AUTOMATED DEMAND RESPONSE IN NEW CONSTRUCTION TECHNICAL DESIGN GUIDELINES

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INTRODUCTION

Demand response (DR) is an energy management strategy that allows electricity consumers to receive financial benefits for temporarily changing their rate of electricity use in response to an external signal. Historically, DR signals were transmitted to facility operators, who initiated pre-established load curtailment procedures at the appropriate time. Technological innovations are making it ever easier to participate in DR. Automated demand response (ADR) uses technology to send signals directly to energy management control systems (EMCSs) or other devices, allowing buildings to shed loads automatically. ADR provides more reliable load reductions because it does not rely on human intervention.

As awareness of the economic and environmental benefits that ADR delivers has grown, a wide variety of stakeholders have come together to enact legal and voluntary standards and incentive programs to help expand the total electrical load under automatic control. This document presents a concise set of practical guidelines for design professionals, project owners, and other stakeholders to identify and incorporate ADR into new construction and major renovation projects in the commercial sector. Major topics include: current ADR-related legal requirements under California's 2013 Title 24 building energy efficiency codes (Chapter 1); estimating a project's potential load shed (Chapter 2); specifying equipment for ADR (Chapter 3); and selecting and specifying an OpenADR 2.0-certified gateway for interacting with utilities' demand response automation servers (Chapter 4).

The goal of this document is to provide design professionals with accessible, practical tools to assist with project design and development. While this document is not meant to be comprehensive of all possible DR solutions, representative examples of load shed calculations, ADR-ready equipment, and specification language are provided. The information presented in this document presumes familiarity with basic demand response concepts and terminology. For more background on demand response and ADR, please see the Energy Design Resources Demand Response Design Brief (http://energydesignresources.com/resources/publications/design-briefs/design-brief-demand-response.aspx).

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PART 1: Title 24 Codes and ADR

California's Title 24 Building Energy Efficiency Standards consist of a set of legal requirements within the California Code of Regulations designed to improve the energy efficiency of California's buildings. State and local government agencies may block construction, occupancy, and/or impose fines when buildings are not constructed in a manner that is consistent with the requirements described in Title 24.

The California Energy Commission (CEC) updates Title 24 standards about every three years with assistance from technical consultants and extensive public input from a variety of industry, nonprofit, utility, and citizen stakeholders. The 2008 version of the standards, which became effective on January 1, 2010, was the first to require that any building system be capable of participating in demand response. The 2013 version of the Title 24 standards, effective July 1, 2014, significantly expanded the scope of demand response-related requirements. The 2013 version also clarified that demand responsive controls must include the ability to respond automatically to event signals, allowing buildings to participate in demand response events without human intervention.

The locations of the Title 24 code language cited here are detailed in Appendix A. The code language itself is available online at: CEC's Title 24 2013 website: www.energy.ca.gov/title24/2013standards

This chapter presents a summary of the 2013 Title 24 ADR requirements and how projects can enhance a building's ADR capability beyond what is legally mandated. All code references provided in this chapter are to the 2013 Building Energy Efficiency Standards, Title 24, Part 6, and Associated Administrative Regulations in Part 1, published by CEC, unless otherwise noted.

Title 24 ADR Requirements

As of July 1, 2014, Title 24 requires that new buildings include ADR-ready controls for electrical loads associated with indoor lighting, heating ventilation and air conditioning (HVAC), and sign lighting. To qualify as ADR-ready, controls must be able to automatically respond to an ADR signal using a "standards based messaging protocol." While not specifically required by law, the best way to ensure that controls meet the messaging protocol requirement of Title 24 is to use products certified as compliant with the OpenADR 2.0 standard. All three major investor-owned utilities in California require OpenADR 2.0-certified equipment for participation in ADR programs. The types of control equipment that are available with OpenADR 2.0 certification include energy management control systems

See Chapter 4 for more information about OpenADR

(EMCS), lighting control systems, and demand responsive setback thermostats (also called occupant controlled smart thermostats or OCSTs). Different versions of the OpenADR 2.0 standard (called "profiles") offer different capabilities. For example, OpenADR 2.0b provides more robust capabilities than OpenADR 2.0a, and therefore provides buildings with greater flexibility for participating in different types of DR programs.

Title 24 mandates that, in addition to being capable of receiving an ADR signal, buildings be capable of automatically implementing up to three DR measures: reducing interior lighting by at least 15%; adjusting space temperature setpoints by at least four degrees Fahrenheit; and reducing electronic message center lighting by at least 30%. The specific requirements vary depending on building system and space use types. Table 1 provides a summary of the ADR-related requirements in Title 24 by building system. Additional information about the requirements for each system follows below.

TABLE 1
2013 Title 24 - Summary of ADR-Related Requirements

Title 24 Summary of ADR-Related Requirements

SYSTEM	DR REQUIREMENT APPLIES TO:	SYSTEM RESPONSE TO DR SIGNAL MUST:	EQUIPMENT NEEDED FOR COMPLIANCE
Lighting	• Building area ≥ 10,000 square feet AND • Habitable spaces where lighting power density > 0.5 watts/square foot	Reduce lighting ≥ 15%	ADR-ready lighting control system or ADR-ready EMCS
HVAC with DDC	Non-critical zones	Adjust space temperature setpoints +4° F (cooling setpoint) and -4° F (heating setpoint)	ADR-ready HVAC control system or ADR-ready EMCS
HVAC without DDC	Non-temperature-sensitive processes		Demand responsive setback thermostat (also called OCST) or ADR-ready EMCS
Sign Lighting	• Electronic Message Centers only AND • Connected load ≥ 15 kW	Reduce lighting ≥ 30%	ADR-ready lighting control system or ADR-ready EMCS

ADR-Related Requirement for Lighting Systems in Title 24

The core Title 24 ADR-related requirement for lighting systems is that commercial buildings greater than 10,000 square feet must have a lighting control system that is capable of receiving DR event signals and reducing the lighting power by at least 15% in habitable spaces where lighting power density is >0.5 watts/square foot.

Examples of spaces that are exempt from the ADR-related requirements for DDC HVAC systems include data centers, telecom and private branch exchange (PBX) rooms, and laboratories

ADR-Related Requirements for HVAC Systems in Title 24

The Title 24 ADR requirements for HVAC systems are divided into two categories, depending on whether the building's HVAC system has direct digital controls (DDC) to the zone level or not. In buildings with DDC, the controls must be capable of automatically and temporarily raising the cooling temperature setpoints and lowering the heating temperature setpoints of non-critical zones by four degrees Fahrenheit in response to a DR event signal. In effect, the system must expand the band of permissible temperatures by four degrees in both directions. The temperature adjustment referenced in Title 24 is relative to the setpoints that are in place for each zone. The absolute setpoints may vary from zone to zone depending on how the space in each zone is used. Raising space temperature setpoints is sometimes referred to as a global temperature adjustment (GTA) strategy. The control system must reset the setpoints to their original positions upon the conclusion of the DR event. An ADR-ready EMCS may be programmed to fulfill this requirement. Alternatively, the system may be configured to perform the required actions in response to the closing (adjustment) and opening (reset) of a dry contact.

For buildings without DDC, Title 24 requires demand responsive setback thermostats (also called OCSTs) that provide the capability of setting different temperature setpoints for at least four periods within a day. The demand responsive setback thermostats in buildings without DDC must also meet a number of other requirements, including ADR-related requirements that are described in an appendix to the main body of the Title 24 code language (Joint Appendix JA5). Appendix JA5 identifies a number of ADR-related requirements that OCSTs must meet, including the ability to receive an ADR signal and adjust temperature setpoints by four degrees Fahrenheit. Appendix JA5 does not require that the ADR-related communications capabilities be built into the thermostats. Instead, thermostats are allowed to have a port into which a module can be inserted that endows the device with the required ADR-related capabilities. The thermostat, or the insertable module, would typically use a wireless communication technology such as WiFi or ZigBee to communicate with an OpenADR 2.0-certified gateway. For example, a module might endow the thermostat with the ability to connect to a stand-alone ADR gateway. As an alternative to an OCST, a building could use an EMCS, as long as the EMCS meets all relevant requirements for OCSTs.

The ADR-related thermostat requirements do not apply to systems that serve process loads that must have constant temperatures to prevent degradation of materials, a process, plants or animals

See Appendix B for more information on wireless communication technologies used in building automation systems

See Chapter 4 for more information on OpenADR 2.0 and ADR gateways.

ADR-Related Requirements for Sign Lighting in Title 24

The Title 24 ADR sign lighting requirement is that electronic message centers with a connected load of at least 15 kW must have controls capable of reducing lighting power by at least 30 percent in response to a DR event signal.

Electronic Message Center (EMC) is a pixilated image-producing electronically controlled sign formed by any light source.

Title 24 Acceptance Testing

The ADR requirements in Title 24 are designed to ensure that buildings are capable of automatically participating in demand response events. As a building code, Title 24 does not require or enforce actual demand response participation once the building is operational. The acceptance requirements and protocols for ADR-related capabilities in Title 24 vary in stringency across building systems.

For more information on the intent of ADR-related requirements in 2013 Title 24, see Application Notes in section 8.6.1 of the Non Residential Compliance Manual.

No acceptance testing is required for the ADR-related sign lighting control measure in Title 24. Instead, an individual (such as the party responsible for the sign lighting control system) must sign a declaration statement on form NRCC-LTS-01-E stating that the sign lighting system is in compliance.

Acceptance testing is also not required for demand responsive setback thermostats (OCSTs) used in non-DDC HVAC systems. Thermostat manufacturers are, however, required to self-certify that their products meet the Title 24 requirements. In order to self-certify, manufacturers must complete and sign an OCST declaration form provided by the CEC with model information, communication standards, and messaging protocol and submit the form electronically to the CEC (www.energy.ca.gov/title24/equipment_cert/ocst/index.html). In practice, a thermostat that meets the other functional requirements of Title 24 (such as four programmable temperature setpoint periods) with built-in wired or wireless communications capabilities, or an expansion port that allows such communications capabilities to be added, is likely to be compliant with Title 24.

For DDC buildings, Title 24 includes a brief acceptance testing protocol that requires demonstrating that the HVAC controls can be activated from a central EMCS or dry contact and that the specified cooling temperature setpoint adjustments occur in the proper zones. The HVAC controls are not required to demonstrate the ability to receive an ADR signal from a remote, external source. Instead, the behavior that is intended to occur during a demand response event may be triggered manually from the control system interface. To document compliance, the form NRCA-MCH-11-A must be completed and certified by a CEC-approved Acceptance Test Technician Certification Provider (ATTCP) prior to inspection.

For interior lighting controls, the Title 24 acceptance requirement includes a detailed testing protocol for evaluating compliance with both the lighting power reduction and the minimum illuminance requirements. The protocols allow demonstrating compliance through changes in either area-weighted illuminance or electrical current. To document compliance, the form NRCA-LTI-04-A must be completed and certified by a CEC-approved ATTCP prior to inspection. If an EMCS is to be used as a lighting control system then form NRCI-LTI-02-E must be completed.

In contrast to HVAC and sign lighting controls, interior lighting controls are technically required by code to demonstrate the ability to receive signals from an external source. Despite this requirement, it is not feasible to set up and test ADR signaling for new construction projects. For example, Internet service is required for ADR signaling, but in many cases is not yet available at a new construction project at the time that building inspection occurs. The purpose of the Title 24 lighting control system acceptance requirement is to ensure that the building's lighting system is capable of automatically participating in DR events. As a result, demonstrating that controls are OpenADR 2.0-certified is a reasonable alternative to demonstrating the ability to actually receive an ADR signal.

