**CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)**

# Upgradeable Setback Thermostats

*2013 California Building Energy Efficiency Standards*

California Utilities Statewide Codes and Standards Team October 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

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**CONTENTS**

## FIGURES

# 1. Overview

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|---|---|
| a. Measure Title | Upgradeable Setback Thermostats |
| 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 programmable 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.<br><br>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.<br><br>This proposal is cost effective in all Title 24 building climate zones except for heating dominated climate zones 1 and 5. |
| 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.<br><br>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.<br><br>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. There is no gas impact estimated for any of the scenarios below.<br><br>These energy savings are per participant, based on the assumption that residential and commercial customers are enrolled in a demand response program that calls 15 4-hour events each summer. We assume that customers will increase their HVAC set point by 4˚F during each demand response period, 20% of residential customers and 10% of |

commercial customers will override the automatic load shed during each demand response period. We assume that the DR signal is received 93% of the time.

Detailed calculations are available in Section 3 - 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 CEC for calculating demand savings; which includes multipliers weighting the savings during the 250 hours of the year considered to be peak. All of these hours take place between May and September. The savings are presented as occurring per unit. Each unit is one HVAC zone with one Upgradeable Setback Thermostat.

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

**Single Family Dwellings (2,100 sf):**

| | Savings per unit[1] | | |
|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) |
| CZ1 | 0 | 0.00 | 0 |
| CZ2 | 28 | 0.19 | 7,907 |
| CZ3 | 16 | 0.10 | 5,005 |
| CZ4 | 35 | 0.28 | 10,280 |
| CZ5 | 0 | 0.00 | 0 |
| CZ6 | 41 | 0.27 | 9,393 |
| CZ7 | 35 | 0.27 | 9,238 |
| CZ8 | 41 | 0.27 | 9,489 |
| CZ9 | 55 | 0.43 | 17,425 |
| CZ10 | 57 | 0.54 | 17,524 |
| CZ11 | 70 | 0.56 | 22,584 |
| CZ12 | 55 | 0.48 | 15,139 |
| CZ13 | 69 | 0.66 | 16,655 |
| CZ14 | 53 | 0.44 | 11,930 |
| CZ15 | 82 | 0.59 | 14,448 |
| CZ16 | 29 | 0.28 | 10,253 |

**Figure 1 2,100sf Single Family Dwelling Savings per unit (UST)**

1. Each unit is one 2,100sf single family Prototype C with one Upgradeable Setback Thermostat. Single family Prototype C is described in Section 2.3.

**Single Family Dwellings (2,700 sf):**

| | Savings per unit[1] | | |
|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) |
| CZ1 | 0 | 0.00 | 0 |
| CZ2 | 46 | 0.33 | 13,412 |
| CZ3 | 21 | 0.15 | 7,480 |
| CZ4 | 48 | 0.41 | 14,571 |
| CZ5 | 2 | 0.01 | 308 |
| CZ6 | 45 | 0.33 | 11,217 |
| CZ7 | 38 | 0.33 | 11,159 |
| CZ8 | 49 | 0.35 | 11,875 |
| CZ9 | 65 | 0.52 | 20,848 |
| CZ10 | 66 | 0.65 | 21,555 |
| CZ11 | 75 | 0.65 | 26,080 |
| CZ12 | 70 | 0.64 | 20,164 |
| CZ13 | 74 | 0.76 | 19,032 |
| CZ14 | 59 | 0.52 | 14,254 |
| CZ15 | 83 | 0.67 | 16,243 |
| CZ16 | 32 | 0.37 | 13,063 |

**Figure 2 2,700sf Single Family Dwelling Savings per unit (UST)**

1. Each unit is one 2,700sf single family Prototype D with one Upgradeable Setback Thermostat. Single family Prototype D is described in Section 2.3.

**Mutli-family Dwellings (870 sf each):**

| | Savings per unit[1] | | |
|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) |
| CZ1 | 0 | 0.00 | 0 |
| CZ2 | 12 | 0.08 | 3,276 |
| CZ3 | 6 | 0.04 | 2,074 |
| CZ4 | 14 | 0.12 | 4,259 |
| CZ5 | 0 | 0.00 | 0 |
| CZ6 | 17 | 0.11 | 3,892 |

| | | | |
|---|---|---|---|
| CZ7 | 15 | 0.11 | 3,827 |
| CZ8 | 17 | 0.11 | 3,931 |
| CZ9 | 23 | 0.18 | 7,219 |
| CZ10 | 24 | 0.22 | 7,260 |
| CZ11 | 29 | 0.23 | 9,356 |
| CZ12 | 23 | 0.20 | 6,272 |
| CZ13 | 29 | 0.27 | 6,900 |
| CZ14 | 22 | 0.18 | 4,942 |
| CZ15 | 34 | 0.24 | 5,986 |
| CZ16 | 12 | 0.12 | 4,248 |

**Figure 3 Multi-family Dwelling Savings per unit (UST)**

1. Each unit is one 870sf multi-family dwelling unit from CEC Prototype E with one Upgradeable Setback Thermostat. Multi-family Prototype E is described in the 2008 Title 24 Residential ACM.

**Small Office (1,000sf per Unit):**

| | Office savings per unit[1] | | |
|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) |
| CZ1 | 8 | 0.02 | 1,194 |
| CZ2 | 27 | 0.13 | 6,204 |
| CZ3 | 22 | 0.09 | 5,091 |
| CZ4 | 24 | 0.14 | 5,517 |
| CZ5 | 23 | 0.07 | 3,447 |
| CZ6 | 18 | 0.09 | 4,263 |
| CZ7 | 17 | 0.11 | 4,591 |
| CZ8 | 23 | 0.10 | 4,393 |
| CZ9 | 27 | 0.15 | 6,970 |
| CZ10 | 23 | 0.19 | 7,322 |
| CZ11 | 23 | 0.15 | 6,552 |
| CZ12 | 26 | 0.17 | 5,964 |
| CZ13 | 24 | 0.20 | 5,528 |
| CZ14 | 22 | 0.14 | 4,325 |
| CZ15 | 25 | 0.14 | 4,015 |
| CZ16 | 15 | 0.11 | 4,119 |

**Figure 4 Small Office Savings per UST**

1. Each unit refers to one Upgradeable Setback Thermostat. This is the average savings per thermostat based on the office prototype having ten USTs. The office prototype is described in detail in Section 2.3.

**Small Retail (4,000sf per unit):**

| | Retail savings per unit (UST) | | |
|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) |
| CZ1 | 25 | 0.23 | 3,426 |
| CZ2 | 61 | 1.15 | 14,119 |
| CZ3 | 59 | 0.84 | 12,754 |
| CZ4 | 65 | 1.34 | 13,720 |
| CZ5 | 56 | 0.66 | 8,550 |
| CZ6 | 47 | 0.80 | 9,656 |
| CZ7 | 51 | 1.08 | 11,295 |
| CZ8 | 58 | 0.90 | 10,350 |
| CZ9 | 68 | 1.35 | 16,766 |
| CZ10 | 60 | 1.65 | 16,969 |
| CZ11 | 61 | 1.35 | 15,246 |
| CZ12 | 62 | 1.47 | 12,903 |
| CZ13 | 64 | 1.74 | 12,382 |
| CZ14 | 65 | 1.35 | 10,790 |
| CZ15 | 74 | 1.33 | 9,710 |
| CZ16 | 39 | 1.01 | 9,876 |

**Figure 5 Small Retail Savings per UST**

1. Each unit refers to one Upgradeable Setback Thermostat. These numbers are the average savings per thermostat based on the small retail prototype that has two USTs. The retail prototype is described in detail in Section 2.3.

Statewide Savings Estimate:

The expected statewide first year savings from the proposed UST measure are presented below in Figure 6. More detail about how these estimates were developed is contained in Section 3.6.

| | |
|---|---|
| | (see table below) |

| | First Year Electric Energy Savings (GWh) | First Year Peak Demand Savings (MW) | First Year Gas Energy Savings (MMtherms) | First Year TDV Energy Savings (TDV KBTU) |
|---|---|---|---|---|
| Residential Statewide | 1.171 | 10.560 | n/a | 304,361,295 |
| Nonresidential Statewide | 0.018 | 0.172 | n/a | 1,171,963 |

**Figure 6 Statewide Savings Estimate**

| | |
|---|---|
| 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.<br><br>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.<br><br>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 will lead to a decrease in emissions and decreased energy consumption by reducing energy usage during peak periods. 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 can be calculated by multiplying the change in statewide electricity consumption by the hourly emissions factors. Because the proposed energy measure will reduce electricity use, this will reduce the required electricity generation, and thereby have a small reduction in mercury emissions from coal-burning power plants, and water consumption from electricity generation. The potential positive environmental impacts are not accounted for in the following tables.

To implement Upgradeable Setback Thermostat, minor increases in raw-materials used to construct thermostats may be required. There will undoubtedly be a range of impacts depending on how manufacturers decide to meet the requirement for upgradeable communication capabilities. For purposes of estimation, we are looking at the material impact of one 18-gram removable communicating module per UST. These numbers are based on a communication removable module that currently exists in the marketplace, and is described in Figure 36 in the appendix of this document. The values for mercury and lead were calculated by using the maximum allowed percentages, by weight, under the European RoHS[1] requirements, which were incorporated into California state law effective January 1, 2010. RoHS allows a maximum of 0.1% by total product weight for both mercury and lead. In practice the actual percentage of mercury and lead in these components may be very much *less* than these values, so the values in the table are conservative overestimates.

**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] | (I) $3.97 \times 10^{-5}$ | (I) $3.97 \times 10^{-5}$ | (I) 0.00066 | N/C | (I) 0.026 | Silicon – (I) 0.0022<br>Gold – (I) 0.0002 |

1. One upgradeable setback thermostat constitutes each unit.

**Water Consumption:**

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

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

[1] http://ec.europa.eu/environment/waste/weee/index_en.htm

**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 are programmable setback thermostats that have an interface for a (removable) communication device, such as a USNAP card or other module using standards based communications.

**Measure Availability:**

The section below describes the products that either meet the proposed requirements or are close to meeting the requirements. A survey of communicating thermostats is presented in Appendix 6.3 - 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

There are thermostats with built-in Wi-Fi communication that connect to an external server. On this external server the user can control their thermostat via a web application, or a smart phone (iPhone). 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<br>◆ Intwine Energy IECT220 WiFi Thermostat<br><br>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 6.3 - Product Availability.<br><br>In summary, our survey found that the market currently has some products that meet all of the proposed requirements, but in limited numbers. More of these products could be modified to comply with the proposed requirements. The proposed code language also includes an exception to allow the CEC Executive Director to evaluate and approve technologies that can provide equivalent functions.<br><br>**Useful Life, Persistence, and Maintenance:**<br><br>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[2]. We use this same assumption for estimating replacement period for residential and nonresidential USTs.<br><br>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. |
| 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 3.5.

[2] 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.

| a | b | c | | d | | e | | f | g | |
|---|---|---|---|---|---|---|---|---|---|---|
| Single Family UST (2,100sf) | 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 | $137 | $68 | $68 | $0 | $0 | $0 | $137 | $68 |
| CZ2 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $500 | -$363 | -$431 |
| CZ3 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $398 | -$262 | -$330 |
| CZ4 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $737 | -$600 | -$669 |
| CZ5 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $0 | $137 | $68 |
| CZ6 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $587 | -$450 | -$519 |
| CZ7 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $585 | -$448 | -$516 |
| CZ8 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $602 | -$466 | -$534 |
| CZ9 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $1,042 | -$905 | -$974 |
| CZ10 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $1,001 | -$864 | -$933 |
| CZ11 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $1,185 | -$1,049 | -$1,117 |
| CZ12 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $846 | -$709 | -$777 |
| CZ13 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $884 | -$747 | -$815 |
| CZ14 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $695 | -$558 | -$627 |
| CZ15 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $667 | -$530 | -$599 |
| CZ16 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $656 | -$519 | -$587 |

| a | b | c | | d | | e | | f | g | |
|---|---|---|---|---|---|---|---|---|---|---|
| Single Family UST (2,700sf) | 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-Adoptio n Costs |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CZ1 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $0 | $137 | $68 |
| CZ2 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $6,782 | -$6,645 | -$6,714 |
| CZ3 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $4,763 | -$4,626 | -$4,695 |
| CZ4 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $8,356 | -$8,220 | -$8,288 |
| CZ5 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $183 | -$46 | -$115 |
| CZ6 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $5,606 | -$5,470 | -$5,538 |
| CZ7 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $5,651 | -$5,514 | -$5,583 |
| CZ8 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $6,031 | -$5,895 | -$5,963 |
| CZ9 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $9,974 | -$9,837 | -$9,906 |
| CZ10 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $9,850 | -$9,713 | -$9,781 |
| CZ11 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $10,950 | -$10,813 | -$10,881 |
| CZ12 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $9,012 | -$8,876 | -$8,944 |
| CZ13 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $8,079 | -$7,942 | -$8,010 |
| CZ14 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $6,645 | -$6,508 | -$6,577 |
| CZ15 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $5,998 | -$5,861 | -$5,930 |
| CZ16 | 30 | $68 | $137 | $68 | $68 | $0 | $0 | $6,683 | -$6,547 | -$6,615 |

| 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 ($) | |
| | | | | | | | | | (c+e)-f | (d+e)-f |
| | | Per Unit | Per Proto Bldg | Per Unit | Per Proto Bldg | Per Unit | Per Proto Bldg | | Based on Current Costs | Based on Post-Adoption Costs |
| CZ1 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $236 | $447 | -$236 |
| CZ2 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,227 | -$543 | -$1,227 |
| CZ3 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,007 | -$323 | -$1,007 |
| CZ4 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,091 | -$407 | -$1,091 |
| CZ5 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $682 | $2 | -$682 |
| CZ6 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $843 | -$159 | -$843 |
| CZ7 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $908 | -$224 | -$908 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CZ8 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $869 | -$185 | -$869 |
| CZ9 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,378 | -$695 | -$1,378 |
| CZ10 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,448 | -$764 | -$1,448 |
| CZ11 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,296 | -$612 | -$1,296 |
| CZ12 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,179 | -$496 | -$1,179 |
| CZ13 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $1,093 | -$410 | -$1,093 |
| CZ14 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $855 | -$172 | -$855 |
| CZ15 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $794 | -$110 | -$794 |
| CZ16 | 15 | $68 | $684 | $0 | $0 | $0 | $0 | $815 | -$131 | -$815 |

| a | b | c | | d | | e | | f | g | |
|---|---|---|---|---|---|---|---|---|---|---|
| Retail - 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 ($) | |
| | | | | | | | | | (c+e)-f | (d+e)-f |
| | | Per Unit | Per Proto Bldg | Per Unit | Per Proto Bldg | Per Unit | Per Proto Bldg | | Based on Current Costs | Based on Post-Adoption Costs |
| CZ1 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $136 | $1 | -$136 |
| CZ2 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $558 | -$422 | -$558 |
| CZ3 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $504 | -$368 | -$504 |
| CZ4 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $543 | -$406 | -$543 |
| CZ5 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $338 | -$201 | -$338 |
| CZ6 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $382 | -$245 | -$382 |
| CZ7 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $447 | -$310 | -$447 |
| CZ8 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $409 | -$273 | -$409 |
| CZ9 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $663 | -$526 | -$663 |
| CZ10 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $671 | -$534 | -$671 |
| CZ11 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $603 | -$466 | -$603 |
| CZ12 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $510 | -$374 | -$510 |
| CZ13 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $490 | -$353 | -$490 |
| CZ14 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $427 | -$290 | -$427 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CZ15 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $384 | -$247 | -$384 |
| CZ16 | 15 | $68 | $137 | $0 | $0 | $0 | $0 | $391 | -$254 | -$391 |

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. This scenario assumes 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).

