CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Guest Room Occupancy Controls

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.

Table of Contents

Table of Figures

1. Purpose

Hotel and motel guest room occupancy schedules are highly variable, and rooms are frequently conditioned while vacant. Guests often leave space conditioning equipment running and lighting on when they leave the room. Installation of occupancy controls have been shown to reduce unnecessary energy consumption in unoccupied guest rooms, while offering additional conveniences to management and staff. The purpose of this CASE report is to calculate the incremental costs, potential energy savings, energy cost savings and life cycle costs resulting from controlling HVAC, lighting, and receptacles in unoccupied guest rooms.

2. Overview

a. Measure Title	Guest Room Occupancy Controls for HVAC and lighting systems
b. Description	The proposed measure would require installation of occupancy controls for HVAC equipment, and all lighting fixtures in hotel/motel guest rooms, including plug-in lighting. Examples of occupancy controls include captive card key controls and sensor-based controls. Guest room occupancy controls will return HVAC equipment to a setback position, and turn off lighting when a hotel or motel room is vacant. An occupancy sensor communicates with a thermostat controlling the HVAC system, as well as with lighting and receptacle circuits. When the room is occupied, guests have control over the thermostat, lighting, and wall outlets. When the room is vacant, the thermostat returns to default settings and the lighting and controlled receptacles shut off. The technology is applicable to all HVAC systems and lighting types.
c. Type of Change	Hotel/motel guest room occupancy controls are recommended as a mandatory requirement for the 2013 California Building Energy Efficiency Standards. The occupancy assumptions for HVAC and lighting systems in guest rooms will change with the adoption of this measure to more closely resemble actual hotel/motel guest room usage patterns. This measure will add language to Section 150 for hotel/motel guest rooms.

d. Energy Benefits

Based upon energy analysis conducted using methodology described in the Methodology section of this report and reported in Analysis and Results, this measure is expected to save 12%-25% of annual guest room HVAC energy use, depending on climate zone, HVAC system type and guest occupancy, and 16% of typical lighting energy use in guest rooms with occupancy controls installed. The table below shows the energy savings range, assuming average room occupancy, in kWh and W per guest room. Because the study used Packaged Terminal Air Conditioners (PTAC) in the simulation runs, there is no gas savings estimated in this report. The majority of savings occur during peak hours, between 12pm and 6pm. Because the savings applies to guest rooms only and not to all hotel/motel space, the savings per square foot has been excluded from the table below.

	Electricity Savings (kWh/yr)	Demand Savings (W)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings (TDV kBtu)	TDV Gas Savings
Per Guest Room CZ 3	155	98	NA	4,741	NA
Per Guest Room CZ 6	188	99	NA	5,274	NA
Per Guest Room CZ 8	171	101	NA	5,034	NA
Per Guest Room CZ 11	199	126	NA	5,922	NA
Per Guest Room CZ 13	210	124	NA	6,043	NA
Per Guest Room CZ 16	181	107	NA	5,277	NA

The savings from this measure results in the following statewide first year savings:

Total Electric Energy Savings (GWh)	Total Gas Energy Savings (MMtherms)	Total TDV Savings ($)
2.19	NA	64,154,425

For this study, HMG focused attention on PTAC systems and lighting, so estimated only electric energy savings. Therm savings may also be realized as a result of this measure in guest rooms with gas heating.

e. Non-Energy Benefits

Occupancy controls reduce daily operating time of HVAC and lighting equipment, thus extending the life of the equipment and reducing the maintenance and replacement costs. Additionally, some occupancy control systems can be centrally wired to allow hotel staff to identify rooms that are unoccupied and deliver more efficient cleaning and maintenance services.

f. Environmental Impact

Installation of guest room occupancy control systems has no known negative impact on the environment, water consumption, or indoor air quality. The materials used in occupancy sensors and controls are small compared to the amount of energy resources they conserve. Components are magnetic or optical decoders, printed circuit boards, logic chips and relays. The environmental impacts of packaging and shipping these small components are insignificant. Aside from reduced CO2 emissions associated with lower energy consumption, longer lasting equipment will reduce the amount of rundown HVAC and lighting equipment needing disposal and replacement.

The material increase reported in the table below assumes materials in the thermostat remain consistent, so includes only the estimated materials for the occupancy sensor. In absence of data specific to occupancy controls, we used values for plastic-cased ballasts, since the components are approximately the same size.

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

	Mercury	Lead	Copper	Steel	Plastic	Others
Per Hotel/Motel Guest Room	0.0005	0.0005	0.15	0.1	0.25	NC

Water Consumption:

	On-Site (Not at the Power plant) Water Savings (or Increase) (Gallons/Year)
Per Hotel/Motel Guest Room	NA

Water Quality Impacts:

Comment on the potential increase (I), decrease (D), or no change (NC) in contamination compared to the base case 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)	NA	NA	NA	NA

g. Technology Measures	**Measure Availability:** Occupancy sensor-based and key card occupancy controls systems are currently on the market from a list of manufacturers across the country including: Energy Eye, Inc., Amerisafe Industries, Onity, INNCOM International, Inc., LTC Enterprises, LLC, Smart Systems International, Entergize, Energex Inc., Goodman Co., L.P., Riga Development, and Watt Stopper. Given that, on average, approximately 80 hotel buildings are built each year in California[1], these manufacturers can easily accommodate the demand resulting from the addition of occupancy control requirements to the 2013 California Building Energy Efficiency Standards for new construction. **Useful Life, Persistence, and Maintenance:** The most common maintenance procedure with occupancy control technologies is battery replacement approximately every two (2) years. Occasionally magnetic sensors need replacement due to wear and tear from guests coming and going frequently, and in rare cases where the occupancy sensor stops communicating with the thermostat, one or more components require replacement. Energy savings related to hotel occupancy sensors are dependent on the type and efficiency of the HVAC and lighting systems used in the hotel guest room. The occupancy control system will result in HVAC and lighting energy savings throughout the product lifetime, assuming the equipment efficiency and average occupancy for a given guest room is also consistent.
h. Performance Verification of the Proposed Measure	Due to the nature of the technology, performance verification will likely be done by the manufacturer and installer of the occupancy control equipment. Many of the systems sold today include warranties and service contracts for follow-up maintenance. No field diagnostic testing is necessary for occupancy controls.

[1] Market Characterization & Program Activity Tracking (MCPAT) Annual reports, 2000-2005.

i. Cost Effectiveness

Cost of equipment and installation vary by technology, system sophistication, geographical region, and number of guest rooms, from $100, up to $500 per guest room. For the purpose of this study, we used an installed cost of $246 for control of the HVAC system, plus $75 for all hardwired lighting and outlets controlled by the system, for a total of $321 installed cost. An additional maintenance cost of $29 includes occasional battery replacement.

Based on these costs and a measure life of 15 years, as per 2013 CEC LCC methodology[2], the life cycle cost savings per guest room ranges from $49 to $203.

a	b	C		D		e		f	G	
Measure Name	Measure Life (Years)	Additional Costs1– Current Measure Costs (Relative to Basecase) ($)		Additional Cost2– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional3 Maintenance Costs (Savings) (Relative to Basecase) (PV$)		PV of Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit	Per Proto Building	Per Unit	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
Hotel Occupancy Control Prototype	15	$321	$32,742	$321	$32,742	$29	$2,958	$45,370 to $56,467	($9,669) to ($20,766)	($9,669) to ($20,766)
Motel Occupancy Control Prototype	15	$321	$11,556	$321	$11,556	$29	$1,044	$14,365 to $18,794	($1,764) to ($6.194)	($1,764) to ($6.194)

ii.

j. Analysis Tools	HVAC energy savings can be quantified using EnergyPro and other compliance software through the adjustment of occupancy schedules to match hotel room usage patterns. Current energy use baselines for HVAC systems in hotel/motel guest rooms assume constant daytime thermostat settings from 6am to 10pm, and constant nighttime settings between10pm and 6am, Monday through Sunday. The current reference methods would need to be updated to include HVAC occupancy schedules that match hotel/motel guest room usage patterns. Lighting energy savings were estimated using a combination of occupancy and time-of-use data, as well as energy savings results from similar control strategies.
k. Relationship to Other Measures	The estimated energy savings resulting from other mandatory and prescriptive envelope, lighting, and HVAC system requirements, such as insulation, setback thermostats, lighting efficacy would be reduced with the inclusion of guest room occupancy controls, but the measures would not be otherwise influenced.

[2] Architectural Energy Corporation, *Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards,* December 14, 2010.

3. Methodology

This section summarizes the methods used to collect data for this CASE report, including occupancy control technologies and costs, stakeholder interest and concerns, and energy savings calculations.

3.1 Energy Analysis Prototypes and Assumptions

The baseline condition for this study is a hotel/motel guest room that complies with 2008 California Building Energy Efficiency Standards for hotels, including the use of thermostats with digital temperature display and setback capability.

Projected energy savings from installation of guest room occupancy controls is estimated based on energy simulation runs performed using EnergyPro 5 with weather files developed for the 2013 Building Energy Efficiency Standards. HMG modeled a prototype hotel and a prototype motel with base case thermostat settings to set a baseline energy use. Occupancy patterns documented in field studies were mimicked in the energy simulation runs to create realistic vacancy schedules. The prototype models were then adjusted to simulate an occupancy control system and the energy use was compared against the baseline. This was repeated in six (6) representative climate zones throughout the California (3, 6, 8, 11, 13 and 16). The dataset and energy savings include results from analysis in all six (6) climate zones.

Two prototypes were used in the energy analysis, in order to represent both low rise and high rise building types. The high rise was represented in the hotel prototype and low rise in the motel prototype. Following CEC protocols, the prototype buildings were between 5,000 and 50,000 square feet, with prescribed glazing evenly distributed among the building orientations. Both prototypes deviated slightly from standard CEC methodology to better represent typical hotel and motel building types and construction practices. For instance, motel guest rooms typically have more exterior wall area than would be represented in a rectangular or square building. These deviations are further explained in the Hotel Prototype and Motel Prototype sections.

