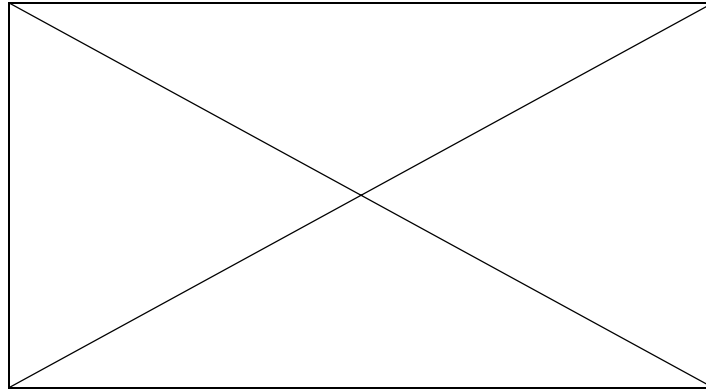


Building X Retrocommissioning Final Report



A study done by
Portland Energy Conservation, Inc. (PECI)
And
Partner

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EXECUTIVE SUMMARY- FINAL OVERVIEW OF PROJECT (3/2003)

Portland Energy Conservation Inc. (PECI) in conjunction with Partner completed a retrocommissioning study of the Building X, for the Client. The study was funded by the Organization Y through the Utility.

The retrocommissioning process involved a coordinated effort between PEGI, Partner, Client Staff, and Utility staff. The retrocommissioning process included, reviewing documents, conducting interviews and field investigations, monitoring and analyzing building systems, developing a findings list with supporting energy saving calculations, and assisting the Client with selecting measures for implementation. After implementation was completed, the measures were observed or monitored to verify functionality. This report presents the results of these efforts.

Retrocommissioning, or existing building commissioning, is an event in the life of a building that applies a systematic investigation process for improving and optimizing a building's operation and maintenance. It is typically an independent process that focuses on the building's energy using equipment such as the HVAC and other mechanical equipment, lighting equipment, and related controls. It may or may not emphasize bringing the building back to its original intended design specifications. In fact, via the process, the retrocommissioning team may find that the original specifications no longer apply. The process may result in recommendations for capital improvements, but its primary focus is to optimize the building systems via tune-up activities, improved operation and maintenance (O&M), and diagnostic testing. Details of the process used in this project are provided later in the report.

The Building X retrocommissioning process began in August of 2001. It involved obtaining documentation about the facility equipment and its operation. Commissioning team members then conducted site visits to further review the Client's equipment and operating parameters. As part of the analysis, selected systems were monitored with data loggers for a one-week period to trend system operation. Thirteen findings with associated energy savings were identified at the facility. Energy savings estimates were made for the significant findings where sufficient data was available and project

scope allowed. The findings were a mix of “operation and maintenance” repairs that had estimated paybacks of two or less years and “capital improvement measures” that were more costly to implement and had longer energy saving payback estimates. An additional five measures were identified as “soft improvement opportunities”. These soft improvements had potential energy saving and equipment maintenance impacts, but the savings estimates were based more on experience rather than energy modeling or engineering estimates.

In January 2002, PECE presented an interim report of these findings to the Client. Over the course of several months, the Client, in consultation with the project team and Utility, selected a number of findings for implementation. Of the findings identified in the Interim Commissioning Report, the Client chose to implement six of the seven operation and maintenance recommendations, four of the six capital improvement measures, and all five of the “soft” improvement opportunities. PECE assisted the Client with developing a scope of work that was integrated into a request for proposal (RFP). See Appendices L and M for PECE comments on the project cost and maintenance service agreement proposals. The Client released the RFP and a contractor was retained to make the repairs and install the capital improvement measures.

The retrocommissioning repairs and capital improvements were completed in conjunction with a remodeling project already taking place at Building X. The repairs and installation of capital improvement measures were completed in November, 2002. Upon completion, Partner undertook a post implementation walk-through and datalogged selected building systems and spaces to verify the functionality of the repairs and newly installed equipment. The post-implementation evaluation indicated that several of the measures did not appear to be performing as expected. PECE developed a memo of follow-up recommendations for the Client and the retrocommissioning team’s work on the project was concluded in February 2002. Response memos from Mechanical Contractor Z and the Client, now indicate that most of these outstanding issues have been addressed. See Appendix N for copies of these memos and datalogging summary graphs.

The measures and findings selected by Client for implementation are summarized below.

Operation and Maintenance Measures. Seven operation and maintenance (O&M) measures were identified in the retrocommissioning study and the owner selected all of these measures for implementation. The implemented measures included:

- Adjusting airflow to the Client Engineer's work space
- Delamping selected work spaces
- Repairing the main air-handler's time clock to provide appropriate scheduling
- Incorporating occupancy based control to Section A offices
- Repairing economizer control to allow for free cooling as designed
- Repairing chiller controls to eliminate cycling and provide 2nd stage lockout
- Repairing boiler controls to provide hot water reset control

The total estimated annual savings for the individual O&M measure implemented by the owner are 93,612 kWh of electricity, 3,092 Therms of natural gas and \$6,148 in annual utility costs. However because modeling software was used for some of these calculations, a 20% discount factor is applied to account for their interactivity of the measures reducing the savings numbers to 74,890 kWh of electricity, 2,472 Therms of natural gas and \$4,918 in annual utility costs respectively. PECE originally estimated the implementation costs for these measures to be approximately \$8,200. However, the Client chose to incorporate these repairs/upgrades into a larger more comprehensive building remodel/equipment upgrade project. Therefore this report does not include the final contractor costs for implementing these measures.

Capital Improvement Measures. Six Capital Improvement measure were identified in the retrocommissioning study and the owner selected four of them for implementation. The implemented measures included:

- Installing variable speed control on the main supply and return fan motors

- Repairing and or replacing flex duct
- Replacing electric space heaters with personal radiant panels
- Rebalancing the building's air flows

The total estimated annual savings for the four individual capital improvement measure implemented by the owner are 89,225 kWh of electricity, 273 Therms of natural gas and \$3,944 in annual utility costs. However because modeling software was used for some of these calculations, a 20% discount factor should be applied to account for their interactivity of the measures reducing the savings numbers to 71,380 kWh of electricity, 218 Therms of natural gas and \$3,155 in annual utility costs respectively. PECE originally estimated the implementation costs for these measures to be approximately \$13,800. However, the Client chose to incorporate these repairs/upgrades into a larger more comprehensive building remodel equipment upgrade project. Therefore this report does not include the final contractor costs for implementing these measures.

Other Measures Considered. Five soft improvement measures were identified in the original retrocommissioning study. All five of these measures were or will be implemented by the Client. They include:

- Boiler repair, efficiency test and optimization
- Change air-handler filters and repair manometer
- Repair the control system air-compressor
- Implement a utility tracking program
- Expand operation and maintenance training and procedures

Total Project Summary. The combined measures implemented by the owner result in an estimated total annual savings of 146,270 kWh and \$8,073 of electrical costs which correspond to a 26% reduction in annual utility costs. Refer to the "Savings Summary" table below for details on the total project savings and costs.