Beyond Title 24

See Chapter 4 for guidance on selecting an appropriate ADR gateway

Title 24 does not strictly require the installation of a gateway that would allow a building to receive ADR signals in the manner that event signals are provided by California's investor-owned utilities. Designers can enhance a building's ADR capability beyond the minimum requirements of the law by installing an OpenADR 2.0-certified gateway solution that positions buildings to receive ADR signals directly from a utility server.

Title 24 requires that a building be capable of automatically implementing up to three DR measures: reducing interior lighting load by at least 15%; adjusting temperature setpoints by at least four degrees (through a thermostat for buildings without DDC; through EMCS for buildings with DDC); and reducing sign lighting by at least 30%. To further enhance a building's ADR capability, designers should consider including additional equipment and control strategies. Please see Chapter 3 for guidance on other equipment and strategies that can help a building shed more load than what is strictly required by Title 24.

By participating in ADR, a building also qualifies for up to two Leadership in Energy and Environmental Design (LEED) credits under Building Design + Construction in the LEED v4 rating system. In areas where demand response programs are available (which includes all major California investor-owned utility territories), new construction and major renovation projects must enroll for a full year in a demand response program to qualify for LEED credit. LEED requires that buildings reduce at least 10% from the peak electricity demand, and may execute load reductions in either a fully automatic or semi-automatic manner. In areas where demand response programs are not available, LEED credit can still be earned if the building is ADR-ready. On-site photovoltaic generation does not qualify a building for the Demand Response credit. For a comprehensive list of requirements for obtaining LEED credits for ADR, please refer the LEED Pilot Credit Library available from U.S. Green Building Council.

More information about the Demand Response LEED Pilot Credit is available from U.S. Green Building Council: www.usgbc.org/node/2613001?return=/credits/new-construction/v4/energy-%26-atmosphere

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PART 2: Estimating Load Shed Potential

This chapter covers three alternative approaches to estimating load sheds. One approach is to use dedicated load shed estimation software. Another approach is to estimate the building energy usage baseline using a publicly available data set on energy end-uses, and then apply rules of thumb for common DR strategies. The third approach is to develop custom spreadsheet-based calculations based on the specific equipment and DR strategies under consideration in a project.

The tools and calculations presented in this chapter can be used to develop an initial sense of the DR potential associated with a particular building. For the LEED Pilot credit (LEED v4), buildings must shed at least 10% of peak demand. The load shed potential, in concert with information about utility tariff structures, demand response programs, and other incentive programs, can help determine the total potential financial benefits that may be available. At the time of writing, participating in a California DR program typically delivers benefits ranging from $25 to $100 per kW of curtailable load. Designers should consult with their local utility representative to discuss the rules and current status of tariffs or demand response programs, as these may vary over time and utility territory.

Once the shed potential of a project has been estimated, designers may wish to consult Chapters 3 and 4 of this document for assistance with selecting and specifying the equipment needed to capture the potential shed. Moving iteratively between load shed potential estimation and equipment specification, designers and project owners can balance the costs associated with different DR strategies and the financial and other benefits associated with the sheds that those strategies make possible.

Software Tools for Estimating Load Shed

Small Commercial Tool

Demand Limiting Assessment Tool (DLAT)

The DLAT is a DR tool that can assist in calculating: peak demand reduction, utility cost savings, and comfort impacts associated with the use of building thermal mass for pre-cooling and demand limiting for a limited number of prototypical small commercial buildings.

https://engineering.purdue.edu/DLAT/

Large Commercial Tool

Demand Response Quick Assessment Tool (DRQAT)

The DRQAT is a DR tool that can assist in calculating energy and demand savings of a large commercial building the economic saving, and the thermal comfort impact for various demand responsive strategies. DRQAT works for office or retail buildings.

http://drrc.lbl.gov/drqat

Title 24 Compliance Tools

The CEC maintains a list of all approved energy analysis programs that are in accordance with Title 24. These programs are used to model and simulate building designs for Title 24 requirements and generate the necessary compliance forms for building permit submissions. The programs do not necessarily include load shed estimation capabilities. Due to the recent transition to the 2013 version of Title 24, few programs are currently available; however the list will be updated as new programs are approved.

http://www.energy.ca.gov/title24/2013standards/2013_computer_prog_list.html

Baselines and Rules of Thumb for Estimating Load Shed

The energy usage baseline of a new building can be estimated using data from the California Commercial End-Use Survey (CEUS). CEUS is a comprehensive study of commercial building energy use in California. The CEUS web interface allows users to select particular building types and climate zones to customize the results. Figure 1 shows a sample CEUS output. Each energy end-use is displayed in its own row; the titles of the available categories of summary information are displayed in column headers.

Example Output from the California Commercial End-Use Survey (CEUS)

End Use	EUFS End-use Floor Stock (kSqFt)	EUI Energy-use Indices (kWh/ EUFS/ Year)	End-use Floor Stock Distribution (%)	EI Energy Intensity (kWh/ Segment FS/ Year)	End-use Energy Distribution (%)	Non-coincident Peak Load (watts/SF)	Connected Load (watts/SF)	Annual Energy Usage (GWh)
		(a)	(b)	(a*b)				
Heating	156,341	0.31	71.2	0.22	1.3	0.17	281.18 SF/kB	48
Cooling	205,974	4.06	93.8	3.8	22.2	1.83	348.69 SF/ton	835
Ventilation	207,029	2.5	94.2	2.36	13.8	0.5	0.9	517
Water Heating	111,482	0.36	50.7	0.18	1.1	0.03	0.21	40
Cooking	216,371	0.1	98.5	0.1	0.6	0.03	0.35	23
Refrigeration	210,245	0.4	95.7	0.38	2.3	0.05	0.23	85
Exterior Lighing	190,589	1.01	86.7	0.87	5.1	0.2	0.21	192
Interior Lighting	219,700	4.72	100	4.72	27.6	1.01	1.13	1,037
Office Equipment	219,700	3.03	100	3.03	17.7	0.59	2	665
Miscellaneous	203,598	0.78	92.7	0.72	4.2	0.17	0.78	159
Process	2,077	7.12	0.9	0.07	0.4	0.01	0.02	15
Motors	149,597	0.78	68.1	0.53	3.1	0.15	0.76	117
Air Compressor	93,888	0.24	42.7	0.1	0.6	0.03	0.05	23
Segment Total	219,700	--	--	17.1	100	4.35	--	3,756

FIGURE 1

Example output from CEUS showing the typical energy use characteristics of a commercial office building. http://capabilities.itron.com/CeusWeb

The highlighted cooling, ventilation, and interior lighting rows in the CEUS output in Figure 1 indicate the energy use for the HVAC and lighting equipment that would typically be expected to participate in DR. The values in the column labeled "Non-coincident peak load (watts/SF)" indicates the magnitude of the loads associated with each end use per square foot of floor area. To estimate the potential load shed in a new building, multiply the load values in that column by the building's total floor area and apply the following rules of thumb:

- The CEUS values should be reduced to 80% for new buildings, because new buildings are typically more energy efficient than the older buildings that were used to derive the CEUS data.
- For cooling, 10% load reduction per four degree Fahrenheit temperature adjustment for decreased chiller compressor loading.
- For ventilation, 17% load reduction per four degree Fahrenheit temperature adjustment for slowing down the air handling fans.
- For interior lighting, 15% reduction due to dimming the lights.

Figure 2 shows an example of a spreadsheet calculation of baseline energy use and demand response potential using CEUS data for a sample 500,000 square foot office building in the Los Angeles climate zone using the rules of thumb described above.

Example Spreadsheet Calculation of Load Shed Potential Based on CEUS Data

End Use	Non-coincidental Peak Load From CEUS (watts/SF)	Sample Building Floor Area (SF)	Load Shed Rule of Thumb		Load Shed Potential (kW)
			New Building EE Factor	End Use Load Reductions	
Cooling	1.83	500,000	80%	10%	73
Ventilation	0.50			17%	34
Interior Lighting	1.01			15%	61
			Total:		**168**

FIGURE 2
Example spreadsheet calculation of load shed potential based on CEUS data

Custom Spreadsheet Calculations for Estimating Load Shed

This section includes example calculations for several common DR strategies: dimming lights, cycling package units, and reducing industrial refrigeration loads. While many more DR strategies are possible, the examples here provide a foundation for developing custom calculations for other strategies. Each example includes an overview of the calculation, the data required to perform the calculation, sample data, and a spreadsheet calculation using the sample data.

DR Strategy: Dimming Lights

Dimming lights is a common DR strategy, and one of the three broad DR measure types required by Title 24. The first sample calculation provided below can be used for estimating the load shed from dimming lights in unconditioned space. Dimming lights reduces the amount of heat being added to a space, which in turn affects the energy used by the HVAC system. The second calculation below can be used for estimating load shed from dimming lights, while accounting for the interactive effects on the HVAC system.

Dimming Lights, Unconditioned Space

Calculation Overview

1. Load Shed (kW) = Baseline kW - DR kW
2. Baseline kW = kW per fixture X Number of fixtures X Baseline Lighting Level
3. DR kW = kW per fixture X Number of fixtures X DR Lighting Level

Definition of Terms

- Baseline kW: the power required by the lighting system during normal operation
- DR kW: the power required by the lighting system during the DR event
- Baseline Lighting Level: the percentage of full output that lights are normally set to deliver
- DR Lighting Level: the percentage of full output that lights are programmed to deliver during the DR event
- Load Shed: the power that would have been required by the lighting system during normal operation that was not required during the DR event due to implementation of the dimming strategy

The types are data required to calculate the load shed for dimming lights is shown in Table 2. Also shown in Table 2 are sample data, assuming two different types of fixtures are installed (Fixture Type A and Fixture Type B). Example spreadsheet calculations using the sample data are shown in Figure 3 (formula view) and Figure 4 (results view).

TABLE 2
Data required and sample data for estimating load shed potential for dimming lights

Data Required and Sample Data

		SAMPLE DATA	
DATA REQUIRED	SOURCE OF DATA	FIXTURE TYPE A	FIXTURE TYPE B
Number of Fixtures	Lighting Design	200	100
kW per Fixture	Lighting Design	0.1	0.075
Baseline Lighting Level	Lighting Design	90%*	80%*
DR Lighting Level	Lighting Design	70%	60%

*Baseline lighting levels are not intended as recommendations - they are provided only as sample values for the purpose of illustrating the calculation.

