PROJECT REPORT

INTERNET-CONNECTED, OCCUPANCY-RESPONSIVE, ADAPTIVE THERMOSTATS FOR UNIVERSITY RESIDENCE HALLS

UC Davis, CA

June 2, 2014

WCEC
WESTERN COOLING EFFICIENCY CENTER

UCDAVIS
UNIVERSITY OF CALIFORNIA

PREPARED FOR:

Karl Johnson

California Institute for Energy & Environment
1333 Broadway, Suite 240
Oakland, CA

PREPARED BY:

Jonathan Woolley
Associate Engineer

Marco Pritoni
Graduate Student Researcher

Paul Fortunato
Outreach Coordinator

Western Cooling Efficiency Center
University of California, Davis
215 Sage Street #100
Davis, CA 95616

wcec.ucdavis.edu

ABOUT THE WCEC

The Western Cooling Efficiency Center was established along side the UC Davis Energy Efficiency Center in 2007 through a grant from the California Clean Energy Fund and in partnership with California Energy Commission Public Interest Energy Research Program. The Center partners with industry stakeholders to advance cooling-technology innovation by applying technologies and programs that reduce energy, water consumption and peak electricity demand associated with cooling in the Western United States.

ABOUT THE STATE PARTNERSHIP FOR ENERGY EFFICIENT DEMONSTRATIONS (SPEED) PROGRAM

The SPEED program is supported by the California Energy Commission and managed through the California Institute for Energy and Environment (CIEE). SPEED demonstrations are coordinated by the CIEE in partnership with the California Lighting Technology Center and the Western Cooling Efficiency Center, both at the University of California, Davis.

TABLE OF CONTENTS

SECTIONS

TABLES

Figures

1.0 EXECUTIVE SUMMARY

Segundo Housing Complex in Davis, California

Many recent field evaluations for communicating and occupancy-responsive thermostats have shown significant annual HVAC savings on the order of 10-20%. However, the form and function for technologies in this space vary widely.

Occupancy responsive thermostats adjust mechanical system operating parameters to reduce energy consumption when a conditioned space is vacant. Unlike occupancy controls for lighting, the value of occupancy control applied to heating and cooling depends on a range of dynamic factors that are difficult to measure and assess with precision. For instance, the efficiency of heating and cooling equipment changes with weather conditions and part- or full-load runtime capacity, while thermal loads depend on the aggressiveness of indoor temperature set-points, and their dynamic relationship to a variety of physical and environmental factors.

This report summarizes results from a series of investigations with one type of occupancy sensing adaptive thermostat installed in a number of residence halls at the University of California, Davis. The technology tested automatically adjusts set-points in each room during vacant periods and enables a number of energy management services such as central schedule control, and limitation of the user set-point range.

Conclusions from the research are supported by the findings that there is high variability for the temperature response and energy use between individual rooms, and between different buildings. The potential for energy savings during vacant periods is subject to coincident meteorological conditions, however, measuring these savings is complicated because thermal loads associated with occupants themselves may have a significant impact on energy use for conditioning during vacant periods. Further, the measured savings for whole building chilled water energy use appears to be greater for periods with low average building occupancy. Overall the study indicates that considerable savings can be achieved in certain instances, but that the impact is highly sensitive to the specific technology implemented and its application.

2.0 ABOUT THE TECHNOLOGY

Many buildings are often mechanically conditioned to a constant set-point, regardless of whether they are occupied or not. Even in instances where set-points and ventilation are scheduled, the pre-programmed operating times reflect assumed occupancy patterns and comfort preferences. In commercial and high rise residential buildings, the same is true for mechanical ventilation. This is a waste of energy and money, but has historically been the only way to manage temperature and indoor air quality without intensive manual regulation by users or facilities managers.

