CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Working Draft Measure Information Template –Upgradeable Setback Thermostats

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team, June 2011

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Upgradeable Setback Thermostats

2013 California Building Energy Efficiency Standards

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1. Purpose

This document presents data necessary to evaluate the economic-potential and market-readiness of Demand Response (DR)-ready thermostats, termed Upgradeable Setback Thermostats, for Part 6 of Title 24. Upgradeable Setback Thermostats are Setback Thermostats which can have DR communication enabled by the end-user by either toggling a manual switch or installing a communication module.

This report contains an overview of the proposed code change, description of the methodology, analysis, results, and the recommended code language.

This proposal is cost effective in all Title 24 building climate zones except for heating dominated climate zone 5.

2. Overview

a. Measure Title	Residential Demand Responsive Thermostatic Controls
b. Description	This measure proposes changing the requirements for setback thermostats in Section 112(c) to require Upgradeable Setback Thermostats (USTs). The term "Upgradeable" refers to the required ability to add a communication module to the setback thermostats. This greatly increases the ease with which homeowners and businesses will be able to participate in demand response programs, and take control of their energy usage and utility bills. This measure examines the feasibility of requiring all setback thermostats installed in new construction in the residential and nonresidential sectors to be capable of adding, or enabling, a communication device that would enable demand response. The report examines the current market for communicating thermostats, including the costs and types of technology currently employed, and anticipated in the near future.
c. Type of Change	Upgradeable Setback Thermostats (USTs) would be required as a Mandatory Measure in all residential dwellings and commercial buildings with unitary HVAC units. Residential dwellings include single family and multi-family dwellings. Commercial buildings affected by this measure include nonresidential buildings using unitary HVAC units without an energy management control system (EMCS). This is most likely to affect smaller offices and retail establishments. The change would necessitate new language in Section 112 of Title 24, Part 6 of the California building energy efficiency standards. The change does not expand the scope of the Standards. It does change the minimum requirements for thermostats in areas already regulated by the Standards. No other changes would be necessary. As a mandatory requirement, USTs are required and cannot be traded off against other building measures. Therefore, there is not a requirement that USTs be simulated as stipulated by a specific rule set in the ACM manual.
d. Energy Benefits	The proposed change will not significantly affect natural gas use because demand response events are more likely to take place during the cooling season in California, rather than during the heating season. Thus, changing the cooling set point will have no effect on heating energy use. These energy savings are based on the following assumptions for both residential and commercial customers. Customers are on a time-of-use rate with peak day pricing (critical peak pricing) by default, and that 30% of residential and commercial customers alike will opt-out of such a rate. We assume that customers are price responsive to the top 1% of hours, and therefore will treat 88 hours of the year as demand response events. We assume that customers will increase their HVAC set point by 4˚F during each demand response period, and that 10% of customers will override the automatic load shed during each demand response period.

Detailed calculations are available in Section 4 - Analysis and Results. The savings as calculated for each prototype building and representative climate zones are presented in the tables below. Demand Savings is calculated as the average demand savings for the Peak Period as defined by the CPUC for calculating program savings; which includes all weekday hours between 12pm and 6pm for July through September. The savings are presented as occurring per unit. Each unit is one HVAC zone with one Upgradeable Setback Thermostat.

The TDV Electricity Savings is based on the 30-year Residential TDV factor for the Residential scenarios and the 15-year Nonresidential TDV factor for the nonresidential scenarios.

There is no gas impact for any of the scenarios below.

Single Family Dwellings:

	Savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	TDV Electricity Savings ($)
CZ1	3	0.00	$71
CZ2	26	0.00	$1,582
CZ3	15	0.00	$1,075
CZ4	28	0.00	$1,712
CZ5	0	0.00	$0
CZ6	18	0.00	$1,308
CZ7	25	0.51	$1,706
CZ8	32	0.18	$1,464
CZ9	58	0.49	$3,229
CZ10	66	0.70	$3,273
CZ11	89	-0.01	$4,180
CZ12	80	-0.01	$3,582
CZ13	84	0.79	$2,669
CZ14	78	0.47	$2,295
CZ15	96	0.01	$1,941
CZ16	52	1.24	$2,637

Figure 1 Single Family Dwelling Savings per unit (UST)

1. Each Upgradeable Setback Thermostat is one unit.
2. The single family prototype is Prototype D, described in Section 3.3.

Multi-family Dwellings:

Multi-Family Dwelling savings per unit (UST)			
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	TDV Electricity Savings ($)
CZ3	5	0.00	$410
CZ6	7	0.00	$540
CZ9	17	0.28	$1,274
CZ12	21	0.00	$1,091
CZ14	21	0.14	$664
CZ16	14	0.40	$793

1. Each Upgradeable Setback Thermostat is one unit.
2. The multi-family prototype is Prototype E, described in Section 3.3.

Offices:

	Office savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	TDV Electricity Savings ($)
CZ3	27	0.09	$410
CZ6	23	0.09	$387
CZ9	26	0.12	$471
CZ12	22	0.11	$343
CZ14	17	0.08	$214
CZ16	18	0.08	$292

1. Each unit refers to one Upgradeable Setback Thermostat.
2. The office prototype is described in Section 3.3.

Retail:

	Retail savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	TDV Electricity Savings ($)
CZ3	37	0.12	$557
CZ6	31	0.12	$506
CZ9	25	0.12	$437
CZ12	30	0.15	$473
CZ14	31	0.15	$388
CZ16	28	0.13	$435

	1. Each Upgradeable Setback Thermostat is one unit. 2. The retail prototype is described in Section 3.3.
e. Non-Energy Benefits	The ability to manage daily peak loads provides the potential to reduce end user electricity bills by limiting the monthly peak demand. The rollout of dynamic pricing by the California utilities over the next several years increases the economic value of customers being able to actively manage their HVAC energy consumption. Owners of DR-ready buildings, buildings with DR controls installed but not necessarily enabled, should see increased property values because the operating cost of buildings they own or lease could be reduced. This can make their property more attractive to future tenants or buyers since there would be a lower cost of operation. Reducing power consumption will reduce the use of the fuels that produce the needed electricity resulting in a positive statewide impact on power plant emissions. Air quality will improve reducing related illnesses and improving community health in general, which in turn should have an impact on the demand for health care services. The economic side benefit that results from cleaner air is increased commerce (productivity), which benefits everyone. Productivity is also increased because business will be able to remain open during times when they may have been inadvertently shut down by a blackout. This also reduces the amount of land and resources that must be dedicated to a larger electricity infrastructure. (PG&E 2007).

f. Environmental Impact

The Upgradeable Setback Thermostat measure does not have any adverse environmental impacts. The measure will lead to a decrease in emissions and decreased energy consumption by reducing energy usage during peak periods.

To implement Upgradeable Setback Thermostat, minor increases in raw-materials used to construct thermostats may be required. Thus slightly more copper, plastic, and other materials would be used in thermostats. The benefits of this measure are a reduction in the number of power plants needed and a reduction in the size of the transmission and distributions system. This reduces the amount of land and resources that must be dedicated to a larger electricity infrastructure. The emissions impacts of this measure are calculated by multiplying the change in statewide electricity and natural gas consumption by the hourly emissions factors. The statewide impacts will be estimated in the final report. The proposed change does not have any potential adverse environmental impacts. Because the proposed energy measure will reduce electricity use, this will reduce electricity generation, and thereby have a small reduction in mercury emissions from coal-burning power plants, and in water consumption from electricity generation. However, because the primary benefit is energy reduction, environmental benefits are not considered here, and all material uses are shown as No Change (NC).

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

	Mercury	Lead	Copper	Steel	Plastic	Others (Identify)
Per Unit Measure[1]	N/C	N/C	N/C	N/C	N/C	N/C
Per Prototype Building[2]	N/C	N/C	N/C	N/C	N/C	N/C

1. Specify the type of unit such as per lamp, per luminaire, per chiller, etc.

For description of prototype buildings refer to Methodology section below.

Water Consumption:

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Unit Measure[1]	N/C
Per Prototype Building[2]	N/C

1. Specify the type of unit such as per lamp, per luminaire, per chiller, etc.
2. For description of prototype buildings refer to Methodology section below.

Water Quality Impacts:

Comment on the potential increase (I), decrease (D), or no change (NC) in contamination compared to the basecase assumption, including but not limited to: mineralization (calcium, boron, and salts), algae or bacterial buildup, and corrosives as a result of PH change.

	Mineralization (calcium, boron, and salts	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	N/C	N/C	N/C	N/C
Comment on reasons for your impact assessment	Measure does not impact water consumption or discharge.	Measure does not impact water consumption or discharge.	Measure does not impact water consumption or discharge.	Measure does not impact water consumption or discharge.

g. Technology Measures

Upgradeable Setback Thermostats would be allowed in two configurations: (1) thermostats with a plug interface for a (removable) communication device, such as a USNAP card, and (2) thermostats with a built-in communicating device with a switch on the thermostat that can turn off the communication capability.

Measure Availability:

Our survey found no thermostat that met all of the requirements of the proposal. Some thermostats have a plug interface, which, when empty, renders the thermostat a Setback Thermostat such as those mandated under current code. However, these thermostats must be removed from the wall to disable communication violating the language of the proposed standard. Similarly, many thermostats have communication built in, but do not have a manual switch to disable communication. Some of these thermostats with built-in communication cannot receive a demand response signal unless this functionality is enabled via a website; however, they still violate the language of the proposed standard.

Manufacturers would modify their devices to comply with the standard if passed to remain compliant. Thermostats with a plug interface could be redesigned to allow access to the communication chip without removing the thermostat from the wall and manufacturers with built-in communication could add a manual switch that disables communication. While these changes are not expected to add significant cost when devices are produced at scale and averaged over a sufficiently long period of time, the fact remains that none of the current devices meet the standard and manufacturers would be forced to redesign existing devices.

The section below describes the products that nearly meet the standard. A survey of communicating thermostats is presented in Appendix 7.1 - Product Availability.

Several thermostats that accept a communication device were identified:

The USNAP Alliance is made up of manufacturers and suppliers who have joined together to create a plug-able communication module standard. The Alliance includes Radio Thermostat Company of America, Sensus, Zome Energy Networks, AzTech, ComVerge, eRadio, EnTek, GE Consumer & Industrial, Intwine, and others. Of these, the following manufactures produce either a thermostat or a Home Area Network which will control a thermostat based on communication received from a USNAP Module:

- Filtrete 3M-50 from 3M
- Radio Thermostat Company of America CT-30
- Comverge’s IntelliTEMP 900 Smart Thermostat
- Smarthome Venstar INSTEON programmable thermostats

No thermostat with built-in communications had the required external switch to turn communications off. There are, however, thermostats with built-in WiFi communication that connect to an external server. On this external server the user can control their thermostat via a web application, their iPhone, or other smart phone. Some of these websites can receive DR signals from the Utility. The consumer can control their enrollment with the Utility giving them the practical equivalent to a physical switch. Thermostats that fall into this category include:

- Intwine Energy IECT210 WiFi Thermostat
- Intwine Energy IECT220 WiFi Thermostat

Additionally, several manufacturers produce a thermostat that receives communications either from a Home Area Network (HAN) or over the internet from a website that can remotely control the device. Manufacturers include Control4, EnergyHub, Honeywell, Intwine, Proliphix, and Tendril. Devices by these manufactures are described in more detail in Appendix 7.1 - Product Availability.

Useful Life, Persistence, and Maintenance:

Thermostat life is not expected to be affected by communication requirements. Thus it seems likely that the service life of the UST would be very similar to that of the standard setback thermostat. The 1999 ASHRAE Applications Handbook estimates that the life of electronic controls is approximately 15 years[1]. We use this same assumption for estimating replacement period for residential and nonresidential USTs.

Thermostats with built-in communication may require replacement if a local utility changes communication protocols. Thermostats with a plug interface might not require replacement. However, the communication module would need to be replaced to support the new communication protocol.

