE International Standard for Information technology -- Telecommunications and information exchange between systems -- Local and metropolitan area networks -- Specific requirements -- Part 2: Logical Link Control,* 7 May 1998, IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-4141, U.S.A.

A1.5 *OpenADR 2.0 Profile Specification B Profile,* Revision Number 1.1 (Final Specification), 17 November 2015, OpenADR Alliance, 16820 Jackson Oaks Drive, Suite 1A, Morgan Hill, CA 95037, U.S.A.

APPENDIX B. REFERENCES - INFORMATIVE

B1 *RESERVED FOR INFORMATIVE REFERENCES*

APPENDIX C. METHODS OF TESTING – NORMATIVE

C1   *Purpose.*   The purpose of this appendix is to prescribe a method of testing for Variable-capacity DR-ready HVAC Systems less than 65,000 Btu/hr to verify the equipment response to DR signals through OpenADR 2.0 and CTA-2045-A communication protocols as defined in Section 6.1.

  C1.1   Testing shall occur at a facility where HVAC systems are tested for capacity and energy efficiency according to the Method of Test for the latest revision of AHRI Standard 210/240.

C2   *Scope.* Section 2.

C3   *Definitions.* Section 3.

C4   *Instrumentation.* This method of test shall utilize power measurement instrumentation that is specified in the latest revision of AHRI Standard 210/240, and calibrated and certified according to that Standard.

  C4.1   Test Tools shall be utilized to simulate signals sent by DR Program Administrator servers that send and receive signals to and from HVAC systems:

  These Test Tools are custom applications designed to connect to the communication interfaces and generate the appropriate messages to assess the functions defined in tables 1 through 4 of Section 6.

  Note: Test Tools are not designed to ensure compliance with the OpenADR and/or CTA-2045-A standards. To ensure that the interfaces meet the requirements set forth in either of these standards, products should undergo separate certification testing with the OpenADR and/or CTA-2045-A standards.

  C4.2   Except as noted below, Rated Load Power in the cooling mode shall be measured at full-load rating conditions, A_{Full}.

  C4.3   Except as noted below, Rated Load Power in the heating mode shall be measured at full-load rating conditions, $H1_N$.

  C4.4   If a break-in period is required by AHRI Standard 210/240, that requirement must be observed for this Method of Test.

  C4.5   When the power of the unit is reduced in the simulation of a DR event, the unit shall be allowed to stabilize for a minimum of 2.0 minutes before power measurements are taken.

  C4.6   All power measurements shall be instantaneous measurements. For purposes of determining compliance with unloading requirements in Continuously-variable Capacity Equipment, twenty measurements each one minute apart shall be taken, and the results averaged and compared with the power specified by the Standard. For determining compliance with unloading requirements in Discretely-variable Capacity Equipment, a single power measurement shall be taken and compared with Rated Load Power.

C5   *HVAC System Testing.* HVAC system being tested shall include outdoor unit, indoor unit and any components necessary to conduct testing per AHRI Standard 210/240 and additional components and or controls required for compliance with this standard. Testing for requirements in Section 6.1 of this Standard shall follow the following requirements:

  C5.1   *Test Setup(s).*

    C5.1.1   *Test Setup(s) for HVAC systems that support the OpenADR interface.* Section 6.2.1 defines the use of two different physical interfaces by which the OpenADR interface on the equipment is accessible, 1) Wired - Ethernet (IEEE/ISO/IEC 8802-2) or 2) Wireless – (IEEE 802.11). These two different interface options require two different test setups each utilizing a Test Tool., and. Figures C1 and C2 illustrate Test Tool is to be

located adjacent to and wired to the equipment in the Test Chamber, however Test Tool may alternatively be located remotely and connected to the equipment by any means of communication capable of sending and receiving the specified signals.