**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): $\text{PV Maint Cost} = \text{Maint Cost} \times \left[\frac{1}{1+\text{d}}\right]^{n}$

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.

| | |
|---|---|
| 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. |

# 2. 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.

## *2.1 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.[3]

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[4].

## *2.2 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

[3] 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).

[4] 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.

### 2.2.1 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.

### 2.2.2 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 3.2 - Technology.

## *2.3 Development of Prototype Building*

| | Occupancy Type (Residential, Retail, Office, etc) | Area (Square Feet) | Number of Stories | Other Notes |
|---|---|---|---|---|
| Prototype 1 | Residential – Single Family | 2,100 | 1 | Prototype C defined in Residential ACM manual, having 20% fenestration equally distributed. |
| Prototype 2 | Residential – Single Family | 2,700 | 2 | Prototype D defined in Residential ACM manual, having 20% fenestration equally distributed. |
| Prototype 3 | Nonresidential – Small Office | 10,000 | 2 | Five zones (plus plenum) per floor, 2008 prescriptive envelope and HVAC requirements (EER 11) |
| Prototype 4 | Nonresidential – Small Retail | 8,000 | 1 | Two conditioned zones (storage and sales floor), front display glazing, 2008 prescriptive envelope and HVAC requirements (EER 11) |

The single family building type is expected to be impacted the most by this proposed measure. For this reason two single family model simulations were performed for all 16 Title 24 California building climate zones using the California Energy Commission building Prototypes C and D from the 2008 Residential ACM Manual. Prototype C is a 2,100 ft², one-story detached home with slab on grade floors, depicted in Figure 7. Prototype D is a 2,700 ft², two-story detached home depicted in Figure 8. Both prototypes include energy features included in the 2008 prescriptive requirements. Including 20% glass area and thermostat set points of 76 degrees Fahrenheit during the day and 83 degrees at night. Details are available from the California Energy Commission.

Visual representations of the residential building models are presented in Figure 7 and Figure 8.

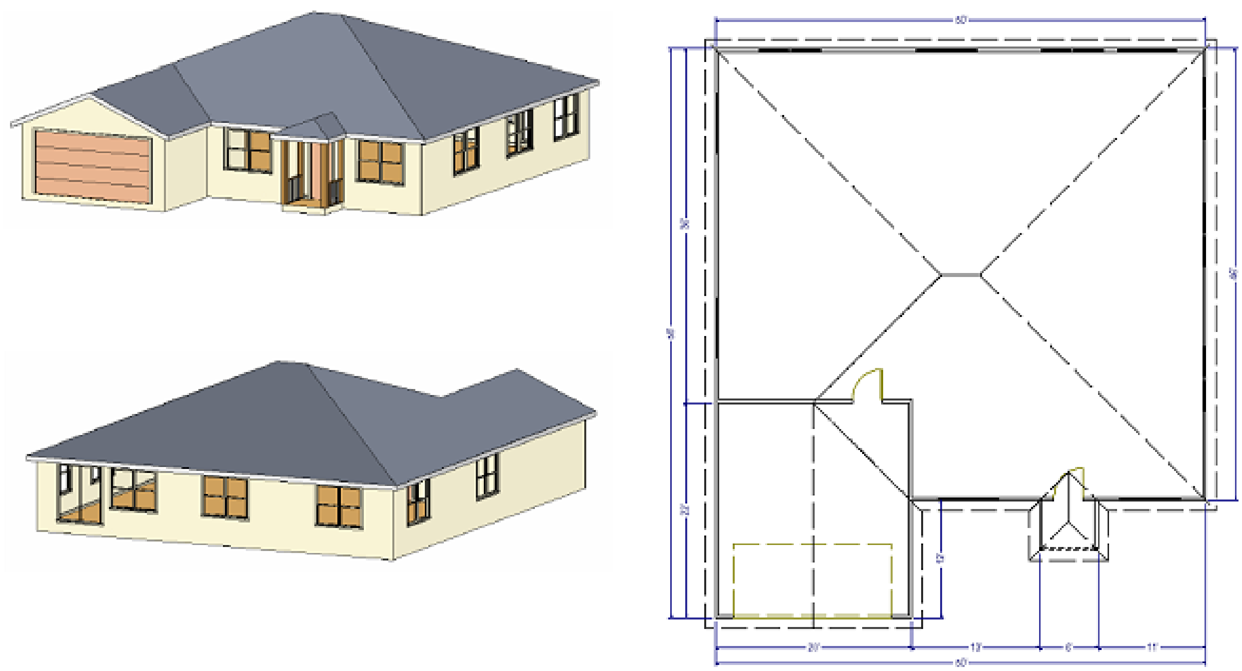

**Figure 7 Prototype C**

**Figure 8 Prototype D**

For nonresidential savings, the analysis used the Small Office and Small Retail eQuest models from the Database for Energy Efficient Resources. The office model is a two story office building with four perimeter zones and one core zone per floor. The total building area is 10,000 sf, and has 10 zones in total. This model was chosen because it simulates the energy impacts over a variety of layouts. A brief description of this prototype is presented in Figure 9. The office occupancy schedule is 7am to 6pm Monday through Saturday, unoccupied Sundays and holidays. The fan and thermostat run times reflect these times, with a thermostat setpoint of 76 F for cooling and 72 F for heating during occupied hours and 86 F for cooling, 62 F for heating during unoccupied hours. The cooling EER is 11 for both nonresidential building prototypes.

| Prototype | Source | Activity Area Type | Area | % Area | Simulation Model Notes |
|---|---|---|---|---|---|
| 14. Office - Small | NCC | Conference Room | 400 | 4.0 | **Thermal Zoning:** The model uses generic thermal zones with all activity area characteristics averaged across the entire zone. **Model Configuration:** Matches NCC prototype. **HVAC Systems:** The prototype uses Rooftop DX systems, which are changed to Rooftop HP systems for the heat pump efficiency measures. |
| | | Copy Room (photocopying equipment) | 200 | 2.0 | |
| | | Corridor | 1,000 | 10.0 | |
| | | Lobby (Office Reception/Waiting) | 500 | 5.0 | |
| | | Mechanical/Electrical Room | 400 | 4.0 | |
| | | Office (Executive/Private) | 7,000 | 70.0 | |
| | | Restrooms | 500 | 5.0 | |
| | | Total | 10,000 | | |

**Figure 9 DEER Small Office Prototype Description**

The small retail model is 8,000 sf, with a general sales floor accounting for 80% of the total area and the remaining area taken up by storage in the back of the building. The only fenestration is in the form of display windows at the front of the store. As a result, the small retail prototype includes four identical copies of the building; each rotated 90 degrees so that each cardinal orientation is modeled simultaneously. The occupancy schedule for the small retail building is assumed to be 8am-9pm, 7 days a week. A brief description of each prototype building in this model is presented in Figure 10. More information about the Database for Energy Efficient Resources is available online at http://www.deeresources.com.

| Prototype | Source | Activity Area Type | Area | % Area | Simulation Model Notes |
|---|---|---|---|---|---|
| 19. Retail - Small | DEER | Retail Sales and Wholesale Showroom | 6,400 | 80.0 | **Thermal Zoning:** One zone per activity area. **Model Configuration:** Matches 1994 DEER prototype **HVAC Systems:** The prototype uses Rooftop DX systems, which are changed to Rooftop HP systems for the heat pump efficiency measures. |
| | | Storage (Conditioned) | 1,600 | 20.0 | |
| | | Total | 8,000 | | |

**Figure 10 DEER Small Retail Prototype Description**

## *2.4 Savings Analysis Methodology*

Building energy simulation was performed using CEC prototype DOE-2.2 residential models (Prototypes C and D, described in Section 2.3 above) and DEER nonresidential prototypes for small office and small retail buildings. Simulations were run in all 16 climate zones using 2008 Title 24 prescriptive requirements for the baseline scenario.

The exact hours of demand response were determined separately for each climate zone. Peak demand response days were identified by the weekday afternoons from 12pm to 6pm with the highest average temperatures plus the highest hourly temperature that afternoon. 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 demand response scenario modeled a four degree temperature setback from 2pm to 6pm on the 15 peak days identified. This type of response is consistent with existing demand responsive thermostat programs that have been administered by the IOUs in the past.

The residential simulation models were run in Micropas for two conditions; standard and curtailment. The standard model uses the following thermostat set points:

- 76 degree F from 8a.m. to 10p.m.

- 83 degree F from 10p.m. to 8a.m.

These are consistent with the 2008 PCT CASE Report (CEC and SCE 2006) and also coincide with the weighted average set point according to Table C5 in the 2009 RASS (**Error! Reference source ot found.**). The curtailment scenario was simulated by increasing the temperature set point by 4˚F in the models during the demand response periods. The difference between the demand response energy usage and the standard energy usage was used 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.

Survey Question: AC thermostat setting in day - C5

| Title 24 Climate Zones | OFF | BELOW 70 F | 70-73 F | 74-76 F | 77-80 F | 80 + F | Total |
|---|---|---|---|---|---|---|---|
| 1 | | 18.4%* | | 63.5%* | 18.1%* | | 100% |
| 2 | 31.50% | 6.10% | 21.90% | 18.10% | 17.30% | 5.1%* | 100% |
| 3 | 45.60% | 9.2%* | 16.00% | 12.60% | 15.30% | 1.3%* | 100% |
| 4 | 39.60% | 12.60% | 16.50% | 14.80% | 13.00% | 3.6%* | 100% |
| 5 | 41.80% | 2.0%* | 6.7%* | 41.3%* | 5.4%* | 2.9%* | 100% |
| 6 | 30.70% | 4.10% | 21.40% | 22.50% | 16.70% | 4.7%* | 100% |
| 7 | 31.60% | 8.00% | 17.70% | 18.20% | 14.60% | 9.90% | 100% |
| 8 | 31.80% | 6.60% | 16.30% | 18.80% | 21.30% | 5.10% | 100% |
| 9 | 27.60% | 6.20% | 17.20% | 18.90% | 25.20% | 4.90% | 100% |
| 10 | 24.20% | 3.00% | 13.40% | 16.90% | 34.10% | 8.50% | 100% |
| 11 | 17.50% | 9.30% | 12.40% | 17.90% | 27.20% | 15.80% | 100% |
| 12 | 22.50% | 8.10% | 11.80% | 17.60% | 33.40% | 6.70% | 100% |
| 13 | 18.40% | 5.50% | 7.30% | 16.70% | 37.50% | 14.70% | 100% |
| 14 | 25.70% | 7.90% | 10.20% | 22.70% | 27.80% | 5.70% | 100% |
| 15 | 6.20% | 3.2%* | 22.00% | 21.60% | 28.80% | 18.30% | 100% |
| 16 | 32.30% | 3.40% | 14.80% | 20.70% | 23.50% | 5.30% | 100% |
| Total | 26.40% | 6.30% | 14.70% | 18.30% | 26.50% | 7.70% | 100% |

**Figure 11 Daytime AC thermostat setting by climate zone (2009 RASS question C5 – excluding "No response" and "Not applicable")**

The nonresidential simulation models used DEER models for small office and small retail buildings, representative of the market that will most likely be effected by the propose measure. These building prototypes are described above in Section 2.3. The office occupancy schedule is 7am to 6pm Monday through Saturday, unoccupied Sundays and holidays. The occupancy schedule for the small retail building is assumed to be 8am-9pm, 7 days a week. The nonresidential simulation models were run in eQuest for the baseline and demand response curtailment scenario. The curtailment scenario was simulated by increasing the temperature set point by 4˚F during the demand response periods. The demand response periods were defined as four hours in the afternoon (2pm-6pm) of the days with the highest average afternoon temperatures (12pm-6pm). This aligns most closely with existing thermostat demand response programs administered by the California IOUs. 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.

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 participating in the DR program receive a DR signal 93% of the time[5]
- Customers respond by allowing their thermostat to automatically setback the cooling set point by four (4) degrees Fahrenheit.
- 20% of Residential customers override each automated demand response event[6]
- 10% of Commercial customers override each automated demand response event
- Residential households with their A/C thermostat set to "Off" during the day are determined per climate zone based on the 2009 RASS question C5 (KEMA 2010), as shown in Figure 11.

Demand Savings is calculated as the average kW savings for the Peak Period as defined by the CEC. This involves applying multipliers to weight the savings that occur during the 250 hours of the year considered to be peak. All of these hours take place between May and September. More information is available from the California Energy Commission.

The PG&E Peak Day Pricing program for small/medium commercial customers serves as an example for a demand response program structure[7], 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

This was the basis for determining how many the model events for simulation. The CASE team chose to assume that DR programs would require, on average, 4 hours of participation on 15 days each year. Our scenario analysis explores the effect on savings by prorating the number of event days up and down from the 15 chosen for the base case.

[5] This percentage is based on findings in the 2004 SCE Final E$T Program Impact Evaluation Report, which states that on average 5% to 7% of thermostats are non-respondents during curtailment events.

[6] This percentage is based on findings in the 2004 SCE Final E$T Program Impact Evaluation Report, which states that between 18 and 21% of customers override the thermostat set point during curtailment events.

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

## 2.5 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.

## 2.6 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 |

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

$\Delta TDV_E$ TDV of electricity

$\Delta TDV_G$ 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 12.

| | Pessimistic | Base case | Optimistic |
|---|---|---|---|
| Annual Hours of Curtailment | 48 | 60 | 60 |
| Temperature Set-up (degrees Fahrenheit) | 4 | 4 | 4 |
| Fraction of Population Participating | 10% | 25% | 70% |
| Fraction overriding voluntary signal - Residential | 30% | 20% | 5% |
| Fraction overriding voluntary signal - Nonresidential | 20% | 10% | 5% |
| % of Thermostats On - Residential | 77% | 77% | 77% |
| % of Thermostats On - Nonresidential | 100% | 100% | 100% |

**Figure 12 Scenario Analysis Assumptions**

## *2.7 Statewide Savings Estimate Methodology*

The statewide energy savings associate with the proposed UST measure will be calculated by multiplying the energy savings per unit by estimated number of units of new construction in 2014. For the residential sector, the savings per single family and multi-family dwelling is calculated separately, and multiplied by the expected number of new construction dwellings, adjusted by the following factors:

- 25% of both residential and nonresidential customers voluntarily enroll in a demand response program that takes advantage of communicating thermostats.
- The percent of residential dwelling units that have an air conditioning system using a thermostat that is required to comply with Title 24 Part 6 Section 112(c).