[1] Table 3 “Estimates of service Lives of Various System Components.” P. 35.3, 1999 ASHRAE Applications Handbook, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

h. Performance Verification of the Proposed Measure	Compliant thermostats should be labeled as such by the manufacturer. Thermostats with built-in communication should either (1) use the protocol the local utility uses for demand response or (2) have the ability to connect to an outside website that re-distributes demand response signals.

i. Cost Effectiveness

Cost effectiveness of the UST is calculated using the life cycle cost methodology as required by the California Energy Commission. Each prototype model had a range of LCC calculated for each climate zone. The results presented here are for the scenario deemed to be the most likely, as described in the Energy Benefits section above. Detailed description of the LCC analysis is available in Section 4.5.

a	b	c		d		e		f	g	
Single Family UST	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit	Per Proto Bldg	Per Unit	Per Proto Bldg	Per Unit	Per Proto Bldg		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
CZ1	30	$68	$68					$71	-$2	-$71
CZ2	30	$68	$68					$1,582	-$1,514	-$1,582
CZ3	30	$68	$68					$1,075	-$1,007	-$1,075
CZ4	30	$68	$68					$1,712	-$1,643	-$1,712
CZ5	30	$68	$68					$0	$68	$0
CZ6	30	$68	$68					$1,308	-$1,240	-$1,308
CZ7	30	$68	$68					$1,706	-$1,637	-$1,706
CZ8	30	$68	$68					$1,464	-$1,396	-$1,464
CZ9	30	$68	$68					$3,229	-$3,160	-$3,229
CZ10	30	$68	$68					$3,273	-$3,205	-$3,273
CZ11	30	$68	$68					$4,180	-$4,112	-$4,180
CZ12	30	$68	$68					$3,582	-$3,514	-$3,582
CZ13	30	$68	$68					$2,669	-$2,601	-$2,669
CZ14	30	$68	$68					$2,295	-$2,227	-$2,295
CZ15	30	$68	$68					$1,941	-$1,873	-$1,941
CZ16	30	$68	$68					$2,637	-$2,568	-$2,637

a	b	c		d		e		f	g	
Multi-Family UST	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit	Per Proto Bldg	Per Unit	Per Proto Bldg	Per Unit	Per Proto Bldg		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
CZ1	30	$68	$547					-	n/a	n/a
CZ2	30	$68	$547					-	n/a	n/a
CZ3	30	$68	$547					$3,281	-$2,734	-$3,281
CZ4	30	$68	$547					-	n/a	n/a
CZ5	30	$68	$547					-	n/a	n/a
CZ6	30	$68	$547					$4,321	-$3,774	-$4,321
CZ7	30	$68	$547					-	n/a	n/a
CZ8	30	$68	$547					-	n/a	n/a
CZ9	30	$68	$547					$10,191	-$9,644	-$10,191
CZ10	30	$68	$547					-	n/a	n/a
CZ11	30	$68	$547					-	n/a	n/a
CZ12	30	$68	$547					$8,725	-$8,179	-$8,725
CZ13	30	$68	$547					-	n/a	n/a
CZ14	30	$68	$547					$5,316	-$4,769	-$5,316
CZ15	30	$68	$547					-	n/a	n/a
CZ16	30	$68	$547					$6,341	-$5,794	-$6,341

a	b	c		d		e		f	g	
Office - UST	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per	Per Proto	Per	Per Proto	Per	Per		(c+e)-f	(d+e)-f

		Unit	Bldg	Unit	Bldg	Unit	Proto Bldg		Based on Current Costs	Based on Post-Adoption Costs
CZ1	15	$68	$1,025					n/a	n/a	
CZ2	15	$68	$1,025					n/a	n/a	
CZ3	15	$68	$1,025					$6,151	-$5,125	
CZ4	15	$68	$1,025					n/a	n/a	
CZ5	15	$68	$1,025					n/a	n/a	
CZ6	15	$68	$1,025					$5,798	-$4,772	
CZ7	15	$68	$1,025					n/a	n/a	
CZ8	15	$68	$1,025					n/a	n/a	
CZ9	15	$68	$1,025					$7,067	-$6,042	
CZ10	15	$68	$1,025					n/a	n/a	
CZ11	15	$68	$1,025					n/a	n/a	
CZ12	15	$68	$1,025					$5,142	-$4,117	
CZ13	15	$68	$1,025					n/a	n/a	
CZ14	15	$68	$1,025					$3,205	-$2,180	
CZ15	15	$68	$1,025					n/a	n/a	
CZ16	15	$68	$1,025					$4,376	-$3,350	

Results for the LCC analysis for retail will be included in the final report.

1. **Current Measure Costs -** as is currently available on the market, and

Post Adoption Measure Costs - assuming full market penetration of the measure as a result of the new Standards, resulting in mass production of the product and possible reduction in unit costs of the product once market is stabilized.

It is assumed that the incremental cost of an upgradeable setback thermostat reduces to zero by the time the end of the useful life of the UST is reached (15 years). If the

Maintenance Costs - the initial cost of both the basecase and proposed measure must include the PV of maintenance costs (savings) that are expected to occur over the assumed life of the measure. The present value (PV) of maintenance costs (savings) must be calculated using the discount rate (d) described in the 2011 LCC Methodology. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows (where d is the discount rate): $PV\ Maint\ Cost = Maint\ Cost \times \left[\frac{1}{1+d}\right]^n$

4. **Energy Cost Savings -** the PV of the energy savings are calculated using the method described in the 2011 LCC Methodology report.

Residential measures are evaluated over a 30 year period of analysis. Nonresidential envelope measures are evaluated over a 30 year period of analysis and all other nonresidential measures are

evaluated over 15 year period of analysis. If the change is a mandatory measure or prescriptive requirement, then it is necessary to demonstrate cost effectiveness. See the "*Methodology*" and "*Analysis and Results*" sections below, and present the detailed analysis there.	
j. Analysis Tools	This measure is proposed as mandatory and will not require the use of analysis tools, because the measure is not subject to whole building trade-offs.
k. Relationship to Other Measures	Any improvement in efficiency of the HVAC system will reduce the potential load shed of demand responsive thermostats.

3. Methodology

This section describes the methodology followed to assess the savings, cost, and cost effectiveness of the proposed code change. The key elements of the methodology are as follows:

- Data Collection
- Development of Prototype Space Models
- Savings Analysis
- Cost Analysis
- Cost Effectiveness Analysis

This work was publicly vetted through our stakeholder outreach process, which through in-person meetings, webinars, email correspondence and phone calls, requested and received feedback on the direction of the proposed changes. The stakeholder meeting process is described at the end of the Methodology section.

3.1 Background

The capacity of the electric power system is determined by the maximum peak demand that the California electric system is called on to deliver. This capacity determines the number of power plants and peak period imports into California that are needed, as well as the size of the transmission and distribution system that must deliver this power. Controlling peak demand is an effective tool when balancing the electrical needs of a growing population against economic, environmental and other constraints (CEC and SCE 2006).

During system peaks, inefficient and marginal power plants are brought on line. These power plants emit more pollutants per kWh and thus controlling peak demand reduces the air emissions. Typically peak demand occurs during hot summer afternoons when the build-up of nitrogen oxides and photochemical smog is the highest. Thus controlling peak demand reduces air emissions when the need to curtail emissions is high.

Electricity prices on the wholesale market in California vary throughout the year. A few critical hours each year have extremely high demand leading to extremely high prices. These high prices make it expensive for utilities to meet peak demand. Resource adequacy rulings require utilities to purchase capacity to meet the system peak load -- potentially at considerable cost. Demand response can be counted towards this capacity reducing pressure on utilities to build new capacity in the form of generators.

The Federal Energy Regulatory Commission defines demand response as “a reduction in the consumption of electric energy by customers from their expected consumption in response to an increase in the price of electric energy or to incentive payments designed to induce lower consumption of electric energy" in Order No. 719.[2]

System reliability (ability to provide power) is increased if consumption can be reduced in a real time manner. When demand outstrips supply, California utilities must resort to rotating outages or blackouts to maintain acceptable system voltage and frequency. The total loss of power in a blackout results in substantial negative impacts to California consumers and industry. The purpose of demand response is to enhance grid reliability and prevent rolling blackouts, which would cause entire neighborhoods to lose all electrical power. The critical peak periods which can lead to the need for rolling blackouts are very rare events, only a few hours a year, so it is therefore more cost effective to have load shed available via demand response than to build large power plants to operate only a few hours a year to meet this load.

The high prices of peak-demand hours are generally averaged into the summer rate or summer, peak-period rate in the most common rate designs in California. However, California utilities are moving towards Peak Day pricing rates that pass the cost of delivering power during these critical periods to the customers consuming during these critical periods. Peak Day pricing rates provide correspondingly lower prices at other times. The critical peak hours do not occur during fixed time periods as is the case for Time-Of-Use (TOU) rates. Instead the Peak Day rates increase rates when the availability of electricity relative to the system wide demand is low.

Peak Day pricing will create an opportunity for consumers to manage their bills. Because customers will be notified of Peak Day events, consumers can reduce their usage during events and realize savings on their electricity bills. The communicating thermostat is an enabling technology that allows customers to automatically manage their air conditioning load in response to the critical price or load curtailment signal. However, to preserve the customer's option to preserve comfort, albeit at an increased cost determined by the rate, the Upgradeable Setback Thermostat must allow the consumer to override the signal.

Additionally, the ability to manage electric load on-demand has the potential to offset the reliability issues associated with renewable energy sources such as solar and wind energy. This ability to manage peak loads could enable California to overcome some of the hurdles associated with meeting the Renewable Portfolio Standards (RPS) goals of 33% by 2020[3].

3.2 Data Collection

HMG conducted an assessment of the demand responsive thermostat market. The purpose of the assessment was to gather supporting data to characterize the following aspects of the DR HVAC market, to estimate the savings from communicating thermostats, and to inform a discussion among

[2] See Wholesale Competition in Regions with Organized Electric Markets, Order No. 719, FERC Stats. & Regs. ¶ 31,281 (2008), order on reh'g, Order No. 719-A, 74 Fed. Reg. 37,776 (Jul. 29, 2009), FERC Stats. & Regs. ¶ 31,292 (2009), order on reh'g, Order No. 719-B, 129 FERC ¶ 61,252 (2009).

[3] http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33implementation.htm

the utilities and manufacturers about the potential requirements for communicating demand responsive thermostats. Types of information collected include, but are not limited to:

- The major types of Demand Response programs offered to customers
- Participation rates of customers in DR programs
- Load shed potential from residential air conditioners
- Technologies enabling load shed of residential air conditioners

This assessment entailed online research of products currently available on the market that enabled demand responsive control of residential HVAC loads, an online survey of stakeholders, and discussions with manufacturers via email, phone, and in-person meetings.

3.2.1 Survey

HMG developed an online survey to gain insight into the current state of the communicating thermostats market as well as potential paths leading into the future. The survey was distributed to manufacturers that were involved in the stakeholder process related to the Title 24 CASE study about demand responsive communicating thermostats.

3.2.2 Technology

We contacted several manufacturers to collect information about product features, availability and price of the various components of a communicating thermostat. Methods of communication include emails, phone calls, meetings in person, and internet research. The findings are presented below in Section 4.2 - Technology.

3.3 Development of Prototype Building

For single family savings the Prototype D (Figure 2) building was chosen. This is the standard design described in the 2008 Residential ACM Manual. Prototype D is a 2,700 ft^2, two-story detached home. Details are available from the California Energy Commission. This building type is expected to be impacted most by the proposed measure. For this reason, the single family model simulation was performed for all 16 Title 24 California building climate zones.

For multi-family savings, the multi-family Prototype E (Figure 3) building was chosen. This is the standard design as described in the 2008 Residential ACM. Prototype E is an eight-unit, two-story multi-family building, with a total conditioned area of 6,960 ft^2. Details are available from the California Energy Commission. Based on common practice, it is expected that a relatively low percent of multi-family dwelling units will meet the conditions that trigger the requirement for an upgradeable setback thermostat is expected to be relatively low. Therefore six climate zones were chosen that are deemed to be representative of the range of weather in California (3, 6, 9, 12, 14, 16) and simulations were run for those representative climate zones.

For nonresidential savings, the analysis used the Medium Office from the DOE set of reference building EnergyPlus models. This is a three-story building, with 5 zones plus plenum per floor. There is a core zone with four perimeter zones on each floor. This model was chosen because it simulates the energy impacts over a variety of layouts. The building is 164 ft. long by 109 ft. wide, for a total area of 53,630 ft² (17,877 ft² per floor). Floor to floor height is 13 ft.

Due to time constraints, this same building was used to also model the energy impacts in a retail scenario. The different occupancy type was simulated by varying the operating schedule, occupant density, lighting power density, equipment power density, and ventilation rate according to Table N2-6 of the nonresidential ACM.

The following parameters were included in the nonresidential analysis:

- Climate zones 3, 6, 9, 12, 14 and 16 were deemed to be representative of the range of weather in California. This set of six representative climate zones was analyzed instead of all 16 Title 24 climate zones due to time and budget constraints.
- Thermostat setback of 0 (base case) and 4 degrees Fahrenheit
- Window to Wall Ratio of 30%

	Occupancy Type (Residential, Retail, Office, etc)	Area (Square Feet)	Number of Stories	Other Notes
Prototype 1	Residential – Single Family	2,700	1	Prototype D defined in Residential ACM manual, having 20% fenestration equally distributed.
Prototype 2	Residential – Multi-Family	6,960	2	Prototype E defined in Residential ACM manual, eight dwelling units.
Prototype 3	Nonresidential – Office	53,630	3	Five zones (plus plenum) per floor, 30% WWR, 2008 prescriptive envelope and HVAC requirements
Prototype 4	Nonresidential – Retail	53,630	3	Five zones (plus plenum) per floor, 30% WWR, 2008 prescriptive envelope and HVAC requirements

