Continuous Commissioning® of the Austin City Hall

Carlos Yagua Jijun Zhou, P.E. Guanghua Wei, P.E. Song Deng, P.E. Dan Turner, Ph.D., P.E.

Energy Systems Laboratory, Texas A&M University
College Station, Texas

James Parker, PMP
City of Austin - Austin Energy
Austin, Texas

ABSTRACT

This paper presents a case study of a Continuous Commissioning[1] (CC) project performed at the Austin City Hall. Various CC measures were implemented and significant energy savings were achieved. The paper illustrates a successfully executed CC project can make an already-efficient building even more energy efficient without compromising occupant comfort.

INTRODUCTION

Newly built in 2004, Austin City Hall is a four-story building located at downtown Austin, Texas and has approximately 115,000 ft^2 of conditioned space. The facility has a 3-story below-the-ground parking garage with 750 parking spaces. In 2006, the building received LEED Gold certification from U.S. Green Building Council, becoming only the second city-owned building to receive such designation in the city. In March 2007, the Energy Systems Laboratory (ESL) of the Texas A&M University was invited to perform an energy assessment of the building and many energy savings opportunities were identified. In early 2008, the ESL was contracted to perform Continuous Commissioning to improve the building's energy performance. The commissioning process involved developing new control sequences and modifying existing control sequences for many HVAC components, including various reset schedules for air handler units (AHUs), terminal boxes, chilled water and hot water loops. Economizer operations for all single duct AHUs were implemented to take advantage of "free cooling" during winter months. Outside air (OA) flow for each AHU was adjusted based on actual needs. Operation schedules were fine-tuned so the AHUs, the chilled water and hot water pumps would only operate when required. Also, several devices and control sensors were calibrated to maintain more accurate and stable control. The CC measures implemented by the ESL made a positive impact on improving the building's energy efficiency. Energy cost savings achieved during the first 12 months since the beginning of the CC project (June 2008 – May 2009) amounts to $70,151 based on actual utility rates. Projected annual savings by the end of 2009 are $78,000, representing 17.2% of the annual utility costs during the baseline period.

HVAC SYSTEMS

The HVAC system is composed of a chilled water heat exchanger, boilers, chilled water and

---

[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.

hot water pumps, ten (10) air-handling units (AHUs), several fan coil units (FCUs), and computer room air conditioning (CRAC) units.

The hot water is supplied by three 2,000 MBTH boilers that operate in sequence as they are needed. There are two 25 hp variable-speed hot water pumps that maintain a constant hot water differential pressure (DP) of 10 psi. The DP sensor is located in the penthouse mechanical room at the end of the loop. A three way mixing/bypass valve in the boiler plant maintains the hot water loop supply temperature setpoint. The schematic of the hot water loop is shown in Figure 1.

The chilled water was provided by utility provider directly through a water-to-water heat exchanger. Two 25-hp variable-speed chilled water pumps maintain a constant chilled water loop DP of 10 psi. The DP sensor is also located in the penthouse mechanical room.

There are 8 single-duct VAV AHUs. These units serve mostly office spaces, conference rooms and common areas. AHUs 5, 6 and 9 have cooling and reheat coils on the mixed air duct to maintain the discharge air temperature, as seen on Figure 2. The VFD modulates to maintain the duct static pressure setpoint. AHUs 1, 2, 3, 4 and 7 have the main preheat and cooling coils located on the return duct, and have preheat and cooling coils on the outside air (OA) duct to pre-treat the OA and maintain the space relative humidity levels, as seen on Figure 3. The single-duct VAV units feed conditioned air to VAV boxes throughout the building. VAV boxes serving perimeter zones are equipped with reheat coils whereas the zones serving interior zones are cooling only. There are 2 single-zone AHUs: AHU-8 is a single-zone VAV unit serving the city council chamber, and AHU-10 is a single-zone constant volume unit serving the walking tunnel that connects the City Hall to a nearby building. AHU-10 has the configuration shown in Figure 2, and AHU-8 has the configuration shown in Figure 3, except that they don't possess duct static pressure sensors. Of all 10 major AHUs, AHUs 1 and 9 are required to run 24/7.

