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Guest Room HVAC Occupancy-Based Control Technology Demonstration

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By Pacific Northwest National Laboratory

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The Department of Energy's technology demonstrations are conducted in consultation with the General Service Administration's (GSA) Green Proving Ground program. The Green Proving Ground leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies and practices, while the Department of Energy-funded technology demonstrations are conducted in both federal and non-federal buildings. Findings are used to support the development of GSA and DOE performance specifications and inform decision-making within federal agencies and the real estate industry. The programs aim to drive innovation in energy and environmental performance in buildings and help lead market transformation through deployment of new technologies.

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I. Executive Summary

Hotel energy use is ranked fifth largest in terms of primary energy use (i.e., lodging) in the commercial building sector (EIA 2003a). The lodging sector constitutes just 2.9% of the total number of commercial buildings in the United States but represents 7.1% of the total floor space (EIA 2003b) and 8% of total commercial sector energy use (EIA 2003a). Hotel guest room energy usage accounts for the majority of energy use within the hospitality industry, typically between 40 and 80%, depending on the hotel size, location, type, heating, ventilation and air conditioning (HVAC) equipment, occupancy and other characteristics (Whitford 1998).

Guest rooms are responsible for much of the energy wasted in the lodging sector. Guest rooms are often left unoccupied for long durations as a result of the nature of guest visits, where HVAC and other end uses are left operational, using energy unnecessarily. Hotels are increasingly interested in using occupancy-based control (OBC) systems to reduce the energy used by unoccupied guest rooms. However, property owners and operators frequently lack confidence that this technology will result in the expected energy savings because of limited energy savings data available from independent sources. This study's purpose is to address these concerns by evaluating the energy savings achieved by a variety of occupancy based controls systems tested in actual U.S. hotels.

This project demonstrates and evaluates the energy savings potential of HVAC OBC systems produced by five manufacturers. These systems were deployed in six different hotels in three metropolitan areas: Washington DC, Dallas TX, and Los Angeles CA. All of these properties utilize packaged terminal air conditioners or heat pump (PTAC/PTHP) HVAC equipment. The research team added instrumentation to the HVAC equipment to monitor equipment amperage draw (a proxy for run-time and energy use) and supply-air temperature.

This report presents data and analysis for the demonstration period initiated in December, 2011 and completed in August, 2012. Data were collected in four 1-month periods over the demonstration duration; each period represented a season or seasonal-shift (winter, spring, spring-to-summer, and summer).

The research team calculated aggregate and location-specific energy savings across the four study periods; Table 1 summarizes the results. All OBC systems performed within the manufacturers' savings claim range of 10% to 30%, as shown below, with an average savings of 18.4% observed. This range was reported by manufacturers prior to the demonstration. The estimated annual energy savings per guest room is also estimated and varies from 167 to 589 kWh/room/yr[1]. Assuming the OBC systems were installed in all guest rooms, each property would save $20.96 to $79.03 per guest room per year, with a simple payback ranging from 5.3 to 15.7 years (based on installed costs).[2] As noted by most manufacturers, the system performance and savings of OBC technology may improve when the systems are integrated to the hotel's property management system (PMS). When properly configured, this PMS integration can allow for deeper temperature set-backs of unrented rooms, affording additional savings. This PMS integration feature was not evaluated as part of this study.

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[1] Annual energy savings are calculated using the percentage savings from this demonstration applied to annual hotel room energy use simulations specific to the cities where the demonstrations were held.

[2] This average total cost savings assumes the savings percentage determined from the subset of guest rooms would be representative of the entire property. It should be noted that significant variance was observed in energy savings results and therefore, the results presented are specific to the properties evaluated; caution should be taken in direct application of these findings to other properties.

Table 1. Guest Room OBC Technology Demonstration Results Summary

Property Name	Property Location	HVAC Equipment Vendor	Average Energy Savings Percent	Calculated Energy Savings[3] (kWh/room/yr)
Courtyard Gaithersburg Washingtonian Center	Gaithersburg, MD	Amana	26.5%	525
Mayflower Renaissance	Washington, DC	Island Aire	18.3%	589
Courtyard Los Angeles Torrance/South Bay	Torrance , CA	LG and Carrier	17.8%	167
TownePlace Suites Los Angeles LAX/Manhattan Beach	Manhattan Beach, CA	LG, Carrier, and Trane	23.2%	255
Courtyard Dallas Addison/Midway	Addison, TX	Trane	13.7%	289
Courtyard Dallas Richardson at Spring Valley	Richardson, TX	Trane	10.8%	228

In comparison to other guest room OBC technology demonstration studies, the percentage and annual energy savings presented are within expected ranges, as summarized in Table 2.

Table 2. Comparative Guest Room OBC Technology Demonstration Study Results

Sponsor/Study	Location	Average Savings Percent	Average Energy Savings (kWh/room/yr)
BPA[1]: Best Western (BPA 2010)	Spokane, WA	12.0%	138
PG&E[2]: Westin (PG&E 2010)	San Francisco, CA	5.6%	62
SDG&E[3]: Hampton Inn (SDG&E 2008)	San Diego, CA	28%	346
SDG&E: Navy Lodge (SDG&E 2008)	San Diego, CA	14%	462

[1] Bonneville Power Association
[2] Pacific Gas and Electric Company
[3] San Diego Gas and Electric Company

The objective of this project was to determine the energy savings potential of OBC technology, deployed in properties with de-centralized HVAC systems across multiple climate and geographical regions. As shown, the OBC technology demonstrates significant energy savings.

Recommendations for Future Research

In order to provide the level of detail necessary for full-scale nation-wide economic analysis (including weather normalization, life cycle costs and return on investment), the research team recommends that future studies:

- Monitor a larger guest room sample size and meter multiple hotel zones or areas
- Assure that all participating hotels have a similar type and vintage of HVAC equipment

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[3] Annual energy savings are calculated using the percentage savings from this demonstration applied to annual hotel room energy use simulations specific to the cities where the demonstrations were held.

- Include a focused commissioning effort of the HVAC systems prior to study, including verification of proper operation, maintenance, and system installation
- Plan for scheduled and consistent maintenance of HVAC systems for duration of study
- Account for the energy savings potential of OBC technology in properties with centralized HVAC equipment

II. Introduction

A. Problem Statement

Hotel energy use is ranked fifth largest in terms of primary energy use (i.e., lodging) in the commercial building sector (EIA 2003a). The lodging sector constitutes 2.9% of the total number of buildings, but 7.1% of the total floor space (EIA 2003b). Specifically, hotel guest room energy usage accounts for the majority of energy use within the hospitality industry, typically between 40 – 80%, depending on the hotel size, location, type, heating, ventilation and air conditioning (HVAC) equipment, occupancy and other characteristics (Whitford 1998).

