ET16SDG1011: Waste-heat recovery from an air conditioner for swimming pool heating

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EXECUTIVE SUMMARY

This report presents the results of a field study documenting energy savings and demand reduction from rejecting waste heat from of a rooftop unit (RTU) air conditioner to a commercial swimming pool. The RTU was custom-built for the application and conditioned a small fitness center of a hotel while rejecting waste heat to the adjacent pool. This study documents natural gas savings due to the reduction in pool heating provided by the on-site gas heater as well as improved air conditioner efficiency when rejecting heat to the pool.

The project objectives were to:

1. Quantify electricity peak demand reduction;
2. Quantify electricity energy savings; and
3. Quantify natural gas energy savings.

Another important objective of this study was to reduce market barriers for further adoption of the technology by documenting the energy savings, and providing simple cost savings estimates based on the observed performance.

A custom RTU was installed that had two heat rejection modes: either to the pool or to the outdoor air. In the first phase of the study, the RTU was set to reject heat to outdoor air only, operating exactly as a conventional system would. The performance in this mode was measured as the “baseline”. Then, the RTU was set to reject heat to the swimming pool, unless the swimming pool temperature exceed 82°F, in which case the RTU controls switched the heat rejection mode to outdoor air. The performance in this mode was measured as the “retrofit”. Additionally, if the pool conditions reached the low temperature limit, the gas pool heater turned on. The facility staff adjusted the low temperature limit during the study between of 78-80°F. The gas heater operated independently of the RTU, ensuring pool temperatures were maintained.

When the system operated in the pool heat rejection mode, the RTU used less energy on average due to the increased heat exchange efficiency of the water-to-refrigerant heat exchanger, and due to the pool temperature being lower than the outdoor temperature during the hottest part of the day.

The coastal climate at the site was mild compared to many inland locations, with maximum outdoor air temperatures rarely exceeding 90°F during the study period. The electricity demand reduction was as high as 12% when switching from the conventional heat rejection mode to pool heat rejection mode at high outdoor air temperatures. The average electricity savings was about 5% over the study period. The pool temperature averaged 79°F over the course of the study, and there was natural gas savings of 29%.

Annual cost savings for the demonstration site were estimated at about $750 per year (Table 1). The cost-savings does not justify the cost of the custom RTU installed for this project, however, other off-the-shelf products have been identified at lower cost that could achieve a simple payback of less than five years. A site with higher average daytime temperatures, and higher maximum temperatures would have higher demand and electricity savings. Furthermore, this study showed that a relatively small RTU (5-Tons) with a load factor of 26% (meaning that the air conditioner was running 26% of the study period) was able to reduce heating demand for a commercial swimming pool by 29%. Air conditioning units that operate more frequently, particularly in early morning hours, would be optimal targets for retrofit and further increase the natural gas savings.

Table 1: Summary of savings

	Annual Energy Savings (kWh/yr)	Annual Nat. Gas Reduction (Therms/yr)	Annual Cost Reductions ($/yr)
New Technology	306	565	620
Time-of-Use Breakdown for Electricity Savings			
Electricity Super Off-Peak 12am-6am	17		
Electricity Off-Peak 6am-4pm	180		
Electricity On-Peak 4pm-9pm	83		
Electricity Off-Peak 9pm-12am	26		

The pool-coupled air conditioner demonstrated here reduced peak electrical demand, electricity and gas consumption. Market research demonstrates that cost-effective methods to achieve these savings are available. To increase adoption of the technology and provide appropriate utility program incentives, the impact of the technology as a function of climate, pool size, air conditioner capacity, and air conditioner load factor would need to be quantified through modeling. The results from the work presented in this report provide an excellent data source to verify model accuracy.

ABBREVIATIONS AND ACRONYMS

A/C	Air Conditioner
BTU	British Thermal Unit
Btu/hr	British Thermal Unit per hour
°C	Degrees Celsius
CFM	Cubic Feet per Minute
c_p	Heat Capacity
EER	Energy Efficiency Ratio
°F	Degrees Fahrenheit
gpm	Gallons Per Minute
h	Enthalpy
in. WC	Inches Water Column
kW	Kilowatt
kWh	Kilowatt-Hour
$\dot{m}$	Mass Flow Rate
ma	Milliamps
OA	Outdoor Air
P	Power
Pa	Pascal
q	Heat Transfer/Capacity

RH	Relative Humidity
RTU	Rooftop Unit
Sq. ft.	Square Feet
T	Temperature
$\dot{V}$	Volume Flow Rate
VDC	Direct Current Volts
VRF	Variable Refrigerant Flow System
YR	Year
ρ	Density

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INTRODUCTION

Air conditioning loads drive peak demand and contribute to overall electric power consumption in California. In the summer, cooling loads are highest in the middle of the day when air conditioners are the least efficient. Rejecting waste heat from an air conditioner to a swimming pool rather than outside air can significantly reduce the peak rejection temperatures, and thus peak electricity demand for the air conditioner. Simultaneously, pool heating costs can be reduced by supplementing or replacing the natural gas pool heater with heat rejected from the air conditioner. This project demonstrated the impact of rejecting air conditioner waste heat to a heated swimming pool, in comparison to a conventional system that rejected heat to ambient air only.

The baseline technology applicable to this study is any existing space cooling equipment such as an RTU or split-system air conditioner, and any pool heating equipment. Depending on the application, there may not be pool heating equipment. Pool heating equipment typically operates on natural gas. For sites with pool heating equipment, the tested technology decreases both heating loads for the pool and electricity used for air conditioning. For sites without a pool heater, the tested technology is expected to achieve additional cooling energy savings because of lower pool temperatures. The heat rejection to a normally unheated pool increases comfort, extending the swimming season.

The new technology improves cooling equipment performance through lower average heat rejection temperatures and improved heat transfer effectiveness. Pool temperatures in California climates are expected to be lower than 85°F, and temperature fluctuations in the day are on the order of a few degrees Fahrenheit. Daytime air temperatures in parts of California often exceed 100°F, and the efficiency of cooling equipment decreases substantially as the rejection temperature increases. The new technology will reject heat to the low temperature pool, substantially increasing the cooling equipment efficiency during peak. Water-to-refrigerant heat exchange is also more efficient than air-to-refrigerant heat exchange.