The newest thermostat technologies capitalize on the recent development of wireless communication protocols, the proliferation of wireless communicating components, and the infusion of the Internet into many aspects of personal life and facility management. Thermostats leverage these tools to enable much more sophisticated control sequences. So-called ‘smart thermostats’ are characterized generally by their communicating capabilities, including web and mobile user interface options, as well as networked control that allows for instantaneous management of multiple thermostats in a facility. Smart thermostats may include occupancy responsive control, adaptive or learning algorithms, demand response capability, fault detection and diagnostics, and runtime optimization features that impact equipment efficiency. These features promise to improve usability, but more importantly they provide automation for schedule and set-point control which could optimize energy while maintaining or improving overall comfort. However, amidst the range of new and emerging thermostat technologies, it is not clear which features actually provide energy savings, which improve level of service, which enhance usability, or which are actually of little technical value.

Telkonet adaptive thermostat

Building from programmable ‘set-back’ thermostats and modern lighting controls, occupancy responsive thermostats adjust operation for heating, cooling, and ventilation when a space is unoccupied. Most occupancy responsive thermostats do this by shifting the temperature back from the occupied temperature set-point. This allows the room temperature to drift and should result in reduced runtime for heating and cooling equipment. In certain applications it may also reduce energy use related to ventilation. Generally, this adjustment is intended to capture energy savings when no occupants are detected while also maintaining a level of service (thermal comfort, indoor air quality, sense of control) during occupied periods. However, understanding the transition from the unoccupied to the occupied state is critical for predicting energy savings. When the set-point is restored, additional energy must be expended for a period of time to recover from the set-back. For example, if the set-back and temperature drift occurs during a hot afternoon, and recovery is in the evening, the energy saved during the set-back period will be greater than energy needed for recovery. There are also conditions for which the energy for recovery exceeds the energy saved during the set-back period. It has also been noted by others that some set-back strategies may also result in periods of unsatisfactory thermal comfort for occupants.

Adaptive controls automatically change operating parameters according to learned and predicted factors. These systems adapt over time according to measured responses. They can learn about system physical characteristics (cooling capacity, temperature response time, etc) and user schedules and preferences in order to predict appropriate set-back periods and ranges. These features can save energy, improve thermal comfort and/or improve convenience and user experience. These learning algorithms can be integrated with features that respond to occupant proximity, or that predict occupant comfort according to user feedback and measured and forecast outdoor temperature.

Other Studies

Several recent studies on occupancy sensing thermostats have concluded that, for the right application the technologies offer significant savings (Table 1).

Description of Thermostat Features for Pilot Evaluations

This study focuses on field evaluation of one occupancy responsive adaptive thermostat technology provided by Telkonet. The thermostat system learns about response capabilities for the heating and cooling equipment and automatically programs a set-back for vacant periods that will allow for a timely recovery to the comfort set-point when a room is again occupied.

The system studied communicates between multiple thermostats on a ZigBEE mesh network, and uses a central internet gateway to allow communication with this network from a web-based user interface. Each thermostat has an on-board (or remote wireless) infrared motion detector. Vacancy in a room triggers adjustment of the active set-point, which allows temperature to drift and results in a reduced duty cycle for the conditioning and ventilation systems. Additionally, the system incorporates an on-board light sensor and logic to distinguish between vacancy and a nighttime condition where occupants are sleeping. The system studied applies a learning algorithm that continually adapts the set-back temperature for unoccupied periods so that a room can recover within an acceptable period when an occupant returns. During occupied periods, users are allowed temperature control, although facility managers may limit the selectable set-point range to avoid excessive heating or cooling by residents.