Moreover, guest rooms are often left unoccupied for long durations as a result of the nature of visiting guests, where HVAC and other end uses are left operational, using energy unnecessarily. Subsequently, occupancy-based control (OBC) systems are becoming increasingly popular to address unoccupied energy use. OBC manufacturers report significant efficiency potential (most report a savings range of 10% to 30%); however, limited independent verification of energy savings exists. Property owners and operators are not confident in the expected energy savings offered by OBC technology based on the limited information available. In 2011, the hospitality sector members of the Commercial Real Estate Energy Alliance (CREEA) identified guest room OBC technologies as a priority for evaluation.

Therefore, the objective of this project is to demonstrate and evaluate the energy savings potential of HVAC OBC systems produced by five manufacturers deployed in six different hotels, in three metropolitan areas: Washington DC, Dallas TX, and Los Angeles CA. Results from this study will demonstrate the savings potential of OBC technologies, providing the hospitality industry with guidance for technology deployment. While this project only addresses OBC technology within the hospitality industry, the technology also has wide applicability, including the healthcare industry.

The results of this study should not be used to compare the performance of one OBC manufacturer against another. Such comparison would be inaccurate because each hotel has unique aspects that dictate the HVAC energy use including hotel location, hotel style and age, HVAC equipment type and age, occupancy patterns, and equipment maintenance practices.

B. Opportunity

Typically, guest room HVAC systems are manually operated via local (e.g., knobs or buttons on a packaged terminal air conditioning (PTAC) unit) or remote (e.g., wall-mounted thermostat) controls. These controls, which are selected by the guest, allow HVAC units to remain operating while a guest room is unoccupied, using energy unnecessarily.

The potential benefit to HVAC OBC technology lies in the ability to reduce energy use during unoccupied periods. During these periods, the OBC system reduces (during heating periods) the temperature set-point of the HVAC equipment (the opposite occurs during cooling periods), thereby, reducing the run-time and energy use of the equipment.

The focus of this study is the reduction in energy use when the guest room is rented, but not occupied. While the technology can achieve savings when the room is not rented, nor occupied, it was found that housekeeping staff randomly changed thermostat set-points and turned HVAC units off during unrented periods. To eliminate the influence of these actions, the analysis focused solely on periods when the guest rooms under evaluation were rented.

Guest room HVAC OBC systems have been commercially available for a number of years and are offered by many manufacturers. The various manufacturers generally offer a similar product (i.e., occupancy sensor enabled thermostat and door switch); however, the control algorithms, wireless features, peripheral sensors, networking capabilities, etc. can vary drastically between different systems. Therefore, each manufacturer should be evaluated separately. Typically, manufacturers will state energy savings ranging from between 10 and 30%, depending on a number of factors including property location, type, climate, etc.

III. Methodology

A. Technology Description

In general, OBC systems utilize occupancy sensing technology to determine when a room is occupied or unoccupied. When a guest enters the room, some form of occupancy sensing, either a door switch, ultrasonic or passive infrared sensor (or a combination) detects the guests' presence. Once a guest is detected, the OBC enables the HVAC system and maintains the temperature set-points selected by the guest.

When the guest leaves the room, the sensing technology detects the unoccupied state, and after a certain period of time, deactivates the HVAC system, maintaining the set-back temperature. The HVAC system will be controlled to maintain the set-back temperature until occupancy is sensed and the sequence begins again. The set-back temperature is set by the manufacturer, though, typically the building operator has input into specific set-points. A key influence in the hospitality industry and barrier to OBC technology adoption is building operator concern that the OBC system will override guest preferences, through inaccurate occupancy detection, thereby allowing the room to become overly hot or cold, which would result in guest complaints and impair lodging reputation.

The OBC technologies demonstrated in this study are retrofit-style thermostat technologies that include an occupancy-sensing component incorporated into the thermostat housing. Some vendors also make use of a wireless remote sensor for greater coverage and better performance. In addition, all OBC systems evaluated in this study made use of a wireless door switch in conjunction with the thermostat-mounted or remote occupancy sensor.

Some of the OBC products are also capable of networking to a front desk property management system, interfacing with building automation systems, and capable of functioning with utility demand response programs. While potentially useful, these features were not tested in this study.

B. Technical Objectives

OBC technologies from five vendors were evaluated. These devices were installed by the vendor in guest room locations chosen by site staff (with input and guidance from researchers) and as specified in the monitoring plan. Each hotel identified four pairs of guest rooms for participation; each of the pairs was chosen to be identical in size, layout and configuration and facing one of the four cardinal directions[4]. Within each guest room pair, the HVAC system in one room would be controlled by the OBC system (i.e., controlled room) and the other would operate as a standard, manually operated thermostat (i.e., baseline room).

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[4] Attempts were made to select guest room pairs with the exterior walls facing north, south, east and west where possible to include thermal loading and wind influences.

The performance metrics evaluated in all rooms include HVAC system amperage draw, supply-air temperature, and room status (rented or non-rented). The run-time of the HVAC system was established via the amperage measurement. Utilizing the HVAC system run-time, supply temperature measurement and the room rental status, a calculation of guest room energy use was determined only for periods during which the room was rented. The baseline and controlled guest rooms, for each pair, were then compared by aggregating the results for the duration of the demonstration period.

C. Demonstration Project Locations

The demonstration sites were chosen with the direction and assistance of Marriott corporate, regional and local engineering staff, with input from Pacific Northwest National Laboratory (PNNL) researchers. It was desired to demonstrate the OBC technology in different climate zones to determine the impact of savings associated with weather. Therefore, three cities; Washington DC, Dallas TX, and Los Angeles CA, were chosen to represent a mixed/humid, hot/humid and hot/dry climates, respectively. In addition, two hotels were chosen in each of the three cities to increase the confidence in the results and allow for additional vendors to participate. Ideally, it was desired to demonstrate the technology in the extreme climates (Zone 1 and 6[5]); however, identifying properties was a found to be a challenge.