Further detail on each individual measure's savings and costs can also be found in the section entitled "Findings, Recommendations, and Implementations".

Note: A building energy modeling package called EZ Sim was used to model the baseline building and calculate the overall savings for some of these measures. The 12-month period ending July 2001, as determined

from EZ Sim Billing Analysis (which summarizes actual raw billing data) was used as the Existing Baseline. The EZ Sim Baseline energy use represents a model of building to compare individual ECMs. Further information on EZ Sim can be found in Appendix L.

SAVINGS SUMMARY PROJECTION-POST IMPLEMENTATION									
Building X									
EXISTING ENERGY USE									
				kWh:	\$0.0396	Blended:	\$0.0480	Gas:	\$ 0.78
Building Area (Sq. Ft.)	Baseline Building	Existing Electric Energy (kWh/Yr)	Existing Electric Demand (kW/Mo)	Existing Nat. Gas (Therms Per Year)	Existing Annual Energy Cost	Existing EUI (BTU/S.F. per Year)	Existing ECI (\$/Sq.Ft. per Year)		
23,210	8/00-7/01 Actual energy use	482,000	100	12,035	\$32,524	122,734	\$1.40		
23,210	EZ Sim normalized baseline model	436,017	92	11,686	\$31,484	118,875	\$1.36		
OPERATION AND MAINTENANCE MEASURES									
Recommendation Selection Owner	PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Nat. Gas Saved (Therms Per Year)	Annual Cost Savings	Implem. Cost	Simple Payback (Years)	% Reduction of Cost Savings
Yes	Yes	O&M 1	Reduce air to city engineers space	2,000	260	\$291	\$75	0.3	0.9%
Yes	Yes	O&M 2	Delamping	2,400	0	\$120	\$50	0.4	0.4%
Yes	Yes	O&M 3	Replace timeclock	14,198	0	\$562	\$500	0.9	1.8%
Yes	Yes	O&M 4	Control room occupancy-based hvac	18,992	1,087	\$1,394	\$2,000	1.4	4.4%
Yes	Yes	O&M 5	Repair economizer	29,018	0	\$1,143	\$1,500	1.3	3.6%
Yes	Yes	O&M 6	Chiller controls upgrade	32,004	0	\$1,265	\$1,500	1.2	4.0%
Yes	Yes	O&M 7	Boiler controls upgrade	0	1,763	\$1,367	\$2,500	1.9	4.3%
Total Recommendation Package as Selected by Peci				93,612	3,090	\$6,148	\$8,225	1.3	19.5%
20% Measure Interaction of total package				74,890	2,472	\$4,918	\$8,225	1.7	15.6%
Total Recommendation Package as Selected by Owner				93,612	3,090	\$6,148	\$8,225	1.3	19.5%
20% Measure Interaction of total package				74,890	2,472	\$4,918	\$8,225	1.7	15.6%
Note: Measures with an (*) in the title are mutually exclusive with other measures									
CAPITAL IMPROVEMENT MEASURES									
Recommendation Selection Owner	PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Nat. Gas Saved (Therms Per Year)	Annual Cost Savings	Implem. Cost	Simple Payback (Years)	% Reduction of Cost Savings
No	Yes	LP-1	Perimeter zone temperature controls upgrade	3,937	175	\$326	\$2,500	7.7	1.0%
Yes	Yes	LP-2	Install VFD on supply and return fans	65,294	(194)	\$2,431	\$7,000	2.9	7.7%
No	Yes	LP-3	T8 electronic lighting upgrade	78,356	0	\$881	\$8,010	9.1	2.8%
Yes	Yes	LP-4	Flex duct upgrade	9,000	0	\$132	\$2,000	1.6	1.1%
Yes	Yes	LP-5	Replace personal heaters with radiant panels	5,776	0	\$277	\$1,800	6.5	0.9%
Yes	Yes	LP-6	Building air balance	9,155	467	\$804	\$3,000	3.7	2.6%
Total Recommendation Package as Selected by Peci				111,518	448	\$5,151	\$24,310	4.7	16.4%
20% Measure Interaction of total package				89,214	358	\$4,121	\$24,310	5.9	13.1%
Total Recommendation Package as Selected by Owner				89,225	273	\$3,944	\$13,800	3.5	12.5%
20% Measure Interaction of total package				71,380	218	\$3,155	\$13,800	4.4	10.0%
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)	Nat. Gas Saved (Therms Per Year)	Annual Cost Savings	Implem. Cost	Simple Payback (Years)	% Reduction of Cost Savings
Total Recommendation Package as Selected by Peci				205,130	3,538	\$11,299	\$32,535	2.9	35.6%
20% Weighted average measure interaction of total package				164,104	2,830	\$9,039	\$32,535	3.6	28.7%
Total Recommendation Package as Selected by Owner				182,837	3,363	\$10,092	\$22,025	2.2	32.1%
20% Weighted average measure interaction of total package				146,270	2,690	\$8,073	\$22,025	2.7	25.6%
"SOFT" IMPROVEMENT OPPORTUNITIES									
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Recommendation Selection Owner	PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Nat. Gas Saved (Therms Per Year)	Annual Cost Savings	Implem. Cost	Simple Payback (Years)	% Reduction of Cost Savings
Yes	Yes	SO-1	Boiler efficiency test & optimization	0	303	\$237	\$350	1.5	0.8%
Yes	Yes	SO-2	Change filters and repair manometer	0	0	\$0	\$100	r/a	0.0%
Yes	Yes	SO-3	Repair the unloader on the air compressor	0	0	\$0	\$300	r/a	0.0%
Yes	Yes	SO-4	Implement a utility tracking program	2,330	214	\$630	\$500	0.8	3.0%

INTERIM REPORT-INTRODUCTION (1/2002)

This report presents the results of the retrocommissioning study performed on Building X located in City Y. This retrocommissioning study was completed as part of an energy-efficiency market-transformation program funded by Organization Z and managed by Utility. Portland Energy Conservation Inc. (PECI) with Partner completed the retrocommissioning study.

Retrocommissioning is an excellent way to obtain energy savings through low cost improvements that optimize building systems so they operate efficiently and effectively. On average, retrocommissioning of existing buildings reduces a building's energy costs by 5% to 20%. The payback for investment in low cost opportunities typically ranges from a few months to two years. In addition, retrocommissioning can improve occupant comfort, reduce indoor air quality problems, and reduce operations and maintenance costs.

METHODOLOGY

Commissioning of existing buildings, or "retrocommissioning" is a systematic process applied to existing buildings to identify and implement operational and maintenance (O&M) improvements and to ensure building system functionality. The primary goal of retrocommissioning is to optimize equipment and system operation so they function together efficiently and effectively.