Figure 2 Prototype D

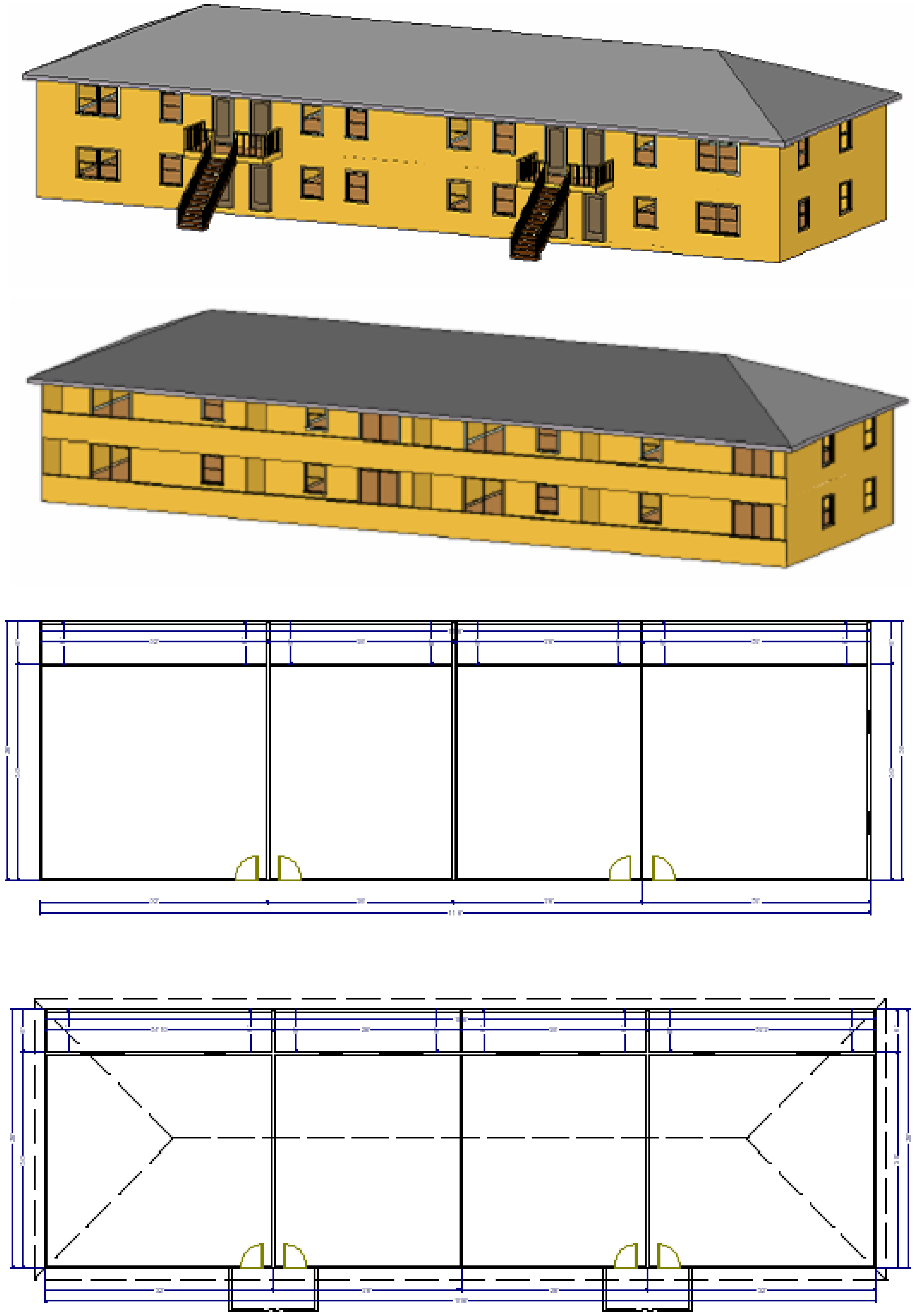

Figure 3 Prototype E

3.4 Savings Analysis Methodology

DOE-2.2 simulation models were created for single family homes, low-rise multi-family homes, office buildings and retail buildings. Simulations for the single family model were run in all 16 climate zones (CZs) as defined in the Title 24 building efficiency standards. Due to time and budget constraints, the remaining multi-family, office and retail simulation models were run in six of the 16 climate zones. The six climate zones analyzed included CZ 3, 6, 9, 12, 14 and 16; which were deemed to be representative of the range of weather in California. These four prototypes are considered to be mostly representative for all buildings in California that will be affected by this measure. Results for an additional small retail building will be included in the final report.

The exact hours of demand response were determined separately for each climate zone. Residential demand response hours were based on the Residential 30-year TDV values while Nonresidential demand response hours used the nonresidential 15-year TDV values. Peak “DR” hours were identified as the 88 hours with the highest TDV (top 1%) for each climate zone. These hours reflect both the hottest days of the year and the hours when energy prices are highest in the California wholesale energy market.

The residential simulation models were run in Micropas for two conditions; standard and curtailment. The standard model uses the “Whole House” hourly thermostat set points as detailed in Table R3-1 of the 2008 Residential ACM Manual (Figure 4). The curtailment scenario was simulated by increasing the temperature set point by 4˚F in the models during the 88 hours of the year with the highest TDV. The curtailment periods ranged from a solitary hour to as many as nine (9) consecutive hours. The demand response energy usage was subtracted from the standard energy usage to calculate savings. Thus these two Micropas models are used to develop the technical demand and energy savings potential estimates in the residential sector. Savings were translated to annual TDV and peak values using CEC approved factors.

Table R3-1 – Hourly Thermostat Set Points

	Whole House		Zonal Control Living Areas		Zonal Control Sleeping Areas		
Hour	Heating	Cooling	Heating	Cooling	Heating	Cooling	Venting
1	65	78	65	83	65	78	Off
2	65	78	65	83	65	78	Off
3	65	78	65	83	65	78	Off
4	65	78	65	83	65	78	Off
5	65	78	65	83	65	78	Off
6	65	78	65	83	65	78	68
7	65	78	65	83	65	78	68
8	68	83	68	83	68	83	68
9	68	83	68	83	65	83	68
10	68	83	68	83	65	83	68
11	68	83	68	83	65	83	68
12	68	83	68	83	65	83	68
13	68	83	68	83	65	83	68
14	68	82	68	82	65	83	68
15	68	81	68	81	65	83	68
16	68	80	68	80	65	83	68
17	68	79	68	79	65	83	68
18	68	78	68	78	65	83	68
19	68	78	68	78	65	83	68
20	68	78	68	78	65	83	68
21	68	78	68	78	65	83	68
22	68	78	68	78	68	78	68
23	68	78	68	78	68	78	68
24	65	78	65	83	65	78	Off

Figure 4 Thermostat Hourly Set Points from 2008 Residential ACM Manual

The nonresidential simulation models were developed in eQuest using an office model that had been developed for the occupancy sensor controlled HVAC CASE measure. These prototypes are described above in Section 3.3. The occupancy assumptions for the nonresidential models are derived from Table N2-6 of the 2008 Nonresidential ACM Manual. The nonresidential simulation models were run in eQuest for three conditions; base case, curtailment of 2 degrees Fahrenheit, and curtailment of 4 degrees Fahrenheit. The curtailment scenarios were simulated by increasing the temperature set point by 2˚F and 4˚F in the models respectively, during the 88 hours of the year with the highest TDV. The curtailment periods ranged from a solitary hour to as many as nine (9) consecutive hours. The demand response energy usage scenarios were subtracted from the base case energy usage to calculate savings. Thus these two eQuest models are used to develop the technical demand and energy savings potential estimates for the commercial sector. Savings were translated to annual TDV and peak values using CEC approved factors.

Sub-Occupancy Type (1)	People per 1000 ft^2 (2)	Sensible heat per person (3)	Latent heat per person (3)	Receptacle Load W/ft^2 (4)	Hot water Btu/h per person	Lighting W/ft^2 (5)	Ventilation CFM/ ft^2 (6)
Office (Greater than 250 square feet in floor area)	10	250	200	1.5	120	0.9	0.15
Office (250 square feet in floor area or less)	10	250	200	1.5	120	1.1	0.15
Retail Merchandise Sales, Wholesale Showroom (Note 10)	33	250	200	1.0	120	1.6	0.25
Tenant Lease Space	10	250	200	1.5	120	1.0	0.15
Theater, Motion Picture) (Note 10)	143	245	105	0.5	60	0.9	1.07
Theater, Performance) (Note 10)	143	245	105	0.5	60	1.4	1.07
Transportation Function (Note 10)	33	250	250	0.5	120	1.2	0.25
Waiting Area	10	250	250	0.5	120	1.1	0.15
All Others	10	250	200	1.0	120	0.6	0.15

(1) Subcategories of these sub-occupancies are described in Section 2.4.1.1 (Occupancy Types) of this manual.

(2) Values based on one half the maximum occupant load for exiting purposes in the CBC. Full value for design conditions. Full year operational schedules reduce these values by up to 50% for compliance simulations and full year test simulations.

(3) From Table 1, p. 29.4, ASHRAE 2001 Handbook of Fundamentals.

(4) From Lawrence Berkeley Laboratory study. This value is fixed and includes all equipment that is plugged into receptacle outlets.

(5) From Table 146-F of the Standards for the applicable occupancy. Compliance software shall use this value for the standard building design when lighting compliance is performed for the zone or area in question.

(6) Developed from 121 and Table 121-A of the Standards.

(7) Refer to residential water heating method.

(8) The use of this occupancy category is an exceptional condition that shall appear on the exceptional conditions checklist and thus requires special justification and documentation and independent verification by the local enforcement agency.

(9) For hotel/motel guest rooms and high-rise residential living spaces all these values are fixed and are the same for both the proposed design and the standard design. Compliance software shall ignore user inputs that modify these assumptions for these two occupancies. Spaces in high-rise residential buildings other than living spaces shall use the values for Housing, Public and Common Areas (either multi-family or senior housing).

(10) For these occupancies, when the proposed design is required to have demand control ventilation by § 121 (c) 3 the ventilation rate is the minimum that would occur at any time during occupied hours. Additional ventilation would be provided through demand controlled ventilation to maintain CO_2 levels according to § 121.

Figure 5 Office and Retail figures for Table N2-6 of the Nonresidential ACM

The energy savings are based on the following assumptions:

- Customers are enrolled in a time-of-use with peak day pricing (critical peak pricing) rate by their electricity provider - 30% opt out (These rate structures are the default for commercial customers in California IOU territory, and are likely to be the default for residential customers by 2014)
- Customers respond to the top 1% of hourly prices (approximately 88 hours each year)
- Customers respond by allowing their thermostat to automatically setback the cooling set point by four (4) degrees Fahrenheit.
- 10% of customers override the automated demand response for each peak hour

Demand Savings is calculated as the average demand savings for the Peak Period as defined by the CPUC for calculating program savings; which includes all weekday hours between 12pm and 6pm for July through September.

The PG&E Peak Day Pricing program for small/medium commercial customers serves as an example for a demand response program structure[4], being the most recently implemented of the IOU rate based Demand Response programs. Key points are summarized below:

- 9-15 event days each year
- Each event day lasts 4 or 6 hours

Assuming 6 hours of participation on 15 days each year provides for 90 hours of demand response annually. This an almost identical number of hours as identified by selecting the top one percent of TDV values (88). Dynamic price rates such as Peak Day Pricing enhance the ability of utility rates to reflect the true cost of providing energy at different times of the day and year, representing the peaks in TDV values more closely than before.

3.5 Cost Analysis Methodology

Thermostat costs were gathered from The Home Depot's website and other online retailers. For each thermostat, the name, vendor, model number, program type (7-day, 5-2, or 5-1-1), communication type, price, power source, and the date information was collected.

- On The Home Depot's website the following was recorded:
  - The lowest cost programmable thermostat that meets current Title 24 requirements
  - All programmable communicating thermostats
  - All alternative products offered by companies selling programmable communicating thermostats
  - Products comparable to the communicating thermostats from Honeywell, a randomly chosen well-known supplier.
- The lowest cost communicating thermostat on Amazon.com was recorded.
- The lowest cost communicating thermostat with U-Snap was recorded on Radio Thermostat Company of America's website.

Together, these prices support cost analysis for communicating thermostat requirements. Communicating thermostats from one brand can be compared to non-communicating thermostats by the same brand to quantify the cost of adding communications from the consumers' point of view. Comparing current communicating thermostats to the lowest cost model on the market provides data for a worst-case cost comparison.

[4] http://www.pge.com/mybusiness/energysavingsrebates/demandresponse/peakdaypricing/facts/charges/

3.6 Cost Effectiveness Analysis

HMG calculated lifecycle cost using methodology explained in the California Energy Commission report *Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards*, written by Architectural Energy Corporation, using the following equation:

$$\Delta LCC = Cost\ Premium - Present\ Value\ of\ Energy\ Savings$$ [1]

$$\Delta LCC = \Delta C - (PV_{TDV\text{-}E} * \Delta TDV_E + PV_{TDV\text{-}G} * \Delta TDV_G)$$

Where:

ΔLCC change in life-cycle cost

ΔC cost premium associated with the measure, relative to the base case

$PV_{TDV\text{-}E}$ present value of a TDV unit of electricity

$PV_{TDV\text{-}G}$ present value of a TDV unit of gas

ΔTDV_E TDV of electricity

ΔTDV_G TDV of gas

We used a 15-year lifecycle as per the LCC methodology for nonresidential HVAC control measures and a 30-year lifecycle per LCC methodology fir residential measures. LCC calculations were completed for each building prototype in six (6) climate zones deemed representative of the range of weather in California. Analysis was performed for three scenarios, pessimistic, base case and optimistic. The base case contains our best estimate of the likely outcome. This provided a range of cost effectiveness to accommodate for varying scenarios.

The parameters modified to perform the scenario analysis for the life cycle cost analysis are outlined in Figure 6.

	Pessimistic	Base case	Optimistic
Annual Hours of Curtailment	88	88	88
Temperature Set-up (degrees Fahrenheit)	4	4	4
Fraction of Population Participating	25%	70%	100%
Fraction overriding voluntary signal - Residential	30%	10%	5%
Fraction overriding voluntary signal - Nonresidential	20%	10%	5%

Figure 6 Scenario Analysis Assumptions

[1] The Commission uses a 3% discount rate for determining present values for Standards purposes.

3.7 Stakeholder Meeting Process

All of the main approaches, assumptions and methods of analysis used in this proposal have been presented for review at one of three public Stakeholder Meetings funded by the California investor-owned utilities (Pacific Gas and Electric, Southern California Edison, and Southern California Gas Company).

At each meeting, the utilities' CASE team asked for feedback on the proposed language and analysis thus far, and sent out a summary of what was discussed at the meeting, along with a summary of outstanding questions and issues.

A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at www.calcodesgroup.com. Stakeholder meetings were held on the following dates and locations:

- Controls and DR topics Stakeholder Meeting 1: July 7th, 2010, San Ramon Conference Center, San Ramon, CA.
- Communicating Thermostat Market Status Meeting: August 23rd, 2010, Southern California Edison Energy Education Center, Irwindale, CA.
- Controls and DR topics Stakeholder Meeting 3: June 1st, 2011, online webinar.

4. Analysis and Results

This section contains detailed energy and cost savings results that are summarized in the energy benefits section of the overview.

4.1 Data Collected

HMG conducted a survey of manufacturers, the full results of which are presented in Appendix 7.2. The survey was distributed online to manufacturers that were involved in the stakeholder process. A limited response was received; the six respondents covered both small and large thermostat manufacturers, in addition to a producer of home management solutions for energy, water and security. The survey consisted of several multiple choices and open ended questions.

Of the five (5) manufacturers that responded to the survey, three produce thermostats, one produces Home Area Networks or Energy Network Gateways, two produce software, and two produce communication modules. Some manufacturers worked in more than one portion of this market.

Responses in Figure 7 show that the manufacturers plan to produce communicating thermostats at a variety of price points. The distribution of products was even across all price points.

