RETROCOMMISSIONING CASE STUDY
“Applying Building Selection Criteria for Maximum Results”

Larry Luskay, Tudi Haasl, Linda Irvine
Portland Energy Conservation, Inc.
Portland, Oregon

Donald Frey
Architectural Energy Corporation
Boulder, Colorado

ABSTRACT
Commissioning of existing buildings, or “retrocommissioning” is a systematic process to identify operational and maintenance (O&M) improvements that optimize building performance and ensure that building systems function together efficiently and effectively (Haasl, Sharp 1999). This paper presents a case study of a utility-funded retrocommissioning evaluation on a 125,000 SF office facility in La Mesa, California. The commissioning process consisted of site visits, interviews with facility staff, data collection and analysis, recommendation of energy conservation measures, and verification of savings. The study identified 13 deficiencies and recommended a suite of three O&M measures, one capital improvement measure and five other measures. The measures selected and implemented by the owner resulted in annual projected savings of 238,000 kWh (9.9%) and utility cost savings of $20,000 (6.9%)[1], with a simple payback of 0.7 years. The project also demonstrated the value of applying rigorous building selection criteria to obtain cost-effective results. This paper profiles the project and discusses lesson learned.

INTRODUCTION
SDG&E Program Background
In the summer of 2001, San Diego Gas & Electric deployed a retrocommissioning pilot study to obtain energy and demand savings (kWh and kW) and raise awareness of the value of retrocommissioning services among local building owners. This is a case study of one project, a 125,000 SF office facility in La Mesa, California. The building was retrocommissioned by Portland Energy Conservation, Inc. (PECI), in conjunction with Architectural Energy Corporation (AEC). The building-specific goals were:

1) Obtain cost-effective energy savings from optimizing operation and maintenance of the building’s energy using systems.

2) Identify and recommend improvements to O&M procedures focusing on those activities that sustain optimal energy performance and reduce operating costs.

3) Identify HVAC-related health and safety issues as they present themselves during the normal course of the retrocommissioning work.

The final report recommended nine of the thirteen identified measures, with the potential to save 335,000 kWh annually, and a simple payback of 0.7 years. The owner selected three of the recommendations for implementation, to realize savings of 238,000 kWh annually. One critical factor in the success of the project was the careful selection of the building to improve the probability of cost-effective savings.

BUILDING SELECTION
Both SDG&E and PECI imposed criteria for selecting a building. The utility required that any candidate building meet certain cost-effectiveness criteria, based on energy savings over the measure life. PECI also applied qualitative criteria for an “ideal” building, and selected one that met most of the criteria.

Qualitative selection criteria include the following:

- Reasonably modern building controls system.
- Not suffering from deferred maintenance.
- Not anticipating near-term capital improvements (which would replace retrocommissioned systems before the payback period had elapsed).
- Qualified in–house staff and/or qualified service contractors who are willing and able to help with commissioning activities.

First Alternative: Post Office
The first candidate was a 57,000 SF Post Office built in 1972. Based on the reports of energy manager, the site met the cost-effectiveness criteria. PECI engineers made an initial site visit to scope the project. At this point, a number of deficiencies were identified.

The pneumatic controls were in various stages of disrepair. Chilled water valves were disconnected

[1] Some measures did not achieve any demand savings or only affected off-peak usage; therefore, the cost savings percentage is smaller than the overall usage savings percentage.

from the control system and forced open, zone damper linkages had been disconnected from damper actuators, and return, exhaust and outside air dampers were not receiving the proper pneumatic control signals to enable an economizer cycle. In essence, the entire pneumatic system had degraded to the point where it was basically inoperable. Before the system could be optimized, it had to be rebuilt, a task beyond the scope and budget of SDG&E's retrocommissioning program.

Due to the need for deferred maintenance and capital improvements, the project team decided to seek an alternative building.

<u>Second Alternative: Office Building</u>

The second facility investigated was a 125,000 SF seven-story office building built in 1983. A site visit confirmed that the facility met the selection criteria.

The facility was controlled by a reasonably modern CSI energy management and control system (EMCS). It was not suffering from deferred maintenance, nor was it anticipating near-term capital improvements that would cancel the benefits of the retrocommissioning. All building systems and equipment were functional, and not nearing the end of their useful life. And perhaps most importantly, there was a qualified in-house staff, ready to help with the effort. The building owner indicated that they occasionally used outside contractors, but did not have a service contract in place.