Retrocommissioning may also result in recommending capital improvements. The basic process includes four fundamental procedures:

- ❑ Investigation and data collection
- ❑ Analysis of data
- ❑ Implementation of recommendations
- ❑ Verification of energy savings

Each of these procedures is discussed in detail below.

INVESTIGATION & DATA COLLECTION

The retrocommissioning process began by collecting and evaluating data pertaining to facility equipment and current operation. The primary tasks for this project are outlined below.

Documentation Review

The first step of the investigative process consisted of obtaining as much building documentation as possible to allow the field staff to become familiar with the building and its systems. The Client supplied 30 months of utility billing data, building control sequences, and blueprints to the retrocommissioning team.

Site Assessment

The next step was to conduct the site assessment. Several days were spent in the building conducting a comfort survey, interviewing staff, analyzing ductwork, inspecting controls, and observing equipment operation over time. The assessment identified several significant findings, as well as areas where additional monitoring and testing was needed.

Monitoring/Data Logging

The facility does not have a central building automation system from which to take trending data. Therefore, several portable instruments were used to monitor building conditions and equipment usage.

A four-channel data logger was used to monitor the HVAC system's temperatures and operations, and the electric load profile of the building. A light meter was used to measure interior light levels, a digital manometer was used to measure airflow in ducts and diffusers, and paper disk temperature recorders were used to record space temperatures. The data from this monitoring was used to develop an operating profile for the facility. PARTNER developed procedures to check for correct economizer operation. Economizer operation, or lack thereof, was determined by metering the supply fan and the return fan and visual observation of system operation.

ANALYSIS OF DATA

PECI and PARTNER analyzed the site interview data, written documentation, monitored data and manual test data. From this work the findings were formalized, estimates for their associated energy savings and implementation costs were developed, and this report generated.

Baseline Calibration

The software analysis tool EZSim was used to develop a calibrated baseline of energy consumption for the facility. The EZSim tool is spreadsheet-based and ties together whole-building level billing data and a simplified engineering simulation model. The program accepts detailed input about the facility such as lighting and equipment loads, building construction, HVAC operation and control setpoints, general occupancy, equipment operating schedules, and local weather data. The tool is designed to quickly “tune” or calibrate the engineering model against the existing monthly energy usage. The program compares the calculated usage profile to the existing usage profile using least-squared curve fit analysis and the user adjusted building input data until the calculated profile matches the existing profile as closely as possible.

Energy Use Analysis

As described above, the building calibration can be used to determine the breakdown of existing energy usage for various pieces of equipment in the facility (end-use profile) and the overall energy usage per square foot (energy use index). The end-use profile allows the user to see where all of the energy is being used in the facility and where opportunities for energy conservation exist. The energy use index can be used to compare energy usage in the existing facility against similar building types under similar weather conditions. Refer to the *Baseline Facility Description* section for detailed discussion of existing energy usage at the facility.

Trend Analysis

The monitored data gathered during the site visit was plotted and the graphs analyzed for any anomalies. Analysis can be used to identify and validate existing energy usage and potential conservation opportunities. For example the data logging graphs entitled “Main Panel, 3 Phases, Labor Day Weekend Sep. 1-3 and Chiller Amps Weekend Sep. 15-16” verify that the chiller was not in setback mode during the unoccupied hours. “Chiller Amps, Week Day Sep. 10-14” also indicated the chiller was running during weekday evenings. Refer to *Appendix C - Data Logging Trend Analysis Figures* for all trend graphs of data collected during the site visit.

Energy Savings Calculations

Energy savings were calculated in a variety of ways. For simple measures, customized spreadsheets based on standard engineering practices and rules of thumb were used to estimate savings. The calibrated building model was used to establish baseline energy consumption and information gathered during the site visit and was used to validate many of the energy savings calculations. Cost savings are generally calculated using the average unit cost per utility. For example, the average cost of electricity is calculated by dividing the total monthly cost, which includes demand costs and taxes, by the monthly consumption. However, some measures may not achieve any demand savings and therefore cannot use the average electricity cost described above. These measures must use the actual electrical energy cost based on the utility rate schedule, including all taxes. For this project the blended (energy cost and demand cost) most recent electricity cost is calculated at \$0.048/kWh, and the average cost of natural gas is calculated at \$0.77/therm. The latest rate schedule dated May 1, 2001 gives the energy charge as \$0.039565/kWh, which includes all taxes. All energy savings cost calculations use either the blended most recent cost of electricity, the electrical energy cost, and/or average cost of natural gas. The monthly energy used since January 1999 can be seen in *Appendix B -- Utility History Analysis Figures*.

Project Costs

Implementation costs are estimated for each measure based on a variety of methods – i.e. contractor budgetary cost estimates, Means Estimating Manual, catalogue prices, and past experience. The cost projections assume that facility staff will complete the installation or be available to assist a contractor with the implementation. However, measurement and verification (M&V) costs, performance bond costs, and audit report costs have not been included, nor have costs associated with development of design documents and specifications that may be required to successfully engineer and implement some of the capital-intensive measures.

Measure Selection

Energy savings, cost savings, and implementation costs were first determined for each measure on an individual basis. All measures were then entered into a summary spreadsheet and prioritized based on estimated. Partner and PECl will assist the owner in determining how to prioritize the measures for implementation.

There are various reasons for not recommending a measure. For example, a measure may be mutually exclusive with another measure and therefore a selection must be made between the two measures. An example of this could be lighting measures where removing lamps (delamping) in selected areas is cost effective, but the owner may wish to completely replace these lamps and fixture as part of larger lighting retrofit in the building. The owner will therefore need to select from these two different options and only be able to take savings from one of the options.

Once the owner has reviewed the proposed measures, the owner then selects which measures they want to implement and a new table will be developed giving the energy savings, cost savings, and implementation cost only for the selected measures. The revised summary table will be included in the final report.

Implementation Of Recommendations

Once the owner has selected the desired measures, the next step is to implement these measures. After approval has been granted, the owner should have their facility personnel implement all the measures within their capability and hire outside contractors for those measures beyond the staff's ability.

Retesting of Implemented Improvements

After the measures are implemented, dataloggers will be reinstalled to verify that measures are working effectively. Site observations and handheld instrument testing will be used for verification of measures where datalogging is not practical.

BASELINE FACILITY DESCRIPTION

General Information

Building X is the facility being studied. The facility was constructed in 1982. It is a 23,210 square foot single story municipal office building with partial basement.

The facility is brick/block walls with a built up flat roof. The roof has several inches of rigid roof deck insulation and the block walls are filled with insulation. All windows are double paned.

General occupancy for the facility is 9 hours per day, 5 days per week. There are approximately 40 full time staff members occupying the building. The computer system in the building operates 24 hours per day, 365 days per year. The server room for the computer system is located in the basement.