Once the hotels were selected by Marriott, PNNL researchers contacted the hotels to communicate the project objectives and confirm their desire to participate. Researchers also screened the properties for HVAC equipment type (i.e., packaged versus fan coil), specifications, and assisted with guest room selection. Once the properties agreed to participate, Marriott corporate staff assigned an OBC vendor and coordinated system installation. The OBC systems were installed solely for this demonstration and are planned to be removed thereafter.

Once the OBC technology installation was completed, a team from PNNL installed the monitoring equipment and verified the OBC systems were installed per the monitoring plan. On at least one occasion, PNNL informed the OBC manufacturer that the system was poorly installed and the manufacturer rectified the installation to meet PNNL guidelines.

IV. M&V Evaluation Plan

A. Facility Description

The OBC technology was installed and demonstrated in six properties located in three metropolitan areas; Washington DC, Dallas TX, and Los Angeles CA. A list of the hotel properties and relevant HVAC equipment information is included in Table 3. Appendix B of this report provides further details on the demonstration sites.

[5] Climate zones as defined by American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 90.1-2010 and International Energy Conservation Code®(IECC) 2012.

Table 3. Guest Room OBC Technology Demonstration Sites and HVAC Description

Property Name	Property Location	HVAC Equipment Vendor	HVAC Equipment Type[6]	Output Capacity Cooling/Heating (Btu/hr)
Courtyard Gaithersburg Washingtonian Center	Gaithersburg, MD	Amana	PTHP	7,000/6,200
Mayflower Renaissance	Washington, DC	Island Aire	PTAC	12,000/11,713
Courtyard Los Angeles Torrance/South Bay	Torrance , CA	LG Carrier	PTHP	LG: 9,300/8,000 Carrier: 8,900/7,700
TownePlace Suites Los Angeles LAX/Manhattan Beach	Manhattan Beach, CA	LG Carrier Trane	PTAC	LG: 9,300/8,000 Carrier: 7,100/6,100 Trane: 11,800/10,800
Courtyard Dallas Addison/Midway	Addison, TX	Trane	PTAC	7,300/6,800
Courtyard Dallas Richardson at Spring Valley	Richardson, TX	Trane	PTAC	7,300/6,800

B. Technology Specification

Five OBC vendors were selected by Marriott in collaboration with PNNL researchers for this demonstration. The OBC systems installed at each property location are provided in Table 4. In addition, some OBC systems included a wireless remote occupancy sensor, rather than a thermostat-mounted sensor, which is noted in Table 4.

To participate in this demonstration, each manufacturer was required to have a two-sensor configuration consisting of an occupancy sensor (passive infrared or ultrasonic) and a door switch. This criterion was selected because of occupancy sensing issues identified by Marriott and others regarding systems that did not have a door switch. The door switch allows OBC systems to know when an occupant enters the room and hospitality building operators are especially critical of systems that fail to identify guests or deactivate the HVAC during the night when occupancy is difficult to detect.

[6] Packaged terminal air conditioner/heat pump

Table 4. Guest Room OBC Technology Demonstration Sites and OBC Technology Description

Property Name	Property Location	OBC System Vendor	OBC System Notes
Courtyard Gaithersburg Washingtonian Center	Gaithersburg, MD	Schneider Electric	• Occupancy-based thermostat • Wireless remote sensor • Wireless door switch
Mayflower Renaissance	Washington, DC	WiSuite	• Occupancy-based thermostat • Wireless remote sensor • Wireless door switch
Courtyard Los Angeles Torrance/South Bay	Torrance , CA	Telkonet	• Occupancy-based thermostat • Wireless door switch
TownePlace Suites Los Angeles LAX/Manhattan Beach	Manhattan Beach, CA	Onity	• Occupancy-based thermostat • Wireless door switch
Courtyard Dallas Addison/Midway	Addison, TX	Schneider Electric	• Occupancy-based thermostat • Wireless remote sensor • Wireless door switch
Courtyard Dallas Richardson at Spring Valley	Richardson, TX	Inncom	• Occupancy-based thermostat • Wireless door switch

C. Metering Plan

C.1. Metering Approach

At the outset, two metering approaches were considered - one a "series" and the other a "parallel" approach. Each approach has benefits and challenges that factored into the final decision, which are highlighted below.

Series Approach: The monitored guest rooms are first operated for a period of time in a "baseline mode," whereby the HVAC system is operated *without* occupancy control. Performance data are collected for this period, and this becomes the system baseline energy use. Once completed, this is followed by the "controlled mode", and the same data points are collected but the system functions *with* occupancy control.

The benefits to the series approach include:

- Consistency of room and equipment from the baseline to controlled periods
- Reduced metering equipment, instrumentation needs, and costs
- Reduced frequency needed to access guest rooms for data collection

Challenges to the series approach:

- Weather conditions will have an effect on HVAC performance due to different periods of performance.
- Potentially longer study duration to capture significant data sets.

Parallel Approach: This approach develops guest room pairs, one *with* and one *without* occupancy control, whereby all monitoring will be identical and completed concurrently. The guestroom pairs are chosen for their commonality; size, orientation, and equipment.

The benefits to the parallel approach include:

- Weather conditions should not impact guest room pairs, assuming the load on each room is consistent.
- Potentially shorter study duration because "baseline" and "controlled" data are collected concurrently.

Challenges to the parallel approach:

- Identification of identical guest room pairs
- Additional metering/instrumentation needs
- Room access for data collection.

After careful consideration, the parallel approach was chosen for this activity largely because of the time benefit of concurrent data collection and the benefit of a true comparison without the need for weather correction.

C.2. Monitoring Parameters/Points

This demonstration focused on monitoring PTAC and PTHP units because of the complexity and uncertainty with monitoring properties with centralized HVAC systems (i.e., fan coils). While the actual configuration did vary by location and HVAC manufacturer, the basics of the PTAC/PTHP instrumentation included:

- **PTAC/PTHP Amperage:** A Hobo U-12, four-channel, data logger (Onset Computer Corp.) and a split core current transformer (CT) were installed in each PTAC/PTHP. The loggers were installed inside the casing of the PTAC/PTHP so as not to be visible to the guests. The CT was installed, by hotel staff, on one of the PTAC/PTHP live power wires. Time series data were recorded at 1-minute intervals, with a memory capacity of roughly 43,000 records (i.e., approximately 30 days).

- **PTAC/PTHP Supply-air Temperature:** A Hobo U-12, four-channel, data logger and remote temperature sensor (mounted in supply-air stream) were installed in each PTAC/PTHP. Similarly, these loggers were installed inside the casing of the PTAC/PTHP. Times series data were recorded at 1-minute intervals, with a memory capacity of roughly 43,000 records.