C5.1.1.1 *Test Setup 1 (OpenADR over Ethernet).* Figure C1 illustrates the test setup for equipment to be operated with OpenADR 2.0 tested either wirelessly or through a wired Ethernet connection.
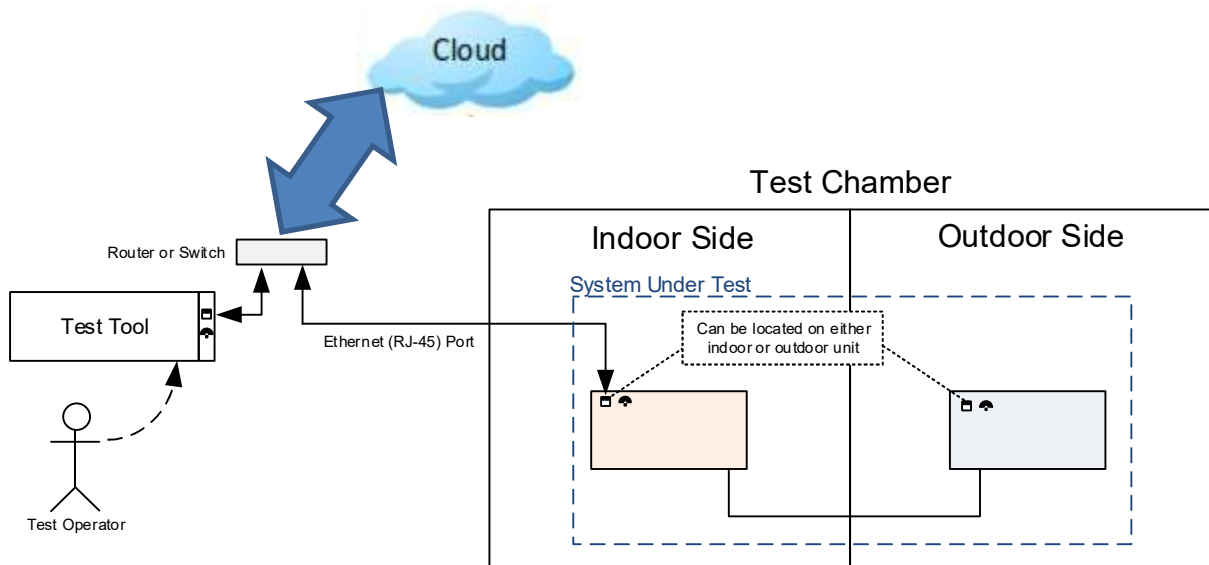
Figure C1. OpenADR Test Setup 1 for Equipment with a wired Ethernet (IEEE/ISO/IEC 8802-2) port
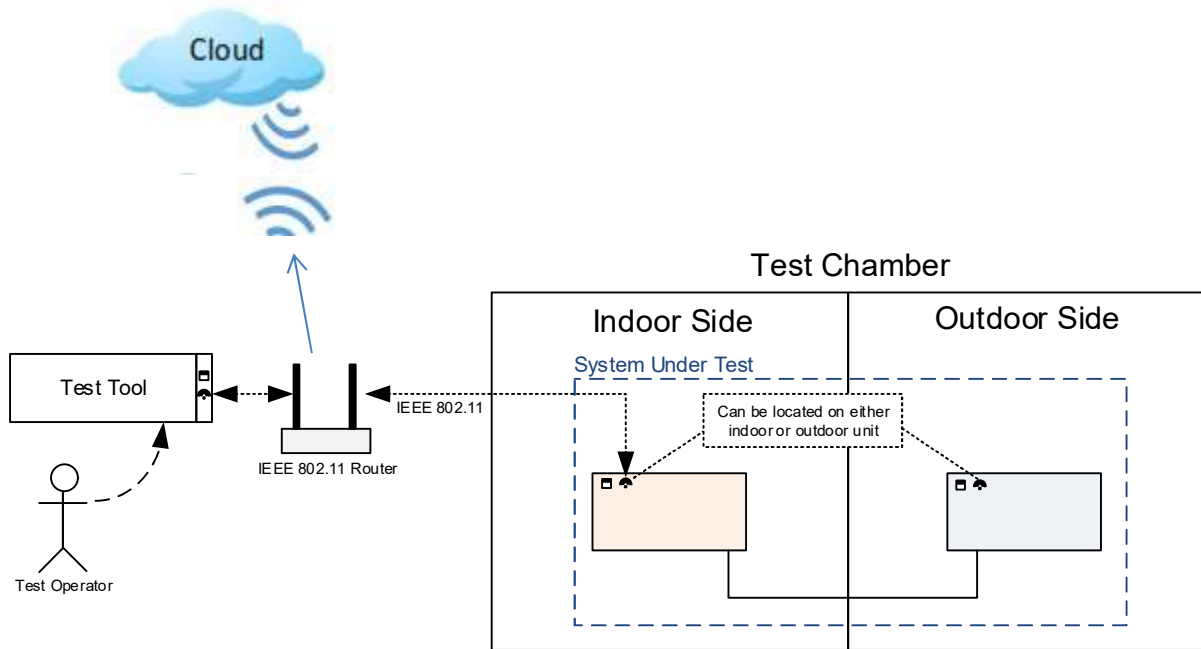
Test Setup 1 Minimum Steps:
1. Connect the computer running the Test Tool to an Ethernet router or switch.
2. Connect the HVAC system to the same router or switch.
   When a switch is used, both computer and equipment shall be configured to operate on the same network.
   When a router is used, the router, computer and HVAC system shall be setup for DHCP.
3. Test operator shall use the Test Tool to verify that the interface has been implemented as defined in Table 3 of Section 6.