The prototypes were developed based on an average guest room size. The guest rooms were arranged in building plans with other hotel/motel space types, including lobbies and service areas, in order to determine appropriate orientations and define interior and exterior walls. These other spaces, however, were excluded from the model, so that model outputs would show energy savings from guest room HVAC equipment only, unaffected by the heating and cooling systems used throughout the rest of the building.

Each guest room was modeled with a packaged terminal air conditioner (PTAC) system for heating and cooling. This system type was chosen based on prevalence in the hotel/motel guest room market, as demonstrated by the Commercial Buildings Energy Consumption Survey (CBECS) 2003. This data is reported in square feet of lodging area conditioned, and by space conditioning equipment type, and shows that the majority is served by PTAC or individual air conditioning systems. Because electric heat was used in the prototype model, no gas savings were accounted for in the primary energy analysis.

3.1.1 Hotel Prototype

The hotel prototype is a 7-story, 102 guest room building of rectangular shape, with metal frame construction and guest rooms on all floors. This prototype is taller than the CEC prototype standard of a one (1) to three (3)-story building, to better represent characteristics of a typical high-rise hotel. The first floor includes a lobby and offices. The core of the building contains elevators, storage, and service spaces. Only the guest rooms were modeled in the software, though the whole building was laid out in order to determine envelope characteristics. Guest rooms are on average 404 square feet (sf), assuming mostly typical 325 sf guest rooms[3], as well as some larger suites. Each room has an 8 foot ceiling height, at least one 6’x 4’ window, and a PTAC unit for heating and cooling. All guest room entry doors open to a central, conditioned (interior) corridor.
Building characteristics:

- JA4: metal-frame walls, Table 4.3.3
- JA4: metal-frame rafter roof, Table 4.2.2, low slope
- Slab-on-grade, uninsulated floor
- Window to Wall Ratio (WWR) = 15.6%

3.1.2 Motel Prototype

The motel prototype is a 2-story, 36-guest room building, arranged in a U-shape, with parking in the middle and an office at one end of the U. This shape was used—rather than the standard rectangular or square building used in CEC methodology protocols—in order to allow each motel guest room two (2) exterior walls, as is typical of a motel. In order to represent motels of all orientations, the U-shape was closed in the prototype to create a square with a courtyard at the center. This modeling technique allowed for a more realistic averaging of guest rooms savings, accounting for all four (4) cardinal orientations. Because the prescriptive glazing requirements vary by orientation, simply doing a cardinal run of the U-shape would not have provided accurate results. Guest rooms average 322 square feet. Each room has an 8 foot ceiling height, one 6’x 4’ window, and a PTAC unit for heating and cooling. All guest room entry doors are on exterior building walls.
Building characteristics:

- JA4: wood-frame walls, Table 4.3.1
- JA4: wood-frame rafter roof, Table 4.2.2, low slope
- Slab-on-grade, uninsulated floor
- Window to Wall Ratio (WWR) = 8.6%

Figure 1 summarizes the hotel and motel prototype characteristics.

---

3 Yancey, Kitty, Does Size Matter?, USA Today, October 16, 2006. (quote by hotel analyst Bjorn Hansen) http://blogs.usatoday.com/hotelhotsheet/room_size/

	Occupancy type	Total building area (Square Feet)	Average guest room area (Square Feet)	Number of guest rooms	Number of stories	Guest room HVAC system type
Hotel Prototype	Hotel	41,230	404	102	7	PTAC cooling with heat pump in each guest room
Motel Prototype	Motel	11,592	322	36	2	PTAC cooling with heat pump in each guest room

Figure 1: Building Prototype Summary Table

3.1.3 HVAC Analysis

In order to simulate temperature settings in guest rooms with occupancy controls, HMG revised the occupancy schedules from the 2008 base case standard, using field data collected by CLTC. The field data indicated whether or not a booked room was occupied but did not provide data on the number of occupants. Note that the Title 24 occupancy schedule utilized in the energy simulation software relates to occupancy levels as a percent of the rated occupancy of a space, not whether a space is occupied, and thus addresses a different quantity than that measured in the CLTC study. The Title 24 occupancy schedule was not altered as part of the HMG analysis.

For each site, average hourly occupancy was calculated for each of the 24 hours in a day, including all rooms with available occupancy data, for the entire study period. The hourly occupancy assumes guest rooms are reserved, and does not take into consideration that some rooms may be vacant for a full 24-hour period, or longer. HMG received data from the CLTC on four (4) hotels. One site was dropped from the dataset because of limited data. For the other three sites, average overall site room occupancy percentages for each hour of the day, numbered 0 - 23 (beginning with midnight to 1am), were determined as summarized in Figure 2, and graphed in Figure 3.

The site-specific hourly room occupancy averages were then averaged into an overall average room occupancy (in %) for each hour in the day. These results are located in the "Average" column of Figure 2. The hourly occupancy averages for the three sites were equally weighted in this all-site hourly average, which included data for 8, 8, and 9 rooms at hotel sites 1, 2 and 3 respectively. Figure 3 illustrates the similarity of occupancy patterns among the three hotels, showing that averaging the data does not flatten the curve of the occupancy schedule.

Hour	Site 1	Site 2	Site 3	Average
0	73%	78%	92%	81%
1	75%	80%	94%	83%
2	76%	81%	94%	83%
3	76%	81%	94%	84%
4	75%	82%	94%	84%
5	75%	82%	93%	83%
6	69%	77%	91%	79%
7	59%	66%	87%	71%
8	49%	50%	80%	60%
9	44%	37%	73%	51%
10	37%	27%	63%	42%
11	35%	23%	53%	37%
12	30%	21%	44%	32%
13	31%	19%	44%	31%
14	34%	21%	45%	33%
15	33%	22%	47%	34%
16	37%	27%	48%	37%
17	39%	31%	51%	40%
18	37%	32%	53%	41%
19	40%	35%	59%	45%
20	45%	43%	67%	52%
21	54%	55%	75%	61%
22	62%	66%	84%	71%
23	68%	74%	90%	77%

Figure 2: Average Occupancy of Hotel Guest Rooms from CLTC Field Study

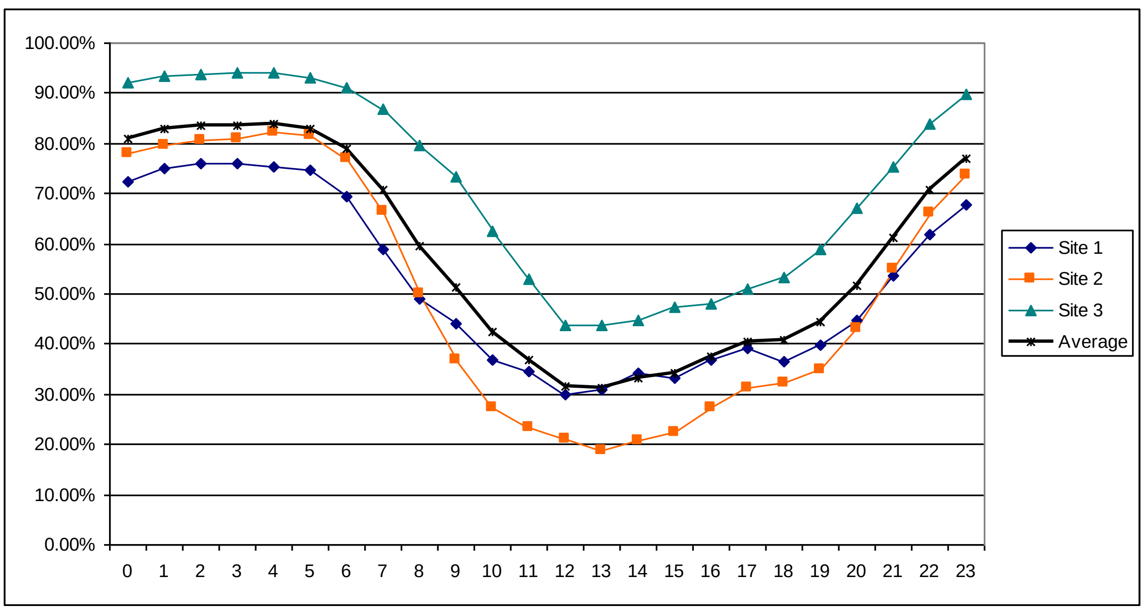

Figure 3: Occupancy Patterns of Hotel Guest Rooms from CLTC Field Study

Energy savings could not be modeled using the developed CASE occupancy percentages directly, since the CASE data is a different metric than Title 24 occupancy schedules. The heating and cooling set point schedules were modified instead. The CASE energy models simulated the effect of the occupancy controls by adjusting HVAC system temperature hourly set points corresponding to the percentage of time a room would be unoccupied over the course of each hour.

The upper, average, and lower occupancy percentages described previously were utilized to modify the HVAC system temperature set point schedules. A 5-degree setback (or setup) from the Title 24 (2008) 24-hour heating and cooling set point schedules was assigned to the percentage of time the room was unoccupied. This 5-degree setback/setup acted, in effect, as the "unoccupied room set point." The modified CASE heating and cooling schedules consisted of hourly set points that are weighted averages of the occupied and unoccupied set points. The modeled hourly set points can be summarized as the following:

Tcool(modeled hourly set point) = Tcool(T24 setpt) + (setup * %hour unoccupied)

Theat(modeled hourly set point) = Theat(T24 setpt) - (setback * %hour unoccupied)

This methodology was applied to both heating and cooling schedules for the Average occupancy conditions. The resulting hourly schedules are listed in Figure 4.