Aside from the promise of energy savings, the technology provides substantial value for facilities management by providing central, web-based, on-demand control of hundreds or thousands of rooms. Room-by-room insight about instantaneous and historical system operation improves maintenance and troubleshooting capabilities. Since the technology does not require integration

Type or Reference	Author	RUNTIME Savings	Link
Report	HMG-CEC	12-24%	Guest Room Occupancy Controls
Report	PNNL	10-25%	Guest Room HVAC Occupancy-Based Control Technology Demonstration
Report	SDG&E	~20%	Guest Room PTAC/PTHP Energy Management System
Press Release	Telkonet	10%	Networked Telkonet SmartEnergy Reinforces New York University's Sustainability Initiatives
Case Study	Telkonet	38%	Galt House Hotel
Case Study	Telkonet	42%	Radisson Hotel & Conference Center, Green Bay, Wisconsin
Case Study	Telkonet	17-25%	Habitat Suites Hotel, Austin, Texas

Table 1: Review of recent studies on occupancy sensing thermostats and key conclusions

Ryerson and Bixby dormitory buildings in Davis, California

with the whole building equipment management system, these features can be installed at a much lower cost than would be required by a traditional wired approach.

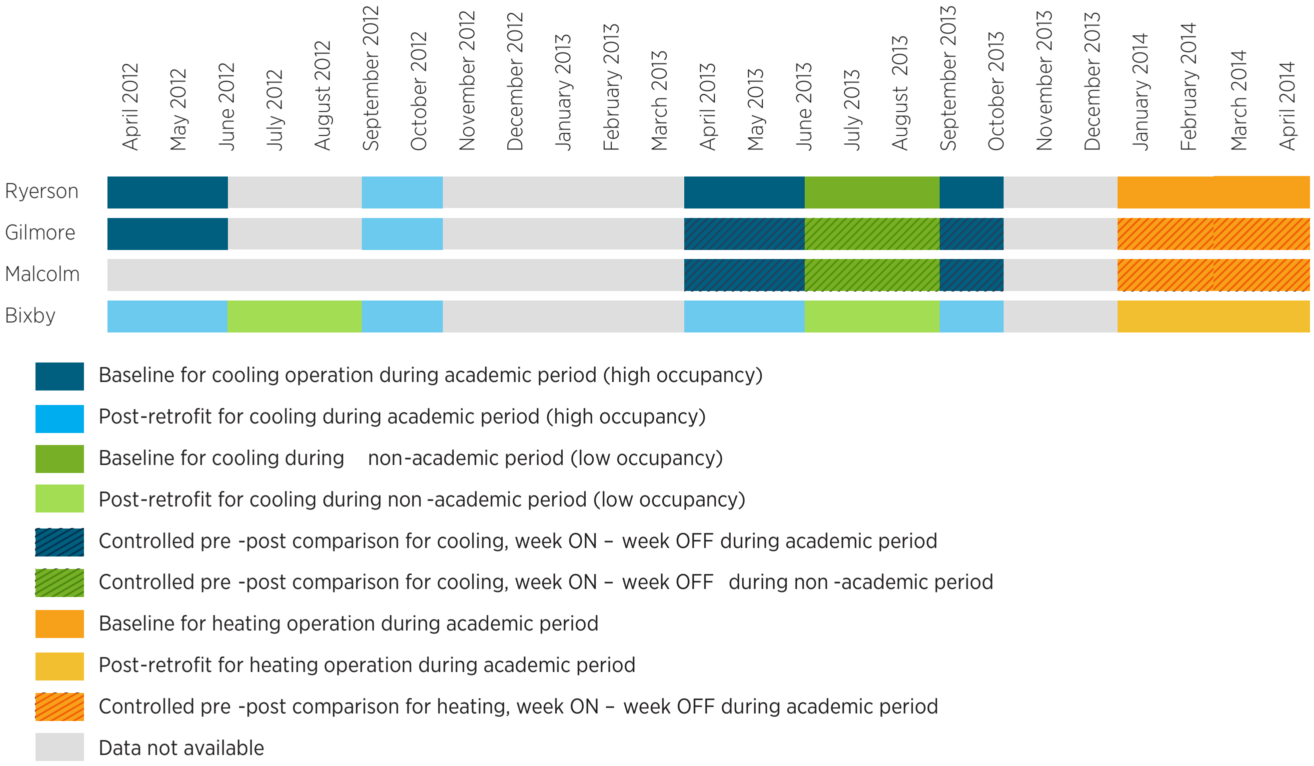
3.0 DEMONSTRATIONS

As part of the State Partnership for Energy Efficient Demonstrations, the Western Cooling Efficiency Center collaborated with Student Housing and the Energy Management Office at the University of California, Davis to monitor and analyze the field performance of occupancy-responsive adaptive thermostat technology. Student Housing sought an advanced thermostat strategy that would improve control of the facilities, simplify maintenance, and reduce energy consumption. In 2011 UC Davis Student Housing piloted this technology in two residence halls. Subsequent installations advanced the pilot to several buildings in 2012, and then rolled the strategy out to all residence halls on campus in 2013. The measure is currently installed in more than 3,000 individual residence hall rooms in 25 separate buildings.

The study began with a review of the system behavior and energy consumption data for Potter Hall, one of the first two buildings retrofit. Evaluation of this building was conducted in parallel with the second phase of installations, and highlighted the importance of considering mechanical system design and control characteristics when applying advanced controls. The building did not achieve energy savings. While the occupancy sensing and adaptive thermostat devices functioned as intended, the research team discovered that due to the physical design of the building mechanical systems, adjusting the call for heating and cooling from the thermostat based on occupancy in each room had practically no effect on actual systems operations. In fact, it appears that the retrofit may have resulted in an increase for fan energy consumption. The