Customer Advanced Technologies Program Presents…

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Energy Research & Development
Sacramento Municipal Utility District
December 15, 2011

Report # ET11SMUD1015

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About the Customer Advanced Technologies Program…

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems, daylighting and a variety of other technologies.

For more program information, please visit:
https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

1 EXECUTIVE SUMMARY

1.1 INTRODUCTION/PROJECT DESCRIPTION

As temperatures rise on hot summer afternoons, the efficiency of conventional cooling systems decline and the efficiency of evaporative cooling systems improve, particularly in dry climates. To add to the value of evaporative systems, they produce no greenhouse gases and the margin of performance above conventional cooling will increase as new cooling systems employ the new refrigerant R-410A. As of January 1, 2010, manufacturers of HVAC systems produce equipment using this new refrigerant to reduce greenhouse gases, but tests by the National Institute of Standards and Technology show that "system performance degrades more using R-410A than with R22, the refrigerant which is being replaced.

These two characteristics, increasing performance of evaporative systems with high temperatures and the increased decline of newer conventional cooling systems, employing R-410A, make the advancement and researching of evaporative systems even more important and urgent particularly since summer peak challenges for utilities throughout the southwest are driven by rising demands for summer cooling. Without dramatic changes in the direction of how buildings are cooled, summer peaking will probably become worse.

Recognizing the need for advanced evaporative systems, manufacturers are working to develop and offer complete standalone systems and retrofits for Roof Top Units (RTU). FlashCool is a prime example of an RTU retrofit evaporative system. It is a pre-cooler, which is retrofit to existing RTU's, which reduces the ambient air temperature with an evaporative process and provides low outside air temperature to the condenser unit. With the reduced air inlet temperature at condenser inlet, the HVAC unit will perform better and save significant energy consumption and peak demand. FlashCool also reclaims the condensate and consumes minimal amounts of water compared to standard pre-coolers.

D&K Metcalf1 Partnership LP, installed FlashCool technology on two air-conditioning (AC) units serving a two-story, multi-tenant office building, located in Rancho Cordova, CA. The two AC units include a 37.5-Ton older Lennox unit and a 40-ton newly installed Trane unit. The newly installed 40-ton unit replaced a 50-ton unit which may or may not have used more electricity for cooling than the new one. The Lennox unit serves the first floor of the building, while the Trane unit serves the second floor of the building.

1.2 ANALYSIS FINDINGS

Nexant, in coordination with HMG, monitored the two AC units with FlashCool for a 14-week period (July 26th to August 12th and August 23nd to November 2nd), and without FlashCool for a two week period (August 12th to August 22nd), to determine the overall impact of the FlashCool Technology on energy consumption, peak demand, and water usage. The analysis findings are:

- Reduced average energy consumption of the AC units by 36,193 kWh a year (AC#1 (LENNOX) by 22,061 kWh/yr and AC#2 (TRANE) by 14,132). The percentage reduction of average energy consumption is 36.9% (AC#1 (LENNOX) by 44.1% and AC#2 (TRANE) by 29.4%).
- Reduced the peak demand of the facility during 4 PM to 7 PM on the hottest days[1] by 8.3 kW (AC#1 (LENNOX) by 5.0 kW and AC#2 (TRANE) by 3.8 kW). The percentage peak demand reduction is 13.1% (AC#1 (LENNOX) by 16.7% and AC#2 (TRANE) by 11.2%).
- Reduced energy usage of the AC units during summer days from 4 PM to 7 PM by 1,376 kWh a year (AC#1 (LENNOX) by 379 kWh[2] and AC#2 (TRANE) by 997 kWh[3]). The percentage reduction of energy usage during peak hours is 19.2% (AC#1 (LENNOX) by 17.6% and AC#2 (TRANE) by 19.7%).
- Maximum water usage rate was calculated to be 18 gallons per hour, which is 2% of the measured recirculation flow as estimated by the manufacturer for the two AC units.
- The annual water usage is calculated to be 35,007 gallons for the AC units, also based on the manufacturer's estimate of 2% of recirculation.

1.3 KEY RECOMMENDATIONS

Recommendations that will help improve, as well as sustain, the project energy savings in the future are as follows:

- The FlashCool unit can be scheduled based on the outside air temperature control, rather than based on timer schedules. The AC units can avoid the unnecessary pump energy consumption, as well as the water usage, during low ambient temperature periods, especially when AC units receive 100% outside air to avail the free cooling benefits.
- The AC units do not have consistent schedules even though the building tenants have regular office hour schedules. The facility should investigate the reasons for varying building time schedules and fix the issues to minimize unit consumption.
- Future investigations should account for the changes (if any) in building operating conditions including occupancy, space temperature set points, and schedules. They should also normalize the energy consumption of HVAC equipment, with and without the technologies, to estimate the true technology savings.
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- Preventative maintenance programs should be implemented for the building to ensure that the installed technology results in the maximum energy saving benefits, and minimal water

[1] The day is considered as a hottest day when the outside air temperature is equal to or above 85°F

[2] AC#1operates for 1 hour during peak hours

[3] AC#2 operates for two hours during peak hours

usage, throughout the technology's life time. Additional staff training will likely improve the system performance.

