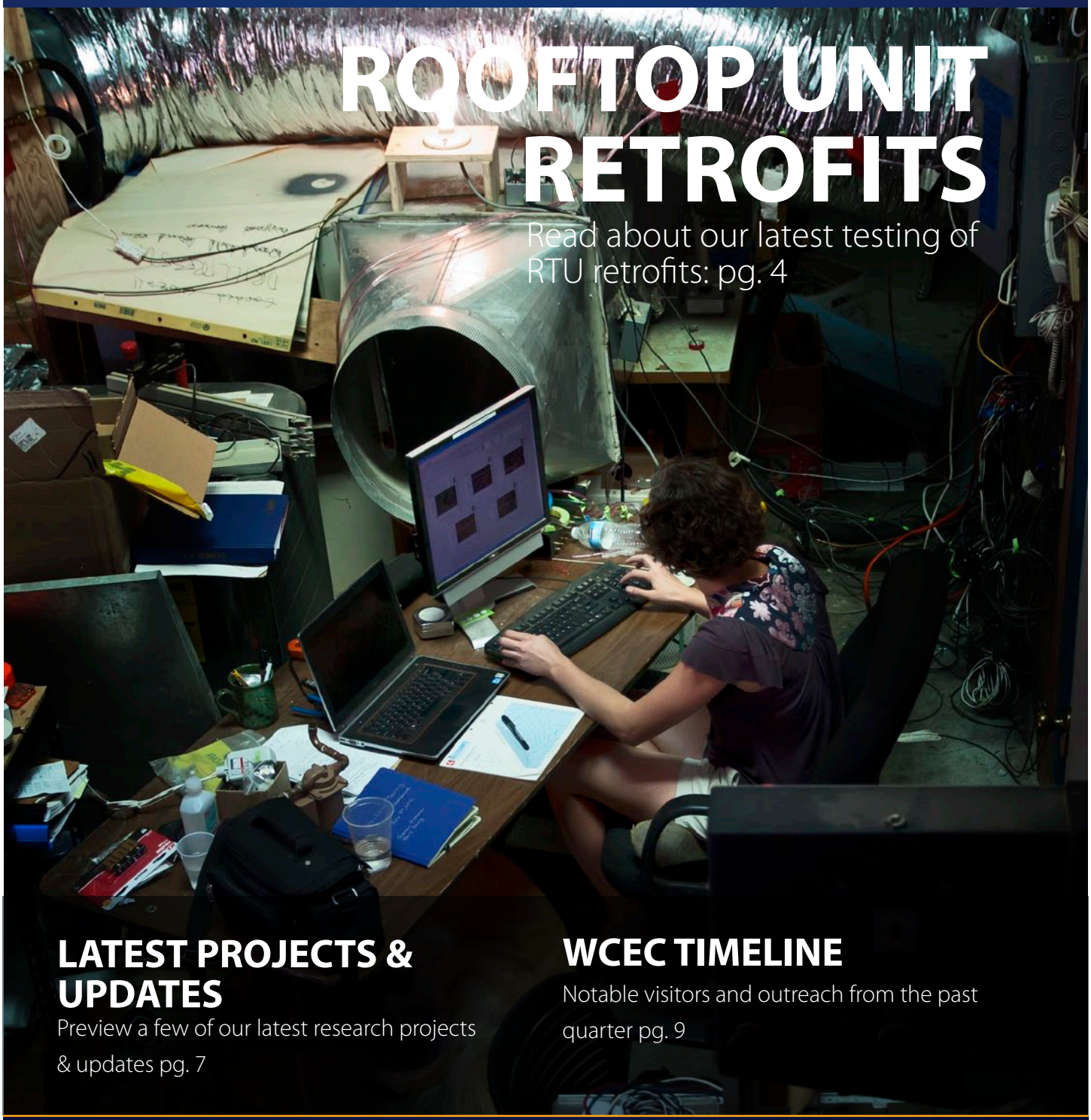
WESTERN COOLING CONNECTION



ROOFTOP UNIT RETROFITS

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UC DAVIS UNIVERSITY OF CALIFORNIA

2012 | Q4

WCEC WESTERN COOLING EFFICIENCY CENTER

LETTER FROM THE DIRECTOR

To our readers,
As 2012 comes to a close, our team is busy wrapping up projects that are coming to an end, while building the case for exciting future research in several funding proposals. In 2012 we made significant progress on a multitude of projects, leading to important findings and milestones. I would like to take the time in this letter to look in retrospect, at the many important milestones of the past year.

