

Retrocommissioning: A Persistence Study

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ABSTRACT

Retrocommissioning (RCx) projects have become more commonplace and their value is increasingly recognized by building owners, property managers, and utilities. These projects generate significant energy savings with little capital cost, thus resulting in high overall cost-effectiveness. However, concerns with regards to persistence remain among some utility program managers and building owners. This paper addresses these concerns by analyzing the persistence of measures installed in 2004 and 2005 through CenterPoint Energy's RCx Program using proven Measurement and Verification (M&V) methods, where applicable, as stated in the International Performance Measurement & Verification Protocol. Projects were selected to ensure that maximum diversity is achieved with respect to market segment, measure type, and RCx service provider.

Six projects out of fourteen, that were part of the 2004 and 2005 RCx Program were chosen and pertinent data was requested and analyzed for all measures that were recommended by the RCx service providers. There were a total of forty three measures considered as part of the study. Thirty seven of these measures exhibited strong persistence, three measures were not implemented, and three measures could not be verified primarily due to logger failure, limited logging/trending potential of the system and the limited time-period at the time of the study. The results of the study indicate a demand reduction persistence of 92% while the corresponding values for energy and cost savings were 99% for those measures that were implemented.

Process

A rigorous project selection process was undertaken to achieve maximum possible diversification in the study. Projects and measures were classified under different buckets, as per the building type, measure type, savings impact and participant RCx service provider. The selection process attempted to include at least one parameter from each bucket. Building Owners were contacted and educated about the intent of the exercise. Certain factors such as the sale of the building, unavailability of building management to support the study and limited on-site logging potential influenced the final selection of projects. Factors used to determine the M&V Approach were as follows

- Measure type
- Existing EMS capability
- Savings impact
- Random sampling, as appropriate

Subsequently, a walkthrough was conducted at each of the selected buildings and feedback from site-personnel was obtained. Consequently, a system and measure checklist was developed for each building. The data collection phase entailed gathering of data from various sources at each site. This included historic trends from the EMS, data recorded from installed

loggers or spot measurements. The collected data was analyzed and results were tabulated to check for persistence. The M&V requirements for each measure were then developed based on measure type, trending and logging potential of the systems along with random sampling, where appropriate. Depending on the project, the time period of data collection was September, October and November, 2007. This paper investigates the persistence of measures that were implemented in 2004 and 2005.

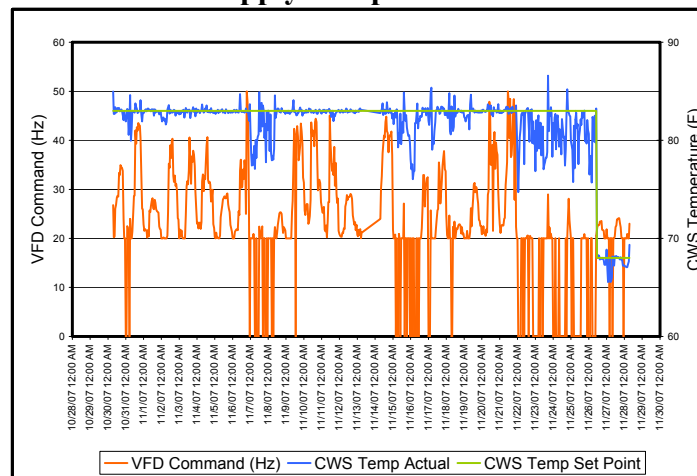
Results

Toyota Center

The Toyota Center, constructed in 2002, is a 7-level multi-purpose arena consisting of a 700,000 gross square feet facility that includes an indoor 20,000 seat stadium, event support spaces and office area in downtown Houston. The project implemented in 2005, resulted in an estimated demand reduction of 765 kW, energy savings of 1,923,858 kWh and cost savings of \$199,404. The implementation cost was \$5,600, resulting in a simple payback of less than one year.

Condenser water reset. A condenser water supply temperature reset strategy (varying between 65°F and 85°F) based on outside air conditions, along with load-limiting the tower fans at 75% speed, was implemented in 2005. The condenser water setpoint, variable frequency drive (VFD) command, condenser water temperature, fan amps, system kW and outside air temperature were measured during 10/30/2007-11/28/2007. As can be seen in Figure 1, the condenser water setpoint varies between 68°F and 85°F based on outside air conditions and the tower fans are less than 45 Hz (75% speed) for most of the measurement period. The maintenance personnel recognize the net chiller savings that can be achieved through the measure and continue to implement this measure manually as dictated by various building loads, thereby demonstrating persistence.