2 INTRODUCTION

2.1 TECHNOLOGY DESCRIPTION

The pre-cooler pump of FlashCool sprays the filtered city water and wets the media pads. The incoming air first pass through FlashCool media on its way to the condenser. The air temperature declines as water in the FlashCool media is evaporated using the sensible heat of air. The lowered condenser air inlet temperature improves the AC unit efficiency. The increased efficiency of the AC unit reduces the unit peak kW and energy consumption.

FlashCool is a bolt-on, ducted, evaporative pre-cooler added to HVAC and Refrigeration condensers. The pictures of FlashCool pre-cooler for Lennox and Trane units are presented in **Figure 2-1** and **Figure 2-2**. The following are the key components of the FlashCool unit:

- Pre-Cooler pump
- Pressurized nozzles that spray water on to the front face of the unit media
- Water spray controllers
- Water valves
- Disposable pre-filter element that prevents dust, cottonwood, leaves, etc., from reaching the evaporative media, which in turn increases media life and reduces maintenance
- Post media drift eliminators
- Sedimentation filtration system that filters the water from sediments
- Duracool evap. cooling media (pads)

According to manufacturer, the FlashCool pre-cooler provides the following advantages over the standard evaporative pre-coolers:

- The unit has oversized cell faces that lower face velocities, resulting in lower static pressures.
- Consists of a post media drift eliminator that:
  - Protects the condenser coils from scale and reduces maintenance, and
  - Stops the leakage of water droplets out of the unit.

- FlashCool contains a disposable pre-filter element that prevents dust, cottonwood, leaves, etc., from reaching the evaporative media, which in turn increases media life and reduces maintenance
- Reclaim condensate up to 30%
- Easy maintenance
- Low weight

Figure 2-1: AC#1 (LENNOX) with Bolt-On FlashCool Pre-Cooler

Figure 2-2: AC#2 (TRANE) with Bolt-On FlashCool Pre-Cooler

2.2 FACILITY DESCRIPTION

D&K Metcalf1 Partnership LP, operates a two-story, multi-tenant office building, located in Rancho Cordova, CA. The building operates from 7AM to 6PM, Monday through Friday, except the college located on the first floor. The college operates from 9AM to 10PM, Monday through Friday. A picture of the building is provided in **Figure 2-3**.

Figure 2-3: View of Building

2.3 HVAC EQUIPMENT DESCRIPTION

The facility has two larger AC units; a 37.5-ton old Lennox unit, and a 40-ton new Trane unit, in addition to multiple smaller units. This newly installed 40-ton unit replaced a 50-ton unit which may or may not have used more electricity for cooling than the new one. The Lennox unit serves the first floor building, while the Trane unit serves the second floor of the building. The Trane and Lennox units operate from 6AM to 6PM. Three smaller units serve the Herald College, located on first floor of the building (which operates from 9AM to 10PM - Monday through Friday). The other smaller units serve the telecommunication and server rooms located in the building.

The Lennox unit has three equally rated 12.5-ton compressors, one 15-HP supply fan, four 1-HP condenser fans, and three 1-HP relief fans. The Trane unit has two compressors: one 16-ton and one 24-ton, one 15-HP distribution fan, four 1.1-HP condenser fans, and two 1.5-HP exhaust fans. FlashCool pre-cooler evaporators were installed on the larger Lennox and Trane units.

3 DATA MONITORING

The monitoring objective was to gather data in order to assess technology performance and compare site data, with and without the Technology. The monitoring was performed in three phases; FlashCool was on in phases #1 and #3, and FlashCool was off in phase #2. The monitoring dates of all three phases are presented in **Table 3-1**.

