OUR RESEARCH THIS YEAR IS FILLED WITH...

...DISCOVERY

Welcome to the Western Cooling Efficiency Center's Year-In-Review for the 2012-2013 year. Inside these pages you will find updates on a variety of HVAC-related technology, policy, and behavioral research. Fueled by California's ambitious goal of Zero Net Energy, WCEC progressed rapidly to become one of the world's premiere HVAC research centers.

With the support of our partners and sponsors, WCEC works holistically to solve our energy problems: from tackling the technical and political complexities of under-served markets such as mixed-use light commercial; innovating on new technology that can seal building envelopes automatically; and writing policy that will advance energy efficiency.

As part of the University of California Davis, WCEC has access to a diverse set of resources spanning multiple disciplines that only a world-class university can provide. Together, with UC Davis' College of Engineering and the Energy Efficiency Center, WCEC is advancing the HVAC industry, progressing towards California's energy goals and opening minds to discover what is truly possible in HVAC energy efficiency.

NASIM TAJMAND, PREPARES WATER EXPERIMENTS AT A HOME IN DAVIS, CA

RAINWATER RECLAMATION: MAKING EVAPORATIVE COOLING MORE SUSTAINABLE

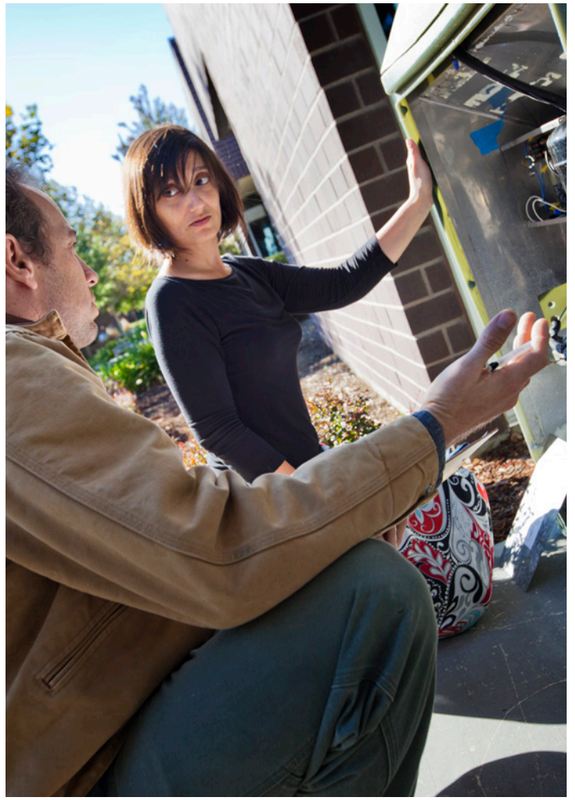
It's clear that evaporative cooling is effective for boosting energy efficiency, but what about evaporative cooling in arid climates where water is less abundant? Is there a practical way to also meet demanding water conservation needs? The answer is yes, through rainwater harvesting. Storing and using rainwater not only provides an alternative residential water source, it also aides in the management of urban residential storm water runoff. So, why is the WCEC still testing the efficacy of rainwater use? The success of rainwater reclamation for evaporative cooling systems must be able to address mineral content, corrosiveness, and potential microbial contamination concerns.

Mineral content increases scale formation and shortens the life of an evaporative cooling system, while also reducing its efficiency. Early testing, however, shows the concentration of mineral content in rainwater is significantly less than that of municipal tap water and meets the non-potable water quality guidelines for microbial contamination developed by the US Environmental Protection Agency (US EPA).

Testing is underway to determine the potential corrosiveness of reclaimed rainwater versus tap water. If final results are positive, rainwater harvesting promises not only a more sustainable solution, but also reduced consumption of water, electricity, chemicals, and water treatment needs (such as water softening).

CURRENT OBJECTIVES

- Characterize the chemical, physical, and microbiological composition of harvested and stored (long term) rainwater for use in evaporative cooling systems
- Conduct an experimental investigation of rainwater usage in an evaporative cooling system to determine bleed water requirements that minimize scaling and corrosion
- Identify operational strategies to minimize the use of bleed water and reduce the water consumption of the evaporative cooling system



BEHAVIORAL FACTORS IN HVAC EFFICIENCY

TRACKING DEVICE WITH THE ENCOURAGING FEEDBACK MESSAGE "KEEP IT GOING!" FOR THE ACTION OF TURNING OFF THE PC AT NIGHT.