The results from the 2009 Residential Appliance Saturation Survey (KEMA 2010) are used to determine the percent of residential dwelling units that have an eligible air conditioning system. Figure 13 provides a breakdown of thermostat settings by Title 24 Building Climate Zone. The assumption is that all categories other than “Not Applicable” would have thermostats required to comply with the UST requirement. Thus the percent “Not Applicable” was subtracted from 100% and multiplied by the expected new construction in 2014 per climate zone, which is detailed in Appendix 6.2.

| Title 24 Climate Zones | OFF | BELOW 70 F | 70-73 F | 74-76 F | 77-80 F | 80 + F | NOT APPLICABLE | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | | 0.4%* | | 1.4%* | 0.4%* | | 97.80% | 100% |
| 2 | 10.10% | 2.00% | 7.00% | 5.80% | 5.50% | 1.6%* | 68.00% | 100% |
| 3 | 4.40% | 0.9%* | 1.50% | 1.20% | 1.50% | 0.1%* | 90.40% | 100% |
| 4 | 19.00% | 6.00% | 7.90% | 7.10% | 6.20% | 1.7%* | 52.10% | 100% |
| 5 | 5.30% | 0.2%* | 0.8%* | 5.2%* | 0.7%* | 0.4%* | 87.40% | 100% |
| 6 | 10.50% | 1.40% | 7.30% | 7.70% | 5.70% | 1.6%* | 65.90% | 100% |
| 7 | 9.00% | 2.30% | 5.00% | 5.20% | 4.20% | 2.80% | 71.60% | 100% |
| 8 | 14.20% | 3.00% | 7.30% | 8.40% | 9.50% | 2.30% | 55.30% | 100% |
| 9 | 16.30% | 3.60% | 10.10% | 11.10% | 14.80% | 2.90% | 41.20% | 100% |
| 10 | 20.50% | 2.50% | 11.30% | 14.30% | 28.80% | 7.10% | 15.60% | 100% |
| 11 | 13.30% | 7.00% | 9.40% | 13.60% | 20.60% | 12.00% | 24.10% | 100% |
| 12 | 17.30% | 6.30% | 9.10% | 13.60% | 25.80% | 5.20% | 22.80% | 100% |
| 13 | 15.00% | 4.50% | 6.00% | 13.70% | 30.70% | 12.00% | 18.20% | 100% |
| 14 | 19.10% | 5.90% | 7.60% | 16.80% | 20.70% | 4.20% | 25.80% | 100% |
| 15 | 5.90% | 3.0%* | 20.80% | 20.40% | 27.30% | 17.30% | 5.20% | 100% |
| 16 | 15.10% | 1.60% | 6.90% | 9.70% | 11.00% | 2.50% | 53.40% | 100% |
| Total | 13.30% | 3.20% | 7.40% | 9.20% | 13.40% | 3.90% | 49.50% | 100% |

**Figure 13 2009 RASS Thermostat setting in day (question C5)**

To calculate expected statewide savings in the nonresidential sector, simulation savings results were converted to a kWh/sf basis. Small offices (less than 30,000sf) were assumed to be required to comply with the UST requirement, while larger offices are assumed to have some sort of energy management control system (EMCS), which exempts them from the UST requirement. A similar logic applied to retail spaces, where building larger than 50,000sf were assumed to have an EMCS, thus exempting them from the UST requirement.

For the rest of the commercial population of building, we conservatively assumed that 10% of all nonresidential building types other than offices, retail, refrigerated warehouse or hospitals would comply with the UST requirement. The rest of the buildings are expected to have energy management control systems (EMCS) that would exempt them from this requirement, while still allowing for their participation in demand response events and programs. Additionally, it would be possible for homeowners and business owners to use the UST to respond to price signals, which could account for greater hours of use and thus increased savings beyond the demand response program that was modeled.

## *2.8 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.

# 3. Analysis and Results

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

## *3.1 Data Collected*

HMG conducted a survey of manufacturers, the full results of which are presented in Appendix 6.4. 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 14 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.

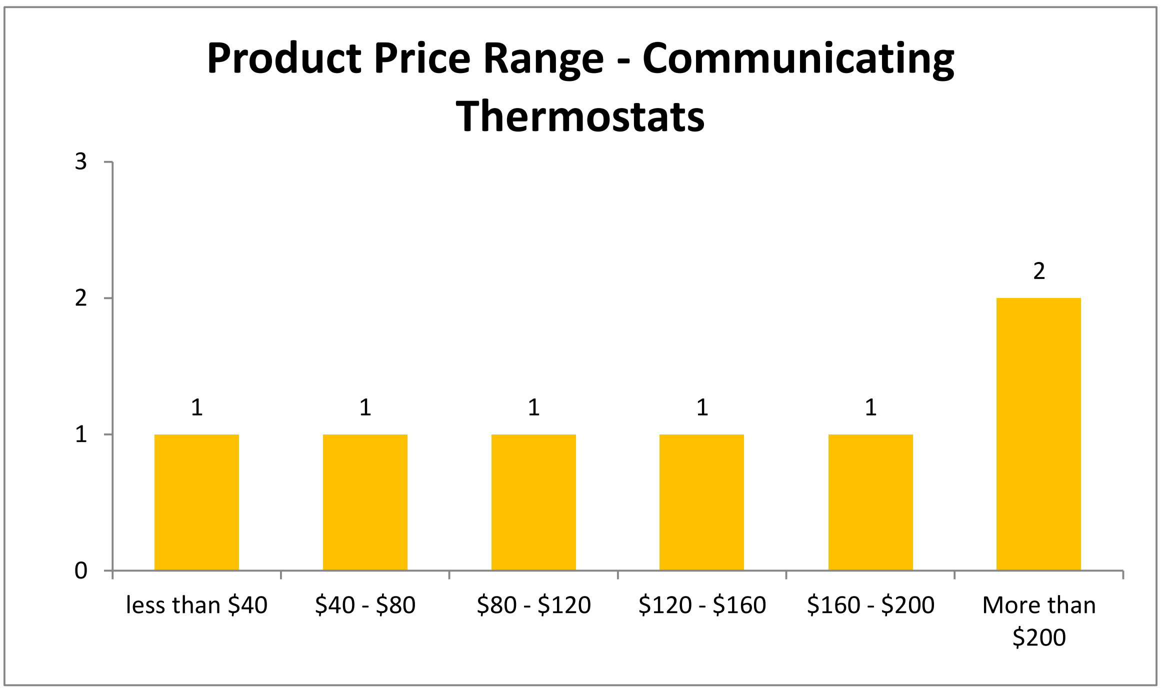


**Figure 14 Price range of communicating thermostats**

All manufacturers indicated they provide WiFi communication (Figure 15). 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.

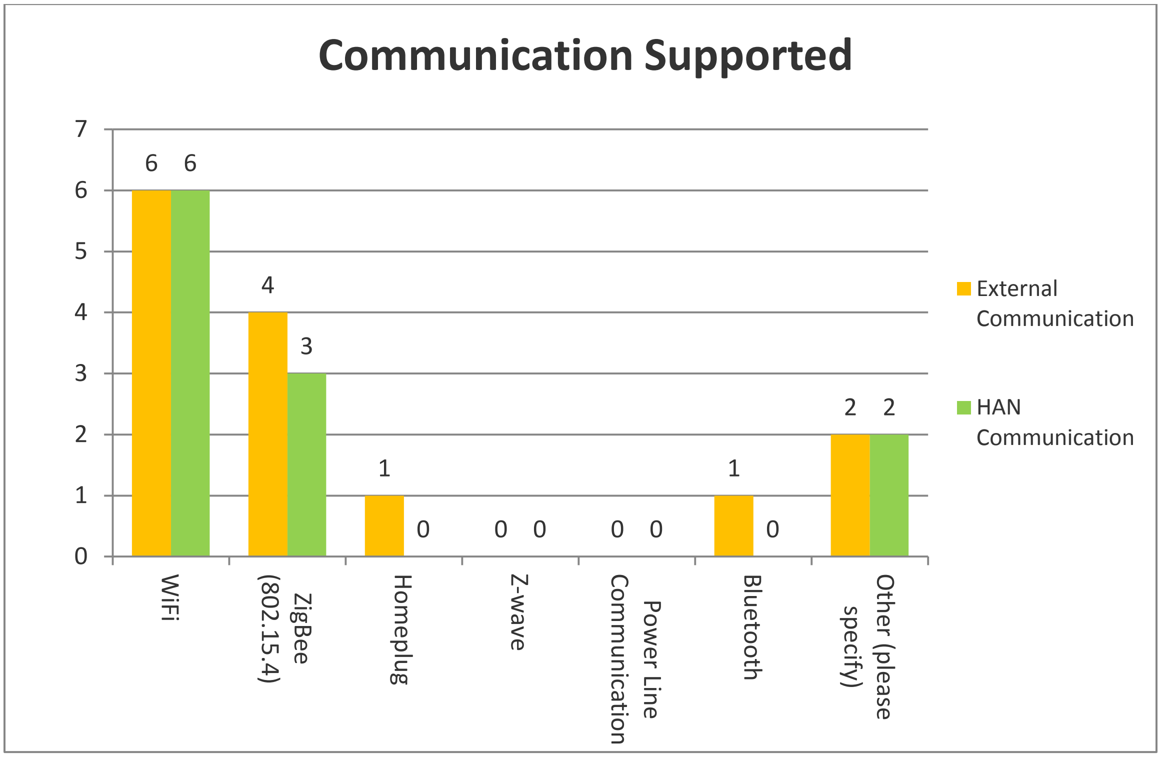


**Figure 15 External and HAN communication of thermostats**

The full results of the survey are available in Appendix 6.4.

## *3.2 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[8].

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

[8] 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[9], 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.

## *3.3 Savings Analysis*

Savings are calculated separately for residential and nonresidential buildings. However, for both sectors the same demand response event days were identified using the fifteen (15) days with the hottest afternoon (12pm-6pm) temperatures in each climate zone. The residential analysis uses the 30-year Residential TDV values to determine the economic value of energy savings while the commercial analysis uses the 15-year nonresidential TDV values.

Results from the 2005 impact evaluation for the Smart Thermostat program run by San Diego Gas & Electric (SDG&E 2005) were used to estimate rates of participation and override for customers in a residential demand response program using communicating thermostats.

Results from the program impact evaluation of the 2004 Southern California Edison Energy$mart Thermostat demand response pilot (SCE 2005) were used to estimate reasonable rates of participation and customer override in a demand response program using communicating thermostats in the small commercial sector. The program included 4,600 thermostats that controlled approximately 19,700 tons of air conditioning (average A/C size was about 4.5 tons). During the 2004 program year, 12

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

curtailment events were called. Analysis was performed for eight of the events, each a 2-hour 4-degree setback event.

The simulation analysis for each prototype building was performed for all 16 California climate zones. Demand Savings is calculated as the average kW savings for the Peak Period as defined by the CEC. This involves applying multipliers to weight the savings that occur during the 250 hours of the year considered to be peak. All of these hours take place between May and September. More information is available from the California Energy Commission.

### 3.3.1 Residential Savings

The results of the Micropas residential simulation models are presented in Figure 16 for the single 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 prototypes were a 2,100 square foot dwelling with a single HVAC zone (one thermostat) and a two-story 2,700 square foot dwelling with a single HVAC zone.

| | 2,100sf Single Family Dwelling Savings | | | |
|---|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) | Present Value of Savings ($) |
| CZ1 | 0 | 0.00 | 0 | $0.00 |
| CZ2 | 55 | 0.38 | 15,514 | $2,686.84 |
| CZ3 | 38 | 0.26 | 12,366 | $2,141.73 |
| CZ4 | 77 | 0.63 | 22,877 | $3,962.01 |
| CZ5 | 0 | 0.00 | 0 | $0.02 |
| CZ6 | 79 | 0.52 | 18,219 | $3,155.29 |
| CZ7 | 69 | 0.54 | 18,154 | $3,143.99 |
| CZ8 | 81 | 0.54 | 18,702 | $3,238.88 |
| CZ9 | 103 | 0.81 | 32,349 | $5,602.40 |
| CZ10 | 102 | 0.95 | 31,074 | $5,381.69 |
| CZ11 | 114 | 0.91 | 36,794 | $6,372.37 |
| CZ12 | 95 | 0.84 | 26,256 | $4,547.24 |
| CZ13 | 114 | 1.09 | 27,433 | $4,751.07 |
| CZ14 | 96 | 0.79 | 21,581 | $3,737.59 |
| CZ15 | 118 | 0.85 | 20,703 | $3,585.45 |
| CZ16 | 58 | 0.57 | 20,356 | $3,525.46 |

**Figure 16 Micropas Results for 2,100sf Single Family Simulation of 4˚F Setback**

| | 2,700sf Single Family Dwelling Savings | | | |
|---|---|---|---|---|
| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) | Present Value of Savings ($) |
| CZ1 | 0 | 0.00 | 0 | $0.00 |
| CZ2 | 91 | 0.64 | 26,317 | $4,557.77 |
| CZ3 | 52 | 0.37 | 18,482 | $3,200.89 |
| CZ4 | 108 | 0.90 | 32,426 | $5,615.80 |
| CZ5 | 6 | 0.02 | 710 | $123.04 |
| CZ6 | 87 | 0.63 | 21,755 | $3,767.79 |
| CZ7 | 75 | 0.65 | 21,929 | $3,797.81 |
| CZ8 | 97 | 0.68 | 23,404 | $4,053.31 |
| CZ9 | 120 | 0.97 | 38,704 | $6,703.03 |
| CZ10 | 116 | 1.15 | 38,221 | $6,619.35 |
| CZ11 | 122 | 1.06 | 42,489 | $7,358.55 |
| CZ12 | 121 | 1.11 | 34,971 | $6,056.62 |
| CZ13 | 122 | 1.25 | 31,349 | $5,429.31 |
| CZ14 | 107 | 0.95 | 25,785 | $4,465.67 |
| CZ15 | 119 | 0.96 | 23,275 | $4,030.89 |
| CZ16 | 64 | 0.73 | 25,934 | $4,491.41 |

**Figure 17 Micropas Results for 2,700sf Single Family Simulation of 4˚F Setback**

The average technical potential load impact for the residential models performing a four degree setback during the fifteen demand response event days are shown by climate zone in Figure 18 and Figure 19. Savings are presented in kWh per prototype building. Each prototype building includes one thermostat zone.