After ensuring that the building met basic criteria, PECI selected the building for the retrocommissioning effort.

FACILITY SYSTEMS DESCRIPTION

The facility is served by a water-source heat pump system. The system is separated into two independent water loops: one serving the east side of the building and one for the west side. Each loop consists of individual heat pumps, two circulation pumps operating in a lead/lag configuration, an evaporative fluid cooler, and a natural gas-fired hot water boiler (see Figure 4 in Appendix B for system diagram). The electrical energy and demand profiles for the facility appear to be normal for the climate and better than average for the region. According to the Commercial Building Energy Consumption Survey (CBECS) for 1999, the average office building in the Western United States uses 84.3 kBtu/SF. (Table C5. Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels, 1999). The pre-retrocommissioning Energy Use Index for the office building was 65 kBtu/SF, well under average.

METHODOLOGY

The retrocommissioning process for this project included four phases:

1) Planning.
2) Investigation, data collection and analysis.
3) Implementation of recommendations.
4) Verification of energy savings.

Each of these procedures is described in greater detail in the following paragraphs.

<u>Planning</u>

The retrocommissioning team developed a retrocommissioning plan for the owners to inform them of the process and expectations for the retrocommissioning effort. The plan includes the following elements:

- Building description.
- Project objectives and scope.
- Project roles and responsibilities.
- Schedule of primary tasks.
- Description of diagnostic testing methods.
- Information categories for the Master Finding Log.
- A monitoring plan, including the analysis techniques and instrumentation requirements.

<u>Investigation</u>

The investigation began with a documentation review. For this project, the past 12 months of utility billing data and partial mechanical plans were available. After reviewing the available documentation, the retrocommissioning team conducted an initial site assessment, spending two days in the building interviewing staff, reviewing control sequences and equipment operating schedules, inspecting and testing equipment, and performing an analysis of the site-gathered data. PECI executed manual test procedures during the site visit to determine system operation. For example, thermostat settings were manipulated during unoccupied periods. The results of the initial site assessment served to identify O&M opportunities and determine which equipment and systems would be monitored in order to detect additional opportunities.

Based on the site assessment and interviews with building operators, the team decided to monitor the following central plant equipment and data points:

- Amperage for the east loop and west loop pump.
- Amperage for the fan and spray pump on each loop's evaporative fluid cooler.
- East and West loop supply and return water temperatures.
- Ambient air temperature.

In addition, the investigation monitored several heat pump circuits that accounted for 35% of the building's units. Four individual heat pumps were monitored in detail to provide insight into unit performance and zone load requirements. The following points were measured for each of the four units:

- supply air temperature
- return air temperature
- compressor amperage
- supply fan amperage

Data was collected using AEC's MicroDataLogger® system, a portable, battery powered, four-channel data logger that records time-series data using a variety of interchangeable sensors and transducers. At the end of the two-week monitoring period, the data loggers were removed and the data was downloaded and analyzed using the ENFORMA® software's suite of graphical visualization tools and conditional filters. These tools provide load shapes and diagnostic plots for quick identification of system operation and problems.

Analysis

PECI and AEC analyzed the data from the investigation phase in order to formalize findings and estimate associated energy savings for correcting each finding. The energy baseline for the building was established using the DOE2.1-E building energy analysis simulation. The model results were compared to actual monthly energy usage to ensure that the model correlated to actual consumption and demand history. Once the baseline model was calibrated, parametric analyses were performed by making changes to the model corresponding to energy conservation opportunities identified during the investigation. This resulted in predicted utility consumption savings for each of the opportunities. The measures were also run together as a package, to account for the interaction between the measures.

The facility's Energy Cost Index (ECI) of $3.41/SF was calculated by dividing the total electricity cost for the preceding year (October 2000 through September 2001) by the total electrical usage. The preceding year coincided with the height of the California energy crisis, when monthly nominal prices rose as high as $0.30/kWh, thus the ECI is unusually high. Electricity charges lowered significantly in the last five months of the preceding year, and appeared to stabilize at approximately $0.12/kWh. For the purposes of this paper, cost savings estimates are calculated against an adjusted cost baseline, assuming a stabilized nominal rate of $0.1211/kWh. Under this assumption, the ECI is actually closer to $2.32/SF.