Technologies are only as effective as the people interacting with them. By understanding the behavioral factors in HVAC, we can design better systems and buildings, and find ways to influence performance-defining behaviors.

WCEC has assembled a team of behavioral and social scientists to support the HVAC Behavioral Research Initiative (HBRI). The goal of the HBRI team is to understand the relationship between our perceptions and behavior with regards to HVAC and to promote potential solutions that may help influence people to act more energy conscious. The team is also undertaking several discrete research projects that shed light on human behavior related to HVAC systems and how it can be influenced.

PATH FORWARD

Results in our research have shown that commitments of people to engage in temporary energy saving actions were successful in creating awareness and desired behavior changes. This also produced motivation to persist in energy saving behaviors in the long term. With that in mind, WCEC will be publishing research from these 4 projects in the coming months, and exploring new potential research opportunities in this field.

CURRENT PROJECTS

WCEC is in various stages of completion for 4 different behavioral research projects, including:

- **Usability of In-Home Energy Displays:** Assessing the impact of user interfaces on energy savings behavior
- **Behavioral Intervention at UC Davis:** Using 'tiny steps' behavior ideas in everyday HVAC energy use
- **Technician Observation Study:** Determining the human factors in HVAC maintenance
- **Advanced System Controls Behavioral Research:** Assessing the everyday usage efficacy of advanced thermostats

WESTERN COOLING CHALLENGE

JONATHAN WOOLLEY, WCEC ENGINEER, SPEAKING AT PG&E'S LAB ABOUT THE WESTERN COOLING CHALLENGE'S NEW ENTRANT, THE MUNTERS EPX 5000

Most HVAC systems are designed as a one-stop solution to heat and cool in any climate region. Though these units can be efficient, they cannot hope to achieve the larger efficiency gains available through a more focused design strategy. Tailoring equipment design to a specific climate type allows manufacturers the ability to optimize their technologies to operate more efficiently in that particular climate. More specifically, in hot and dry climate zones, the use of evaporative technologies to cool or pre-cool air can have a significant impact on energy savings.

The Western Cooling Challenge is a multiple winner competition that encourages HVAC manufacturers to develop climate-appropriate rooftop packaged air conditioning equipment that will reduce electrical demand and energy use in Western climates by at least 40% compared to current federal standards. WCEC's ultimate goal with the Challenge is to create a consistent, reliable benchmark for new climate-appropriate technologies that will inform building owners, policy makers and utilities. The Challenge is also a platform to work with manufacturers to advance the application of these climate-appropriate technologies and advocate for them.

MONITORING OF THE SEELEY CLIMATE WIZARD INDIRECT EVAPORATIVE ADD-ON RETROFIT

PATH FORWARD

- Analyze data from 4 Trane® Voyager DC units at various locations in California and 11 DualCool™ retrofits at Target
- Collect data on 3 Seeley Climate Wizard and 3 Coolerado M50 Indirect Evaporative add-on units in California
- Collect and analyze data on the Munters® EPX 5000 at the City of Temecula Civic Center and in the laboratory

CURRENT FINDINGS

- WCC Certified equipment is **over 40% more efficient** than current standard units
- Trane Voyager DC™ met the challenge requirements, becoming the first WCC-certified product from a major manufacturer
- Initial data on the Munters® EPX 5000 shows a reduction in **whole building HVAC peak electrical demand by more than 20%**
- Monitoring and evaluating 3 Seeley Climate Wizard and 3 Coolerado M50 Indirect Evaporative Coolers in California

Climate-appropriate air conditioning systems capture substantial energy savings at peak

CATON MANDE, WCEC ENGINEER, INSTALLING MONITORING EQUIPMENT ONTO THE COOLERADO M50 INDIRECT EVAPORATIVE ADD-ON RETROFIT

TECHNOLOGY DEMONSTRATIONS

WCEC's demonstration efforts highlight some of the most appropriate HVAC technologies, and provide a reliable, unbiased perspective on the market readiness, cost effectiveness, and project-by-project appropriateness for various technologies. The Technologies Demonstrations program is a catalyst for creating best practices that will inform and guide policy decisions that ultimately impact the broader energy efficiency marketplace.

This work, to design and facilitate the market adoption of energy-efficient technologies in lighting and HVAC, relies heavily on the continued support from our partners: SPEED (the State Partnership for Energy Efficient Demonstrations), CEC (California Energy Commission) and CIEE (California Institute for Energy and the Environment). Our demonstration activities are public-private collaborations that foster the deployment of advanced technologies, with special focus on implementing energy efficiency strategies in coordination with facilities managers and planners at large public institutions such as the University of California, the California State University, the Department of General Services, and local municipalities.