The southeast portion of the main floor will undergo a remodel in late December 2001 or January 2002 to provide enclosed offices for several people. It is recommended that the scope of work for these changes include the identified retrocommissioning measures affecting the ducting, lighting and zone controls. The layout for the remodel is in *Appendix A*.

Heating Ventilating and Air Conditioning (HVAC) System

The current HVAC system is one built in place air handler with a supply fan and return fan (both with variable inlet vanes) and terminal reheat boxes. The air handler is located in the mechanical room in the basement. The perimeter zones also have hot water baseboard radiation units. Supply air is cooled with a chilled water cooling coil in the air handler.

Cooling

Chilled water for the building is supplied by a 60 Ton McQuay Model WHRO60C3 chiller, two compressors each rated at 35 HP, 460 Volts, 61 amps (RLA). A 3 HP pump delivers the chilled water to a Pace air-handler coil rated at 20,000 cubic feet per minute (CFM), 680 MBH.

A new auxiliary chiller was installed in the basement in July 2001 to serve the computer room.

Heating

The hot water boiler is an Ajax Model WGFD-700 rated at 700 MBH in, 560 MBH out. The combustion efficiency for the boiler in its current condition has been estimated to be between 60% and 75%.

Fans

The supply fan is 18 HP. The total amount of air delivered to the building is estimated at 22,700 CFM from the air-handlers nameplate data. The return/exhaust air fan is 2 HP and is tied to the operation of the supply fan. There are 3 exhaust fans, a 1650 CFM exhaust fan for the main rest rooms, a 90 CFM fan for a smaller rest room and a 400 CFM exhaust fan connected to the blue print machine.

HVAC Controls

All of the terminal reheat units are controlled by thermostats located throughout the facility. Supply air is cooled in the central air handler and sent to the terminal reheat units. Depending on space conditions, room thermostats send a signal to these boxes to open or close allowing more or less cooling air into the space. A minimum setting on the boxes allows a minimum amount of fresh air into the space to maintain good indoor air quality. If the space is calling for heat, the damper opens allowing more air into the space, the heating water valve then opens for the heating coil and allows hot water to warm up the supply air. Currently the chiller is manually turned off during heating season (from approximately October to April) and the boiler is turned off during cooling season.

Hot water radiant heaters, also served by the boiler, are located around the outside walls to provide additional heat in the perimeter zones. They are controlled by separate thermostats. Often these thermostats are in different rooms than the thermostat controlling the terminal reheat boxes. In some cases, this causes the two systems to fight each other since one thermostat may be calling for cooling and the other for heating.

Electrical Systems

Interior Lighting

The interior lighting for the facility includes fluorescent, incandescent, and compact fluorescent fixtures. The majority of the fluorescent fixtures have T12 lamps with magnetic ballasts. Light levels ranged from 10 to 25 foot-candles for the hallways; 40 to 60 foot-candles for the open area office work surfaces and 30 to 130 on desktops in enclosed offices. Most areas are within the Illumination Engineering Society (IES) standards. However, four offices are significantly overlit.

Exterior Lighting

The exterior lighting for the facility includes high intensity discharge (HID) parking area light fixtures. Walkway lighting is from post mounted HID's. Several specialty areas such as the flags and memorial are illuminated by large incandescent floods and spots. The canopy of the building is also illuminated by several recessed soffit fixtures.

Lighting Controls

All interior lights are controlled by toggle switches, with a few areas using double switching to allowing variable lighting levels. All exterior lights are controlled by photocells. During our site visits, no outdoor lights appeared to be operating during daylight hours.

Miscellaneous Electrical Systems

Miscellaneous electrical equipment at the facility includes a central computer server, personal computers, several personal heaters and general office plug loads.

Operations & Maintenance Procedures

Currently, in-house personnel perform some equipment operation and maintenance. This includes adjusting thermostats, replacing light bulbs and general repairs. Outside contractors are used if facility staff is unavailable or unable to remedy a problem or to perform more complex maintenance procedures. Outside contractors typically change filters on the central air handler, adjust airflows, change the chilled and hot water set points, and adjust the supply air temperature set points.

Energy Utilization

The Facility uses electricity and natural gas to meet its energy needs. The facility used 482,000 kWh of electricity (\$18,323) and 12,036 therms of natural gas (\$8,497) for the 12-month period between June 2000 and July 2001. This corresponds to an energy use index (EUI) of 122,734 BTU/sq ft./yr and an energy cost index of \$1.40/sq. ft./year. Note that this is up substantially from the beginning of the data. See *Appendix B – Utility History Analysis Figure* for the 30-month utility history and analysis on a monthly basis.

The electrical energy and natural gas usage profiles for the facility appear to be normal. The electrical energy consumption for the facility follows a typical “bell-shaped” pattern, with a rather constant load and mechanical cooling occurring mostly during the summer months. The electrical demand profile indicates that the base load is about 70 kW, with some cooling occurring during spring and fall months, and then full cooling during the summer months. The natural gas consumption profile also follows a classic “bell-shaped” curve, with peak consumption during winter months. Refer to the “Building X Gas and Electric Billing” graphs located in *Appendix B – Utility History Analysis Figures*.

Baseline Adjustment

Occasionally retrocommissioning findings and recommendations may require that systems be brought up to present code requirements, which can increase energy consumption in some cases. Existing facilities that met all building codes at the time the facility was constructed are not required to meet current codes. However if major modifications are made or equipment is replaced, compliance with the current codes must be satisfied. For example installing a new HVAC system will require that the new unit meet current minimum outdoor air requirements. Depending on what the codes were when the facility was constructed, the new minimum outside air requirements could be significantly higher and result in increased energy consumption. In this situation, the existing energy consumption baseline may be adjusted to reflect the existing equipment with the increased energy consumption due to increased outside air.

FINDINGS, RECOMMENDATIONS & IMPLEMENTATION

General Discussion

Each of these findings and subsequent recommendations has been written to give the reader an understanding of the non-energy benefits involved along with a summary of the estimated savings. The finding numbers match the numbers on the summary table in the executive summary for easy reference.

Operation and Maintenance Measures (O&M)

O&M – 1 - Reduce air to Engineers' Space

Finding Description

The Client's Engineer currently has his office in the space previously used for the computer server. This space had high air flow requirements because of the heat generated by the computer equipment. The airflow was not reduced when the space was converted to offices. This results in wide temperature swings and an uncomfortable space for the occupants.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- Yes	Indoor Air Quality – No
Demand Savings - No	Comfort - Yes	Maintenance and reliability – No

Recommendation

To reduce the airflow, one of the two diffusers in this space should be removed and the flexible duct connection be sealed at the main duct.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	2000 kWh/yr	Estimated Annual Cost Savings -	\$291
Estimated Peak Demand Savings -	0 kW	Estimated Implementation Cost -	\$75
Estimated Annual Natural Gas Savings -	250 Therms/yr	Simple Payback (yrs) -	0.3

Suggested Implementation Plan

Disconnect the supply air to one of the two diffusers serving this space, remove the diffuser and replace the opening with a ceiling tile,

and seal the duct at the main trunk duct. Time permitting, this could be accomplished by in-house staff.