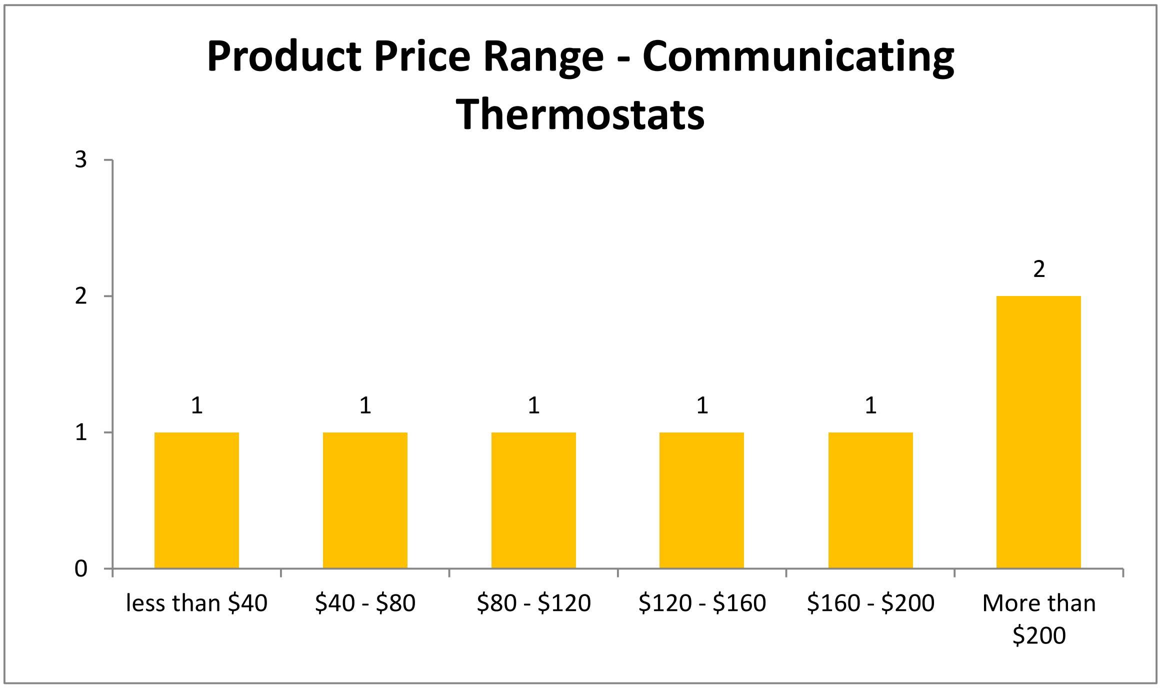

Figure 7 Price range of communicating thermostats

All manufacturers indicated they provide WiFi communication (Figure 8). The next most commonly supported communication types was ZigBee. HomePlug and BlueTooth communication were each supported by one manufacturer. The types of external communication recorded as “Other” included ClimateTalk and swappable radio modules.

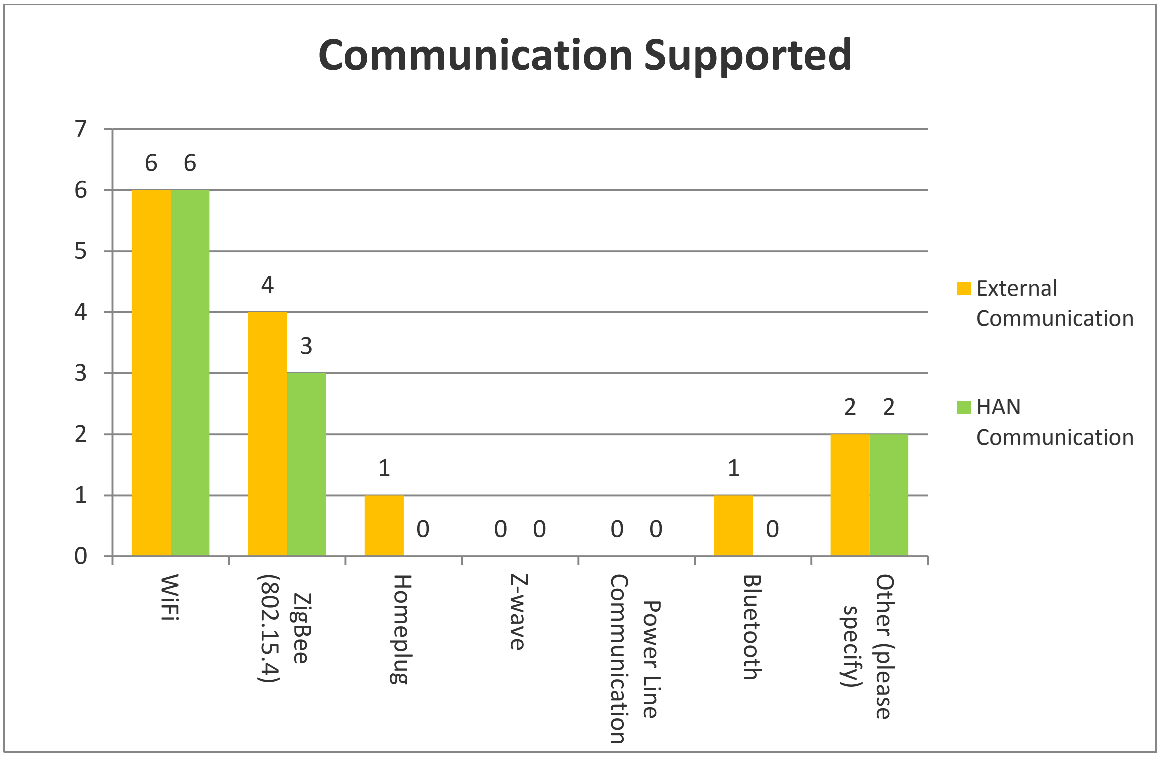

Figure 8 External and HAN communication of thermostats

The full results of the survey are available in Appendix 7.2.

4.2 Technology

The ability to manage peak demand will require communication between the utilities providing information about price or a request to shed load, and appliances in the home or place of business. Air conditioning is the largest load that coincides with peak days, which usually occur on hot summer afternoons. According to the CPUC, residential and commercial air-conditioning represent more than 30% of summer peak electricity loads[5].

The cost of electricity is highest during times of peak demand. Reducing peak demand decreases the average cost of electricity and increases economic efficiency. The move to time-of-use with peak-day pricing structures reinforces the importance of being able to manage demand in response to electricity prices. The upgradeable setback thermostat (UST) is an enabling technology that allows customers to automatically control their air conditioning set point in response to elevated prices events or demand response dispatch signals. Studies have shown that the use of enabling technology, such as a

[5] http://www.cpuc.ca.gov/cfaqs/howhighiscaliforniaselectricitydemandandwheredoesthepowercomefrom.htm

communicating thermostat, provides almost double the load impact of demand response using pricing or incentives alone (Faruqui and Sergici 2010).

Another method of managing energy use is to network the various appliances and control them from a central interface. This is a growing sector and it is popular because it enables scheduling and manual control of disparate end uses. The origin of the residential energy network design was homeowner convenience, but it is now being applied to demand response in the home.

One recently released device in this arena, The Smart Grid Home Controller by BuLogics[6], receives utility protocol information from the smart meter translates it for consumption by appliances utilizing the Z-Wave Home Area Network. This translation feature makes the device a "bridge" between the protocols. The BuLogic Smart Grid Home Controller can control devices using many protocols including ZigBee Smart Energy Profile.

Another similar device is the EnergyHub Home Base which controls thermostats and plug loads using ZigBee. The EnergyHub Home Base is able to receive commands from the utility over the internet, or from the meter using Itron's® ERT® or ZigBee.

One advantage of having a gateway is that the communications used by in home appliances (thermostats, water heaters, et cetera) would not need to change if the Advanced Metering Infrastructure were to change communication protocols. Instead of changing all devices to a new protocol, only the bridge, or gateway, would need to be changed. Costs and savings associated with using a residential energy network were not analyzed for this measure.

4.3 Savings Analysis

Savings are calculated separately for residential and nonresidential buildings. For both sectors the top 1% (88 hours) of TDV values have been identified. The residential analysis uses the 30-year Residential TDV values, while the commercial analysis uses the 15-year nonresidential TDV values.

We assume that customers are price responsive to the top 1% of hours, and therefore will treat 88 hours of the year as demand response events. We assume that customers will increase their HVAC set point by 4˚F during each demand response period, and that 10% of customers will override the automatic load shed during each demand response period. We also assume that a critical peak pricing program conducive to demand response participation is the default rate for all customers and 30% of customers opt-out of this rate. Due to time and budget constraints, the savings for the multi-family and nonresidential scenarios are calculated for climate zones 3, 6, 9, 12, 14, and 16, which were deemed to be representative of the range of weather in California. The analysis for the single family prototype building was performed for all 16 California climate zones. Demand Savings is calculated as the average demand savings for the Peak Period as defined by the CPUC for calculating program savings; which includes all weekday hours between 12pm and 6pm for July through September.

[6] http://www.bulogics.com/smartgrid.html

4.3.1 Residential Savings

The results of the Micropas residential simulation models are presented in

	Single Family Dwelling savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Residential TDV $ Value
CZ1	3	0.00	$71
CZ2	26	0.00	$1,582
CZ3	15	0.00	$1,075
CZ4	28	0.00	$1,712
CZ5	0	0.00	$0
CZ6	18	0.00	$1,308
CZ7	25	0.51	$1,706
CZ8	32	0.18	$1,464
CZ9	58	0.49	$3,229
CZ10	66	0.70	$3,273
CZ11	89	-0.01	$4,180
CZ12	80	-0.01	$3,582
CZ13	84	0.79	$2,669
CZ14	78	0.47	$2,295
CZ15	96	0.01	$1,941
CZ16	52	1.24	$2,637

Figure 9 for the single family and multi-family prototypes. These results are the technical potential of savings without being adjusted to account for rates of participation or user-override. The results are calculated by subtracting the standard case from the proposed curtailment scenario; thus positive numbers indicate savings. It is important to remember that the single family prototype is a 2,700 square foot dwelling with a single HVAC zone (one thermostat). The multi-family prototype is a 6,960 square foot prototype with eight individual dwelling units, this eight separate HVAC zones (eight thermostats). Each multi-family dwelling unit is assumed to be the same size; 870 square feet. The first group of columns titled “kTDV/ft2-yr” is multiplied by the square footage of the model to calculate the TDV-dollar savings.

Some of the climate zones show negative demand impacts. This could be a result of the rebound effect after a demand response event for air conditioning. However, the magnitudes of the adverse effects on demand are small enough to be within the margin of error.

	Single Family Dwelling savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Residential TDV $ Value
CZ1	3	0.00	$71
CZ2	26	0.00	$1,582
CZ3	15	0.00	$1,075
CZ4	28	0.00	$1,712
CZ5	0	0.00	$0
CZ6	18	0.00	$1,308
CZ7	25	0.51	$1,706
CZ8	32	0.18	$1,464
CZ9	58	0.49	$3,229
CZ10	66	0.70	$3,273
CZ11	89	-0.01	$4,180
CZ12	80	-0.01	$3,582
CZ13	84	0.79	$2,669
CZ14	78	0.47	$2,295
CZ15	96	0.01	$1,941
CZ16	52	1.24	$2,637

Figure 9 Micropas Results for Single Family Simulation of 4˚F Setback

Multi-Family Dwelling savings per unit (UST)			
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Residential TDV $ Value
CZ3	5	0.00	$410
CZ6	7	0.00	$540
CZ9	17	0.28	$1,274
CZ12	21	0.00	$1,091
CZ14	21	0.14	$664
CZ16	14	0.40	$793

Figure 10 Micropas Results for Multi-Family Simulation of 4˚F Setback

The savings for the residential models are shown by climate zone in Figure 11. Savings are presented in TDV dollars per thermostat zone. Each multi-family dwelling unit is approximately one-third the size of the single family dwelling unit, helping to explain why the savings are so much greater for the single family scenario. The savings values presented in Figure 11 have been reduced by the base case assumptions of a 70% participation rate and 10% override rate.