60%

Fan power savings

DEMAND CONTROL KITCHEN VENTILATION RESEARCH COMPILATION

By sensing when kitchen cook surfaces are being used and adjusting the exhaust ventilation to match, energy expended by kitchen fume hoods can be reduced significantly. Fan energy savings on the order of 60% are typical, and additional savings are realized when the energy to condition the air is taken into account.

22%

Reduction in cooling energy consumption

EVAPORCOOL RTU RETROFIT AT BEALE AIRFORCE BASE

Evaluation of the EvaporCool™ pre-cooler took place at Beale Air Force Base on a 50-ton chiller. Initial results showed a 22% reduction in energy consumption over the standard chiller without the pre-cooler.

The Technologies Demonstrations program is a catalyst for creating best practices

50 CFM per inch

Potential savings from over-ventilation in a sash-dominant space

SHUT-THE-SASH: FUME HOOD VENTILATION IN LABORATORIES

The SPEED program, in partnership with the Alliance to Save Energy (ASE) and Lawrence Berkeley National Laboratory (LBNL) is concluding an in-depth study of energy consumption of fume hoods and the effectiveness of "Shut-the-Sash" campaigns on University campuses. The goals of the study are to determine the typical configuration of California University laboratories, to estimate the amount of energy that can be saved with ideal sash management, and to understand which factors make the Shut-the-Sash campaign effective.

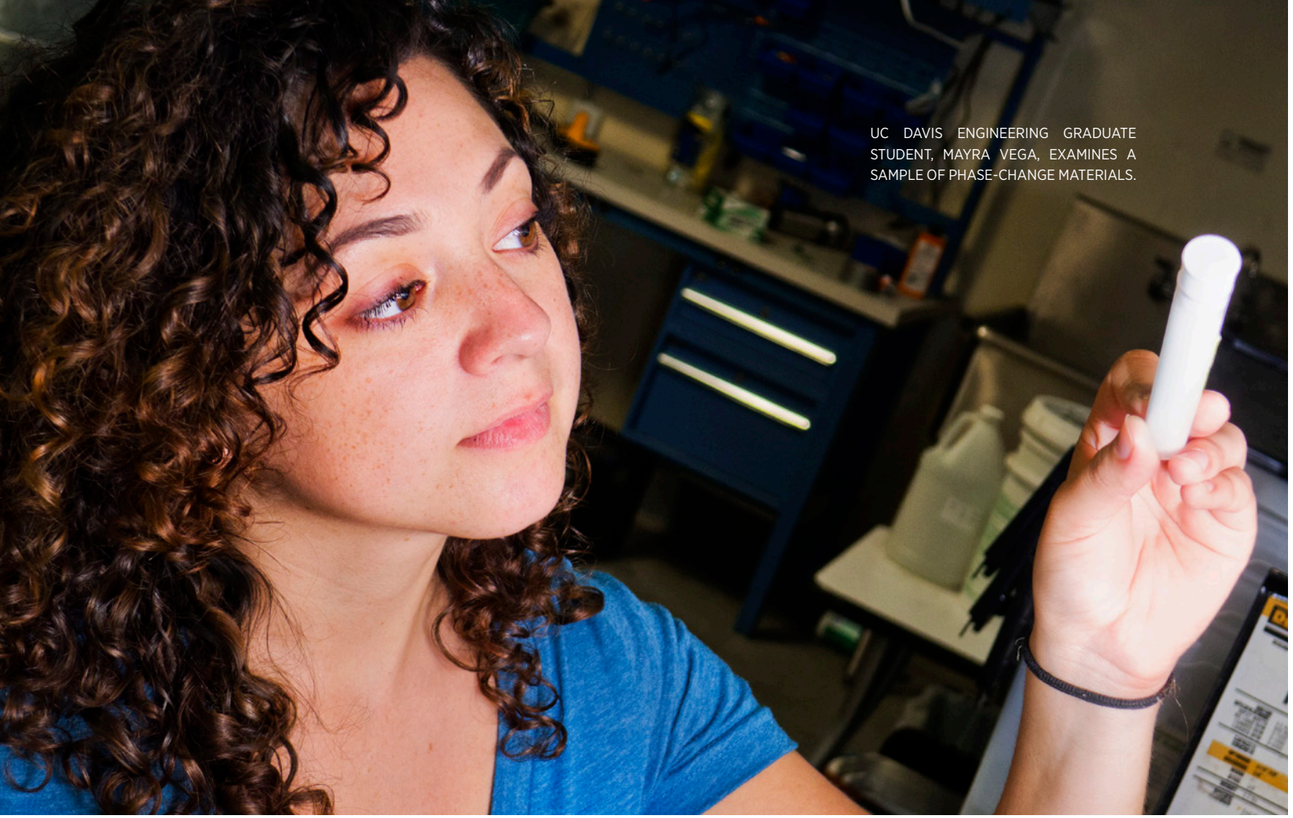
ROOFTOP SOLAR ARRAY AT THE GRADUATE SCHOOL OF MANAGEMENT BUILDING IN DAVIS, CALIFORNIA