Hour	**Title 24 Setpoints**						**Full 5-degree offset**						**Weighted by Average Occ. %**					
	Heating			Cooling			Heating			Cooling			Heating			Cooling		
	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday
1	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
2	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
3	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
4	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
5	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
6	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
7	68	68	68	78	78	78	63	63	63	83	83	83	67	67	67	79	79	79
8	68	68	68	78	78	78	63	63	63	83	83	83	67	67	67	79	79	79
9	68	68	68	78	78	78	63	63	63	83	83	83	66	66	66	80	80	80
10	68	68	68	78	78	78	63	63	63	83	83	83	66	66	66	80	80	80
11	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
12	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
13	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
14	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
15	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
16	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
17	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
18	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
19	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
20	68	68	68	78	78	78	63	63	63	83	83	83	65	65	65	81	81	81
21	68	68	68	78	78	78	63	63	63	83	83	83	66	66	66	80	80	80
22	68	68	68	78	78	78	63	63	63	83	83	83	66	66	66	80	80	80
23	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79
24	60	60	60	78	78	78	55	55	55	83	83	83	59	59	59	79	79	79

Figure 4: Set Point Schedules for Energy Analysis

The modified HVAC schedules were then input into the energy simulation software. Two simulations were run for each climate zone evaluated. The base case used standard Title 24 24-hour heating and cooling schedules and the proposed case utilized the heating and cooling set point schedules as described above.

Note that no allowance was made in the energy simulation for the percentage of rooms actually rented or not rented at a given time. All rooms were modeled with the same heating and cooling schedules described above, based on the field data. The energy savings are therefore conservative, and will likely be greater in hotels/motels with unrented guest rooms. In addition, since the CLTC field data did not cover multiple seasons, no seasonal adjustments were made to occupancy percentages or the corresponding modified heating and cooling schedules derived from the field data.

3.1.4 Lighting Analysis

The lighting energy savings resulting from installation of guest room occupancy control was analyzed separately from HVAC savings because of the difference in typical use patterns (HVAC set points tend to remain constant throughout the day, whereas lighting is turned on or off depending on user needs). In addition, HVAC energy use and savings is heavily dependent on climate, whereas typical lighting energy use and savings is expected to be uniform across the state.

Using the typical guest room lighting layout described in the 1999 California Lighting Technology Center study (CLTC 1999), HMG assumed the following wattages for a typical guest room lighting types:

- Bathroom lighting: 96W (3 @32W, fluorescent or compact fluorescent)
- Bedside lighting: 52W (2 @26W, compact fluorescent)
- Desk lighting: 26W compact fluorescent
- General lighting: 52W (one 26W compact fluorescent downlight at entry, one additional 26W compact fluorescent for general illumination in the room)

The resulting maximum installed wattage is 226W per guest room.

Hotel room occupancy patterns were determined based on data from the CLTC field study, described above in section 3.1.3 (CLTC 2008). Figure 3, above, shows the occupancy pattern results of the CLTC field study.

In addition to typical guest room lighting layouts and occupancy patterns described above, HMG utilized results from the 1999 CLTC study which measured the use of the various lighting types in typical guest rooms. Figure 5, below, illustrates the usage patterns for each lighting type in the guest room (for the purpose of this CASE study, the line in Figure 5 labeled “floor” is considered to represent general (recessed) lighting in the guest room).

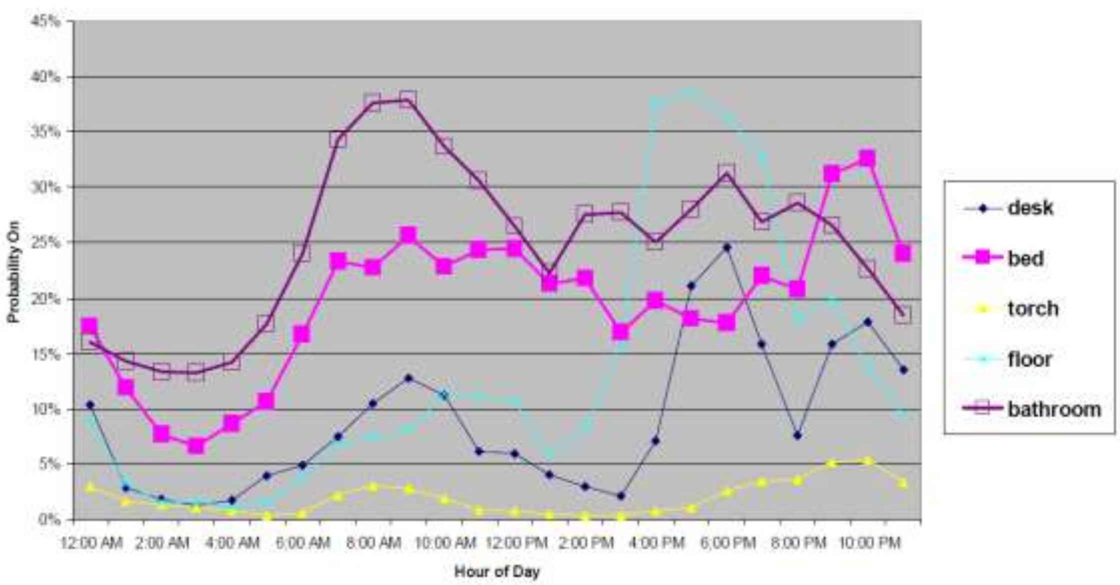

Figure 5: Use Patterns for Guest Room Lighting Types

3.2 Cost Effectiveness

HMG determined cost effectiveness through collection of occupancy control system costs for equipment and installation and use of life cycle cost methodology developed for the 2013 California Building Energy Efficiency Standards, prepared for the CEC by AEC.[4] Cost collection and LCC methodology are discussed in this section.

3.2.1 Market Pricing

In preparation for their field study in San Diego, CLTC collected cost data on several occupancy control systems, per guest room. The cost can vary by number of guest rooms (bulk purchasing), so the values collected are rough estimates, and include all equipment and installation costs. HMG additionally confirmed the accuracy of these estimates informally through the manufacturers' stakeholder interviews.

Maintenance costs were estimated based on the cost of batteries and replacement thermostats quoted for the CLTC field study. The maintenance costs assumed battery replacement annually. It is highly likely, however, that reduced maintenance costs for HVAC equipment, due to less running time, would offset the maintenance and replacement costs associated with occupancy control systems. Without more data on reduced HVAC maintenance costs, we are assuming an increased maintenance cost.

3.2.2 Lifecycle Cost (LCC) Analysis

HMG calculated lifecycle cost analysis 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:

$$\Delta LCC = \text{Cost Premium} - \text{Present Value of Energy Savings}$$[5]

$$\Delta LCC = \Delta C - (PVTDV\text{-}E * \Delta TDVE + PVTDV\text{-}G * \Delta TDVG)$$

Where:

ΔLCC	change in life-cycle cost
ΔC	cost premium associated with the measure, relative to the base case
PVTDV-E	present value of a TDV unit of electricity
PVTDV-G	present value of a TDV unit of gas
ΔTDVE	TDV of electricity
ΔTDVG	TDV of gas

We used a 15-year lifecycle as per the LCC methodology for nonresidential HVAC measures. LCC calculations were completed for two building prototypes, in all six (6) climate zones analyzed.

3.3 Statewide Construction Estimates

HMG referenced statewide construction forecast estimates published by the CEC in the Quarterly Fuel and Electricity Report (QFER). The construction estimates are in million square feet and broken

[4] Architectural Energy Corporation, Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards, December 14, 2010, 2005.
[5] The Commission uses a 3% discount rate for determining present values for Standards purposes.

down by climate zone. To translate this number into a number of forecasted guest rooms built, HMG used data obtained from Hotel Online (in partnership with Build Central) on hotel new construction activity for 2010.[6] Hotel Online reports the number of guest rooms in each hotel beginning construction in the year 2010, but does not report square footage. HMG divided the CEC 2010 hotel statewide new construction forecast (4.877 million square feet) by the total number of guest rooms built in 2010 (6,679 guest rooms) to find a per guest room square footage that includes non-guest room hotel spaces. The result was 730 square feet of total hotel/motel space per guest room. Because this code change proposal will take effect January 1, 2014, first year statewide energy savings are based on 2014 new construction area of 9.098 million square feet. We divided the 2014 CEC new hotel construction forecast, in square feet, by 730 square feet to find the estimated number of guest rooms to be built in 2014. The table below **Error! Reference source not found.Error! Reference source not found.**shows the representative climate zone distribution and estimated number of guest rooms built annually in each.

Representative Climate Zone	Actual Climate Zone	2014 Construction Forecast (million sq.ft.)	# of Guest Rooms Forecasted 2014	
3	2	0.2897	397	2,739
	3	0.7912	1,084	
	4	0.7694	1,054	
	5	0.1494	205	
6	6	0.5004	685	1,606
	7	0.6718	920	
8	8	0.9430	1,292	4,293
	9	2.1910	3,001	
11	10	0.3304	453	3,054
	11	0.1656	227	
13	12	1.3375	1,832	2,827
	13	0.4934	676	
	14	0.1896	260	
	15	0.0436	60	
16	16	0.1977	271	318
	1	0.0345	47	
	TOTAL	**9.0982**		**12,459**

Figure 6: New Hotel Construction by Representative Climate Zones

Using average energy savings calculations for each of the climate zones and estimates of the number of guest rooms built in each climate zone group, HMG estimated the energy savings potential from adoption of hotel guest room occupancy controls into the 2013 California Building Energy Efficiency

6 http://hotels.buildcentral.com/projects/search_result.asp?action=search&searchproduct=18&provider_id=1000&category_id=1050&product_id=1093&subscriptiontype=0&UID={4B4C83F7-3C8C-49E2-AB62-9AD082FFA64F} sourced February 17, 2011

Standards. The rate of construction for hotels and motels is roughly equivalent[7]. HMG therefore averaged the hotel energy savings per guest room with the motel energy savings per guest room in each climate zone to complete the calculation. Results can be found in the Analysis and Results section.