outcome can be attributed to the fact that each fan coil serves multiple rooms, and that the operation of these fan coils is managed in part by the central building automation system according to temperature in the corridors. This example suggests that integration of advanced controls must carefully evaluate the specific operating scheme for the mechanical equipment which it intends to control. If certain portions of the overarching sequence of operations managed by some factor other than the thermostat, improved thermostat controls may have little bearing on actual system behavior.

Following the pilot at Potter Hall, this study turned attention toward four dormitory buildings in the Segundo Housing Complex. The four buildings are similar, 5-story concrete-and-steel structures originally constructed in 1965. In these buildings, each thermostat has direct and complete control over a fan coil unit dedicated to each room. This avoids the problems encountered previously described at Potter. These residence halls each have 110 rooms and various common spaces, such as corridors, meeting rooms, laundry rooms and bathrooms. Conditioning for the common spaces is served by a central air handler. Bedrooms occupy about 50% of the total floor area, and are equipped with two-pipe, three-speed fan coil systems for heating and cooling. All rooms are restricted to either cooling or heating during any given period. Chilled water and steam supplied from the campus central plant are generally switched only once per season. Fresh air ventilation is provided by central exhaust and through operable windows.

The occupancy sensing adaptive thermostats were installed for Bixby Hall in September 2011 as part of the first pilot phase. Installation in Malcolm, Gilmore and Ryerson followed in May, June and July 2012 respectively. In all cases, the new thermostats replaced unrestricted manual thermostats, but they did not control the corridors. The research team collected data in cooling seasons and during periods of high and low occupancy corresponding to the academic quarter and summer conference housing periods (Table 2). Data included whole building chilled water energy consumption, outside air temperature, occupancy, thermostat state, active set-point temperature (or set-back temperature), room temperature, and fan coil run time in every room. Since historical whole-building chilled water energy consumption data was only available for Ryerson and Gilmore, data from cooling season performance in September – October 2012 (post-installation) were compared against chilled water energy consumption data from April – May 2012 (pre-installation). Further, from April 2012 to February 2013, the thermostats in Gilmore and Malcolm were switched between an occupancy-responsive mode and a conventional operating mode in alternating weeks (ON-OFF). This allowed for comparison both in academic and non-academic periods (Table 2).



