Demonstration of Evaporative Pre-Cooling for Rooftop Air Conditioning Units

EPRI and the Tennessee Valley Authority (TVA) demonstrated three commercial technologies at four sites in Energy Efficiency Demonstration 2.0. One of the demonstrations was of an evaporative pre-cooling system for rooftop air conditioners at a facility in Mississippi. Energy Efficiency Demonstration 2.0 focused on commercial customer applications where significant energy savings could be achieved.

Background

Air conditioners (A/Cs) are a significant driver of utility load shapes in many parts of the United States during hot weather. Although there have been many efforts to decouple temperature and A/C power, few viable approaches have resulted. Applying evaporative pre-cooling to the A/C condenser is a potential method for improving A/C capacity and efficiency during hot weather.

Evaporative pre-cooling is most efficient with ambient conditions of high temperatures and low relative humidity. The benefit of evaporative cooling comes from reducing the effective temperature for the condenser (see Figure 1). Based on manufacturer data for typical packaged rooftop A/Cs, an outdoor temperature decrease from 95°F to 85°F would be expected to result in a 4–5% increase in cooling capacity along with a 9–10% reduction in compressor power. Increased capacity and decreased power combine for an overall efficiency improvement and potential peak demand reduction.

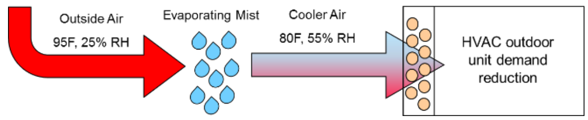

Figure 1. Illustrative example of evaporative pre-cooling for condenser air

Evaporative pre-cooling provides the greatest likelihood of energy savings in hot, dry climates such as the southwestern United States. The potential for savings may also exist in hot/humid climates.

Demonstration Overview

The primary goal of this demonstration was to evaluate whether evaporative pre-cooling systems could save energy and reduce demand in locations with a hot/humid climate. A secondary goal was to see how these systems would affect water consumption.

An evaporative pre-cooling system ("system") was installed in July 2014 on two 12.5-ton rooftop air conditioner units (RTUs) at a distribution facility in Mississippi. The two RTUs cool a small server room within the facility. The server room was selected because it has a year-round continuous cooling load that would allow cooling data to be collected throughout the year.

The system installed for this demonstration was a retrofit technology intended to add an evaporative pre-cooling function to an existing condenser. Magnets were used to attach frames to the outdoor unit, which houses spray nozzles and a removable mesh media to catch water. The outdoor air passes through the media and the moisture on the media is evaporated into the air approaching the condenser coil. The evaporation of the moisture cools the air, reducing the effective temperature to which the condenser coil is exposed. A control box metered water flow based on outdoor temperature and humidity. The installation also included pumps to increase water pressure. Figures 1 and 2 show the A/C units prior to and after installation.

Figure 2. A/C units prior to system installation

Figure 3. A/C units after system installation

EPRI installed data acquisition software to monitor the performance of the A/C units and the system. Data points included power and energy metering on both RTUs, ambient air temperature and humidity and local temperature measured behind the filter media for each evaporative pre-cooling unit. Water flow was also measured. Indoor temperature and relative humidity were measured with wireless sensors at two locations inside the server room and the data were transmitted to a central data acquisition hub on the roof. Data were recorded in one-minute intervals and transmitted to EPRI via cell modem.

Results

Data collection began in June 2014 with monitoring of the RTUs prior to installation of the system, which was installed in early July. Subsequent baseline logging periods (during which the system was shut down remotely but the hardware was left in place) were recorded from October 22, 2014 through May 29, 2015 and from August 28 through September 8, 2015. There was a period of downtime for on-site maintenance from July 7-29, 2015.

Data analyzed for a week of hot weather with the system operating showed that the temperature behind the evaporative pre-cooling media stayed significantly lower during hot outdoor hours. The data also indicated that the A/C units had significantly reduced power consumption during hot outdoor temperature periods.

Figure 3 shows the result of averaging performance across several similar weather days into a 24-hour, average hourly profile. On the left-hand side, baseline data from September 3–7, 2015 are shown; on the right-hand side, treatment data from July 31 through August 4, 2015 are shown. The relative humidity is also shown, and the power consumption of the two A/C units is combined and called total power. The temperature was slightly higher and the relative humidity slightly lower during the treatment days, but on average the baseline and treatment weather were very similar. The cooled air temperature behind the evaporative pre-cooling media was significantly cooler during the treatment: rather than closely following the mid-day outdoor temperature profile, the temperature stayed relatively flat at approximately 75–78°F during the daytime hours. The total power was also impacted: in the baseline case, the average power during the afternoon was in the range of 20 to 21 kW; in the treatment case, it stayed between 17 and 19 kW. The reduction was significant during the important late afternoon hours in which utilities often record peak energy use. For example, at 3:00 PM (15:00 hours), the power was 20.5 kW in the baseline case, and in the treatment case it was about 17.5 kW. This is a 3 kW (14.6%) reduction in power.