Note: The HVAC system must be configured to communicate with the Test Tool. At minimum, the equipment must have instructions and means for the test operator to configure the following parameters:
   URL or TCP/IP address of the Test Tool
   VENName
   Security certificates

C5.1.1.2 *Test Setup 2 (OpenADR over wireless Ethernet IEEE 802.11 with the option of access to a Cloud Server).* Figure C2 illustrates the test setup for the HVAC system to be operated with OpenADR 2.0 tested through a wireless Ethernet interface. The test setup may implement a Cloud Server for connection to the HVAC system. The test setup may also include a thermostat, system controller, or establish connectivity with a remote communication device.
For the Cloud Server approach, the HVAC system shall be registered with an account on the server associated with the manufacturer or an aggregator. The manufacturer shall provide written instructions on account setup, access, and use. The manufacturer may set up a unique account for the purpose of this test.

Figure C2. OpenADR Test Setup 2 for System with a wireless Ethernet (IEEE 802.11) interface
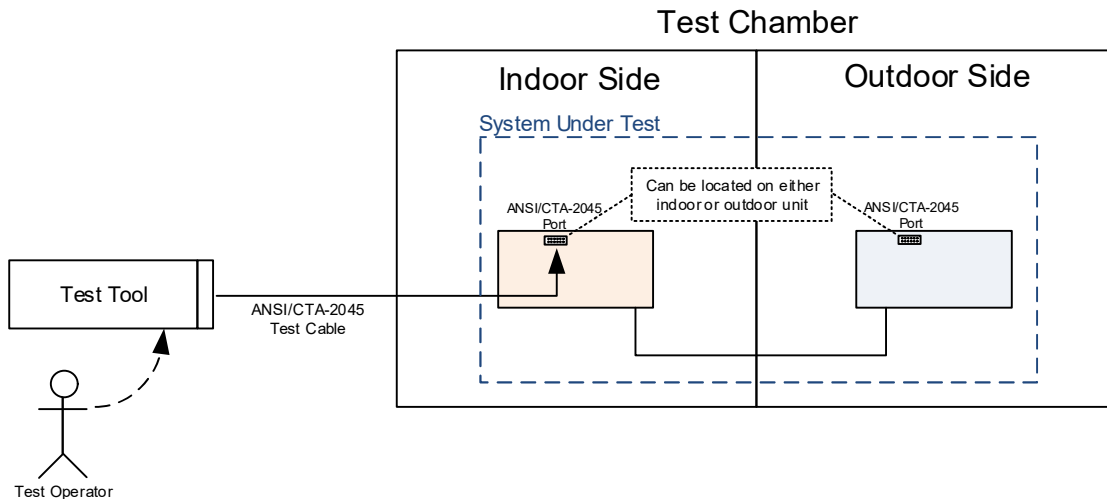
Test Setup 2 Minimum Steps:
1. Connect the computer running the Test Tool to a local IEEE 802.11 (Wi-Fi) router.
2. Connect the HVAC system either wired or wirelessly to the same router. The means to a physical connection to the HVAC system may be through a thermostat, Wi-Fi module, or direct equipment connection provided by the manufacturer.
   Note: the router, computer and HVAC system shall all be configured to support DHCP.
3. Test operator shall use the Test Tool to verify that the interface has been implemented as defined in Table 3 of Section 6. If the Cloud Server approach is chosen, the Test Tool shall communicate with the account associated with the manufacturer or aggregator Cloud Server.
   Note: The HVAC system must be configured to communicate with the Test Tool. At minimum, the equipment must have instructions and means for the test operator to configure following parameters:

