RTU EFFICIENCY OPTIMIZERS

California State University Long Beach and San Diego State University

CATALYST RTU Efficiency Optimizer installed at San Diego State University's Aztec Aquaplex in San Diego, California

COOLING ENERGY & CO_2 SAVINGS
24-56%

ENERGY REDUCTION
365 kWh/yr-ton

PROBLEM

Packaged cooling equipment also known as Rooftop Units (RTUs) are used in 46% of all commercial buildings, and serves approximately 69% of the commercial building cooled floor space in the U.S. The ubiquitous use of these pieces of equipment is due to the ease by which they can be designed into a building, low capital cost, and a modular nature that allows for easy demarcation of energy billing and maintenance responsibility between multiple tenants of a single building. However, RTUs are notoriously inefficient because they're often oversized, improperly installed, and inadequately maintained. In addition, even though the technology for improving RTU energy efficiency is well understood, the forces driving design tend to favor low first costs and ease of installation rather than energy efficiency and robust design.

SOLUTION

Several new retrofit controllers are now available for single-zone rooftop-unit (RTU) air conditioners that take advantage of energy saving techniques not previously economically possible. These retrofits work by replacing the simplistic stock control unit with new digital controls, new sensors, and often upgrade the single speed supply fan motor to take advantage of variable frequency drive (VFD) motor controllers. The controllers make use of multiple energy saving techniques and will often reduce supply airflow to better match partial building loads, more carefully control outside air ventilation to the minimum amount necessary to maintain indoor air quality, implement advanced economizer controls eliminating the need to operate the compressor when advantageous ambient conditions prevail, and also implement continuous monitoring and failure detection and diagnostics (FDD) to notify the user when the RTU needs maintenance.

ENERGY SAVINGS

In order to maintain acceptable indoor air quality packaged units are often operated continuously regardless of whether heating or cooling is required. Forcing air through ductwork can be a highly energy intensive task. For air flowing in unrestricted ducts, energy use increases as the cube of airflow increase. This means that for every doubling of airflow volume, energy consumption will increase by a factor of 8. Likewise a reduction of airflow by ½ will yield a corresponding reduction in energy consumption to 1/8 of the previous amount. Anything that can be done to reduce the amount of air supplied to a space, or to reduce the rate at which it is supplied, can have enormous energy savings effects.

On all but the most demanding days, an air conditioner will have much more capacity than needed to match the building load. Traditional controllers will operate the packaged unit supply fan at full airflow and conditioning capacity until space temperature is met, and then remain operating at full airflow capacity to maintain required ventilation without conditioning the outside air. Once the indoor space temperature drifts from set point, conditioning will resume. With this simple control the package unit is always operating its supply fan at full speed and always bringing in a fixed amount of outside ventilation air regardless of need. In contrast, the retrofit controller will slow the supply fan and circulate only the amount of air necessary to maintain space temperature. This can yield significant savings during part load operation.

A second energy savings technique, known as demand control ventilation (DCV) reduces the amount of outside air that is introduced into a space by modulating the outdoor-air damper to deliver only the amount of outdoor air necessary to maintain indoor air quality. This is accomplished by taking CO2 measurements of the return air stream and maintaining space CO2 below a certain threshold. This control minimizes the amount of unconditioned outdoor air that needs to be conditioned, further saving heating and cooling energy.

Improved economizer operation is another technique that contributes to energy savings. Economizers are simple dampers on package units that will allow outdoor air to be directly fed to indoor space for cooling when the ambient temperatures are favorable. Most economizers are factory set to perform this switch over at 55F. Additional sensors can be employed to perform this switchover whenever the outside air is cooler than the return air. Furthermore, the use of temperature and humidity sensors coupled with advanced logic can be used to perform this switch over based on air enthalpy rather than merely just dry bulb temperature.

Finally, improvements in monitoring and analysis of historical performance and energy consumption can allow for failures to be detected and repaired in a timely manner. Instead of catastrophically failing to deliver occupant comfort, air conditioning equipment tends to slowly and over a long period of time increase its energy consumption. Monitoring and diagnostics allows for the unit to trend energy consumption over long periods of time and indicate to facilities personnel when the unit is operating at decreased efficiency. More advanced systems may even be able to recommend specific maintenance actions to be performed.

INSTALLATION

The installation of the retrofit controller is straightforward and can be completed by two trained HVAC technicians in less than four hours. The basic steps to the installation are to install a supply fan VFD motor controller in the supply cabinet, install the RTU controller in a weather-proof enclosure, install temperature and humidity sensors, and also take control of existing outside-air / economizer damper actuators. After the new controls are installed, the unit is calibrated and tested. In this process none of the factory equipment protection features are overridden and the package unit continues to interface with the building through the same thermostat control wiring that existed before, no new thermostat controller is required.