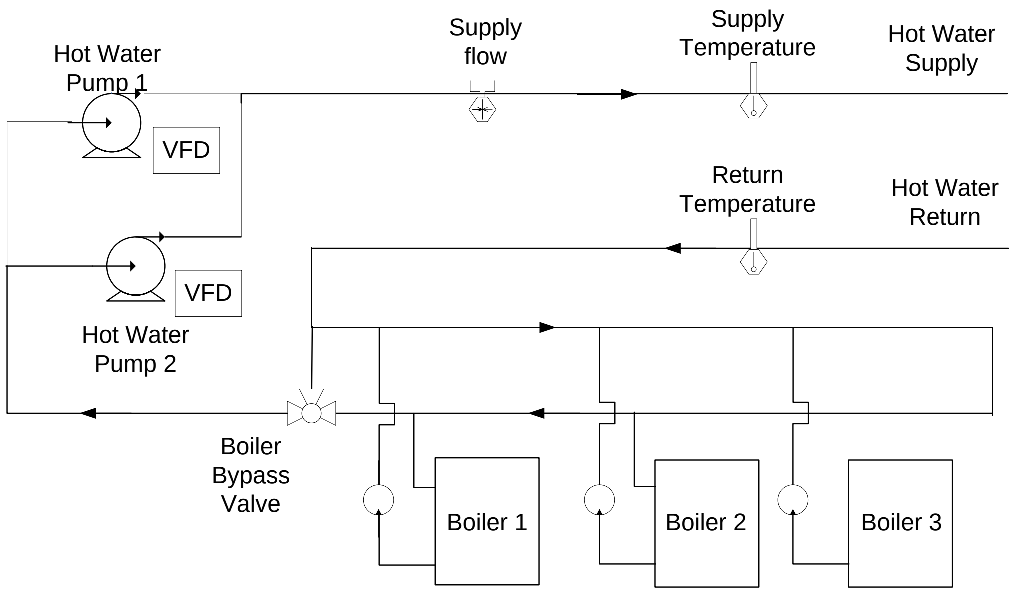

Figure 1. Schematic of the Hot Water System

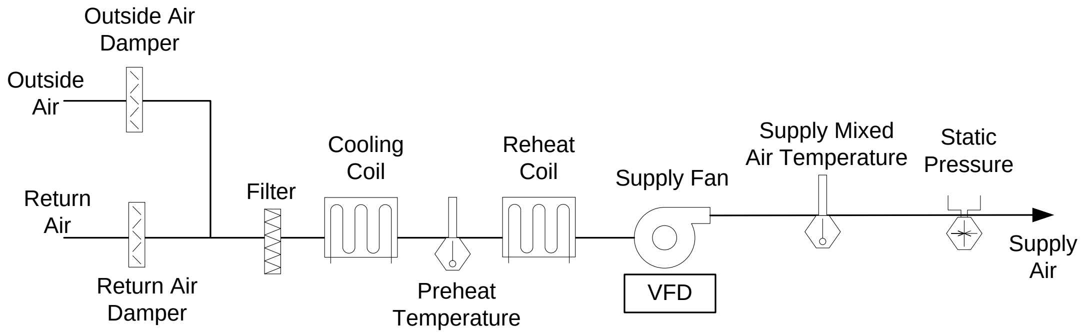

Figure 2. Single-duct VAV AHU (AHU-5, 6 and 9)