60%

More efficient than buildings in its class

GALLAGHER HALL LEED PLATINUM TECHNOLOGY STUDY

Davis' Gallagher Hall houses the Graduate School of Management. This 89,000 SF building has earned a LEED Platinum rating and stands out on campus as an example of smart building design. Innovative engineering including radiant heating and cooling, a dedicated outside air system, and solar management make this building roughly 60% more efficient than similar buildings in its class. WCEC is performing an in-depth analysis of the building's energy flow and evaluating the unique technologies this building utilizes.



UC DAVIS ENGINEERING GRADUATE STUDENT, MAYRA VEGA, EXAMINES A SAMPLE OF PHASE-CHANGE MATERIALS.

PHASE CHANGE MATERIALS FOR HYDRONIC SYSTEMS

CURRENT FINDINGS

- Microencapsulated paraffin is thermally stable for this application – the particles show no loss of thermal capacity or increase in supercooling after many hundreds of cycles
- Repeated cycling through a centrifugal pump in a closed loop suggests smaller capsules are less susceptible to damage, with capsules below 10-microns in diameter appearing to survive unscathed

Water is a common, and generally efficient, means for thermal distribution around buildings. This is accomplished by heating or cooling the water to a temperature above or below room conditions and pumping it to fan coils or radiant panels. However, transporting thermal energy by means of a material that changes phase (freezing/melting or condensing/boiling) allows much more energy to be transported by the same amount of material. This is because it takes a lot of energy to change phase. Some modern air conditioning systems do this by circulating refrigerants instead of water. However, a conventional water distribution system can be made to act like a refrigerant-transport system by adding encapsulated balls of Phase Change Material (PCM). By pumping a slurry of water and encapsulated PCM instead of just water, the dramatic increase in heat carrying capacity means that far less of the slurry needs to be pumped to meet demand compared to a traditional water system.

PATH FORWARD

In the coming months we will further study the effects of capsule size on breakage rates by performing a closed loop pumping test on smaller capsules. We will also study the heat transfer properties of PCM slurries in a hydronic system we have built in our laboratory, and will field test the PCM slurry in a building located at UC Davis.

The unique characteristics of multi-family buildings are either unaddressed or forced to adhere to guidelines developed for entirely different purposes

MULTI-FAMILY VENTILATION

Multi-Family buildings are a unique class of structure with specialized design demands and distinctive energy use profiles. The WCEC's Multi-Family Ventilation project, which is part of a larger PIER funded project addressing several code relevant measures specific to multi-family buildings, intends to investigate and identify the unique ventilation challenges encountered in multi-family buildings. Ultimately, the Multi-Family Ventilation project will recommend changes to California building codes to improve performance and reduce energy use in multi-family buildings, while also simplifying existing building codes.

PATH FORWARD

WCEC will test proposed recommendations through a variety of models and simulation scenarios. We are also working with building owners to conduct a field study to demonstrate alternative approaches to improving the performance of central shaft ventilation systems.

CURRENT FINDINGS

- Two seemingly arbitrary sets of ventilation code requirements differentiate ventilation for essentially the same buildings. This leads to excess ventilation and energy waste
- WCEC is working to consolidate code requirements based on empirical evidence
- WCEC has identified specific modifications to code requirements for envelope tightening, duct leakage and proper balancing

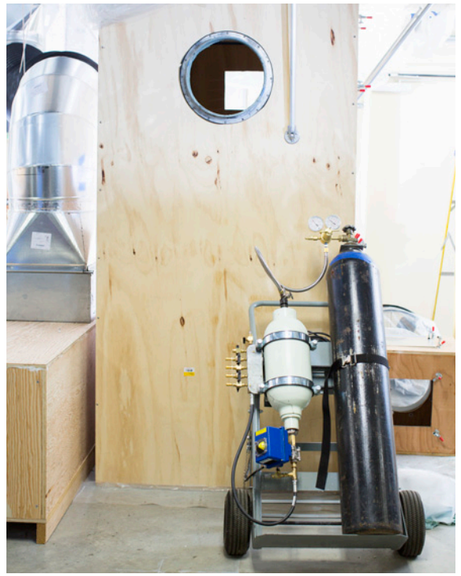
AEROSOLIZED SEALANT FOR BUILDING ENVELOPES