FIGURE 3
Example spreadsheet calculation of load shed potential for dimming lights, formula view

Example Spreadsheet Calculation: Formula View

	A	B	C	D	E	F	G
1	Number of Fixtures	Full Output Lamp Wattage	Baseline Lighting Level	Baseline kW	DR Lighting Level	DR kW	Load Shed
2	(#)	(kW)	(%)	(kW)	(%)	(kW)	(kW)
3	200	0.1	0.9	=A3*B3*C3	0.7	=A3*B3*E3	=D3-F3
4	100	0.075	0.8	=A4*B4*C4	0.6	=A4*B4*E4	=D4-F4
5							
6						Total Load Shed For Dimming Lights:	=SUM(G3:G4)

Example Spreadsheet Calculation: Results View

	A	B	C	D	E	F	G
1	Number of Fixtures	Full Output Lamp Wattage	Baseline Lighting Level	Baseline kW	DR Lighting Level	DR kW	Load Shed
2	(#)	(kW)	(%)	(kW)	(%)	(kW)	(kW)
3	200	0.1	90%	18	70%	14	4
4	100	0.075	80%	6	60%	4.5	1.5
5							
6						Total Load Shed For Dimming Lights:	5.5

FIGURE 4

Example spreadsheet calculation of load shed potential for dimming lights, results view

Dimming Lights, Accounting for HVAC Interaction

Calculation Overview

1. Total Load Shed = Lighting Load Shed + HVAC Load Shed
2. Lighting Load Shed = Lighting Baseline kW – Lighting DR kW
3. Lighting Baseline kW = kW per fixture X Number of fixtures X Baseline Lighting Level
4. Lighting DR kW = kW per fixture X Number of fixtures X DR Lighting Level
5. HVAC Load Shed = Lighting Load Shed X Conversion Factor X Return Air Percentage X Chiller Efficiency (X Ducted Return Factor, if applicable)

Definition of Terms

- Lighting Baseline kW: the power required by the lighting system during normal operation
- Lighting DR kW: the power required by the lighting system during the DR event
- Baseline Lighting Level: the percentage of full output that lights are normally set to deliver
- DR Lighting Level: the percentage of full output that lights are programmed to deliver during the DR event
- Lighting Load Shed: the power that would have been required by the lighting system during normal operation that was not required during the DR event due to implementation of the light dimming strategy
- HVAC Load Shed: the power that would have been required by the HVAC system during the normal operation that was not required during the DR event due to the implementation of the light dimming strategy
- Conversion Factor: constant representing the relationship between the units used to measure electrical loads (kW) and cooling loads (tons)
- Chiller Efficiency: the amount of electrical power (kW) required by the chiller per ton of cooling capacity provided (tons) (specific to chiller)
- Return Air Percentage: the percentage of the total air flow that is not supplied by outside air
- Ducted Return Factor: the amount by which chiller efficiency is reduced when the return air travels through ducts instead of a plenum

The types of data required to calculate the load shed for dimming lights while accounting for HVAC interaction are shown in Table 3. Also shown in Table 3 are sample data, assuming two different types of fixtures are installed (Fixture Type A and Fixture Type B). Example spreadsheet calculations using the sample data are shown in Figure 5 (formula view) and Figure 6 (results view).

TABLE 3
Data required and sample data for estimating load shed potential for dimming lights while accounting for HVAC interaction

Data Required and Sample Data

DATA REQUIRED	SOURCE OF DATA	SAMPLE DATA FIXTURE TYPE A	SAMPLE DATA FIXTURE TYPE B
Number of Fixtures	Lighting Design	1,000	200
kW per Fixture	Lighting Design	0.15	0.1
Baseline Lighting Level	Lighting Design	90%*	90%*
DR Lighting Level	Lighting Design	70%	60%
Chiller Efficiency (kW/ton)	Chiller Manufacturer	0.68	
Air systems Min. Outside Air (OSA)	HVAC Design	20%	
Percent of Return Air	1- OSA	80%	
Conversion Factor (ton/kW)	Physical Constant	0.2844	

*Baseline lighting levels are not intended as recommendations - they are provided only as sample values for the purpose of illustrating the calculation.

FIGURE 5
Example spreadsheet calculation of load shed potential for dimming lights while accounting for HVAC interaction, Formula View

Example Spreadsheet Calculation: Formula View

	A	B	C	D	E	F	G
1	Number of Fixtures	Full Output Lamp Wattage	Baseline Lighting Level	Baseline kW	DR Lighting Level	DR kW	Lighting Load Shed
2	(#)	(kW)	(%)	(kW)	(%)	(kW)	(kW)
3	1000	0.15	0.9	=A3*B3*C3	0.7	=A3*B3*E3	=D3-F3
4	200	0.1	0.9	=A4*B4*C4	0.6	=A4*B4*E4	=D4-F4
5							
6						Load Shed For Dimming Lights:	=SUM(G3:G4)
7							
8		Lighting Load Shed	Conversion Factor	Return Air Percentage	Chiller Efficiency	Ducted Return Factor	HVAC Load Shed
9		(kW)	(ton/kW)	(%)	(kW/ton)	(%)	(kW)
10		=G6	0.2844	=Assumptions	0.68	NA	=B10*C10*D10*E10
11							
12							
13						Total Load Shed for Dimming Lights, Accounting for HVAC Interaction:	=G6+G10

FIGURE 6
Example spreadsheet calculation of load shed potential for lighting dimming while accounting for HVAC interaction, results view

Example Spreadsheet Calculation: Results View

	A	B	C	D	E	F	G
1	Number of Fixtures	Full Output Lamp	Baseline Lighting Level	Baseline kW	DR Lighting Level	DR kW	Lighting Load Shed
2	(#)	(kW)	(%)	(kW)	(%)	(kW)	(kW)
3	1000	0.15	90%	135	70%	105	30
4	200	0.1	90%	18	60%	12	6
5							
6						Load Shed For Dimming Lights:	36
7							
8		Lighting Load Shed	Conversion Factor	Return Air Percentage	Chiller Efficiency	Ducted Return Factor	HVAC Load Shed
9		(kW)	(ton/kW)	(%)	(kW/ton)	(%)	(kW)
10		36	0.2844	80%	0.68	NA	5.57
11							
12							
13						Total Load Shed for Dimming Lights, Accounting for HVAC Interaction:	41.57

DR Strategy: Cycling Package Units

Cycling package units is a DR strategy that may be used on facilities served by package air conditioning units. This strategy entails turning off package air conditioning units, or groups of units, for short periods of time, during the DR event. Package unit cycling is not one of the measures required by Title 24, so including hardware or controls programming to allow a facility to cycle package units would enhance a facility's ADR capability beyond code. In some cases, package unit fans may be left on while compressors are turned off to minimize occupant discomfort. The sample calculation provided below assumes that the entire package unit is turned off, and that the package unit efficiency value includes fan energy consumption.

Calculation Overview

1. Package Unit Cycling Load Shed = Baseline Total Package Unit kW – DR Total Package Unit kW
2. Baseline Total Package Unit kW = Number of Package Units X Package Unit Capacity X 12/Energy Efficiency Ratio (EER) X Baseline Load Factor
3. DR Total Package Unit kW = # Package Units X Package Unit Capacity X 12/Energy Efficiency Ratio (EER) X DR Load Factor
4. DR Load Factor = (1 – (DR Off Time Duration X DR Off Time Frequency)/60) X Baseline Load Factor

Definition of Terms

- Package Unit Capacity: the cooling capacity, in tons, of each package unit
- Energy Efficiency Ratio (EER): The cooling capacity of a package unit (btu/h) per electrical power required for operation (W) (EER is specific to the package unit; 12/EER = the energy efficiency of the package unit in kW/ton)
- Baseline Load Factor: the percentage of time all package unit compressors and fans are expected to be operating, on average, under normal conditions
- DR Load Factor: the percent of time all package unit compressors and fans are expected to be operating, on average, during a DR event
- DR Off Time Duration: the amount of consecutive time, in minutes, that a package unit is turned off during a DR event
- DR Off Time Frequency: the number of times per hour that a package unit is turned off during a DR event

The types of data required to calculate the load shed for cycling package units are shown in Table 4. Also shown in Table 4 are sample data. A sample package unit cycling plan, from which the DR load factor term in Table 4 is derived, is shown in Table 5. Example spreadsheet calculations using the sample data are shown in Figure 7 (formula view) and Figure 8 (results view).

TABLE 4

DATA REQUIRED AND SAMPLE DATA FOR CALCULATION OF LOAD SHED POTENTIAL FOR CYCLING PACKAGE UNITS

Data Required and Sample Data

DATA REQUIRED	SOURCE OF DATA	SAMPLE DATA
Number of Package Units	HVAC Design	6
Package Unit Capacity (tons)	HVAC Design or Manufacturer	8
Energy Efficiency Ratio (btu/Wh)	HVAC Design or Manufacturer	9.0
Baseline Load Factor	HVAC Design	100%
DR Off Time (minutes)	Cycling Plan	20
DR Off Time Freq. (#/hour)	Cycling Plan	1
DR Load Factor	Calculated from Cycling Plan	66.7%

TABLE 5

SAMPLE PACKAGE UNIT CYCLING PLAN

Sample Package Unit Cycling Plan

CYCLING PLAN: TURN OFF ONE UNIT FOR 20 MINUTES ONCE PER HOUR				
UNIT #	0:00-0:20	0:20-0:40	0:40-0:60	OFF TIME FREQUENCY (TIMES/HOUR)
1	off	on	on	1
2	on	off	on	1
3	on	on	off	1
4	off	on	on	1
5	on	off	on	1
6	on	on	off	1

FIGURE 7

EXAMPLE SPREADSHEET CALCULATION OF LOAD SHED POTENTIAL FOR CYCLING PACKAGE UNITS, FORMULA VIEW

Example Spreadsheet Calculation: Formula View

	A	B	C	D	E	F	G	H
1	Number of Package Units	Package Unit Capacity	Package Unit EER	Baseline Load Factor	Baseline kW	DR Load Factor	DR kW	Package Unit Cycling Load Shed
2	(#)	(tons)	(btu/WH)	(%)	(kW)	(%)	(kW)	(kW)
3	6	8	9	1	=A3*B3*12/C3*D3	0.667	=A3*B3*12/C3*F3	=E3-G3
5								
6							Load Shed For Cycling Package Units:	=SUM(H3:H4)

FIGURE 8

EXAMPLE SPREADSHEET CALCULATION OF LOAD SHED POTENTIAL FOR CYCLING PACKAGE UNITS, RESULTS VIEW

Example Spreadsheet Calculation: Results View

	A	B	C	D	E	F	G	H
1	Number of Package Units	Package Unit Capacity	Package Unit EER	Baseline Load Factor	Baseline kW	DR Load Factor	DR kW	Package Unit Cycling Load Shed
2	(#)	(tons)	(btu/WH)	(%)	(kW)	(%)	(kW)	(kW)
3	6	8	9	100%	64.0	67%	42.7	21.3
5								
6							Load Shed For Cycling Package Units:	21.3

DR STRATEGY: Reducing Industrial Refrigeration Loads

Industrial facilities with significant refrigeration loads, such as cold storage warehouses, can often safely turn off some refrigeration equipment for limited periods during DR events. Refrigeration load reduction is not required by Title 24, so programming that allows a building to use this strategy would provide a facility with ADR capability beyond code. This strategy typically involves a subset of the equipment being turned off until the air temperature rises by a predetermined amount. The amount that the air temperature is permitted to rise depends on the refrigerated products' tolerance to temperature changes, and varies by product. Once the temperature setpoint is reached, the equipment is turned back on again. The sample calculation below illustrates how to calculate the load shed associated with turning a subset of the refrigeration equipment off. In this example, all equipment except for the larger of two compressor motors is turned off.