A typical installation of the two Hobo U-12 data loggers is shown in Figure 1, where the data loggers are highlighted by the red box. The supply-air temperature probe can also be seen in the supply plenum. The exterior casing of the PTAC has been removed for illustrative purposes only.

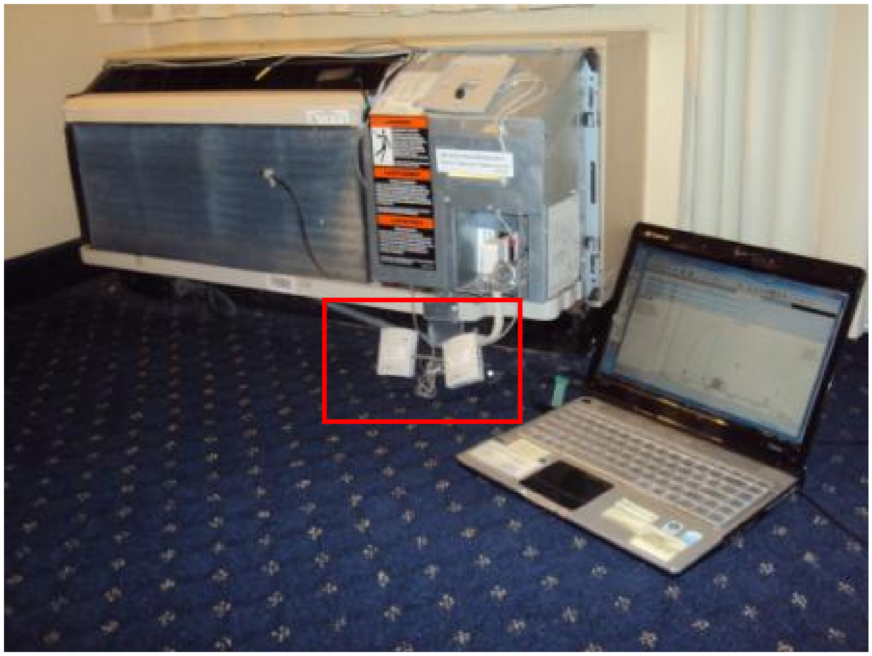

Figure 1. Photograph of a PTAC (exterior casing removed) showing two data loggers (inside highlighted box) at the Courtyard Dallas Richardson at Spring Valley, Richardson, Texas.

C.3. Guestroom Occupancy

A critical analytic component of this demonstration is an accurate accounting of occupancy for each room monitored. There were two occupancy trends requested to be captured by the hotel: a recorded of room status as either "rented" or "non-rented." These reports were generated and provided by the hotel staff.

The original protocol called for OBC technology manufacturers to provide a times-series record of room occupancy for comparison. However, after receiving occupancy data from all manufacturers, it became clear that these data were not in the requested form (time-series interval), nor were they consistent in their presentation. These challenges led researchers to opt for an approach that couples collected data with daily hotel rental records (provided by hotel staff) to arrive at the guest room rental state.

C.4. Sampling and Metering Duration

As indicated above, data was sampled at a 1-minute interval. This relatively tight sampling interval was recommended to assure fluctuations in HVAC system operation were accurately captured. The duration of the monitoring was over an 8-month period, with four 1-month data sets captured. The specific periods of performance corresponding to each demonstration site are provided in Table 5.

The original monitoring protocol included cooperating with hotel staff to carry out data collection activities. Upon completion of the metering installation, it became clear that hotel staff did not have the time, nor access to a laptop computer, to make this a reliable and feasible path. The backup protocol utilized a PNNL contractor to travel to each site and download data on a bi-monthly basis. While this protocol precluded the ability to retrieve a contiguous data set, it did allow for data to be collected spanning critical weather seasons (winter, spring, and summer).

Table 5. Guest Room OBC Demonstration Period of Performance Summary

Property Name	Property Location	Data Set 1	Data Set 2	Data Set 3	Data Set 4
Courtyard Gaithersburg Washingtonian Center	Gaithersburg, MD	12/4/2011 – 1/2/2012	2/16/2012 – 3/15/2012	4/21/2012 – 5/19/2012	7/22/2012 – 8/19/2012
Mayflower Renaissance	Washington, DC				
Courtyard Los Angeles Torrance/South Bay	Torrance , CA	1/30/2012 – 2/28/2012	3/19/2012 – 4/16/2012	6/4/2012 – 7/2/2012	7/28/2012 – 8/25/2012
TownePlace Suites Los Angeles LAX/Manhattan Beach	Manhattan Beach, CA				
Courtyard Dallas Addison/Midway	Addison, TX	1/29/2012 – 2/26/2012	3/17/2012 – 4/14/2012	6/2/2012 – 6/30/2012	7/26/2012 – 8/30/2012
Courtyard Dallas Richardson at Spring Valley	Richardson, TX				

V. Results

Guest room HVAC run-time was analyzed in a pair-wise comparison of baseline and controlled rooms by summing the 1-minute data for only days during which the guest room was rented. The daily run-time was then aggregated across the metering period. Once aggregated, the data were compared (baseline to controlled) to calculate savings. All savings were calculated as an aggregated percentage, because the data were collected as amperage and temperatures, which are not direct energy measurements.

An example of the monthly run-time for the four guest room pairs located at the Courtyard Dallas Richardson at Spring Valley property are shown in Figure 2 for the month of February, 2012. Similarly, Figure 3 shows the run-time (i.e., energy) savings percentage for each guest room pair, where it is obvious that the savings varied substantially from 1.6 to 19.6%. However, on average, the OBC technology saved approximately 10.35%.

Because of the large variance associated with the run-time savings, the data needed to be averaged over long periods in order to provide an overall picture of average performance. However, it should be noted that the run-time savings varies because of many factors including occupancy profiles, guest selected temperature set-points, load variance between guest room pairs and other unknown factors. Therefore, the savings will only be presented as an aggregate savings for each property in an attempt to eliminate factors outside the control of OBC technology.