O&M 2 – Delamping - Remove selected ballasts and lamps from fixtures

Finding Description

Four offices have light levels that are significantly higher than recommended by the Illumination Engineering Society (IES). High lighting levels not only waste lighting and cooling energy, but can cause headaches and eyestrain from the excessive glare created on computer monitors.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- No	Indoor Air Quality – No
Demand Savings – Yes	Comfort – Yes	Maintenance and reliability - No

Recommendation

It is recommended one ballast and two lamps be removed from selected light fixtures in those office that are over lit and where the occupant feels it would improve their working atmosphere. It is estimated about 10 fixtures could be modified. The ballast would be disconnected yet left in place to be used as a spare if the other ballast failed.

This option should be implemented if the Client decides to not retrofit the entire building with T-8 lamps and electronic ballasts, as discussed later in finding "LP-3 Lamp Replacement". However, because the payback on this measure is very short, it could still be implemented if LP-3 were selected and there was to be a year or more lag before the retrofit is implemented.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	2400 kWh/yr	Estimated Annual Cost Savings -	\$120
Estimated Peak Demand Savings -	0 kW	Estimated Implementation Cost -	\$50
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (yrs) -	0.4

Implementation Plan

One ballast would be disconnected and two lamps removed from selected fixtures in offices that are currently over lit. This could be

accomplished by in-house staff provided they are qualified to work with the electrical components.

O&M - 3 – Replace HVAC Timeclock – Install new timeclock to control air-handler operation

Finding Description

It was discovered during a site visit that the timeclock / optimal-start controls for the central air handler were not functioning. When the building was constructed, optimal start function was a relatively new consideration and had not yet been perfected with pneumatic systems. It has since been found that pneumatic systems are far less effective in this action than the newer and less expensive electronic controllers. Because the installed control system was not able to satisfy the needs of the building, it was disabled as an optimal start controller early in its career. Additionally, the time clock function is not currently operating, allowing the air handler to operate 24 hours per day, 7 days per week.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- No	Indoor Air Quality – Yes
Demand Savings – No	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

It is recommended the original time clock / pneumatic optimal start controller be replaced with a new and more sophisticated timeclock.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	14,198 kWh/yr	Estimated Annual Cost Savings -	\$562
Estimated Peak Demand Savings -	0 kW	Estimated Implementation Cost -	\$500
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (yrs) -	0.9

Note: This measure has been calculated very conservatively. We believe that higher savings are probably likely from this measure.

Implementation Plan

Purchase and install a new electronic time clock to control the air handler operation. The time clock can be programmed to shut down the air handler during nights, weekends, and holidays. The installation should be done by a qualified contractor.

O&M 4 – Room A Air Control - Provide Occupied/Unoccupied mode for the Room A

Finding Description

The meeting room A has capacity for a large crowd but is only utilized to its full capacity for several hours per week. The airflow into the room remains constant throughout the day regardless of the occupancy level in this space.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- Yes	Indoor Air Quality – Yes
Demand Savings – No	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

Ideally, provide a means of closing off the airflow the room for those times when it is empty and increase airflow depending on the number of occupants. At minimum, use an occupancy based control to fully close the damper to this space when it is unoccupied. The control may also be tied to the lighting so the lights are also automatically turned off when the room is not occupied. Lighting saving is not included in the saving estimate.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	13,392 kWh/yr	Estimated Annual Cost Savings -	\$1,394
Estimated Peak Demand Savings -	KW	Estimated Implementation Cost -	\$2,000
Estimated Annual Natural Gas Savings -	1,087 Therms/yr	Simple Payback (years) -	1.4

Implementation Plan

Hire an experienced HVAC Engineer, to design the needed modifications and controls for this strategy and have a qualified contractor install and program the controls.

O&M 5 – Repair Economizer

Finding Description

During several visits, observations indicated that no outside air was coming into the air handler during normal business hours when the building was fully occupied and instrumentation indicated no outside air was coming into the building during cool evening hours.

When the HVAC system was designed and installed, the ability to use outside air to cool the building was integral in attaining comfort year around and reduce mechanical cooling energy. Outside air can be drawn into the building any time it is cooler than the return air and the building needs cooling. This is called “Economy cooling”. At no time during the survey was this function occurring. Many mornings during the study the outside air was in the 50’s and the chiller was running to cool the 80-degree return air back down to 50°F.

The supply and return air fans are tied together as can be seen in the charts in *Appendix C – Data Logging and Trend Analysis* and were originally set up to insure there was an adequate amount of outside air coming into the building to maintain good air quality. During every visit to the site, there was little or no outside air being taken into the building even when conditions would allow the use of economy cooling. At sometime in the past, either the airflow ratios were modified or the damper sequencing was changed. Data logging showed the outside air temperature and mixed air temperatures were close to the same at all times (refer to Outside Air and the Mixed Air in *Appendix C – Data Logging and Trend Analysis*). Observations also indicated that airflow appeared reversed so it went out the outside air intake. As can be seen in the photos in *Appendix A*, the Outside Air temperature sensor was located in the outside air duct just inside the damper where normal damper operation would allow outside air to flow over the sensor. If the fans have been adjusted so the return fan is overpowering the supply fan, this reversed airflow can happen even when dampers are closed since, due to their nature, dampers are never completely tight. As this is repaired, adequate outside air will be taken in.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings --	Indoor Air Quality – Yes
Demand Savings -	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

Further investigate the damper sequencing and then repair the economizer to use outside air for improving comfort and reducing mechanical cooling. The economizer should be the first stage cooling. The success of this improvement is dependent on addressing the maintenance issues with the VAV system at the air

handler. The pneumatic control of the return/exhaust air fan and supply air fan must be tuned and fully functional for this measure to work optimally (see LP-2). Economy cooling typically presents one of the best opportunities for obtaining energy savings while improving the working environment.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	29,018 kWh/yr	Estimated Annual Cost Savings -	\$1,148
Estimated Peak Demand Savings -	KW	Estimated Implementation Cost -	\$1,500
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (years) -	1.3

Suggested Implementation Plan

Hire an experienced HVAC technician who has proven expertise in troubleshooting and repairing pneumatic systems, to implement this strategy. In-house staff could assist by ensuring all maintenance issues are completed prior to or during the tuning of the economizer and VAV fan control. For example the dampers, vanes, and linkages should be able to move freely and easily, and actuator diaphragms should be in good condition. Additionally, the Client should consider moving the OSA temperature sensor from the air duct to a weather protected location outside the building.