Calculation Overview

1. Total Refrigeration Load Shed = Compressor kW + Evaporator Fan kW + Cooling Tower Fan kW
2. Compressor kW = (Number of Motors X Motor Power X Conversion Factor X Load Factor) / Motor Efficiency
3. Evaporator Fan kW = (Number of Motors X Motor Power X Conversion Factor X Load Factor) / Motor Efficiency
4. Cooling Tower Fan kW = (Number of Motors X Motor Power X Conversion Factor X Load Factor) / Motor Efficiency

Definition of Terms

- Motor Power: the rated power, in horsepower, that a motor is designed to deliver
- Conversion Factor: constant representing the relationship between the units used to measure electrical loads (kW) and motor power (horsepower)
- Load Factor: the percentage of the time the motor is operating under average conditions
- Motor Efficiency: the useful, shaft output power of a motor as a percentage of the total electric power required for its operation

The types of data required to calculate the load shed for reducing refrigeration loads are shown in Table 6. Also shown in Table 6 are sample data. Example spreadsheet calculations using the sample data are shown in Figure 9 (formula view) and Figure 10 (results view).

Table 6

Data required and sample data for calculation of load shed potential for reducing industrial refrigeration loads

Data Required and Sample Data

DATA REQUIRED	SOURCE OF DATA	SAMPLE DATA			
		MOTOR POWER (HP)	NUMBER OF MOTORS	MOTOR EFFICIENCY	LOAD FACTOR
Compressor Motor Data	HVAC Design or Manufacturer	200	1	*	*
		150	1	95%	80%
Evaporator Motor Data	HVAC Design or Manufacturer	5	3	90%	90%
		7.5	1	90%	90%
Cooling Tower Motor Data	HVAC Design or Manufacturer	20	1	90%	70%
Conversion Factor (kW/hp)	Physical Constant	0.746			

*Not required because in this example, the larger compressor motor will not be turned off during the DR event.

Figure 9

Example spreadsheet calculation of load shed potential for reducing industrial refrigeration loads

Example Spreadsheet Calculation: Formula View

	A	B	C	D	E	F	G
1		Motor Power	Number of Motors	Motor Efficiency	Load Factor	Conversion Factor	Refrigeration Load Shed
2	Equipment	(hp)	(#)	(%)	(%)	(kW/hp)	(kW)
3	Compressor	150	1	0.95	0.8		=B3*C3/D3*E3*F3
4	Evaporator	5	3	0.9	0.9		=B4*C4/D4*E4*F3
5	Evaporator	7.5	1	0.9	0.9		=B5*C5/D5*E5*F3
6	Cooling Tower	20	1	0.9	0.7	0.746	=B6*C6/D6*E6*F3
7							
8						Total Refrigeration Equipment Load Shed:	=SUM(G3:G4)

Figure 10

Example spreadsheet calculation of load shed potential for reducing industrial refrigeration loads

Example Spreadsheet Calculation: Results View

	A	B	C	D	E	F	G
1		Motor Power	Number of Motors	Motor Efficiency	Load Factor	Conversion Factor	Refrigeration Load Shed
2	Equipment	(hp)	(#)	(%)	(%)	(kW/hp)	(kW)
3	Compressor	150	1	95%	80%	0.746	94.2
4	Evaporator	5	3	90%	90%		11.2
5	Evaporator	7.5	1	90%	90%		5.6
6	Cooling Tower	20	1	90%	70%		11.6
7							
8						Total Refrigeration Equipment Load Shed:	105.4

PART 3: Specifying ADR End Use Equipment

This chapter provides an overview of lighting and HVAC equipment that can be used for ADR. It also includes example specifications and scope of work descriptions for purchasing, installing, and commissioning equipment to ensure the building is ADR-capable. Moving iteratively between equipment specification based on the guidance in this chapter and shed potential estimation using the tools in Chapter 2, designers and project owners can balance the costs associated with different DR strategies and the financial and other benefits associated with the sheds that those strategies make possible.

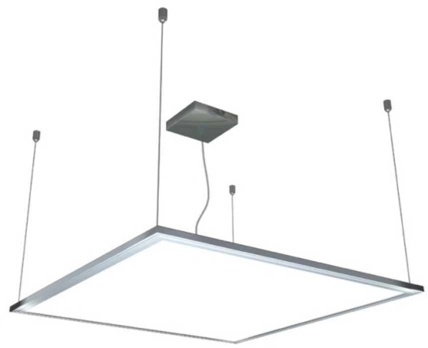
This section covers equipment that can be used to implement the three broad measure types required by Title 24: reducing interior lighting levels by at least 15%, adjusting temperature setpoints by at least four degrees Fahrenheit, and reducing sign lighting levels by at least 30%.

Regardless of the end-use equipment installed, in order to respond to ADR signals during DR events, all devices must be connected to an OpenADR 2.0-certified gateway that can communicate with a utility server. In some cases, building system controls, such as advanced wireless lighting controls, may be capable of acting as their own ADR gateway. In other cases, the building systems will be controlled by an EMCS, which may be connected to a stand-alone ADR gateway, or may itself serve as the ADR gateway. Selecting an appropriate ADR gateway is covered in Chapter 4.

OpenADR 2.0 is the protocol used to communicate between the ADR gateway and the utility server, but is not typically used to communicate between the ADR gateway and individual equipment. Common wireless technologies (WiFi, ZigBee, and EnOcean) that are sometimes used to connect building end-use equipment to the EMCS or ADR gateway to form an internal network are described in Appendix B. Common network communication protocols used to structure equipment information exchanged over the internal building network are described in Appendix C.

Lighting

FIGURE 11
Hanging LED lighting panel



Recent developments in lighting control technology allow a wide range of DR control strategies for lighting. There are three lighting control infrastructure types with various strengths and limitations, any of which can be used for DR:

- Traditional lighting controls, switches or circuit breakers, must be wired in series with the luminaires and provide basic control functionality.
- Additional control signals or control wiring, such as power-line carrier signals or low-voltage wires, can be added to provide more signaling functionality and addressability.
- Wireless communications technologies such as ZigBee or Wi-Fi, can be used to establish a lighting controls network (see Appendix B).

The luminaire output controlled by this infrastructure may be continuously dimmable, multi-step output, or simply on-off. Continuously dimmable and multi-step dimmable luminaires are increasingly popular in new construction.

The control infrastructure types and luminaire types described above can be used in various combinations to create a DR design strategy. The three DR strategies below can be used to comply with Title 24 ADR requirements for lighting systems using existing technology:

A. Addressable lighting system
B. Centralized powerline dimming control
C. Wireless advanced lighting control system

These three strategies are described in more detail below. Regardless of the strategy used, the extent to which lighting is reduced in a DR measure should be calibrated to avoid safety, productivity or eyestrain issues. For example, one approach is to reduce hallway lighting to the minimum “emergency” levels required for safety and leave other lighting levels untouched.

Strategy A: Addressable Lighting System

FIGURE 12
Digital Addressable Lighting Interface

With an addressable lighting system, each fixture can be controlled individually. An addressable lighting system such as DALI (Digital Addressable Lighting Interface) can be used to allow a central control unit to set the lighting output for each fixture individually over a two-conductor signal wire. The individual luminaires should be equipped with continuous or multi-step dimmable ballasts or LED drivers that can be customized to set standard output levels and reduced output levels for DR events.

Strategy B: Centralized Powerline Dimming Control

An effective method for enabling DR in smaller buildings uses a type of powerline carrier signal with a system that has centralized control of dimmable ballasts. Like Strategy A, it requires luminaires with continuous or multi-step dimmable ballasts or LED drivers, but they must also be powerline carrier-compatible. This method also requires a lighting control panel downstream of the breaker panel. Unlike strategy B, it does not require a second wiring network in addition to the power conductors, as the control signals are added as a signal on top of the electric alternating current waveform.

Strategy C: Wireless Advanced Lighting Control System

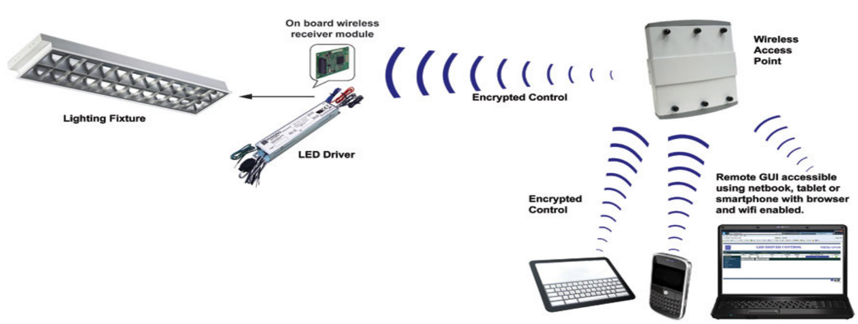


FIGURE 13
Wireless Advanced Lighting Control System

Like strategy A above, a wireless control system can allow light output at each luminaire to be individually set. These systems can work with all types of output control ballasts or drivers, but will offer the most options when paired with continuously-dimmable technologies. They do not require additional control wiring, but will require a network of wireless control units and a central control server.

There are more than a dozen advanced lighting control systems with competing features and varying system topologies. More and more advanced lighting control manufacturers are having their control systems certified by the OpenADR Alliance as compatible with the industry-standard OpenADR 2.0

protocol. The characteristics common to most are:

- Control at the level of the individual luminaire
- Compatibility with all types of luminaire output control from continuous dimming to on/off
- Integration of input signals from occupancy and vacancy sensors and photocell control, including the ability to customize vacancy delay settings and daylighting levels
- Web interface to allow remote system monitoring and control
- Lighting energy use dashboard and data analytics

These systems offer excellent ADR features, enabling customers to fully customize settings for both standard daytime and demand response event periods. They allow a DR-output percent reduction to be set at a facility-wide level and also to set special DR reduction levels in any area. These lighting systems can control and (where possible) dim multiple lamp types on a single system: LED, fluorescent, HID and incandescent. These systems are best specified by contacting the manufacturer or their distributor as system familiarity is required to specify a complete system.

Heating, Ventilation, and Air Conditioning Equipment

Unitary Air Conditioners

Unitary air conditioners are the most common type of HVAC equipment and usually have the simplest controls. They make up a majority of all HVAC installations and are most often controlled with thermostats. Units that are not controlled by an individual thermostat are controlled with an EMCS. Thermostats or EMCSs can be upgraded to contain or be controlled by new hardware or software that will allow them to respond to an ADR signal. In addition to thermostats and EMCS, several new add-on products are creating packaged ADR solutions for unitary air conditioner equipment.

FIGURE 14
Unitary air conditioning unit

Thermostats are the most basic types of controllers that change the operation (and thus kW consumption) of HVAC equipment by changing the indoor temperature setpoint. Onboard controllers can execute more sophisticated operations because they have more granular control. Among other capabilities, onboard controllers can control fan speeds, cooling stages, and the number of compressors running. To execute DR strategies, thermostats and unit controllers are either wired or wirelessly connected to a central controller (or local cloud network) which instructs them on how components of the HVAC unit should shed load during a demand response event. Controller costs collected for unitary AC equipment range from $169 to $1,800 per unit, with the low range of costs representing simple thermostat controls and the high range of costs representing onboard controllers. Unitary ACs can vary in capacity from 3 tons to 150 tons per unit. Larger tonnage AC units tend to reduce the cost per kW shed for unitary controls. Facilities with existing EMCSs already have a connection between the EMCSs and the existing unit controllers. Load shed strategies can be programmed into the energy management control system without paying for additional unit controllers. Therefore, there are no unit controller incremental costs for projects with central EMCSs.