2012 Milestones

• Trane Voyager DC meets the requirements for the Western Cooling Challenge: the first major manufacturer to meet our stringent criteria and proving this system is well suited to save energy and money in California
• Water Management: we discovered that magnesium and calcium react differently to standard water treatment strategies (aka bleed), leading to important implications for water usage in evaporative cooling systems
• Aerosol Building Envelopes: we successfully sealed over 50% of the leaks in a home at rough-in stage of construction. We also sealed over 70% of the leaks in a finished home in Davis, CA.
• Fault Detection & Diagnostics: WCEC's efforts in Fault Detection & Diagnostics led to a Title 24 code change that will require new RTUs to have some form of Fault Detection.

Looking Ahead to 2013

As we look into 2013, WCEC will dramatically increase our research capabilities as we take over our new 2,000 square foot laboratory. At the end of January we will move into our new offices and shortly thereafter ramp up testing for energy efficient RTUs, retrofits, and a host of HVAC technologies.

WCEC is also investigating research opportunities that include heating efficiency and gas pipeline sealing research. Stay tuned for more information in future newsletters as this work gets closer to realization.

In This Issue

WCEC has some exciting updates to our current projects and some new additions. Please note, we cannot cover every project in each Newsletter:

> Featured article: RTU Retrofits
> Latest Projects and Updates
> WCEC Outreach efforts timeline and notable visitors

Mark Modera, *Director*
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WCEC is an element of the Energy Efficiency Center at the University of California, Davis, with a mission to "partner with stakeholders to identify technologies, conduct research and development, disseminate information, and facilitate programs that reduce cooling system electrical demand and energy consumption in the Western United States."

WCEC Affiliates

Beutler
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Integrated Comfort
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Octus Energy
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Seeley
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Xcel Energy
Sacramento Municipal Utility District
California Energy Commission

WCEC Research Partners

National Renewable Energy Laboratory
New Buildings Institute
Lawrence Berkeley National Laboratory
Gas Technology Institute
Pacific Northwest National Laboratory
Oak Ridge National Laboratory
California Institute for Energy and Environment
Consol Energy

Personnel Updates

Happy Holidays from WCEC! Erica McKenzie, our great water specialist is moving to Colorado. She will be greatly missed, but we wish her the best on her future endeavors as a groundwater remediation specialist at the Colorado School of Mines.

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Please let us know at **wcec@ucdavis.edu** *if you would like to be added to or removed from our mailing list.*

ROOFTOP UNIT RETROFITS

WCEC engineer Perry Young installing an air to hot water heat exchanger for conditioning of the test chamber air

It is estimated that roughly 70% of the non-residential space in California is conditioned by packaged roof-top units (RTUs). This prevalence makes these units a key component of any energy efficiency programs targeting non-residential buildings. However, addressing the energy performance of this equipment is complicated by their longevity. Stand-alone RTUs are estimated to last approximately 20 years on average. This long replacement cycle limits the market penetration rate of new energy-efficient HVAC packaged equipment in light commercial buildings.

Another issue associated with this type of equipment is that RTUs have an electrical load factor on the order of 20% in California. Load factor is defined as the ratio of average annual electricity consumption to coincident peak electricity demand. This low load factor stems from the fact that cooling compressors (which represent the largest power draw in this equipment) are off for much of the year, but are generally running simultaneously across the population during peak electricity demand times. This translates to a disproportionate peak electric demand associated with RTUs, which in turn translates to a poor use of capital for utilities in California.

One option for improving the energy efficiency and lowering peak electricity demand of RTUs within a shorter time frame is an initiative to improve energy efficiency through cost effective RTU retrofits. These strategies are focused on the facilitation of self-sustaining business models for profitably delivering comprehensive RTU retrofits that save electricity and natural gas, while significantly reducing peak electricity demand. Simplified calculations suggest significant energy savings potential for retrofits of RTUs. As an example, evaporative pre-cooling of condenser air has been shown to reduce compressor energy use by 10-40%, depending upon the climate.