   > Router's SSID
   > Router's security
   > Router's passkey
   > URL or TCP/IP address of the Test Tool
   > VENName
   > Security certificates

C5.1.2 *Test Setup for HVAC system that support the CTA-2045-A interface.* Section 6.2.2 defines the specifications for connecting HVAC system using the CTA-2045-A standard. The setup requires a Test Tool. The "CTA-2045-A Test Cable" is the physical hardware required to connect the Test Tool to the equipment. Figure C3 illustrates Test Tool is located adjacent to and wired to the system in the Test Chamber, however the Test Tool may alternatively be located remotely and connected by any means of communication capable of accurately sending and receiving the specified signals. The test setup may also include a thermostat or system controller.

C5.1.2.1 *Test Setup 3 (HVAC System with an CTA-2045-A Interface).* Figure C3 illustrates the test setup for system to be tested with the CTA-2045-A communication port.

Test Chamber

Figure C3. Test Setup 3 for System with a CTA-2045-A Communication Port

Test Setup 3 Minimum Steps:
1. Connect the computer running the Test Tool to the equipment using an CTA-2045-A Test Cable
2. Test operator shall use the Test Tool to verify that the interface has been implemented as defined in Table 1 of Section 6.

C5.2 *Configuration Requirements utilizing CTA-2045-A contained in Section 6:* The "system Capabilities" query contained in Table 1 shall be sent to the system and the response verified to accurately represent the required equipment information.

C5.3 *Management performance requirements utilizing CTA-2045-A:* The signals described in Section 6, Table 2, shall be sent from and to the CTA-2045-A Communications Simulator, and the specified system response verified.

C5.3.1 Testing at cooling rating point conditions as specified in AHRI Standard 210/240 (95 ˚F outdoor ambient) A_{Full}. For each test, the "Determining Degree of Unloading" and "Operational State Query" messages identified in Table 1 shall be issued prior to and during the test event and verified to properly represent the equipment state.

C5.3.1.1 Using a wattmeter, test and confirm that upon receipt of signal requiring a 30% power reduction, that the total system input power is reduced to a maximum of 70% of the Rated Load Power of the system.

C5.3.1.2 Using a wattmeter, test and confirm that upon receipt of signal requiring a 60% power reduction, that the total system input power is reduced to a maximum of 40% of the Rated Load Power of the system. If, however the particular unit being tested is a Discretely-variable Capacity system that is not capable of 60% unloading, confirm that it returns a message to the simulator that it is not capable.

During the 60% power reduction test described above, a customer override shall be initiated from the equipment user interface. It shall be verified that upon the customer override that the equipment returns to normal operation and that the equipment sends the message to the utility that the override has occurred.

C5.3.1.3 Using a wattmeter, test and confirm that upon receipt of signal requiring that the system turns to off mode, that the system input power is turned off, except for any power utilized by the compressor crankcase heater and controls.