Common DR shed strategies for unitary air conditioners include global temperature adjustment, unit cycling, compressor lockout, and smart cycling. A global temperature adjustment strategy entails raising the thermostat setpoints. This causes air conditioning units to cycle or turn off until the indoor temperature reaches the new, higher temperature. The units will then continue to run for less time, because of lower cooling needs. Unit cycling entails directly turning off an entire unit or a number of units for a specified period of time. An example would be turning off half the building's air conditioning units for 30 minutes, and then turning off the other half for the next 30 minutes as the first half is turned back on. Larger unitary air conditioners with multiple compressors have the ability to lock out individual compressors instead of cycling entire air conditioning units off. Variable speed drives can reduce fan speeds during temperature adjustments or cycling to shed additional kW. "Smart cycling" is similar to unit cycling in that units are turned on and off, but smart cycling uses computerized controls logic and system feedback to cycle off units that are less necessary for occupant comfort. Another type of smart cycling available to buildings with multiple package units is to use technology that controls the timing of compressor operation across units to prevent simultaneous operation. This strategy allows units to continue functioning with a reduced compressor duty cycle during a DR event, but reduces the total coincident load.

Global temperature adjustment is the only DR strategy that Title 24 requires HVAC equipment be ready to perform automatically (via setback thermostat or EMCS)

Variable Refrigerant Flow Systems

Variable Refrigerant Flow (VRF) systems are a class of HVAC equipment that have the capability of varying refrigerant flow in order to achieve different space temperature setpoints. VRFs are currently sold exclusively with the manufacturers' own integrated controls, which often come with demand limiting features that can be leveraged for use in demand response. VRFs currently represent a relatively small portion of the U.S. market.

FIGURE 15
VRF System

VRF systems are related to mini-split and multi-split air conditioning systems. Split systems are so named because, in contrast to unitary air conditioners, they consist of separate outdoor and indoor units. The outdoor unit contains the compressor, condenser, outdoor fan(s), circuit board and a heat exchanger coil. The indoor unit consists of a heat exchange coil, air filters, and fan. A multi-split is similar to a mini-split, but includes multiple indoor evaporators connected to a single condensing outdoor unit. Both mini-splits and multi-splits are classified as ductless direct expansion (DX) equipment because they rely on refrigerant lines and coils (or heat exchangers) rather than air ducts to transfer heat to and from conditioned spaces.

Like mini-splits and multi-splits, VRF systems are ductless DX equipment, but are typically more complex and have larger capacities. VRF systems can have many evaporators of differing capacities and configurations, and simultaneous heating and cooling of zones within a building. While mini- and multi-split systems range from 0.75 to 10 tons, VRFs are sized anywhere from 10 to over 200 tons.

VRF systems have demand response because of their inherently flexible design allowing precise control and delivery of the minimum cooling energy that is needed. Each VRF system has individual evaporator units that by default segregate a building into zones, and which are all connected to a central condensing system located outside of the building. Each outdoor condensing unit has a variable speed compressor, and in the most flexible systems, each indoor evaporator unit has a variable speed fan. The zone-based configuration and variable speed technology allows granular and precise control within any facility using VRF technology. In contrast, traditional air conditioners are direct expansion systems that offer limited or no modulation capabilities.

VRFs have factory built-in demand limiting strategies for energy efficiency that include setting a maximum kW operating point, compressor lockout, and global temperature adjustment. These strategies can be directly applied in demand response. Unlike unitary AC equipment, the costs and load shed capabilities of a VRF system do not depend on the size of the installation.

The estimated load shed from VRF demand response strategies averages approximately 0.18 kW load shed per ton, which is comparable to the average load shed potential for unitary AC using the unit cycling strategy.

Chillers

Chillers are components of large, complex HVAC systems. Each component of a chiller system typically originates from different manufacturers. The chiller in a chilled water cooling system uses a majority of a system's electric load, but must work together with the air distribution system, water pumping loop and other components to effectively cool a building. Furthermore, each chiller system is customized for the building that it cools. A chilled water cooling system may use equipment from different manufacturers for the chiller, water tower, pumps, piping, duct work, and air handlers. All of these different components are then controlled by a controls service provider, which may or may not supply any of the other systems.

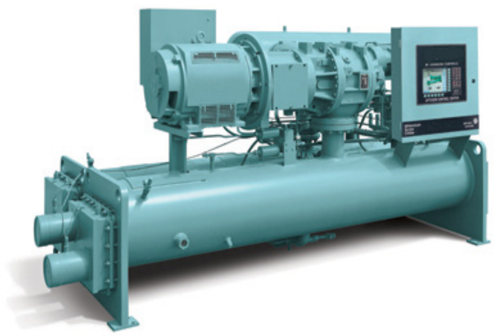


FIGURE 16

Screw-type chiller

Chillers are generally controlled by a large building EMCS that controls multiple building systems (e.g., HVAC, lighting, and security). In order for a chiller HVAC system to shed load, all of the components of the HVAC system must work in a coordinated fashion. If the EMCS is not programmed for DR, executing a load shed strategy at the chiller level could cause other components of the HVAC system to increase their load to make up for the reduced performance of the chiller. For example, if a chiller controller were to raise the chilled water temperature for a demand response event, the air handler fans may try to increase airflow over the warmer water coils in order to supply the same amount of cooling to a space. Thus, the load reduction from supplying warmer chilled water to the coils is offset by an increase in fan power. The optimal controls strategy thus needs to take into account the chiller operation plus all of the "balance of system" component operations to ensure that the kW load reduction for demand response is realized.

The majority of the project costs to prepare chiller systems to participate in ADR are in the configuration and connection, and software upgrade costs to the EMCS. Minimal physical equipment would need to be installed, regardless of the chiller size or capacity. A substantial amount of time is needed on addressing the balance of system components, so that they work in coordination with the chiller when executing demand response strategies. If the chiller HVAC system is properly controlled, it is estimated that the demand range of load shed is between 0.11 kW/ton and 0.22 kW/ton load shed. This falls within a similar range as unitary AC and VRFs load shed strategies. The variation in load depends on the type of chiller installation (air vs. water-cooled) and the demand response strategy. Chiller installations usually range from 80 tons to 2,000 tons.

Construction Scope of Work Documentation

This section includes sample scope of work language that may be used in construction documents to specify ADR-capable equipment. The sample specifications provided in this section include some details that would enhance the ADR capabilities of a building beyond what is strictly required by Title 24. For HVAC systems, Title 24 requires that the building be capable of adjusting the temperature setpoints of individual zones (for buildings with DDC) or thermostats (for buildings without DDC). Therefore, language that requires control over specific components of the HVAC system, such as chiller compressor loading or refrigerant flow rates, would be enhancing the building's ADR capability beyond the minimum legal requirements.

Another way the specification language in this section may enhance a building's ADR capability is by requiring that equipment have the ability to achieve a greater magnitude of load reduction than the minimum required by Title 24. Title 24 requires that interior lighting be capable of being reduced by at least 15%, temperature setpoints by at least four degrees Fahrenheit, and sign lighting by at least 30%. Language that requires, for example, that ballasts be capable of dimming to 50%, would enhance the building's ADR capability beyond Title 24.

Finally, some equipment specifications in this section include language regarding OpenADR 2.0-certification. The building must include at least one OpenADR 2.0-certified gateway in order to automatically participate in DR events, but OpenADR 2.0 certification is not strictly required by Title 24. Therefore, including this requirement in a specification enhances the buildings ADR capability beyond code. There are multiple profiles of the OpenADR 2.0 protocol, and which version is required may vary by utility and specific project characteristics. Please consult with utility ADR program personnel to receive guidance regarding which OpenADR 2.0 profile is required for a specific project.

Lighting Specification

The following language provides an example of how lighting equipment suitable for participating in ADR can be described in construction documents. The details in the example language can be called out as a reference in the legend and assigned a number to place on the lighting layout drawings where these fixtures are specified.

Requiring a lighting system with the ability to dim to 50% during a DR event enhances the building's ADR capability beyond Title 24, which mandates a minimum of 15%

> Project to include the installation of one thousand six hundred (1,600) 42 Watt linear fluorescent 2-lamp fixtures containing 2x28 Watt T8 premium energy saver lamps with electronic ballasts capable of dimming to 50% of full power upon receipt of a demand response signal. Dimming ballasts shall utilize DALI as the communications protocol. All installed fixtures will interface with occupancy and daylight sensors installed for energy efficiency.

The following example of equipment specification in a scope spreadsheet is typically provided to the construction contractor during the construction phase of the project to ensure that the correct equipment is installed during construction. This table can specify the manufacturer of the lamps and ballasts if the construction manager wants to specify equipment from a specific manufacturer in their design/build criteria. This is a generalized example.

Table 7

Sample lighting equipment specification

Line #	Bldg	Space ID	Fixture Code	Fixture Description	Fixture Watts	# of Fixtures	Lamp Type	Ballast Type	Sensors Required
18	300	Floors 2-9 Open Office Areas	F42WLL-R	82 CRI, 18,000 HR. RSA, Fluorescent, (2) 48" T-8 lamp, Premium PRS Ballast, RLO	42	1,600	F28T8-PIREM-ES	Elec-PIREM-R, DALI, Dimmable to 50%	Occupancy, Daylight

Setback Thermostat Specification and Example Products

The following language provides an example of how ADR-ready thermostats can be described in construction documents. Figure 17 provides two examples of commercially available ADR-capable thermostats.

> Thermostat shall provide a pair of setpoint time and temperature parameters for at least four operating periods that collectively govern thermostat operation during the 24-hour day. Thermostat to be capable of responding to a demand response event signal from the Energy Management Control System (EMCS) or include OpenADR2.0b certified software enabling communication with the utility Demand Response Automation Server. Response to event signal shall include a user-programmable temperature setpoint adjustment upon event initiation and reset to standard setpoint schedule upon event completion.

Requiring that a thermostat be OpenADR2.0b certified enhances the buildings ADR capability beyond Title 24, which requires that a setback thermostat contain a port into which a module that confers the ability to receive ADR signals can be placed.

FIGURE 17

Examples of thermostats that can be used for ADR. These products are listed here only as examples and are not endorsed in any way by the authors of this document.

VRF Specification

The following language provides an example of how VRF equipment suitable for participating in ADR can be described in construction documents. The details in the example language can be called out as a reference in the legend and assigned a number to place on the VRF layout drawings where this equipment is specified.

> The project includes the installation of twenty (20) 24 ton VRF HVAC systems. The controls for these VRF systems are to be capable of responding to a demand response event signal from the facility Energy Management Control System (EMCS). The event signal will initiate the demand response control sequence of operations such all VRFs will reduce their refrigerant flow to each zone by a preset amount that can be user selected, within the EMCS, from a menu of choices. The choices available to the user will be 75%, 67%, and 50% of full refrigerant flow. In order to facilitate grouping of these VRF endpoints, each VRF endpoint will be individually addressable in the EMCS so that it can be identified by the demand response sequence of operations.

Requiring that refrigerant flow can be directly controlled in a DR event enhances a building's ADR capability beyond Title 24, which requires that HVAC systems be capable of global temperature adjustment

Chiller Specification

The following language provides an example of how chiller equipment suitable for participating in ADR can be described in construction documents. The details in the example language can be called out as a reference in the legend and assigned a number to place on the central plant layout drawings where this equipment is specified.

Requiring that chiller loads be directly controlled in a DR event enhances a building's ADR capability beyond Title 24

> The project includes the installation of twenty (20) 400 ton frictionless chillers. The controls for these chillers are to be capable of responding to a demand response event signal from the facility Energy Management Control System (EMCS). The event signal will initiate the demand response control sequence of operations such that the operating compressors will reduce their loads to a preset amount that can be user selected, within the EMCS, from a menu of choices. The choices to be available to the user will be 75%, 67%, and 50% of full chiller capacity. In order to facilitate individual compressor control, each of the compressors will be addressable in the EMCS so that it can be identified and controlled by the demand response sequence of operations.