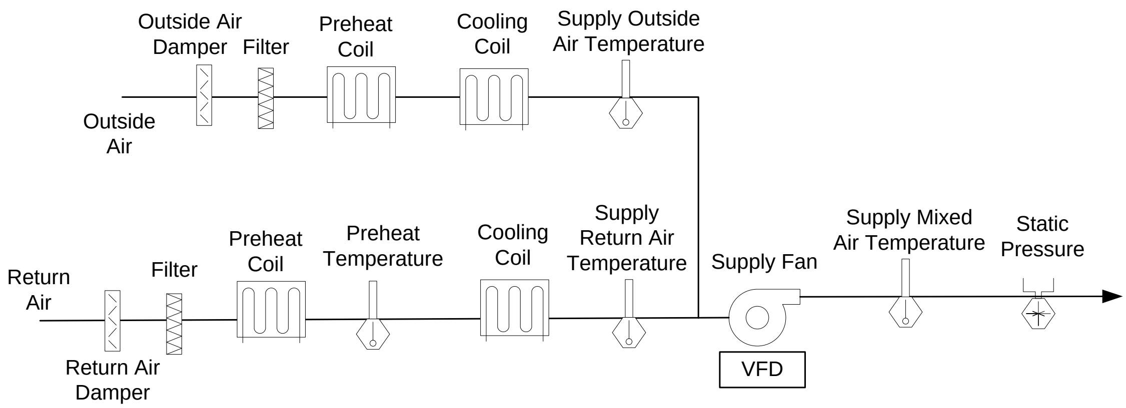

Figure 3. Single-duct VAV AHU with pretreated outside air (AHUs 1, 2, 3, 4 and 7)

All of the units have modulating OA dampers that control the OA flow setpoints, which were reset based on CO_2 levels of the areas they are serving. The CO_2 sensors are located in the return air ducts. For each AHU, there is a minimum and a maximum OA flow setpoints limiting the amount of OA.

The VAV boxes are controlled to maintain the space temperature setpoint. Each wall thermostat can adjust the temperature setpoint and has an "override" button that sends a signal to the corresponding AHU to turn it on in case the occupants require air conditioning during scheduled off periods.

Exhaust fans are located throughout the building. They are turned on and off largely following the occupancy schedules for the areas they are serving. The FCUs serve mostly mechanical rooms and small rooms, except for FCUs J1 and J2, which serve the coffee shop attached to the City Hall building, but it is not included in the scope of this project.

There are 9 CRAC units which maintain the servers and racks below 75°F all the time. They are located in the basement of the building and need to run 24/7.

In the building's underground parking garage, there are two (2) 100 hp OA supply fans, and four (4) 50 hp exhaust air fans. These fans provide fresh air to the garage which goes three stories below the ground level. The fans have variable frequency drives (VFDs) and are modulated in unison to maintain the carbon monoxide (CO) levels in the garage below 25 ppm. The fans speed up as the CO levels rise, and the rest of the time they remain at minimum speed. They control the maximum CO reading out of 93 sensors.

PROBLEMS IDENTIFIED

- Many of the units' OA flow stations were out of calibration. The sensor readings were still relatively high (above 450 cfm) when the OA dampers were fully closed.
- The existing operating schedules for the AHUs were not following actual occupancy schedules. For example, AHU 8 was scheduled to run from 6 am to midnight, even though the council chamber is mainly used for council meetings that are held on most Thursdays only.
- Ten (10) out of twenty (20) space temperature sensors (thermostats) that were randomly checked were found to be in need of calibration (off by at least 1°F).
- The thermostats had a very wide adjustment range. The cooling setpoint can be set as low as 71°F and the heating setpoint can be set as low as 75°F. This can cause potential simultaneous cooling and heating in common areas where temperature setpoints are significantly different.
- Air economizer is facilitated but was not programmed for all AHUs to take advantage of free cooling.
- Freeze-stats for AHUs 1, 2, 3, 4, 7 and 8 were installed before the OA pre-heat coils instead of after. To prevent coil freeze, the OA supply air temperature setpoint was set to 69°F whenever outdoor air temperature drops below 55°F, causing significant waste in both heating and cooling.
- There was no setback for the OA flow during low occupancy time periods.
- Garage supply/exhaust fans were very sensitive to CO changes in the garage and cause the fan speed control to over-react, causing fan power spikes.
- The boilers were kept running during much of the summer months while there was virtually no heating demand in the building.
- Both the chilled water and the hot water loop DP setpoints were held constant at 10 psi all year round.
- Some key sensors were significantly out of calibration. Some control devices were not functioning properly. A master deficiency list was created and provided to the facility for corrective actions.

SELECTED CONTINUOUS COMMISSIONING MEASURES

Implement air economizer cycle and improve OA control

Originally, the OA flow setpoint was linearly reset between the minimum and the maximum setpoints as the CO_2 level increase from 700 ppm to 880 ppm. Now, the OA flow setpoint is determined from three conditions:

1) OA flow is reset with a PID feedback loop control to maintain the CO_2 level at 880 ppm.
2) Air economizer cycle were implemented for all AHUs to take advantage of free cooling when outdoor air temperature is between 35°F and 64°F. Under economizer mode, the OA flow is controlled to maintain the discharge air temperature setpoint.
3) Total OA flow needs to be maintained above total exhaust flow. Building exhaust fans are scheduled based on area occupancy schedules. As total exhaust flow drops, the OA minimum flow drops accordingly, as shown in Table 1.