BACKGROUND

Rejecting waste heat from an air conditioning process to a swimming pool has many benefits. Previous modeling efforts indicated that the energy as a result of rejecting heat to a swimming pool rather than ambient air could be as high as 25-30% of the annual air conditioning energy for an unheated pool [1]. The cooling energy savings is attributed to the pool temperature generally being lower than outdoor air temperature during cooling, more effective heat exchange between water/refrigerant vs air/refrigerant, and the higher heat capacity of water over air. These changes decrease the required compressor power and simultaneously increase the capacity of the system. The pump energy needed for the water/refrigerant heat exchanger is less than the fan energy needed for air/refrigerant heat exchange.

In addition to electricity savings from more efficient cooling operations, gas savings were also expected since delivering waste heat to the pool offsets natural gas heating for the pool. Natural gas savings in large pools can be offset with a single, relatively small air conditioner. The pool in this study was estimated at 75,000 gallons. For reference, a residential pool sized 15'x30'x5' holds 17,000 gallons, while a competition pool sized 82'x163'x10' holds 1,000,000 gallons. The air conditioner in this study had a nominal cooling capacity of 5-tons, which was expected to displace 0.94 therms of natural gas used for heating for each hour of air conditioning operation. Packaged RTUs are ubiquitous in California and provide and estimated 75% of the cooling to commercial buildings in the state [3]. With over 1.2 million in-ground swimming pools in California [4], the opportunity presented by this technology is significant.

ASSESSMENT OBJECTIVES

This report presents the results of a field study documenting energy savings and demand reduction from rejecting waste heat from of a rooftop unit (RTU) air conditioner to a commercial swimming pool. The RTU was custom-built for the application and conditioned a small fitness center of a hotel while rejecting waste heat to the adjacent pool. This study documents natural gas savings due to the reduction in pool heating provided by the on-site gas heater as well as improved air conditioner efficiency when rejecting heat to the pool.

The main project objectives were to:

1. Quantify electricity peak demand reduction;
2. Quantify electricity energy savings; and
3. Quantify natural gas energy savings.

Another important objective of this study was to reduce market barriers for further adoption of the technology by documenting the energy savings, and providing simple cost savings estimates based on the observed performance. Other objectives included assessing whether the pool over-heated frequently, the simplicity of the controls and operation, and whether pool heating needs generally coincided with air conditioning loads.

TECHNOLOGY EVALUATION

This assessment was conducted by the UC Davis Western Cooling Efficiency Center (WCEC) at a hotel in San Diego, CA. A custom RTU was installed (Figure 1) to condition the hotel fitness center that had two heat rejection modes: either to the adjacent swimming pool or to the outdoor air. In the first phase of the study, the RTU was set to reject heat to outdoor air only, operating exactly as a conventional system would. The performance in this mode was measured as the "baseline". Then, the RTU was set to reject heat to swimming pool, unless the swimming pool temperature exceeded 82°F, in which case the RTU controls switched the heat rejection mode to outdoor air. The performance in this mode was measured as the "retrofit". Additionally, if the pool conditions reached the low temperature limit, the gas pool heater turned on. The facility staff adjusted the low temperature limit during the study between of 78-80°F. The gas heater operated independently of the RTU, ensuring pool temperatures were maintained.

A field study was chosen for this assessment as a means to understand the real-world performance of the technology. Furthermore, since the system included a pool, which is subject to insolation, surface evaporation, and other modes of heat transfer, a field study is the only feasible way to characterize the performance of the system. The field data includes all of the important weather parameters that can be used to validate system models. A validated model would allow results to be extended to other climate zones, and a parametric modeling study could be conducted in the future to provide design guidelines for implementation of the technology in a variety of climates for various pool sizes and air conditioner applications.

FIGURE 1: PHOTO OF RTU INSTALLED AND MONITORED FOR THIS PROJECT

TECHNICAL APPROACH/TEST METHODOLOGY

Researchers conducted the evaluation by comparing the performance of the system in air-source mode versus water-source mode, as well as the reduced heating demand of the pool when the system was in water-source mode.

FIELD TESTING OF TECHNOLOGY

The new technology was a custom RTU that added a water-to-refrigerant heat exchanger to a typical air conditioner design. The water-source heat exchanger was connected to the pool water loop, and heat rejected by the RTU was rejected to the pool when in water-source mode. The control system was designed to allow the research team to switch the heat rejection mode between the pool and ambient air. This strategy allowed for comparisons between the two modes of operation. It should be noted that other technologies are capable of providing the same functionality, a few examples of which are described in the Market Barrier section below.

The RTU provided heating, cooling and ventilation to a 700 square foot hotel fitness center. The RTU was controlled by a standard thermostat in the gym, while a separate thermostat in the RTU determined whether condenser heat was rejected to the outdoor air or pool water. The RTU performance in air-source mode was a function of outdoor temperature and indoor air conditions, while in water-source mode it was a function of pool water temperature and indoor air conditions.

Pool water was diverted from the standard pool filtering loop and sent to the RTU for cooling operations (Figure 2). The total length of the pool loop was about 75 feet of 2-inch schedule 40 PVC pipe. The pool was estimated to be roughly 75,000 gallons and had a surface area of about 1,900 sq. ft. The impact on pump power was minimal since the loop was plumbed in parallel to the standard pool heater, so that the flow rate through the pool heater was reduced, decreasing friction losses. A one-time measurement of the impact of the additional water loop on pump power showed about a 2% (20 Watt) increase. In addition, pool filtering occurred 24 hours a day, resulting in no additional pool pump runtime. For these reasons, changes in pumping power were not included in the analysis. The water flow through the RTU was designed to be at least 3 gpm per ton of cooling capacity, resulting in a minimum flow of about 15 gpm for the 5-ton unit. Increased water flow tends to increase cooling efficiency at the expense of additional pump power. The conventional pool heater was a 399,000 btu/hr gas fired system with a thermal efficiency of about 80%. Water was constantly sent through the pool heater which switched on when water temperature dropped below the pool water temperature low limit setpoint.