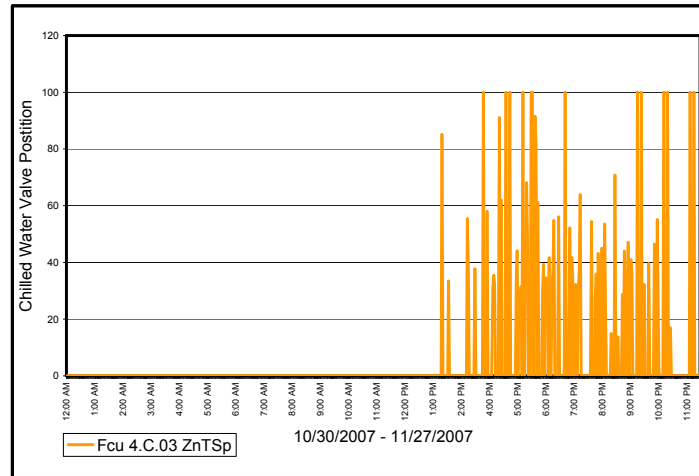
Figure 1. Condenser Water Supply Temperature and VFD Command vs. Time



Optimized suite operation, event day. An optimized suite operation was implemented in 2005, which turned on the Fan Coil Units two hours rather than five hours before an event started. The fan coil unit chilled water valve position and zone temperature was measured during 10/30/2007-

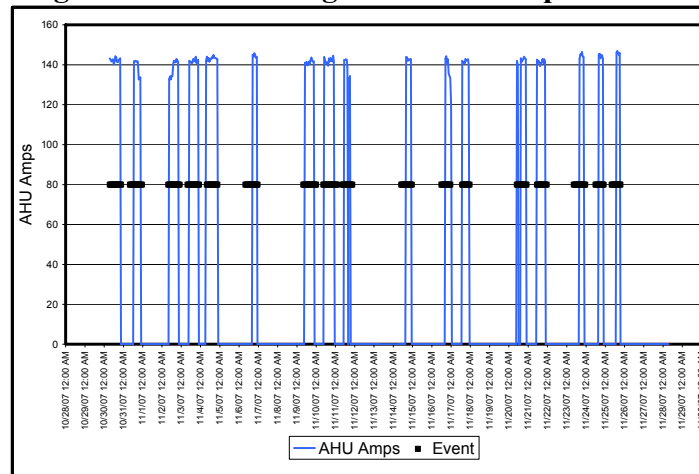
11/28/2007. Figure 2 is a plot of the chill water valve position during the measurement period against time of the day. Most of the events at Toyota Center start between 4:00 PM and 6:00 PM. As can be seen from Figure 2, the chilled water valves for the fan coil units opened approximately two hours before events (4:00 PM – 6:00 PM) on event days demonstrating persistence for this measure.

Figure 2. Fan Coil Unit 4.C.03: Chilled Water Valve Position: Event Day Profile



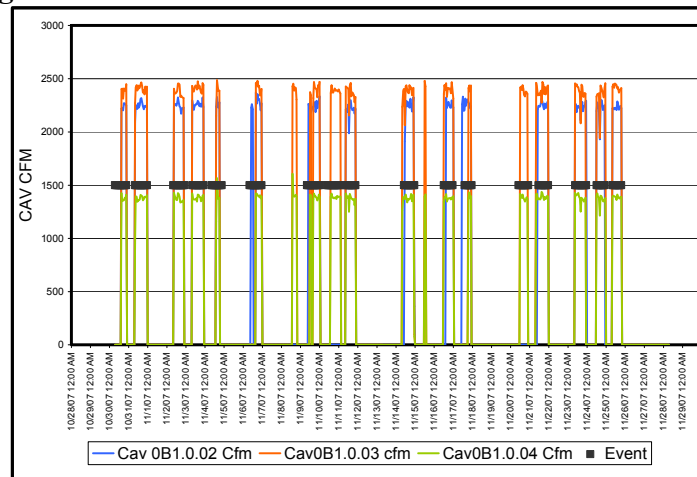
Optimized bowl unit operation, non-event day. In order to keep the building positively pressurized during non-event days, the operations personnel in the past operated one arena with an air handling system in standard operating mode. The proposed measure was to allow the outside air fan to operate at full speed, to slow down the supply air fan to match the outside air volume and to turn off the return fan. The energy savings primarily stemmed from reduced fan and chiller operation. The supply fan amps, return fan amps, outside air fan speed, and damper positions was measured during 10/30/2007-11/28/2007. As can be seen from Figure 3, the site operations management determined at the time of the implementation that the arena could be operated during non-event times without the air handling system. This indicates persistence and illustrates an instance, where the owner has determined additional savings opportunities beyond what was initially proposed.

Figure 3. Air Handling Unit 6.A.1 Amps vs. Time



VAV / CAV isolation, non-event day. Certain air handling units operated on non-event days, providing conditioned air to administrative and support areas, in addition to providing air to spaces that required air-conditioning only during event days. The measure implemented in 2005 entailed the isolation of event day areas from the air handling unit by programming the variable and constant air volume boxes along with the reheat valves to a 100% closed position. The fan speed, fan kW, and air flow (cfm) from a sample number of affected boxes was measured during 10/30/2007-11/28/2007. Figure 4 is a plot depicting the flow rate from the boxes during the measurement period. The black bars indicate event days. As can be seen, the box remained closed and air flow was zero during non-event days, thereby indicating persistence.

Figure 4. Constant Air Volume Boxes Flow Rate vs. Time



Houston Center

Houston Center is located in downtown Houston and the project was comprised of three buildings: One Houston Center, a 48 story, 1.3 million square feet high-rise office building constructed in 1978; Two Houston Center, a 40 story, 1,453,609 square feet high-rise office building constructed in 1976; and Four Houston Center, a 16 story, 1,037,631 square feet high-rise office and retail shopping mall constructed in 1983. The project implemented in 2004 resulted in an estimated demand reduction of 1,080 kW, energy savings of 686,403 kWh and cost savings of \$44,616. All measures were implemented by in-house staff.