To calculate the value of the kWh savings, the DOE-2 simulation model used an extensive time-of-use rate structure reflecting the more stable, post-crisis rates. Spreadsheet calculations used either an average cost of $0.078 kWh when no demand savings were available, or $0.1211/kWh when demand savings could be claimed. The measures selected by the owner will save over $20,000 (6.9% of total energy costs, based on the adjusted baseline ECI.) If the owner had implemented all recommended measures, the savings would have been $29,000 (10.1% based on the adjusted baseline ECI.)

Implementation costs were estimated for each measure based on a variety of methods, including contractor cost estimates, R.S. Means cost estimation guidebooks, and manufacturer price lists. The costs assumed that facility staff would be available to assist a contractor with the implementation.

Once the energy savings and implementation costs for each measure were established, PECI entered all measures into a summary spreadsheet and prioritized them based on simple payback. Typically, retrocommissioning attains an overall simple payback in two years or less (Gregerson, 1997). Table 1 in Appendix A presents a summary of findings and recommendations.

Findings

Although the primary focus of a retrocommissioning effort is to identify low-cost/no-cost O&M opportunities, the investigation may also identify capital improvement measures. This investigation resulted in thirteen findings – four O&M measures, four capital improvement measures and five other measures. "Other Measures" include those O&M measures that save energy but don't meet the "low-cost/no-cost" test (less than two year payback), or measures that have only non-energy benefits. The following describes a selection of the recommended measures in more detail.

Scheduling and programming improvements.
The CSI EMCS controls the water-source heat pump system by scheduling operation of the heat pumps, maintaining loop temperature, and controlling operation of the water loop circulation pumps. Monitoring revealed that several heat pumps were commanded on when the building was unoccupied, water loop circulation pumps ran continuously, and fluid cooler spray pumps ran during unoccupied times. PECI recommended that schedules for each heat pump unit be reviewed and reprogrammed to correspond to the same schedule, with individual schedules modified as necessary to meet special requirements. The retrocommissioning team also recommended that the water loop pump control logic should be reprogrammed in the CSI system so that the pumps respond to a direct scheduled start/stop command from the CSI and not from heat pump status. Finally, the CSI system is equipped with a "building manager" feature that allows occupants to call into the automated system and request cooling during normally unoccupied hours. The retrocommissioning team recommended that this system should be reviewed and reincorporated into the system, with a rate to cover off-hour service.

Estimated Annual Electric Savings: 219,460 kWh

Estimated Annual Cost Savings: $17,118

Actual Implementation Costs: $243

Simple Payback: 0 years

Owner Action: All heat pump operating schedules were reviewed and modified as necessary. Circulation pumps, cooler fans and spray pumps were programmed to operate only when a heat pump is scheduled to operate. A graph of the average daily load shapes for selected heat pumps, pre and post-retrofit, is found in Appendix B.

Rewire heat pump supply fans.
Monitoring suggested that the supply fans on the individual heat pumps operated regardless of whether the unit's compressor was enabled or not through the CSI EMCS. It was determined that the relays were wired at each heat pump such that when the EMCS turned the unit off according to program, only the compressor was disabled. Signals for cooling or heating coming from the thermostat during unoccupied hours were turning the supply fans on. Since the water loop pumps were programmed to turn on whenever a heat pump was operating, this also caused the pumps to turn on. The recommendation was to rewire the relays at each heat pump so that the entire unit is disabled by the EMCS signal, not just the unit's compressor.

Estimated Annual Electric Savings: 66,405 kWh

Estimated Annual Cost Savings: $5,180

Implementation Costs: $8,531

Simple Payback: 1.6 years

Owner Action: The owner chose not to implement this finding.

Trim west loop pump impeller.
The west end water loop is served by a 20 HP pump, designed to deliver 600 GPM. Measurements of pump discharge and suction indicated that the pump was in fact delivering 750 GPM. The recommendation was made to trim the impeller to a size that would deliver design flow rate with the main balancing valve wide open. Pump curve analysis predicted that design flow could be achieved with a 7.6-inch impeller, but the smallest impeller that can be used in the pump is 8 inches. This measure delivers both electrical and demand savings.