Reset AHU duct static pressure setpoints

Before CC, the duct static pressure setpoints for the VAV units were kept constant. Now, the duct static pressure setpoints are reset between the minimum and the maximum setpoints (different from unit to unit), based on VAV box damper positions and the OA temperature. The temperature-based reset linearly adjusts the duct static pressure setpoint based on outdoor air temperature while the damper-based reset tries to keep the maximum box damper position at 90%. The control algorithm selects the lower of the two.

Improve the discharge air temperature setpoint

Before CC, the discharge air temperature setpoint was reset based on the boxes load between 55°F and 65°F. After CC, the reset was modified so it would also be based on the OA temperature, linearly resetting between 55 and 65°F when the OA temperature was between

60°F and 40°F, respectively. Also, only when at least one box is calling for heating the discharge air temperature will be reset, the reset of the time it will be kept at 55°F, disregard the temperature-based reset. The reset is disabled and DAT is set back to 55°F whenever the humidity mode is on.

Table 1. Minimum OA flow setpoint during low occupancy times

AHU	Pre-CC minimum OA setpoint (cfm)	Post-CC minimum OA setpoint (cfm)
AHU-1	2000	532
AHU-2	2000	766
AHU-3	2800	607
AHU-4	800	752
AHU-5	1800	872
AHU-6	2800	1307
AHU-7	1350	779
AHU-8	1600	304
AHU-9	600	199
AHU-10	400	400

Relocate freeze-stats and modify freeze-protection control

Before CC, the freeze-stats on most AHUs were mistakenly installed before the outside-air preheat coils, making it impossible to implement freeze-protection sequences (e.g. shutting down unit, open cooling/heating coil valves etc.). To prevent potential freeze, the outside air was heated to 69°F whenever outdoor air is below 55°F to make sure no freeze would ever occur. This caused significant waste in both heating and cooling.

After CC, the freeze-stats were moved to after OA preheat coils and proper freeze-protection sequences were implemented. The preheat setpoint is lowered to 45°F.

VAV box temperature and flow setback during unoccupied periods

As mentioned earlier, most of the AHUs already have an on/off schedule. AHU 1 and 9 are the only two AHUs that are required to run 24/7 primarily due to the existence of a few individual rooms housing data communication and broadcasting equipment. Instead of shutting down the units like other AHUs, the two AHUs are now implemented with occupancy schedules. During unoccupied periods, temperature and minimum flow setpoints for VAV boxes serving non-critical rooms are setup or setback to save energy.

Implement chilled water and hot water DP resets

Before CC, both the chilled water and the hot water loop DPs were maintained at constant 10 psi. The DP setpoints are now reset based on outdoor air temperatures.

Improve garage supply/exhaust fan operations

The two supply and four exhaust fans in the garage add up to 400 hp capacity, although they are running at their minimum speeds (24 Hz) most of time. They speed up in unison when the maximum CO level in the garage starts to rise above the setpoint (25 ppm). Most of time, the maximum CO level is well below the setpoint. Before CC, the PID loop controls for the supply and exhaust fan speeds were very sensitive to CO changes and caused the fan speed control to over-react and quickly drove all fans to max speeds, causing fan power spikes.

After CC, the PID loops were tuned to be more stable. The fans would not be ramped to high speeds before CO level starts to drop, avoiding fan power spikes. Meanwhile, the minimum speeds for the fans were also dropped to 18 Hz.

Reduce hot water loop heat loss and standby loss

A more aggressive hot water temperature reset schedule was implemented to further lower the hot water supply temperature as the heating demand reduces.

In addition, the modified control sequence disables the hot water system when the outdoor air temperature is above 75°F. This prevents the boilers and the hot water pumps from turning on due to incidental calls for heating from one or two VAV boxes due to local control issues. Also, it will help identify faulty boxes and cold spots in the building faster.