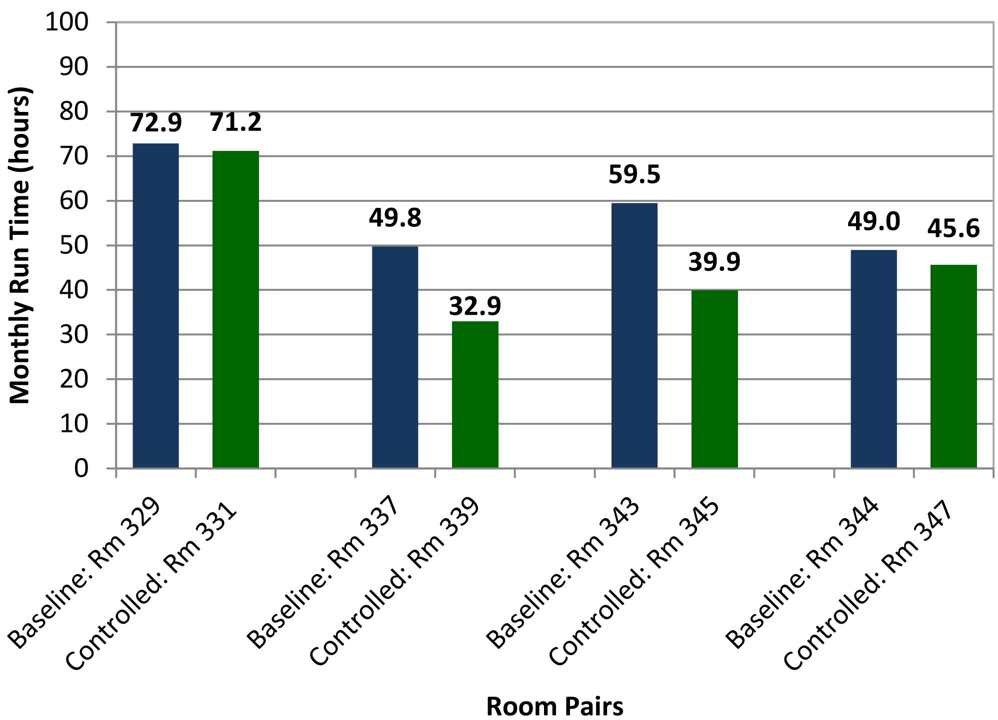

Figure 2. Guest Room PTAC Monthly Run-time Hours, Courtyard Hotel Richardson, TX in February, 2012

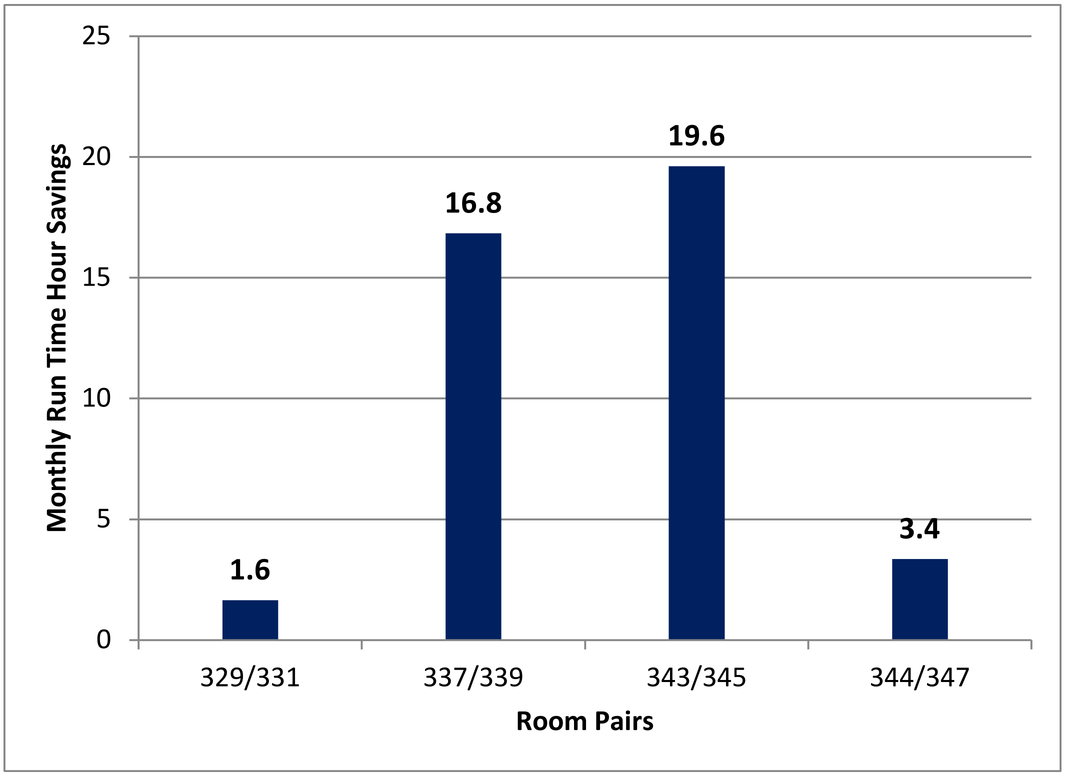

Figure 3. Guest Room PTHP Monthly Occupied Run-time Savings, Courtyard Hotel, Richardson, TX in February, 2012

VI. Summary Findings and Conclusions

A. Overall Technology Assessment at Demonstration Facility

Guest room HVAC system run-time was measured in six hotels in three cities of differing climates. Within each hotel, eight guest rooms were monitored in four pairs. Each guest room pair had one room with the OBC HVAC system (i.e., controlled room) and one room with a standard thermostat-controlled HVAC system (i.e., baseline room). The four pairs were selected for their relative orientation to include the four cardinal directions.

While the scope of this study did not allow annual energy consumption versus climate measurements to be made, annual PTAC and PTHP energy use estimates are available for each state, obtained from detailed hourly building energy simulations (DOE 2008a). In addition, annual energy use estimates by typical meteorological year (TMY2) cities were obtained to represent the pertinent cites in this demonstration and are presented in Table 6[7]. The data represent simulated average annual energy consumption estimates for energy usage for equipment just meeting current federal efficiency standards, and reflect specific modeling assumptions, among which are ventilation provided at the PTAC or PTHP unit (as opposed to central ventilation) and an average building occupancy rate of 63%.