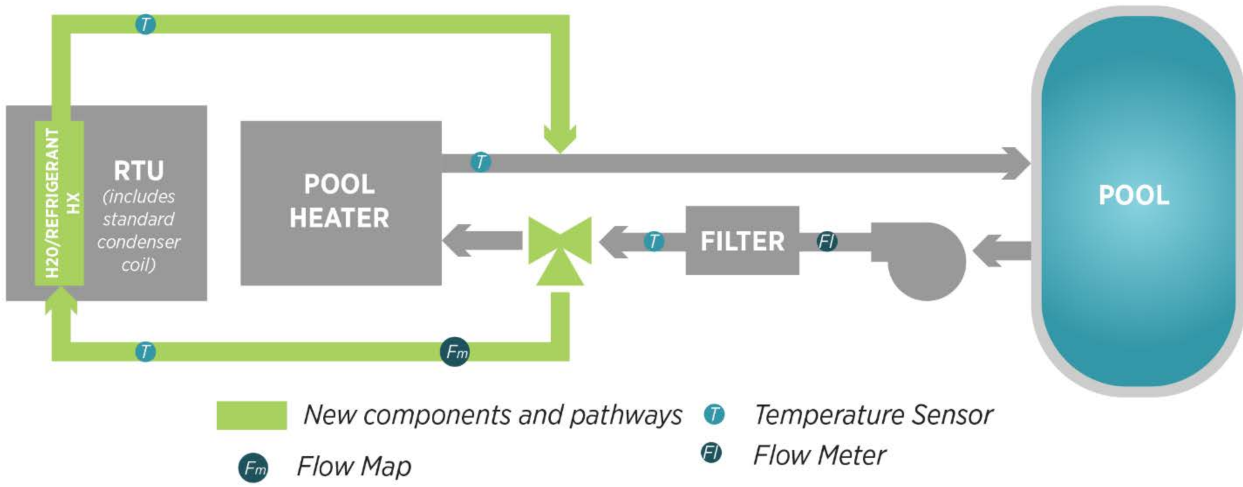

FIGURE 2: SCHEMATIC DIAGRAM OF THE SYSTEM

TEST PLAN

The WCEC conducted tests to determine the reduction in pool heater gas use and air conditioning energy use when rejecting waste heat from an air conditioner to a swimming pool. To make appropriate comparisons between the conventional system and the new system, researchers recorded the weather parameters that can significantly affect system performance, which included outdoor air temperature, humidity, wind speed, wind direction, precipitation and barometric pressure (Table 2). Researchers also monitored the natural gas consumption of the conventional pool heater and electrical power draw of the RTU. Since the same unit was used to compare conventional performance to the test technology system performance, other variables such as the condition of the evaporator coil, refrigerant charge, and airflow were identical.

FIGURE 3: POWERED FLOW-CAPTURE HOOD USED FOR MEASURING RTU AIRFLOWS

Pool water temperature was measured at multiple locations in the system including at the exit of the pool pump, at the exit of the conventional pool heater, and at the inlet and exit of the water-to-refrigerant heat exchanger in the RTU (Figure 2). The water flowrate through the heat exchanger in the RTU was measured to determine heat rejected to the pool. The pool pump current was monitored to determine pump speed.

WCEC monitored the delivered cooling with temperature and humidity sensors at the return before mixing with outdoor air and supply of the RTU (Table 2). Airflow through the system was measured with a powered flow-capture hood for each damper configuration observed (Figure 3). A differential pressure sensor across the fan was used to monitor fan operation and outdoor air damper position of the RTU was monitored to determine the ventilation rate. Cooling performance data was only analyzed when the system was operating at steady state, defined as operating for at least two full minutes.

Researchers sampled data every minute with a DataTaker model DT-80. The DataTaker relays information to a secure FTP server at the end of each day using a cellular network. If the cellular connection could not be established, the DataTaker stored the data internally until it could be transmitted or downloaded.

Performance results, including electricity and natural gas consumption, were compared for similar outdoor, indoor, and pool temperature conditions.

INSTRUMENTATION PLAN

TABLE 2: INSTRUMENTATION TABLE

Measurement Type	Manufacturer and Model #	Accuracy	Signal Type
Outdoor Air Temperature	Vaisala WXT520	±0.3°C	RS-485
Outdoor Air Humidity	Vaisala WXT520	±3%	RS-485
Wind Speed	Vaisala WXT520	±3% at 10 m/s	RS-485
Wind Direction	Vaisala WXT520	±3°	RS-485
Precipitation	Vaisala WXT520	<5%	RS-485
Barometric Pressure	Vaisala WXT520	±0.5 hPa	RS-485
Water Temperature Exiting Pool Pump	Omega RTD-NPT-E-1/4	±0.2°C	Ohms
Water Temperature Entering RTU	Omega RTD-NPT-E-1/4	±0.2°C	Ohms
Water Temperature Exiting RTU	Omega RTD-NPT-E-1/4	±0.2°C	Ohms
Water Temperature Exiting Heater	Omega RTD-NPT-E-1/4	±0.2°C	Ohms
Supply Air Temperature	Vaisala HUMICAP HMP110	±0.2°C	0-10 VDC
Supply Air Humidity	Vaisala HUMICAP HMP110	±1.7%	0-10 VDC
Return Air Temperature	Vaisala HUMICAP HMP110	±0.2°C	0-10 VDC
Return Air Humidity	Vaisala HUMICAP HMP110	±1.7%	0-10 VDC
RTU differential Pressure	Dwyer 677B	+/-0.01in. WC	4-20mA
Pool Water Flowrate through RTU	Omega FMG811-HF	±1% of reading	Pulse
Natural Gas Flowrate	Alicat MW	0.4% of reading + 0.2% of full scale	RS-485
RTU Power	Dent Powerscout 3	±1%	RS-485
Pool Pump Current	Dent Powerscout 3	±1%	RS-485
Damper Voltage	Dent Voltage Monitor	N/A	Volts

DATA ANALYSIS

INDOOR CAPACITY

The return and supply air flow rates were measured with a powered flow-capture hood, and the outdoor air was calculated from a flow conservation assuming negligible changes in density (Equation 1). The mass flow rate was determined from the volumetric flow rate and air density, according to Equation 2.