ID	Task Name	Start Date	End Date
1	Logger Installation/Spot Measurements (FlashCool ON)	7/26/2011	7/26/2011
2	Continuous Monitoring (FlashCool ON)	7/26/2011	8/12/2011
3	Logger Removal/Data download & Logger Re-launch	8/12/2011	8/12/2011
4	Logger Installation/Spot Measurements (FlashCool OFF)	8/12/2011	8/12/2011
5	Continuous Monitoring (FlashCool OFF)	8/12/2011	8/22/2011
6	Logger Removal/Data download & Logger Re-launch	8/22/2011	8/22/2011
7	Logger Installation/Spot Measurements (FlashCool ON)*	8/23/2011	8/23/2011
8	Continuous Monitoring (FlashCool ON)	8/23/2011	11/2/2011
9	Logger Removal & Data download	11/2/2011	11/2/2011
**kW data of AC units for a period between Sept 6th to Sept 30th*			

Table 3-1: Dates for Different Phases of Project Monitoring

3.1 MONITORING PARAMETERS

The details of monitoring parameters, logger type, type of measurements, and measurement units are presented in Table 3-2.**Point#**	**Equipment**	**Quantity**	**Logger Type**	**Measurements**	**Units**
1	New Trane Packaged DX Unit*	1	Elite Dent Pro	Power	kW, kWh
2	New Trane Unit Pre-Cooler Pump	1	Elite Dent Pro	**Amps; one time measurements on voltage and pf	kW, kWh
3	New Trane Unit Pre-Cooler Recirculation Water Flow	1	Ultrasonic Flow Meter	Water Flow	Gallons
4	New Trane Unit Supply Temperature	1	HoBo Data Logger	Temperature	Deg. F
5	New Trane Unit Return Temperature	1	HoBo Data Logger	Temperature	Deg. F
6	New Trane Unit Pre-Cooler Inside Pad Temperature	1	HoBo Data Logger	Temperature	Deg. F
7	Old Lennox Packaged DX Unit*	1	Elite Dent Pro	Power	kW, kWh
8	Old Lennox Unit Pre-Cooler Pump	1	Elite Dent Pro	**Amps; one time measurements on voltage and pf	kW, kWh
9	Old Lennox Unit Pre-Cooler Recirculation Water Flow	1	Ultrasonic Flow Meter	Water Flow	Gallons
10	Old Lennox Unit	1	HoBo Data	Temperature	Deg. F

	Supply Temperature		Logger		
11	Old Lennox Unit Return Temperature	1	HoBo Data Logger	Temperature	Deg. F
12	Old Lennox Unit Pre-Cooler Inside Pad Temperature	1	HoBo Data Logger	Temperature	Deg. F
13	Outside Air Temperature	1	HoBo Data Logger	Temperature	Deg. F
14	Outside Air RH	1	HoBo Data Logger	Relative Humidity	%RH
*The entire unit including the distribution fans were monitored together **The objective is to calculate power (kW and kWh) from these measurements					

Table 3-2: Monitoring Parameters and Equipment

3.2 SPECIFICATIONS OF MONITORING EQUIPMENT

The specifications of monitoring equipment are presented here in **Table 3-3**.

Logger Type	Measurement Range	Accuracy
Dent ElitePro Power Phase Meter	Current: 0-6000A; Voltage: 0-600V (AC/DC)	<1% of reading exclusive of sensor (0.2% typical)
Fuji Time Delta-C Electric Flow Meter with FLD22 Detector	Pipe Dia. Range: 0.5-235 Inch; Velocity: 0-105 ft/s; Fluid Turbidity: 1000 mg/L max;	Flowrate: +/-1.0%
4-channel HoBo Data Logger		Data: +/- 4.5% of full scale
HoBo Data Logger	Temperature: -4 to158F: RH: 5% to 95%RH	Temperature: +/- 0.63F from 32 to122F; RH: +/-2.5% from 10% to 90%RH

Table 3-3: Specifications of Monitoring Equipment

4 RESULTS, ANALYSIS, AND DISCUSSIONS

4.1 ANALYSIS METHOD

From the measures parameters described in the **Data Monitoring** Section, the following calculations were made to characterize FlashCool performance:

- **AC Unit Electric Energy Consumption**: The AC unit energy is the sum of energy consumption from the compressors, distribution fans, and condenser fans. The AC unit energy consumption is the summation of kW over the monitored interval.

$$E = \sum kW$$

- **Pre-Cooler Pump Electric Energy Consumption**: The pump energy is calculated to be the product of the monitored amperage, voltage, and power factor, over the monitored interval.

$$E = \sum Amp \times V \times PF \times \sqrt{3}$$

- **Annual kWh**: The team obtained the TMY weather data from the applicable downtown Sacramento area to perform an estimate on the annual kWh usage, based on the monitored data for 14 weeks. This is done by first grouping the hourly OAT's from TMY data into temperature bins; each temperature bin covers a temperature range of 4°F. Then, the annual energy consumption is calculated by multiplying the power in kW corresponding to each temperature bin, by the annual number of hours with OAT within that temperature range.

$$E_{annual} = \sum_{i=1} kW_i \times n_i$$

where
kW_i is the averaged monitored power within the bin temperature range
n_i is the annual number of hours which fall within the bin temperature range

4.2 MONITORING RESULTS

This section displays the analyzed results, and discusses the implications on FlashCool's performance and operation.