[7]http://hotels.buildcentral.com/projects/search_result.asp?action=search&searchproduct=18&provider_id=1000&category_id=1050&product_id=1093&subscriptiontype=0&UID={4B4C83F7-3C8C-49E2-AB62-9AD082FFA64F} sourced February 17, 2011

4. Analysis and Results

Research and analysis of the hotel/motel occupancy controls for guest room HVAC and lighting showed cost-effective application in both new construction and retrofit projects. This report proposes mandatory requirements for occupancy controls for guest rooms in new construction only. It is recommended that this measure be considered for retrofit requirements in a future code update. This section discusses HMG's findings in the categories of system pricing energy savings, and cost-effectiveness.

4.1 System Pricing

Though most manufacturers were hesitant to quote the price of equipment and installation of occupancy control systems without having an actual hotel project to bid, many informally agreed that the cost varied between $200 and $500 per guest room system controlled. Cost variables included hardwired or wireless system choice, type of occupancy sensor, project location, and system sophistication (e.g. whether the system was wired for central hotel control). Figure 7 shows estimated costs per hotel/motel guest room, as collected by CLTC as part of their occupancy control field study in San Diego. More information about each of these systems is included in section 7.1.1 of this report.

Occupancy Control Manufacturer/Product	**Cost per Guest Room**
Onity System - Stand Alone	$270
INNCOM System - Stand Alone	$325
Energy Eye System	$280
Smart Systems	$230
Watt Stopper	$100
Lodging Technology Corp.	$270
Average	**$246**

Figure 7: Occupancy Control System Cost Estimates (CLTC field study)

HMG averaged the costs of various occupancy controls systems to find an expected installed cost of $246 per guest room. This cost was used in the life-cycle cost analysis in section 4.3.1 below.

4.1.1 Maintenance Costs

The cost of replacement batteries is estimated at $3 per year, or $48 over the life of the equipment. In present value terms, this is $29 per guest room.

4.2 Energy Savings

Assumptions and analysis methodology for all energy savings reported can be found in the Section 3.1 of this report.

4.2.1 HVAC Savings

Guest room occupancy controls in rooms with average occupancy are estimated to save between 12 and 24% in heating and cooling energy, based on a 5-degree setback when the room is vacant per

energy simulation completed by HMG. This equates to annual savings per square guest room ranging from 75 to 181 kWh, depending on climate zone and room type. The lowest calculated savings occurred in Climate Zone 3, and highest in Climate Zone 13, as illustrated in Figure 8**Error! Reference source not found.**.
.

CZ	Hotel	Motel	Average
3	75.69	111.00	93.35
6	94.95	157.37	126.16
8	87.83	130.87	109.35
11	106.42	167.47	136.95
13	114.34	181.07	147.71
16	88.64	149.89	119.26

Figure 8: HVAC kWh Savings per Guest Room

A more complete set of energy savings outputs for both prototypes, in all representative climate zones, can be found in Figure 25 and Figure 26 in the Appendices.

Peak savings on HVAC controls ranged from 60 to 104 kWh, as shown in the table below.

CZ	Hotel	Motel	Average
3	52.10	72.49	62.29
6	52.43	72.87	62.65
8	52.79	76.28	64.54
11	75.19	104.33	89.76
13	71.60	104.18	87.89
16	60.80	81.47	71.13

Figure 9: Peak HVAC Energy Savings in Watts per Guest Room

The TDV energy savings were calculated for each of the two prototypes, in each of the six (6) representative climate zones, using 2013 TDV values. Results ranged from 8.17 to12.95 kTDV/sq.ft. of guest room and are illustrated in Figure 10**Error! Reference source not found.**.

CZ	Hotel	Motel	Average
3	8.17	8.65	8.41
6	9.25	10.61	9.93
8	8.82	9.66	9.24
11	11.04	12.39	11.72
13	11.20	12.95	12.07
16	9.26	10.62	9.94

Figure 10: HVAC kTDV/sq.ft. Savings

4.2.2 Lighting Energy Savings

Lighting energy savings from guest room occupancy control systems could be realized any time a guest leaves the room without turning off the lights. Unfortunately, no data are available that explicitly describe the percentage of time for which lighting is left on in unoccupied guest rooms.

However, the PIER Hotel Bathroom Lighting Control System case study measured savings resulting from a combination occupancy sensor and nightlight in hotel guest room bathrooms (CEC 2005). While this data is specific to bathroom occupancy, rather than guest room occupancy as a whole, it represents the best available occupancy-based energy savings data for hotel guest rooms. Figure 11, below, shows the reduction in lighting usage measured by the PIER study resulting from the installation of occupancy controls in hotel bathrooms. Savings numbers shown indicate the reduction in time-of-use for each block of time.

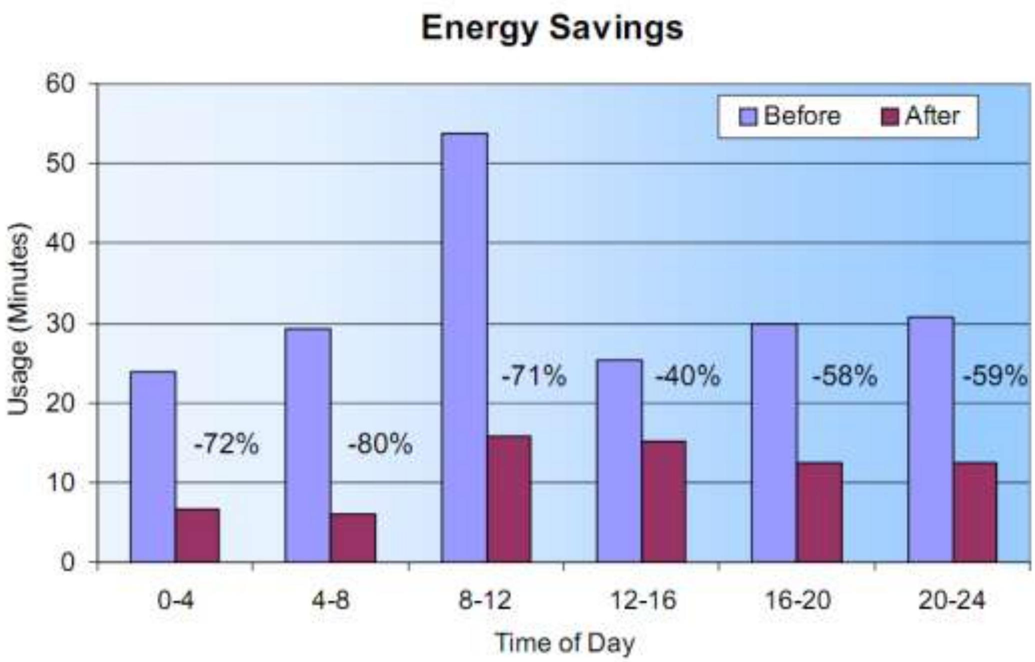

Figure 11: Energy Savings Measured by the PIER Hotel Bathroom Lighting Control Study

As shown in Figure 11, the PIER Study separated savings into six 4-hour periods throughout the day. Much of the savings from this study occur during nighttime hours, when it is likely that the guest room is occupied (while the occupant is sleeping), but there is also considerable savings during daytime hours when the guest room is more likely to be unoccupied.

To create a proxy for potential savings from a guest room occupancy control system, HMG assumed that savings between 11am (check-out time) and 5pm (early evening) were the result of bathroom lighting being left on when the guest room was unoccupied. Hours outside this range were assumed not to have any guest room occupancy control savings due to the higher likelihood that the guest room is occupied.

Claiming all the savings in Figure 11 for the period 11am-5pm assumes that the bathroom savings were due to those rooms being completely unoccupied—this results in a slight overestimate of savings because it’s possible that some of the rooms were occupied but the occupants weren’t using the bathrooms. However, this overestimate of savings is more than cancelled out by the underestimate that results from assuming no savings at all outside the 11am-5pm period.

We applied these same savings to the other lighting in the room (not just the bathroom lighting) to create a prediction of savings for the whole room.

To estimate potential lighting savings from guest room occupancy controls, time-of-use savings percentages shown in Figure 11 were applied to usage rates for each guest room lighting type, as shown in Figure 5 (section 3.1.4, above), for the daytime hours of 11am to 5pm. Figure 12, below, shows the potential savings from guest room occupancy controls for each lighting type, per guest room.

	Average Savings Between 11am and 5pm	**Annual Savings (kWh/year)**
Bathroom	16%	32.8
Bedside	15%	13.8
Desk	12%	2.5
General	22%	12.9
Total		**62.0**

Figure 12: Estimated Lighting Savings

4.2.3 HVAC and Lighting Combined Energy Savings

HMG added HVAC and lighting control savings per guest room together for combined energy savings shown in Figure 13, Figure 14, and Figure 15 below.

CZ	**HVAC**	**Lighting**	**Total**
3	93.35	62.0	155.35
6	126.16	62.0	188.16
8	109.35	62.0	171.35
11	136.95	62.0	198.95
13	147.71	62.0	209.71
16	119.26	62.0	181.26

Figure 13: Combined HVAC and Lighting kWh Savings per Guest Room

CZ	**HVAC**	**Lighting**	**Combined**
3	62	36	98
6	63	36	99
8	65	36	101
11	90	36	126
13	88	36	124
16	71	36	107

Figure 14: Combined Peak HVAC and Lighting Savings (Watts) per Guest Room

CZ	HVAC	Lighting	Combined
3	3,044	1,697	4,741
6	3,577	1,697	5,274
8	3,337	1,697	5,034
11	4,225	1,697	5,922
13	4,346	1,697	6,043
16	3,580	1,697	5,277

Figure 15: Combined HVAC and Lighting kTDV Savings per Guest Room

The per guest room figures were multiplied by the number of guest rooms in the prototype buildings to find the per prototype savings displayed in Figure 16, Figure 17, and Figure 18.