Estimated Annual Electric Savings: 19,890 kWh

Estimated Peak Demand Savings: 6.0 KW

Estimated Annual Cost Savings: $2,409

Estimated Implementation Costs: $2,426

Simple Payback: 1 year

Owner Action: The owner chose not to implement this measure.

Reduce condenser water loop temperature and install VFDs.
CSI energy management modulates the fluid cooler fan and spray pump to maintain water loop temperature leaving each fluid cooler at 85°F. Reducing the condenser water loop temperature set point from 85°F to 75°F will improve the individual heat pump compressor operating efficiencies, resulting in electrical consumption and demand savings. As a consequence, fluid cooler fan operation will increase, but the efficiency improvement for all 175 heat pumps will far outweigh any fan energy increase. The measure also includes installing variable frequency drives for infinite fan modulation in order to maintain loop temperature setpoint.

Estimated Annual Electric Savings: 46,000 kWh

Estimated Peak Demand Savings: 9 kW

Estimated Annual Cost Savings: $6,000

Estimated Implementation Costs: $10,400

Simple Payback: 1.7 years

Owner Action: The owner chose to implement a variation on this measure, reducing condenser water loop temperature and installing two-speed motors on each fluid cooler. Notably, the implementation cost for two-speed motors was higher than for VFDs, and the savings were lower, but the owner preferred the two-speed motors.

Estimated Annual Electric Savings: 31,000 kWh

Estimated Peak Demand Savings: 9 kW

Estimated Annual Cost Savings: $4,000

Actual Implementation Cost: $14,150

Simple Payback: 3.5 years

Inspect fluid cooler chemical treatment. Chemical concentration is maintained in an evaporative cooler by adding fresh water and chemicals into the unit. This process is commonly known as “bleed.” When evaporation rate is very high, the water bleed and chemical infusion can be large in order to maintain the desired concentration level. During the site visit, it was noted that a large amount of water was bled from the east loop fluid cooler, several times within the course of a few hours. There was not a large evaporative load on the system. In addition, during the same time frame, the west loop fluid cooler did not bleed any water at all, yet it appeared to be operating and cycling in a similar fashion to the east loop cooler. The retrocommissioning team recommended that the owner contact the chemical treatment company and ask to have both fluid cooler chemical systems inspected.

The owner was already aware of the problem, and the system was repaired. Although there were no energy benefits to be obtained by correcting this problem, there were other cost savings. Excessive bleed from the cooler wastes not only water, but chemicals as well.

Implementation

A retrocommissioning study identifies potential low-cost/no-cost measures to optimize building systems efficiency and operation. However, it is up to the owner to select and implement the measures. In some cases, the retrocommissioning provider is contracted to help the owner solicit bids, select contractors, and implement the measures. In others, the owner assumes all responsibility for implementation. In this case, the building owner was responsible for implementing their selected measures. After soliciting bids for various measures and consulting with a trusted service contractor, the owner chose to:

- Reduce condenser loop water temperature.
- Implement scheduling changes and programming improvements.
- Install two 25 HP two speed motors on fluid cooler fans.
- Inspect Fluid Cooler Chemical Treatment.

Overall, the actual implementation costs were $14,400. The measures are predicted to pay for themselves in energy savings in 0.7 years.

Notably, the owner chose not to implement several recommended measures, including rewiring the heat pump supply fans, trimming the west loop pump impeller, and installing variable frequency drives. One barrier to implementation was that the owner had previously had a negative experience with variable frequency drives. Based on the prior experience, the owner selected the two-speed drives instead.

Verification

This project selected two approaches to M&V from the International Performance Measurement and Verification Protocol (IPMVP, 2000): Calibrated Simulation and Partially Measured Retrofit Isolation. The first approach, Calibrated Simulation, was used for whole building savings analysis. This method is more accurate and quicker than using monthly energy bills. A baseline was established through DOE-2.1-E hourly building energy simulation program. The DOE-2 model was calibrated to the last twelve months of utility data and further to end use data as measured during diagnostic testing. Annual energy savings were identified for each measure and for the building as a whole.

The second method, Partially Measured Retrofit Isolation, was used for the measures that did not lend themselves to M&V using the calibrated model approach. This method uses engineering calculations verified with site inspections and short-term monitoring. After the owner implemented the recommendations, a sampling of the systems was remonitored to verify energy savings. Approximately half of the original data-loggers were reinstalled to monitor system operation over a two-week period. The new data was compared to the original, pre-implementation data, to establish savings.