Energy savings resulted from troubleshooting

In one example, AHU-6 was noticed to run continuously disregard the unit operation schedule implemented. Field investigation revealed that the space temperature sensor of one VAV box in the area was in the direct path of a computer exhaust fan. The sensor reading stayed around 90°F. In control sequence, the AHU will not be allowed to shut down if the highest space temperature is above the unoccupied temperature setpoint (82°F) even scheduled to do so. Once the problem was identified, the computer was moved away from the temperature sensor and the AHU was shut down at nights and weekends as scheduled.

In another case, a relative humidity sensor was bad and was constantly reading above 80%, which prevented another AHU from shutting down during scheduled periods.

Sensor Calibration

All key sensors were field verified and calibrated as needed. These included chilled and hot water valves, damper actuators, flow stations, and temperature sensors for 117 boxes.

SAVINGS ANALYSIS

Major Continuous Commissioning measures were completed for implementation during the period from June 2008 through March 2009. The result of energy consumption analysis proves the CC measures had made a positive impact on improving the building's energy efficiency. Energy cost savings achieved during the first 12 months of the CC project (June 2008 – May 2009) amounts to $70,151 based on actual utility rates, as shown in Figure 4. Projected annual savings by the end of 2009 are $78,000, representing 17.2% of the annual utility costs during the baseline period. The accumulated savings by the end of 2009 (June 2008 – Dec 2009) is expected to reach $112,000.

Weather normalized baseline models were developed for the three major utilities (electricity, chilled water, and natural gas) using the monthly utility bills. The baseline period is the 12-month period (June 2007 through May 2008) prior to the implementation of the first major CC measure. Figures 5, 6 and 7 present weather-normalized consumption data to clearly demonstrate the differences among three groups of data: before, between and after the CC implementation period. All three figures show a clear reduction from baseline pattern. The measured energy savings correspond to 7.9% for electricity, 17.3% for chilled water and 41.6% for natural gas.

ACKNOWLEDGEMENTS

The success of the project was the result of close cooperation and coordination among all parties involved in the project, including the Austin City Hall, Austin Energy, the city's Building Services department and the ESL. The authors would like to thank the Austin City Hall Facility Management personnel, especially Ms. Brenda Loney and Mr. Jose Leyva, for their constant support and willingness to provide requested data and information. We are grateful to Dr. Juan Carlos Baltazar of the ESL for providing the detailed energy analysis found in this paper.

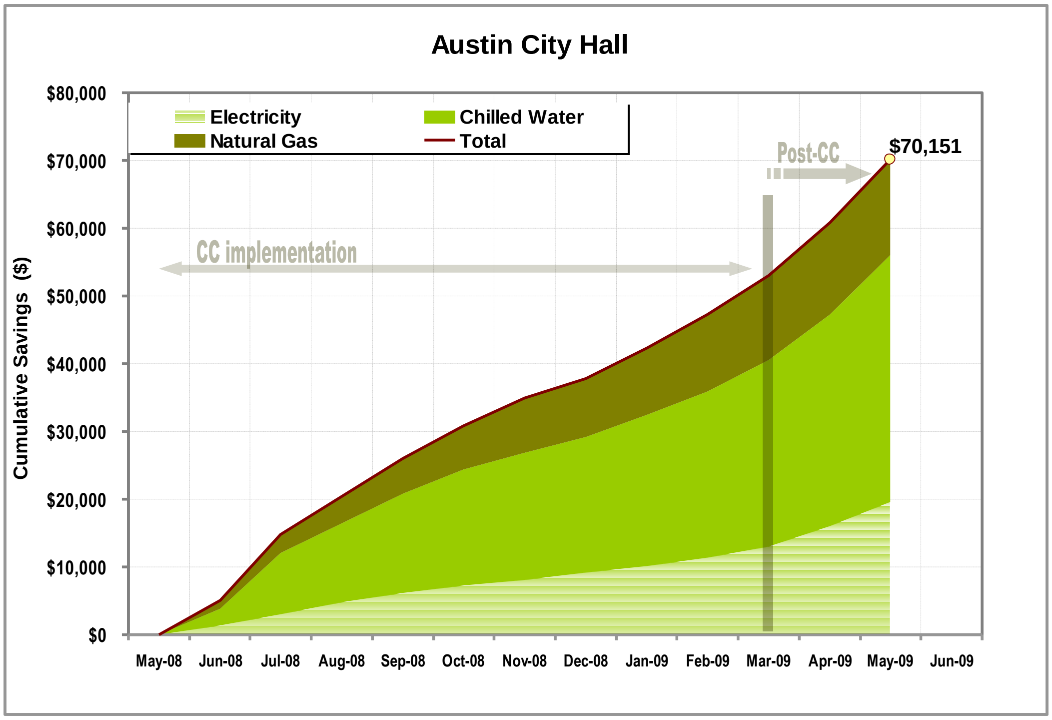

Figure 4. Cumulative cost savings during the first 12 month since CC was started (June 2008 Through May 2009, based on actual utility rates)