CZ	Hotel	Motel	Average
3	14,045	6,228	10,136
6	16,009	7,897	11,953
8	15,283	6,943	11,113
11	17,179	8,261	12,720
13	17,987	8,750	13,369
16	15,365	7,628	11,497

Figure 16: Combined HVAC and Lighting kWh Savings per Prototype Building

CZ	Hotel	Motel	Average
3	88	108	98
6	88	109	99
8	89	112	101
11	111	140	126
13	108	140	124
16	97	117	107

Figure 17: Combined Peak HVAC and Lighting Savings (Watts) per Prototype Building

CZ	Hotel	Motel	Average
3	310,471	161,403	235,937
6	364,886	184,077	274,481
8	340,386	173,108	256,747
11	430,943	204,703	317,823
13	443,324	211,171	327,248
16	365,162	184,140	274,651

Figure 18: Combined HVAC and Lighting kTDV Savings per Prototype Building

4.2.4 Energy Savings in Referenced Studies

HMG compared field data and building energy simulation from similar studies to justify our energy saving estimates. In most cases, measured and estimated energy savings were higher in other studies, but were also for retrofit applications on an on/off control. Retrofit applications begin with higher baseline energy use and more room for improvement, so have inflated energy savings. On/off occupancy controls also yield higher energy savings than the 5-degree setback proposed in this report.

Honeywell Utility Solutions Smart Systems Installations

Honeywell Utility Solutions has been installing the Smart Systems power controller and optical sensor in California hotels and motels since October 2006 on behalf of Pacific Gas & Electric. Smart Systems International has been collecting data on the systems it has installed since 1994; the originally estimated Controller runtime reduction was 45% per installation when a 20-minute recovery strategy is utilized. Honeywell has completed over 14,000 installations in PG&E's territory, finding that the reduction in Thermostat runtime is 44% of the Air Conditioner unit runtime. Based on 15% random sample of the installations the new Controller runtime reduction is 48%.

Using runtime reduction data from monitored hotels/motels in California, average operating power estimates for AC cooling power from the DEER database, and estimated duty cycles for various climate zones throughout California, the Honeywell Utility Solutions Work Paper shows power (kW) savings per PTAC unit in California climate zones (1-5, 11-13, 16).8 The range of power savings is 0.33– 0.52 kW per PTAC unit (or guest room assuming 1 PTAC per room). Based on climate zone operating assumptions published in this work paper this equates to energy consumption values per guest room of 63.0 kWh/yr (CZ3), 340 kWh/yr (CZ11) and 348 kWh/yr (CZ13).

Honeywell Utility Solutions retrofit data show that in hot climates (climates with many cooling degree days) hotel/motel occupancy sensors can achieve large energy savings by cycling off HVAC equipment when appropriate. Projected retrofit energy savings are considerably higher than new construction savings for CZ11 (340 kWh/yr vs. 104 kWh/yr) and CZ13 (348 kWh/yr vs. 117 kWh/yr).

8 Honeywell Utility Solutions, Work Paper WPHWLSSC0908: Telkonet PTAC Controller & Thermostat, September 2009. Prepared for Pacific Gas & Electric Company

SCE Field Performance of a Card Key Energy Saving System for Hotels and Motels[9]

In 1998, Southern California Edison completed six months of field monitoring of the energy usage of a standard guest room, and compared it to an identical room with a card-key energy-saving system installed to control lighting and HVAC equipment. The hotel was located in Palm Springs, California. The energy-saving system, a retrofit application, turned three (3) lamps and the heat pump used for heating and cooling off when the guest room was unoccupied.

The savings identified by this comparison of two guest rooms was great, at nearly 48% lighting savings, 43% heating and cooling savings, and 44% total energy savings. The total kWh saved was approximately 375 kWh. This is significantly higher than the energy savings projected by HMG in this CASE report for several reasons. In a retrofit application, the efficiency of the HVAC and lighting systems is typically lower, leaving more room for improvement in energy efficiency. For example, the base case in SCE's study does not have a setback thermostat. Additionally, SCE's study examined the savings from turning off the HVAC system, while the measure proposed in this report is a 5 degree offset rather than an on/off control for HVAC.

PG&E Card-Key Guestroom Controls Study[10]

Architectural Energy Corporation (AEC), on behalf of Pacific Gas and Electric, conducted a similar study in which card-key controls were installed in four (4) guest rooms in each of two hotels, one new construction and one retrofit. Each room was monitored for five (5) weeks with inactive controls, to collect baseline energy use, and then five (5) weeks with active controls. The card-key system turned the HVAC system, bedside lamps, and bathroom lighting to the off position when the room was unoccupied (card-key removed from switch).

The study report suggests that an accurate energy savings estimate could not be developed with such a small sample. The actual energy savings reported showed an average savings of 28% or 357 kWh per guest room. Building simulation conducted for this study produced a similar output of about 27%. The HVAC savings ranged from 20% to 32%. Through building simulation, the study also examined a 2-degree set-back scenario, which estimated HVAC savings from 1% to 6 %.

HMG's results are consistent with AEC's, falling between the 2-degree and on/off scenarios. HMG found HVAC savings ranging from 12% to 23% with a 5-degree setback.

SDG&E Hotel Guest Room Occupancy Controls[11]

The California Lighting Technology Center, on behalf of San Diego Gas and Electric, monitored four (4) hotels in 2008 with guest room occupancy controls installed (retrofit) for the HVAC system, over a period of six (6) months. At each hotel four (4) or five (5) rooms had active controls with a 5-dgree setback, and the same number of similar rooms without active controls. Regression analysis allowed CLTC to extrapolate the field data for estimating annual savings across multiple climate zones. A

9 Lau, Henry, "Field Performance of a card Key Energy Saving System for Hotels and Motels," 2000.

10 Architectural Energy Corporation, "Emerging Technologies Program, Application Assessment Report #0801: Card-Key Guestroom Controls Study," September 2009. Prepared for Pacific Gas and Electric Company.

11 California Lighting and Technology Center, "Hotel Guest Room Energy Controls," December 4, 2008. Prepared for San Diego Gas & Electric Company.

wide range of savings was reported from 7% to 72% for cooling, -122% to 79% for heating, and 53% to 73% for fans, for an estimated total of 12 to 2,600 kWh per guest room per year.

The large variation in CLTC's field data makes it difficult to draw conclusions. However, for the two hotels for which total kWh saved are reported, the total HVAC savings ranges from 27% to 32%, and from 1% to 17%. The relatively low savings are from an extended stay hotel ,which has higher occupancy rates than other hotels. HMG's range of 12% to 23% falls right between the results for the two hotels.

4.3 Cost-effectiveness

The section describes the life-cycle cost analysis for guest room occupancy controls first for HVAC systems, and then for adding control of hardwired and plug-in lighting using the same occupancy control system.

4.3.1 HVAC Cost-Effectiveness

Hotel/motel guest room occupancy controls were found to be marginally cost effective, using 2013 LCC methodology. When energy savings per hotel room and motel room are averaged for each climate zone, life cycle cost ranged from $4 in Climate Zone 3 to a savings of $112 in Climate Zone 13.

Figure 19 and Figure 20 show that HVAC controls in hotel guest rooms are cost effective in all climate zones analyzed, except Climate Zone 3. When combined with lighting lifecycle savings reported in section 4.3.2, the measure is cost-effective in all climate zones.

	Hotel	**Motel**	**Average**
CZ 3	($18.79)	$26.99	$4.10
CZ 6	($57.69)	($29.07)	($43.38)
CZ 8	($42.06)	($1.95)	($22.00)
CZ 11	($121.98)	($80.06)	($101.02)
CZ 13	($127.59)	($96.05)	($111.82)
CZ 16	($58.02)	($29.23)	($43.62)

Figure 19: Lifecycle Cost Savings for HVAC Controls per Guest Room by Climate Zone

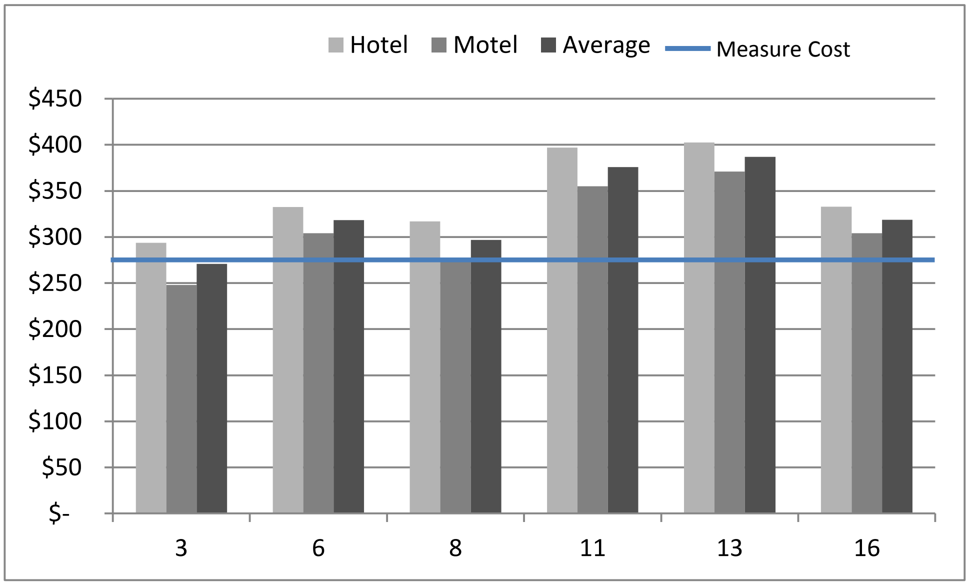

Figure 20: Present Value of TDV Energy Savings

4.3.2 Lighting Cost-Effectiveness

Based on the lighting energy savings estimates described in section 4.2.2, 15-year TDV savings are estimated at $150.01 per guest room (for all guest room lighting).