	April 2012	May 2012	June 2012	July 2012	August 2012	September 2012	October 2012	November 2012	December 2012	January 2013	February 2013	March 2013	April 2013	May 2013	June 2013	July 2013	August 2013	September 2013	October 2013	November 2013	December 2013	January 2014	February 2014	March 2014	April 2014
Ryerson	🟦	🟦	⬜	⬜	⬜	🔷	🔷	⬜	⬜	⬜	⬜	⬜	🟦	🟦	🟩	🟩	🟩	🟦	🟦	⬜	⬜	🟧	🟧	🟧	🟧
Gilmore	🟦	🟦	⬜	⬜	⬜	🔷	🔷	⬜	⬜	⬜	⬜	⬜	▦	▦	▩	▩	▩	▦	▦	⬜	⬜	▨	▨	▨	▨
Malcolm	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	⬜	▦	▦	▩	▩	▩	▦	▦	⬜	⬜	▨	▨	▨	▨
Bixby	🔷	🔷	🟢	🟢	🟢	🔷	🔷	⬜	⬜	⬜	⬜	⬜	🔷	🔷	🟢	🟢	🟢	🔷	🔷	⬜	⬜	🟨	🟨	🟨	🟨

🟦 Baseline for cooling operation during academic period (high occupancy)
🔷 Post-retrofit for cooling during academic period (high occupancy)
🟩 Baseline for cooling during non-academic period (low occupancy)
🟢 Post-retrofit for cooling during non -academic period (low occupancy)
▦ Controlled pre -post comparison for cooling, week ON – week OFF during academic period
▩ Controlled pre -post comparison for cooling, week ON – week OFF during non -academic period
🟧 Baseline for heating operation during academic period
🟨 Post-retrofit for heating operation during academic period
▨ Controlled pre -post comparison for heating, week ON – week OFF during academic period
⬜ Data not available

Table 2: Data periods utilized for study

Summary of Technology Assessment

Data analysis used a multiple change-point regression model to characterize the baseline chilled water and hot water energy consumption as a function of several independent variables (outdoor temperature, 24 hour temperature history, and building occupancy rate). The methods for pre-post comparison adhered to the principles established by ASHRAE Guideline 14: Measurement of Energy and Demand Savings. Measured chilled water and hot water consumption from each post-retrofit dataset was compared to a projected baseline that uses the regression model to predict energy consumption that a baseline system would have used during the post-installation conditions. For the experiment that involved alternating weeks with the occupancy-responsive feature enabled and disabled, the combination of all weeks with the feature disabled were used as baseline.

Overall results for chilled water and hot water energy savings are shown in Table 3. Chilled water savings during the academic periods is limited. In fact, there is no measurable difference during these periods. However savings exceeds 20% during the summer non-academic months. These results are restricted to an assessment of chilled water energy use, and do not estimate the electric impacts related to fan power in all fan coil units.

It appears that the major difference between savings potential in the academic and non-academic periods is a result of the fact that occurrences of vacancy in each room during the non-academic period are more coincident with vacancy throughout the building. Although whole building occupancy during the academic period is only 60-70% on average, the occurrences of vacancy in each room are more disaggregate and sporadic. For example in the academic period, some students leave for class for a few hours, but adjacent rooms tend to remain occupied. The building may only be 50% occupied, but the distribution of vacant rooms tends to occur as a checkerboard spread across the building, and the periods of vacancy in each room is often too short to allow temperature to drift all the way to the set-back.

To the contrary, occupancy patterns over the summer period are more regular, and vacancy in one room is more likely to correspond to vacancy throughout the building. During this time, residence halls are used as conference housing with no permanent residents. Periods of vacancy tend to be much longer, indoor/outdoor temperature difference is generally larger, and indoor temperature tends to drift all the way to the set-back temperature when rooms are unoccupied. The summer period also experiences periods with much lower occupancy, in fact, average occupancy during the period is only 10%.

Practically, in the summer a prolonged set-back in 90% of the rooms produces an effect similar to an increase of the whole building set-point by a few degrees. We hypothesize that if vacancy in rooms during the academic period was more prolonged, and more synchronous with vacancy in adjacent rooms, the same level of whole building average occupancy would yield greater savings. 10% hot water savings was realized during the heating academic period.