Building envelope leaks are a significant factor in energy consumption, accounting for over 30% of the total energy used for HVAC. Sealing buildings by means of aerosolized sealant particles is a promising technology, providing a comprehensive solution that can dramatically reduce the total leakage in buildings.

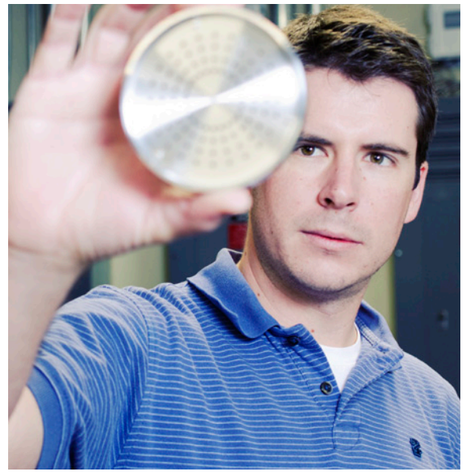
Sealing building envelopes saves energy by eliminating infiltration of unwanted, unconditioned air, reduces the loss of conditioned air and reduces the demand for cooling and heating. Existing envelope sealing practices require many contractor hours, manually sealing leaks with no guarantee that the majority of leaks have been found or sealed. Sealing building envelopes with aerosol particles eliminates the guess-work—sealing leaks a person is unlikely to notice—all while providing instantaneous feedback and verified results.

PATH FORWARD

After our current round of laboratory testing to determine proper nozzle and sealant efficacy, WCEC will begin field trials in up to 10 single-family homes with Build America. We will also conduct field trials in multi-family units in the coming year. These field trials will be used to create proper installation and procedure protocols that will guide and standardize the use of this technology by outside contractors. As this technology moves into production scale, these protocols will ensure that the technology being deployed will be consistent in quality, economically viable, and time efficient.



WCEC ENGINEERS IN THE FIELD AT VARIOUS STAGES OF AEROSOL RESEARCH



CURRENT FINDINGS

- Successfully **sealed over 50% of available leaks** in 7 different residential buildings at various stages of construction
- Tested a variety of different sealant mixtures to balance tackiness, clogging and ease of cleaning
- Worked with nozzle manufacturers to develop more practical nozzle designs
- Developed new injector system that is more economical, completely modular and will hold enough sealant to complete a job without being refilled

GREY SEAL FROM THE AEROSOLIZED SEALANT AT AN APARTMENT IN DAVIS, CA

Automating the process of sealing leaks in buildings can save over 30% on the total energy used for HVAC.

ROOFTOP UNIT (RTU) RETROFITS

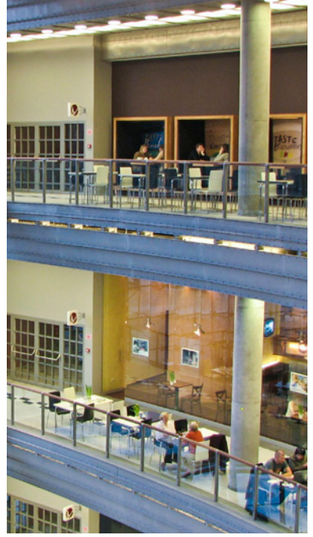
Replacement opportunities for RTUs are few and far between; retrofitting existing RTUs with energy efficient parts and technologies that are affordable could be an appealing proposition to building owners and facilities managers. RTU retrofits can provide significant energy savings—between 20-50%—and many evaporative options work even more efficiently in the hottest conditions, thereby reducing peak electricity demand. The WCEC is:

- Working with ASHRAE to develop a standard protocol to properly benchmark, test and evaluate the performance of retrofit evaporative pre-coolers
- Testing various RTU Retrofits in WCEC's new laboratory utilizing standards set by WCEC and ASHRAE
- Retrofits under review include Evaporative Pre-Coolers, High Efficiency and Variable-Speed Motors, Controls and Monitoring products

OCCUPANCY SENSING THERMOSTATS

Occupancy sensing thermostats have the capability to adjust temperature set-points or ventilation system operation when a space is vacant. Adaptive control algorithms can use occupancy state, user feedback, and measured environmental variables to learn about use patterns, occupant comfort preferences, and system dynamics. This information can be used to adjust operating schedules, and to automate temperature settings during occupied and vacant states. These capabilities, coupled with network controlled, and internet-based user interfaces, promise a variety of energy efficiency opportunities while at the same time improving comfort and level of service.