O&M -6 – Chiller Controls - Improve Chiller Controls to eliminate cycling and lock out 2nd stage at low loads

Finding Description

The chiller cycles on and off frequently during daytime and evening hours. In addition, the second stage of the chiller is activating when the additional cooling capacity is not required causing the chiller to not run efficiently. The excessive cycling has a very damaging effect on the chiller and will lead to premature failure of the compressors. This will require expensive rebuild and/or replacement of the compressors.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- No	Indoor Air Quality - No
Demand Savings - No	Comfort – No	Maintenance and reliability - Yes

Recommendation

A controller should be installed on the chiller that will:

- a) At a minimum, provide time of day scheduling control.
- b) Lock out the second stage if the outside temperature falls below a certain setpoint. Testing of the control needs to be done to determine the optimal OSA temperature for the lock-out point.
- c) Reset the chilled water temperature according to outdoor temperature and time of day/operating mode
- d) Control the chiller so it uses a minimum run time and off time to reduce short cycling and keep the chiller from failing prematurely.
- e) Allow economy cooling as the first stage of cooling when feasible.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	32,004kWh/yr	Estimated Annual Cost Savings -	\$1,266
Estimated Peak Demand Savings -	KW	Estimated Implementation Cost -	\$1,500
Estimated Annual Natural Gas Savings -	Therms/yr	Simple Payback (years) -	1.2

The measure will also reduce the repair and maintenance costs for the chiller.

Implementation Plan

Contact the chiller manufacturer and determine feasibility to accomplish the above points and the recommended type of control to accomplish it. This measure should also be considered along with the recommendation for a new electronic time clock for the supply fan (see O&M 3) The new time clock might be able to perform the scheduling function for the chiller, the minimal recommendation.

O&M -7 Boiler Controls – Adjust building control system to provide hot water reset control

Finding Description

The heating water temperature is currently not being reset. With a constant setpoint, the boiler produces hot water at a higher temperature than necessary, and wastes energy.

Because the boiler has not had a combustion analysis or tune up for several years it is assumed to be running 10 the 15% below the rated

efficiency (see OSI – 1). This maintenance issue should be addressed prior to or along with the implementation of this measure.

General Finding Impacts

Energy Savings - No	Natural Gas Savings -- Yes	Indoor Air Quality - No
Demand Savings - No	Comfort - No	Maintenance and reliability - Yes

Recommendation

Install the appropriate controls to reset heating water according to outside air temperature.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	kWh/yr	Estimated Annual Cost Savings -	\$1,367
Estimated Peak Demand Savings -	KW	Estimated Implementation Cost -	\$2,600
Estimated Annual Natural Gas Savings -	1,753 Therms/yr	Simple Payback (years) -	1.9

Implementation Plan

This is a straight-forward measure and is typical for heating water systems to reduce energy use and maintain comfort. Hire an outside boiler contractor to analyze the boiler efficiency, tune the boiler and install the controls for heating water reset.

CAPITAL IMPROVEMENT MEASURES FOR FURTHER INVESTIGATION (Measures with paybacks longer that two years)

Although the goal or retrocommissioning is to identify and help the owner implement low-cost or quick payback type operational improvements, it is important to identify possible retrofit or longer payback (LP) opportunities as part of the investigation. With the exception of the recommendation to consider a computerized DDC control system for the building, PECCI and PARTNER used modeling and engineering calculations to establish some rough energy savings estimates for these longer payback measures. This is done to help the facility staff determine which measures might warrant further investigation. Only the LP measures that have energy saving estimates are included in the "Saving Summary Projection" table.

LP - 1 - Perimeter Zone Temperature Controls

Finding Description

In the perimeter areas, the heating thermostats for the radiant hot water heaters are separate from the thermostats controlling the variable air volume terminal box serving the same areas. In many cases, the thermostats serving the same zone are often located in different rooms. This situation can result in simultaneous heating and cooling, higher energy usage, and occupant discomfort.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- Yes	Indoor Air Quality – No
Demand Savings - No	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

The two existing perimeter zone thermostats for each zone should be replaced with a single zone thermostat strategically located to monitor and control the temperature throughout the zone. It should have the following capabilities:

- a) Provide cooling control to the terminal reheat box
- b) Control air flow from the terminal box
- c) Reduce cooling to minimum when perimeter heating is engaged
- d) Stage heat so during mild heating requirements, only one level of heat is used, preventing wide swings in temperature

It is also recommended the balance of the thermostats be calibrated to insure they are also accurately monitoring and controlling the space temperatures.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	3,937 kWh/yr	Estimated Annual Cost Savings -	\$326
Estimated Peak Demand Savings -	0 kW	Estimated Implementation Cost -	\$2,500
Estimated Annual Natural Gas Savings -	175 therms / yr.	Simple Payback (yrs) -	7.7

Suggested Implementation Plan

A single new thermostat should be installed in each zone to replace the existing thermostats. The new thermostats should be electronic so they can later be connected to a centralized energy management control system, if the Client decides to upgrade to a direct digital control system.

Hire an experienced HVAC Engineer, to design the needed modifications and controls for this strategy and have a qualified contractor install and set up the controls

LP – 2 – Supply and Return Fans VFD - Install a variable frequency drive on the supply fan and the return fan

Finding Description

The supply and return fans each have inlet vanes to control the amount of airflow they allow through them. The pneumatic control of the fans appears to need repair and tuning to ensure the variable air volume (VAV) system is functioning as intended. However, technology has progressed allowing airflow to be more accurately controlled and fan energy usage reduced by using variable speed drives (VFDs) on the fan motors.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- No	Indoor Air Quality – Yes
Demand Savings - No	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

It is recommended a new electronic variable speed drive be installed on the supply and return fans and drives be controlled by duct pressure, building pressure and time of day control strategies. An alternative to this is to repair (possibly replace) and tune the existing pneumatic controls so the VAV systems function as it was originally intended. The saving estimates below are based on replacing the existing controls with a VFD for the fans.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	65,294 kWh/yr	Estimated Annual Cost Savings -	\$2,431
Estimated Peak Demand Savings -	0 kW	Estimated Implementation Cost -	\$7,000
Estimated Annual Natural Gas Savings -	-194 Therms/yr	Simple Payback (yrs) -	2.9

Implementation Plan

Block open or remove the existing inlet vanes on the supply fan and the return fan. Install new variable speed drives on each of the two fans. The supply air fan would be controlled by the building-operating mode and also by the duct pressure. The return fan would

be controlled by the building pressure and the building-operating mode.

Hire an experienced HVAC Engineer, to design the needed modifications and controls for this strategy and have a qualified contractor install and program the VFD controls.