The first two years of a WCEC initiative to retrofit RTUs consists of the following activities:

- Develop a test protocol and analysis method for impacts of Condenser-Air Pre-Coolers
- Survey and analyze RTU fan operating patterns and quantify potential impacts of efficient fans/motors as retrofit technologies

Test Protocol Development

Evaporative pre-coolers pass the inlet air through a wet evaporative media, decreasing the dry bulb air temperature toward

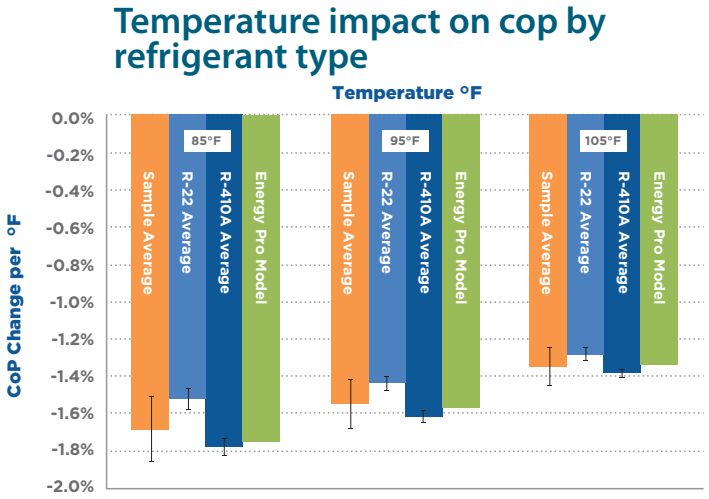
the wet bulb temperature. There are a large number of evaporative pre-coolers available on the market; however, no standard exists by which to measure their performance, so WCEC has authored a draft laboratory test protocol for condenser-air pre-coolers. The laboratory test protocol assesses the energy savings and water use of evaporative pre-coolers with respect to outdoor dry bulb and wet bulb temperatures. The protocol also has tests for assessing the impacts of wind and hard water on pre-cooler operation. WCEC is working to get the protocol established as an ASHRAE test standard. At the July 2012 meeting in San Antonio, Texas, ASHRAE technical committee 5.7 approved the Title Purpose and Scope for the proposed "Method of Test for Determining Energy Performance and Water-Use Efficiency of Add-On Evaporative Pre-Coolers for Unitary Air Conditioning Equipment" and will be sending it to the standards committee.

WCEC is currently using the draft protocol to test three evaporative pre-cooler products. The objective is to evaluate the protocol while gathering data on three commercially available products: Daikin's "Ene-cut", Mist Ecology's "AC Spritzer," and Greenway Design Group's "Cool-N-Save". While waiting for construction of a new 2,000 ft^2 laboratory, WCEC has constructed a temporary test facility (Figure H1) capable of testing a 3-ton condensing unit with pre-cooler installed. Testing of the baseline condensing unit has been completed and testing of the pre-coolers is currently underway. Results for the pre-cooler testing are expected in Fall 2012.

Furthermore, WCEC is developing an analysis tool to quantify the impact of pre-coolers on energy savings of the RTU stock in California. While the protocol will quantify the pre-cooling delivered and the energy savings of the condensing unit under test, additional work is needed to estimate the energy savings for a typical RTU in California. RTUs are more efficient when the outside air temperature is cooler, but the efficiency increase with respect to temperature decrease varies among units. A preliminary analysis of 26 RTU models shows that RTUs with refrigerant R-410A are slightly more sensitive to temperature changes than RTUs with refrigerant R-22 (Figure H2). However, the difference is small, and both data sets are in good agreement with assumptions used by a Title 24 compliant energy modeling program, Energy Pro. WCEC is continuing to analyze manufacturer RTU data to determine the expected mean and range of the slope of RTU performance. This data will be combined with laboratory test data to determine the expected energy savings impacts of pre-coolers on RTUs in the field.