- For the period of our study in Bixby Hall (UC Davis), fan coils (cooling) operated on average 25% of the time in occupied rooms, while fan coils in vacant rooms remained off near entirely.
- Further research aims to measure energy impacts during the heating season, and to better isolate the impact of the adaptive control algorithm from other thermostat features.



MULTI-TENANT LIGHT COMMERCIAL

WCEC is working to address the traditionally under-served market termed Multi-Tenant Light Commercial (MTLC). MTLC buildings are defined as having 2-25 small tenants in a building owned by a single landlord. Examples of MTLC buildings are strip malls, office parks and mixed use properties. Retrofitting these buildings represents a real challenge for several reasons. Low access to capital, principal-agent problems (the owner typically does not pay the utility bills) , short-term leases, and a large variety of end-use types are some of the barriers identified for this market.

- **DATA COLLECTION:** WCEC collected field data on MTLC buildings that include physical characteristics of the buildings, technology currently installed and energy use via energy audits in more than 50 buildings.
- **TECHNOLOGY SELECTION:** Currently modeling the interaction of diverse lighting and HVAC technologies with the goal of creating reliable, economically viable, energy efficient turn-key packages for the MTLC market.

FAULT DETECTION & DIAGNOSTICS

Many faults with Roof-Top air conditioners (RTUs) go unnoticed because of their rarely-visible location on the roof. Often these units will continue working even though they have mechanical problems; but their effectiveness, particularly their efficiency, can be greatly diminished if left unchecked. Fault Detection and Diagnostics (FDD) are tools that can increase the lifespan and efficiency of these systems by notifying facilities managers or building owners remotely if a fault is present, such as a malfunctioning economizer or improper refrigerant charge.

- WCEC's research helped change California's Title 24 Energy Code to now require some form of FDD implementation in all new RTUs effective January 1st, 2014. As newer units replace older ones, the energy savings due to mandatory FDD will have a significant impact on energy use in the coming years.

HVAC TECHNICIAN INSTRUMENT LAB

The HVAC Technician Instrument Lab (HTIL) project posits the question: What if HVAC technicians misdiagnose or overlook certain faults (especially improper refrigerant charge) because their HVAC measurement tools or procedures may not be accurate? Simply knowing there is a problem, but not being able to accurately diagnose or treat it, can lead to decreased efficiency and longevity in HVAC equipment and can have a negative impact on customer trust in the HVAC contractor industry.

The HTIL laboratory apparatus allows WCEC to test a variety of these HVAC tools to determine if they are properly diagnosing faults such as improper refrigerant charge. Another portion of this research includes the human behavioral aspect of HVAC diagnosis, and will study the common procedures of many different contractors so as to determine the efficacy of their training.

WCEC also mentored students from the College of Engineering at UC Davis on the development of a more effective temperature sensor tool for technician field work.

MODELING INDIRECT EVAPORATIVE COOLERS

The core technology for Indirect Evaporative Cooling (IEC), the heat exchanger, is the most critical component in advanced IEC or hybrid IEC/DX systems. Because these systems offer various configurations, and their performance is heavily dependent on operating conditions and the climate, a practical, accurate IEC heat exchanger model is needed for building simulations to properly characterize these technologies.

- WCEC will continue to refine the model and carry out further experimental work on heat exchanger performance, e.g. the effect of pin size and spacing on heat transfer and pressure losses.

Thank you to our Affiliates & Partners

Airmax®
American Honda Motor Co, Inc.®
Belimo®
Beutler Corporation®
California Energy Commission
Carrier Corporation®
Coolerado®
Daikin Industries, Ltd.®
Davis Energy Group®
E-Source
Evaporcool®
Integrated Comfort, Inc.®
Los Angeles Department of Water & Power
Munters® Corporation®
NV Energy
Pacific Gas and Electric Company®
Sacramento Municipal Utilities District
Seeley International Pty. Ltd.®
Sempra Energy® Utilities
Sheet Metal Workers International Assoc.
Southern California Gas Company®
Southern California Edison®
Tokyo Gas
Walmart®
Wells Fargo
Xcel Energy®