4.2.1 AC Unit Energy Consumption with and without FlashCool

The analysis assumed that the building conditions, including the tenant occupancy, HVAC setpoints, and controls, are identical throughout the monitoring period. The average kWh of AC units (designated AC#1 (LENNOX) and AC#2 (TRANE)), that includes distribution and condenser fans with and without FlashCool unit, is calculated with respect to ambient temperature using the calculation method described in **Section 4.1**. The results are plotted in **Figure 4-1**, **Figure 4-2**, **Figure 4-3**, **Figure 4-4**, **Figure 4-5**, and **Figure 4-6**. The energy savings are calculated for two scenarios; the first scenario considers both the economizer and the compressor mode operations, and the second scenario consists of only the compressor mode operation (excludes economizing mode data). The monitored data indicates that the AC units with FlashCool for scenario #1 results in a 34.5% weighted average kWh reduction for AC#1 (LENNOX), and an 11.1% weighted average for AC#2 (TRANE). The scenario #2 monitored data indicates that the AC#1 (LENNOX) with FlashCool unit reduces its air conditioning energy usage by a weighted of average 11.5%, while AC#2 (TRANE) reduces its energy by a weighted average of 4.0%. The energy savings at high ambient temperatures were resulted due to the unloading of compressors with the reduced compressor lift, and therefore can be attributed to FlashCool operation. The AC#1 (LENNOX) unit resulted more energy savings at higher ambient temperatures compared to AC#2 (TRANE), as AC#1 (LENNOX) with FlashCool was able to unload its smaller capacity compressors easily, compared to AC#2 (TRANE)'s larger capacity compressors.

The analysis also estimated the peak kW reduction for hours between 4PM and 7PM; the data indicates that the AC#1 (LENNOX) unit reduces its peak kW by a weighted average of 19.5%, and the AC#2 (TRANE) unit reduces its peak kW by a weighted average of 15.4%. The peak kW savings of AC#2 may be greater than 15.4% if compared to the 50-ton unit it replaced. The results are presented in **Figure 4-5** and **Figure 4-6**.

