Continuous Commissioning® And Energy Management Control Strategies at Alamo Community College District

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ABSTRACT

This paper presents an overview of energy savings through the optimization of facility Heating, Ventilation, and Air Conditioning (HVAC) systems for the college campuses of the Alamo Community College District. This Continuous Commissioning® process includes energy management control strategies that focus on utility rate structures. Detailed commissioning activities of the College district and Central Plants are discussed and documented, and overall savings are provided.

Continuous Commissioning® (CC®)[1] of the Alamo Community College District (ACCD) main campuses located in San Antonio, Texas began in June 2002. The three largest campuses, San Antonio College, St. Philips College, and Palo Alto College underwent the CC® process. The project was completed in August of 2006. The success of the initial project created the opportunity to expand the CC ® process throughout the college district. Utility data was provided by the Alamo Community College District in conjunction with the local municipal utility company.

ACCD's enterprise energy strategy to achieve persistence of savings is to closely monitor savings deviation and by training facility HVAC personnel at each campus in the Continuous Commissioning® processes as well as the District-wide metering of individual building energy consumption; and the development of a strategic, District-wide Energy Management Plan.

INTRODUCTION

Implementation of Continuous Commissioning measures specific to the Alamo Community College District (ACCD) in San Antonio, Texas was performed by the Energy Systems Laboratory (ESL) of Texas A&M University and the Facility Division of ACCD. The CC measures were implemented on the three largest college campuses, San Antonio College (930,340 ft^2), St. Philips College (544,908 ft^2), and Palo Alto College (350,321 ft^2). Also included in the project were selected administration buildings located throughout San Antonio.

The overall project included Energy Cost Reduction Measures (ECRM's) which focused on the replacement and/or retrofitting of the existing heating, ventilating, and air conditioning (HVAC) equipment. ESL and ACCD facility personnel formed CC teams at each campus and worked together to implement the potential energy saving opportunities identified in the initial CC assessment report, which ranged from variable air volume terminal box calibrations to central plant optimization for each campus. The Continuous Commissioning process began in June of 2002 and continued until August of 2006. The success of the initial project created the opportunity to expand the CC ® process throughout the college district. Phase II began in September 2007 and in presently underway.

[1] Continuous Commissioning® and CC® are Registered Trademarks of the Texas Engineering Experiment Station. Contact the Energy Systems Laboratory, Texas A&M University for further information. For clarification, the ® trademark symbol will not be used in the remainder of this paper.

Summarized information on the District-wide CC measures implemented will be provided, followed by a savings analysis. The savings analysis is based on weather-normalized gas and electric consumption information provided by the Alamo Community College District in conjunction with the local utility provider.

CAMPUS DESCRIPTION

ACCD had 5 campuses and 4 administration buildings at the beginning of this project (2002). This project, however, only impacted 3 campuses and all 4 administration buildings. The three largest campuses, San Antonio College, St. Philips College, and Palo Alto College underwent the CC® process. Each college campus has a central plant which provides chilled water and hot water for the majority of the buildings. There are a few buildings on each campus that operate in a standalone mode, where they provide their own chilled water and hot water. All three campuses use a primary/secondary distribution system for each of their chilled water and hot water systems. Figure 1 shows the typical chilled water system found at the three campuses. The only difference between each campus system is the number and/or capacity of the chillers.

The design intent of each building is typical of most colleges and universities, designed as classrooms and science labs. It was found that classroom spaces were often being converted into computer labs, especially in older buildings. In some cases, comfort became an issue because the functionality of the space changed without making appropriate changes to the HVAC system and operations.

The types of air handler systems used throughout the district campuses varied. For instance, San Antonio and St. Philips College had single duct variable air volume systems as well as single and multi-zone constant volume air handlers. A few dual duct variable air volume air handlers are in operation at San Antonio College. Palo Alto College is similar to the other campuses; however, the majority of the air handlers are constant volume air handlers serving variable air volume distribution systems. In other words, only the terminal boxes are variable air volume.