Table 3: Savings calculated during Academic and non-Academic periods

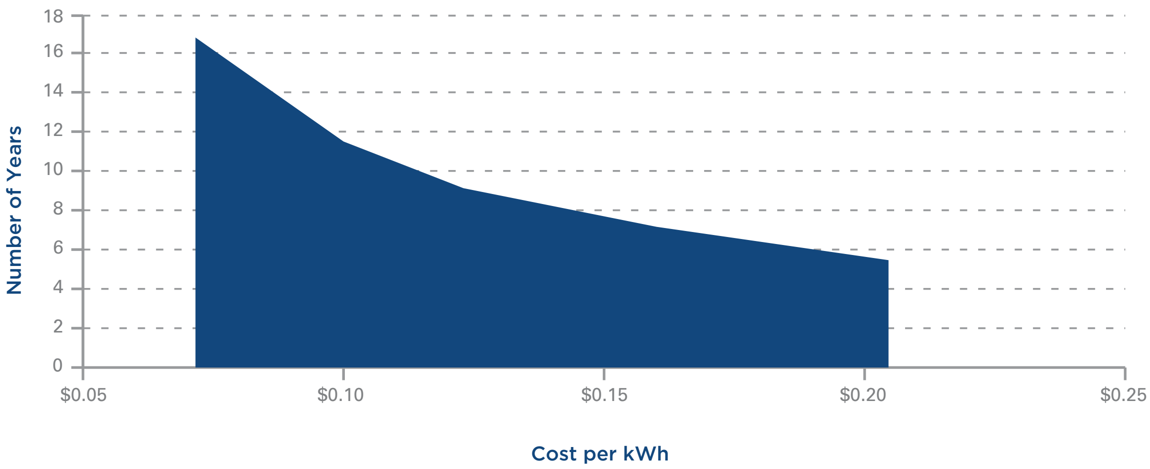
Building	Study Period	Savings
Ryerson	Pre-post Comparison | Cooling | Spring 2012 vs Fall 2012 | Academic Period	3.4%
Gilmore	Pre-Post Comparison | Cooling | Spring 2012 vs Fall 2012 | Academic Period	0.0%
Gilmore	Week ON - Week OFF Control | Cooling | Summer 2013 | Non-Academic	29.0%
Malcom	Week ON - Week OFF Control | Cooling | Spring 2013 | Academic Period	2.8%
Malcom	Week ON - Week OFF Control | Cooling | Summer 2013 | Non-Academic	21.6%
Malcom	Pre-Post Comparison, Week ON - Week OFF Control | Cooling | Fall 2013 | Academic Period	6.2%
Malcom	Week ON - Week OFF Control | Heating | Winter-Spring 2014 | Academic Period	9.9%
Gilmore	Week ON - Week OFF Control | Heating | Winter-Spring 2014 | Academic Period	9.5%

In terms of project economics, Table 4 shows a generalized project savings and costs estimation for this technology. As was seen in this project the primary savings were found to be during the summer months when the building experienced reduced and unpredictable occupancy. The plot shown as Figure 1 illustrates how simple payback changes with changing utility rates based off a unit cost of $350 each, with a total material and installation cost of 38,500 per building.

Table 4: Performance results for both heating and cooling modes during both high and low occupancy levels

Telconet Performance Results from 110 buildings at UC Davis				
Operation mode	Heating		Cooling	
Occupancy level	Low	High	Low	High
H/CW energy in period (kWh)	44,291	198,544	61,163	38,413
Energy Savings	7%	7%	25%	3%
Site Energy savings (kWh)	16,513		16,486	
Distribution Efficiency	0.8		0.8	
Plant Efficiency	0.8		3	
Source Energy Savings (kWh)	25,801		6,869	

Figure 1: Payback vs. Electricity Cost



Lessons Learned

The very first installation of this technology in a residence hall in Davis with a different mechanical system setup showed low energy savings because the thermostats were not integrated appropriately into the existing control scheme for the building mechanical system. That experience serves as a reminder that as the complexity of building systems increases, minor changes in a sequence of operations, and small misunderstandings about system function can have broad impacts on building function that may counteract energy savings potential.