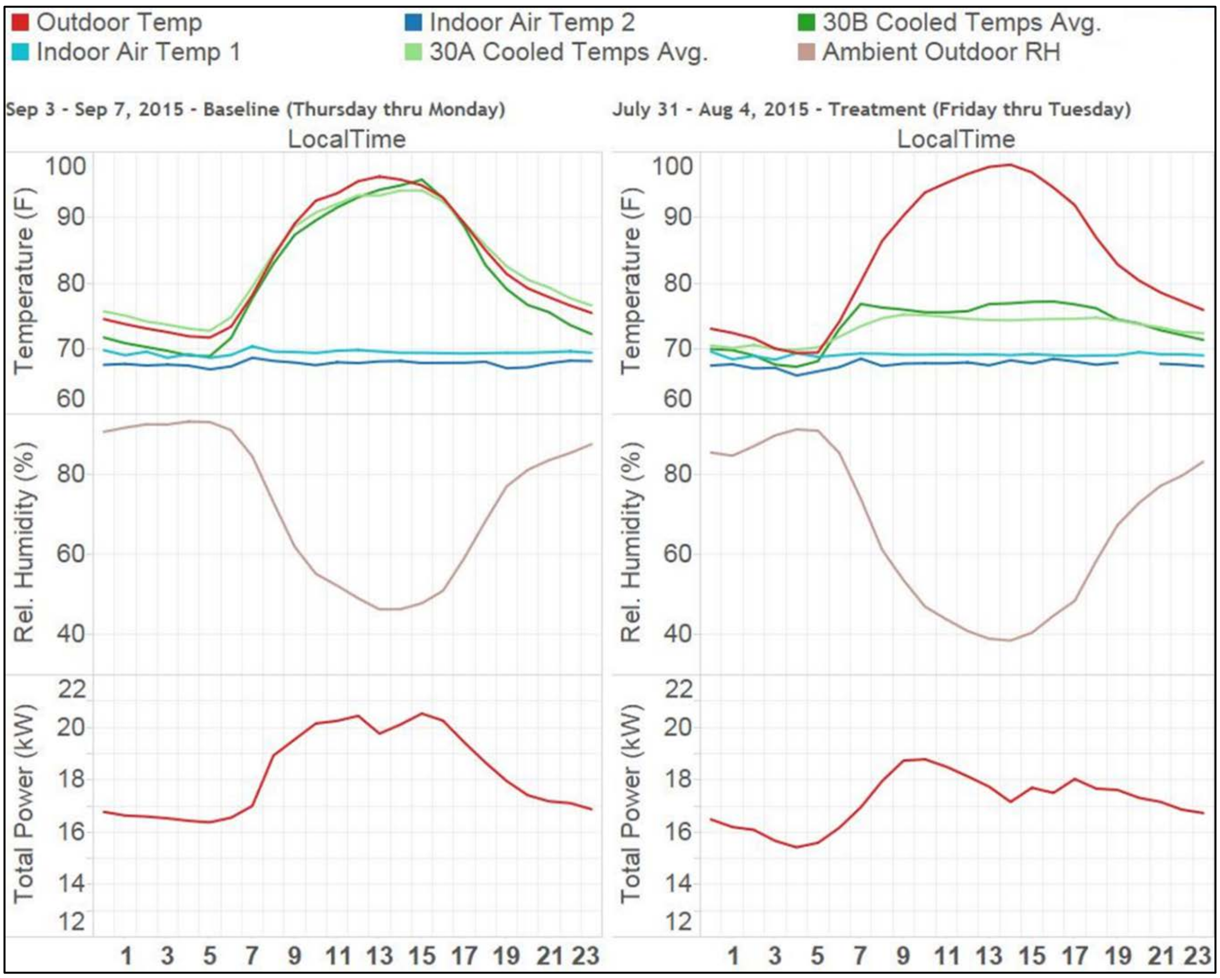

Figure 4. 24-hour average temperature, relative humidity and power profiles for five-day baseline and treatment periods with similar weather

Energy savings were estimated by extrapolating the measured data. The rooftop temperature was measured to calculate the reduction in average hourly power. The calculation assumed a linear savings increasing with outdoor temperature for temperatures above 80°F, with no change for conditions below 80°F. The total energy savings projected for this site during the study was 6,385 kWh.

Water flow metering data were collected beginning in the summer of 2015. These data showed that water consumption was more than 120 gallons per day during hot months.

The installed cost for this system was $9,050, which included installation of a booster pump. To estimate payback, an average energy savings of 5,495 kilowatt hours (kWh) per year was used. The payback period for this equipment depends on the site-specific energy and demand charges as well as whether the demand savings are coincident with the billed demand. The calculated average of energy savings over two years (5,495 kWh per year) was used to estimate payback. Anticipated payback periods were calculated for three scenarios: no demand charge and demand charges of $5/kW and $10/kW. Table 1 shows the estimated payback periods.

Table 1. Estimated payback period

Energy Cost		Payback Period in Years	
		$0.05/kWh	$0.10/kWh
Demand charge	None*	33	16
	$5/kW	22	13
	$10/kW	17	11

*non-coincident

There may be applications in which this technology could have a quicker payback period. For instance, in large, packaged HVAC systems located conveniently at ground level and near an existing water supply, installation costs would be relatively lower than those for this demonstration site, which required a crane, a pump and longer electrical runs.

Summary

The evaporative pre-cooling hardware installed on two A/C units in Mississippi saved energy and reduced demand during hot afternoon hours for the facility. The findings of this study suggest that evaporative pre-cooling may indeed be viable in hot-humid climates—and not just in the hot-dry climates for which the technology is most often recommended. However, site selection is important. Installation costs can add up quickly if additional water lines, water treatment, pumps, cranes for roof mounting, and other factors become necessary. Under the conditions of this installation, a payback of less than 10 years is unlikely. However, sites with lower installation costs and where peak A/C power reduction would also result in a lower billed peak could potentially achieve a payback of less than 10 years.

Further Information

*Energy Efficiency Demonstration 2.0: Results of Four Demonstration of Three Commercial Technologies (*3002009947*)*.

Energy Efficiency Demonstration Final Report (1025437) and *Energy Efficiency Demonstration: Executive Summary* (1025438).

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