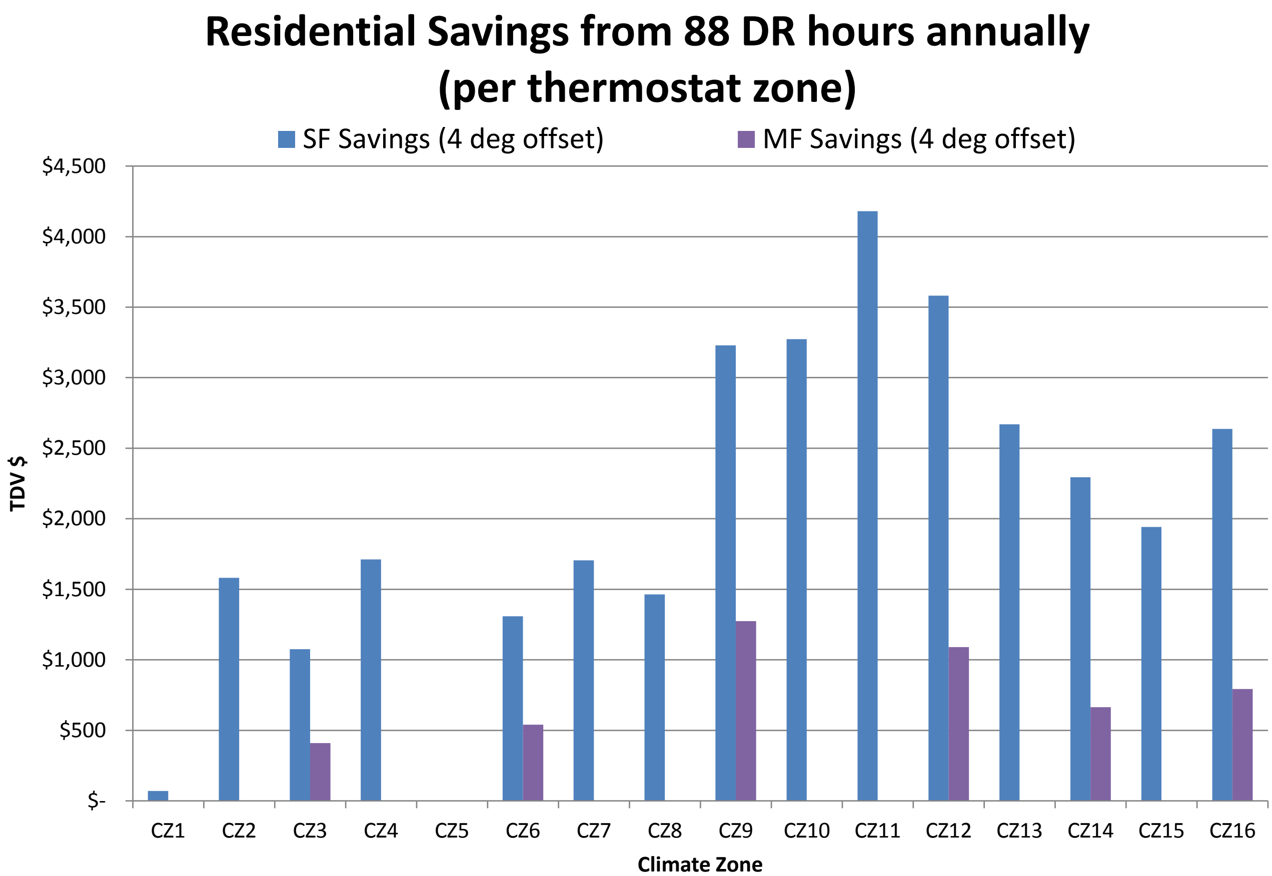

Figure 11 Residential Savings per UST by Climate Zone

4.3.2 Nonresidential Savings

The results of the eQuest nonresidential simulation models are presented in

	Office savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Office TDV Electricity $ Savings
CZ3	27	0.09	$410
CZ6	23	0.09	$387
CZ9	26	0.12	$471
CZ12	22	0.11	$343
CZ14	17	0.08	$214
CZ16	18	0.08	$292

Figure 12 and

	Retail savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Retail TDV Electricity $ Savings
CZ3	37	0.12	$557
CZ6	31	0.12	$506
CZ9	25	0.12	$437
CZ12	30	0.15	$473
CZ14	31	0.15	$388
CZ16	28	0.13	$435

Figure 13 for the office and retail prototypes, respectively. These values represent the technical potential of the savings of a 4 degree Fahrenheit setback on each of the 88 top hours of the year. The dollar value is calculated using the nonresidential 15-year TDV multipliers. Savings for the nonresidential sector were modeled based on the prototype described in Section 3.3 - Development of Prototype Building. The prototype buildings included 15 thermostat zones (five per floor) in the 53,630 ft² model. The parameters regarding operating schedule, occupant density, lighting power density, equipment power density, and ventilation rate were varied to simulate occupancy type according to Table N2-6 of the nonresidential ACM.

	Office savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Office TDV Electricity $ Savings
CZ3	27	0.09	$410
CZ6	23	0.09	$387
CZ9	26	0.12	$471
CZ12	22	0.11	$343
CZ14	17	0.08	$214
CZ16	18	0.08	$292

Figure 12 Office Prototype eQuest Results (4˚F Setback)

	Retail savings per unit (UST)		
Climate Zone	Electricity Savings (kWh)	Demand Savings (kW)	Retail TDV Electricity $ Savings
CZ3	37	0.12	$557
CZ6	31	0.12	$506
CZ9	25	0.12	$437
CZ12	30	0.15	$473
CZ14	31	0.15	$388
CZ16	28	0.13	$435

Figure 13 Retail Prototype eQuest Results (4˚F Setback)

Savings in 15-year nonresidential TDV dollars per upgradeable setback thermostat are presented in Figure 14 for both the office and retail prototypes. These values have been adjusted to reflect the base case assumption of 70% participation rate and 10% override rate.

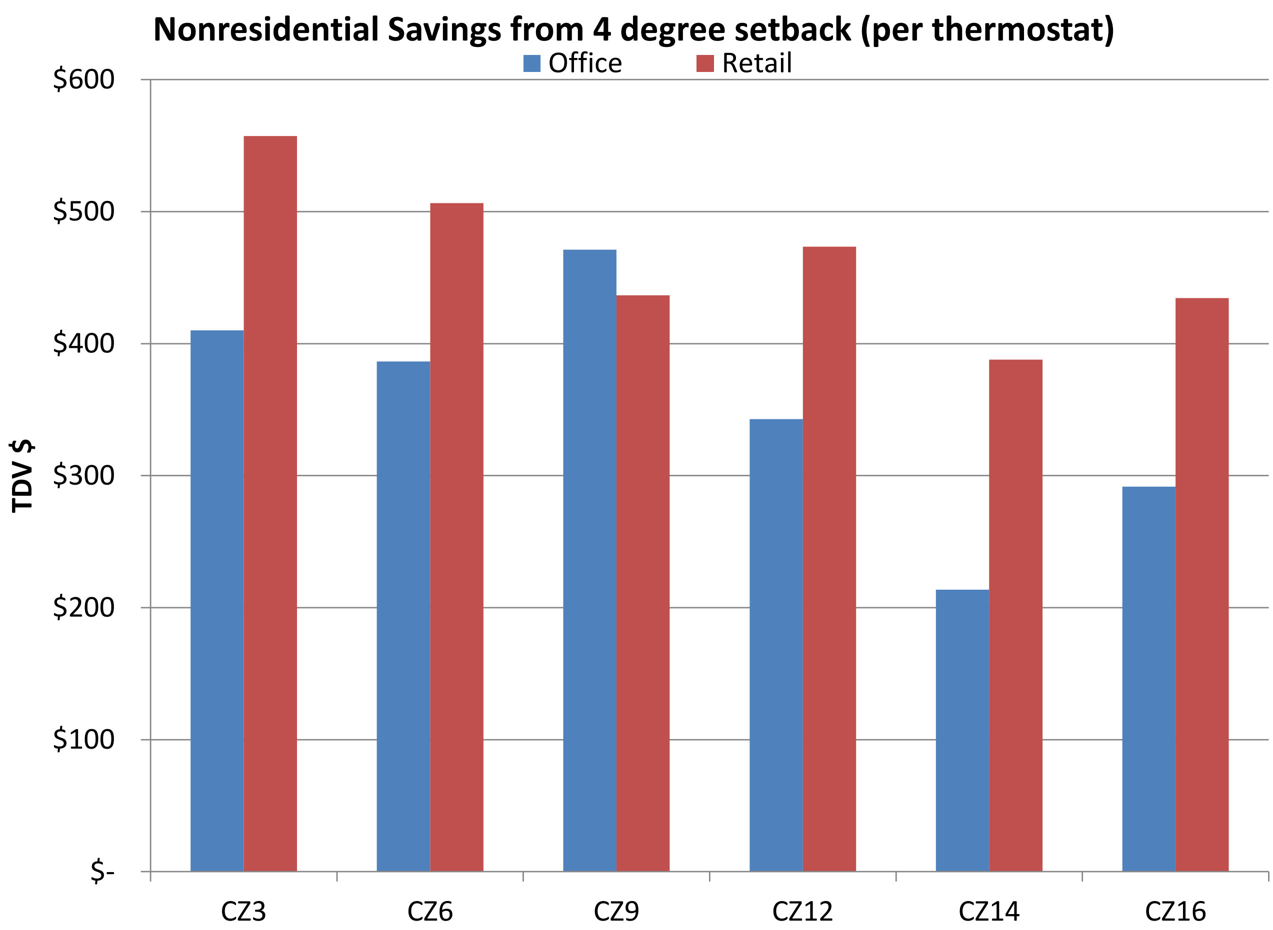

Figure 14 Nonresidential Savings per UST by Climate Zone

4.4 Cost Analysis

In addition to the information collected by the survey of manufacturers, prices of communicating thermostats currently available were obtained from the websites of prominent retailers such as the Home Depot, Amazon.com and PexSupply.com.

The incremental cost of a compliant thermostat is estimated to be $68.36. Based on the 1999 ASHRAE estimate of median useful lifespan for electronic controls, we assume that the thermostat will be replaced every fifteen years. This means that the cost per unit of the proposed measures is $68.36. The Residential sector uses a 30-year lifecycle, which would require replacement of the thermostat after 15 years based on the estimated useful life (ASHRAE 1999). However, it is assumed that the 15 years after this measure is adopted into code, the incremental cost will have dropped to zero.

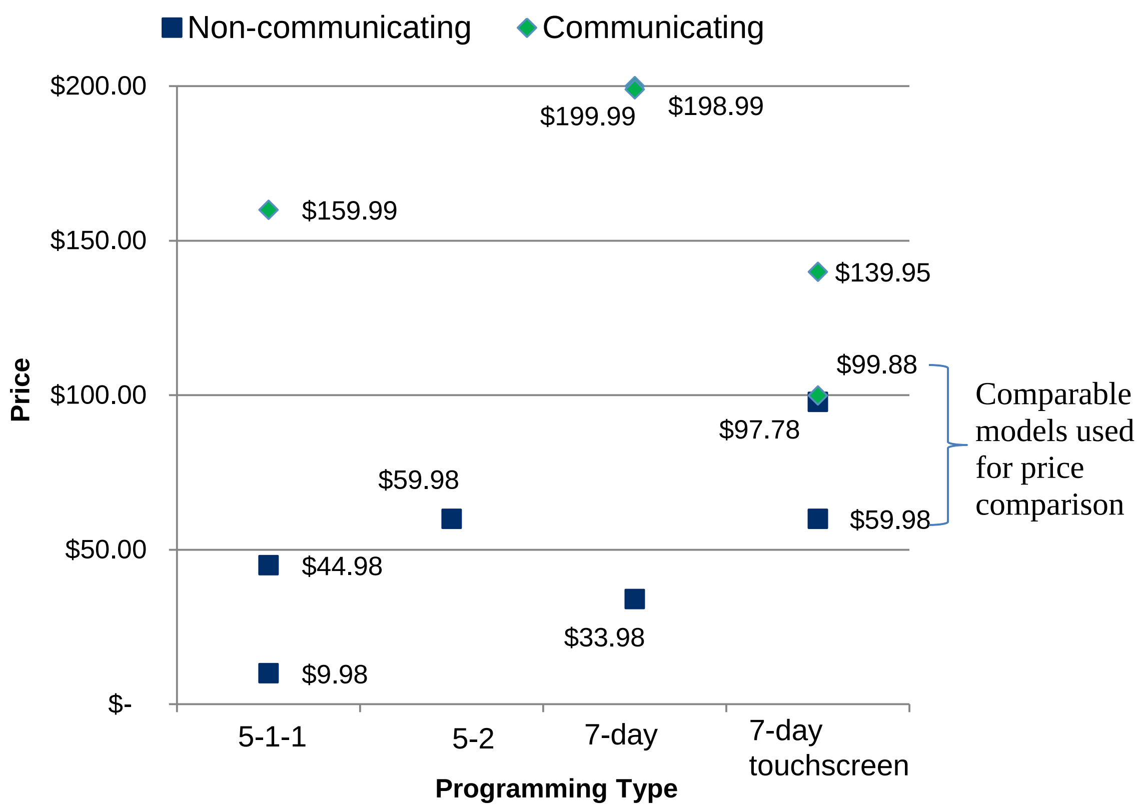

Figure 15 Cost of Thermostats Collected from HomeDepot.com

The basis for estimating the marginal cost comes from the survey of thermostats available at HomeDepot.com. A 7-day programmable touchscreen thermostat was identified in two distinct configurations; one without any communication capabilities and one with two USNAP ports and a WiFi communication module included. The cost difference between these two models is $39.90. On the same website a thermostat adapter is available for $96.82 which adds INSTEON compatibility to a 7-day or 5-1-1 day programmable thermostat. INSTEON is a proprietary home automation network protocol that uses radio frequency and powerline communications.

4.5 Cost Effectiveness Analysis

The savings calculated from USTs is dependent upon the assumptions one uses for participation rates, rate design etc. Thus we have developed three scenarios from a pessimistic estimate of savings to an optimistic estimate of savings. Along this continuum in the middle is the "base" scenario which we believe to be a reasonably likely outcome of the statewide application of thermostats and a supporting utility rate design that returns most of the resource acquisition value to UST owners who allow their thermostat to be set-up during the curtailment periods.

In nonresidential buildings, the life of the thermostat is same as the period of analysis, 15 years. Therefore the present value of the incremental equipment cost is the same as the incremental first cost, or approximately $68.

A scenario analysis shows the cost effectiveness under various assumptions. The assumptions for each scenario are detailed in Figure 6. For the base case, we assume that 70% of the population participates in the DR programs (30% opt out of any demand response pricing program), demand response events are triggered during the 88 highest value hours of the year (top 1%), and 10% of the participants override the four degree setback during each event. For this scenario, the savings exceed the cost of the thermostat.

The results in

Single family LCC Scenario Analysis	**Pessimistic**	**Base case**	**Optimistic**
CZ1	0.29	1.03	1.56
CZ2	6.43	23.14	34.90
CZ3	4.37	15.73	23.72
CZ4	6.95	25.04	37.76
CZ5	0.00	0.00	0.00
CZ6	5.31	19.13	28.85
CZ7	6.93	24.95	37.63
CZ8	5.95	21.42	32.30
CZ9	13.12	47.23	71.22
CZ10	13.30	47.88	72.20
CZ11	16.99	61.15	92.21
CZ12	14.56	52.40	79.02
CZ13	10.85	39.04	58.88
CZ14	9.33	33.57	50.62
CZ15	7.89	28.40	42.82
CZ16	10.71	38.57	58.16

Figure 16 and

Retail LCC Scenario Analysis	**Pessimistic**	**Base case**	**Optimistic**
CZ3	2.26	8.15	12.29
CZ6	5.54	19.93	30.05
CZ9	1.77	6.39	9.63
CZ12	1.92	6.93	10.44
CZ14	1.58	5.67	8.56
CZ16	1.77	6.36	9.59

Figure 19 indicate the cost-effectiveness is dependent on climate zone, and even more highly dependent upon the scenario of assumptions used to calculate savings; but that USTs are generally cost-effectiveness across almost all scenarios and climate zones. Our best estimate at predicting savings (the base case) indicates that USTs are cost-effective everywhere except climate zones 1 and

5 due to the low cooling load in those areas. However, the results are dependent upon the rules that are created for demand response programs and how people respond.