EMCS Specification, Sample Programming, and Screenshots

Each facility is unique and requires EMCS custom programming to accommodate its particular characteristics, even for normal operation. Similarly, the DR strategies for each building must also be custom programmed. Typically, building contractors will contact vendors of EMCS to specify what capabilities the system will have when commissioned, including its DR capabilities and strategies. Increasingly, EMCS vendors offer their own integrated OpenADR 2.0-certified software solutions, allowing the EMCS to serve as the ADR gateway for the entire building.

The following is example language that may appear in the specifications of an EMCS to ensure that the EMCS is ADR capable. The language below should appear in the EMCS programming instructions within the design drawing package. This specific language will instruct the EMCS programming team what sequences to program in response to the inputs from the event signaling device. Equipment can be identified in separate priority load reduction groups designed to enable various levels of curtailment, or all equipment can be part of a single curtailment group and curtailed as a whole.

Software and hardware shall be capable of performing automated demand response (ADR). The ADR programming shall be certified for communicating with the OpenADR 2.0b (Open Automated Demand Response) communication standard to receive demand response signals from the utility or other demand response provider.

The program will automatically shed and restore electrical loads as defined for demand response, which includes, but is not limited to load shed Priority Groups 1, 2, and 3 as defined under Demand Response.

At a minimum, ADR programming will provide for global temperature reset and lighting dimming. Additional strategies may include pre-cooling as well as elevator and electrical equipment curtailment strategies as is acceptable to tenants.

When the demand response event is over, the system shall return to normal operations without causing the peak loads of the facility to rise above the current monthly operating peak demand set during normal operations.

Contractor should verify that outside air (OSA) damper operates in conjunction with supply fan speed, so reduction in fan speed doesn't reduce OSA below code minimum.

Requiring that an EMCS be OpenADR2.0b- certified enhances the building's ADR capability beyond Title 24, which requires the HVAC and lighting control systems to be capable of responding to ADR signals but does not include a method for verifying the receipt of external signals

The following language provides documentation of how ADR is integrated into an EMCS. This documentation is an example of what could be submitted as part of the requirements for LEED v4 DR credit, but may be useful for specifying or documenting ADR strategy programming more generally. The language below includes one possible combination of system settings that could be used as a protocol for responding to an ADR signal. The specific settings should be carefully selected with due consideration of the limitations and capabilities of the specific building and HVAC system being designed. For example, hospitals and clean rooms typically cannot restrict supply air flows, so limiting fan speeds would not be a feasible part of a DR protocol for those building types.

- The ADR strategy is programmed into the facility EMCS and is programmed to react to two (2) digital inputs from the ADR authority allowing 4-four control states as follows:
- DI-1 Open & DI-2 Open – Normal Operations
- DI-1 Closed & DI-2 Open – Warning of Pending Event (typically day ahead notification)
- DI-1 Open & DI-2 Closed – Not Used for this Protocol (usually Pre-Cooling Command)
- DI-1 Closed & DI-2 Closed – Initiate Demand Response Protocol as follows:
  - Raise Chilled Water Set Point 6 Deg F from 48°F to 54°F
  - Limit all VFDs to 75% speed and limit chilled-water valve positions to 75% open
  - Reduce common area lighting to 50% of maximum light output.
- Each programmed point requires an override button to allow the facility engineers to opt out of individual measures.
- Additionally, a master override is required to disable all curtailment activities.

Programming an EMCS to directly adjust HVAC system settings or to dim lighting to 50% in response to an ADR signal would enhance the ADR capability of the building beyond Title 24

Figures 18 and 19 below show screenshots of the programmed EMCS, showing how fan power speeds and loads are reduced in the DR event. Figure 18 shows the EMCS during normal operation, where fan speeds are at 96.7% and Figure 19 shows the EMCS after curtailment signal is active, where fans speeds have been reduced to 75% per the DR strategy.

FIGURE 18

EMS during normal operation before the curtailment signal is active. The fans are modulating at 96.7%

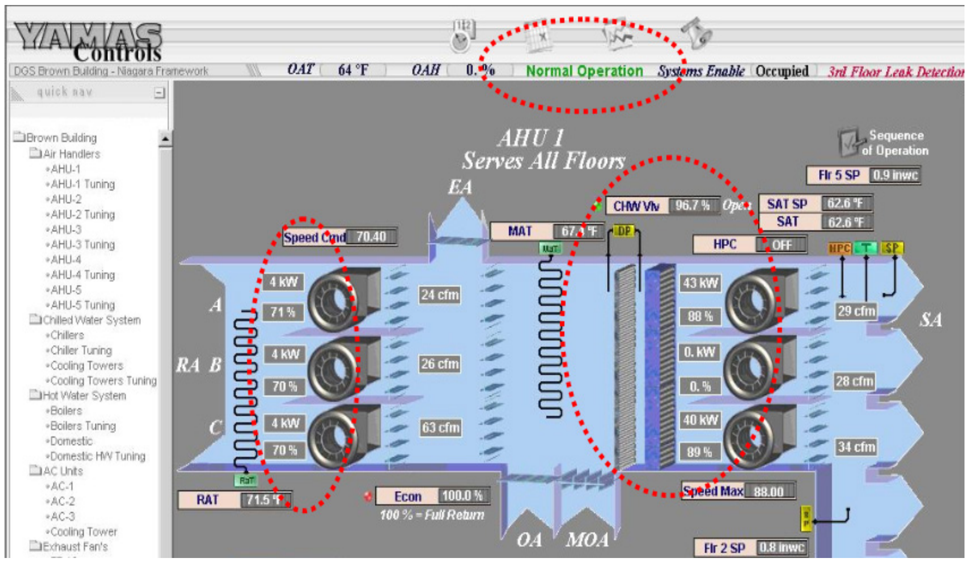
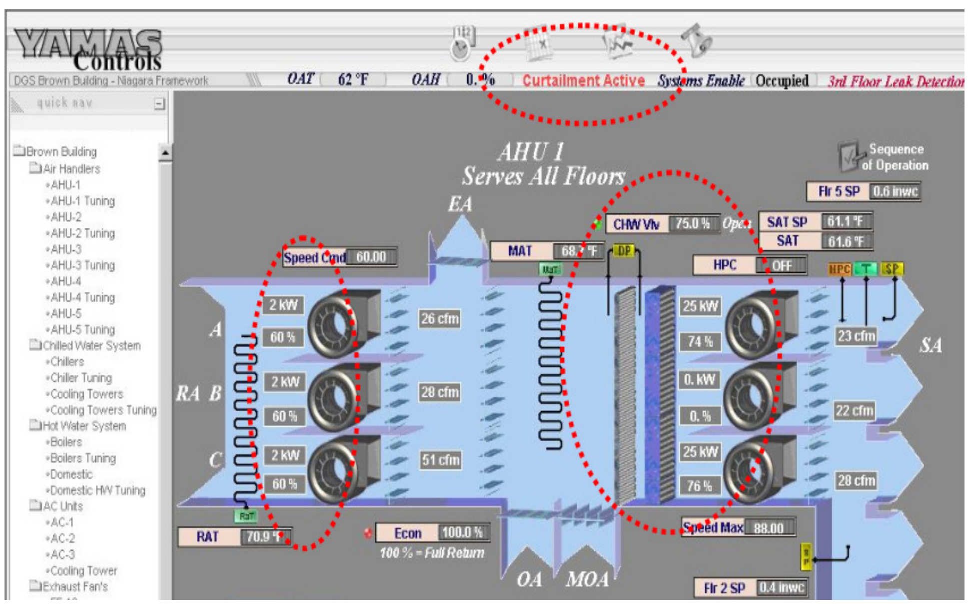


FIGURE 19

EMS during curtailment operation when the curtailment signal is active. Fans are modulating at 75% (only appropriate for systems where air supply restriction is feasible)



PART 4: Developing Appropriate ADR Gateway Solutions

In order to participate in ADR, building equipment must receive a signal from a server that indicates when demand response events begin and end. For the purposes of this document, an ADR gateway is defined as hardware or software client that exchanges information about DR events with a remote server. One example of a simple ADR gateway is a CLIR (Client and Logic with Integrated Relay) box, which was one of the first ADR gateways to be deployed in California. The phrase "CLIR box" is sometimes used as a generic term for a simple, hardware-based ADR gateway, but there are now a wide variety of ADR gateways available on the market, ranging from simple hardware clients with dry contacts to sophisticated hardware and software solutions that integrate into a facility's EMCS. This chapter provides guidance on selecting an ADR gateway

Overview of the OpenADR 2.0 Communications Protocol

OpenADR 2.0 is the industry standard protocol for ADR signaling used in all the investor-owned utility ADR programs in California. By establishing a common framework for exchanging DR-related information, OpenADR allows ADR gateways produced by different manufacturers to receive and execute responses to the same event signal. OpenADR is designed to interoperate with any energy management or controls system and the protocols they use, such as BACnet (see Appendix C). The OpenADR protocol is a non-proprietary, open standard originally developed by the Demand Response Research Center at Lawrence Berkeley National Laboratory in conjunction with California investor-owned utilities and the California Energy Commission. OpenADR is currently managed by the nonprofit organization OpenADR Alliance. To participate in ADR programs operated by investor-owned utilities in California, gateways must be certified in one of the available OpenADR 2.0 profiles by the OpenADR Alliance (rules may vary by project and utility; see "Certification" section below for differences between profiles).

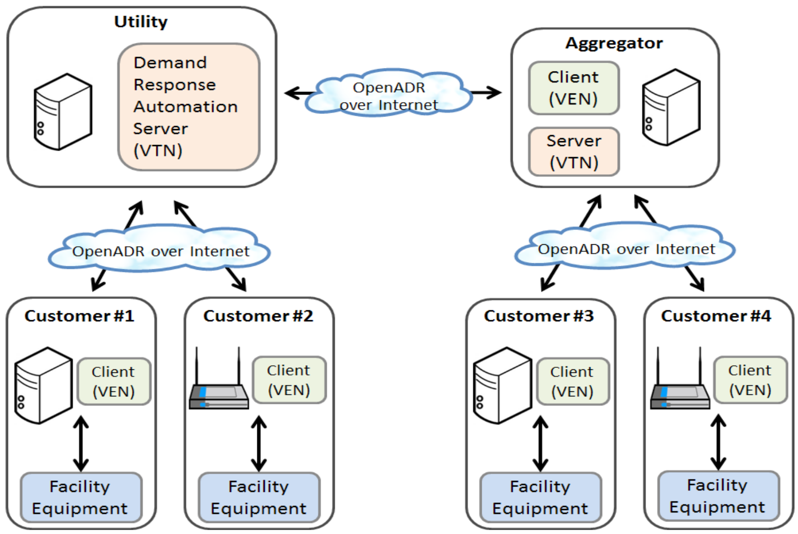
The ADR Network

OpenADR communications take place over a network of two-way signaling nodes (see schematic diagram in Figure 20). The investor-owned utilities in California use a Demand Response Automation Server (DRAS) to originate event signals. Like CLIR box, the phrase "Demand Response Automation Server" is the name of a specific product, but is also used as a generic term for the utility-operated node in the ADR network. The gateways at each participating facility in the utility's territory acquire information about the event from the utility's DRAS and then transmit information back to the server about the building's ability to participate. In cases where customer loads are aggregated by a third party, an intermediary gateway operated by the aggregator receives the event signal from the utility and relays that signal to individual facilities.