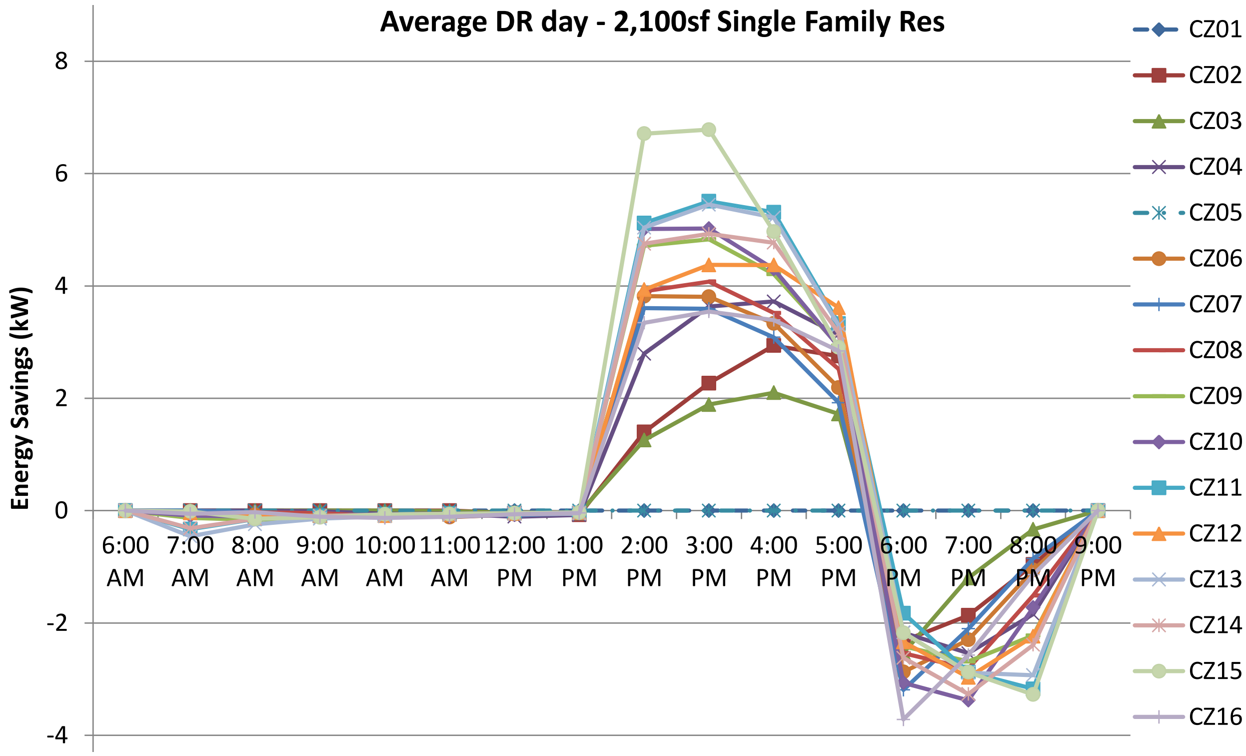


**Figure 18 Technical Potential for Average DR Day – 2,100sf Single Family model**

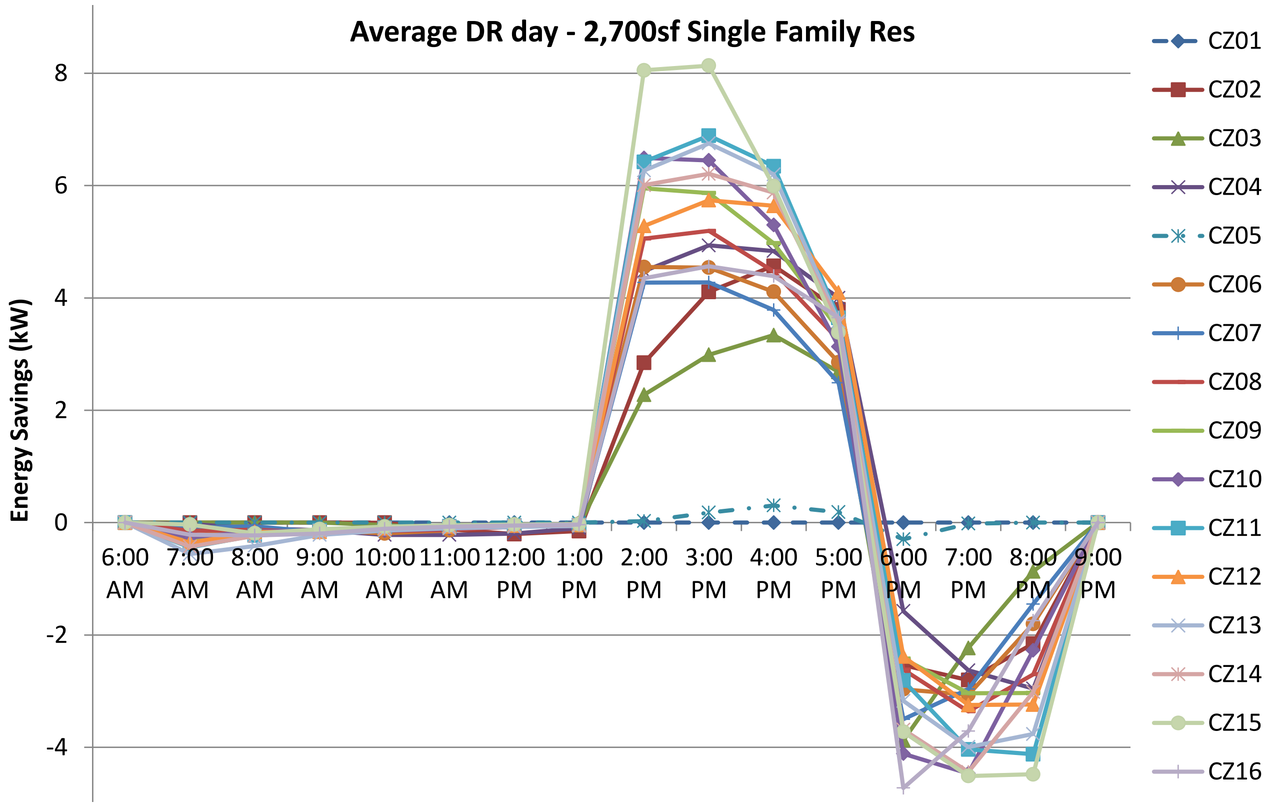


**Figure 19 Technical Potential for Average DR Day – 2,700sf Single Family model**

The expected average load impacts per participant using the single family residential models are presented below in Figure 21 and Figure 22. The average hourly savings have been adjusted to account for the base case assumptions presented in Figure 20, which account for variables that exist in reality that cause savings to be less than the simulated technical potential. The savings for each climate zone have also been adjusted to account for the percent of thermostats set to "Off" during the day as reported in the 2009 RASS (KEMA 2010), ranging from 6% to 45% of thermostats in that climate zone.

| Parameter | Percent |
|---|---|
| Percent of UST population receiving signal | 93% |
| Percent of participating population overriding DR signal – (Residential) | 20% |

**Figure 20 Residential Savings Adjustment Factors**

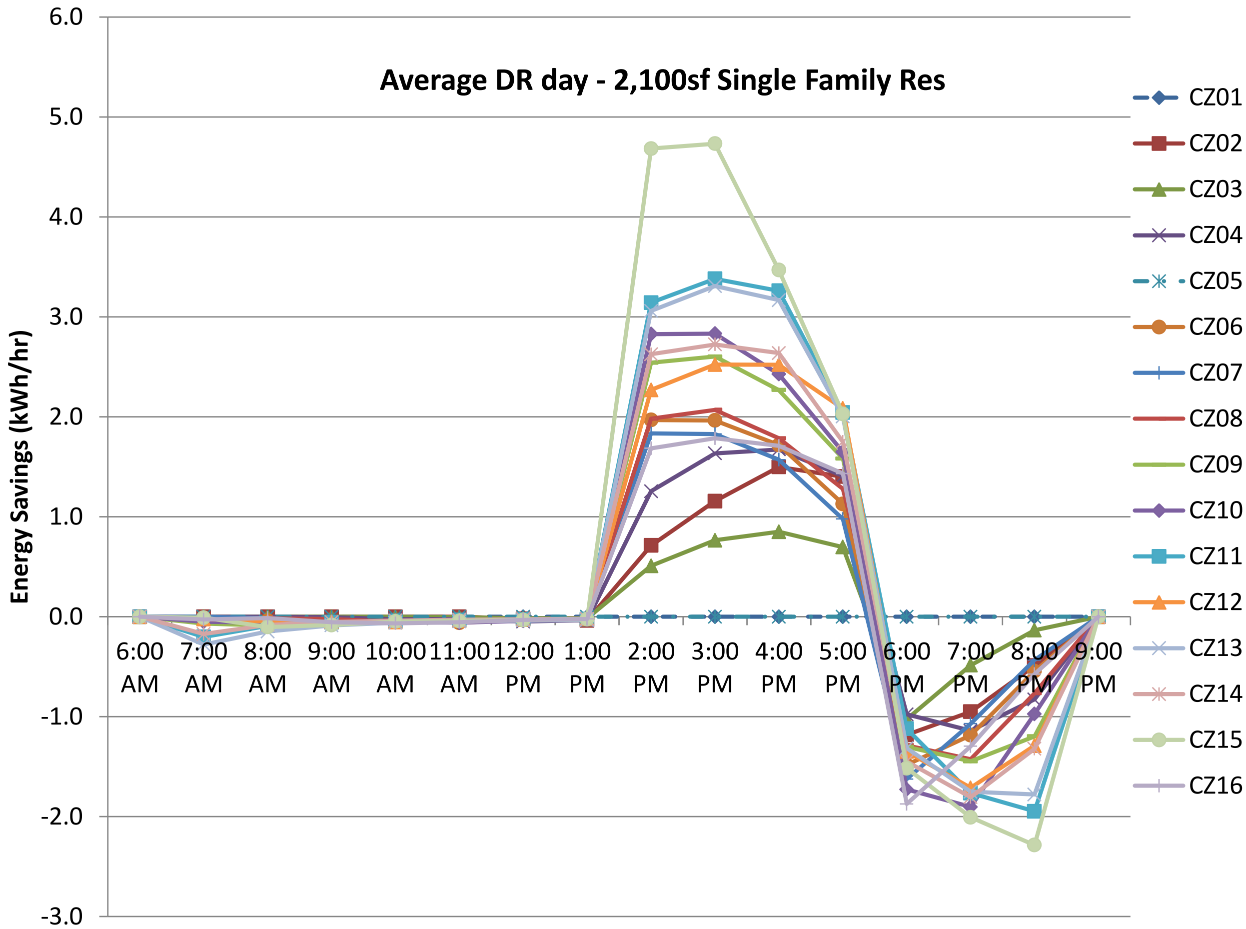


**Figure 21 Load impact for Average DR day participant - 2,100sf Single Family Model**

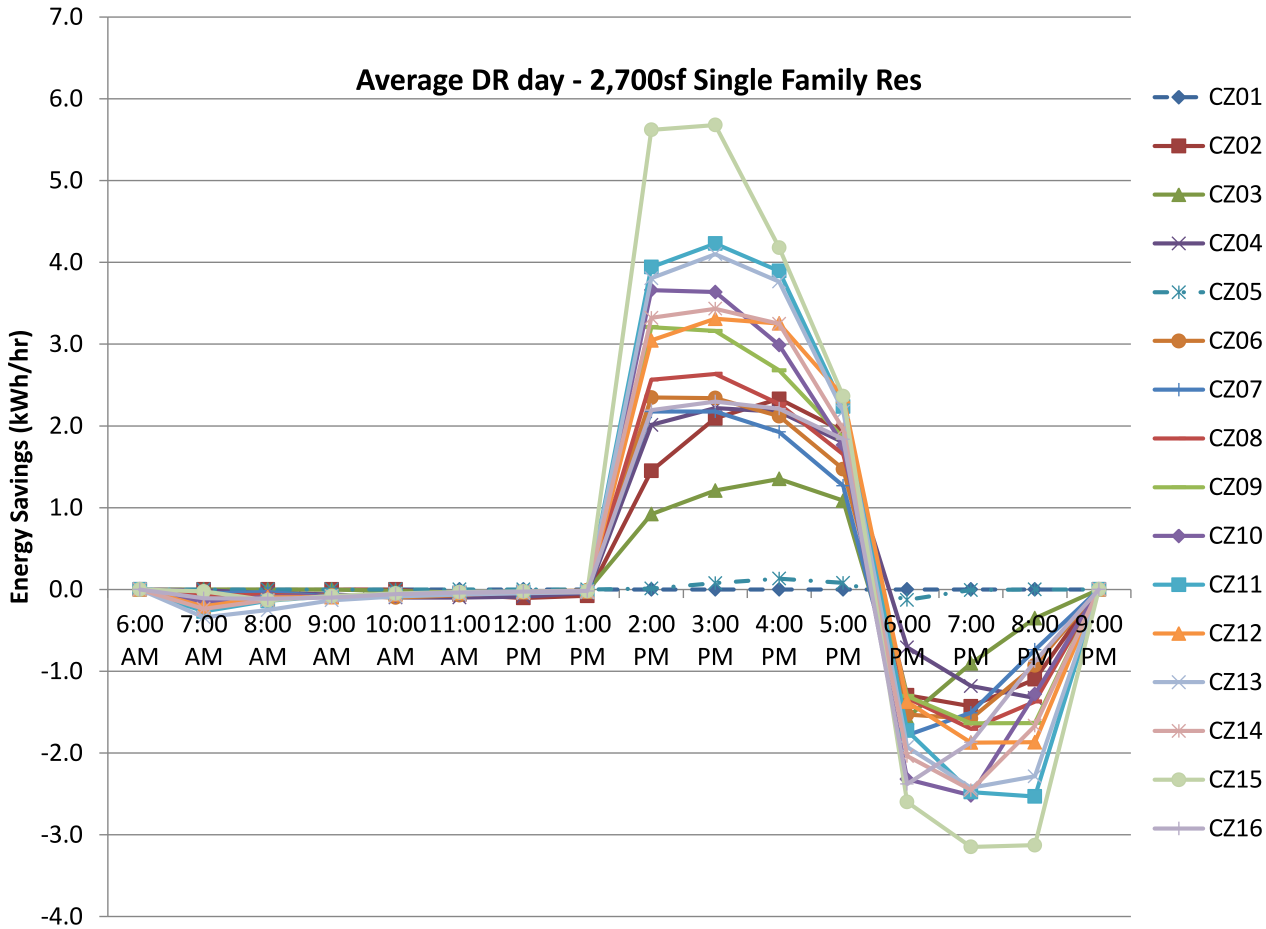


**Figure 22 Load impact for Average DR day participant - 2,700sf Single Family Model**

### 3.3.2 Nonresidential Savings

The results of the eQuest nonresidential simulation models are presented in Figure 23 and Figure 24 for the small office and small retail prototypes, respectively. These values represent the potential savings from a participant in a DR program with a 4 degree Fahrenheit setback from 2pm-6pm on each of the 15 hottest weekdays 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 2.3 - Development of Prototype Building. The small office prototype building included 10 thermostat zones (five per floor) in the 10,000 sf model. The energy savings are presented as the total for the building. Each orientation has the same glazing in this model, therefore accounting for the energy savings differences due to orientation in the one prototype. These results are also relatively conservative, considering the average thermostat zone size of 1,000 sf. More floor area per thermostat could theoretically realize greater savings during demand response events.

| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) | Present Value of Savings ($) |
|---|---|---|---|---|
| CZ1 | 83 | 0.19 | 11,943 | $1,063 |
| CZ2 | 274 | 1.27 | 62,043 | $5,522 |
| CZ3 | 223 | 0.89 | 50,909 | $4,531 |
| CZ4 | 236 | 1.40 | 55,169 | $4,910 |
| CZ5 | 232 | 0.69 | 34,466 | $3,067 |
| CZ6 | 181 | 0.88 | 42,629 | $3,794 |
| CZ7 | 168 | 1.10 | 45,908 | $4,086 |
| CZ8 | 227 | 0.98 | 43,926 | $3,909 |
| CZ9 | 265 | 1.47 | 69,697 | $6,203 |
| CZ10 | 229 | 1.88 | 73,216 | $6,516 |
| CZ11 | 226 | 1.45 | 65,521 | $5,831 |
| CZ12 | 258 | 1.68 | 59,637 | $5,307 |
| CZ13 | 235 | 1.97 | 55,283 | $4,920 |
| CZ14 | 223 | 1.39 | 43,248 | $3,849 |
| CZ15 | 254 | 1.41 | 40,149 | $3,573 |
| CZ16 | 147 | 1.13 | 41,190 | $3,666 |

**Figure 23 Office Prototype Savings per participant (4˚F Setback – whole building)**

The electricity savings are total building energy usage throughout the year. CEC approved TDV multipliers were used to convert the 8760 energy usage to TDV values, and the difference between the baseline and curtailment scenario is the savings presented here. The demand savings presented in Figure 23 and Figure 24 are calculated using CEC approved multipliers that weight the kW savings that occur during the top 250 hours of the year. The nonresidential 15-year TDV multiplier was used to convert TDV energy to TDV dollars. The TDV dollar value is the value of these energy savings each year over fifteen years.

| Climate Zone | Electricity Savings (kWh) | Demand Savings (kW) | TDV Electricity Savings (TDV kBTU) | Present Value of Savings ($) |
|---|---|---|---|---|
| CZ1 | 50 | 0.47 | 6,853 | $610 |
| CZ2 | 123 | 2.29 | 28,239 | $2,513 |
| CZ3 | 118 | 1.69 | 25,509 | $2,270 |
| CZ4 | 130 | 2.67 | 27,440 | $2,442 |
| CZ5 | 112 | 1.32 | 17,100 | $1,522 |
| CZ6 | 94 | 1.59 | 19,312 | $1,719 |
| CZ7 | 102 | 2.15 | 22,591 | $2,010 |
| CZ8 | 116 | 1.79 | 20,700 | $1,842 |
| CZ9 | 135 | 2.69 | 33,531 | $2,984 |
| CZ10 | 120 | 3.30 | 33,938 | $3,020 |
| CZ11 | 123 | 2.69 | 30,491 | $2,714 |
| CZ12 | 123 | 2.95 | 25,805 | $2,297 |
| CZ13 | 127 | 3.48 | 24,764 | $2,204 |
| CZ14 | 129 | 2.71 | 21,581 | $1,921 |
| CZ15 | 147 | 2.67 | 19,420 | $1,728 |
| CZ16 | 79 | 2.03 | 19,753 | $1,758 |

**Figure 24 Retail Prototype Technical Potential (4˚F Setback)**

The retail prototype model is 8,000 sf, and consists of two thermostat zones; 6,400sf of sales floor and 1,600sf of storage area. The savings presented are the average for four identical retail prototype building modeled in each of the four cardinal orientations. This was done because there is an uneven distribution of glazing, with no windows in the storage area and all of the windows in the sales floor area.

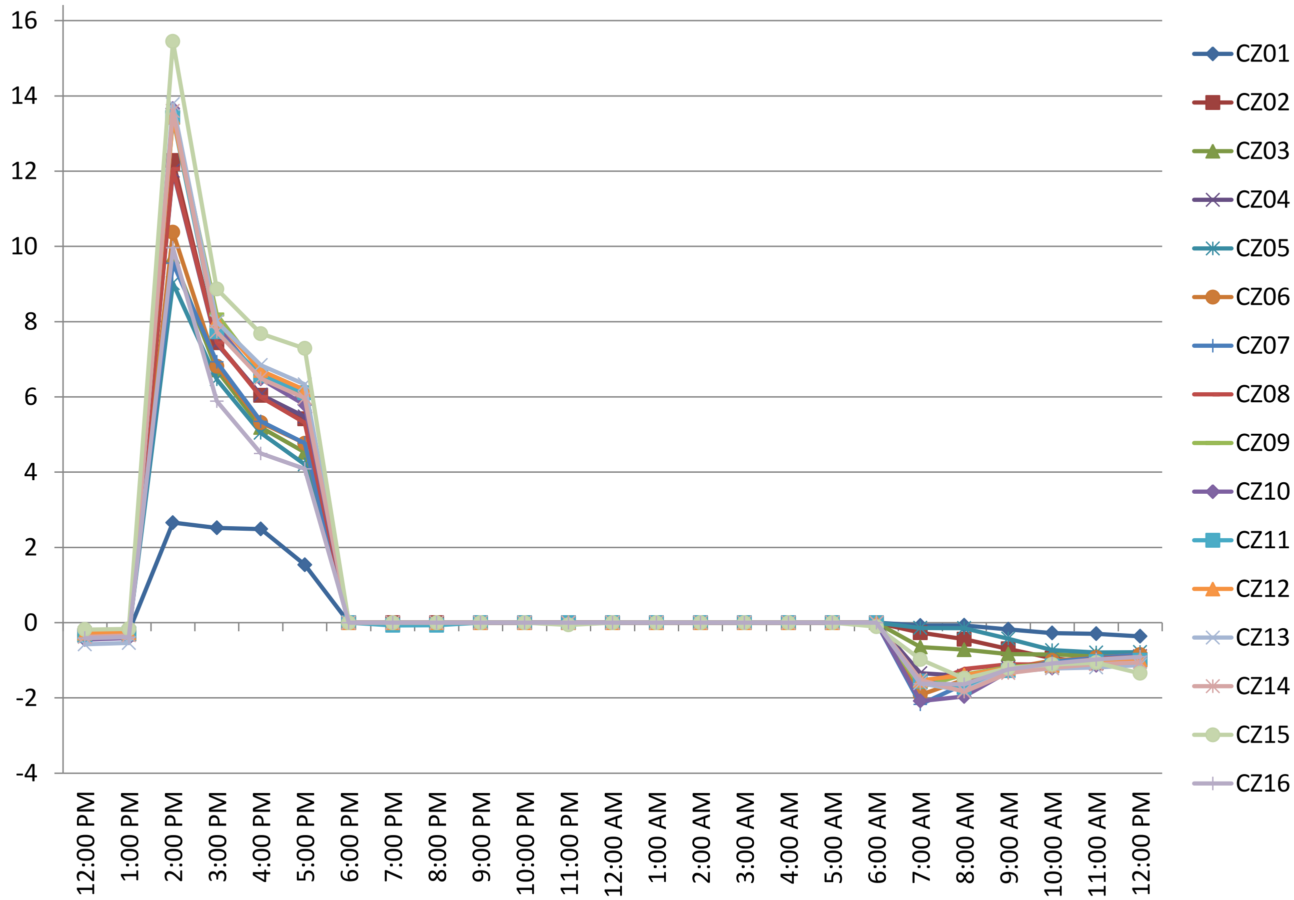


**Figure 25 Office Prototype Technical Potential Load Impact**

The average load impact results for the office prototype show a delayed rebound from the thermostat setback the morning after the DR event. This is due to the office occupancy schedule running from 7am to 6pm. The end of the thermostat setback for the DR event coincides with the thermostat setting up for the night. Therefore the temperature floats overnight higher than it would otherwise, and the rebound can be seen the morning after the event, starting at 7am. Under a different schedule, the rebound could potentially have a larger impact immediately following the end of the DR event. However, this schedule seems relatively likely for small offices in general.

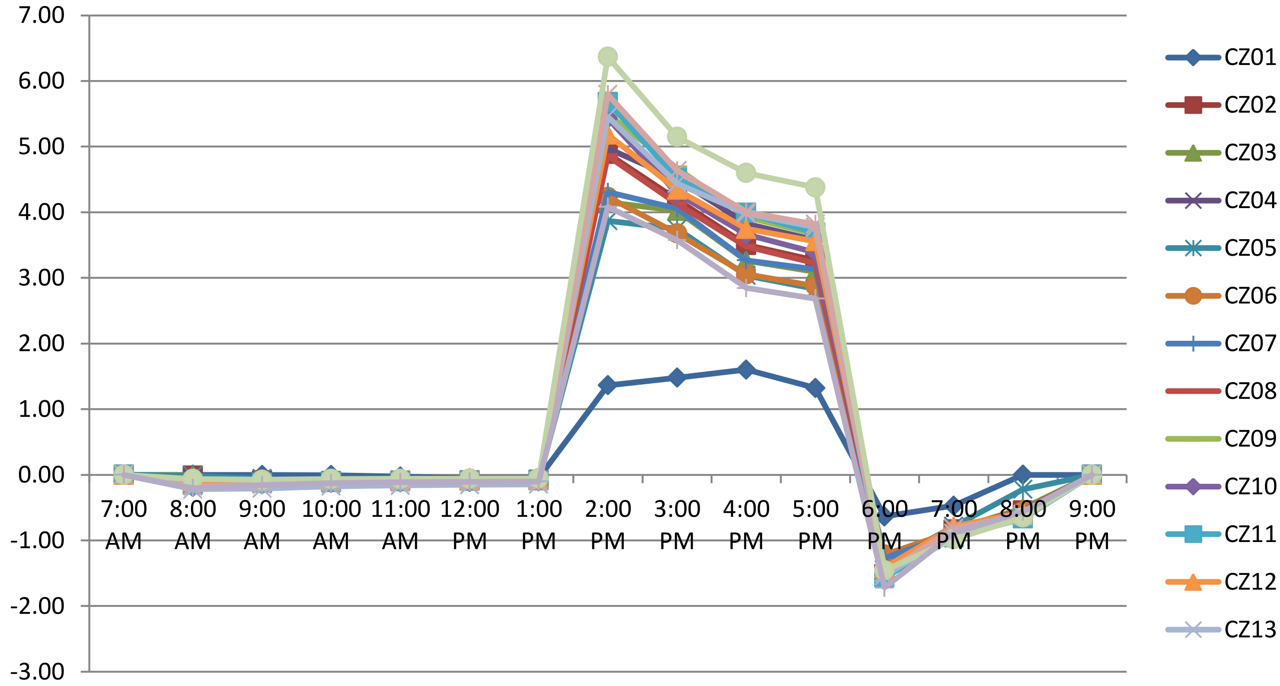


**Figure 26 Retail Prototype Technical Potential Load Impact**

Figure 26 shows the average load impact of a four-hour four-degree thermostat setback in a small retail building. The relative magnitude of the kW savings during the demand response event across climate zones is generally two to five times that of the rebound following the thermostat setback.

### *3.4 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.

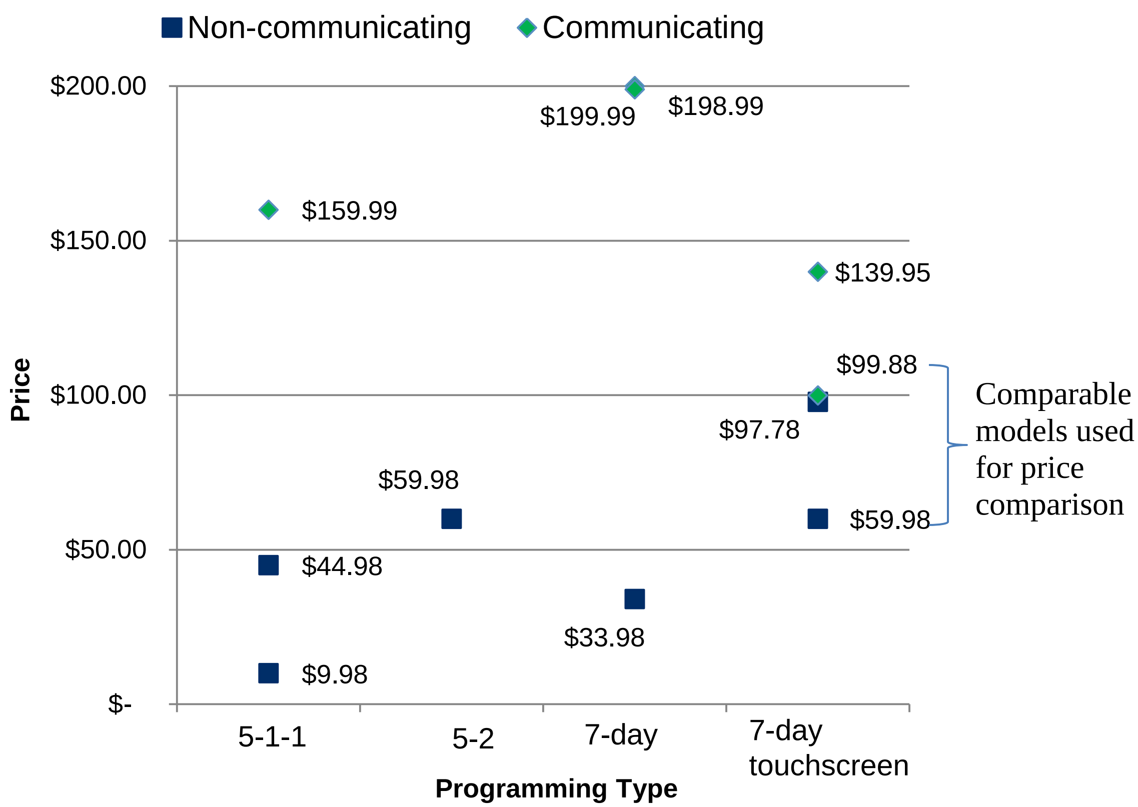


**Figure 27 Cost of Thermostats Collected from HomeDepot.com**

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.

## *3.5 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. In residential buildings, a 30-year life cycle is assumed, which requires two thermostats according to the assumption that thermostats have a 15-year measure life. Conservatively assuming that the incremental cost of these thermostats does not come down over the next fifteen years, the total cost for two thermostats is $112.24 assuming a 3% discount rate over the 15 year measure life.