In the second phase of pilot installations, there were some minor commissioning challenges with the thermostats themselves, but no major failings were observed. The small challenges encountered were all addressed through software updates. It is worth noting that throughout the course of this study, the authors have observed multiple software advances for the technology which have increased reliability, and expanded functionality and usability.

Proper placement of the occupancy sensors for these systems is critical. False occupancy readings can be caused by furniture placement or other obstructions, thermal flow within the sensors' field of vision, or activity outside a window such as passing cars. Experience from installation at other universities suggests that the ceiling is the best location to install sensors.

Additional Benefits of the Technology

In general UC Davis Student Housing has been pleased with the thermostat systems and most recently installed the devices for every residence hall room on campus. Interestingly, while the system has benefits as an energy efficiency measure, the asset management functionally provided seems to be the major driving factor for the technology. The potential for room-by-room insight to support diagnostics and troubleshooting, as well as global control of set-points and schedules for thousands of rooms from a web interface on a computer are invaluable capabilities.

4.0 CONCLUSIONS & RECOMMENDATIONS

There are many applications where occupancy responsive, adaptive, and otherwise 'smart' thermostats can derive substantial savings and operational benefits. Some of the applications that might be most appropriate include:

1. **Single family homes and apartments** (large fraction of vacancy, wholly controlled mechanical system, and independent thermal zone dominated by external loads)
2. **Small- and medium-sized businesses** – especially offices (large fraction of vacancy, independently controlled systems, limited thermal interaction between zones, dominated by external loads).
3. **Laboratories** – (or other spaces where ventilation rates can be controlled on an occupancy signal, and conditioning loads are dominated by outdoor conditions)
4. **Hotels, Apartments & Dorms** – (large fraction of vacancy, limited thermal interaction between occupied zones and vacant zones – predict better savings where vacancy is organized in blocks).

For residence halls connected to central plants in hot and dry climates like Davis, this study indicates that energy savings during the summer period is substantial, but the savings were much less for cooling during academic periods. Heating savings of around 10% are also significant. There may be energy benefits associated with other features for these thermostats but the occupancy sensing adaptive algorithms did not result in a measurable impact at UCD during academic periods. Future studies should monitor the fan power and energy use controlled by the thermostats. Broader adoption of the technology for residence halls requires careful consideration for the specific application, and measured expectations for the annual energy savings and operational advantages..

Decisions about where to deploy occupancy responsive thermostats need to be guided by testing designed to determine whether or not room temperature will drift back to the set-back temperature for significant amounts of time. If cooling loads are merely transferred to adjacent rooms, and zone temperature does not drift very far, then occupancy responsive set-back may not capture savings.

This analysis does not capture the potential for savings that is available from improved programming and scheduling capabilities. This should be estimated separately for any application in question. A large portion of the savings reported from other residence halls that have installed this technology is suggested to have come from the ability to constrain set-point limits. Most ‘smart’ thermostats provide networked communications that allow for simple management and set-point control in hundreds of rooms at once. Further, systems can easily be shifted to extreme set-backs during holidays.

If estimating the potential for savings for future projects, we recommend a number of application-specific characteristics that should be considered:

1. Mild climates will achieve a smaller magnitude of savings than extreme climates.
2. Application should minimize the number of areas that are not controlled by occupancy responsive functions, especially when the zones have some thermal interconnection.
3. The technology should be applied where zone-by-zone control can be accomplished, and where doing so does not result in diminished equipment performance.
4. During academic periods, residence halls operate with a relatively high degree of occupancy, and occurrences for vacancy are spread across a building in a very irregular and heterogeneous way. When vacant rooms are surrounded by occupied and conditioned zones, the tendency to drift toward a set-back temperature is diminished – thermal load for a vacant room in set-back is transferred to adjacent conditioned zones.
5. During academic periods, a large fraction of vacancy events persist for a relatively short time. For short periods of vacancy, a large fraction of the theoretical savings opportunity is consumed by the energy use required for recovery.
6. The adaptive set-back strategy will have a more significant impact in inefficient buildings, where the indoor load is more closely coupled to environmental conditions, and a relaxed set-point results in a larger total energy benefit. Buildings with large ventilation conditioning load are also good candidate for this technology.
7. Quick and easy tests should help to identify savings potential for the building:
    a. Test rooms proposed for occupancy responsive controls by adjusting set-point and observing thermal behavior. If the temperature does not drift to a set-back then there is little opportunity for savings (other mechanisms are conditioning the zone).
    b. Consider occupancy throughout the year. Long periods of vacancy, or low average occupancy offer larger savings opportunity. If vacancy periods align with periods of peak conditioning requirements, the building has more potential savings.