The hours of operation for the district are from 6:00 AM – 11:00 PM, Monday through Friday. Campuses are also open on Saturdays for continuing education courses.

Energy monitoring strategies for the district were limited. Electrical meters were found in each building throughout the campus. San Antonio College had additional thermal metering for each building. Chilled water flow control valves were installed on each building to control the amount of chilled water used. No documentation as to the amount of chilled water required for each building was found. The data being collected by the energy management control system was not being used to its full potential. Two different energy management control systems are installed at each campus.

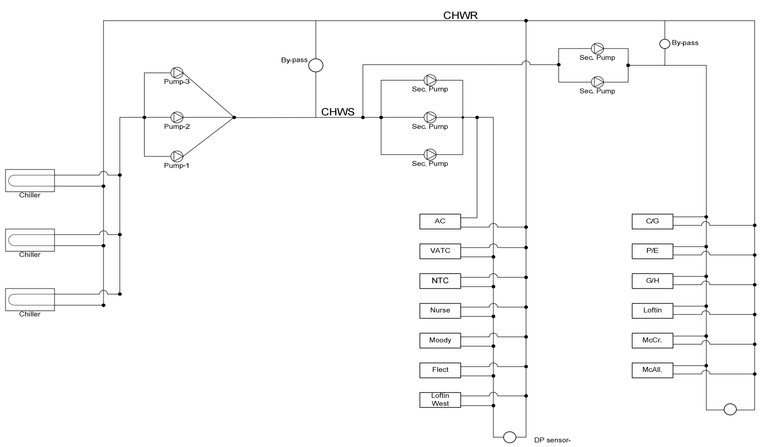

Figure 1: Typical chilled water distribution system.

Half of the buildings are on control system "A" and the other half are on control system "B", with the central plant being on one of the control systems. In situations like these it is very difficult to coordinate control systems. To add to the situation, the control systems are pneumatic hybrids, pneumatic transducers and EP switches translate analog output signals to pneumatic signals for actuator control.

OPERATING CONDITIONS PRIOR TO CONTINUOUS COMMISSIONING

ACCD buildings and central plants are very well maintained. Each campus HVAC division is staffed with extremely knowledgeable personnel and has a very good preventative maintenance program. However, there was room for improvement in the control system area or Energy Management Control System (EMCS).

The initial assessment in 2002 by the ESL of each campus HVAC system operation identified similar issues. Central plants were operated 24/7, running at full capacity and air handlers were being turned on earlier than necessary. Normally classes begin at 8:00 AM every morning but the air handlers were turned on at 4:00 AM, all at one time. This creates a huge electrical demand at start-up.

The typical air handler schematic for the CAV and VAV systems is shown in Figure 2. In some instances VAV air handlers were equipped with return fans and used return air volume tracking control strategies.

This basically means that the return air fan tracks the supply fan by an airflow differential, where the differential is theoretically the amount of outside air being drawn into the air handler. The discharge air temperature algorithms used throughout the district were intended to maintain constant value of 55°F, regardless of outside temperature. For dual duct units, the hot deck temperatures were maintained at 140°F year round. Similar algorithms were used for supply air static pressure. Constant setpoint values ranging from 1.5 to 5.0 in H_2O were used, depending on the system. And, in some of the "canned" software programs, supply air temperature reset schedules based on return air temperature were used.

Economizer capabilities varied at each campus. San Antonio and St. Philips Colleges had a few buildings with air handlers that were not designed with economizers. Every air handler at Palo Alto College was designed with economizer capability. The typical economizer control strategy, used district wide, was based on maintaining a mixed air temperature setpoint of 55°F. The control strategy enabled the economizer when the outside air temperature was below 55°F. If the mixed air chamber got too cold, the preheat algorithm would activate and warm the air. In order to meet the discharge air temperature setpoint, the chilled water valve would open. This type of control strategy can result in wasteful simultaneous heating and cooling. Enthalpy based economizer strategies were also found disabled at San Antonio and St. Philips Colleges. The relative humidity sensors became unreliable after being exposed to saturation conditions for extended periods.