Monitored data showed that the programming schedules had been changed as recommended. Therefore, the schedules used in the DOE-2 model to estimate energy savings are accurate.

LESSONS LEARNED

This case study holds several lessons for future retrocommissioning efforts.

1) A strict project screening process is crucial for obtaining cost-effective savings.

Both the utility and the retrocommissioning provider applied cost-effectiveness criteria in selecting the project. The strongest candidates for retrocommissioning are buildings with relatively modern controls systems and a ready and willing staff. In addition, the benefits of retrocommissioning can only last until the next retrofit, when systems and equipment must be re-optimized to work together, so the building should be retrocommissioned in conjunction with a retrofit, or soon thereafter, rather than when a retrofit is imminent.

If the team had chosen the first alternative, the Post Office with extensive deferred maintenance and an inoperable controls system, the entire budget would have been spent fixing the broken system, rather than optimizing an operable system. (Fixing the system is a worthwhile goal, but not the object of this retrocommissioning effort.)

2) Look out for the informal owner-contractor relationships and bring these contractors to the table. The success of a retrocommissioning effort depends on the cooperation of all project players – the owner, the commissioning provider, O&M staff, and service contractors. All of these players should be at the table from the project's inception. In this project, we did not include a service contractor because the owner did not have a standing service contract with any contractor. However, there was an informal agreement that the owner would contact their contractor when needed. This relationship proved to be as important as a service contract. When the owner received the recommendations, the owner consulted with their contractor. Because the contractor had not been on board since the inception, he was not aware of the reasoning behind the recommendations. The contractor recommended against trimming the pump impellers, which probably contributed to the owner's decision not to implement this measure. In retrospect, the contractor should have been a part of the retrocommissioning team from the beginning.

Another benefit of including the preferred service contractor is the opportunity to get accurate estimates of implementation costs and specify exactly what should be done. In this study, the estimated implementation costs for certain measures differed considerably from the actual implementation costs – actual costs were much less for rescheduling controls, and more for installing two speed motors. By including the service contractor at the table, the retrocommissioning provider can ask for estimates directly, and ensure that the estimates are for the services that the provider recommended.

Depending on the owner's skill and knowledge, he or she may not know exactly what to ask for, or what they should expect to receive. When the contractor is at the table from the start, he will better understand what the retrocommissioning provider is recommending and why, and will be able to more accurately estimate implementation costs.

3) Owners' decisions are influenced by past experience. In this case, the owner's previous experience with VFDs led him to avoid them. If the owner's biases can be anticipated, there is more of a chance that they can be influenced.

CONCLUSIONS

Retrocommissioning is a cost-effective source of energy savings, even in buildings with lower than average energy consumption. The combined measures implemented by the owner result in a 9.9% reduction in annual energy use and 6.9% reduction in annual utility costs. The simple payback is 0.7 years.

Despite the success of the project, SDG&E does not currently plan to implement more retrocommissioning, in part because the CPUC has only authorized retrofit and information programs. Unlike an equipment retrofit, retrocommissioning is not a "widget" that yields predictable savings over the known life of a measure. It is a process that enables building owners to realize savings, if they choose to implement the recommendations and they manage the changes so that they persist.

As this case study demonstrates, owners may choose not to implement certain recommendations. In addition, when they do decide to implement recommendations, they will not necessarily choose the ones with the quickest payback. Owner choices are dictated more by advice from trusted relationships and past experience. Yet even when they choose not to implement all of the recommendations, they are gaining a more thorough understanding of how their building works, and gaining an educated, aware building staff, a prerequisite for future efficiency improvements. If building staff are involved in helping with the retrocommissioning effort, they become aware of energy saving possibilities and can continue to watch for efficiency opportunities in this building and other buildings in which they work, long beyond the scope of the retrocommissioning project.

REFERENCES

Haasl, Tudi and Terry Sharp. *A Practical Guide for Commissioning Existing Buildings*. US DOE. 1999.

Gregerson, Joan. “Cost-Effectiveness of Commissioning 44 Existing Buildings,” in *Proceedings of the 5th National Conference on Building Commissioning*. PECI. 1997.

Commercial Building Energy Consumption Survey, Table C5. Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels, 1999. www.eia.doe.gov/emeu/cbecs/detailed_tables_1999.html.