Table 6. PTAC and PTHP Annual Energy Use for Selected TMY2 Cities

TMY2 City	Capacity	Cooling Energy Use (kWh/room/yr)	Heating Energy Use (kWh/room/yr)	Total Energy Use[1] (kWh/room/yr)
PTAC				
Baltimore, MD	9,000	558	1,851	2,806
	12,000	634	1,988	3,217
Fort Worth, TX	9,000	1,007	711	2,112
	12,000	1,151	776	2,517
Los Angeles, CA	9,000	464	257	1,100
	12,000	511	294	1,374
PTHP				
Baltimore, MD	9,000	547	1,072	1,982
	12,000	621	1,251	2,414
Fort Worth, TX	9,000	987	336	1,693
	12,000	1,127	419	2,100
Los Angeles, CA	9,000	455	132	941
	12,000	500	185	1,214

[1] Total energy use includes fan, cooling and heating energy.

The OBC technology energy performance analysis has resulted in savings percentages commensurate with manufacturer estimates of between 10% and 30%. While savings varied significantly room-to-room and over

[7] Energy use estimates from underlying TMY2 city data were obtained through communication with DM Winiarski at PNNL, as city specific energy data are not available in the DOE Life-Cycle Cost Spreadsheet, which only provides data at the state level and which, by design, did not include electric resistance heating energy consumed by PTAC equipment.

any given period, the aggregated savings by hotel varied between a low of 10.8% and a high of 26.5%, as summarized in Table 7. The annual energy savings per guest room was calculated using the annual energy use estimates provided in Table 6 and include both heating, cooling and fan energy use.

As noted by most manufacturers, the system performance and savings of OBC technology may improve when the systems are integrated to the hotel's PMS. When properly configured, this integration can allow for deeper temperature set-backs of unrented guest rooms affording additional savings. This PMS integration feature was not evaluated as part of this study.

Table 7. Guest Room OBC Technology Evaluation Results Summary

Property Name	Property Location	HVAC Equipment Vendor	Average Savings Percent	Calculated Energy Savings (kWh/room/yr)
Courtyard Gaithersburg Washingtonian Center	Gaithersburg, MD	Amana	26.5%	525
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Courtyard Dallas Richardson at Spring Valley	Richardson, TX	Trane	10.8%	228

In addition, simple payback estimates can be made using the total number of guest rooms for each property (see Appendix VII.B for details), assumed energy rates and installed costs, which were provided from the manufacturers, and are specific to each demonstration property. The overall simple payback ranged from 5.3 to 15.7 years, as shown in Table 8, which ranges significantly from property to property because of the assumed energy use, utility rate differences and installed cost ranges.

Table 8. Guest Room OBC Technology Simple Payback Summary

Property Name	Property Location	Calculated Energy Savings (kWh/room/yr)	Annual Cost Savings[1] ($/room/yr)	OBC Installed Cost[2] ($/room/unit)	Simple Payback (yr)
Courtyard Gaithersburg Washingtonian Center	Gaithersburg, MD	525	$70.49	$375	5.3
Mayflower Renaissance	Washington, DC	589	$79.03	$426	5.4
Courtyard Los Angeles Torrance/South Bay	Torrance , CA	167	$21.92	$345	15.7
TownePlace Suites Los Angeles LAX/Manhattan Beach	Manhattan Beach, CA	255	$33.43	$348	10.4
Courtyard Dallas Addison/Midway	Addison, TX	289	$26.59	$375	14.1
Courtyard Dallas Richardson at Spring Valley	Richardson, TX	228	$20.96	$375	17.9

[1] Cost savings assumes average electricity rates of $0.1342/kWh, $0.131/kWh and $0.0919/kWh for Washington, DC, California and Texas, respectively (EIA 2010a, b, c).

[2] Installed costs were provided by manufacturers and represent costs specific to the properties used in this demonstration.

The data and findings presented here *should not* be used to compare one manufacturer's performance with another. All tested OBC equipment performed at an expected and satisfactory level for the climate and HVAC system it was paired with. It is probable that differences in performance between each property are more closely correlated with weather, guest occupancy profile, HVAC system type and its operation, installation, and maintenance.

There are numerous factors that influence the variance of OCB technology energy savings observed during this demonstration. The key variables affecting measureable OBC energy savings in this demonstration include:

Room occupancy profile: The occupancy profile (i.e., how frequently they are rented) for each guest room evaluated in this study varied significantly and impact HVAC run-time and corresponding energy savings.

Guest occupancy profile: Detailed hourly guest occupancy data could not be obtained and therefore, the occupancy patterns of the guests in the demonstration rooms is likely to have varied significantly, which can impact energy savings.

Guest HVAC settings: To minimize guest disturbance, each guest was able to control the HVAC thermostat to their desired temperature. Therefore, variances between different guest preferences (i.e., some guests like a hot room, while others enjoy a cold room) will impact energy use and subsequently savings.

OBC system set-points: The OBC systems each utilize their own manufacturer selected temperature set-points for heating set-back and cooling set-up. These set-points were dictated by Marriott local hotel engineering staff, to ensure guest comfort, but are likely not consistent through the demonstration sites. In addition, each OBC manufacturer utilizes a different time delay prior to changing HVAC operation, and this time delay may impact energy savings.

HVAC features: A wide range of PTAC and PTHP units are used throughout this demonstration and the age, function and upkeep of these units is likely to have impacted energy savings.

Climate influence: It is expected that the ambient climate, which affects the HVAC load, could impact energy savings between different hotels and climate zones in this demonstration. However, the variance observed at each hotel and between hotels was so large that climate influence is not the dominant influence. It is suspected that occupancy patterns are the dominant influence to savings variances.

During this assessment and numerous site visits, a number of recommendations were noted for considerations for future evaluation and overall OBC/HVAC operation and efficiency.

Future evaluation considerations:

- Consider a larger sample size at each hotel – metering of a block of rooms comprising a hotel zone or major area.
- Consider allowing full integration of the thermostats with the PMS to evaluate the full savings potential.
- Consider all participating hotels having similar/same type and vintage of HVAC equipment.
- A focused commissioning effort of the HVAC systems prior to study should be considered. This activity should include verification of proper operation, maintenance, and system installation.
- Consider provisions for scheduled and consistent maintenance of HVAC systems for duration of study.

OBC/HVAC operation and efficiency:

- HVAC unit installation (i.e., fit in through-wall sleeve) should be reviewed for tightness of fit to assure infiltration is minimized.
- HVAC units should be maintained to assure filter and coils are cleaned on a regular basis.
- As OBC thermostats are installed, consider regular reviews of remote sensors and door switches to make sure they are present, property attached, and operational.