Fan-powered terminal boxes with hot water reheat are the typical configurations. The minimum air flow setting in each terminal box was found to be approximately 50% of the maximum airflow setting. Many of the terminal boxes were operating in heating mode during the summer time, creating unnecessary cooling loads for the chilled water system. Very few terminal boxes were set up on DDC (Direct digital control). The majority of the terminal boxes are pneumatic and required calibration.

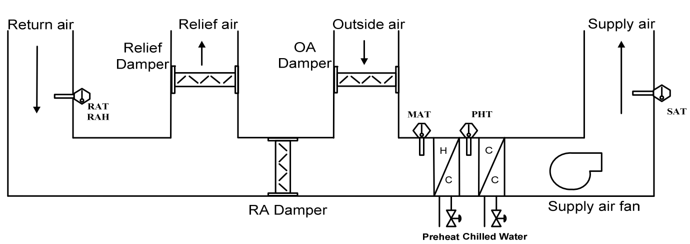

Figure 2: AHU Schematic

The central plants at the San Antonio and St. Philips Colleges operated continuously (Chillers and boilers), mainly because some of the building air handlers were not designed with economizers. When free cooling was available (outside air temperature below 55°F) these buildings can only use mechanical cooling. Because Palo Alto College air handler units were designed with economizers, the central plant could be turned off when outside conditions allowed, typically below 55°F.

Excessive pumping power was also identified for the chilled water and hot water distribution systems at each campus. The secondary chilled water differential pressure control algorithms for San Antonio and Palo Alto Colleges maintained constant setpoint values, 30 psi and 18 psi, respectively. The hot water systems maintained similar values. At St. Philips, the chilled water differential pressure was maintained at 15 psi. A campus wide steam distribution system is used at St. Philips with heat exchangers located in each building for hot water generation. No differential pressure control algorithms existed for hot water.

CONTINUOUS COMMISSIONING (CC)

Prior to the implementation of the CC process at each campus, CC teams were developed, consisting of the campus HVAC foreman, EMCS technician, maintenance staff, and ESL Engineers. At the beginning of each site visit the CC team would be briefed on CC measures to be implemented. While working in the field, the CC Engineer would work side-by-side with the HVAC staff. This allows the technicians to better understand the CC methodology and provide input.

The potential CC measures that were implemented at ACCD were approved by the Director of Facilities and/or his designee and are listed in the following sections.

Terminal Box Optimization

Initial observation of the terminal boxes throughout the district indicated that all single duct VAV terminal boxes required calibration. The main issue with trying to calibrate the terminal boxes was that they were pneumatically controlled and were very time consuming. Box calibration had to be scheduled during nights and weekends. This was the preferred solution so that it would not affect the normal class schedules. Terminal boxes that were on DDC were randomly spot checked. Representative samples were taken to determine if calibration would be required. DDC terminal boxes were mainly used on the dual duct systems.

The calibration procedure for calibrating the pneumatic controllers required that the terminal box be commanded to full cooling and then heating through the use of the pneumatic thermostat. The key adjustment that was made to the controllers was the minimum airflow setting. The minimum airflow settings were found to be approximately 50 % of the maximum airflow setting. This often requires the use of reheat at the terminal box to keep the space served by the terminal box to an acceptable comfort temperature (72-74°F). The minimum airflow setting was reduced to 20% of the maximum airflow setting by the CC team. By making this key universal adjustment to the VAV boxes, it has positively impacted the operation of the HVAC systems. VAV air handlers began reducing fan speeds and the amount of reheat used to condition the spaces also reduced

Air Handler Optimization

AHU Occupied/Unoccupied Schedules.