Optimized chiller start/stop and chilled water supply reset. At One Houston Center, the measure primarily entailed that the chillers start and stop based on load requirement, rather than a fixed operating schedule. Also, a chilled water reset strategy was implemented based on chilled water pumping pressure, or differential pressure (DP). The chilled water supply temperature was allowed to float between 43°F to 50°F based on DP of 18psi – 26psi. At Two Houston Center, the measure entailed that the chillers start and stop based on load requirement, rather than a fixed operating schedule. Also, a chilled water reset strategy was implemented based on chilled water return temperature. The chilled water supply temperature was allowed to float between 42°F to 47°F based on the chilled water return temperature of 60°F - 55°F. At Four Houston Center, the measure entailed that the chillers start and stop based on load requirement, rather than a fixed operating schedule. All the measures were implemented in 2004. Outside air temperature, chilled

water supply, chilled water return, flow, differential pressure, energy consumption of the chiller and cooling tower fans were measured between 8/30/2007-10/17/2007.

As can be seen from Figure 5, a linear relationship exists between chilled water supply temperature and differential pressure at One Houston Center. The decrease in differential pressure results in a reduced chilled water supply temperature. A similar linear relationship exists between the chilled water supply and chilled water return temperature at Two Houston Center (Figure 6). As the chilled water return temperature reduces, the chilled water supply temperature increases. Chiller sequencing as per load requirements can be clearly seen at One Houston Center (Figure 7), Two Houston Center and Four Houston Center (Figure 8) due to the different number of chillers running at both the buildings. Prior to the implementation of the measure, two chillers constantly ran at One and Two Houston Center during business hours. At Four Houston Center three chillers constantly ran during business hours. Since the implementation, chillers are switched on and off, as per load requirements, rather than operate on a fixed schedule. The chilled water reset strategy along with the chiller sequencing based on load requirements can be seen in operation three years after implementation, demonstrating persistence for this measure.

Figure 5. One Houston Center: Chilled Water Supply Temperature vs. Chilled Water Differential Pressure (9/17/2007 - 10/17/2007)

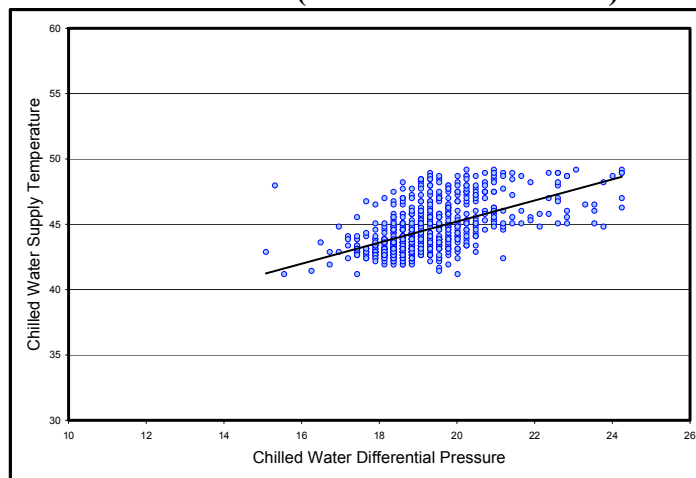


Figure 6. Two Houston Center: Chilled Water Supply Temperature vs. Chilled Water Return Temperature (9/17/2007 - 10/17/2007)

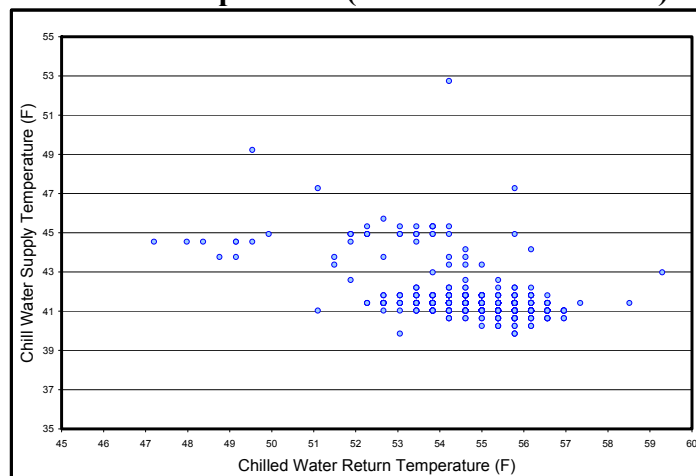


Figure 7. One Houston Center: Weekday Chiller Operation (8/30/2007 – 10/16/2007)