The only costs associated with guest room occupancy controlled lighting would be the additional relay or power pack to control lighting, or an additional receiver for wireless systems. The cost of an additional relay to control hardwired lighting in wired control system is assumed to be approximately $30 and an additional $45 to control plug-in lighting, well below the $151.01 TDV lighting savings estimated above. Lighting savings add approximately $76 to the LCC savings estimated above, making guest room occupancy controls cost effective for hotel and motel guest rooms in all climate zones analyzed. Figure 21, below, reflects the combined lifecycle cost for HVAC and lighting controls.

	Hotel Room	Motel Room	Average
CZ3	($94.79)	($49.01)	($71.90)
CZ6	($133.69)	($105.07)	($119.38)
CZ8	($118.06)	($77.95)	($98.00)
CZ11	($197.98)	($156.06)	($177.02)
CZ13	($203.59)	($172.05)	($187.82)
CZ16	($134.02)	($105.23)	($119.62)

Figure 21: ΔLCC Savings for HVAC and lighting controls per Guest Room by Climate Zone

4.4 Statewide Savings Estimates

A conservative calculation estimates that adding a mandatory requirement for occupancy controls for guest room HVAC and lighting to the 2013 California Building Energy Efficiency Standards will save 2.19 GWh of site energy annually and reduce peak energy demand by 1,294 kW. This is based on calculations and assumptions outlined in the Methodology section of this report; Figure 22**Error! Reference source not found.** summarizes the guest room energy savings in each climate zone that contribute to the statewide savings estimate.

Climate Zone	Site Electric Energy Savings (kWh/ guest room)	Peak Demand Savings (watts/ guest room)	kTDV/guest room	# of Guest Rooms Estimated to Claim Credit Annually	Total Energy Savings (kwh)	Total Peak Reduction (kW)	Total kTDV
CZ 03	155	98	4,741	2,738	425,344	269	12,979,702
CZ 06	188	99	5,274	1,605	301,997	158	8,464,856
CZ 08	171	101	5,034	4,292	735,443	432	21,605,328
CZ 11	199	126	5,922	679	135,085	85	4,020,816
CZ 13	210	124	6,043	2,827	592,838	350	17,083,724
CZ 16	181	107	5,277	318	57,642	34	1,678,011
			Total	**12,141**	**2,190,707**	**1,294**	**43,554,286**

Figure 22: Statewide Energy Savings

5. Recommended Code Language

Proposed language for the standards includes section number and original standards language in black font, deleted text is ~~in red text with hard strikeouts~~ and added language contained is in blue font and underlined.

5.1 Building Energy Efficiency Standards

SECTION 122 – REQUIRED CONTROLS FOR SPACE-CONDITIONING SYSTEMS
Space-conditioning systems shall be installed with controls that comply with the applicable requirements of Subsections (a) through (h).

(c) **Hotel/Motel Guest Room and High-rise Residential Dwelling Unit Thermostats.** Hotel/motel guest room thermostats shall have:

1. Numeric temperature setpoints in °F; and
2. Setpoint stops accessible only to authorized personnel, to restrict over-heating and over-cooling.

High-rise residential dwelling unit thermostats shall meet the control requirements of Section 150(i). Hotel/Motel guest room thermostats shall also meet the requirements 150(q).

SECTION 130 – LIGHTING CONTROLS AND EQUIPMENT—GENERAL

(a) Except as provided in Subsections (b) and (c), the design and installation of all lighting systems and equipment in nonresidential, high-rise residential, hotel/motel buildings, and outdoor lighting subject to Title 24, Part 6, shall comply with the applicable provisions of Sections 131 through 139. All lighting controls and equipment shall be installed in accordance with the manufacturer's instructions.

(b) **Indoor Lighting in High-rise Residential Dwelling Units and Hotel/Motel Guest Rooms.** The design and installation of all lighting systems, lighting controls and equipment in high-rise residential dwelling units and in hotel/motel guest rooms shall comply with the applicable provisions of Section 150(k). Lighting controls in Hotel/Motel Guest rooms shall also meet the requirements of Section 150(q).

SECTION 150 – MANDATORY FEATURES AND DEVICES
Any new construction in a low-rise residential building shall meet the requirements of this Section. Dwelling units in high rise residential or in hotel /motel buildings shall meet the applicable requirements in subsections (i), (k), and (q).

(q) Hotel/Motel Guest Room Automatic Control of HVAC and Lighting. In hotels and motels, all hardwired lighting, HVAC equipment, and half of the receptacles serving each guest room shall be automatically controlled so that no more than 30 minutes after the guest room has been vacated, the power for lighting and controlled receptacles will turn off and the HVAC set points will raise by at least 5°F (3°C) in the cooling mode and lowered by at least 5°F (3°C) in the heating mode.

Controlled receptacles shall meet the following requirements:

1. Electric circuits serving controlled receptacles shall be equipped with automatic shut-off controls; and
2. At least one controlled receptacle shall be installed within 1 foot from each uncontrolled receptacle or a split-wired duplex receptacle with one controlled and one uncontrolled receptacle shall be installed; and
3. Controlled receptacles shall have a permanent marking to differentiate them from uncontrolled receptacles.

5.2 ACM Manuals

The ACM Manual Schedule Tables will be updated with the following changes and additions to Section 2.4.3 Schedules:

- Table N2-7 – Schedule Types of Occupancies & Sub-Occupancies will include an additional line for Hotel/Motel Guest Room with Occupancy Controlled Setback Thermostat and Lighting.
- Addition of Table N2-X - Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) with Occupancy Controlled Setback Thermostat and Lighting

Hotel Function Area	Table N2-9: Hotel Function
~~Hotel/Motel Guest Room with Setback Thermostat~~	~~Table N2-10:Residential/with setback~~
~~Hotel/Motel Guest Room without Setback Thermostat~~	~~Table N2-11:Residential/without setback~~
Hotel/Motel Guest Room with Occupancy Controls	Table N2-X: Residential with Occupancy Control
Hotel/Motel Hallways	Table N2-9: Hotel Function

Figure 23: Excerpt from Table N2-7: Schedule Types of Occupancies and Sub-Occupancies

Table N2-X - Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) with Occupancy Controlled Setback Thermostat

Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating	(ºF)																							
WD	59	59	59	59	59	59	67	67	66	66	65	65	65	65	65	65	65	65	65	65	66	66	59	59
SAT	59	59	59	59	59	59	67	67	66	66	65	65	65	65	65	65	65	65	65	65	66	66	59	59
Sun	59	59	59	59	59	59	67	67	66	66	65	65	65	65	65	65	65	65	65	65	66	66	59	59
Cooling	(ºF)																							
WD	79	79	79	79	79	79	79	79	80	80	81	81	81	81	81	81	81	81	81	81	80	80	79	79
SAT	79	79	79	79	79	79	79	79	80	80	81	81	81	81	81	81	81	81	81	81	80	80	79	79
Sun	79	79	79	79	79	79	79	79	80	80	81	81	81	81	81	81	81	81	81	81	80	80	79	79
Lights	(%)																							
WD	10	10	10	10	10	30	45	45	45	45	9	18	18	18	18	13	13	30	60	80	90	80	60	30
SAT	10	10	10	10	10	30	45	45	45	45	9	18	18	18	18	13	13	30	60	80	90	80	60	30
Sun	10	10	10	10	10	30	45	45	45	45	9	18	18	18	18	13	13	30	60	80	90	80	60	30
Equipment	(%)																							
WD	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
SAT	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Sun	10	10	10	10	10	30	45	45	45	45	30	30	30	30	30	30	30	30	60	80	90	80	60	30
Fans	(%)																							
WD	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
SAT	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Sun	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on	on
Infiltration	(%)																							
WD	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
SAT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sun	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
People	(%)																							
WD	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
SAT	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Sun	90	90	90	90	90	90	70	40	40	20	20	20	20	20	20	30	50	50	50	70	70	80	90	90
Hot Water	(%)																							
WD	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
SAT	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5
Sun	0	0	0	5	5	5	80	70	50	40	25	25	25	25	50	60	70	70	40	25	20	20	5	5

Figure 24: ACM Table N2-X - Residential Occupancy Schedules (Including Hotel/Motel Guest Rooms) with Occupancy Controlled Setback Thermostat and Lighting

6. Bibliography and Other Research

6.1 Referenced Documents

Architectural Energy Corporation, "*Card-Key Guestroom Controls Study"* (DRAFT), June 2009. Prepared for Pacific Gas & Electric Company.

Architectural Energy Corporation, "*Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards*," December 14, 2010. Prepared for the California Energy Commission.

Architectural Energy Corporation, "*Emerging Technologies Report Application Assessment Report #0609: Marketable Technologies for the Hospitality Industry*, "September 2007. Prepared for Pacific Gas & Electric Company.

Architectural Energy Corporation, "*Emerging Technologies Program, Application Assessment Report #0801: Card-Key Guestroom Controls Study*," September 2009. Prepared for Pacific Gas and Electric Company.

California Energy Commission, Public Interest Energy Research (PIER) program. "Hotel Bathroom Lighting Control System." 2005. Publication number: CEC-500-2005-141-A26.

California Lighting and Technology Center, "*Hotel Guest Room Energy Controls*," December 4, 2008. Prepared for San Diego Gas & Electric Company.