Single family LCC Scenario Analysis	Pessimistic	Base case	Optimistic
CZ1	0.29	1.03	1.56
CZ2	6.43	23.14	34.90
CZ3	4.37	15.73	23.72
CZ4	6.95	25.04	37.76
CZ5	0.00	0.00	0.00
CZ6	5.31	19.13	28.85
CZ7	6.93	24.95	37.63
CZ8	5.95	21.42	32.30
CZ9	13.12	47.23	71.22
CZ10	13.30	47.88	72.20
CZ11	16.99	61.15	92.21
CZ12	14.56	52.40	79.02
CZ13	10.85	39.04	58.88
CZ14	9.33	33.57	50.62
CZ15	7.89	28.40	42.82
CZ16	10.71	38.57	58.16

Figure 16 Single Family Life Cycle Cost Scenario Analysis

Multi-family LCC Scenario Analysis	Pessimistic	Base case	Optimistic
CZ3	1.01	3.65	5.51
CZ6	1.34	4.81	7.26
CZ9	3.15	11.35	17.11
CZ12	2.70	9.72	14.65
CZ14	1.64	5.92	8.93
CZ16	1.96	7.06	10.65

Figure 17 Multi-Family Life Cycle Cost Scenario Analysis

Office LCC Scenario Analysis	Pessimistic	Base case	Optimistic
CZ3	1.67	6.00	9.05
CZ6	1.57	5.65	8.53
CZ9	1.91	6.89	10.39
CZ12	1.39	5.02	7.56
CZ14	0.87	3.13	4.71
CZ16	1.19	4.27	6.43

Figure 18 Office Life Cycle Cost Scenario Analysis

Retail LCC Scenario Analysis	Pessimistic	Base case	Optimistic
CZ3	2.26	8.15	12.29
CZ6	5.54	19.93	30.05
CZ9	1.77	6.39	9.63
CZ12	1.92	6.93	10.44
CZ14	1.58	5.67	8.56
CZ16	1.77	6.36	9.59

Figure 19 Office Life Cycle Cost Scenario Analysis

This measure is cost effective even with pessimistic assumptions for all scenarios analyzed except for heating dominated climate zones 1 and 5.

4.6 Statewide Savings Estimate

To be included in Final Report.

5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

As part of this measure, Section 112 should be modified as presented below, changing the existing requirement for setback thermostats to require upgradable setback thermostats. Section 112 does not allow for tradeoff against other building features.

SECTION 112 – MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

(c) Thermostats. All unitary heating and/or cooling systems including heat pumps that are not controlled by a central energy management control system (EMCS) shall have a**n** **Upgradeable Setback** Thermostat **(UST) that is certified by the manufacturer to the Energy Commission to meet the requirements of Subsections 112(c)(1), 112(c)(2), and 112(c)3 below:**

1. **Setback Capabilities**. All ~~*thermostats*~~ **USTs** shall have a clock mechanism that allows the building occupant to program the temperature set points for at least four periods within 24 hours. Thermostats for heat pumps shall meet the requirements of Section 112(b).

2. **Upgradeable Capabilities. USTs shall not include onboard communication devices and shall have at least one industry standard expansion/communication port, which will allow for the installation of a removable communication module. If the communication module is not present, the UST shall function as a programmable setback thermostat. When the communication module is installed by the occupant, the UST shall be capable of both receiving and responding to demand response (DR) signals including price and emergency signals sent by the utility. USTs, with the communication module installed, shall be capable of receiving and responding to the DR signals as follows:**

   A. **Price Events. Upon receiving a price event signal, the UST shall adjust the thermostat setpoint by the number of degrees indicated by the user for the duration specified in the event signal. The UST, upon installation of the communication module by the occupant, shall default to price event offsets of +4°F for cooling and -4°F for heating when a DR signal is present; however, occupants shall be able to change the offsets and thermostat settings at any time. The UST shall have the capability to allow occupants to define setpoints for heating and cooling in response to price signals as an alternative to temperature-offsetting response, as described in Reference Joint Appendix JA5.**

   B. **Emergency Events. Upon receiving an emergency event signal, the UST shall respond to a specific offset contained in the emergency signal for heating and cooling modes, as described in Reference Joint Appendix JA5.**

   C. **Override Function. For all DR events, including price and emergency events, the UST shall include a physical override function, which when**

activated by the occupant, restores the UST to the conditions just prior to the current DR event.

3. **Other Required Capabilities. USTs shall also have the following capabilities onboard, as described in Reference Joint Appendix JA5:**

   A. **The expansion/communication port shall be readily accessible to the occupant for installing and removing the communication module. The occupant shall be able to insert or remove the communications module without the need to use tools or hardware.**

   B. **Provide user information regarding communications system connection status, type of event DR event, such as price or emergency, and other maintenance-related information. This information shall be on the standard UST display, using a Liquid Crystal Display, standalone indicator using Light Emitting Diodes, or other means.**

   C. **At a minimum, standardized terminal mapping of terminal numbers 1-9. This approach must include 24 volt power supply, both analog and digital USTs, and must support heat pumps with resistance heat strips and reversing valve in both residential and small commercial packaged units.**

   D. **Include the capability to randomize, over a 30-minute period after the end of an event, the time at which the thermostat returns to the programmed setpoint.**

   E. **Include the capability to allow the occupant to restore the default temperature offsets and setpoints to levels specified in 112(c)2A and Reference Joint Appendix JA5.**

EXCEPTION 1 to Section 112(c): Gravity gas wall heaters, gravity floor heaters, gravity room heaters, non-central electric heaters, fireplaces or decorative gas appliances, wood stoves, room air conditioners, and room air-conditioner heat pumps need not comply with this requirement. Additionally, room air-conditioner heat pumps need not comply with Section 112(b).

EXCEPTION 2 to Section 112(c): Other devices within the heating and cooling system capable of providing equivalent demand response functionality described in Section 112(c) that is approved by the Executive Director.

EXCEPTION 3 to Section 112(c): Thermostats installed in existing buildings including new additions to existing buildings, may be equipped with onboard communication devices provided that the thermostats are equipped with a physical on/off switch that cuts off power to the onboard communication device without affecting normal functioning of the setback thermostat.

6. Bibliography and Other Research

List and describe each of the research studies, reports, and personal communications that provide background for this research. Identify all resources that have been pursued to further this measure. Identify all "experts" that were involved in further developing the change, all research and analysis reports and documents that were reviewed, and all industry standards that were consulted (e.g., ASTM, UL, ASHRAE test procedures, etc.). Include research that is underway that addresses the measure/change. Indicate if data or information will be produced in time to be used in this update of the Standards.

Faruqui and Sergici, "Household Response to Dynamic Pricing of Electricity: A Survey of the Experimental Evidence," February 15, 2010.

[CEC and SCE] California Energy Commission and Southern California Edison. "Demand Responsive Control of Air Conditioning via Programmable Communicating Thermostats (PCTs)." Posted February 15, 2006. http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-02-22+23_workshop/2006-02-15_PROGRAMBLE_COMM.PDF

[PG&E]

Table 3 "Estimates of Service Lives of Various System Components." P. 35.3, 1999 ASHRAE Applications Handbook, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA.

7. Appendices

If appropriate, use one or more appendices to present lengthy data tables, referenced studies, or other information that would otherwise disrupt the flow of the report.

7.1 Product Availability

We contacted several manufacturers to collect information about product features, availability and price of the various components of a communicating thermostat. The findings are grouped below into members of the U-SNAP alliances, and independent thermostat manufacturers. The U-SNAP alliance provides for a removable communicating component, whereas many of the independent manufacturers have a specific communication type built into the product they are selling.

7.1.1 U-SNAP alliance members

The U-Snap alliance is made up of a group of members interested in developing, influencing or using a connectivity standard for linking Home Area Network products to utility smart meters (www.usnap.org). The term "U-SNAP" is an acronym for Utility Smart Network Access Port. The initial idea for U-SNAP emerged in 2007 when the California Energy Commission (CEC) was considering the concept of Programmable Communicating Thermostats (PCTs) as part of its Title 24 energy efficiency program. Like the USB port on a PC that allows a myriad of applications, the U-SNAP card provides a common connector between the communications module and the application (thermostat, energy display, load controller, PHEV etc.). Members include Utilities, Device Manufacturers (Thermostats, In-Home Displays, Load controls modules, etc), Industry Consultants, Research Labs, etc. listed below are some of the members that are of particular interest as part the CASE study examining the requirement for upgradeable setback thermostats.

Figure 20: U-Snap module and internal chip

Comverge

Figure 21: Comverge SuperStat

Comverge worked with White-Rodgers to develop the SuperStat. Available as a 5-1-1 or 7-day programmable thermostat, it can communicate one or two-way, using Comverge Maingate systems (powerline carrier), or ZigBee SEP 1.0. The thermostat employs an adaptive algorithm that controls cycles using percentage-based commands and monitors historical operation. It is remotely configurable via the web. The SuperStat is compatible with direct load control, price responsive demand, and critical peak pricing programs. It is available in various models of increasing functionality, and can display current energy price, usage and monthly bill data.

Comverge also sells the Comverge Apollo™ Demand Response Management System Software for Smart Grid applications. Due to the decision to market to Utility DR programs, pricing was unavailable to the general public.

GainSpan

Figure 22: GainSpan GS1011

GainSpan is a low power Wi-Fi semiconductor company and spin-off of Intel. GainSpan provides an ultra low power Wi-Fi single chip solution for battery-powered or energy-harvesting-based sensor applications that can run sensor devices for up to 10 years on a single AA battery.

GainSpan's GS1011 chip is a highly integrated ultra low power Wi-Fi system-on-chip (SOC) that contains an 802.11 radio, media access controller (MAC), baseband processor, on-chip flash memory and SRAM, and an applications processor in a single package. It is compatible with IEEE 802.11 b/g/n radio protocols. Requires a 3.3V power source. They also provide serial to Wi-Fi software which allows an external microcontroller to access a WiFi network via a serial connection to the GainSpan GS1011 SOC (system-on-chip).

Intwine Energy

Figure 23: IECT220 Figure 24: IECT210

Intwine Energy sells two Intwine Connected Thermostats, the IECT210 and IECT220. Both thermostats have Wi-Fi connectivity and 7-day programming, although the 220 has more independent periods per day (seven) compared to the 210 model (four).

Our Home Spaces (Janet Peterson)

Figure 25: Our Home Spaces screenshots of interfaces and gadgets

Our Home Spaces provide the interface that allows remote control of WiFi enabled thermostats. Their system is based on the U-Snap WiFi enabled thermostats, but can work with most WiFi thermostats, depending on the in-home router setup. Additionally they provide a monitoring service, based on 2-way communication.

The screenshots below are from the website for Our Home Spaces (www.ourhomespaces.com). They include a communicating thermostat, a thermostat gadget

Radio Thermostat Company of America

Figure 26: CT30 thermostat

Tim Simon of Radio Thermostat Company, founded the U-Snap Alliance. Thermostats are compatible with U-Snap radios in the following formats: ZigBee (Smart Energy 1.0 and Home Automation), Z-Wave, Wi-Fi, and RDS (one way FM).

The CT30 is a touchscreen thermostat that retails for $120 including a WiFi or Z-wave communication module ($100 without the communication module). Radio Thermostat Company of America is also OEM for many of the leading retailers of U-Snap compatible thermostats currently on the market.

7.1.2 Independent Thermostat manufacturers

Energate

Figure 27: Inspiration and Pioneer Smart Thermostats with user interface

Energate is currently developing two lines of smart thermostats that display energy information for residential use. The Pioneer and Inspiration Series of Smart Thermostats are both wall-mounted thermostats. They display current and cumulative energy usage as well as estimated cost. The interface is an LCD display of text, graphs, or animation, with six buttons for user input. The newer (Inspiration) Series uses near-field touch sensor technology in place of buttons. The Smart Thermostats control the HVAC system, and display whole house energy usage. The thermostats use the internet to communicate with the utility and receive messages, and link into the AMI network to receive usage data.

Control4

Figure 28: Control4 Wireless Thermostat (CCZ-T1-W)

The Control4® Wireless Thermostat communicates over a ZigBee (802.15.4) mesh network. It is remotely accessible via the web with subscription to 4Sight. Control4 focuses on home networking solutions, including home theater, lighting and security, in addition to thermostats. They now also offer the Control4 Energy Management System 100, designed to help utilities optimize load management. The EMS 100 incorporates communication standards, including ZigBee and WiFI, to encourage consumers opt-in to demand response event and energy efficiency programs.

Cooper Industries Ltd bout Cannon Technologies

Figure 29: Honeywell UtilityPRO

Cooper Power Systems advocates the use of the Honeywell UtilityPRO. These PCTs can be programmed over the internet, and support demand response cycling programs in addition to ramping of temperature setpoints. They also offer the option of data logging.

General Electric

Figure 30: GE Security SmartCommand Thermostat

General Electric sells the GE Security SmartCommand Thermostat. This thermostat has a RS485 serial communication port built in to it. Typically, the thermostat will be used on the SmartCommand network and connected to the SmartCommand automation controller. The SmartCommand automation controller has RS 232 port, RS 485 port, and Cat-5 ethernet port which enables connection to the internet. This also allows for networking of HVAC, lighting, security, intercom, audio systems and more into the same network.

HAI

Figure 31: HAI Omnistat2

The Omnistat2 is a programmable, communicating thermostat. It has an expansion port for wireless communication, and includes digital technology that learns the heating and cooling patterns of the home it is in, and uses this information to optimize energy efficiency and comfort.