B. Best Practices

The results of this study indicate that guest room HVAC OBC technology has the potential to save energy in the range of 10 to 30% and should be considered for implementation. This study found annual cost savings ranging from $20.96 to $79.03 per guest room with a simple payback of 5.3 to 15.7 years. Some caution should be afforded to the broad application of these results because these are specific to the properties evaluated, guest preferences observed, OBC manufacturers participating and the HVAC systems monitored. In addition, only eight rooms were studied at each property, which is typically about 3% of the total guest room count.

The incumbent technology consists of manual HVAC operation via local knobs and buttons or remotely mounted thermostats. OBC technology represents a feedback to the HVAC equipment and allows the HVAC equipment to reduce energy use when the guest is not present. In addition to energy savings, the reduced operation may also positively impact equipment lifespan and maintenance requirements.

OBC technology is suitable for application in all property types within the hospitality industry due to multiple configurations available to adapt to various guest room layouts, property styles, etc. This technology is also well suited for retrofit as a result of wireless capabilities and similar configuration as existing technology. In addition, this technology lends itself well to the healthcare industry; specifically in hospital rooms, where spaces may remain unoccupied for long periods.

Finally, additional savings may be possible when OBC systems are fully integrated with the hotel PMS, as well as communications for remote diagnostics of function, setting, and efficiency opportunity. This was outside the scope of this study but is an opportunity for future research and analysis.

C. Barrier and Enablers to Adoption

Although OBC technology is widely adopted internationally, there are several barriers that have impeded its adoption in the U.S. market. Primarily, some building owners and operators are resistant to change, especially change that is perceived as more complex. OBC technology may be perceived as a complicated technology that may be prone to guest complaints, operational and maintenance issues and engineering staff avoidance. Secondly, limited data exists regarding actual savings verified by an independent party; most savings values are provided by the OBC manufacturers. In addition, limited data is available for multiple climate zones and hotel configurations (i.e., packaged versus centralized HVAC equipment).

Currently, there are no national industry energy standards that explicitly require OBC technology to be installed in hotels and motels. However, ASHRAE Standard 90.1-2010 (ASHRAE 2010) and 2012 IECC (IECC 2012) both identify off-hour control requirements that OBC technology would address. Although, both ASHRAE and IECC provide an exception to off-hour controls for zones with heating and cooling capacities less than 15,000 and 6,800 Btu/h, respectively. The ASHRAE standard will likely exempt most PTAC/PTHP equipment; however, IECC may not. Therefore, OBC technology may be required in states that adopt the 2012 IECC energy standard. Practically, these standards only apply to new construction but may be interpreted for retrofit situations as well.

At the state level, however, California's proposed 2013 Title 24 Standard (CEC 2012) requires "hotel and motel guess rooms have captive key card controls, occupancy controls or automatic controls […]" with 5°F heating and cooling set-backs. Should this proposed energy standard be adopted, OBC technology would be explicitly required in California properties. A detailed search regarding other states has not been performed, but it's assumed that the majority of other states would not require OBC technology.

An issue encountered during the installation of the OBC systems was inappropriate occupancy sensor location. This issue did not occur often and was corrected immediately. The occupancy sensor must be located where guest movement can be detected throughout the majority of the guest room (i.e., not in a confined hallway or facing a wall). Installation of the occupancy sensor is critical for determining occupancy, especially during sleeping hours when guest movement is minimal. Many manufacturers utilize a door switch and assume, regardless of the occupancy sensor detection, that from when a door opens until it closes, the room is occupied. This eliminates issues with reduced comfort during sleeping hours, but may also reduce energy savings by ignoring actual unoccupied periods.

In addition, some issues were encountered with damage to the OBC technology components including broken occupancy sensors, which are mounted to the thermostat, broken (or missing) door switches, etc. The technology is prone to guest damages because of the increased number of components (and guest curiosity factor) compared to the incumbent technology.

Moreover, the condition of the HVAC systems is expected to have a significant impact on the energy savings potential of the OBC technology. In some cases, the HVAC systems were found in poor operating condition or improperly installed (i.e., large gaps around through-wall sleeves allowing outside air to infiltrate the room).

D. Market Potential

Estimates of the cost effectiveness of the OBC technology have been made and the simple payback ranges from 5.3 to 15.7 years. However, based on the method used to estimate the annual HVAC energy consumption and the variance of energy savings found, caution should be applied in using these values to predict the full-scale deployment cost effectiveness of the OBC technology (see recommendations for future research, page 3).

OBC technology is suitable for new construction and retrofit projects. The technology need not be paired with other major renovations because manufacturers have adopted installation configurations specifically for independent retrofit applications. However, to reduce costs, the OBC technology should be installed across an entire property, where economy-of-scale can provide economic incentives and additional features at a minimal cost increase (e.g., many manufacturers offer networked solutions that tie into building automation and property management systems).

Approximately 25,000 hotels in the U.S. utilize packaged HVAC equipment, which accounts for 21% of the total number of hotels. These 25,000 properties use approximately 10.3 trillion Btu of electricity per year for heating and cooling, which is 37% of the total lodging sector use (EIA 2003c[8]). Assuming, this heating and cooling is only used by the packaged HVAC units, the OBC technology is estimated to save 1.9 trillion Btu per year, assuming an average energy savings of 18.4% observed during this demonstration.

E. Recommendations for Installation, Commissioning, Training and Change Management

The OBC manufacturers estimate the useful life of their systems to be around 10 years, with a warranty of at least 1 year covering parts and labor, as summarized in Table 9.

Table 9. Guest Room OBC Technology Manufacturer Lifetime and Warranty Summary

Manufacturer	Useful Life (yr)	Warranty (yr)
WiSuite	15	1
Telkonet	15 to 20	1
Onity	10	1
Schneider Electric	10	2
Inncom	10 to 15	1

This study did not identify any acceptability issues among hotel staff or guests. However, on average, only 3% of the hotels guest rooms were participating in this demonstration so any guest complaints or staff issues may have gone unnoticed. In addition, a formal survey of guests or staff was not performed.

A critical installation consideration regarding OBC technology is occupancy sensor placement. Care should be taken to ensure the occupancy sensor is located in a position to detect movement within the entire guest room. Specifically, sensors should be positioned in view of beds such that motion during sleep hours can be detected. Sensors should also be located in each room within suites to ensure that motion is detected. Door switches, in conjunction with occupancy sensors, is recommended (and was a pre-requisite of this demonstration) because this may eliminate issues with motionless guests during sleeping hours.