Schematic Diagram of an ADR Communications Network

FIGURE 20

Schematic diagram of ADR communications network



In OpenADR terminology, a gateway that originates an event signal is acting as a virtual top node (VTN), and a gateway that receives an event signal is acting as a virtual end node (VEN). A utility's DRAS is the primary VTN in an ADR communications network. There are two modes through which a VTN and A VEN can exchange information: pull and push. Pull mode communications can be understood using a chalkboard metaphor. The utility VTN publishes information as if writing on a chalkboard. The customer's ADR gateway, acting as a VEN, regularly reads the information on the VTN chalkboard (a process called "polling"). When the information indicates normal conditions, the VEN allows normal building operations to proceed. When a DR event is called, the VTN erases the chalkboard and writes different information indicating that an event is active. When the VEN reads the chalkboard, it registers the new message and engages the building's controls system to execute a set of pre-determined load management strategies. In push mode signaling, the VTN is able to initiate a connection to the VEN on its own, without waiting for the VEN. Some ADR gateway options provide both push and pull capabilities.

The gateways operated by aggregators act as both VENs and VTNs. Aggregator gateways act as VENs when they acquire signals from the utility VTN and act as VTNs when they relay signals to their subscriber VENs. In some cases, aggregators communicate with subscriber equipment using proprietary protocols that do not conform to the OpenADR 2.0 standard. For a new building to be ADR-ready without being tied to the proprietary signaling technology of a vendor contract, the ADR gateway must be OpenADR 2.0 certified. Choosing OpenADR 2.0 certified products ensures the building will be able to understand and take advantage of the entire array of signals and data communication coming from the utility VTN.

Opting Out

While OpenADR provides the means for electricity providers and aggregators to communicate price, reliability, and DR event signals to customers, not all customers will be able to participate fully in every demand response event of the season. OpenADR provides opt-out or override functionality such that customers can choose not to participate if an event comes at a time when it would be prohibitively difficult or undesirable to reduce load.

Security

Many organizations are hesitant to allow unsecured entities access to their networks, or to allow any outside device to reside behind their firewall. OpenADR 2.0-certified VENs provide a range of built-in security features. Designers can further augment those features by choosing installation options that reduce the risk of cyber intrusion.

Different versions of the OpenADR 2.0 protocol provide different security measures. OpenADR 2.0a uses basic authentication, which is in use across much of the Internet. A username and password are assigned to the customer VEN, providing access to correct account on the utility VTN. Without the username and password, no connection can be made and no information can be exchanged. OpenADR 2.0b uses Transport Layer Security (TLS), a more advanced method. Customers requiring a level of security beyond that of a typical Internet HTTP transaction should select a VEN that is 2.0b certified. Instead of a username and password, 2.0b nodes use certificate authentication to identify and grant access to the correct users. A third-party certificate authority assigns certificates, containing both public and private keys, to both the VTN and the VEN. When the VEN polls the VTN for an event notification signal, the information is encrypted using the public and private keys. Since the VTN and the VEN are the only entities with the correct certificate, only the VTN and VEN have the keys required to open, read, and interact with the message. Certificate-based encryption provides security at each end of the connection, strengthening the entire network and allowing the utility VTN and the customer VEN to communicate their information payloads in a secure environment.

For customers with exceptionally high requirements for data security, designers can choose additional safeguards that allow even the most sensitive environments to participate in ADR. The most secure option for a customer involves two steps: 1) installing a dedicated DSL line; and 2) selecting a simple hardware VEN. The DSL line ensures that ADR data transmissions are separate from any network connections the customer uses for its business purposes. Simple hardware VENs that operate simply by opening and closing dry contact relays when they receive event signals are simply not capable of acquiring or transmitting any other kind of information. The detailed execution of the response to an event signal is then performed by the customer's own control system.

Certification

In order to ensure a high level of performance and comply with California investor-owned utility requirements, designers should be sure to select OpenADR-certified equipment. OpenADR Alliance partners with Intertek to provide testing services for ADR equipment. Manufacturers submit products to Intertek's ISO 17025 accredited test facility, where they undergo rigorous testing to meet the requirements of the OpenADR 2.0 specification. If a product passes testing, it is officially designated OpenADR-certified and included on the OpenADR Alliance's list of certified products.

There are currently two OpenADR 2.0 certifications available through the OpenADR Alliance. The 2.0a profile was designed to support basic DR services. The primary purpose of developing 2.0a was to convert the first-generation OpenADR 1.0 standard into a format that could later be scaled to enable a more sophisticated set of signaling and reporting features. The OpenADR 2.0b profile was designed to implement additional features not included in OpenADR 1.0, including expanded communication from the VEN to the VTN for locational dispatch, telemetry, reporting, and data analysis.

Selecting an ADR Gateway Solution

There are a number of ADR gateway solutions available on the market. Designers can browse all OpenADR Certified products on the OpenADR Alliance website: (http://www.openadr.org/products). Figure 6 presents examples of ADR 2.0 certified gateway solutions. Equipment in the online database is categorized by Product Type (VTN, VEN, or both), OpenADR 2.0 Profile (a or b), communication methods ("pull" or "pull and push" modes), and methods of data transport and security.

One of the major distinguishing characteristics between gateways designed to be used as VENs is whether they are hardware or software. Hardware systems utilize dry contact relays that open or close depending on the type of signal being sent by the utility VTN. While such systems have historically been prized for security, OpenADR 2.0 certification ensures that software applications offer a similar level of security and reliability as hardware systems, but with the flexibility of having no physical installation and, in the case of 2.0b-certified VENs, a more robust set of features.

The functions supported by specific OpenADR 2.0-certified gateways will vary by the vendor – some products are designed specifically for lighting applications, HVAC equipment, multi-building sites, or electric vehicles. Many have web dashboards and advanced metering capabilities. Since all of the products adhere to the rigorous OpenADR Certification standards, they can all perform the functions required to participate in ADR in California investor-owned utility territories.

Some installation questions to consider when selecting and locating equipment are:

- Hardware or software? Hardware gateways are often suitable for smaller buildings or where security is a major concern. Software gateways are more likely to be used in larger buildings, particularly when the gateway is integrated into the building EMCS by the same vendor.
- How large is the equipment? Some hardware is as small as a typical wireless router and can be directly connected to existing controls systems using Ethernet connections. Other products

will need to be mounted on a wall near an outlet and can require more complex connections.

- Does the gateway use wireless technology? A gateway that relies on a cellular connection to communicate with the utility VTN, or a Wi-Fi or ZigBee-based signal to communicate with building equipment, may have difficulty achieving the required signal strength in basement electrical closets and maintenance rooms.
- Does the equipment require a dedicated and/or on-site computer? Some solutions are designed to be accessed remotely using Internet browsers or smartphone apps, but designers should verify whether a dedicated and/or on-site server is required.

Gateway Installation and Testing

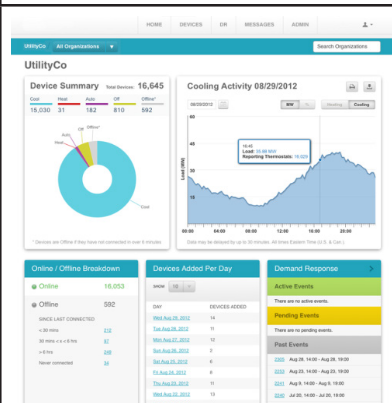
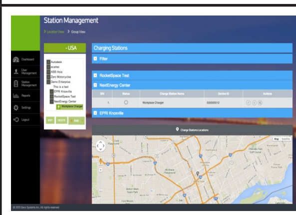
Once the appropriate hardware or software product is installed and connected to the building's controls system per manufacturer documentation, the ADR gateway must be connected with the appropriate VTN. This typically occurs only after the building is occupied, the internal network is configured, and internet service is available. A local utility's DRAS administrators will create an account and provide a username and password to the customer. It is important that IT departments are involved in the installation process, as the majority of connection issues occur due to network access issues or firewall changes. Knowing firewall and network access information – such as whether the network features static IP or DHCP, or utilizes a proxy server – is necessary to configuring the VEN for initial connection to the utility VTN. This information should be provided to the installer ahead of time to prevent complications on-site.

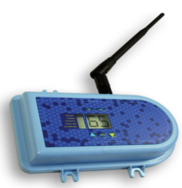
Once the appropriate network information is entered in both the customer VEN and utility VTN, a test event will be issued by the utility DRAS operator in cooperation with the facility manager to check for end-to-end connection problems. A complete system test ensures the VTN, VEN, and building controls system are communicating properly, and that load reduction goals are able to be met. Once a successful test is completed, and the appropriate personnel are satisfied that an event signal will initiate operations necessary to shed load, a customer will be ready to participate in a utility's DR program.

TABLE 8

Examples of OpenADR 2.0 Certified ADR Gateways from the OpenADR Alliance Website

Examples of OpenADR 2.0 Certified ADR Gateways from the OpenADR Alliance Website

OADR PROFILE	PHOTO	WEBSITE INFO
A		Wireless platform provides web-based remote access to all system and device management, enterprise-wide and individually addressable device control. Full-feature control of lighting and select other features. Online dashboard w/ snapshots of energy usage across system by zone. Multi-facility management, simple web interface, report generation, DR interact.
A		Real-time two-way DR management system. Customizable online web portal. Logs all device transactions, event triggers, device state changes, etc. for easy communication w/ utility VTN - excellent for measurement & verification reporting. Extensive device compatibility - can interact with many existing thermostats, compressors, water heaters, pumps, etc. Can communicate over a variety of communication networks with controls systems.
B		Cloud-based application allows customers to optimize how they buy, use, and shed electricity. Provides advanced metering and real-time energy information. Remote access by computer or app. Links to Network Operations Center - manages events and monitors connectivity 24/7/365. Wireless machine-to-machine controls available.
A		Local hardware server - Energy manager interface communicates with existing BMS. Provides web-based interface, no software needed. Per-fixture, multi-tiered energy profiles to ensure appropriate dimming based on space utilization need.
B		End-to-end open-standard solution for electric vehicle charging. Offers real-time network and price monitoring. Supports multiple charging station technologies.

OADR PROFILE	PHOTO	WEBSITE INFO
B		Hardware system, IP-based network controller. Supports telemetry and integrates with most building/energy management systems. Contains standard applications for multiple demand response applications.
A		Open-source based vendor. System designed for centrally-managed multi-site businesses. Allows a customer to act as a self-aggregator and participate in ADR programs without installing additional equipment. Gateway software connects to range of Opus building controllers.
B		Hardware solution. Implements and supports interval data logging support - near real-time telemetry and price conveyance. First company to certify both OpenADR 2.0a VTN servers and OpenADR 2.0a VEN clients or end nodes.
A		Web-based platform deployed either as a hosted service or client-side application, seamlessly interfacing the utility VTN server with industry-standard energy management systems.
A		Designed for the light/medium commercial markets. Wireless control system, cloud-based interface with remote access.
A		Designed for granular curtailment and staggered cycling of HVAC systems as opposed to universal temperature setbacks. Allows energy savings and consistent reduction with subtler changes and less impact on occupants.
A		Hardware solution designed for small/medium commercial venues. Standalone EMS with no need for dedicated computer. Supports ZigBee, INSTEON, A10 and X10 devices. Intuitive user interface for easy OpenADR setting configuration.