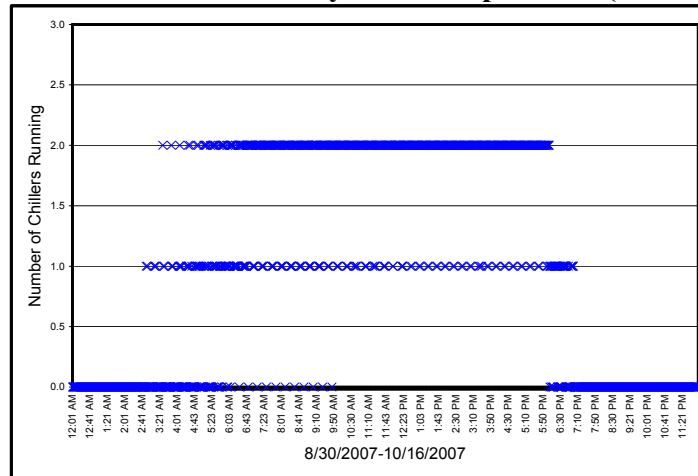
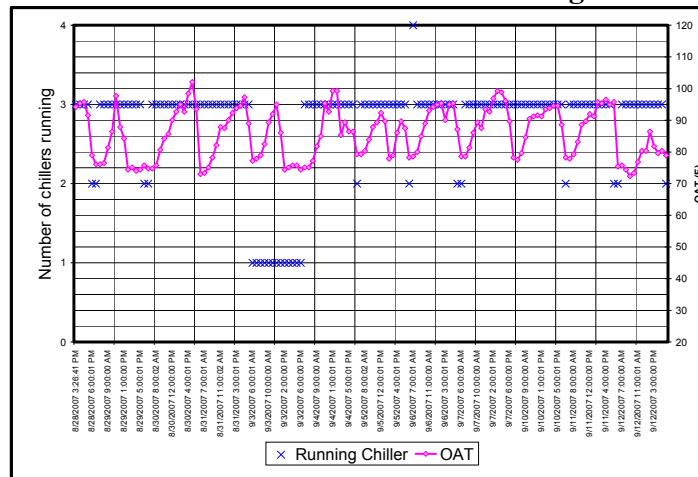


Figure 8. Four Houston Center: Chiller Running Status vs. Time



University of Houston

Constructed in 1971, the McElhinney Building is a three-story building housing classrooms and offices. The conditioned floor area is roughly 48,709 square feet. The three-story Tech II Building encompasses classroom and office space and is about twenty-eight years old. Both buildings, occupied from 7 AM to 10 PM on weekdays were part of the RCx project. The project implemented in 2005, resulted in an estimated demand reduction of 183 kW, energy savings of 955,969 kWh and cost savings of \$47,798. The implementation cost was \$122,790, resulting in a simple payback of two and a half years.

Addition of VFD's to air handling units. At McElhinney, dual duct air-handling units conditioned the space by mixing hot and cold airstreams in the required amounts needed by the space by means of dampers at the air-handling unit. At the Tech II Building, the air-handling units have inlet guide vanes for fan control; however, these inlet guide vanes were not operational. As a result, the fans were not controlled and operate at full capacity. The measure implemented in 2005, consisted of adding variable speed drives to the air-handling units to reduce fan speed and electrical consumption. Static pressure, damper position, outside air

temperature and fan speed was measured during 10/1/2007-10/30/2007. Figures 8 and 9 show the outside air temperature and fan speed at McElhinney and Tech II Building during the measurement period. Prior to implementation, the fans ran at a constant single speed. The installation of the drives and resultant modulation of fan speed due to outside air temperature, confirms persistence for this measure.

Figure 8. McElhinney Building: Fan Speed (%) and Outside Air Temperature vs. Time

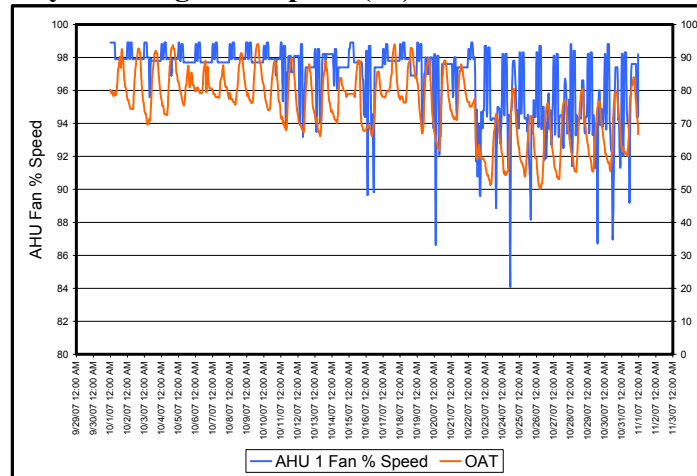
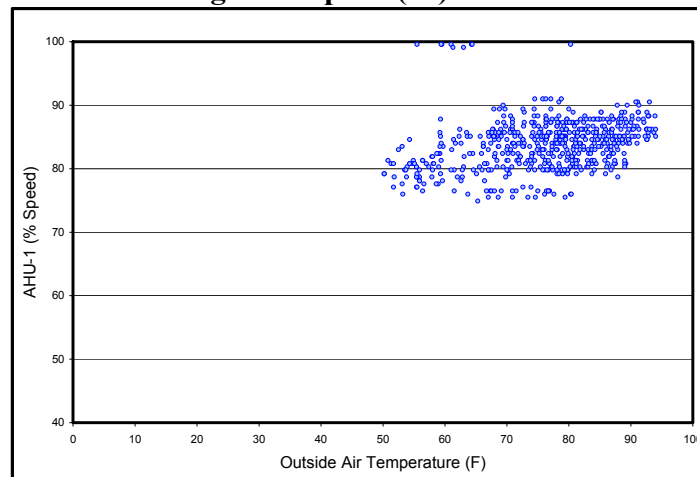
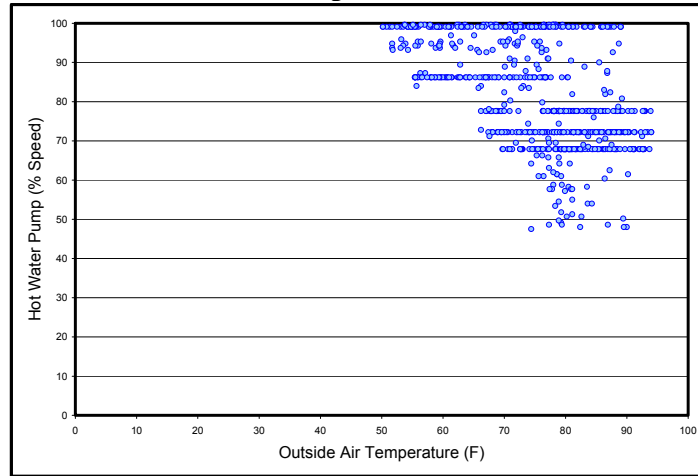