International Performance Measurement & Verification Protocol, 2000. Website: www.ipmvp.org

APPENDIX A
Table 1

SAVINGS SUMMARY PROJECTION
Allied Plaza

EXISTING ENERGY USE

Building Area (Sq. Ft.)	Baseline Building	Existing Electric Energy (kWh/Yr)	Average Electric Demand (kW/Mo)	Existing Natural Gas (Therm Per Year)	Existing Annual Energy Cost	Existing EUI (kBTU/Sq.Ft. per Year)	Existing ECI ($/Sq.Ft. per Year)
125,000	2000-2001 Total Energy Use	2,394,824	592	0	$427,608	65.39	$3.42

Note: Energy Use Index (EUI) and Energy Cost Index (ECI) are based on gross building square footage

OPERATION AND MAINTENANCE MEASURES

Recommendation Selection Owner	Recommendation Selection PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Gallons Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	% Reduction of Cost Savings
Yes	Yes	1	Scheduling and Programming Improvements	219,460	0	$17,118	$243	0.0	4.0%
No	Yes	2	Rewire Heat Pump Supply Fans	66,405	0	$5,180	$8,531	1.6	1.2%
No	No	5	Reduce Condenser Water Loop Temperature*	20,000	0	$2,800	$50	0.0	0.7%
No	Yes	8	Trim West Loop Pump Impeller	19,890	0	$2,409	$2,426	1.0	0.6%
Total Recommendation Package as Selected by PECI				305,755	0	$24,707	$11,200	0.5	5.8%
	5%		Measure interaction of total package	290,467	0	$23,472	$11,200	0.5	5.5%
Total Recommendation Package as Selected by Owner				219,460	0	$17,118	$243	0.0	4.0%
	5%		Measure interaction of total package	208,487	0	$16,262	$243	0.0	3.8%

Note: Measures with an (*) in the title are mutually exclusive with other measures

CAPITAL IMPROVEMENT MEASURES

Recommendation Selection Owner	Recommendation Selection PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Therm Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	% Reduction of Cost Savings
No	No	3	Install Variable Frequency Drives on Fluid Cooler Fans*	28,000	0	$3,000	$10,000	3.3	0.7%
No	No	4	Install Two-speed Motors on Fluid Cooler Fans*	16,000	0	$1,690	$14,100	8.3	0.4%
Yes	No	6	Reduce Condenser Water Loop Temperature and Install Two-speed Motors*	31,000	0	$4,000	$14,150	3.5	0.9%
No	Yes	7	Reduce Condenser Water Loop Temperature and Install Variable Frequency Drives*	46,000	0	$6,000	$10,400	1.7	1.4%
Total Recommendation Package as Selected by PECI				46,000	0	$6,000	$10,400	1.7	1.4%
	5%		Measure interaction of total package	43,700	0	$5,700	$10,400	1.8	1.3%
Total Recommendation Package as Selected by Owner				31,000	0	$4,000	$14,150	3.5	0.9%
	5%		Measure interaction of total package	29,450	0	$3,800	$14,150	3.7	0.9%

Note: Measures with an (*) in the title are mutually exclusive with other measures

TOTAL PROJECT SUMMARY (O&M and Capital Improvement Measures)

		Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Therm Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	% Reduction of Cost Savings
Total Recommendation Package as Selected by PECI		351,755	0	$30,707	$21,600	0.7	7.2%
5%	Overall measure interaction of total package	334,167	0	$29,172	$21,600	0.7	6.8%
Total Recommendation Package as Selected by Owner		250,460	0	$21,118	$14,393	0.7	4.9%
5%	Overall measure interaction of total package	237,937	0	$20,062	$14,393	0.7	4.7%

OTHER MEASURES CONSIDERED

Recommendation Selection Owner	Recommendation Selection PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Therm Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	% Reduction of Cost Savings
No	Yes	9	Tune-up Heat Pumps	25,000	0	$2,800	$20,700	7.4	0.7%
No	Yes	10	Modify East Loop Pump Flow Rate	0	0	$0	$0	0.0	0.0%
Yes	Yes	11	Inspect Fluid Cooler Chemical Treatment	0	0	$0	$0	0.0	0.0%
No	Yes	12	Install Automatic Two-way Control Valves on each Heat Pump	36,838	0	$3,030	> $17,500	> 5	0.7%
No	Yes	13	Close Water Loop Make-up Line Valve	0	0	$0	$0	0.0	0.0%
Total Recommendation Package as Selected by PECI				61,838	0	$5,830	$20,700	3.6	1.4%
	5%		Measure interaction of total package	58,746	0	$5,539	$20,700	3.7	1.3%
Total Recommendation Package as Selected by Owner				0	0	$0	$0	N/A	0.0%
	5%		Measure interaction of total package	0	0	$0	$0	N/A	0.0%