LP 3 – Lighting System Replacement - Replace the existing T-12 lamps with T-8 lamps and electronic ballasts

Finding Description

The majority of the building lighting system uses T-12 fluorescent lamps with magnetic ballasts in a T-grid suspended ceiling system.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- No	Indoor Air Quality – No
Demand Savings - No	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

It is recommended the existing T-12 lamps and magnetic ballasts be replaced with T-8 lamps and electronic ballasts. If this option is chosen, the Client should carefully reevaluate the lighting requirement for the various areas of the building. Potential changes could include moving fixtures where office layouts have changed, and replacing of fixtures where glare is a problem.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	18,356 kWh/yr	Estimated Annual Cost Savings -	\$881
Estimated Peak Demand Savings -	8 kW	Estimated Implementation Cost -	\$8,010
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (yrs) -	9.1

Implementation Plan

As the remodel plans are being prepared, the balance of the building can be evaluated for changes. Most of the lighting systems are very well designed with only a few offices needing improvement. Those improvements can be included in the remodel since all of the lighting in that area will have to be redone anyway. The existing fixtures can have the ballast replaced with a new electronic ballast that will drive the new T-8 lamps.

LP – 4 – Supply Air Flex Duct - Redo supply diffuser flex duct runs in the ceiling air plenum

Finding Description

Much of the flex ductwork that supplies air to the ceiling diffusers is twisted or bent. It appears that many of the air diffusers were in different locations when the flex duct was installed during building construction. As the diffusers were moved, many of the flex duct runs are now longer than necessary or being routed to the opposite side of the main supply duct causing the flex duct to be twisted or bent.

The inside of flex duct is very rough when compared to rigid metal duct. The rough flex duct surfaces and the excessive bends and twists have reduced the airflow to some office spaces. To compensate for this reduced airflow, the air handling system runs at a higher pressure, adding additional frictional losses and causing more fan energy usage.

Photos of some of these duct runs are in Appendix A. Several runs could have nearly 20 feet of excess flex duct removed if the ductwork was repositioned.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- No	Indoor Air Quality – Yes
Demand Savings – Yes	Comfort – Yes	Maintenance and reliability - No

Recommendation

Remove excess flex ducts so that unnecessary twists and bends are eliminated.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	9000 KWh/yr	Estimated Annual Cost Savings -	\$432
Estimated Peak Demand Savings -	0 kW	Estimated Implementation Cost -	\$2,000
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (yrs) -	4.6

Implementation Plan

The engineer chosen to do the remodel of the HVAC design should also assess the duct layout.

Survey the air distribution system in conjunction with the remodel and the air balance to determine the optimum location of the duct

take-off points from the main supply duct in relation to the location of the diffuser.

Recommend appropriate changes of take-offs from the main supply duct. If long runs are necessary, or it is more cost effective to use the existing take-offs, the use of sheet metal duct should be considered.

LP 5 - Personal Radiant Panels – Replace personal heaters with radiant panels

Finding Description

Several people have individual space heaters to help them stay comfortable. The space heaters normally draw 1000 to 1500 watts and cycle on and off frequently, which can cause harmonics on the same electrical circuits that serve the desktop computers.

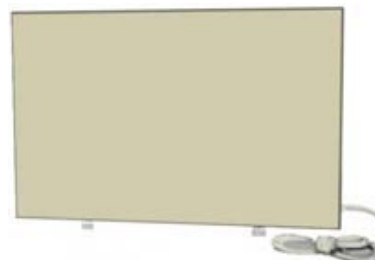
In addition, there is concern about existing circuit breakers serving these heaters tripping possibly indicating the building electrical system may be approaching its capacity.

General Finding Impacts

Energy Savings - Yes	Natural Gas Savings -- No	Indoor Air Quality - No
Demand Savings – No	Comfort - Yes	Maintenance and reliability - Yes

Recommendation

It is recommended the existing heaters be eliminated from the building and be replaced with small radiant panels that consume only 170 watts. This will reduce the capacity and cycling problems.



Estimated Economic Impact Summary

Estimated Annual Energy Savings -	5776 kWh/yr	Estimated Annual Cost Savings -	\$277
Estimated Peak Demand Savings -	4 kW	Estimated Implementation Cost -	\$1,800
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (years) -	6.5

Note: This savings estimate was based on the assumption that the individual space heaters are being turned off at night by the users. If heaters are being left on at night, the annual energy savings will be higher and the simple payback will be shorter. Also, this measure

may be necessary once the heating controls are optimized (see O&M-8, and LP-1,) and the building is rebalanced (see LP-7). The savings from eliminating the space heaters all together would be much greater.

Implementation Plan

Provide small radiant heater panels to those employees who are uncomfortable. See Appendix F for a sample of radiant panels. Or, eventually eliminate the space heaters based on the success of other heating measures.

LP 6 – Building Air Balance – Perform an air balance on the entire building after the remodel is completed and the VAV system is repaired and tuned.

Finding Description:

Improper airflow rates can cause discomfort and indoor air quality problems, which in turn can reduce worker productivity. Several areas in the building have seen their usage change since the building was originally constructed, yet the airflow to those areas have remained the same. Also, when adjustments were made in selected areas, many times these adjustments did not take into account the effect they might cause on other areas of the building.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- No	Indoor Air Quality - Yes
Demand Savings – No	Comfort - Yes	Maintenance and reliability - Yes

Recommendation

Following the remodel and implementation of the other items listed in this report, hire a consultant to perform a building wide air balance.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	9,155 kWh/yr	Estimated Annual Cost Savings -	\$804
Estimated Peak Demand Savings -	KW	Estimated Implementation Cost -	\$3,000
Estimated Annual Natural Gas Savings -	467 Therms/yr	Simple Payback (years) -	3.7

Implementation Plan

Hire an experienced and qualified test, adjusting, and balancing engineer to do this type of work. Carefully monitor his procedures and methods to insure he is thorough in his approach and results.

LP-7 – Install a Computerized Energy Management Control System

A major recommendation for the Client to consider is replacing the aging pneumatic system with a computerized energy management control system. The following lists several energy-efficient control strategies for incorporation into the new system.

- ❑ Time of day scheduling
- ❑ Optimal start
- ❑ Monitor and control the VAV system using a variable frequency drive on each fan or by interfacing with the present pneumatically controlled fan vanes
- ❑ Implement integrated economy cooling (at minimum, use the economizer as first stage cooling)
- ❑ Implement setback and setup mode for HVAC
- ❑ Reset supply air temperature according to either outside air temperature or actual building needs
- ❑ Reset duct static pressure control
- ❑ Comfort (temperature) control for all zones including improved perimeter temperature control

If the current pneumatic system is repaired and tuned up, it is capable of doing several of these functions. However, pneumatic systems require constant maintenance and upkeep to ensure that the strategies persist. This should be considered when determining the cost effectiveness of replacing this system.