The scenario analysis shows the cost effectiveness under various assumptions. The assumptions for each scenario are detailed in Figure 12. For the base case, we assume that 25% of the population participates in the DR programs, demand response events are triggered during the 15 hottest hours of the year, and 20% of the participants override the four degree setback during each event. For this scenario, the savings exceed the cost of the thermostat in both the residential and nonresidential prototypes, for all climate zones except for 1 and 5.

| Single family 2,100sf Benefit-Cost Ratio Scenario Analysis | Pessimistic | Base case | Optimistic |
|---|---|---|---|
| CZ1 | 0.00 | 0.00 | 0.00 |
| CZ2 | 0.85 | 3.05 | 10.57 |
| CZ3 | 0.54 | 1.92 | 6.67 |
| CZ4 | 1.11 | 3.96 | 13.74 |
| CZ5 | 0.00 | 0.00 | 0.00 |
| CZ6 | 1.01 | 3.62 | 12.57 |
| CZ7 | 1.00 | 3.56 | 12.36 |
| CZ8 | 1.03 | 3.66 | 12.70 |
| CZ9 | 1.88 | 6.71 | 23.27 |
| CZ10 | 1.89 | 6.75 | 23.43 |
| CZ11 | 2.44 | 8.71 | 30.21 |
| CZ12 | 1.64 | 5.85 | 20.28 |
| CZ13 | 1.80 | 6.43 | 22.30 |
| CZ14 | 1.29 | 4.60 | 15.96 |
| CZ15 | 1.56 | 5.57 | 19.32 |
| CZ16 | 1.11 | 3.96 | 13.72 |

**Figure 28 2,100 sf Single Family Benefit-Cost Ratio Scenario Analysis**

| Single family 2,700sf Benefit-Cost Ratio Scenario Analysis | Pessimistic | Base case | Optimistic |
|---|---|---|---|
| CZ1 | 0.00 | 0.00 | 0.00 |
| CZ2 | 1.45 | 5.17 | 17.93 |
| CZ3 | 0.80 | 2.87 | 9.96 |
| CZ4 | 1.57 | 5.61 | 19.47 |
| CZ5 | 0.03 | 0.12 | 0.41 |
| CZ6 | 1.21 | 4.33 | 15.01 |
| CZ7 | 1.21 | 4.31 | 14.93 |
| CZ8 | 1.28 | 4.58 | 15.89 |
| CZ9 | 2.25 | 8.03 | 27.84 |
| CZ10 | 2.33 | 8.31 | 28.81 |
| CZ11 | 2.82 | 10.06 | 34.88 |
| CZ12 | 2.18 | 7.79 | 27.02 |
| CZ13 | 2.06 | 7.35 | 25.49 |
| CZ14 | 1.54 | 5.50 | 19.07 |
| CZ15 | 1.75 | 6.26 | 21.72 |
| CZ16 | 1.41 | 5.04 | 17.48 |

**Figure 29 2,700 sf Single Family Benefit-Cost Ratio Scenario Analysis**

| **Multi-family 870sf Benefit-Cost Ratio Scenario Analysis** | **Pessimistic** | **Base case** | **Optimistic** |
|---|---|---|---|
| CZ1 | 0.00 | 0.00 | 0.00 |
| CZ2 | 0.35 | 1.26 | 4.38 |
| CZ3 | 0.22 | 0.80 | 2.76 |
| CZ4 | 0.46 | 1.64 | 5.69 |
| CZ5 | 0.00 | 0.00 | 0.00 |
| CZ6 | 0.42 | 1.50 | 5.21 |
| CZ7 | 0.41 | 1.48 | 5.12 |
| CZ8 | 0.42 | 1.52 | 5.26 |
| CZ9 | 0.78 | 2.78 | 9.64 |
| CZ10 | 0.78 | 2.80 | 9.71 |
| CZ11 | 1.01 | 3.61 | 12.51 |
| CZ12 | 0.68 | 2.42 | 8.40 |
| CZ13 | 0.75 | 2.66 | 9.24 |
| CZ14 | 0.53 | 1.91 | 6.61 |
| CZ15 | 0.65 | 2.31 | 8.00 |
| CZ16 | 0.46 | 1.64 | 5.69 |

**Figure 30 Multi-family Benefit-Cost Ratio Scenario Analysis**

In order to determine cost effectiveness of the UST measure in multifamily dwelling units, the energy savings from the 2,100sf single family prototype in each climate zone were calculated on a kWh/sf basis, and applied to the CEC multi-family prototype, prorated for dwelling size. The CEC multi-family prototype (Prototype E) is an eight-dwelling building, with each dwelling having an area of 870sf. The cost effectiveness results are presented above in Figure 30. Once again, climate zones 1 and 5 do not have high enough cooling loads to prove the UST cost-effective. Climate zone 3 also shows up as having a benefit-cost ratio of less than one under the assumption that the incremental cost of the UST does not decrease over time. If we instead assume that over 15 years the incremental cost of the UST reduces down close to zero, climate zone 3 would prove the UST cost-effective (as demonstrated in the Overview section summarizing life cycle cost analysis).

| Office Benefit-Cost Ratio Scenario Analysis | Pessimistic | Base case | Optimistic |
|---|---|---|---|
| CZ1 | 0.11 | 0.39 | 1.20 |
| CZ2 | 0.57 | 2.02 | 6.22 |
| CZ3 | 0.47 | 1.66 | 5.11 |
| CZ4 | 0.51 | 1.80 | 5.54 |
| CZ5 | 0.32 | 1.12 | 3.46 |
| CZ6 | 0.39 | 1.39 | 4.28 |
| CZ7 | 0.43 | 1.49 | 4.61 |
| CZ8 | 0.41 | 1.43 | 4.41 |
| CZ9 | 0.65 | 2.27 | 6.99 |
| CZ10 | 0.68 | 2.38 | 7.35 |
| CZ11 | 0.61 | 2.13 | 6.57 |
| CZ12 | 0.55 | 1.94 | 5.98 |
| CZ13 | 0.51 | 1.80 | 5.55 |
| CZ14 | 0.40 | 1.41 | 4.34 |
| CZ15 | 0.37 | 1.31 | 4.03 |
| CZ16 | 0.38 | 1.34 | 4.13 |

**Figure 31 Small Office Benefit-Cost Ratio Scenario Analysis**

| Retail Benefit-Cost Ratio Scenario Analysis | Pessimistic | Base case | Optimistic |
|---|---|---|---|
| CZ1 | 0.32 | 1.12 | 3.44 |
| CZ2 | 1.31 | 4.60 | 14.17 |
| CZ3 | 1.18 | 4.15 | 12.80 |
| CZ4 | 1.27 | 4.47 | 13.77 |
| CZ5 | 0.79 | 2.78 | 8.58 |
| CZ6 | 0.89 | 3.14 | 9.69 |
| CZ7 | 1.05 | 3.68 | 11.33 |
| CZ8 | 0.96 | 3.37 | 10.38 |
| CZ9 | 1.55 | 5.46 | 16.82 |
| CZ10 | 1.57 | 5.52 | 17.03 |
| CZ11 | 1.41 | 4.96 | 15.30 |
| CZ12 | 1.19 | 4.20 | 12.95 |
| CZ13 | 1.15 | 4.03 | 12.42 |
| CZ14 | 1.00 | 3.51 | 10.83 |
| CZ15 | 0.90 | 3.16 | 9.74 |
| CZ16 | 0.91 | 3.21 | 9.91 |

**Figure 32 Small Retail Benefit-Cost Ratio Scenario Analysis**

The results presented above indicate that 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 most 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. Climate zones 1 and 5 should mostly remain unaffected, since RASS estimates that 89% and 84% of homes in those areas, respectively, do not have any air conditioning (KEMA 2010). How these results translate to reality will be dependent upon the rules that are created for demand response programs and how people actually decide to respond to them.

To show that the UST measure was cost-effective even under conditions that would yield conservatively low savings estimates, we derated our results to match the average demand reduction experienced by the Summer Discount Plan being run by Southern California Edison. Whereas the Summer Discount Plan, a residential load-control cycling program that gives customers the option of cycling their air conditioners off 50%, 67% or 100% of each demand response event hour, the technical analysis used by this report for the UST that simulates the thermostat being set up by 4 degrees during the demand response period.

An impact analysis of the Summer Discount Plan found that in a 1 out of 2 weather year (i.e. every second year the weather would be more extreme) found that this HVAC cycling program reduced peak demand by an average of 1.46 kWh/hr over the 4 hour event (Freeman, Sullivan & Co., 2009). The energy impact of the Summer Discount Plan is plotted as the purple line with x's in Figure

33. In comparison, the simulation analysis for a UST that sets up the thermostat by 4 degrees over the demand response period, found that the statewide weighted demand reduction was 2.28 kWh/hr; this is shown as the red curve at the top of Figure 33. The UST simulation demand reduction results were averaged for just those climate zones eligible for participation in the SCE Summer Discount Plan (climate zones 6-10, 14-16); which resulted in a predicted UST weighted demand reduction of 3.07 kWh/hr. We then normalized the UST simulation results to the Summer Discount Plan results by multiplying the UST simulation hourly impacts by a derating factor of 48% (1.46/3.07).

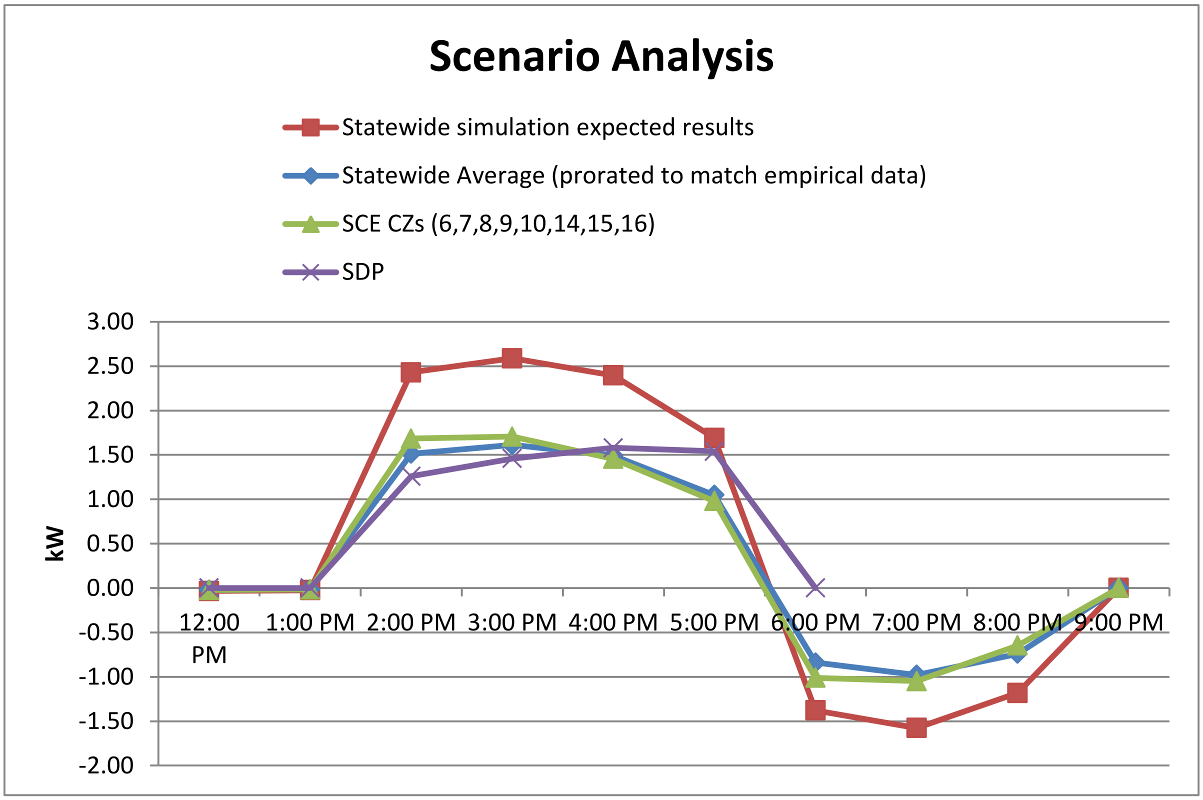


**Figure 33 Weighted State-wide average load impacts per event – scenario analysis**

Applying this derating factor to the UST simulation load impacts for each climate zone and calculating the cost effectiveness results in the values presented in **Error! Reference source not ound.**. The outcome of this calculation is that even using the conservatively low savings associated with the derated results (1.46 kWh/hr instead of 2.28 kWh/hr), the UST measure remains cost effective in all climate zones except for 1 and 5. Of the other 14 climate zones, all but two have a benefit-cost ratio of at least 1.9 to 1, thus the UST is very cost effective, even when considering that it might have performance comparable to air conditioner cycling rather than a thermostat set point set up.

| | CZ 01 | CZ 02 | CZ 03 | CZ 04 | CZ 05 | CZ 06 | CZ 07 | CZ 08 | CZ 09 | CZ 10 | CZ 11 | CZ 12 | CZ 13 | CZ 14 | CZ 15 | CZ 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benefit Cost Ratio | 0.0 | 1.6 | 1.01 | 2.1 | 0.0 | 1.9 | 1.9 | 1.9 | 3.5 | 3.5 | 4.6 | 3.1 | 3.4 | 2.4 | 2.9 | 2.1 |

**Figure 34 Benefit Cost Ratio Under Summer Discount Program Scenario**

## *3.6 Statewide Savings Estimate*

The total energy and energy cost savings potential for this measure are presented by building type and climate zone in Section 3.3. These unit estimates were then reduced to account for participation, override and communication failure rates for analysis of cost effectiveness, as described in Section 3.5. These savings estimates from the cost effectiveness calculation are then scaled to produce the statewide estimate of new construction when multiplied by the percent of the population that is expected to be affected by the proposed measure.

The expected number of residential dwellings required to comply with the UST requirement in 2014 was calculated to be 69,721 single family dwellings and 10,981 multi-family dwellings. The savings per dwelling for the two single family prototypes were averaged and then multiplied by the expected number of single family dwellings in new construction. The energy savings was calculated as an average between the two single family prototypes because according to the 2009 RASS, the average size of a single family home constructed between 2001 and 2008 was 2,424 sf, which is almost same as the average size of the two single family prototypes used in the analysis (2,400sf). The savings for multi-family dwelling units was calculated by applying the energy savings per sf from the 2,100sf prototype simulation and prorating it for an 870sf multi-family dwelling unit, as specified by Prototype E in the 2008 Title 24 Residential ACM. These savings were multiplied by the number of multi-family dwellings that are expected to be constructed in 2014.

To calculate expected statewide savings in the nonresidential sector, simulation savings results were converted to a kWh/sf basis. Small offices (less than 30,000sf) were assumed to be required to comply with the UST requirement, while larger offices are assumed to have some sort of energy management control system (EMCS), which exempts them from the UST requirement. A similar logic applied to retail spaces, where building larger than 50,000sf were assumed to have an EMCS, thus exempting them from the UST requirement.

For the rest of the commercial population of building, we conservatively assumed that 10% of all nonresidential building types other than offices, retail, refrigerated warehouse or hospitals would comply with the UST requirement. The rest of the buildings are expected to have energy management control systems (EMCS) that would exempt them from this requirement, while still allowing for their participation in demand response events and programs. Additionally, it would be possible for homeowners and business owners to use the UST to respond to price signals, which could account for greater hours of use and thus increased savings beyond the demand response program that was modeled.