CASE STUDIES

The SPEED program conducted two field studies incorporating the Transformative Wave Technologies CATALYST RTU Efficiency Optimizer product in the summer and fall of 2013. As described above, all new retrofit controllers rely on modulating supply air flow to reduce energy consumption. The CATALYST does this by indexing the fan to one of three speeds (40, 75, or 90 percent of full speed), based on whether the RTU is in ventilation or stage 1 or 2 cooling mode. The CATALYST controller also incorporates demand control ventilation based on CO2 sensor feedback, advanced differential economizer control, and monitoring and failure diagnostics through its web-enabled eIQ Platform.

DEMONSTRATION RESULTS

CSU LONG BEACH, DANCE COMPLEX

Climate Zone	System Size	Heating	Savings
6	10-ton	Natural Gas	51%

CSULB's unique Dance Center, completed in 1994, provides 93,000 square-feet of studio space, a 250-seat theater, a Dance Therapy Clinic and a Dance Notation Computer Lab. A Trane 10 ton RTU with gas heating serves the second floor dance clinic, and studio/classroom.

Being an educational dance studio, the space served experiences large swings in occupancy, and intermittent heavy physical exertion by the sometimes large number of occupants. The unit is scheduled to operate between the hours of 5:00AM and 8:00PM Mondays – Friday, 6:00AM – 5:00PM Saturdays, and 8:00AM – 5:00PM on Sundays.

The CATALYST controller at CSU LB showed excellent energy savings with consistent 30%- 70% savings throughout the 6 months of observation. Savings seemed to increase as the season moved into winter. Optimal use of the economizer is one of the features of the retrofit controller, and this may explain this behavior.

SAN DIEGO STATE UNIVERSITY, AZTEC AQUAPLEX

Climate Zone	System Size	Heating	Savings
7	8-ton	Natural Gas	29%

Built in 2006, the Aztec Aquaplex is the second newest of the five recreational facilities in the complex. The facility has a lobby, two conference rooms, office space, restroom/shower facilities, laundry room and boiler and pump room. The total building footprint is 7,100 square feet (sqft).

Open to the public, the facility operates Monday through Thursday from 10:00 AM to 9:00 PM, Friday from 10:00 AM to 7:00 PM, and Saturday through Sunday from 10:00 AM to 6:00 PM. All HVAC systems are run during this period. The competition pool is regularly utilized by the SDSU swim team and dive team for practice and competitions before and after public operation hours.

Space heating and cooling for the lobby and office space is provided by an 8-ton, roof top, Carrier packaged system with an air-side economizer. Facility staff confirmed the economizer is currently not operable. The conference rooms are served by a 2-ton, Mitsubishi mini split heat pump system for cooling and heating. Preventative maintenance is provided by the AS Building Services staff. The facility does not have a building automation management system.

The CATALYST controller at SDSU saw more varied savings over the observation period. In the course of investigation, the SDSU unit was diagnosed with a malfunctioning outdoor air temperature sensor which

CSU LONG BEACH ENERGY SAVINGS

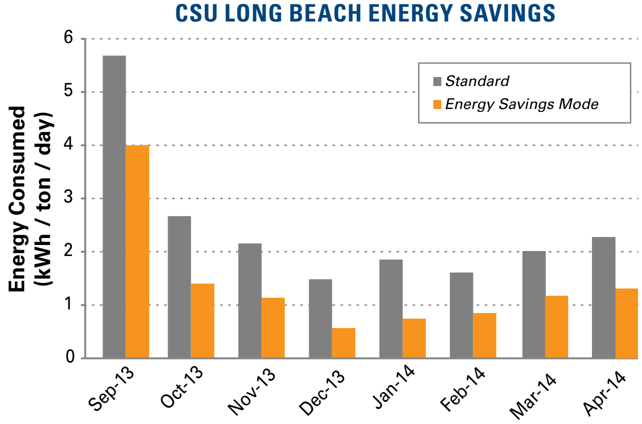

Figure 1: Energy savings from the CATALYST system in Energy Savings Mode compared to Standard Mode (Standard Mode shows similar performance before the CATALYST retrofit)

SAN DIEGO STATE ENERGY SAVINGS

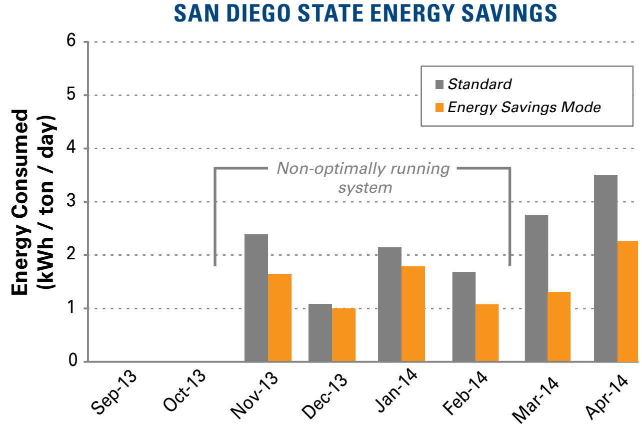

Figure 2: Energy savings from the CATALYST system in Energy Savings Mode compared to Standard Mode (Standard Mode shows similar performance before the CATALYST retrofit)

DEMONSTRATION RESULTS (CONTINUED)

caused the unit to perform less than optimally. The sensor problem was rectified in mid-February and subsequent savings results have more closely resembled the CSU LB results. Savings estimates are based on the months of operation after the sensor issue was resolved and are expected to be in line with the CSU LB savings.