C5.3.2 Testing at heating mild ambient rating point conditions as specified in AHRI Standard 210/240 (47°F outdoor ambient), at $H1_2$ conditions for Discretely-variable Capacity system and $H1_N$, if tested, for Continuously-variable Capacity Equipment. If the $H1_N$ test was not conducted for Continuously-variable Capacity Equipment, the $H1_2$ testing shall be used.

C5.3.2.1 Using a wattmeter, test and confirm that upon receipt of Stage 1 signal requiring a 30% power reduction, that the total system input power is reduced to a maximum of 70% of the Rated Load Power of the system.

C5.3.2.2 Using a wattmeter or voltmeter, test and confirm that upon receipt of Stage 2 signal requiring that all resistance heat be turned off, that the resistance heat is indeed turned off.

C5.4 *Configuration Requirements utilizing OpenADR 2.0 in Section 6:* The "Utility Setup" query contained in Table 3 shall be sent to the equipment and the response verified to accurately represent the required system information.

C5.5 *Communication and management performance requirements utilizing OpenADR 2.0.* The signals described in Section 6 shall be sent from and to the OpenADR 2.0 Communications Simulator, and the specified system response verified.

C5.5.1 Testing at cooling rating point conditions as specified in AHRI Standard 210/240 (95 °F outdoor ambient), A_{Full}. For each test the "x-AHRI_STATUS" report identified in Table 4 shall be issued prior-to and during the test event and verified to properly represent the system state.

C5.5.1.1 Using a wattmeter, test and confirm that upon receipt of signal requiring a 30% power reduction, that the total system input power is reduced to a maximum of 70% of the Rated Load Power of the equipment.

C5.5.1.2 Using a wattmeter, test and confirm that upon receipt of signal requiring a 60% power reduction, that the total system input power is reduced to a maximum of 40% of the Rated Load Power of the equipment. If, however the particular unit being tested is a Discretely-variable Capacity Equipment that is not capable of 60% unloading, confirm that it returns a message to the simulator that it is not capable.

During the 60% power reduction test described above, a customer override shall be initiated from the equipment user interface. It shall be verified that upon the customer override that the equipment returns to normal operation and the equipment sends a message to the utility that the override has occurred.

C5.5.1.3 Using a wattmeter, test and confirm that upon receipt of signal requiring that the system turns off, that the system input power is turned to off mode, except for any power utilized by the compressor crankcase heater and controls.

C5.5.2 Testing at heating mild ambient rating point conditions as specified in AHRI Standard 210/240 (47 °F outdoor ambient), at $H1_2$ conditions for Discretely-variable Capacity Equipment and $H1_N$, if tested, for Continuously-variable Capacity Equipment. If the $H1_N$ test was not conducted for Continuously-variable Capacity Equipment, the $H1_2$ testing shall be used.

C5.5.2.1 Using a wattmeter, test and confirm that upon receipt of Stage 1 signal requiring a 30% power reduction, that the total system input power is reduced to a maximum of 70% of the Rated Load Power of the equipment.

C5.5.2.2 Using a wattmeter or voltmeter, test and confirm that upon receipt of Stage 2 signal requiring that all resistance heat be turned off, that the resistance heat is indeed turned off.

C6 Other Requirements only for Continuously-variable Capacity Equipment, regardless of communication protocol employed.

C6.1 *Five-Second Ramp Requirement:* Using a wattmeter, test and verify that changes in power induced by signals in C5.3 and C5.5 are ramped over an interval of a minimum of five seconds.

APPENDIX D. RECOMMENDED BEST PRACTICES – INFORMATIVE

D1   *Additional recommendations for all DR-ready HVAC System.*

    D1.1   *Control Indicator.* DR-ready HVAC Systems should include an indicator light(s) or other message(s) on its user interfaces to signify when the system is being controlled by the DR Program Administrator, or when it is operating during a Peak Load Pricing Event. The light or message should remain on until the indoor temperature has recovered to consumer's set point.