The estimate of statewide savings results in the figures presented below in Figure 35.

| | First Year Electric Energy Savings (GWh) | First Year Peak Demand Savings (MW) | First Year Gas Energy Savings (MMtherms) | First Year TDV Energy Savings (TDV KBTU) |
|---|---|---|---|---|
| Residential Statewide | 1.171 | 10.560 | n/a | 304,361,295 |
| Nonresidential Statewide | 0.018 | 0.172 | n/a | 1,171,963 |

**Figure 35 Statewide Savings Estimate for UST**

# 4. 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 expansion port which will allow for the installation of a removable module to enable Demand Responsive Control through standards based communications (including but not limited to ZigBee or WiFi) and standards based messaging protocols (Smart Energy Profile (SEP), OpenADR or others defined in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards (CoS)). Installation of the module shall upgrade the programmable setback thermostat to a communicating setback thermostat. After the communication module is installed and the occupant has enrolled in a program or subscribed to a messaging service, the UST shall be capable of both receiving and responding to Demand Response Signals. USTs, with the communication module installed, shall be capable of receiving and responding to the Demand Response Signals as follows:**

   A. **Event Response**

      **i. Upon initial installation of the communication module by the occupant, the UST shall default to offsets of +4°F for cooling and -4°F for heating relative to the current setpoint in response to DR events or pricing signals. The current setpoint is the setpoint that existed just prior to the current DR event.**

      **ii. The UST shall have the capability to allow occupants to modify the default offsets with user defined offsets for cooling and heating relative to the current setpoint in response to DR events and pricing signals.**

iii. **Override Function: Occupants shall be able to change the offsets and thermostat settings at any time, including during DR events.**

iv. **A Demand Response Signal shall trigger the UST to adjust the thermostat setpoint for Demand Response Control by either the default number of degrees or as established by the user.**

v. **When a price signal indicates a price in excess of the price established by the user, the UST shall adjust the thermostat set point for Demand Response Control by either the default number of degrees or as established by the user.**

vi. **The DR event shall start either immediately or at a specific start time as specified in the event signal and continue for the duration specified in the event signal or until the occupant overrides the event set point.**

vii. **The thermostat's price response shall start either immediately or at a specific start time as specified in the pricing signal and continue for the duration specified in the pricing signal or until the occupant overrides the event set point.**

viii. **The UST shall have the capability to allow occupants to define setpoints for cooling and heating in response to DR and pricing signals as an alternative to temperature-offsetting response, as described in Reference Joint Appendix JA5.**

ix. **At the end of the DR event, the thermostat set point shall be set the set point that is programmed for the point in time that the event ends.**

B. **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 on the standard UST display, using a Liquid Crystal Display, standalone indicator using Light Emitting Diodes, or other means regarding**

i. **communications system connection status**

ii. **DR or pricing event information**

iii. **other maintenance-related information.**

C. **At a minimum, standardized terminal mapping of terminal numbers 1-6. 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. **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.**

F. **Reference default program as specified in Energy Star XXX.**

**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.**

# 5. Bibliography and Other Research

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http://www.calmac.org/publications/Final_2004_SCE_E$T_Program_Impact_Eval_Report_g.pdf

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.

# 6. Appendices

## *6.1 Non-Residential Construction Forecast details*

### 6.1.1 Summary

The Non-Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from Dodge construction database, the demand forecast office future generation facility planning data, and building permit office data.

All CASE reports should use the statewide construction forecast for 2014. The TDV savings analysis is calculated on a 15 or 30 year net present value, so it is correct to use the 2014 construction forecast as the basis for CASE savings.

### 6.1.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ) as well as building type (based on NAICS codes). The 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and additional construction. Total construction is the sum of all existing floor space in a given category (Small office, large office, restaurant, etc.). Additional construction is floor space area constructed in a given year (new construction); this data is derived from the sources mentioned above (Dodge, Demand forecast office, building permits).

Additional construction is an independent dataset from total construction. The difference between two consecutive years of total construction is not necessarily the additional construction for the year because this difference does not take into consideration floor space that was renovated, or repurposed.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has provided CASE authors with the ability to aggregate across multiple building types. This tool is useful for measures that apply to a portion of various building types' floor space (e.g. skylight requirements might apply to 20% of offices, 50% of warehouses and 25% of college floor space).

The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022 (or 10-12 years in the future), and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years' construction (over the life of the measure). The CEC non-residential construction forecast is the best publicly available data to estimate statewide energy savings.

#### 6.1.3 Citation

"NonRes Construction Forecast by BCZ v7"; Developed by Heschong Mahone Group with data sourced August, 2010 from Abrishami, Moshen at the California Energy Commission (CEC).

### *6.2 Residential Construction Forecast Details*

#### 6.2.1 Summary

The Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from the California Department of Finance and California Construction Industry Research Board (CIRB) building permits. The Department of Finance uses census years as independent data and interpolates the intermediate years using CIRB permits.

CASE stakeholders expressed concern that the Residential forecast was inaccurate compared with other available data (in 2010 CEC forecast estimate is 97,610 new units for single family and the CIRB estimate is 25,526 new units). In response to this discrepancy, HMG revised the CEC construction forecast estimates. The CIRB data projects an upward trend in construction activity for 2010-2011 and again from 2011-2012. HMG used the improvement from 2011-2012 and extrapolated the trend out to 2014. The improvement from 2011-2012 is projected to be 37%. Instead of using the percent improvement year on year to generate the 2014 estimate, HMG used the conservative value of the total units projected to be built in 2011-2012 and added this total to each subsequent year. This is the more conservative estimate and is appropriate for the statewide savings estimates. Based on this trend, the new construction activity is on pace to regain all ground lost by the recession by 2021. The multi-family construction forecasts are consistent between CEC and CIRB and no changes were made to the multi-family data.

| Residential New Construction Estimate (2014) | | | |
|---|---|---|---|
| | Single Family | Multi-family Low Rise | Multi-family High Rise |
| CZ 1 | 378 | 94 | - |
| CZ 2 | 1,175 | 684 | 140 |
| CZ 3 | 1,224 | 863 | 1,408 |
| CZ 4 | 2,688 | 616 | 1,583 |
| CZ 5 | 522 | 269 | 158 |
| CZ 6 | 1,188 | 1,252 | 1,593 |

| | | | |
|---|---|---|---|
| CZ 7 | 2,158 | 1,912 | 1,029 |
| CZ 8 | 1,966 | 1,629 | 2,249 |
| CZ 9 | 2,269 | 1,986 | 2,633 |
| CZ 10 | 8,848 | 2,645 | 1,029 |
| CZ 11 | 3,228 | 820 | 81 |
| CZ 12 | 9,777 | 2,165 | 1,701 |
| CZ 13 | 6,917 | 1,755 | 239 |
| CZ 14 | 1,639 | 726 | - |
| CZ 15 | 1,925 | 748 | - |
| CZ 16 | 1,500 | 583 | - |
| Total | 47,400 | 18,748 | 13,845 |

**Residential construction forecast for 2014, in total dwelling units**

### 6.2.2 Additional Details

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ). These 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and decay rate. Total construction is the sum of all existing dwelling units in a given category (Single family, Multi-family low rise and Multi-family high rise). Decay rate is the number of units that were assumed to be retrofitted, renovated or demolished. The difference in total construction between consecutive years (including each year’s decay rate) approximates the new construction estimate for a given year.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has segmented all multi-family buildings into low rise and high rise space (where high rise is defined as buildings 4 stories and higher). This calculation is based on data collected by HMG through program implementation over the past 10 years. Though this sample is relatively small (711), it is the best available source of data to calculate the relative population of high rise and low rise units in a given FCZ.

Most years show close alignment between CIRB and CEC total construction estimates, however the CEC demand forecast models are a long-term projection of utility demand. The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022, and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure), however to estimate next year's construction, CIRB is a more reliable data set.

#### 6.2.3 Citation

"Res Construction Forecast by BCZ v4"; Developed by Heschong Mahone Group with data sourced September, 2010 from Sharp, Gary at the California Energy Commission (CEC).

## *6.3 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.

### 6.3.1 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 36: U-Snap module and internal chip**

***Comverge***


**Figure 37: 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 38: 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 39: IECT220 Figure 40: 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 41: 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](http://www.ourhomespaces.com)). They include a communicating thermostat, a thermostat gadget

***Radio Thermostat Company of America***

**Figure 42: 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.

### 6.3.2 Independent Thermostat manufacturers

***Energate***


**Figure 43: 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 44: 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 45: 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 46: 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 47: 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 48: 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 49: 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 50: 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).

## *6.4 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.

### 6.4.1 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.

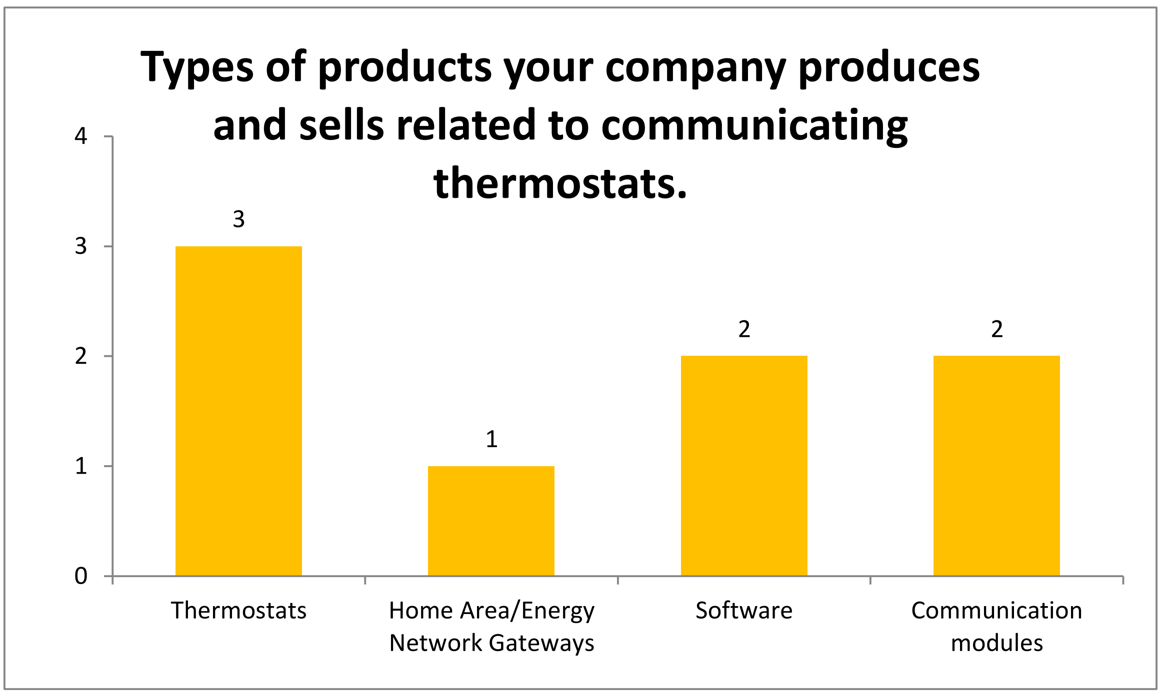


**Figure 51 Types of products sold by manufacturers surveyed**

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.

### 6.4.2 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.

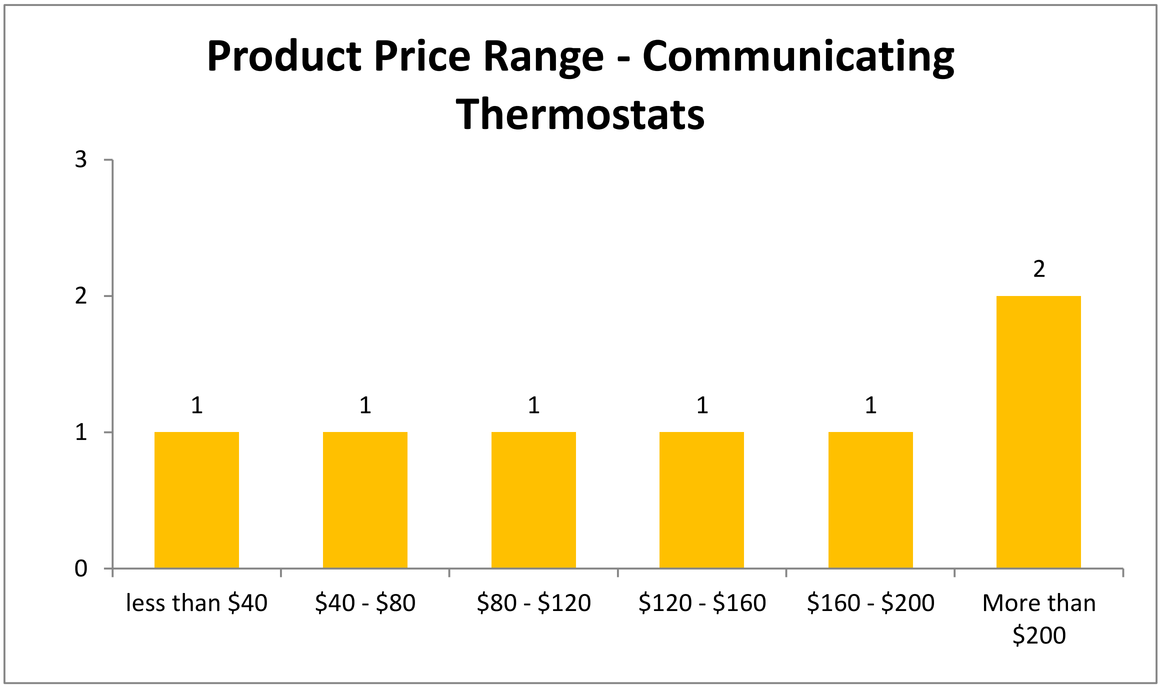


**Figure 52 Price range of communicating thermostats**

### 6.4.3 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 53). 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.