Figure 9. Tech II Building: Fan Speed (%) vs. Outside Air Temperature



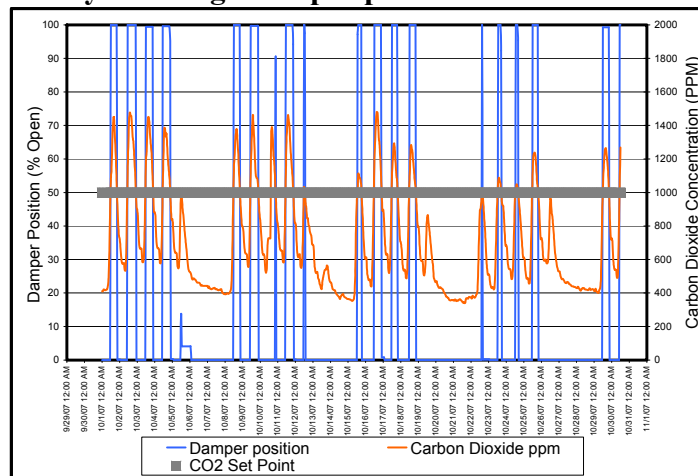
Hot water pump speed controls. Variable speed drives were installed in 2005 at each of the heating hot water pumps in response to reduced reheat requirements due to variable-air-volume measures at the buildings. Differential pressure, pump speed, hot water supply and return temperature was measured during 10/1/2007-10/30/2007. As can be seen from Figure 10, the variable speed drives were installed and the pump speeds exhibited modulation between 50% - 100%, thereby demonstrating persistence.

Figure 10. Tech II Building: Heating HW Pump Percent Speed vs. Outside Air Temperature



Demand based ventilation controls. This measure entailed a demand-based outside air intake strategy, with the installation of CO₂ sensors, actuators and controls. Prior to implementation of the measure, outside air intakes for the building were constant at the 100% open position, regardless of occupancy levels. The measure was implemented in 2005 with a CO₂ parts per million (PPM) setpoint of 1000 PPM. The damper position and corresponding CO₂ setpoints were monitored during 10/1/2007-10/30/2007. Figure 11 is a plot depicting the damper position and CO₂ concentration during the measurement period. The grey bar indicates the CO₂ setpoint of 1000 PPM. The damper opens to 100% only when the actual CO₂ PPM value exceeds 1000 PPM indicating superior controls, good data quality and persistence for this measure.

Figure 11. McElhinney Building: Damper position and CO2 Concentration vs. Time



Wharton Junior College

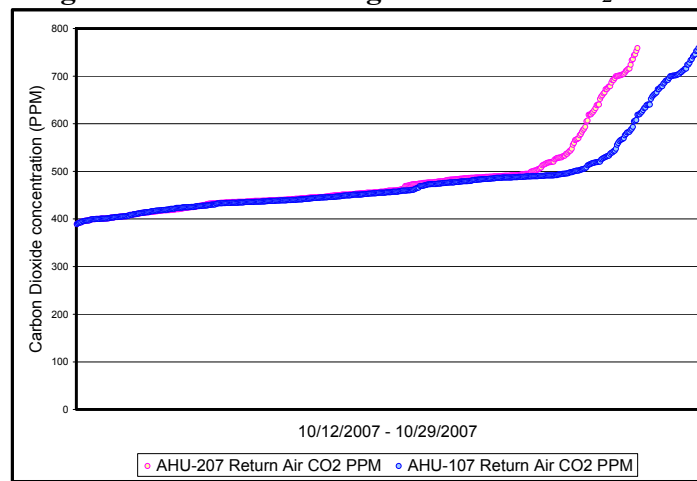
The campus at Wharton Junior College houses several buildings including laboratories, classrooms, dormitories, offices, computer facilities and libraries. The project implemented in

2004, resulted in an estimated demand reduction of 187 kW, energy savings of 535,091 kWh and cost savings of \$34,285. The implementation cost was \$2,917, resulting in a simple payback of less than one year.

Partial delamping in overlit areas and photosensor control for the exterior lights were installed as per the findings of the RCx service provider. An inspection carried out on September 27, 2007 indicated the owner having implemented all the findings.