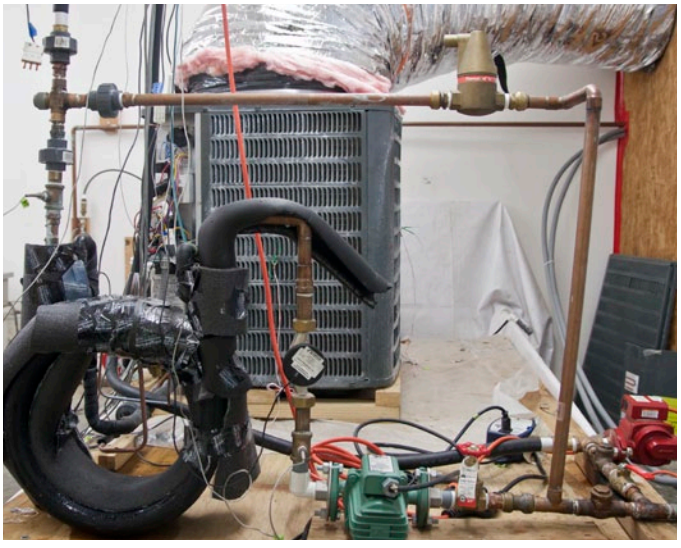
RTU Fan survey

A cursory analysis of the DEER database (Database for Energy Efficient Resources) suggests that the electricity use of commercial RTUs is split roughly equally between the compressor and the fans. The analysis behind these numbers, based principally on computer simulations, seems to imply that RTU fans are run continuously, rather than cycling with the compressor. This is not surprising, as Title 24 energy performance calculations require non-residential buildings to meet ASHRAE Standard 62.1 for ventilation. For code compliance purposes in buildings with RTUs this is generally achieved by having RTU fans run continuously (at least during occupied hours). The exception is for the subset of these buildings that have dedicated ventilation systems.



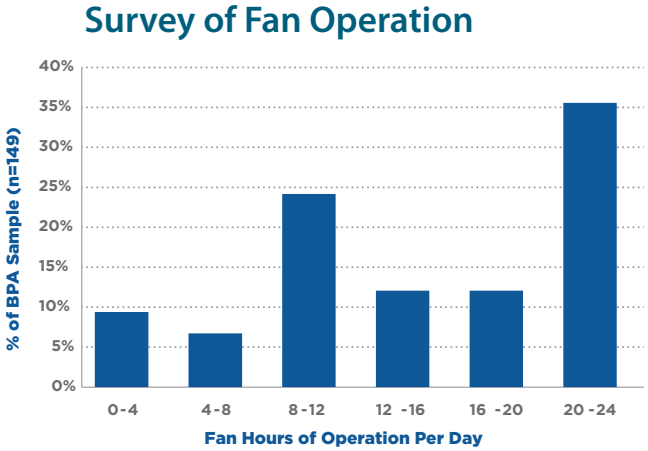
An analysis of 26 RTUs showed that those with 410-A refrigerant have a slightly larger efficiency decrease when temperature is increased when compared to units with R-22.

Anecdotal evidence, as well as field research from the mid-1990s, suggest that a significant fraction of RTUs operated with the fan cycling with the compressor (or furnace), similar to most residential systems. Whether or not the fan is cycling with the compressor is a very important consideration with respect to the energy

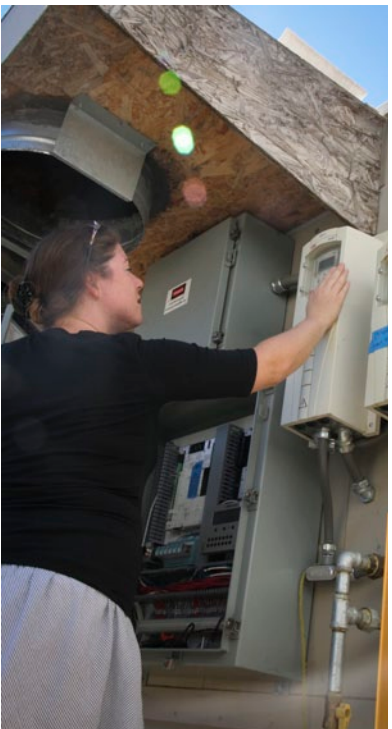


savings to be expected from a fan retrofit program for existing RTUs, impacting the savings by as much as a factor of three. Something that can be even more problematic would be a utility program that winds up actually increasing electricity consumption by turning a cycling fan into a continuous-operation fan in order to assure ventilation-code compliance.