EQUATION 1: OUTDOOR AIR VOLUMETRIC FLOW RATE

$$\dot{V}_{OA} = \dot{V}_{supply} - \dot{V}_{return}$$

EQUATION 2: GENERAL EQUATION TO DETERMINE MASS FLOW RATE FROM VOLUMETRIC FLOW RATE

$$\dot{m} = \rho * \dot{V}$$

Researchers calculated the capacity according to Equation 3, where the enthalpy was determined from psychrometric functions using measured temperature and relative humidity.

EQUATION 3: RTU COOLING CAPACITY

$$q_{EvapCoil} = \dot{m}_{return} * h(T, RH)_{return} + \dot{m}_{OA} * h(T, RH)_{OA} - \dot{m}_{supply} * h(T, RH)_{supply}$$

EER

The energy efficiency ratio (EER) was calculated according to Equation 4. The units of RTU power are W, and the units of evaporator capacity are BTU/hr.

EQUATION 4: EER CALCULATION

$$EER = q_{EvapCoil}/P_{RTU}$$

RTU WATER HEATING

To calculate the heating provided to the pool by the RTU, researchers used the inlet and outlet temperatures of the water-to-refrigerant heat exchanger, and water flow rate. A primary assumption in Equation 5 is that there is negligible heat loss or gain in the pipes between the RTU and the pool.

EQUATION 5: RTU HEATING DELIVERED TO THE POOL

$$q_{RTU/Pool} = \dot{m}_{H2O,RTU} * c_{p_{H2O}} * (T_{RTU,out} - T_{RTU,in})$$

The water flow rate diverted to the RTU was measured using a water flow meter (Table 2). The instrument used was problematic and had periods where it did not report the water flow. During these periods, a relationship of water flow to pool pump current was used to determine water flow rate (Table 3). This method is valid because the pump was operated at only two speeds with fixed-resistance plumbing. The mass flow rate was determined by multiplying the volumetric water flow rate by the water density according to Equation 2.

TABLE 3: FLOW CURRENT CORRELATIONS

Pump Amps	Volume Flow Rate
AMPS<2	0
2<AMPS<4.5	16
8<AMPS<11	21

RESULTS

Table 4 shows the dates, average ambient air and pool water conditions for the periods of baseline and retrofit operation. The table shows that the average pool temperature and the outdoor air conditions for the two periods were very similar. Figure 4 shows the daily average outdoor temperature and humidity conditions for the baseline and retrofit periods.

TABLE 4: AVERAGE AMBIENT AIR, MIXED-RETURN AIR, AND POOL CONDITIONS FOR BASELINE AND RETROFIT PERIODS

	Dates	Avg. Outdoor Air Temp. ºF	Avg. Outdoor Air Relative Humidity	Avg. Mixed Air Temp. °F	Avg. Mixed Air Relative Humidity	Avg. Pool Temp ºF
Baseline	7/21-8/5	71.3	78%	72.5	74.6	78.7
Retrofit	8/16-9/12	71.6	77%	72.7	72.8	78.6