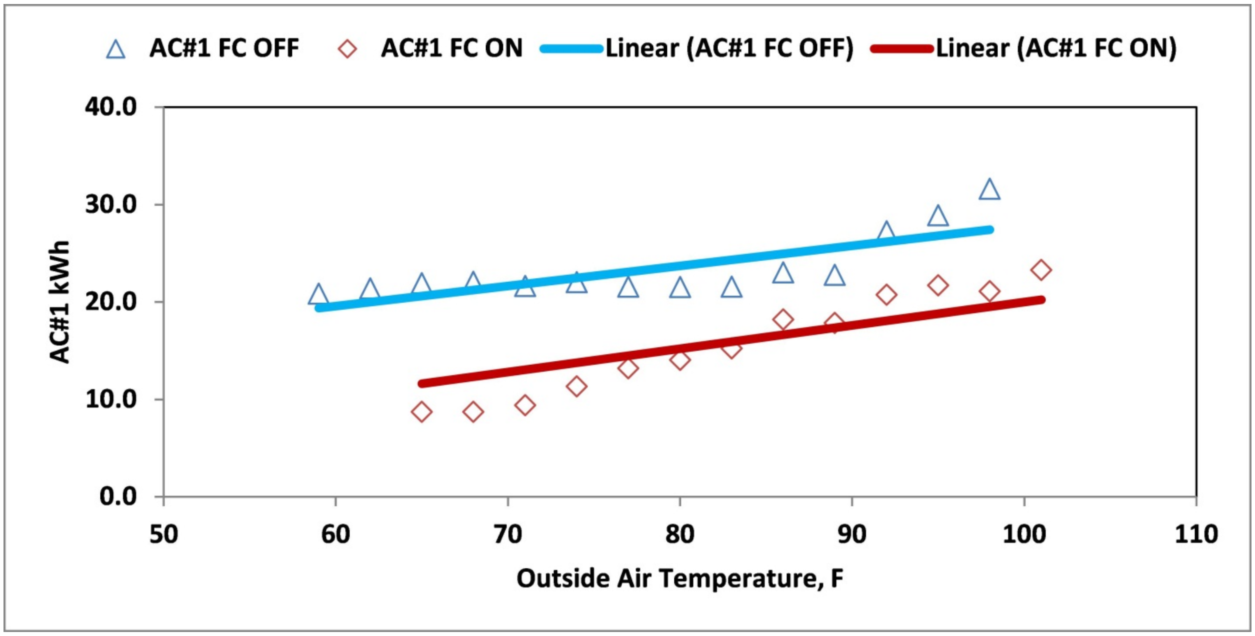

Figure 4-1: AC#1 (LENNOX) KWH vs. Outside Air Temperature

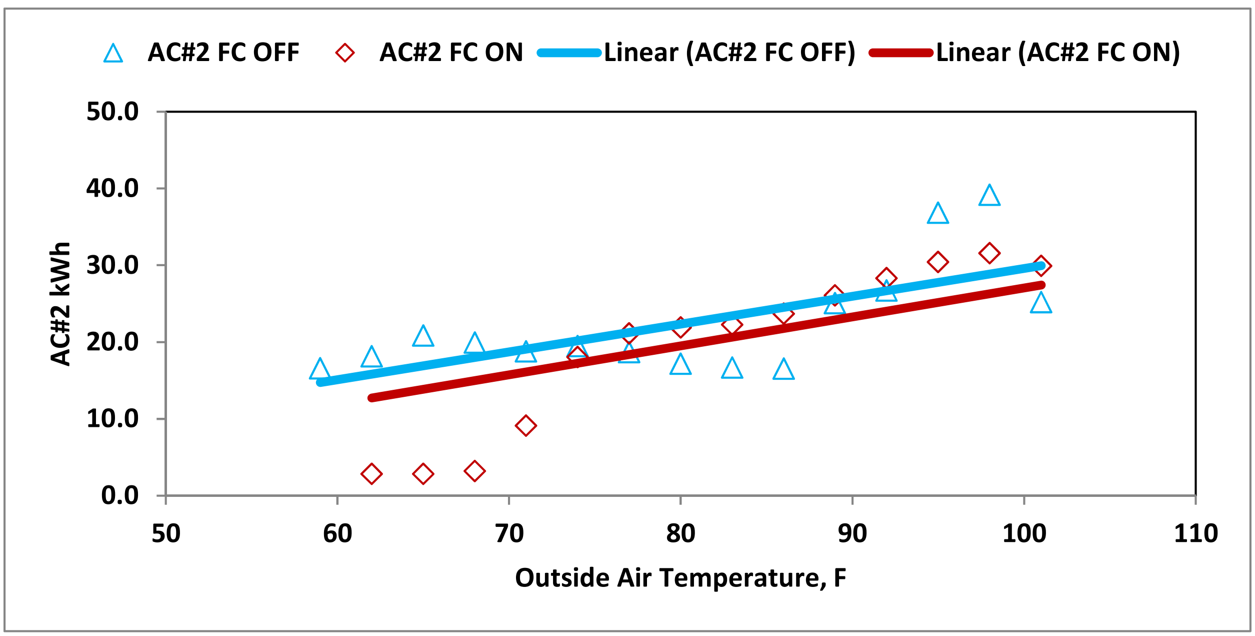

Figure 4-2: AC#2 (TRANE) KWH vs. Outside Air Temperature

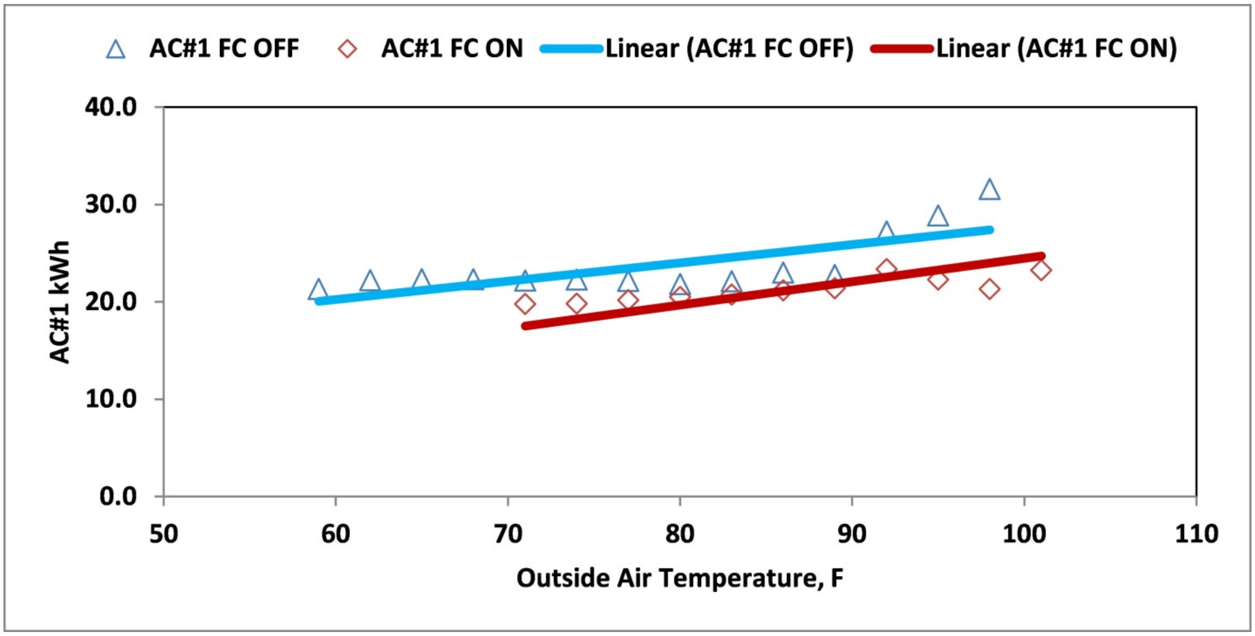

Figure 4-3: AC#1 (LENNOX) KWH vs. Outside Air Temperature - Non Economizing Mode

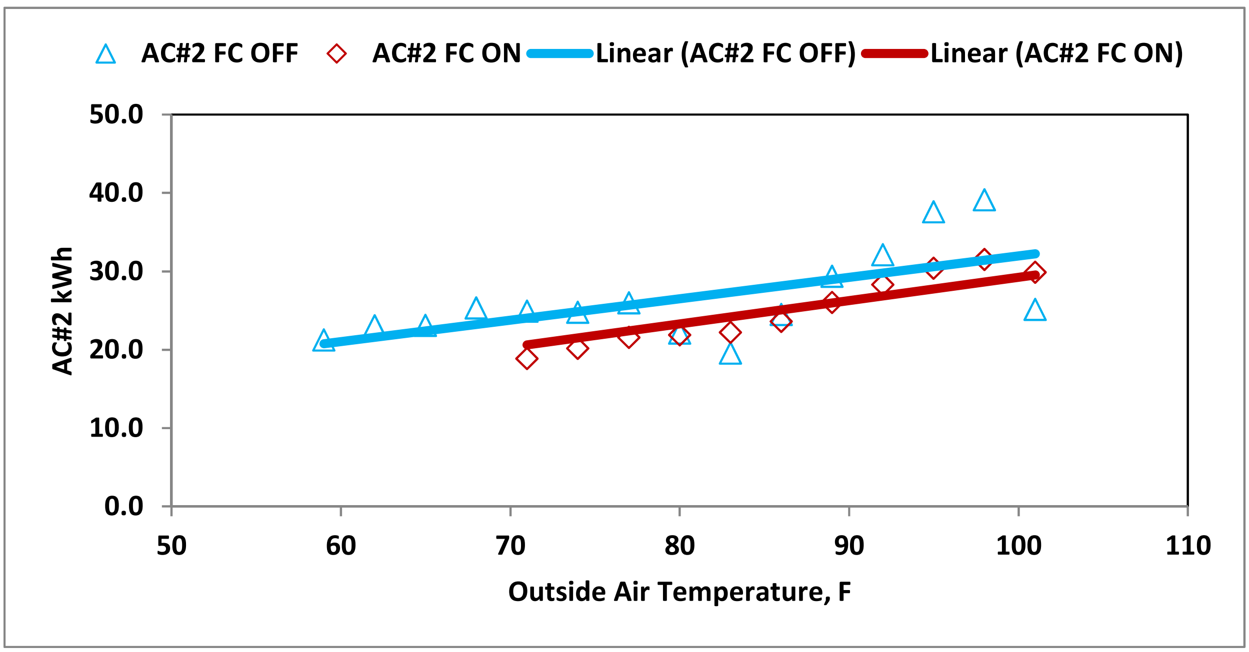

Figure 4-4: AC#2 (TRANE) KWH vs. Outside Air Temperature - Non Economizing Mode

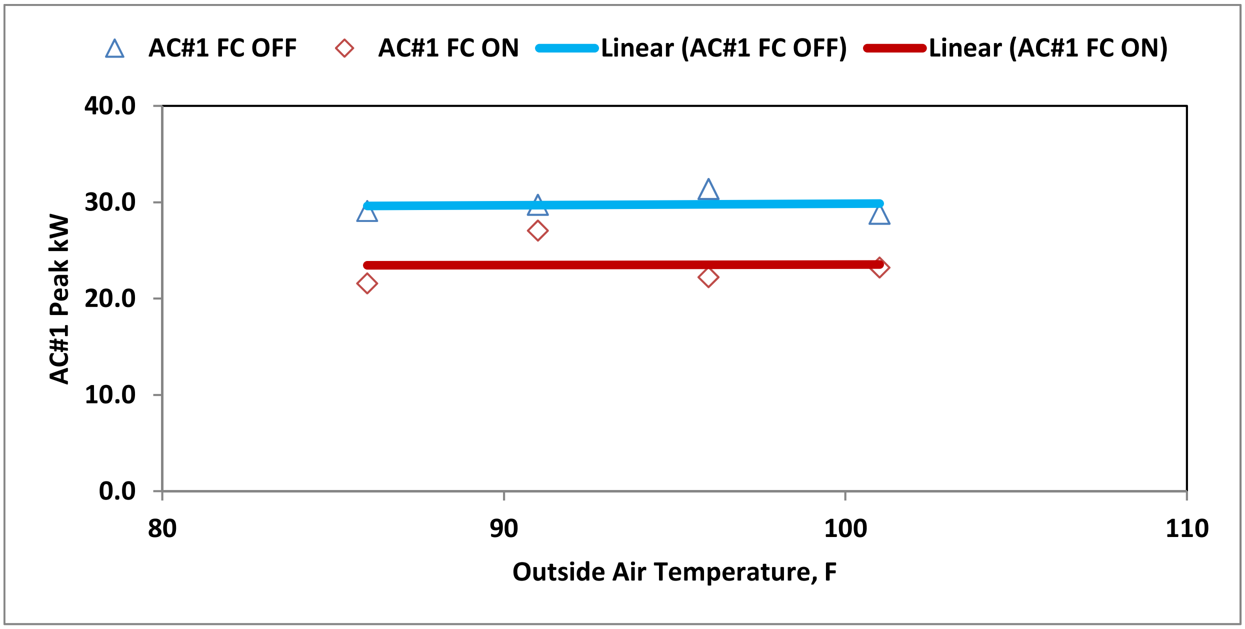

Figure 4-5: AC#1 (TRANE) PEAK KW vs. Outside Air Temperature

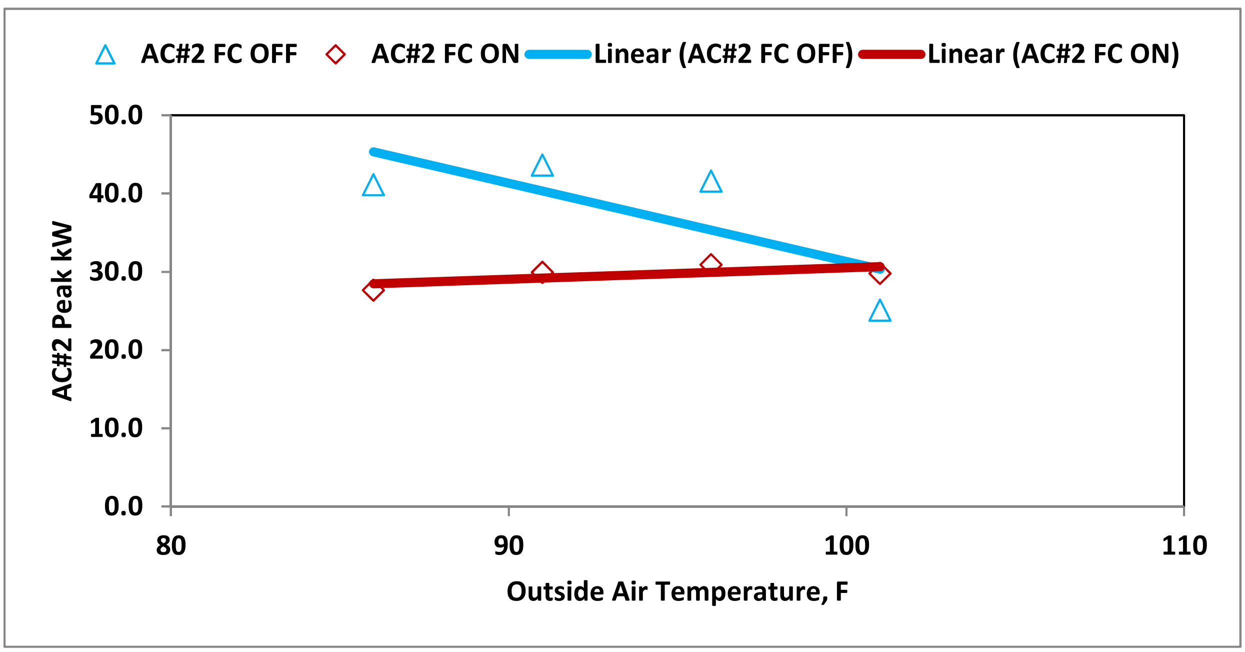

Figure 4-6: AC#2 (TRANE) PEAK KW vs. Outside Air Temperature

4.2.2 Water Energy Consumption

The recirculation flow of the FlashCool units is measured part of study as makeup pipeline is too small to measure its flow with the ultrasonic flow meter. According to the manufacturer, approximately 98% of the water is recirculated and 2% of the water is lost through the evaporation process. The makeup water flow of FlashCool units is conservatively calculated to be 2% of the total water flow, based on the manufactures estimate and is appears to be consistent with the low flows observed in the makeup pipeline. The AC#1 (LENNOX) unit approximately consumes 8.5 gph[1], and the AC#2 (TRANE) unit approximately consumes 9.6 gph[2], whenever the FlashCool operates. The total annual usage of water for the two units is estimated to be 35,007. The combined annual water usage of the AC#1 (LENNOX) and AC#2 (TRANE) units is about 34.5% of the annual water usage of a family of three, that typically requires 100,000 gallons per year. The details of the AC Units' water consumption are presented in Table 4 1.