CONCLUSION

Over the course of this study retrofit efficiency optimizers showed savings over multiple locations and during all observed months. These savings ranged from 24% - 56%. Figure 3 shows a breakdown of the energy consumption for the RTU at CSU LB in STD mode and CATALYST enabled ESM mode. The plot shows that the bulk of energy savings comes from more efficient use of the "Fan Only" mode, likely a direct benefit of the VFD installation and the lower fan speeds that this controller makes possible. While "S1" operation shows savings from operating in ESM mode, "S2" operation does not show any significant savings. This can be attributed to the fact that once an RTU is called into Stage 2 operation, it is most likely running at full capacity and there is less opportunity for energy savings.

Installations at these sites cost between $2,500 and $3,000 for the equipment and included the optional eIQ equipment and monitoring service package. A total of 10 man-hours was budgeted for labor, as 2 people working for 5 hours. It should be noted that a simultaneous effort to retrofit multiple units at once would have yielded lower installation costs.

Typically, in California, savings range from 40% to 65% with most of the savings being electrical, though some gas savings may be seen in cooler weather. Partnership savings that could be applied to the CSU LB project would be $1,700 based on performance to date. Using the installed system cost with incentive and taking into account the cost of energy, Figure 4 shows the estimated payback period for this technology. While the studies performed show a wide range in the potential energy savings, both show that implementing retrofit RTU optimizer controllers can result in significant energy savings.

ADDITIONAL RESOURCES

A recently released PNNL field study evaluated a total of 66

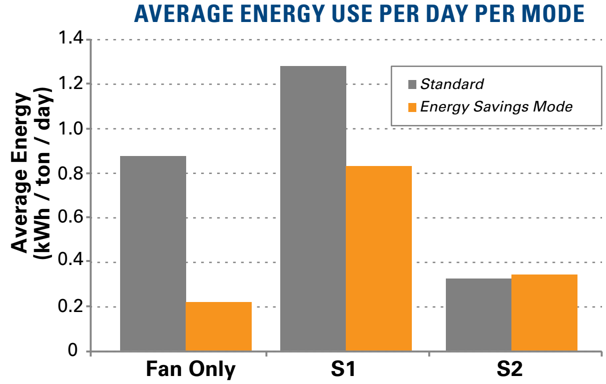

Figure 3: Energy consumption at CSU Long Beach in various modes of operation

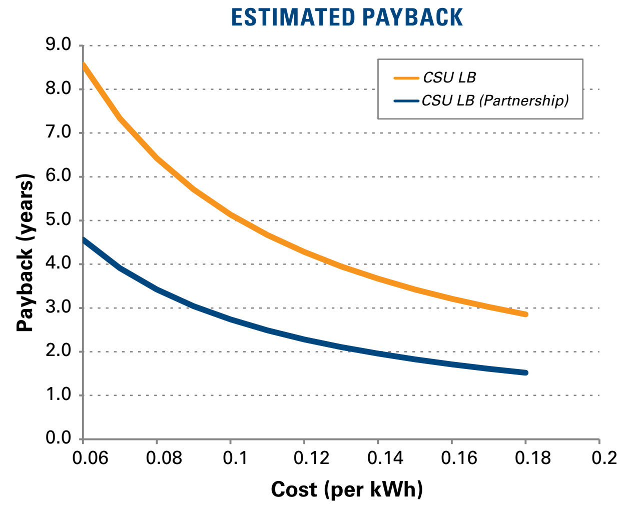

Figure 4: Estimated payback in years based on cost per kWh

RTUs on 8 different buildings retrofitted with the CATALYST advanced controller for improving RTU operational efficiency. The key findings of this report showed that the advanced controller reduced the normalized annual RTU energy consumption between 22% and 90%, with an average of 57% for all RTUs. It also found that for a utility electricity rate of $.10 / kWh average payback for the retrofit equipment and installation was 3 years.

Wang W, S Katipamula,H Ngo, R Underhill, D Taasevigen and R Lutes. 2013. Advanced Rooftop Control (ARC) Retrofit: Field-Test Results. PNNL-22656, Pacific Northwest National Laboratory for the U.S.

More information about the CATALYST system by Transformative Wave: http://transformativewave.com/

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.

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

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