Based on walk through surveys and information provided by ACCD facility personnel it was determined that runtime hours for the air handlers could be reduced. Trend data analysis indicated that most spaces could be conditioned to a temperature range of 72-74°F within thirty minutes of air handler startup. Therefore the original starting time of 4:00 AM was delayed until 6:00 AM. However, keeping in mind the energy utility rate schedules it would not be beneficial for ACCD to start all their equipment up at one time. Staggering building startup on time intervals would help keep electrical demand to a minimum. For example, the campus has 20 buildings and they need to be at occupied conditions by 7:30 AM. If students arrive early for class, then the air handlers need to be started by 7:00 AM. This means that at 6:00 AM the first set of 5 buildings need to be started. The second set of 5 buildings would then be started 15 minutes later and the remaining set of 5 buildings thereafter until all the buildings are in operation.

Supply Air Temperature Reset Schedules

Linear reset schedules based on outside air temperature were implemented into the air handler control strategies on all three campuses

(See Figure 3). The standard supply air temperature reset schedule algorithm for the air handlers sets the supply air temperature to 64°F when the outside air temperature is 40°F or below. When the outside air temperature rises to 70°F or above, the supply air temperature setpoint reduces and maintains 55°F. The supply air temperature setpoint will vary linearly between the maximum and minimum settings based on the outside air temperature. There are a few deviations to the basic reset schedule. For example, air handlers that serve interior and exterior zones can develop hot spots because of the warmer supply air temperature. A more conservative approach was taken; the maximum setting for the supply air temperature setpoint must be reduced to 58°F.

Static Pressure Reset Schedules.

Static Pressure reset schedules have been programmed into all VAV air handlers control strategies.

The typical static pressure reset schedules are linear and based on outside air temperature. The static pressure maximum and minimum setting are based on field measurements and varied. Figure 4 shows a typical static pressure reset schedule based on outside air temperature implemented at ACCD. The use of static pressure reset schedules will reduce energy consumption during the fall and spring time periods as cooling loads are typically lower as compared to summertime.

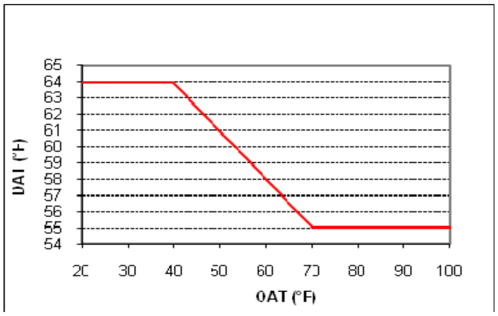

Figure 3: Typical supply air temperature reset schedule based on outside air temperature.

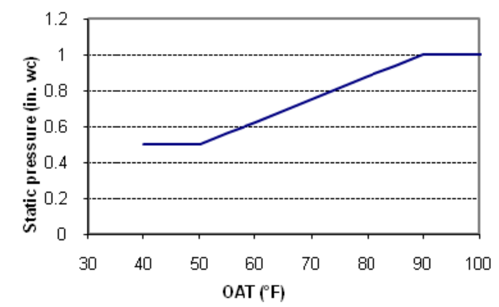

Figure 4: Typical static pressure reset schedule based on outside air temperature.

Humidity control.

Based on the initial assessment it was determined that the relative humidity sensors used to monitor and control space relative humidity needed to be replaced. The faulty sensors were causing the control system to enable humidity control when it was not needed. Humidity sensors were replaced and relative humidity setpoints were adjusted, not to exceed 55%. In some cases the humidity setpoints were as low as 45% and as high as 65%. Additional point configuration was done to enable the point alarm if the humidity sensor became unreliable or exceeded their limits.

Economizer mode.

Originally, the economizer control strategy was based on mixed air temperature. The mixed air damper modulated to maintain a programmed mixed air temperature setpoint. This control strategy was modified to incorporate the discharge air temperature in lieu of the mixed air temperature. The mixed air dampers now modulate to maintain a discharge air temperature setpoint minus 2°F. The 2°F offset is used to compensate for heat generated by the fan and stage free cooling with mechanical cooling. The mixed air temperature sensor is now only used as a troubleshooting reference point.