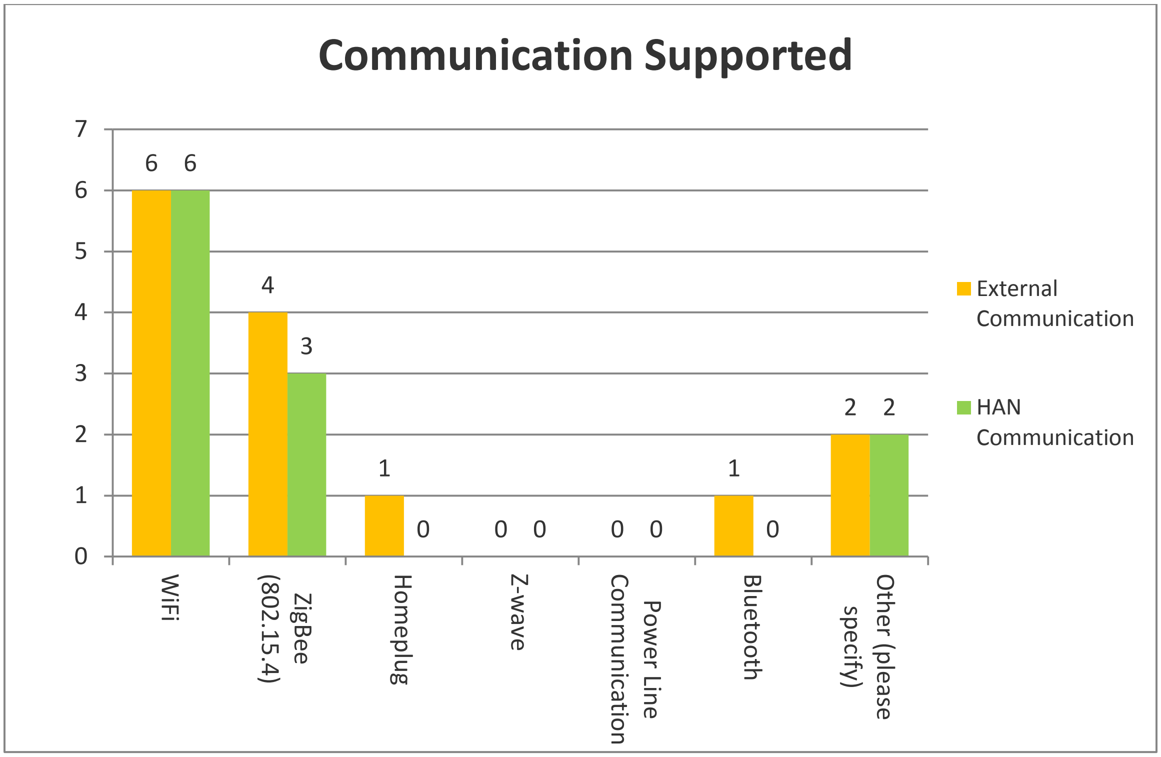


**Figure 53 External and HAN communication of thermostats**

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 54. 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.

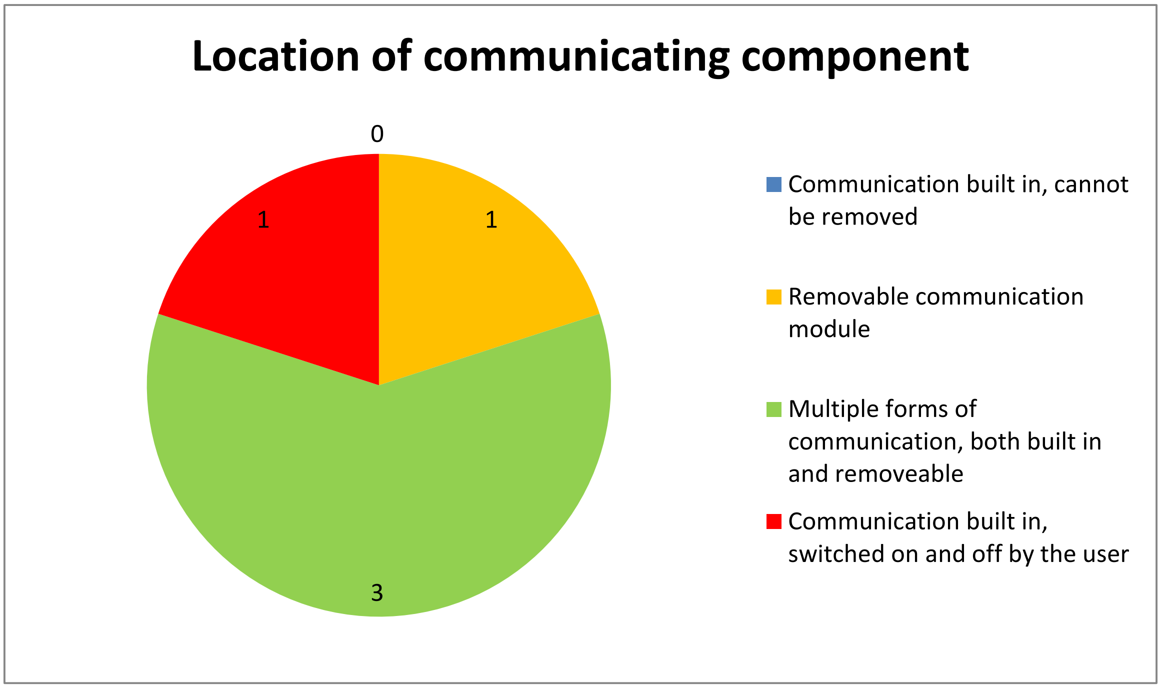


**Figure 54 Location of communication component.**

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 55. 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.

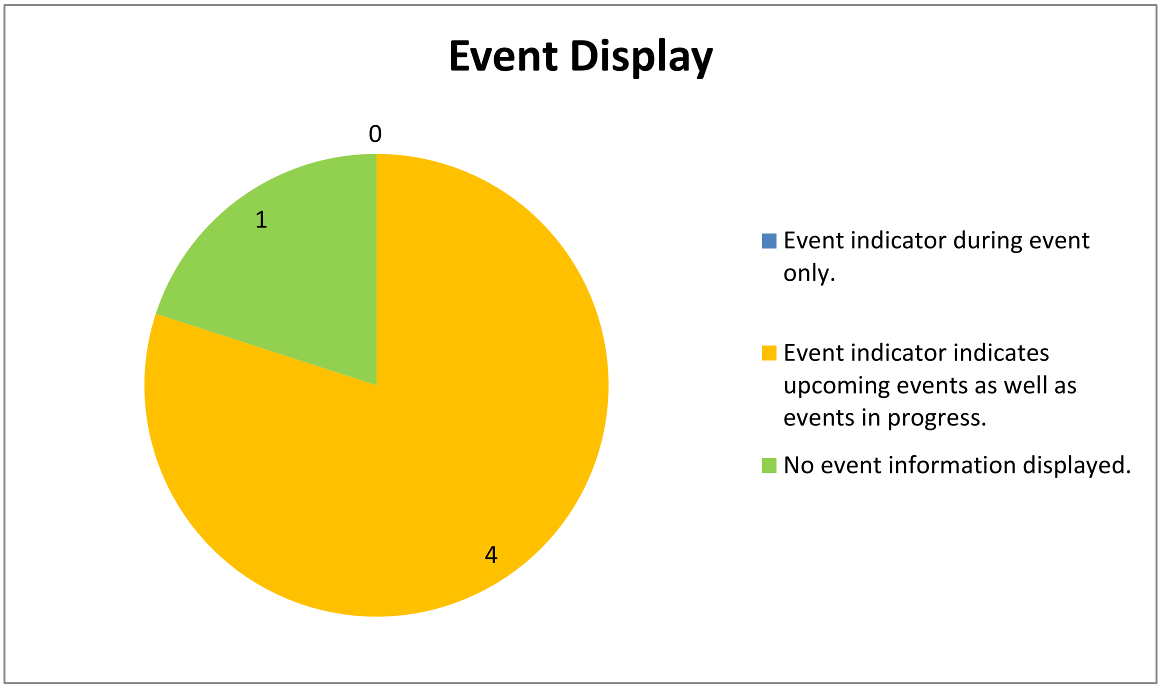


**Figure 55 Event display types implemented by surveyed manufacturers.**

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 56 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.

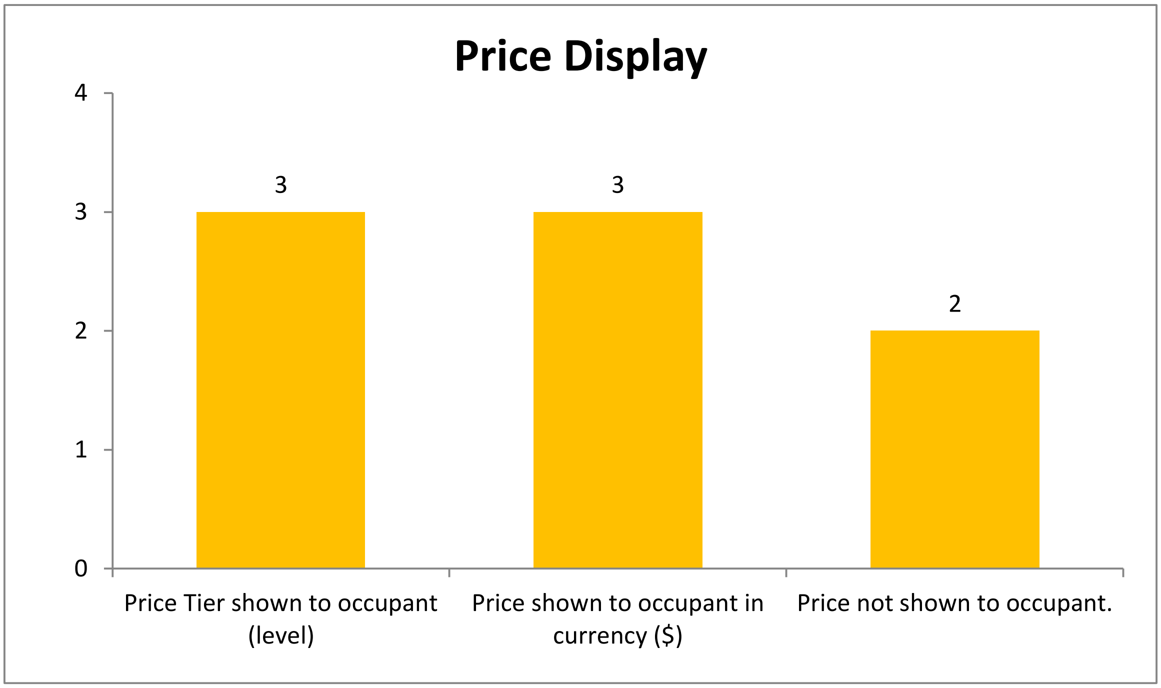


**Figure 56 Price display types implemented by surveyed manufacturers.**

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 57. 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.

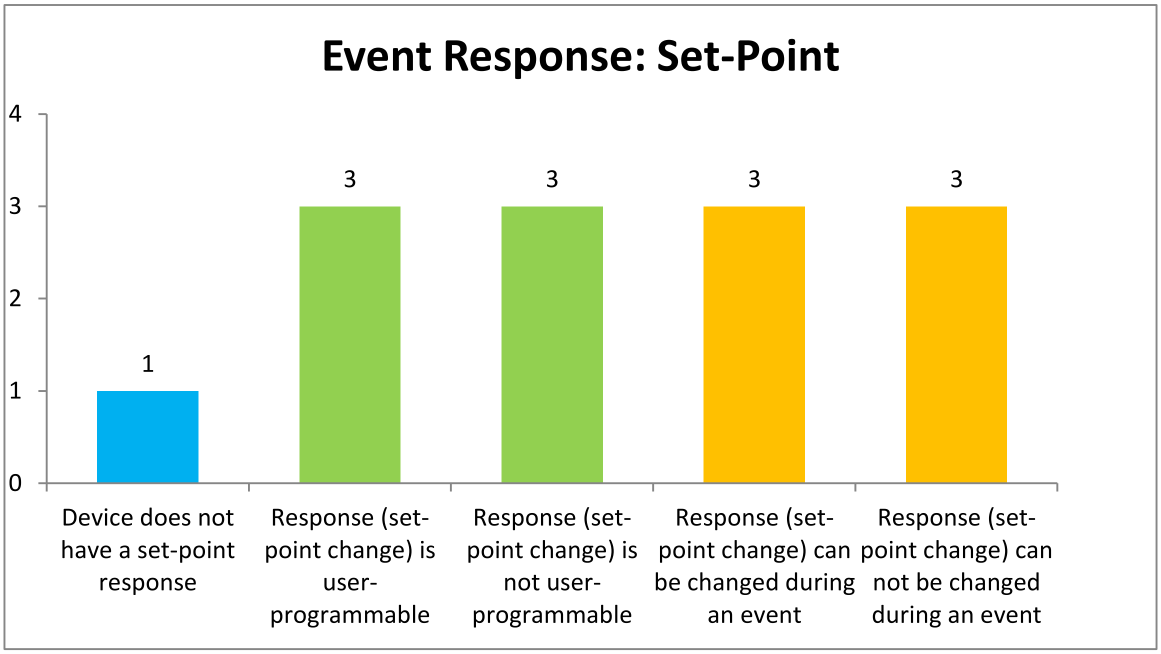


**Figure 57 Set-point response programming supported by surveyed manufacturers.**

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 58, 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.

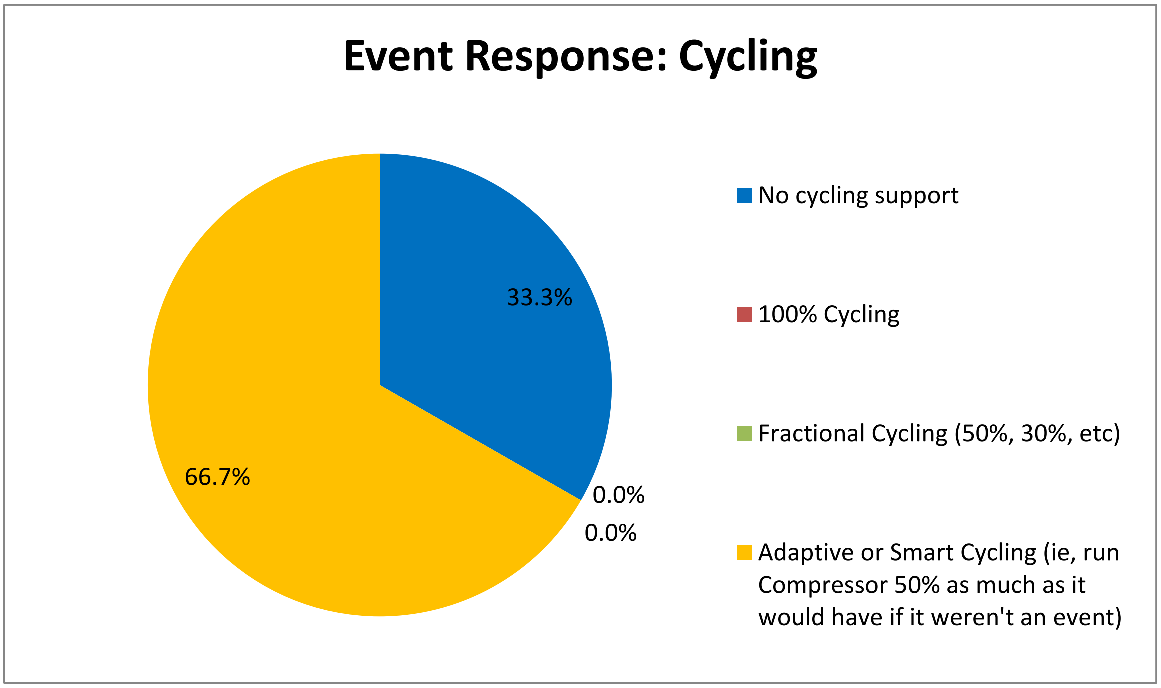


**Figure 58 Cycling strategies supported by surveyed manufacturers.**