Water Usage	AC#1	AC#2	Total
Recirculation Water Usage, GPH	420	468	888
Makeup Water Usage, GPH	8.6	9.6	18.2
Makeup Water Usage, Gallons per Day	77.0	63.0	140.0
Makeup Water Usage, Gallons per Year	19,249	15,757	35,007

Table 4-1: Water Consumption of FlashCool

[1] The maximum makeup water use is estimated to be the 2% of the total water flow including the recirculation water based upon the discussion with the manufacturer

[2] The maximum makeup water use is estimated to be the 2% of the total water flow including the recirculation water based upon the discussion with the manufacturer

5 CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions and recommendations of Nexant's Technology Evaluation of the FlashCool Evaporative System.

5.1 ANALYSIS FINDINGS

A team of Nexant and HMG staff members monitored the two AC units with FlashCool, and without FlashCool, for a 14-week period (July 26, 2011 to November 2, 2011) to determine the overall impact of the FlashCool Technology on energy, peak demand, and water usage. Our analysis findings are as follows:

- Reduced average energy consumption of the AC units by 36,193 kWh a year (AC#1 (LENNOX) by 22,061 kWh/yr and AC#2 (TRANE) by 14,132). The percentage reduction of average energy consumption is 36.9% (AC#1 (LENNOX) by 44.1% and AC#2 (TRANE) by 29.4%).