Honeywell

Figure 32: Honeywell Wireless FocusPRO® System

Honeywell has developed two thermostats that can be networked into software developed by In2Networks. The VisionPRO and FocusPRO systems are programmable thermostats that can provide energy information when paired with the In2Networks software, described below.

Proliphix thermostats

Figure 33: Proliphix Uniphy Network thermostat

Proliphix has a couple different lines of network thermostats available on the market. The models for residential use have varying levels of functionality, with the basic series including Internet communication via wired Ethernet and a web browser control interface. The thermostats connect to any broadband Internet service for remote management and control. Using a Web browser interface, property owners can easily check temperature settings and alarm conditions, or create custom temperature schedules.

Tendril

Figure 34: Tendril "Set Point" Thermostat

Tendril has developed the Tendril Set Point, a thermostat that communicates with a variety of in-home devices. The thermostat has a built-in ZigBee/802.15.4 radio that is compatible with ZigBee SEP 1.0, enabling it to receive over-the-air firmware and software updates. It is also capable of receiving text messages and alerts, in addition to automatically responding to real-time pricing information or demand response signals. It can also be linked in to the Tendril Vantage, a web-based portal that allows for more in depth energy analysis and control of networked devices that are part of the Tendril Residential Energy Ecosystem (TREE).

7.2 Survey

The survey was distributed online to manufacturers that were involved in the stakeholder process related to the Title 24 CASE study about demand responsive communicating thermostats. A limited response was received; the six respondents covered both small and large thermostat manufacturers, in addition to a producer of home management solutions for energy, water and security.

The survey consisted of several multiple choices and open ended questions. Information collected from the survey questions is presented in the following section.

7.2.1 Types of products

The survey asked respondents to indicate which types of products their company produces and sells in relation to residential communicating thermostats.

Responses include:

a. Thermostats
b. Home Area/Energy Network Gateways
c. Software
d. Communication modules
e. Other (please specify)

Of the five (5) manufacturers that responded to the survey, three produce thermostats, one produces Home Area Networks or Energy Network Gateways, two produce software, and two produce communication modules. Some manufacturers worked in more than one portion of this market.

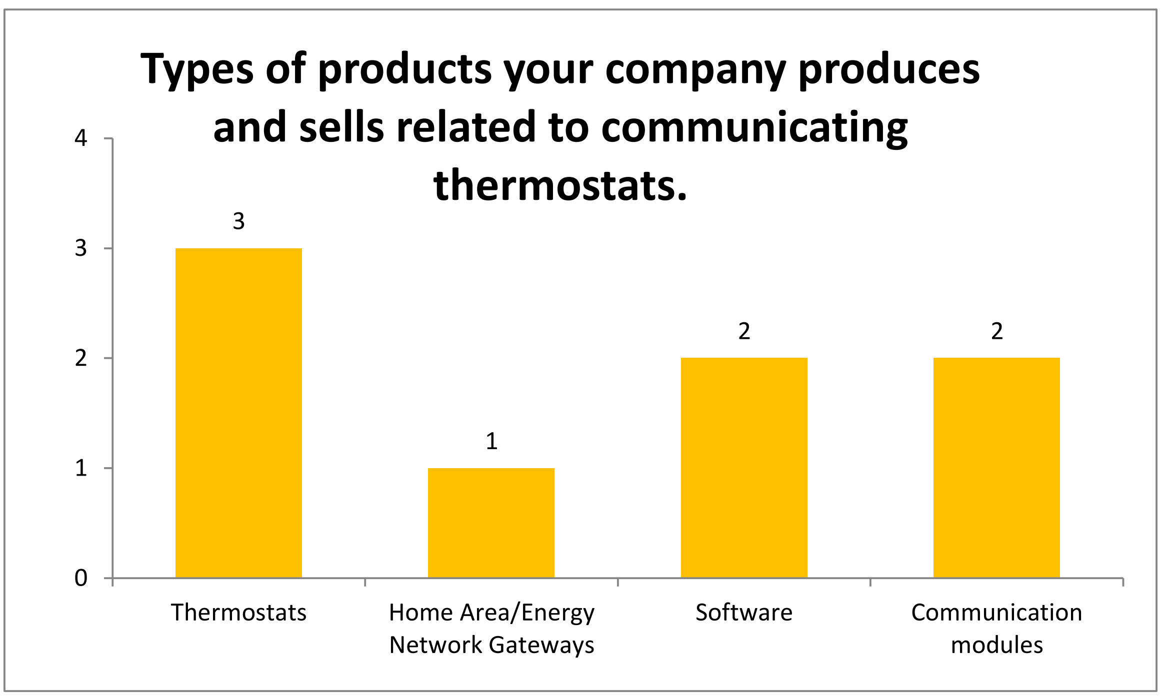

Figure 35 Types of products sold by manufacturers surveyed

2. Currently Available Products. Please describe products currently on the market that fit the niche of communicating thermostats. Please indicate ability to participate in DR programs (load shed or temp offset or price based), current cost and preferably a link to more information about the product.

   Open ended responses.

3. Future Plans/Products – Please describe your company's plans with regards to communicating thermostats. What is the business plan for the next 3, 5, 10 years? How do you see the growing Smart Grid affecting your plans for thermostats, particularly with regard to Demand Response program capabilities?

   Open ended responses.

7.2.2 Pricing of communicating thermostat related products

The survey asked respondents to indicate the price range of HVAC controls your company currently sells. Please include only products that have communication and demand response capabilities. Response options include:

- Less than $40
- $40 - $80
- $80 - $120
- $120 - $160
- $160 - $200

Responses show that the manufacturers plan to produce communicating thermostats at a variety of price points. The distribution of products was even across all price points.

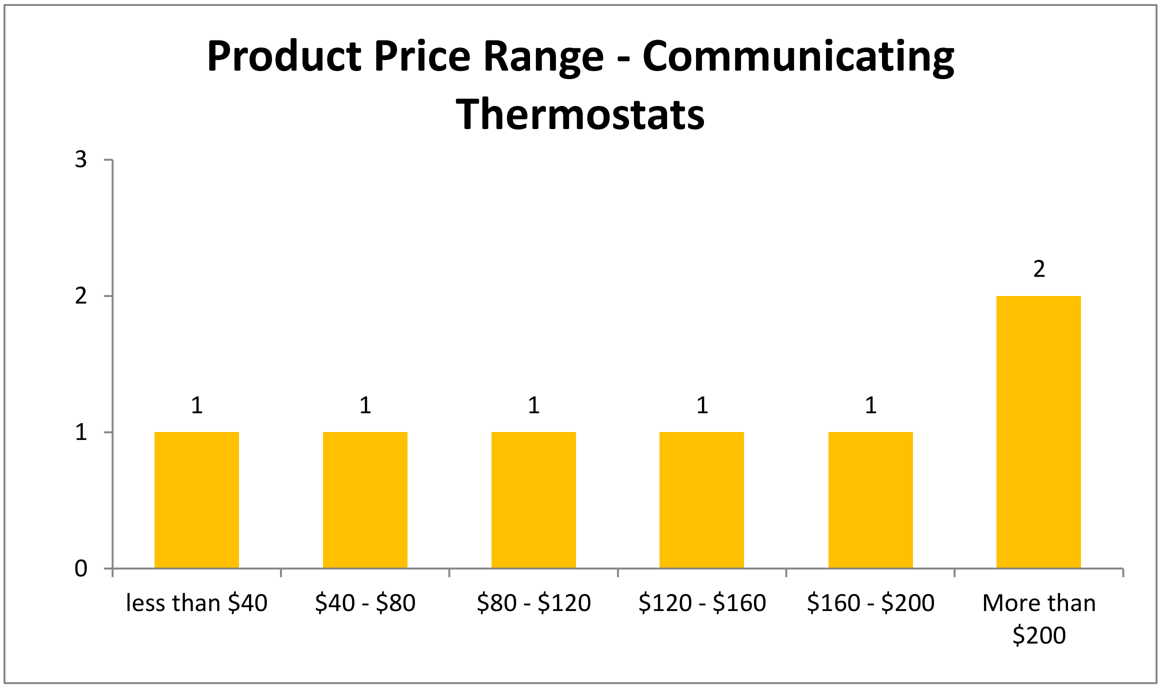

Figure 36 Price range of communicating thermostats

7.2.3 Types of Communication Supported

The survey asked respondents to select all communication protocols supported by their thermostat/gateway products for external communication (Including compatibility with Smart Meters or online demand response programs) and for communication within the Home Area Network (HAN) - i.e. communication with-in the home.

Response options include:

- WiFi
- ZigBee (802.15.4)
- Homeplug
- Z-wave
- Power Line Communications
- Bluetooth
- Other (please specify)

All manufacturers indicated they provide WiFi communication (Figure 37). The next most commonly supported communication types was ZigBee. HomePlug and BlueTooth communication were each supported by one manufacturer. The types of external communication recorded as “Other” included ClimateTalk and swappable radio modules.

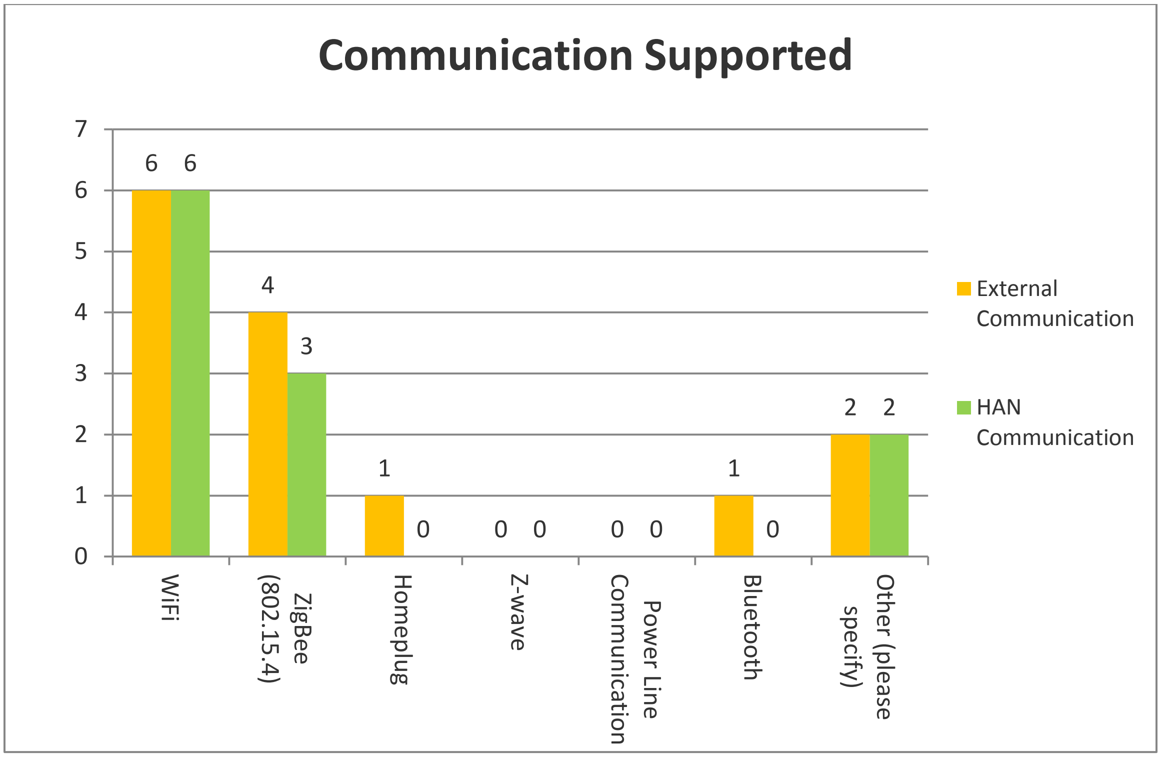

Figure 37 External and HAN communication of thermostats

4. Location of communicating component – Is the communicating component built into the device, or can it be removed by the end user while maintaining regular functioning of the device (sans communication)?
   a. The communication hardware is built in to the device, but it can be switched on and off by the end user (software).
   b. There are multiple forms of communication embedded in the device, some built in and some removable.
   c. The communication relies on a module that can plug into and be removed from the device by the end user without affecting the performance of the device other than the ability to communicate.
   d. The communication is built into the device. It cannot be removed.

Responses are shown in Figure 38. None of the manufacturers responding to the survey produced a thermostat with built-in communication that could not be removed. One manufacturer produced a thermostat with a removable communication module. Three manufacturers produce thermostats with more than one communication type. One manufacturer produces a thermostat with built-in communication that the user can modify.

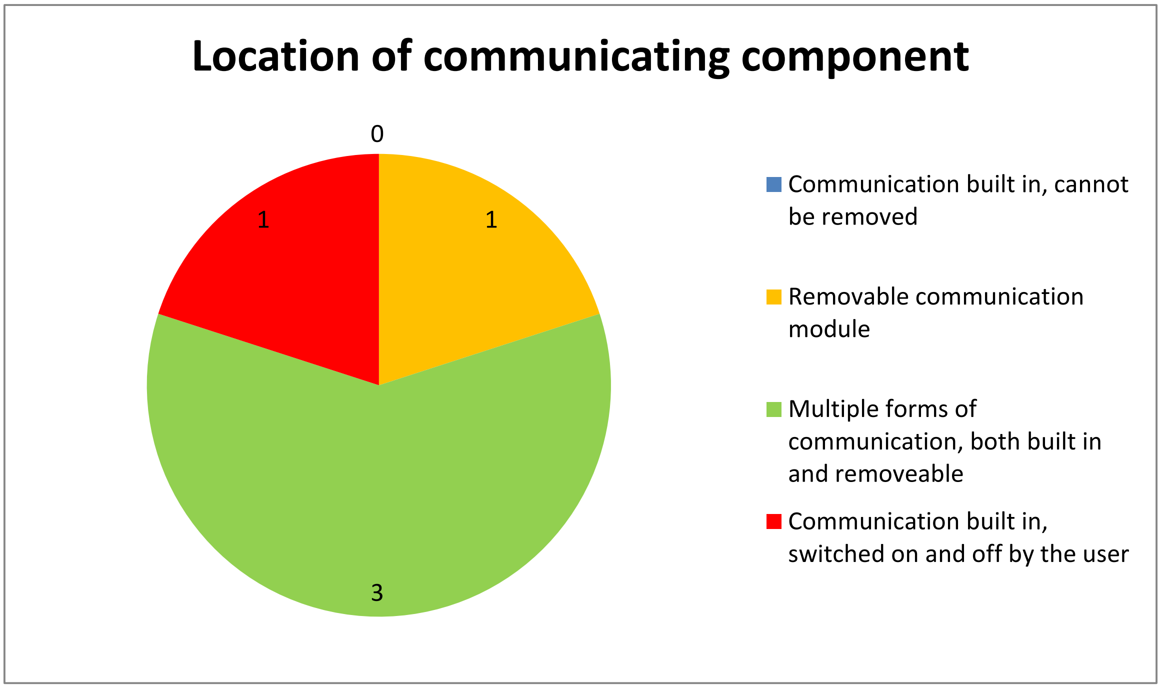

Figure 38 Location of communication component.