Enthalpy based economizer control strategies which were operating with unreliable humidity sensors were removed and replaced with fixed dry bulb temperature based economizer control strategies. The control point for economizer was set at 65°F (dry bulb). According to ASHRAE standard 90.1-2007 economizers are not required in the region for which ACCD resides (Climate region 2A). However with the modifications made to the economizer algorithms ACCD, has been able to benefit from the use of free cooling (Zhou, 2008).

As part of the freeze protection strategy, the preheat coil will modulate to maintain the preheat temperature setpoint of 45°F. At this temperature, the preheat coil does not conflict with the dampers or cooling coil. In very cold weather when the damper is at minimum outside air, the preheat air temperature could drop below 45°F. This will enable the preheat valve, even if the air handler shuts down during unoccupied time periods.

Simultaneous Heating and Cooling.

The possibility of central station heating was eliminated at the air handler level by reducing the preheat setpoint from 50-52°F to 45°F, depending on the air handler program. All the heating is now being done at the terminal box level by the reheat coil. This control strategy has performed well in most cases because many of the air handler systems serve interior and exterior zones. The interior zones will typically be in cooling mode regardless of outside ambient conditions while the exterior zones, which can be influenced by outside ambient condition, can be in either heating or cooling mode.

Central Plant Optimization

Hot water/steam system.

Hot water supply temperature reset schedules based on outside air temperature were implemented for the hot water systems(see Figure 5). When the outside air temperature reaches below 30°F, the maximum hot water supply temperature setpoint is 140°F. When the outside air temperature reaches 70°F the minimum hot water supply temperature setpoint of 100°F is reached. The hot water supply temperature will vary linearly as the outside air temperature varies between its maximum and minimum settings.

The clinic and hospital PCU pumps were programmed to turn off when the outside air temperature reached above 70°F. Turning off the hot water to the reheat coils for non-critical areas reduced the natural gas consumption and indirectly made a positive impact on the chilled water consumption for the hospital and clinic during summertime operation.

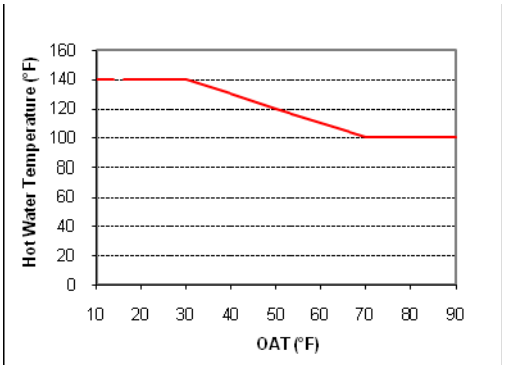

Figure 5: Hot water reset schedule.

Chillers, and Secondary Chilled Water Loop.

The San Antonio College and St. Philips College central plants used similar control algorithms. Chiller staging was optimized based on chiller run load amp percentage (RLA %) and chilled water reset schedules were implemented. St. Philip's chillers plant used return water as the basis for resetting the chiller supply water temperature. San Antonio College's Chiller plant used run load amp percentage to reset the chiller supply water temperature. Initially both central plans were able to be shutdown at night for at least 5 hours. However, St. Philips was not able to continue because of server rooms that required 24 hour cooling. Supplemental cooling was recommended as a means to shutdown the plant on a permanent basis.

Palo Alto College's chiller plant control strategy was different. Optimization was limited because of sensor inputs and obsolete equipment. Chiller staging was based on supply water temperature and chiller ΔT. Chiller supply water temperature resets were not able to be implemented because of obsolete equipment. Upgrades to the chiller controls were recommended and will be implemented in the future.