Outside air controls: install new variable volume dampers. The Peace and Fine Arts buildings had non-functional actuators on their outside air dampers. In addition to installing new dampers and actuators in 2004, college personnel installed CO₂ sensors in the return air stream of the air handlers and programmed the facility automation system to open outside air dampers only in response to CO₂ concentrations greater than 800 PPM (Figure 12). During the monitoring period (10/12/2007-10/29/2007), the CO₂ concentration stayed below 800 PPM and the dampers did not open. The installation of the dampers and CO₂ sensors, with a tie-in back to the EMS indicates that the owner has gone beyond the findings of the RCx service provider, by implementing a demand based ventilation schedule. Hence, the measure persists.

Figure 12. Peace Building: Monitored CO₂ PPM



Chilled water pump control. The two variable-speed secondary chilled water plants at the Fort Bend Tech Center operated at or near 100% speed all the time prior to the retrocommissioning project. The proposed measure entailed the rebalance of the entire chilled water system, checking of controls and sensors, replacement of the faulty differential pressure sensor and the installation of an additional sensor at the end of the chilled water loop. Prior to implementation of the measure in 2004, both pumps ran at 100% speed all the time. Due to the imbalance of the pumps, the variable air volume (VAV) fans ran at 100% speed, since the chilled water control valves were not able to properly control supply air temperature. With colder than needed supply air temperatures, the VAV boxes would go to the heating position which, contrary to original design intent, must open wide in order to allow enough flow to engage electric strip heats. The spaces got overcooled and opened the VAV boxes further to introduce more “cold” air, but because the chilled water valves didn’t close, the space kept getting colder and the need for more heat was induced.

The pump speed, differential pressure, static pressure at the air handling unit, fan speed and supply air temperature was measured during 10/9/2007 -10/31/2007. Data collected during

this time indicates a single operational pump running at 80% speed (Figure 13). A few data points indicated both pumps running; however, further review of the data show this occurred only at the time of system start-up. The implementation of the chilled water controls, resulted in the ability for the system to operate a reduced static pressure. As can be seen from Figure 14, the fans exhibited greater modulation and ran between 70% - 90%. Thus measures implemented in 2004 are currently still operational, as per the recommendations made by the RCx service provider, indicating persistence.

Figure 13. Fort Bend: Pump Speed and Number of Running Pumps

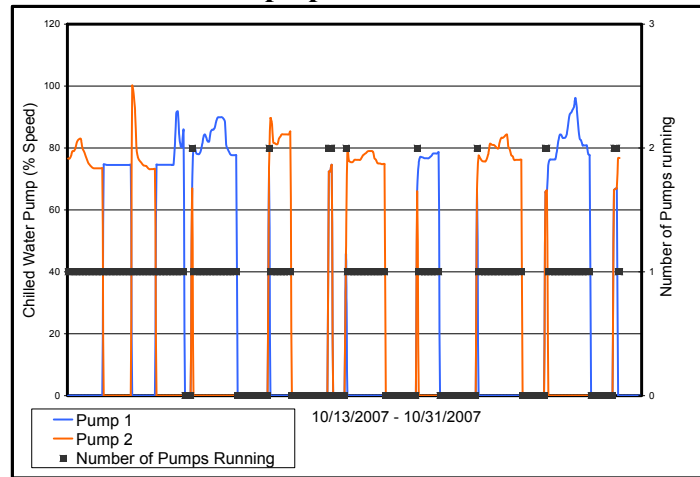
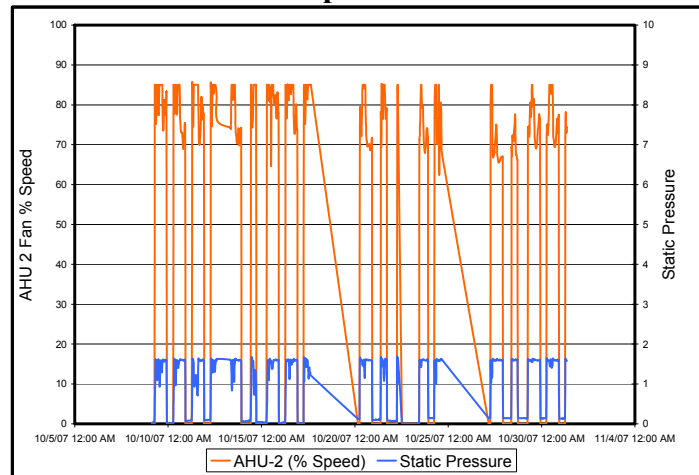


Figure 14. Fort Bend: Fan Speed and Static Pressure vs. Time



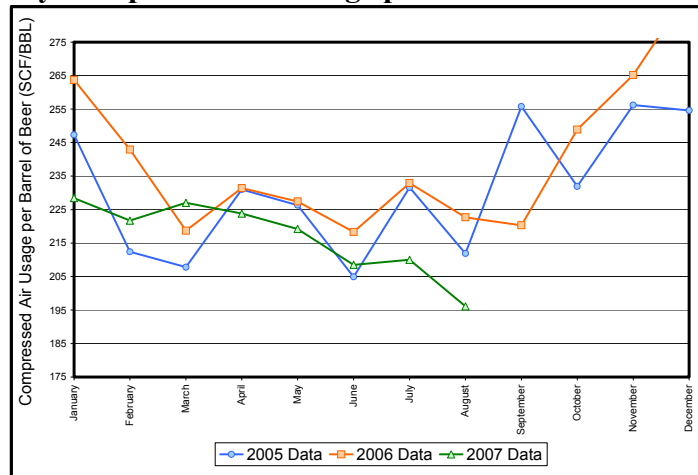
Anheuser Busch

The Anheuser-Busch (AB) brewery is roughly two million square feet with a total capacity (2007) of 12.5 million barrels of beer. Several measures were proposed by the RCx service provider including fixing leaks, implementation of a leak detection program, modification of air assists, windjet replacements, installation of blowers, and conveyer belt modifications. The project resulted in an estimated demand reduction of 263 kW and energy savings of 2,527,383 kWh. It may not be economically practical to verify persistence on a systemic level due to the complexity of compressed air usage, the dynamic nature of compressed