5. Event Display – Please indicate if the event is displayed to the user.
    a. Event indicator during event only.
    b. Event indicator indicates upcoming events as well as events in progress.
    c. No event information displayed.

Results are shown in Figure 39. Four manufacturers' thermostats indicate upcoming events as well as events in progress. One manufacturer's thermostat did not indicate events at all. None of the manufacturer indicated an in-progress event without also indicating a warning about upcoming events.

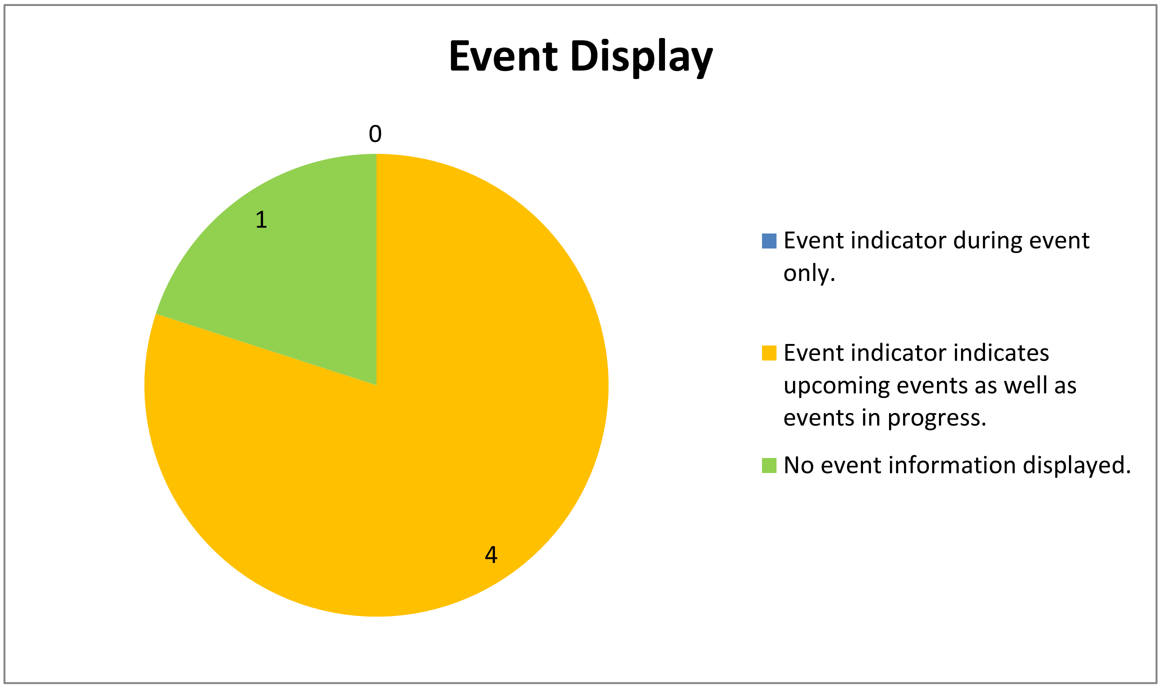

Figure 39 Event display types implemented by surveyed manufacturers.

6. Price Display – Please indicate if the current price can be displayed to the user.
    a. Price Tier shown to occupant (Off-Peak, Peak, Critical, or Low, Medium, High).
    b. Price shown to occupant in currency (dollars and cents).
    c. Price not shown to occupant.

Results in Figure 40 show three manufacturers produce thermostats that display the price tier, three manufacturers product thermostats that show the current price of power in dollars, and two manufacturers produce a thermostat that does not indicate the current price of power.

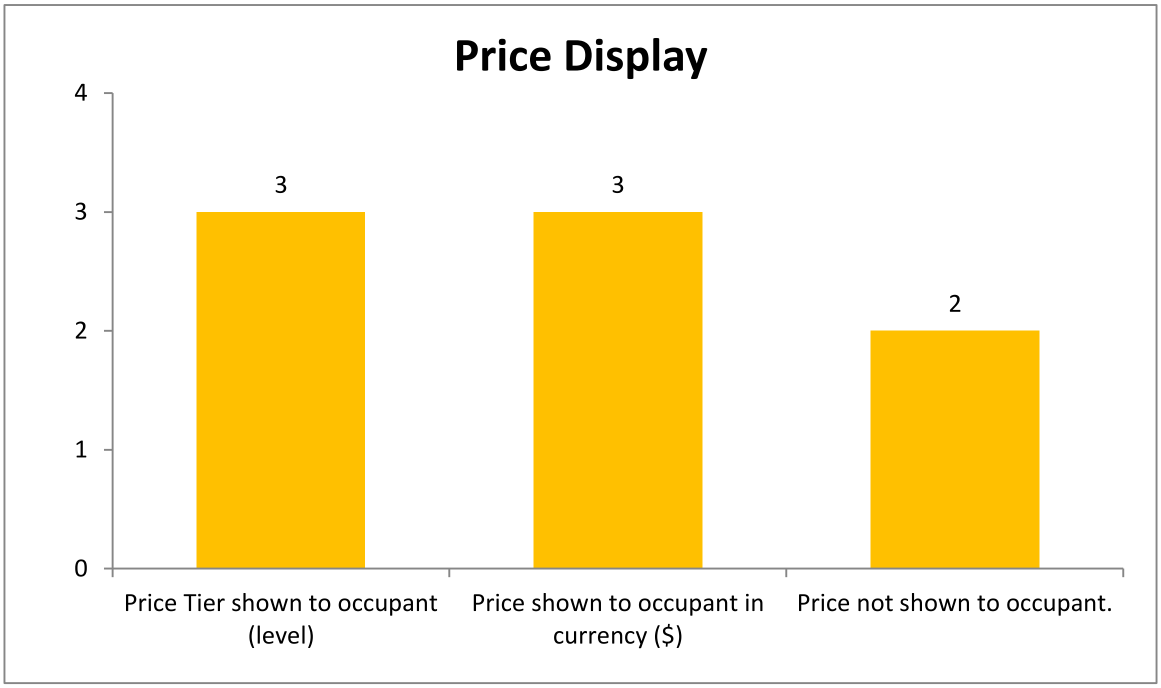

Figure 40 Price display types implemented by surveyed manufacturers.

7. Event Response: Set-Point – Please indicate if user's can modify event response.
   a. Response (set-point change) is user-programmable
   b. Response (set-point change) is not user-programmable
   c. Response (set-point change) can be changed during an event
   d. Response (set-point change) cannot be changed during an event
   e. Device does not have a set-point response

Results are presented in Figure 41. One manufactured indicated they produce at least one thermostat with no automatic response to pricing signals. Three manufacturers indicated they produce at least one thermostat in which the customer can program the response to events and three manufacturers indicated they produce at least one thermostat where the customer cannot program the response to events. Similarly, three manufacturers indicated they produce at least one thermostat in which the customer can adjust the thermostat set point during events and three manufacturers indicated they produce at least one thermostat where the customer cannot adjust the thermostat set point during events.

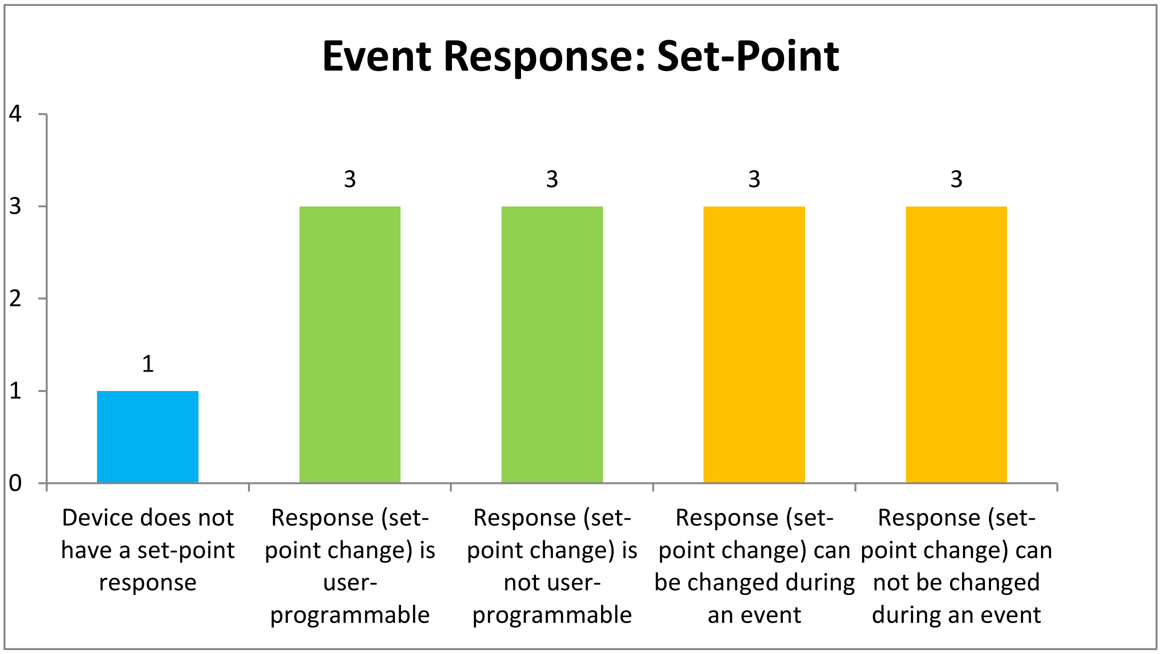

Figure 41 Set-point response programming supported by surveyed manufacturers.

8. Event Response: Cycling – Please indicate if your product can cycle the compressor of controlled systems.
    a. No cycling support
    b. 100% Cycling
    c. Fractional Cycling (50%, 30%, etc)
    d. Adaptive or Smart Cycling (ie, run Compressor 50% as much as it would have if it weren't an event)

As shown in Figure 42, two of the six thermostat manufactures indicated they do not support cycling while four of the six manufacturers indicate they support "smart" cycling. None of the manufactures supported 100% cycling or fractional cycling. Manufactures noted that 100% and fractional cycling are usually implemented with controls on the compressor, not in the thermostat itself.

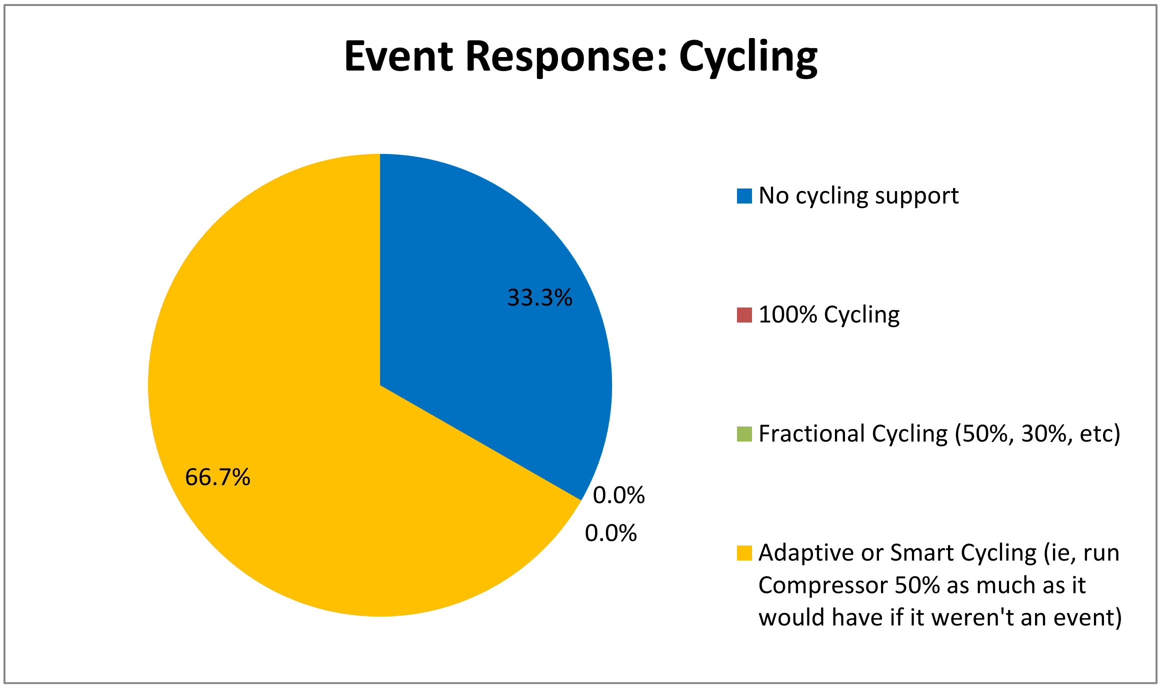

Figure 42 Cycling strategies supported by surveyed manufacturers.