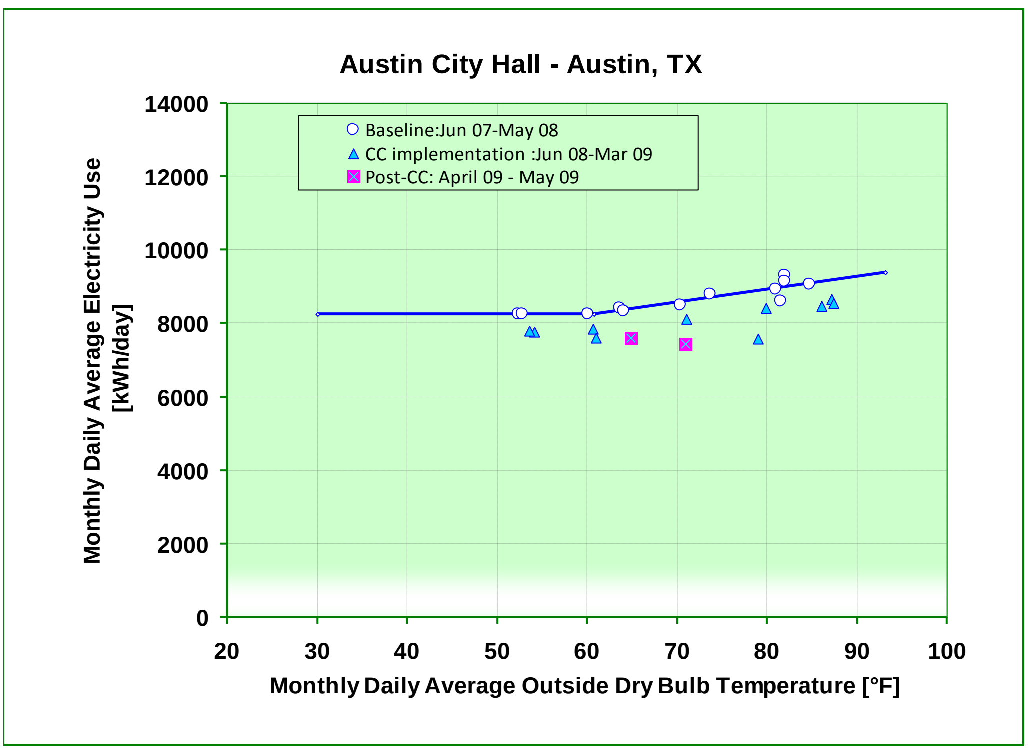

Figure 5. Comparison of electricity usage between the base year and the first 12 months since CC was started