- Reduced the peak demand of the facility during 4 PM to 7 PM on the hottest days[1] by 8.3 kW (AC#1 (LENNOX) by 5.0 kW and AC#2 (TRANE) by 3.8 kW). The percentage peak demand reduction is 13.1% (AC#1 (LENNOX) by 16.7% and AC#2 (TRANE) by 11.2%).
- Reduced energy usage of the AC units during summer days from 4 PM to 7 PM by 1,376 kWh a year (AC#1 (LENNOX) by 379 kWh[2] and AC#2 (TRANE) by 997 kWh[3]). The percentage reduction of energy usage during peak hours is 19.2% (AC#1 (LENNOX) by 17.6% and AC#2 (TRANE) by 19.9%).
- Maximum water usage rate was 18 gallons per hour[4] for the AC units.
- The annual water usage is calculated to be 35,007 gallons for the AC units.

5.2 RECOMMENDATIONS

Recommendations that could help to improve, as well as to sustain, the project energy savings in the future are as follows:

- The FlashCool unit can be scheduled based on the outside air temperature control, rather than based on timer schedules. The AC units can avoid the unnecessary pump energy consumption, as well as the water usage, during low ambient temperature periods, especially when AC units receive 100% outside air to avail the free cooling benefits.

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[1] The day is considered as a hottest day when the outside air temperature is equal to or above 85°F

[2] AC#1operates for 1 hour during peak hours

[3] AC#2 operates for two hours during peak hours

[4] The maximum makeup water use is estimated to be the 2% of the total water flow including the recirculation water based upon the discussion with the manufacturer

- The AC units do not have consistent schedules even though the building tenants have regular office hour schedules. The facility should investigate the reasons for varying building time schedules and fix the issues to minimize the unavoidable unit consumption.
- The current investigation did not capture the air temperature after the pre-cooler pad (to estimate the ambient temperature drop due to the FlashCool technology) even though the logger was correctly installed. It is recommended to install multiple thermo couple temperature loggers across the FlashCool cell face to determine the actual average air temperature.
- Future investigations should account for the changes (if any) in building operating conditions including occupancy, space temperature set points, and schedules. They should also normalize the energy consumption of HVAC equipment, with and without the technologies, to estimate the true technology savings.

- Preventative maintenance programs should be implemented for the building to ensure that the installed technology results in the maximum energy saving benefits, and minimal water usage, throughout the technology's life time. Additional staff training will likely improve system performance.

Appendix A — MONITORED DATA

Monitored data are provided electronically.

Appendix B SAVING ANALYSIS

Analysis spreadsheets are provided separately in electronic form.