California Lighting and Technology Center, "*Lighting Energy Savings Opportunities in Hotel Guestrooms*," October 1999. Prepared for the Office U.S. Department of Energy.

E Source, "*Increasing Energy Savings with Hotel-Room Automation*," 2009

Honeywell Utility Solutions, "*Work Paper WPHWLSSC0908: Telkonet PTAC Controller & Thermostat*," September 2009. Prepared for Pacific Gas & Electric Company.

Itron Inc., "*California Commercial End-Use Survey Result*s," 2006. Prepared for California Energy Commission (CEC-400-2006-005).

Lau, Henry, "*Field Performance of a card Key Energy Saving System for Hotels and Motels*," 2000.

Market Characterization & Program Activity Tracking (MCPAT) Annual reports, 2000-2005.

Pacific Gas and Electric Company, "*Application Assessment Report #0801: Card-Key Guestroom Controls Study*," September 2009.

RLW Analytics, "*California Nonresidential New Construction Study*," 2001. Prepared for California Public Utilities Commission.

RLW Analytics, "*Savings By Design Program Evaluation*," 2007. Prepared for California Public Utilities Commission

6.2 Personal Communications

John Kriss, Director of Engineering, Mondrian Hotel

Dan Gilligan, VP of Energy and Environmental Technology, Accor North America, Inc.

Anna Marie. Energy Eye

John Tavares, VP of Sales/Marketing, INNCOM International, Inc.

Lee Stevens, Energy Products, LLC

7. Appendices

7.1 Technology Data and Market Conditions

Through interviews with manufacturers and review of product literature, HMG collected information on a wide range of product types and options, including the benefits and limitations of each type, and maintenance issues and technical problems.

7.1.1 Available Products

Through product research and stakeholder interviews, HMG has determined that the market is ready for installation of occupancy controls for HVAC and lighting systems in hotel/motel guest rooms. Hotel stakeholders are accepting of the technology. The variety of products and manufacturing companies allow for adaptation to unique HVAC and lighting system types and applications, as well as competition in the market place. This section provides an extensive, though not comprehensive, list of ten (10) occupancy control manufacturers and descriptions of the products they offer. The system capabilities reported by each manufacturing company were neither confirmed by HMG, nor are we recommending any one product over another. Manufacturers provided rough cost data for occupancy equipment and installation and confirmed their ability to respond to an increase in demand if the measure is adopted into 2013 California Building Energy Efficiency Standards for new construction.

Amerisafe Industries

An infrared sensor and a magnetic switch installed at the front door of the room determine if a guest is inside the guest room or not. Once the guest opens the door and exits the room the Infrared Sensor scans the room to see if another guest is still inside. If not, the System will turn OFF the lights and then follow the preset program, set by the hotel staff, which may be:

- Turn OFF the A/C until the guest returns.
- Turn the A/C intermittently ON and OFF accordingly (For example, 5 minutes ON 15 minutes OFF)
- Keep the temperature at a preset level by observing the "optional" thermostat.

The System will keep the room at a pleasant temperature and at an acceptable relative humidity level. An important feature of this product is the Status Indicator, installed outside of the room door which eliminates guest annoyance, since hotel staff may easily determine if a guest is inside the room or not.

Energy Eye Energy Management Control Systems

Energy Eye produces both a hard wired and wireless occupancy controlled systems.

The hard wired system is for new construction and gut rehabilitation only. Hardwired systems are able to have a secondary control for lighting and do not have the problem of interference present for wireless technology. Although the hardwired system is cheaper on a per unit basis (because the customer does not have to pay for the wireless technology) the cost of the electrician used for the installation can be just as costly if not more so.

The wireless system utilizes a door switch and ceiling mounted passive infrared occupancy sensor. When the door is opened or closed, the system searches for an occupant and determines if the room is occupied. When the room is occupied the PTAC is completely controlled by the user. When the room is unoccupied and the pre-set time delay has passed, the PTAC is shut off unless the room temperature drifts outside of the pre-set temperature range.

The Energy Eye System is capable of detecting whether or not a guest room is occupied through information transmitted to the HVAC Control Module by the company's Passive InfraRed (PIR) Detector and Micro Door Sensor. Energy Eye offers an optional door sensor that will tell an HVAC system to shut off five minutes after a balcony or patio door is left open.

Because of its Advanced Logic technology, the system will not turn off when a guest is sleeping. This is because the PIR detector only needs to see the occupant enter the room the first time.

Entergize

Entergize has a Guest Room Energy Management System that utilizes a key card to control both guest room HVAC energy costs as well as lighting and electrical loads. When a key card is inserted into a master control switch upon entry into the guest room it activates all the power in the room - for lighting, HVAC, TV, etc. As long as the key card remains in the control switch slot, the power remains on. As the guest leaves the room, the key card is removed, which turns the power off.

The system is wireless, using microchip control RF (radio frequency) communication, and average room installation takes less than 30 minutes. The system may be overridden, room by room, at guest request simply by providing an additional key, and significantly reduces guest room lockout caused by key card left in room. The system works with all types of guest room HVAC systems and voltages.

Energex Inc.

Energex offers wired and wireless options that incorporate passive infrared or ultrasonic sensor technology. Like other systems, the sensors power down heating and cooling equipment after guests leave their rooms. Energex also offers a sliding window or door auto shut-off feature to ensure heating and cooling systems do not run when sliding doors or windows are open.

Energex Energy Management System includes an option for a wireless information and communication network using a Palm Pilot or one's own PC. The system allows the building's staff to know whether a room is occupied in real time, to communicate messages to each other, and to provide 'head end control.'

Goodman Co. L.P.

The DigiSmart Control System, an operations management tool to be used with its Amana brand PTACs, employs self-configuring, radio frequency (RF)-based wireless mesh technology. To create the mesh, an antenna is plugged into the control board of each PTAC. With the mesh network, one can control and monitor all PTACs from a single control point. The DigiSmart system includes in-room wireless thermostats and occupancy sensors, and a Web-based control platform. Multiple buildings can be networked together via the Internet.

INNCOM Digital Thermostat (EMCS enabled)

INNCOM offers systems of varying levels of sophistication.

- Simple digital thermostat with a motion sensor incorporated into it.
- Digital thermostat and a door switch

- Thermostats can then be networked for central control and reporting through Inncom's INNcontrol software

The INNCOM e4 can replace virtually any existing thermostat currently in use. It has the ability to directly control almost any HVAC fan coil unit (FCU), packaged terminal air conditioner (PTAC), or other unit types ranging from 24V to 277V, without additional relays or transformers.

With the addition of a passive infrared (PIR) motion sensor and door switch, the e4 becomes the brain of an efficient standalone energy management system. This system utilizes a door switch and ceiling mounted passive infrared occupancy sensor. When the door is opened or closed, the system searches for an occupant and determines if the room is occupied. When the room is occupied the PTAC is completely controlled by the user. When the room is unoccupied and the pre-set time delay has passed, the PTAC is shut off unless the room temperature drifts outside of the pre-set temperature range.
For areas with high labor costs or restrictive electrical codes, installation can be wireless by using INNCOM's patented IR and/or RF technology.

Linking all guest room thermostats with INNCOM's INNcontrolTM provides more powerful energy management and many additional capabilities.

Expansion options include:
- Room occupancy status reporting
- Remote HVAC control
- Guest room HVAC diagnostics
- Peak demand load shedding
- PMS/BMS interface
- Automatic lighting control
- Remote mini-bar access reporting
- Remote smoke detector annunciation

Lodging Technology

Lodging Technology's flagship product is GEM System. GEM System determines the physical presence of guests by detecting infrared body heat. When a guest has left a room for a specified period, the GEM System takes control from the normal thermostat and resets room temperature to energy conserving levels. The system also provides real time information on room occupancy to housekeeping, front desk and security.

The system connects to all HVAC systems including PTACs, heat pumps, split systems and fan coil units of any voltage.

Onity SensorStat Energy Management Control Systems

This system utilizes a door switch and ceiling mounted passive infrared (PIR) occupancy sensor. When the door is opened or closed, the system searches for an occupant and determines if the room is occupied. When the room is occupied the PTAC is completely controlled by the user. When the room is unoccupied and the pre-set time delay has passed, the temperature on the thermostat is set back to a pre-set temperature range. The thermostats can also be networked for central control and reporting.

Onity offers several solutions including the SensorStat DDC, which merges digital temperature control (DDC) with PIR sensing. Onity's SensorStat 2000X utilizes PIR occupancy sensing to reduce energy waste by taking control of the HVAC or thermostat while the room is not occupied and automatically setting the temperature to an optimum energy saving level.

Onity also offers a wireless option. The SensorStat Wireless DDC thermostat control can also network with other thermostats. The wireless network can tie in the HVAC controller, door/window switches, PIR motion sensors, electronic locks, safes, lighting switches, minibars, and any other device operating on the same RF protocol standard. Networking capability allows a hotel to create a central command station that monitors the status and activity of each device in every room.

Riga Development

The WiSuite Environmental Management System allows property owners automate and control the energy efficiency of every room. The WiSuite system automatically self-configures into a wireless mesh network of 'WiStat' digital thermostats, appliances and receivers installed throughout a building. The WiStats and other appliance controls monitor the rooms' environment, reducing energy use in unoccupied rooms, and alerting staff to potential problems.

A WiSuite Control Center, accessible from any Web browser, lets facility managers and front desk hotel staff control the devices wirelessly, monitor their status, and set up custom schedules. To completely automate energy savings, WiSuite connects to a hotel's existing reservation system through the WiSuite Reservations Bridge, enabling it to automatically respond to check-in and check-out dates and times. The WiSuite system does not operate like other technologies that incorporate in-room and/or door sensors, and does not power HVAC systems up or down based on guests entering or leaving a room.