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[8] Estimates obtained using Commercial Building Energy Consumption Survey Microdata files, accessed via the Building Energy Data Sifter Beta program, Beta Version 1.00, developed by Elliott, DB and RZ Schultz, Pacific Northwest National Laboratory, Richland, WA, which is currently not publically available.

VII. Appendices

A. Future OBC Specification Development Considerations

This initial task serves to establish a foundation upon which specification development can be initiated. Future field work is recommended to identify key performance criteria, proper installation techniques, and periodic maintenance requirements for optimized energy savings.

Below are key considerations necessary for future specification development:

HVAC Systems Operations and Maintenance:

- Determine impacts resulting from different system configurations (e.g., through-wall with and without a sleeve, chimney configurations, etc.)
- Understand performance impacts associated with system maintenance

OBC Technology Installation:

- Understand performance impacts associated with OBC installation location and HVAC system integration
- Evaluate impacts of different OBC communication types (e.g., wired vs. wireless)
- Determine minimum system component requirements
- Components critical to operation
- Form factor concerns

OBC Operations and Maintenance:

- Understand OBC function and user interface
- Determine minimal OBC configuration, temperature set-backs, and operating schedules
- Understand OBC maintenance requirements
- Other potential benefits/attributes
    - Remote maintenance scheduling
    - Remote diagnostics
    - Complaint confirmation/resolution

OBC Building Operations Integration:

- OBC potential/optimization with climate/climate zone
- OBC appropriateness for differing hospitality configurations
    - Quick stay/single room/business hotel
    - Extended stay/multiple room
    - Vacation/family orientation
    - Business orientation
    - Guest access to/use of operable windows or sliding glass doors
    - Understand performance impacts associated with housekeeping and management interactions

B. Demonstration Site Information

B.1. Courtyard Dallas Addison/Midway, Addison, Texas

The Courtyard Dallas Addison/Midway, located at 4165 Proton Drive, Addison, Texas contains 134 guest rooms and 11 suites.

Figure 4. Photograph of the Courtyard Dallas Addison/Midway.

Figure 5. Photograph of a Trane PTAC unit and Schneider Electric OBC thermostat at Courtyard Dallas Addison/Midway

Figure 6. Photograph of a Schneider Electric Wireless Door Switch and wireless occupancy-sensor at Courtyard Dallas Addison/Midway.

B.2. Courtyard Dallas Richardson at Spring Valley, Richardson, Texas

The Courtyard Dallas Richardson at Spring Valley is located at 1000 South Sherman, Richardson Texas and contains 137 guest rooms and 12 suites.

Figure 7. Photograph of the Courtyard Dallas Richardson at Spring Valley.

Figure 8. Photograph of a Trane PTAC unit and Inncom OBC thermostat at the Courtyard Dallas Richardson at Spring Valley.

Figure 9. Photograph of an Inncom Wireless Door Switch at the Courtyard Dallas Richardson at Spring Valley.

B.3. Courtyard Los Angeles Torrance/South Bay, Torrance, CA

The Courtyard Los Angeles Torrance/South Bay is located at 1925 West 190th Street, Torrance California and contains 139 guest rooms and 12 suites.

Figure 10. Photograph of the Courtyard Los Angeles Torrance/South Bay.

Figure 11. Photograph of a Carrier PTAC unit and Telkonet OBC thermostat at Courtyard Los Angeles Torrance/South Bay

B.4. TownePlace Suites Los Angeles LAX/Manhattan Beach, Manhattan Beach, CA

TownePlace Suites Los Angeles LAX/Manhattan Beach is located at 13300 Aviation Boulevard, Hawthorne, California and contains 144 suites.

Figure 12. Photograph of the TownePlace Suites Los Angeles LAX/Manhattan Beach.

Figure 13. Photograph of a Carrier PTAC unit and Onity OBC thermostat at TownePlace Suites Los Angeles LAX/Manhattan Beach

Figure 14. Photograph of a Onity Wireless Door Switch at TownePlace Suites Los Angeles LAX/Manhattan Beach.

B.5. The Mayflower Renaissance, Washington, DC

The Mayflower Renaissance hotel is located at 1127 Connecticut Avenue NW, Washington, District of Columbia and contains 583 guest rooms and 74 suites.

Figure 15. Photograph of the Mayflower Renaissance.

Figure 16. Photograph of an Island Air PTHP unit and a WiSuite OBC thermostat at the Mayflower Renaissance.


Figure 17. Photograph of a WiSuite Wireless Occupancy Sensor and a Wireless Door Switch at the Mayflower Renaissance.

B.6. Courtyard Gaithersburg Washingtonian Center, Gaithersburg, MD

The Courtyard Gaithersburg Washingtonian Center is located at 204 Boardwalk Place, Gaithersburg, Maryland and contains 203 guest rooms and 7 suites.

Figure 18. Photograph of the Courtyard Gaithersburg Washingtonian Center.

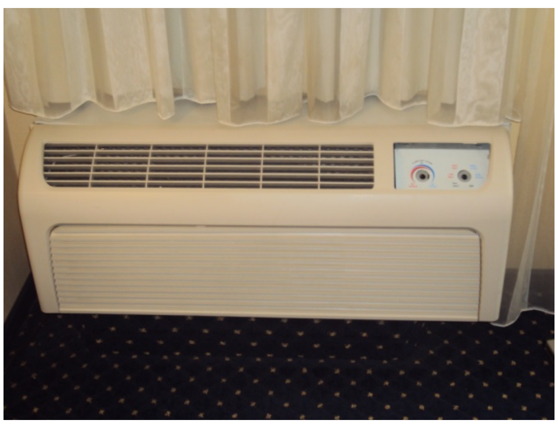

Figure 19. Photograph of an Amana PTHP unit and Schneider Electric OBC Thermostat at Courtyard Gaithersburg Washingtonian Center.

Figure 20. Photograph of a Schneider Electric Wireless Occupancy Sensor and Wireless Door Switch

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A. Glossary

ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BPA	Bonneville Power Administration
CREEA	Commercial Real Estate Energy Alliance
CT	Current transformer
HVAC	Heating, ventilation and air conditioning
IECC	International Energy Conservation Code
OBC	Occupancy based controls
PNNL	Pacific Northwest National Laboratory
PTAC	Packaged terminal air conditioners
PTHP	Packaged terminal heat pumps
PG&E	Pacific Gas and Electric Company
PMS	Property Management System
SDG&E	San Diego Gas and Electric Company
TMY	Typical meteorological year