5.0 RELATED RESOURCES & REVIEW OF PROJECT OUTCOMES

Over the course of the effort to evaluate occupancy sensing adaptive thermostat controls, Western Cooling Efficiency Center and CIEE have published a number of different reports and papers that address different aspects of the research findings and technology opportunity.

1. **Occupancy Sensing Adaptive Thermostat Controls – A Market Review and Observations from Multiple Field Installations in University Residence Halls (Woolley, Peffer ACEEE 2012)**
    - Presents a framework for characterizing advanced thermostat control strategies (classification, market and cost assessment)
    - Discusses range of target applications for adaptive thermostat technologies (hotels, residence halls, conference or assembly halls are good candidates)
    - Examines challenges encountered with application in one residence hall (Potter)
    - Presents preliminary results from another installation (Bixby), indicating that reduction in equipment runtime for each room during vacant periods is significant.
2. **CIEE Technical Report: Advanced Thermostat Controls (Johnson, Peffer, Woolley, SPEED report 2012)**
    - Presents a general description and background of currently available thermostat technologies, including occupancy-sensing, advanced algorithms, engaging interfaces and networked systems.
    - Describes anecdotal results from two field installations of occupancy-sensing thermostats in residence at other universities
    - Concludes this technology has opportunities, but there are not enough field studies measuring savings.
3. **Occupancy Sensing Adaptive Thermostat Controls for University Residence Halls (Pritoni, Woolley, Mande, Modera. prepared for Journal publication)**
    - Explores the relationship between Telkonet system behavior and whole building chilled water use and dynamics
    - Discusses parameters that have an impact on room temperature and runtime reduction
    - Calculates savings in Bixby for pre-post retrofit: 30% during fall-spring cooling season
    - Calculates the impact of occupancy-sensing feature on energy use. The impact is large, but there is uncertainty what portion of this savings is related to reduced internal gains, and what portion can be attributed to the thermostat control features.

4. **Why Occupancy-Sensing Adaptive Thermostats Do Not Always Save - and the Limits for When They Should (Woolley, Pritoni, Peffer ACEEE 2014)**
    - Shows results for several well controlled pre-post and ON-OFF experiments on four more buildings during 2012-2014. Chilled water savings are close to zero during the spring-fall academic period and around 20% in the summer non-academic period.
    - Presents a theoretical framework and a simulation model to understand the impact of set-back strategies
    - Reviews additional studies in the literature
    - Provides recommendations on the selection and installation of this technology

6.0 Collaborators

UC Davis Facilities Management funded the purchase of the Telconet Thermostats and commissioning. California Institute for Energy and Environment, UC Davis Western Cooling Efficiency Center, provided project management, technical guidance, and performance evaluation.

Any questions about this project, including technology costs, can be directed to:

JONATHAN WOOLLEY
UC Davis
Western Cooling Efficiency Center
jmwoolley@ucdavis.edu
wcec.ucdavis.edu

MARCO PRITONI
UC Davis
Western Cooling Efficiency Center
mpritoni@ucdavis.edu
wcec.ucdavis.edu

KARL JOHNSON
California Institute for Energy and Environment
Karl.johnson@uc-ciee.org
uc-ciee.org

For more resources and information, including technology catalogs, business case studies and demonstration maps, visit PARTNERSHIPDEMONSTRATIONS.ORG.