Differential pressure reset schedules were implemented into the secondary pump control strategy for all three campuses. San Antonio College had the largest reduction in differential pressure. The original differential pressure was 30 psi. It was reduced to 4.5 psi. However, the loop ΔT for all three campuses was extremely low, indicating over pumping and inefficient use the chilled water. Once the loop ΔP's were reduced, slowing the water down, the ΔT began to increase. St. Philip's chilled water loop improved the most, from a ΔT of 4°F to 13°F.

Boiler plant optimization

Limited boiler controls were available. They are staged on and off based of supply water temperature and are operated 24 hours a day. The simplest way to reduce energy consumption was to turn the boilers off when the outside air temperature was above 60°F. This simple CC measure made the largest impact at ACCD. There was no need to operate the boilers at 140°F during the summer. Palo Alto College was the only campus that could implement automatic control logic to enable and disable the boilers based on outside air temperature. San Antonio College Facility personnel have to manually turn off their boilers.

UTILITY RATE SCHEDULES

It is not uncommon for large corporations as well as large universities or colleges such as ACCD to be classified as a large power service by the utility provider. The electrical rate schedules that are typically used what is called a demand ratchet schedule. During summer billing, usually between June through September which are considered high electrical demand periods, are monitored by the utility company. The highest kilowatt (peak demand) that is recorded in a 15 minute period during these months is used to set what is known as the ratchet. During the remainder of the months, October through May of the following year, a percentage of the peak will be used for billing. Normally the utility provider will provide a set of conditions in their rate schedule as to the billing scenarios. For example, during the months of June through September the monthly demand can be based on actual monthly demand or a set minimal demand value, whichever is larger. For the remainder of the year or the ratcheting period, the rates are similar. Billing demand can be based on the actual demand, a set minimum value, or a percentage of the highest peak demand measured during the summer months, whichever value is the greatest.

ENERGY MANAGEMENT CONTROL STRATEGIES

Throughout this paper, control strategies are mentioned as part of the overall CC process. In some instances control strategies were developed and targeted at cost savings from utility rate schedules. Control strategies implemented by ACCD consist of:

1) HVAC System Optimization via CC
2) Utility Rate Structures
3) Central Power Plant Optimization

The simplest and one of the most effective energy management strategies that target the demand rate schedule are the occupancy schedules. Originally buildings throughout the district were brought online simultaneously, creating high electrical demands. To reduce the demand buildings were brought online in groups and in 15 minute interval. Basically a trade-off between demand and consumption charges was made. Paying for kilowatt hours (kWh) is normally cheaper that paying for kilowatts (kW).

An important control strategy implemented at ACCD was the chiller staging. While working onsite during the summers, it was notice that there were excessive electric power bumps during the peak load of the day which caused the chiller plants to go offline and then be automatically restarted by the controller. There was no sequence of operations provision in the existing programming to limit the number of chiller coming online at once. Therefore once the controllers rebooted all the chiller and their associated pump would start.

To correct this problem situation and preclude setting a new peak demand load, ESL developed a sequence of operations that would limit the number of chillers during normal staging and whenever a power bump occurred. When the lead chiller cannot maintain the cooling and the lag chiller was called, the lead chiller would unload to a predetermined condition and maintain that condition until the lag chiller started and reached the same condition as the lead. Once these conditions were met, the chillers were released to a normal operating mode. In the event that a power bump occurred, the chiller would restart in the original staging sequence but would be limited to 50 % of its RLA (Run load amps) for 30 minutes and then be released to normal operation. All the parameters in the demand limiting are adjustable, including the time duration so that the sequence can be optimized for each facility.

SUB-METERING

As part of the CC process, ACCD requested that all building electrical meters be verified by ESL. Meters that were found to be reading incorrectly were identified, replaced, and re-verified. All building electrical data is now being collected by their energy management control systems. ACCD has made a significant investment in sub metering their existing buildings as part of a district wide metering plan which will be used to identify buildings that need attention and/or retrofit projects. This will also be instrumental in closely monitoring and identifying any savings deviation.