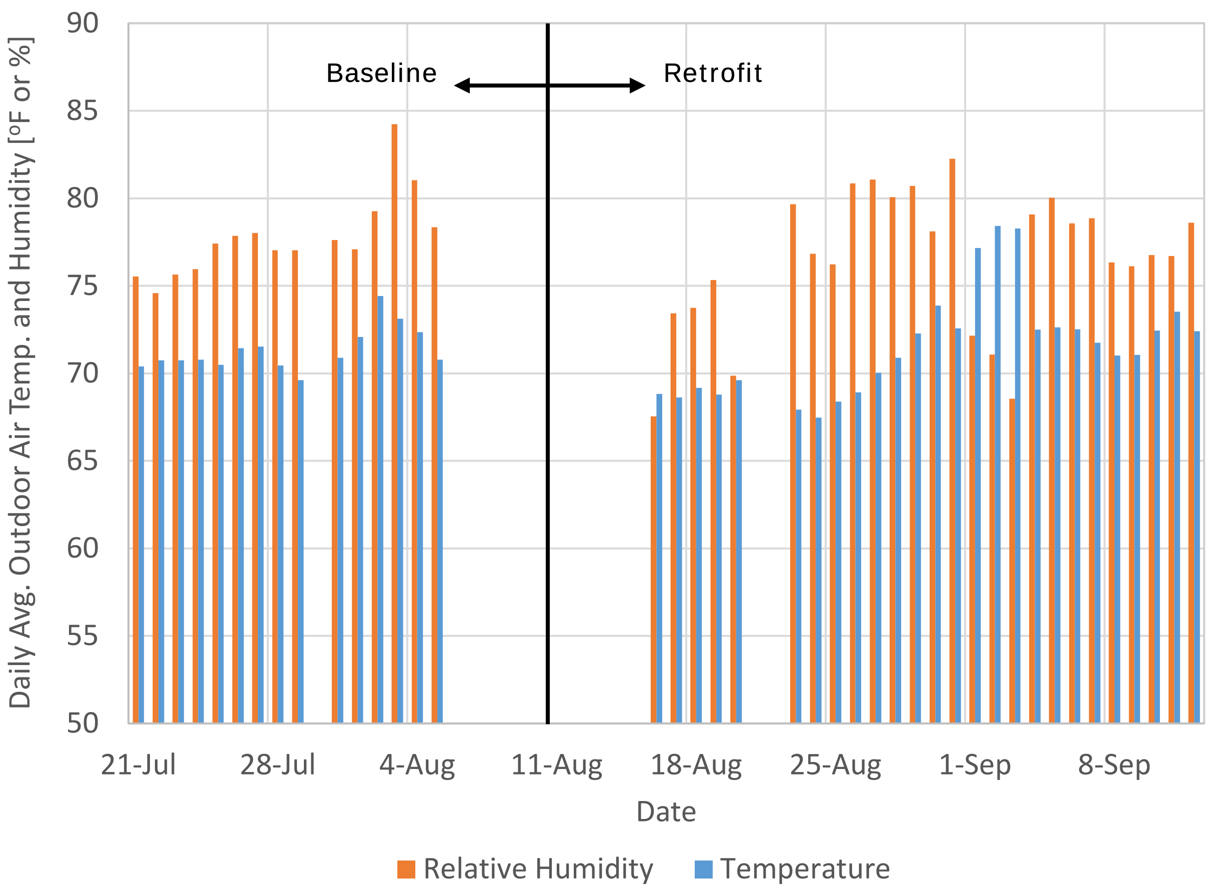

FIGURE 4: DAILY AVERAGE OUTDOOR TEMPERATURE AND HUMIDITY CONDITIONS FOR BASELINE AND RETROFIT PERIODS

Figure 5 shows the energy efficiency ratio (EER) for the baseline and retrofit periods versus outdoor air temperature. Conventional air conditioners are strongly dependent on the outdoor dry bulb temperature whereas the system that rejects heat to the pool is dependent on the pool temperature. The pool temperature range is shaded in grey over the plot and shows a much narrower range of temperature fluctuation. The plot shows that the performance of the two systems was very similar across all outdoor air conditions. There appears to be a slight reduction in performance of the air-source system at temperatures above 85°F, while the water-source system maintains its efficiency. Even when outdoor air temperatures are lower than the pool temperature, the performance of the water-source system was better than that of the air-source mode due to the improved condenser effectiveness when rejecting to water rather than air. On average over the study period, there was about a 5% improvement in efficiency when using the water-source mode with the pool.

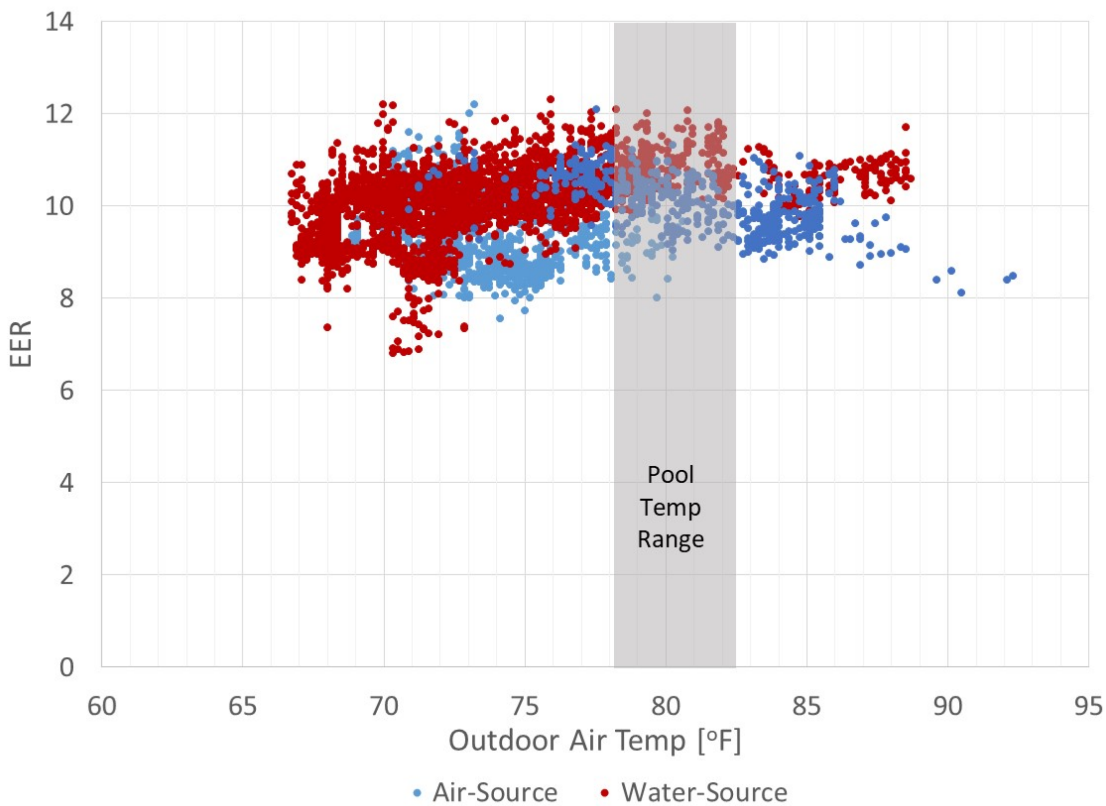

FIGURE 5: EER VS OUTDOOR AIR TEMP

In addition to the reduced energy consumption of the water-source system, there is potential for peak demand reduction considering the maximum pool temperatures only reached about 82°F while ambient air temperatures exceeded 90°F. Figure 6 shows an example of the electricity demand response when heat rejection mode was switched from the water-source to air-source. The plot demonstrates that the change in temperature across the refrigerant/water coil dropped abruptly to 0°F, signaling the switch to air-source heat rejection; simultaneously, the power draw increased 8% from about 6 kW to 6.5 kW. This result was typical of the trends observed throughout the study. The maximum reduction in power draw observed during the study was 12%, and the average reduction was 5% (Figure 7). The reduction in electrical demand increased as the outdoor air temperature increased, suggesting that there may be higher demand savings as outdoor air temperature rises. The site for this study had a mild climate, and other inland sites are more likely to see higher demand reduction. Figure 7 also shows the average gas consumption, in Therms/day, for each period. For the baseline period, the gas consumption averaged 10.7 Therms/day, and the average consumption during the retrofit period was 7.6

Therms/day. This represents a 29% reduction in pool heater gas use during the study period.