An analysis of a survey of 149 RTUs in the Pacific Northwest completed by Bonneville Power Authority (BPA) determined that 35% of RTUs have the fan running 24hrs/day. A significant portion (25%) run 8-12 hours/day, which is consistent with the expected number of occupied hours for a commercial building. WCEC and subcontractor Davis Energy Group are currently surveying 200 RTUs in California to determine the percentage of fans that are run continuously. Data is expected to be available in Fall 2012. The resulting data set will be combined with existing data to estimate the energy savings potential from fan retrofits (such as high efficiency motors and fan speed control).



Survey of Fan Operation of 149 RTUs in Pacific Northwest



Our Latest Projects & Updates

*(Only a partial list of projects currently being researched. Check **wcec.ucdavis.edu** for more information on other concurrent projects)*

Western Cooling Challenge Update

The Trane Voyager DC was laboratory tested at Intertek Labs by the UC Davis Western Cooling Efficiency Center, and has been certified to pass the rigorous Western Cooling Challenge performance requirements. Trane is now the second manufacturer to achieve UC Davis' Challenge certification, an effort sponsored by Southern California Edison, California Energy Commission and Pacific Gas & Electric. Read More »

Commercial Controls Research

WCEC will research and model different advanced HVAC controls kits available in the market (Catalyst, Enerfit, DigiRTU, JADE, etc.) and smart thermostats (Nest, EcoBee, Honeywell Prestige, etc.). The WCEC will work to create simple models that can predict the performance of these types of systems and correlate simulation results with laboratory and field tests.

Internally, WCEC's modeling goals will help expand the analysis for the Multi-Tenant Light Commercial Project and the RTU Retrofit Initiative. Externally, WCEC's modeling may provide vital data to Utilities for Demand Side Management program decisions, ultimately leading to rebates for those systems that provide true energy efficient value and increased market penetration for this market segment. In addition, several of these control devices and packages may be evaluated for their human-device interactions and how human behavior affects their effectiveness.

Aerosol Sealing of Building Envelopes

This quarter a Master's student at the WCEC completed a thesis on CFD simulations of aerosol sealant deposition in a duct to predict sealing efficiency. The aim of the CFD simulation was to provide greater resolution of information on the deposition mechanisms. Using CFD, the investigation focused on the change over

time in the deposition locations, rates and efficiency as well as changes to the flow as the leak is sealed. Additionally, the use of numerical methods provides the opportunity to investigate the relationship between particle diameter, streamline characteristics and deposition. Since the generation of a mono-disperse aerosol is not feasible these relationships are unclear in experimental data. Using numerical methods a single particle can be traced from its point of injection, through the flow and to the location of deposition (if the particle deposits). By specifying the diameter and injection point of each particle and determining if and where they deposit the relationships between these three parameters can be determined. This research is a prelude to further modeling of particle transport in larger buildings to improve injection methods for sealing building envelopes.