air and the small savings produced by the identified measures, when compared to total end use. However, the parameter which can be used as a mode of comparison is the standard cubic feet of compressed air consumed per barrel of beer produced.

The project was implemented between December 2005 and June 2006. Figure 15 compares compressed air usage per barrel of beer produced during 2005, 2006 and 2007. The monthly compressed air used per barrel of beer produced reduced significantly in 2007, when compared to 2006 and 2005. The AB Facility has implemented an aggressive energy management policy, leak detection program and continuously monitor their compressed air usage. The reduction in compressed air usage and continual strong energy management policy demonstrates persistence at the facility level, rather than a systemic level.

Figure 15. Monthly Compressed Air Usage per Barrel of Beer Produced: 2005-2007



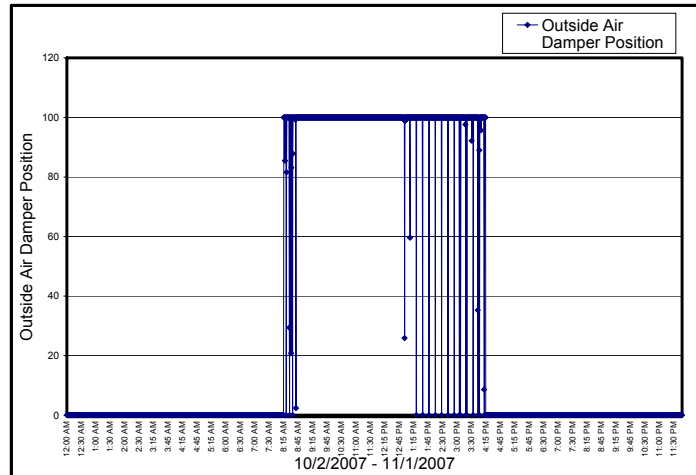
Humble Independent School District

Three schools were part of this RCx project. Jack Fields Elementary was built in 1995 with a total floor area of 76,200 square feet. Timberwood Middle was built in 1998, with a total floor area of 151,400 square feet. Whispering Pines Elementary was built in 1991, with a total floor area of 68,000 square feet. The project implemented in 2005, resulted in an estimated demand reduction of 410 kW, energy savings of 130,347 kWh and cost savings of \$8,474. The implementation cost was \$29,926, resulting in a simple payback of three and a half years.

Revised thermal storage operation. The measure entailed a revision in thermal storage operation. The revised operation implemented in 2005 entailed the charging of the storage tanks at night (11 PM to 5 AM), using the chillers from 5 AM to 12 PM and subsequently operate the storage tank to cool the building (12 PM till close). The intent was to minimize electrical demand during the utility’s peak time by keeping the chillers offline during the ‘on-peak’ period. Screenshots and control sequences programming obtained in November 2007 confirmed the revised thermal storage operation.

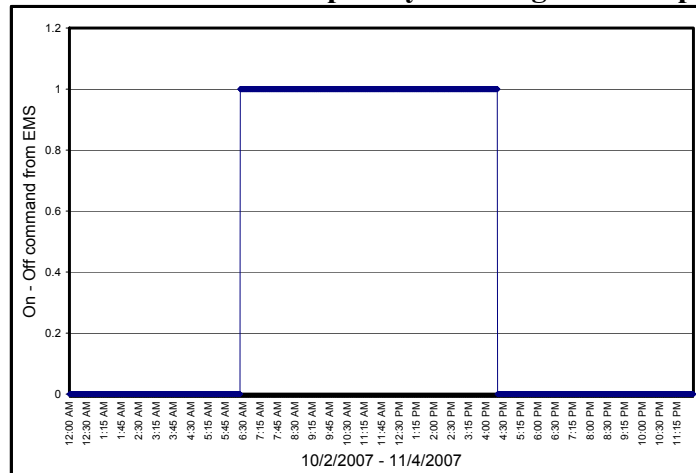
Shut off outside air when not needed. Originally, the outside air damper opened at the same time the air handling unit started (6:30 AM) and stayed open until the units are turned off (4:30 PM). The measure was implemented in 2005 and entailed the opening and closure of outside air dampers to coincide with occupancy, thereby reducing outside air intake. Outside air damper position was recorded during 10/2/2007-11/1/2007 and as can be seen from Figure 16, the dampers open at 8:15 AM and go to the closed position at 4:00 PM indicating persistence.