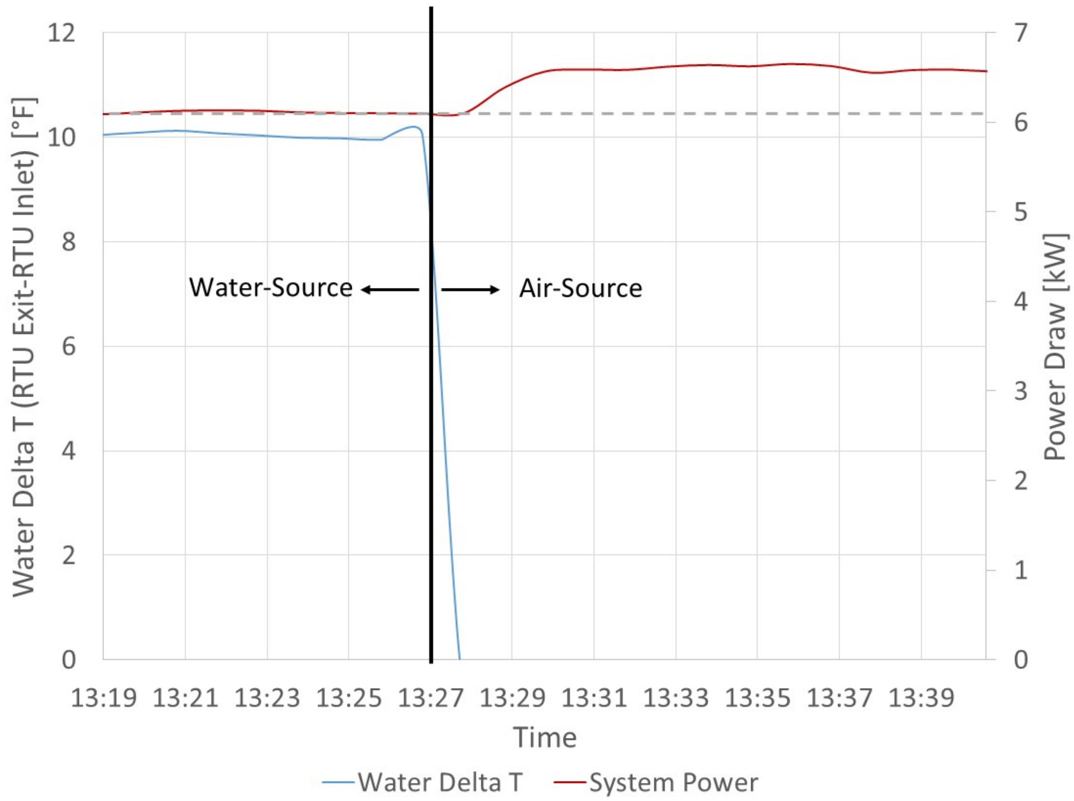

FIGURE 6: EXAMPLE OF ELECTRIC DEMAND CHANGE DUE TO CHANGE IN MODE OF HEAT REJECTION

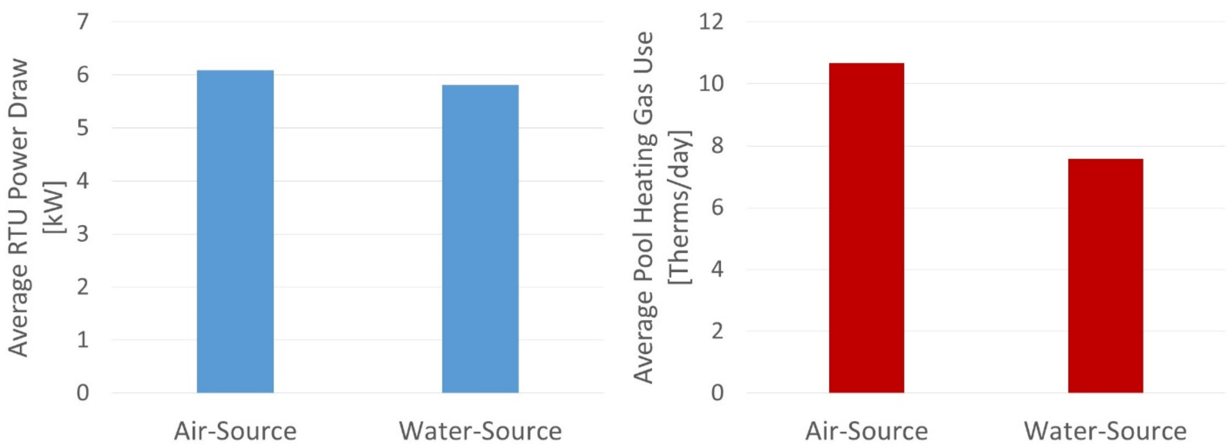

FIGURE 7: BASELINE VS RETROFIT PEAK POWER DRAW AND POOL HEATING GAS USE

Figure 7 shows the average daily profile of pool-heater gas use. The profile shows that the majority of pool heating occurred overnight from 10pm to 10am. Note that the heater gas use was generally out of phase with air conditioning needs for the fitness center, resulting in additional pool heating when the pool may not have required heating. The large thermal mass of the pool allowed the additional heating during the day to carry over into nighttime hours, which accounts for the lower pool-heater gas consumption overnight. Using a pool cover during hours when the pool is closed would be one way to reduce the pool heating needs at night.