PERSONNEL TRAINING

In addition to the development of a district – wide metering plan, ACCD sent individuals from their HVAC divisions to formalized training provided by their local controls company. It was found that most facility personnel did not understand how to navigate their control systems and were not using them to their full extent. Technicians that have had formalized training are more productive and offer more value to their employer.

Much of ACCD's energy training through the CC process was provided by the ESL field Engineers. Engineers and HVAC technicians working side-by-side proved to be valuable. If problems occurred while the ESL Engineer was off-site, the HVAC technicians were able to address the situations and resolve them. As mentioned previously, this is a team effort.

ENERGY MANAGEMENT PLAN

In conjunction with the development of a district-wide metering plan, ESL is assisting ACCD with the development of an Energy management plan, in accordance with the State Energy Conservation Office (SECO) Senate Bill 12 and HB 3693 which requires state agencies to implement all cost-effective energy-efficiency measures to reduce electric consumption by existing facilities; adopt a goal of reducing electric consumption by 5 percent a year for 6 years, beginning September 1, 2007; and report annually to SECO.

SAVINGS ANALYSIS

Determination of savings for all of the ACCD campuses is based on option C of the International Performance for Measurement and Verification Protocol (IPMVP) which corresponds to Whole–facility energy measurement. Actual monthly utility charges and meter readings were provided by ACCD Facilities and the local utility provider. The energy consumption data of each campus was weather normalized to generate baseline consumption models. These models were applied to the post CC period weather conditions to determine the energy use that each campus would have had if the Continuous Commissioning measures were not applied. The difference between the actual consumption in the post CC and the estimated energy consumption from the baseline models provides the energy savings. The cumulative electricity, electric demand, and gas savings at these three campuses total approximately $2,981,568 for the time period between June 2002 and March 2006, approximately 70 months (See Figure 6). This includes the savings from Continuous Commissioning, replacing the cooling tower, and a comprehensive lighting retrofit. The total savings-to-date based on 2002 utility rates is $2,155,099 since June 2002.

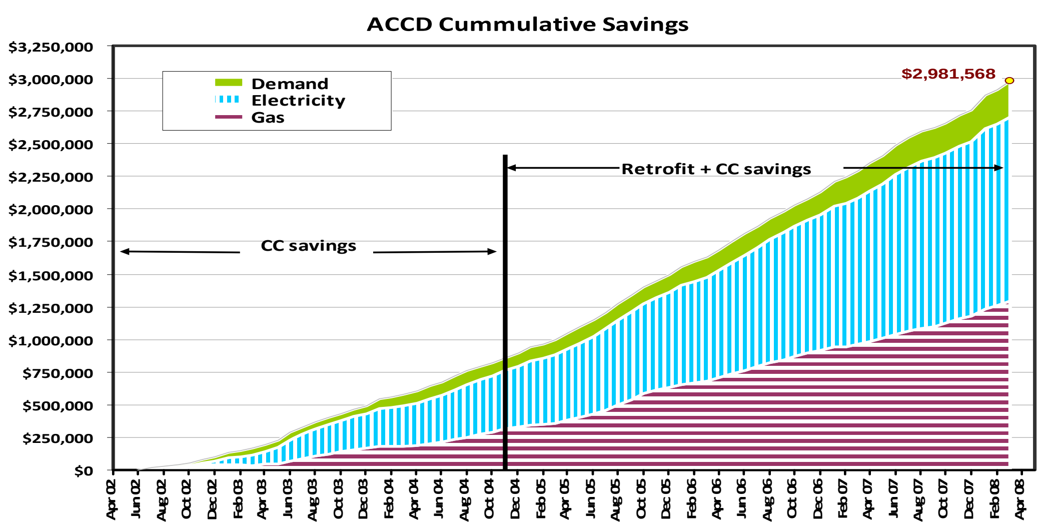

Figure 6: Cumulative Energy Cost Savings at PAC, SPC, and SAC (Based on Actual Utility Rates)

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