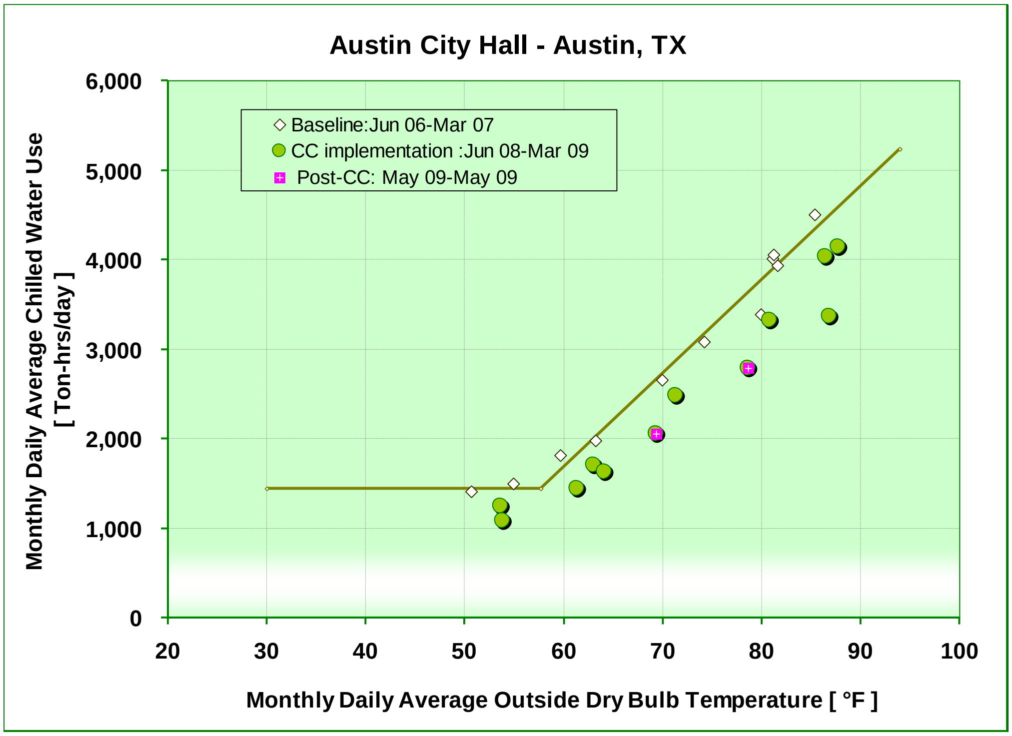

Figure 6. Comparison of chilled water usage between the base year and the first 12 months since CC was started

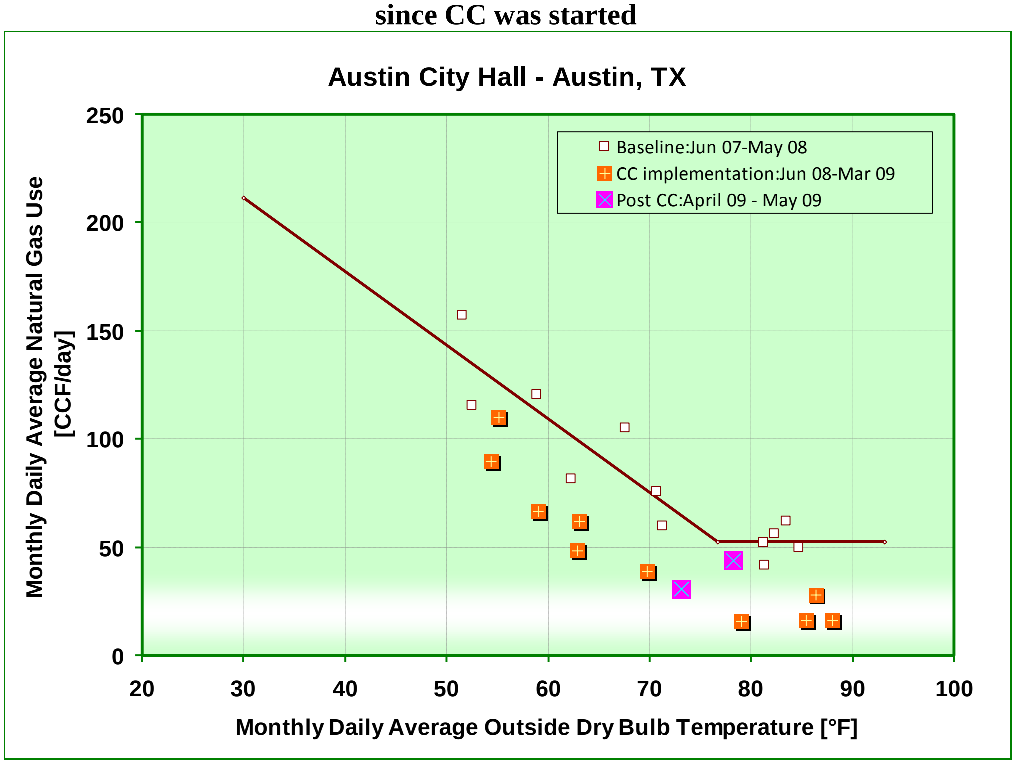

Figure 7. Comparison of natural gas usage between the base year and the first 12 months since CC was started