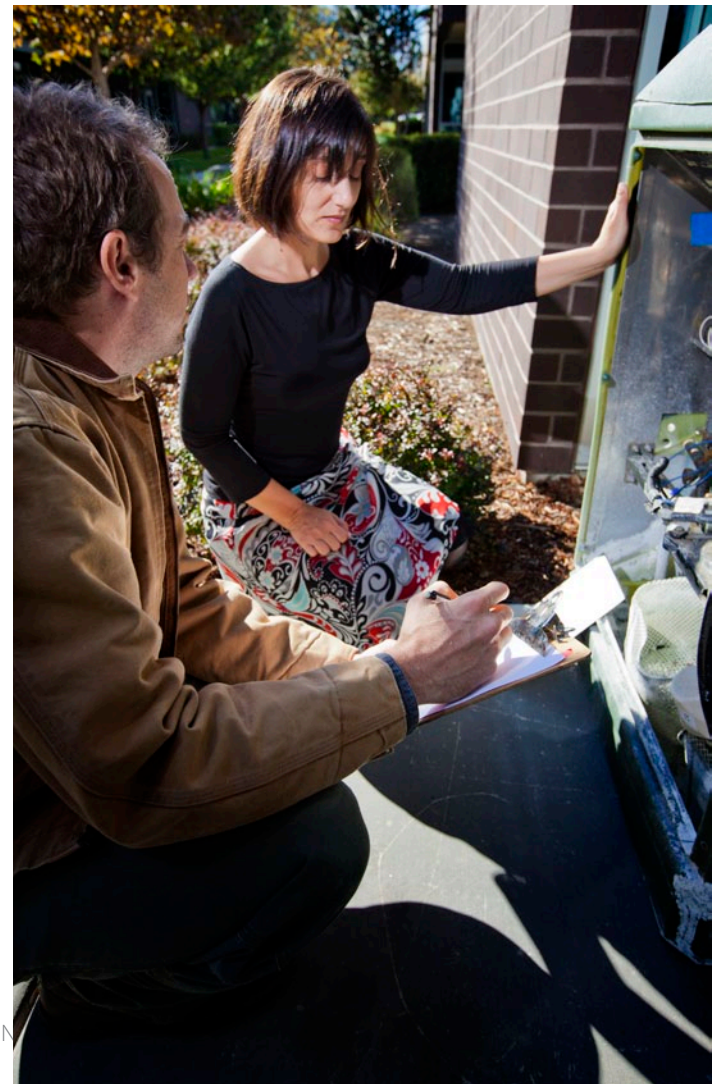
The next quarter will focus on developing the injection system used to seal building shells. Airless nozzle types are being investigated to reduce the equipment needed to install the aerosol and allow for multiple injection points. In addition to designing an injection system, WCEC will be working with Tremco to test alternative sealant materials. The desired material will be atomizable, dry non-tacky, pass the appropriate building codes, and have good cohesion and adhesion. Small scale testing of both the injection system and new sealants in the WCEC lab have already begun and show promising results on both the new injection system and the new sealant's effectiveness. WCEC will look at sealant use efficiency and sealing rate in the coming months.