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Appendix A: ADR-Related Elements in 2013 Title 24

The ADR-related requirements in Title 24 are found in several different documents. Table A1 presents a summary of location of major references to ADR-related requirements throughout the Title 24 documents. Tables A2, A3, and A4 present a summary of the Title 24 ADR-related requirements for interior lighting, HVAC, and sign lighting system, respectively. The code language in these tables has been slightly modified for clarity. For exact code language, please refer to CEC's Title 24 2013 website: http://www.energy.ca.gov/title24/2013standards/index.html.

TABLE 1A

Locations of Major References to ADR-Related Requirements In Title 24

BUILDING SYSTEM	CODE	COMPLIANCE MANUAL		APPENDICES	REQUIRED FORM FOR ACCEPTANCE
		GUIDANCE	TESTING PROCEDURE		
DR in General	100.1 (definitions); 130.5(e)	8.6.1 (app. notes); 12.2 (commissioning)			NRCC-CXR-02-E (commissioning)
Interior Lighting	130.1(e); 130.5(f)(1)	5.4.5-6	13.8.4	NA 7.6.3.2	NRCI-LTI-02-E
HVAC-with DDC	120.2(b); 120.2(h)	4.5.1(o)	13.7.22	NA 7.5.10	NRCA-MCH-11-A
HVAC-no DDC	110.2(c); 120.2(b)	4.5.1(b)4		JA 5	OCST declaration form
Sign Lighting	130.3(a)(3)	7.3.3			NRCC-LTS-01-E

TABLE 2A

Title 24 Indoor Lighting ADR-Related Requirements

CRITERIA	TITLE 24 ADR REQUIREMENTS	CODE REFERENCE
• Buildings larger than 10,000 square feet • Habitable spaces where the lighting power density is greater than 0.5 watts/square foot • Other exceptions apply - see §130.1(e) for details	Lighting power must be capable of being lowered by a minimum of 15 percent below the total installed lighting power in response to an ADR signal using at least one standards-based messaging protocol.	§130.1(e); §130.5(e); §100.1: Definition of Demand Response Signal; §100.1: Definition of Demand Responsive Control;
	Lighting shall be reduced in a manner consistent with uniform level of illumination requirements as listed in Title 24 Table 130.1 A Multi-Level Controls and Uniformity Requirements.	§130.1: Table 130.1 A
	An EMCS is optional – it may be substituted for a lighting control system if it complies with all relevant lighting control system requirements.	§130.5(f)(1)

TABLE 3A

Title 24 Sign Lighting ADR-Related Requirements

CRITERIA	TITLE 24 ADR REQUIREMENTS	CODE REFERENCE
New connected lighting power load greater than 15 kW. Exceptions apply.	Controls must be capable of reducing the lighting power by a minimum of 30 percent upon receipt of an ADR signal.	§130.3(a)(3); §100.1: Definition of Demand Response Signal; §100.1: Definition of Demand Responsive Control

Title 24 HVAC ADR-Related Requirements

TABLE 4A

CRITERIA	TITLE 24 ADR REQUIREMENTS	CODE REFERENCE
• HVAC system with DDC to the zone level • Non critical Zones (Zones in which reset of zone temperature setpoint during a demand response event will not disrupt a process served by the zone. See §100.1, Definition of Critical Zone and Definition of Non-Critical Zone	Controls must be capable of responding automatically to an ADR signal using at least one standards-based messaging protocol.	§120.2(b); §120.2(h)(5)(C); §130.5(e); §100.1: Definition of Demand Response Signal; §100.1: Definition of Demand Responsive Control;
	Controls must be capable of remotely increasing the operating cooling temperature setpoints by 4°F or more in all non-critical zones upon receiving a signal from a centralized contact or software point within the EMCS.	§120.2(b); §120.2(h)(1)
	Controls must capable of remotely decreasing the operating heating temperature setpoints by 4°F or more in all non-critical zones upon receiving a signal from a centralized contact or software point within the EMCS.	§120.2(b); §120.2(h)(2)
	Controls must capable of remotely resetting the temperatures in all non-critical zones to original operating levels upon receiving a signal from a centralized contact or a software point within the EMCS.	§120.2(b); §120.2(h)(3)
	Controls must be capable of being programmed to provide an adjustable rate of change for the temperature adjustments.	§120.2(b); §120.2(h)(4)
	Controls must have a Disable feature that allows authorized facility operators to disable the controls.	§120.2(b); §120.2(h)(5)(A)
	Building must have an EMCS or dry contacts to allow manual, global adjustment of heating and cooling setpoints from a single point by authorized facility operators.	§120.2(h)(5)(B); Non-Residential Compliance Manual 4.5.1(o) and 13.7.22
• HVAC system has thermostatic controls for all unitary single zone air conditioners, heat pumps, and furnaces • System not serving process load that must have constant temperatures to prevent degradation of materials, a process, plants or animals. • Other exceptions apply – see §120.2(b)(4)	All thermostats must have a clock mechanism that allows the building occupant to program the temperature setpoints for at least four periods within 24 hours. An EMCS is optional – it may be substituted for thermostatic controls if it meets all thermostat requirements below.	§120.2(b); §110.2(c); §130.5(f)(2)
	Thermostats must comply with specifications for Occupant Controlled Smart Thermostats (OCST) specified in Reference Joint Appendix JA5, including having the capability of responding automatically to an ADR signal using a standards-based messaging protocol.	§120.2(b); Reference Joint Appendix JA5; §110.2(c)
	An EMCS is optional – it may be substituted for thermostatic controls if it meets all thermostat requirements below.	§130.5(f)(2); §120.2(b); Reference Joint Appendix JA5

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Appendix B: Wireless Technology in Building Automation

This appendix covers three representative wireless technologies used to transmit information within an internal building network of equipment, sensors, and control devices. Wireless communications technologies are different from network communications protocols, like BacNet or LonWorks, that provide a common structure for the equipment information being shared over the network. BacNet and LonWorks can be used to structure information that is communicated using either wired (or wireless technologies. Network communications protocols are covered in Appendix C.

Wireless communications technologies should also be distinguished from OpenADR 2.0, which is a protocol that provides a common structure specifically for information related to DR events. Like BacNet or LonWorks, OpenADR 2.0 can be used to structure information that is passed over either wired or wireless networks. However, OpenADR 2.0 is typically used to communicate between remote locations, rather than within a building's internal network.

Depending on its capabilities and configuration, an ADR gateway (or OpenADR 2.0-certified EMCS) may communicate using a combination of wired and wireless technologies. For example, a gateway may communicate with the utility utility VTN using OpenADR2.0 through a wired Internet connection, and communicate with individual building thermostats using a wireless technology. Alternatively, an ADR gateway could be connected to building equipment using a wired Ethernet connection and use a wireless connection to nearby router, which then provides a wired connection to the Internet.

About Wireless Communication Technologies

Wireless technologies used in building automation systems typically transfer data through radio waves. When combined with building energy management systems, wireless technology offers many benefits including the ability to easily relocate sensors and reliable performance. Wireless is often the solution in buildings where running wire is problematic or a controller is not conveniently located.

Wireless sensor transmitters and associated standard protocols are coming of age in building management systems. Wireless technology has become more reliable with improved security and better transmission rates. There have been many technological advances, including battery-free, energy-harvesting devices in wireless installations.

Wireless system devices have finite communication distances. These systems are economically applied in large open-air areas with a direct line of sight between network nodes (such as gymnasiums, arenas, hallways, etc.). In these locations, wireless signal strength is much greater.

A wireless network for building automation can offer benefits over wired systems:

- Wireless systems usually are less expensive to install. Wiring and conduit can be costly—without the high costs of wiring, most wireless projects are less expensive.
- Depending on the architecture of the building, wireless systems often are easier to implement.
- Future wireless system additions or changes will disrupt tenants less than similar changes with a wired system.

Representative Wireless Technologies

Three popular wireless technologies that enable connected devices to communicate with each other are Wi-Fi, ZigBee, and EnOcean. Details on each of these technologies are provided below.

Wi-Fi

Wi-Fi is the industry name for wireless communication technology based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards. It is commonly used for connecting computers and smartphones to the Internet in residential and commercial buildings. Wi-Fi typically operates at 2.4 GHz, although 5 GHz is also possible.

ZigBee

ZigBee encompasses a suite of protocols based on the IEEE 802.15 standard. IEEE 802.15 is a short-distance, low-power wireless communication standard with lower data rates than Wi-Fi. ZigBee is commonly associated with "mesh networks" in which signals can be transmitted from any node to any other node across any device in the network, rather than through a central hub. In the U.S., ZigBee operates at 916 MHz and 2.4 GHz.

EnOcean

EnOcean technology is based on the International Standards Organization/ International Electrotechnical Commission (ISO/IEC) 14543-3-310 standard. Like ZigBee, EnOcean technology specializes in low data rates and low power consumption. EnOcean technology is often associated with "energy harvesting" devices that operate without batteries. In the U.S., EnOcean operates at frequencies of 902 MHz, 868.3 MHz and 315 MHz.

Appendix C: EMCS Network Communications Protocols

EMCS network communications protocols are becoming a part of the vocabulary for understanding energy management systems and how they communicate within a facility and between other entities outside the facility. In this section we discuss the two most common communication protocols, BACnet and Lon Works. EMCS network communications protocols are different from the underlying wired or wireless technologies through which data may be transferred from one device to another. Wireless technologies are covered in Appendix B.

EMCS network communications protocols should also be distinguished from the OpenADR 2.0 protocol. Like OpenADR 2.0, the network communications protocols described here are used to structure data to facilitate communications between devices. The major difference is that OpenADR 2.0 covers information specifically related to DR events, whereas EMCS network communications cover a broad variety of data related to building equipment status and control. Also, unlike OpenADR 2.0, EMCS network communications protocols primarily serve internal building networks, and are not used to communicate with a utility VTN.

BACnet

The network communications protocol called BACnet™ stands for Building Automation and Control network. Developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), BACnet is a communications and data protocol suite designed to allow building equipment and systems manufactured by different companies to work together. It is the only open, consensus-developed standard in the building controls industry. (Visit bacnet.org for more information.)

BACnet is a true, non-proprietary, open protocol communication standard. This means that there are no proprietary chip sets or protocols used. BACnet is a specification that is designed to be used at all levels of an energy management and control system, and it uses a single protocol across all levels of the network. The BACnet standard defines data communication for computer equipment used for monitoring and controlling HVAC, refrigeration, and other building systems. The BACnet rules relate specifically to the needs of building automation and control equipment. For example, the rules specifi cally include such things as ways to ask for the value of a temperature, the status of a pump, or when a certain fan operates.

The BACnet protocol can be used to provide a connection between existing stand-alone networks, with gateways, between BACnet and building networks

The LonWorks Platform

LonWorks networks are another common standard in the building industry. LonWorks systems are supported by over 1,000 companies in the buildings industry, and are available for a variety of applications, including access control, elevators, energy management, fire/life/safety, HVAC, lighting, metering.

Using the LonWorks platform, devices from multiple vendors can cooperate as part of a single integrated network. LonTalk is designed to provide communications on a variety of physical media for a wide range of products and systems. It is designed to support twisted-pair wiring, power-line wiring, radio frequency and infrared communication, as well as coaxial and fiber optics media.

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