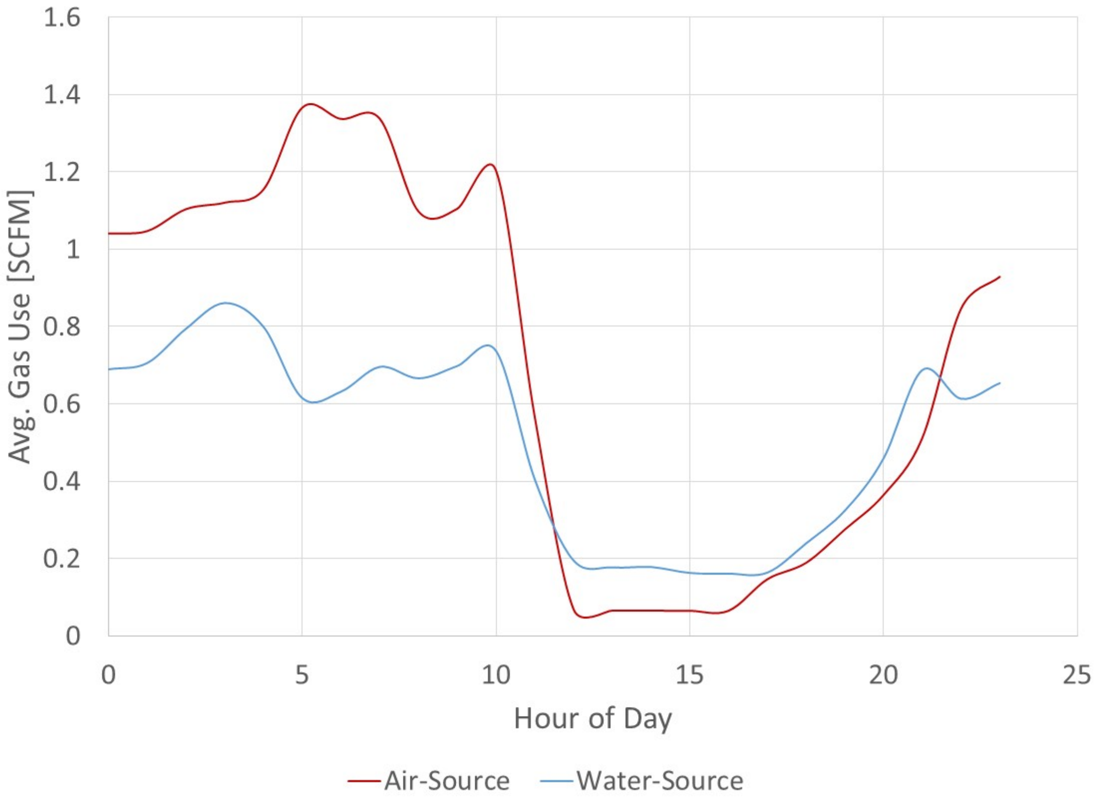

FIGURE 8: AVERAGE DAILY PROFILE OF POOL-HEATER GAS USE

Figure 8 shows an example of the profile of pool temperature and air conditioning heat rejection to the pool over a two-day period during which no gas pool heating occurred. At the beginning of each day, the pool temperature started slightly over 81°F. On the first day, there was a significant amount of air conditioning heat rejection to the pool starting at about 5 AM, which slowed the cooling of the pool. The following day, there was not much air conditioning heat rejection to the pool which caused the pool to cool about 0.5°F more than the prior day. The pool also reached a higher maximum temperature during the afternoon on the first day due to the air conditioning heat added earlier in the morning. This behavior demonstrates how heat added to the pool on one day carried over to the next day, reducing the heating requirements for the pool.

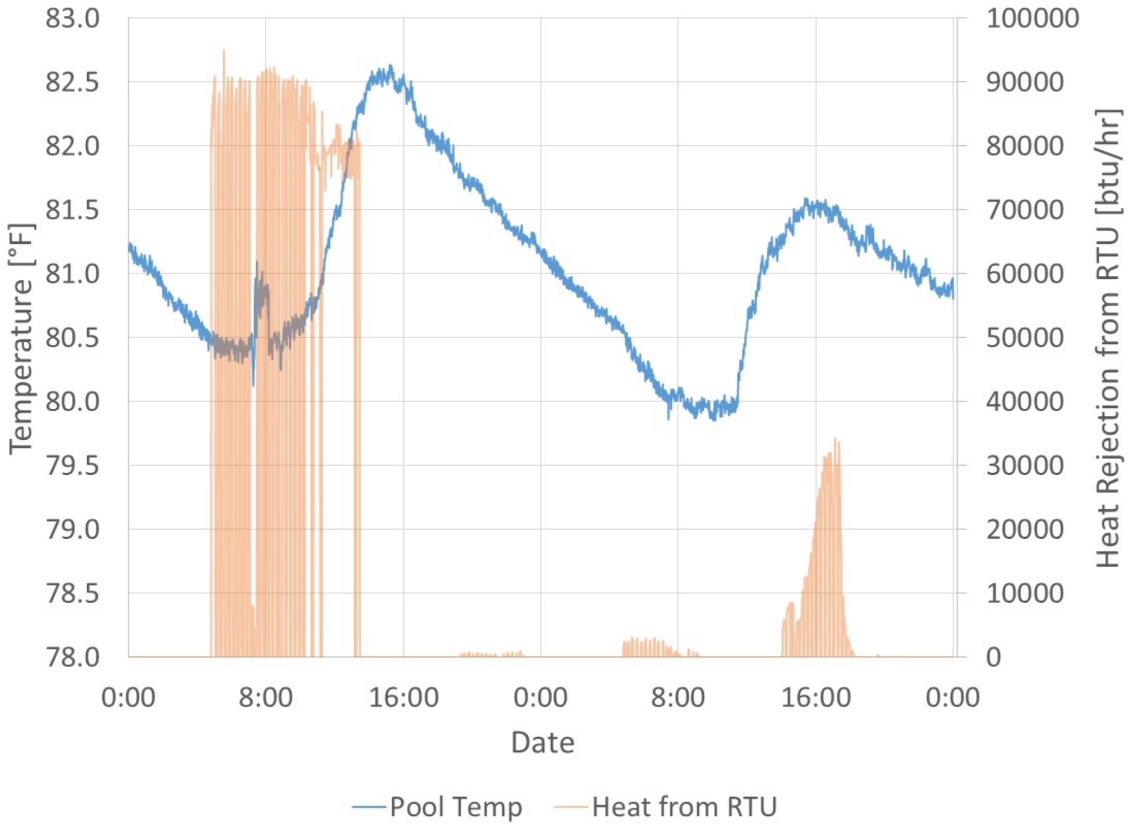

FIGURE 9: EXAMPLE PROFILE OF POOL TEMPERATURE AND AIR CONDITIONING HEAT REJECTION TO THE POOL

DISCUSSION

The results of this assessment show that rejecting waste heat from an air conditioner to a pool can simultaneously reduce natural gas consumption for pool heating and reduce peak power draw for cooling. In addition, the total cooling energy use decreased when rejecting heat to the pool rather than ambient air. The technology performed as expected with lower electricity savings in the relatively mild weather at the site. Electricity savings are expected to be higher at inland locations where ambient air temperatures are hotter; however, gas savings are likely to be reduced due to a reduction in heating requirements for the pool. To maintain gas savings, a smaller air conditioner could be used to heat a larger pool in hotter climates with less pool heating needs. The results highlight the critical need for considering design factors, especially matching the sizing of the pool and air conditioner based on climate and air conditioner loads.

In the demonstration conducted, the technology provided an average of 5% electricity demand reduction, although at times reductions of up to 12% were observed. The demand reductions were fairly consistent throughout the day with between 4% and 7% reductions for each hour when cooling was observed. The highest demand reductions were shown during early morning hours between 5-6 AM and mid-day between 11PM-1PM. Demand reduction is dependent on the ambient site conditions and the pool temperature. With a relatively constant pool temperature, the demand reduction increases as the ambient temperature increases. The pool temperature is another factor in total demand reduction, and demand reduction decreases with increasing pool temperature.