Behavioral Research Update

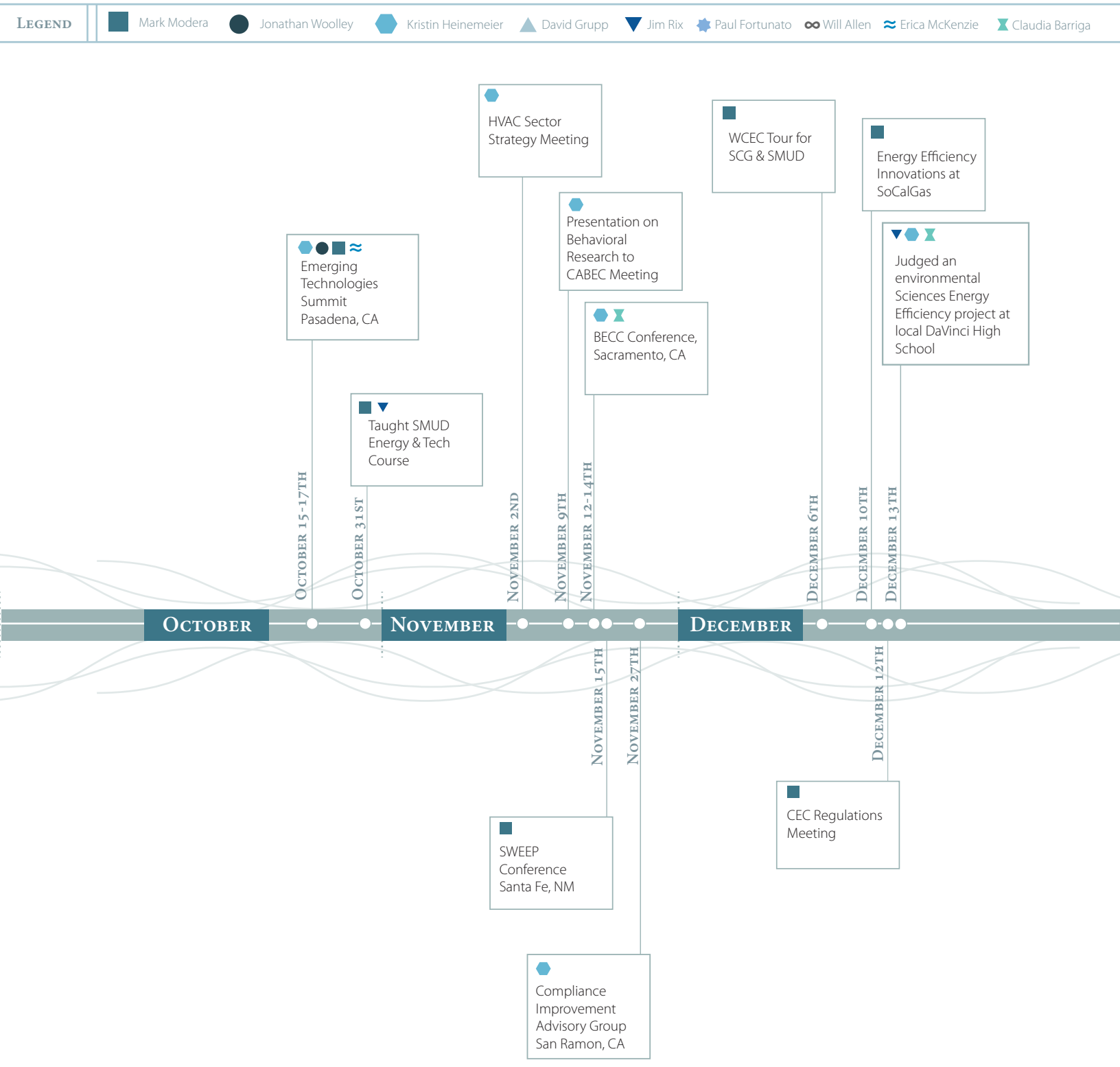
During this quarter, we have worked on creating the database of existing researchers and research on HVAC and social behavior. One tentative conclusion of this work is that, so far, research in HVAC and Behavior has advanced significantly on some target areas, while other important areas remain under-researched. There is a core set of academic, consulting and industry researchers active in the area of thermostat usage, advanced thermostat usability, and efficiency and energy saving potentials of advanced/learning thermostats.

It has been significantly more difficult to identify research agendas around the areas of contractor, technician and manufacturer behavior, although field research in new HVAC technology implementation (in particular its failures) sometimes call for attention to this area. Other than through utility program evaluations, this area, which may be vital to appropriate selection, installation, maintenance, and retrofitting of cooling systems, remains under-researched in the energy efficiency and behavior sectors. Research regarding behavior, energy efficiency and cooling is centered on the interaction of users and thermostats, and only marginally interested in interactions between users and cooling equipment, or users and cooling "professionals".

The WCEC Behavior Research initiative has conducted two studies in this under-developed area, all of which detected relevant obstacles to the promotion and effective deployment of energy efficiency programs related to cooling. The "Technician Observation Study" found that HVAC maintenance technicians are unlikely to promote energy efficiency measure to customers or to conduct HVAC maintenance up to industry standards. Technicians appear to have the necessary training to do so, but constraints set by the industry structure and perceived customer priorities get in the way. Our "Understanding Maintenance Behavior Study" found that although residential end highly value their air conditioner, they perceive it as a durable, low-tech, low-maintenance technology. These perceptions are a barrier for the promotion of high-quality efficiency oriented maintenance services, retrofits or replacements, and they show that attitudes towards the equipment can be as relevant to energy efficiency solutions as attitudes towards interfaces (such as the thermostat). The "Understanding Maintenance Behavior Study" also identified problems in the implementation of utility incentive programs for maintenance. Small business owners consider program implementation too cumbersome, and program incentives too low, to be worth their involvement.



WCEC NOTABLE OUTREACH EVENTS TIMELINE



WCEC NOTABLE VISITORS TIMELINE