APPENDIX B: Measurement and Verification Results

Figure 1: Pre- and Post-retrofit Monitored Heat Pumps, 5th Floor

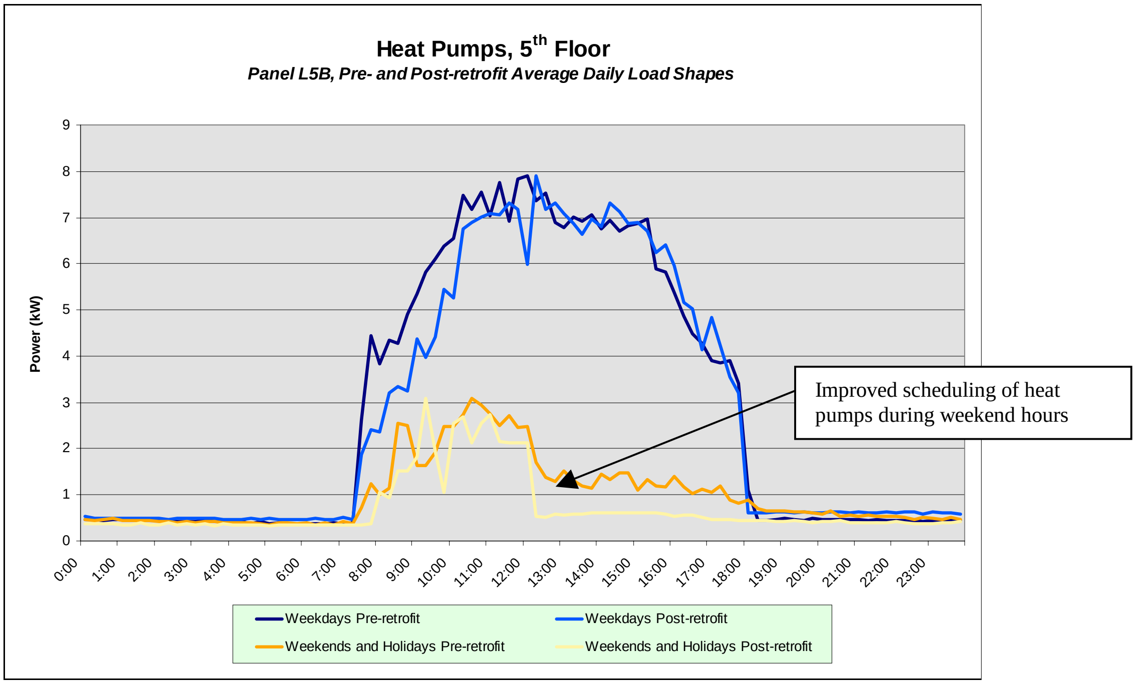

Figure 2: Pre- and Post-Retrofit Monitored Water Loop Pump #4