The air conditioning efficiency of the RTU under both air-side heat rejection mode and water-side heat rejection mode was similar with an average reduction of about a 5% attributed to water-side. The energy savings, like the demand savings, were dependent on the pool temperature and the ambient temperature, and the savings are expected to differ from site to site. The site for this study had mild weather, with average outdoor air temperatures of 70°F. Higher savings are expected in a warmer climate.

When rejecting waste heat to water, researchers observed 29% reduction in pool-heater gas use, or a savings of 3 therms per day. The gas savings depend on the pool temperature, pool setpoint, and the RTU run time. In this study, the pool was shaded and in a mild climate requiring more heating than if the pool were unshaded. These factors resulted in more potential for gas use reductions.

This field study shows that the water-source method had improved performance compared to the air-source method, in that it reduced total electricity consumption, gas consumption, and electricity demand. The water-source system is not more complex than the air-source system, and depending on the climate, the only extra maintenance needed for the water-source system would be winterizing. Winterizing would consist of draining the pipes on the roof and would only require a couple of additional inexpensive system components. Using a secondary heat transfer loop would allow a glycol solution to be used in the RTU system preventing the need for winterization.

MARKET BARRIERS

The technology demonstrated was a custom-built RTU, making the cost of the equipment substantially more than a standard RTU. For this project the materials cost alone was three-times the cost of the other standard packaged RTUs that were installed at the same site, and the additional plumbing and structural work due to the increased weight increased the installation costs as well. Other technologies exist that would allow for all of the same operations, but these technologies are not necessarily marketed for operation with a pool. For example, manufacturers of variable refrigerant flow (VRF) systems include options for water heating components to be added, however they recommend that a secondary loop with an additional water-to-water heat exchanger be installed to isolate the VRF system from the pool water. VRF systems are designed for multi-zone heating and cooling in buildings. The pooling heating add-on for the VRF system operates by rejecting air-conditioning heat to the pool water when possible. It also heats the pool water using an electric heat pump to transfer heat from outdoors to the pool when needed. This means that a natural gas pool heater is not required for this design, eliminating the cost of the heater in new construction. The cost analysis for the VRF system would need to account for expected energy savings due to conditioning the indoor space with the VRF, in addition to savings from the pool-heating strategy. While adding water heating capability to a VRF system is estimated to cost about $10,000, the additional isolating heat exchanger is expected to increase the cost to about $20,000 [5].

For retrofit applications, all that is needed is a refrigerant-to-water heat exchanger installed in parallel with the existing condenser unit. This solution maintains the air-source condenser coil and gas furnace. HotSpot Energy sells a system precisely for this application, which costs about $2,000 for a 5-ton system plus installation costs (estimated at about $1,500 for residential applications where air conditioning equipment is close to pool filtering equipment) [6]. There are also water-source heat pumps, but with this technology there would be no option for rejecting heat to air to prevent overheating of the pool, and they typically do not include a gas furnace for heating.

An additional barrier to the technology is maintenance as contractors may not be familiar with the technology. While it is a relatively simple concept, if maintenance contractors do not understand the basic functionality of the system then it could lead to inappropriate thermostat setpoints for pool temperature, preventing the system from rejecting heat to the pool. This is precisely what occurred in this project when the custom HVAC unit was commissioned to reject to the pool whenever the pool was 80ºF, while the existing pool heater setpoint was 82F, meaning that the custom HVAC unit would never trigger the water rejection mode. The RTU in this study was essentially the same as a conventional system other than the water-source condenser, meaning that all other maintenance was identical.

Researchers performed a cost analysis based on the electricity and gas savings results from this demonstration (Table 5). The savings were based on a 29% reduction in gas use, 5% reduction in electricity use, and 12% peak reduction. The cost savings estimates were based on six months of performance similar to the performance observed in the monitoring period.

TABLE 5: COST SAVINGS ANALYSIS

Category	Estimated Annualized Savings	Unit	Cost per Unit (using blended rate)	Annual Cost Savings
Natural Gas	565	Therms	$1.00	$565
Electricity Super Off-Peak 12am-6am	17	kWh	$0.18	$3
Electricity Off-Peak 6am-4pm	180	kWh	$0.18	$32
Electricity On-Peak 4pm-9pm	83	kWh	$0.18	$15
Electricity Off-Peak 9pm-12am	26	kWh	$0.18	$5
Total Cost Savings	-	-	-	$620

The cost of the retrofit in this study was much higher than what would be expected with a more mature technology. Assuming the cost of an auxiliary water/refrigerant heat exchanger as a retrofit to an existing RTU is $3,500, the simple payback for this technology would be 5.6 years.

CONCLUSIONS AND RECOMMENDATIONS

This assessment documents the measured natural gas, electricity energy and demand reduction associated with rejecting waste heat from an air conditioner to a pool rather than ambient air at a hotel fitness center near the coast in San Diego. The results show that even in mild climates, a single 5-ton RTU can offset a significant amount of natural gas required for pool heating. Natural gas for pool heating was reduced by 29% during the observation period in the summer of 2017. Electricity savings were a result of improved heat exchanger effectiveness using water rather than air and reduced heat sink temperatures during peak periods. With a more mature technology, the payback estimated for the technology is less than five years.

The results also showed the impact of pool and RTU size on the behavior of the system, and highlight the importance of design tools to maximize performance. This installation was characterized to have a relatively large pool compared to the air conditioning load rejected to it. The pool was therefore able to absorb the load from the air conditioner without overheating during the monitoring period. Supplemental pool heating with a gas heater was used to maintain pool temperature setpoints at night when air conditioning was not used.

To increase adoption of the technology and provide appropriate utility program incentives, the impact of the technology as a function of climate, pool size, air conditioner capacity, and air conditioner load factor would need to be quantified through modeling. A previous effort validated a model for predicting the thermal behavior of a pool in multiple climate zones. The results from the work presented in this report provide an excellent data source to verify model accuracy for a heated pool in San Diego. The WCEC proposes that a tool be developed to estimate gas and electricity saving potential of air conditioners connected to heated pools. The tool would take into account the air conditioner size, existing heater efficiency, and specific pool parameters to estimate the impact.

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