Smart Systems International

The SS1000 uses a wireless radio network to communicate with occupancy sensors. When the guest room is vacant, the SS1000 automatically reduces the energy consumption of the PTAC. In addition, it constantly performs patented scientific calculations to ensure that the comfort temperature is achieved within a specified time frame upon the occupant's return. The SS1000 works with the SS2000 motion/infrared occupancy sensor. It resembles a smoke detector. The SS5000 thermostat is also part of the overall system. Smart Systems can be installed quickly as a retrofit application since the communication link between the sensor and the controller is wireless.

7.1.2 Stakeholder Surveys

HMG also communicated with industry stakeholders in order to determine acceptance and use of occupancy control technologies. Conversation topics included current use of occupancy sensor technologies, receptiveness to occupancy control installation, variation of system types, common maintenance issues and guest satisfaction. The following questions were asked:

- Do you currently use this technology or a similar technology to control space heating or cooling or lighting? Have you used anything similar in the past?
  - If so, how has it affected everyday hotel operations?
  - How have the guests reacted to the hotel occupancy controls?
  - What kind of heating system is used in your hotel rooms (central, PTAC, hydronic, etc)? What kind of occupancy control system was installed?

- Have you had any problems with the equipment? If so, how was the problem resolved?
- How does the hotel currently limit or control operation of heating, air conditioning, and lighting in unoccupied guest rooms?
- How do you see your hotels benefitting from this technology?
- How do you see this technology affecting check-in/out and normal operation?
- Are there any issues you'd anticipate following the installation of occupancy controls?

Interviews of stakeholders within the hotel industry revealed positive experience with the technology and openness to installation. The main concern among those that had no experience with the technology was guest comfort, while those whose hotels had the technology installed reported few guest complaints. The interviews summarized in this section are representative of the collection of conversations held with hotel stakeholders. Hotel interviewees typically fell into one of two categories: no experience with the guest room occupancy control technology, but interested in exploring the possibility of installation, or they install the technology in every hotel guest room in every hotel. Very few of the hotel stakeholders contacted reported installation of the technology in only a portion of their hotels.

Mondrian Hotel

The Mondrian Hotel does not currently have occupancy control technology installed, but conveyed "support of any system that will conserve energy", so long as guests remain comfortable. The major benefit to the hotel of such a technology would be the energy savings when a guest room has nobody checked into it, suggesting current housekeeping practices do not include shut-off or setback of HVAC equipment upon check-out.

Accor North America, Inc.

The Accor North America hotel group includes Ibis, Motel 6, Novotel, Sofitel, and Studio 6. Within this group, approximately 70 hotels, averaging 110 units per hotel have occupancy control technology installed. The group has installed several types of control systems including hardwired and wireless variations, with various methods of sensing occupancy.

Of the various occupancy sensor types, the door sensor is reported to fail most often, needing replacement due to wear and tear from repeated opening and closing of guest room doors. The sensor associated with the least complaint is completely within the thermostat unit. In order to prevent problems with detecting motion at night – because of the lack of motion and therefore the system shutting down – they have built into the system a failsafe at night. Where an override occurs, and the system stays on all night. Because most of the energy savings occurs in the day, this override has little effect on overall energy savings.

Also mentioned was the convenience offered by systems that can be wired together for monitoring and control from a central point. This would allow hotel staff to know when rooms are vacant, when maintenance is required, and for equipment to be controlled from the facilities department. In his vision of an ideal future, the utility company would be able to send the facilities department a signal to try and reduce energy during a peak period. With central control of individual thermostats, the facilities department could setback all thermostats during this time, saving the hotel money.

Guest complaints have typically been due to hardware failure. Much of this is likely due to bumping of guests and luggage against system components. Very few complaints t couldn't be immediately resolved. Accor North America has generally seen a 2.5 to 3 year return on investment in occupancy control systems. Installation of occupancy control systems is therefore standard in all new hotels in this group.

***Guest Survey Results from AEC Card-Key Guest Room Controls Study*[12]**

In a field study conducted by AEC, on behalf of PG&E, AEC surveyed guests about satisfaction with room temperatures in guest rooms with active and inactive key-card occupancy controls. Card-key controls in this study shut off (rather than set-back) HVAC equipment when guest rooms were vacant, yielding worst case temperature conditions with use of this technology. Guests were asked a series of questions about satisfactory room temperature upon arrival, during stay, and upon return to the guest room after being out. More than 80% of guests in rooms with active and inactive controls reported that room temperatures were just right upon arrival and 90% of guests were satisfied with room temperature during their stay. Of the guests in rooms with active key-card controls, 70% reported that room temperatures were just right when returning after being out and their HVAC equipment being shut-off for a period of time. In the same pool of guests in rooms with active controls, only 13% of guests reported any change in temperature as inconvenient. Only 4% reported this inconvenience as unacceptable. It should be noted that in guest rooms with inactive controls, 5% of guests reported an unacceptable inconvenience with the temperature change, in rooms whose HVAC equipment had not been shut-off while they were away.

7.2 Energy Analysis Outputs

Figure 25 and Figure 26 contain the output data set and energy analysis calculations for the hotel and motel building prototypes.

12 Architectural Energy Corporation, Card-Key Guestroom Controls Study (DRAFT), June 2009. Prepared for Pacific Gas & Electric Company.

Climate Zone	Case	TOTAL Energy	Savings		HVAC Energy	Savings		TOTAL Energy*	Savings*		2013 TDV	Savings		T24 2013 Peak Demand*	Savings*	
		kBTU/sf-yr		%	kBTU/sf-yr		%	kwh/yr		%	kTDV/sf-yr		%	kW		%
3	Base	15.83			4.61			184,779			105.90			31.79		
	Avg Occ	15.17	0.66	4.2%	3.95	0.66	14.3%	177,058	7,721	4.2%	97.73	8.17	7.7%	26.47	5.3	16.7%
6	Base	17.75			6.54			207,236			115.86			33.4		
	Avg Occ	16.92	0.83	4.7%	5.71	0.83	12.7%	197,551	9,685	4.7%	106.60	9.25	8.0%	28.0	5.3	16.0%
8	Base	16.67			5.46			194,665			110.97			33.5		
	Avg Occ	15.90	0.77	4.6%	4.69	0.77	14.0%	185,706	8,959	4.6%	102.15	8.82	7.9%	28.2	5.4	16.1%
11	Base	18.26			7.05			213,179			132.01			47.9		
	Avg Occ	17.33	0.93	5.1%	6.12	0.93	13.2%	202,325	10,855	5.1%	120.97	11.04	8.4%	40.3	7.7	16.0%
13	Base	19.07			7.86			222,690			133.79			45.7		
	Avg Occ	18.07	1.00	5.2%	6.86	1.00	12.7%	211,027	11,663	5.2%	122.59	11.20	8.4%	38.4	7.3	16.0%
16	Base	16.72			5.50			195,190			116.35			39.8		
	Avg Occ	15.94	0.77	4.6%	4.73	0.77	14.1%	186,149	9,041	4.6%	107.09	9.26	8.0%	33.6	6.2	15.6%
								* (per prototype building)						* (per prototype building)		

Figure 25: Hotel Prototype HVAC Energy Analysis Outputs and Calculations Table

Climate Zone	Case	TOTAL Energy	Savings		HVAC Energy	Savings		TOTAL Energy*	Savings*		2013 TDV	Savings		T24 2013 Peak Demand*	Savings*	
		kBTU/sf-yr		%	kBTU/sf-yr		%	kwh/year		%	kTDV/sf-yr		%	kW		%
3	Base	14.38			3.17			76,510			98.89			14.5		
	Avg Occ	13.63	0.75	5.2%	2.42	0.75	23.6%	72,514	3,996	5.2%	90.23	8.65	8.8%	11.9	2.6	18.0%
6	Base	17.09			5.88			90,899			113.49			15.5		
	Avg Occ	16.02	1.07	6.2%	4.81	1.07	18.1%	85,233	5,665	6.2%	102.88	10.61	9.3%	12.8	2.6	17.0%
8	Base	15.70			4.49			83,493			106.42			15.3		
	Avg Occ	14.81	0.89	5.7%	3.60	0.89	19.8%	78,782	4,711	5.6%	96.75	9.66	9.1%	12.5	2.7	18.0%
11	Base	18.70			7.48			99,426			137.01			23.5		
	Avg Occ	17.56	1.13	6.1%	6.35	1.13	15.1%	93,397	6,029	6.1%	124.62	12.39	9.0%	19.7	3.8	16.0%
13	Base	19.85			8.64			105,527			142.00			23.3		
	Avg Occ	18.62	1.23	6.2%	7.41	1.23	14.2%	99,008	6,518	6.2%	129.06	12.95	9.1%	19.5	3.8	16.1%
16	Base	17.59			6.38			93,542			122.57			18.7		
	Avg Occ	16.57	1.01	5.8%	5.36	1.01	15.9%	88,146	5,396	5.8%	111.96	10.62	8.7%	15.8	2.9	15.7%
								* (per prototype building)						* (per prototype building)		

Figure 26: Motel Prototype Energy Analysis Outputs and Calculations Table

7.3 ASHRAE 189.1-2009 Guest Room Controls Requirements

Section 7.4.3.12 Automatic Control of HVAC and Lights in Hotel/Motel Guest Rooms. In hotels and motels with over 50 guest rooms, the lighting switched outlets, television, and HVAC equipment serving each guest room shall be automatically controlled such that the lighting, switched outlets, and televisions will be turned off and the HVAC setpoint raised at least 5°F (3°C) in the cooling mode and lowered at least 5°F (3°C) in the heating mode whenever the guest room is unoccupied.

7.4 Non-Residential Construction Forecast Details

7.4.1 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.

7.4.2 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.

7.4.3 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)