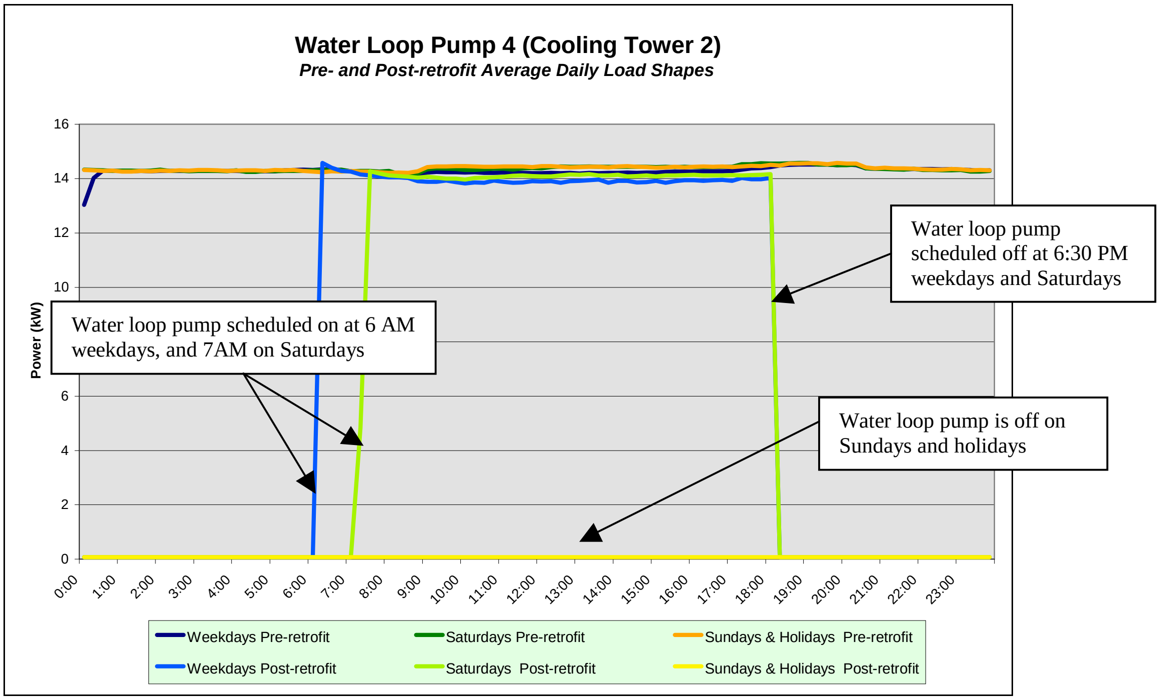

Figure 3: Pre- and Post-retrofit Monitored Spray Pumps (#1 and #2)

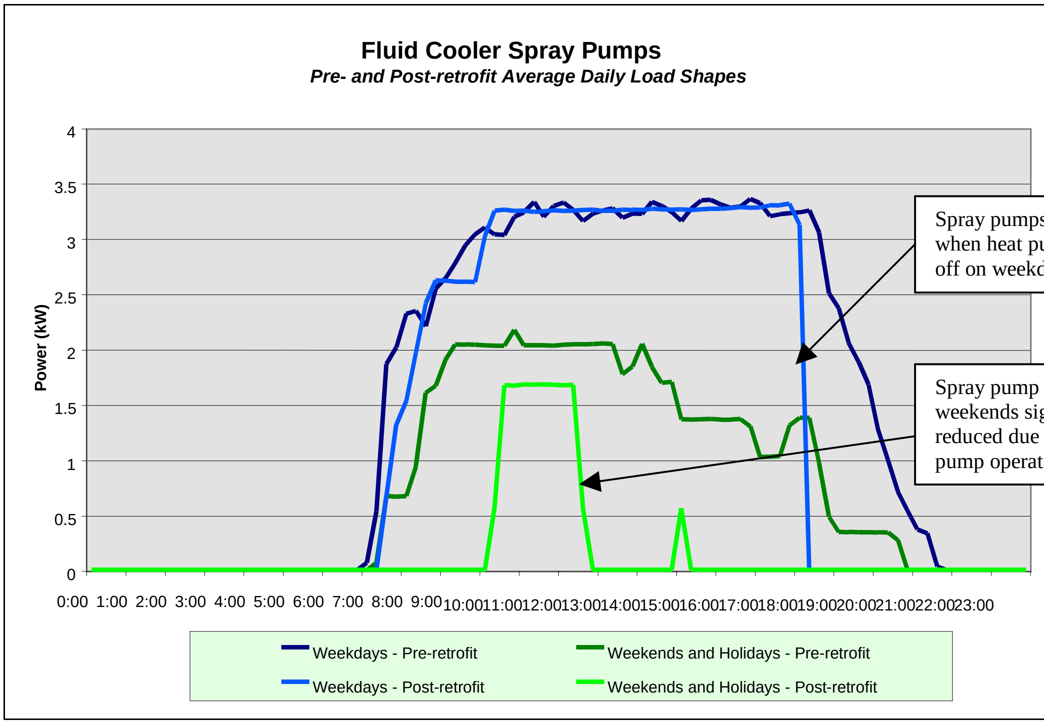

Figure 4: Typical System Diagram for Both East and West Heat Pump Loops