Figure 16. Whispering Pines: Outside Air Damper Position Profile during 10/2/2007 – 11/1/2007



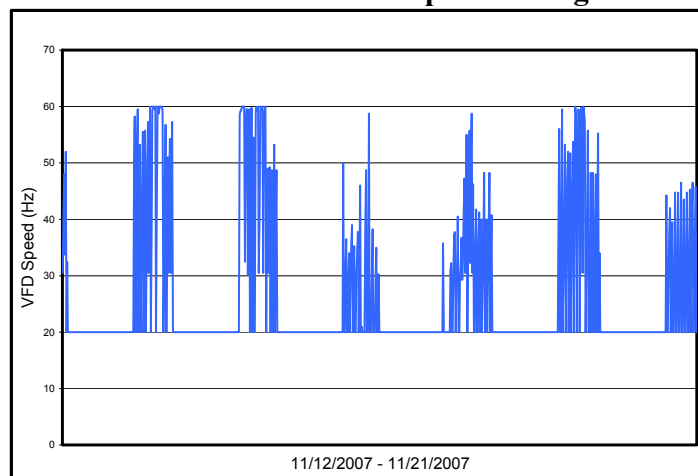
Automatic control for temporary buildings. The building lights and air-conditioning were turned off manually during the evening, but the facility personnel believed that in reality are left on several hours longer than intended, sometimes even all night, by custodial staff. The measure, implemented in 2005, was to add programmable thermostats, an Energy Management System relay and automate the start/stop operation of the temporary buildings. Temporary building on/off status from the Energy Management system was recorded during 10/2/2007 and 11/1/2007. As can be seen from Figure 17, the building lights and HVAC are switched off and remain off between 4:30 PM and 6:30 AM, indicating persistence for this measure.

Figure 17. Timberwood: Temporary Building Start/Stop Profile



Addition of VFD's to air handling unit. The Cafeteria Air Handling Unit was single zone constant volume air handling unit. It experienced a wide variation in occupancy load during the day, with lunch hours being the heaviest. The measure was implemented in 2005 and entailed the addition of variable frequency drives to the air handling unit in order to modulate according to load. Parameters measured were drive command, fan speed (%) and drive frequency during 11/12/2007-11/21/2007. As can be seen from Figure 18, variable speed drives have been installed and the unit fan speeds modulated between 20-60 Hz indicating measure persistence.

Figure 18. Jack Fields: Cafeteria AHU VFD Speed during 11/12/2007 – 11/21/2007



Summary

Table 1 lists the participant project summary as part of this study. Table 2 lists the measures that were included as part of this study and the charts thereafter, summarizes the results of the study. The three classifications are:

- Measure persists – Measure exhibits persistence
- Not implemented – Owner has not implemented the measure
- Unverifiable – Measure persistence cannot be verified due to logger failure, limited logging/trending potential of the system or time-period during which the data was obtained.

Table 1. Participant Projects: Summary Savings

Project	Program Savings (kW)	Annual Energy Savings (kWh)	Annual Billing Savings (\$)	Implementation Costs (\$)	Simple Payback
Toyota Center	765	1,923,858	\$199,404	\$5,600	0.03
Houston Center	1,080	686,403	\$44,616	\$0	0.00
University of Houston	183	955,969	\$47,798	\$122,790	2.60
Wharton Junior College	187	535,091	\$34,385	\$2,917	0.09
Anheuser Busch	263	2,527,383	unavailable	unavailable	unavailable
Humble ISD	410	130,347	\$8,474	\$29,926	3.53
TOTALS	2,888	6,759,051	-	-	-

Table 2. Persistence Study Result Summary

Classification	Count	Demand Reduction (kW)	Energy Savings (kWh)	Cost Savings (\$)
Measure Persists	37	2,241	6,417,509	\$313,223
Not Implemented	3	607	140,191	\$8,051
Unverifiable	3	189	37,521	\$2,754
Totals	43	3,037	6,595,221	\$324,028

Conclusions

The measures included in this study exhibited strong persistence with regards to changes in control sequences, installation of equipment and operational strategies. The high persistence can be attributed to certain key features of the program, listed below

- A streamlined Request for Qualification process to select qualified RCx service providers
- A comprehensive customer application enabling targeting of valid projects
- Program design to target at least 300,000 sq feet per project, preferably with an EMS
- The inclusion of a Planning phase and Investigation phase, which eliminates low savings-potential projects, thereby ensuring cost-effectiveness
- The inclusion of a Verification Phase as an added incentive to RCx service providers to ensure measure-installation after owner implementation
- A strong, transparent communication with building owners during each phase
- Third-party review of savings calculations and report at the end of each phase by Nexant, thereby improving accuracy of calculations and increasing owner-confidence in the recommended measures
- Annual workshops held for RCx service providers and building owners

In certain cases, the building personnel have gone above and beyond the recommendations of the RCx service providers and implemented additional Energy Conservation Measures. The exposure of building personnel to (a) different ways of saving energy by simple operational changes, without sacrificing the comfort levels for occupants, and (b) the realization of building personnel to continually monitor and make improvements are some of the goals, besides energy savings and demand reduction, of CenterPoint Energy's RCx market transformation program. The results of the study indicate that demand reduction and energy savings are persistent and building owners are achieving significant benefits due to the Program. The Program is currently in its fifth year, with an increased participation by building owners and RCx service providers, indicating a gradual market transformation underway in CenterPoint Energy's Service territory.