“Soft” Improvement Opportunities:

A third category of recommended measures are listed as “Soft” Improvement Opportunities. These recommendations will help extend the building’s equipment life and reduce energy expenditures. The energy saving for these are difficult to estimate and are based on experience rather than modeling or engineering calculations

SIO-1 - Boiler Combustion Efficiency Test – Perform combustion efficiency test and check burner

Finding Description

The burner on the boiler is noisy and varies in pitch during both the purge cycle and while firing. Burners are intended to be very constant in their operation and shouldn't chatter or cycle. Also, the purge cycle, at over 2 minutes, seems much too long.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- Yes	Indoor Air Quality – No
Demand Savings – No	Comfort – No	Maintenance and reliability - Yes

Recommendation

Have combustion analysis done on burner and have the burner carefully checked for proper operation. Unless neglected, 18 years of operation is not excessive for a hydronic (hot water) boiler such as the one used by Building X. However, burners do need to be periodically replaced as moving parts wear out or technology improvements are developed. The burner needs to be tested and likely replaced with a newer model.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	KWh/yr	Estimated Annual Cost Savings -	\$237
Estimated Peak Demand Savings -	KW	Estimated Implementation Cost -	\$350
Estimated Annual Natural Gas Savings -	303 Therms/yr	Simple Payback (years) -	1.5

Implementation Plan

Hire a very competent boiler expert to carefully test and inspect the boiler and burner. Have this expert develop an appropriate scope of work for optimizing this boiler. Hire this expert or another contractor to bring the boiler back into proper operation. A form for combustion testing is included in Appendix L – Boiler Information.

SIO-2 - Filter Bank Changing - Repair Manometer to measure pressure across filter bank and use these readings determine when the filters need to be changed for future operations

Finding Description:

The best way to determine if filters need to be changed is to monitor the pressure drop across them. There is an inclined manometer in place to do this but it has dried out and is no longer usable.

General Finding Impacts

Energy Savings – No	Natural Gas Savings -- No	Indoor Air Quality - Yes
Demand Savings – No	Comfort - No	Maintenance and reliability - Yes

Recommendation

Repair or replace the manometer and determine the proper pressure drop at which the filters need to be replaced. This can be done either by contacting the air handler manufacturer or having a qualified engineer calculate it. Post a plaque on the air handler close to the manometer showing the pressure drop that indicates action needs to be taken as outlined in the procedures in Appendix J

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	0 kWh/yr	Estimated Annual Cost Savings -	\$0
Estimated Peak Demand Savings -	0 KW	Estimated Implementation Cost -	\$100
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (years) -	N/A

An invoice to service the air handler and change the filters was submitted early in 2001 for \$742. It is not known if the manometer would indicate more frequent changes or less. If more frequent, then the filter cost would go up but the fan energy would go down. If less frequent, then the fan energy might go up, but filter expenditures could drop. Either way, the system will operate better and more efficiently.

Implementation Plan

Repair or replace the manometer and have a professional engineer determine at what pressure the filters need to be changed at. Then clearly post it at the manometer and have the filters changed accordingly.

See Appendix J for suggested Filter Replacement Procedures.

SIO-3 Air Compressor Controls – Repair unloader on air compressor for pneumatic controls

Finding Description

The unloader on the air compressor that provides air for the pneumatic control system is non-functional or missing. Under normal operation, the compressors starts and stops 4 to 6 time an hour, 24 hours per day, 365 days a year. With a non-functioning unloader, the compressor must start against the pressure in the reservoir tank. A non-functioning unloader will lead to premature failure of the compressor. The compressor is a critical component of

the building HVAC system and must be safe-guarded. If this compressor were to fail during cold weather, more costly problems could occur with other HVAC components.

General Finding Impacts

Energy Savings – No	Natural Gas Savings -- No	Indoor Air Quality – No
Demand Savings – No	Comfort – No	Maintenance and reliability – Yes

Recommendation

It is recommended the compressor have the unloader repaired if it has one, if not, install an unloader on it.

Estimated Economic Impact Summary

Estimated Annual Energy Savings -	0 kWh/yr	Estimated Annual Cost Savings -	\$0
Estimated Peak Demand Savings -	0 KW	Estimated Implementation Cost -	
Estimated Annual Natural Gas Savings -	0 Therms/yr	Simple Payback (years) -	N/A

Implementation Plan

Repair the existing or install a new unloader on the air compressor allowing it to start against ambient air pressure, thus greatly reducing the wear on the compressor.

SIO-4 Implement a Utility Tracking Program -

Finding Description

Several commercially available software programs can be used to track utility consumption and costs. These programs can assist facility operators in benchmarking energy usage, identifying consumption anomalies, as well as help better manage all utilities at the facility. If the building gets off track, the problems can be found early on and fixed, thus reducing the operating cost. It can also indicate mechanical problems that might be caught early and expensive repairs can be minimized.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- Yes	Indoor Air Quality – No
Demand Savings – Yes	Comfort – Yes	Maintenance and reliability - Yes

Recommendation

Purchase and use a utility tracking program. The California Energy Commission offers a free downloadable handbook entitled Energy Accounting: A Key Tool in Managing Energy Costs, that includes tips on choosing software as well as general advice on tracking utility bills. The handbook can be found at the following website - http://www.energy.ca.gov/reports/efficiency_handbooks/index.html

Estimated Economic Impact Summary

For our calculations, we have estimated that 2% energy savings can be achieved by benchmarking and tracking utility usage at the facility. There are several utility tracking programs available on the market, ranging from \$250 up to \$5,000 or more depending on the types of features offered. We have assumed that a reasonable program can be purchased for \$500

Implementation Plan

It is recommended a utility tracking program be implemented.

SIO-5 Expand O&M Training - Send building operators to NWBOA training

Finding Description

Many of the maintenance items currently sourced to outside contractors can be planned and overseen more effectively if the individuals responsible for the buildings receive more training.

General Finding Impacts

Energy Savings – Yes	Natural Gas Savings -- Yes	Indoor Air Quality – Yes
Demand Savings – Yes	Comfort - Yes	Maintenance and reliability - Yes

Recommendation

Provide building operator training for the individuals who are responsible for the buildings operated by the city. An information packet already supplied to the City by NWBOA outlines this training program.

Estimated Economic Impact Summary

This is an operation improvement.

Implementation Plan

Send selected open minded individuals to the training provided in Boise by the North West Building Operators Association (NWBOA) every fall. The second level is usually presented in the spring. Each is a 6-day course that covers subjects ranging from roofs to lighting to controls to equipment. The cost is \$600 for Level 1.

IMPLEMENTATION OF RECOMMENDATIONS

Implementation Options Explained

There are many ways to implement a recommendation. Low-cost measures are usually well suited for in-house implementation to save project costs, although they can be contracted out. Capital improvements are usually contracted out directly to an installing contractor, or turned over to a performance contractor for financing and implementation. We suggest the owner consider several different equipment options.

Currently the local utilities do not have any financial assistance programs. Utility is developing a program to encourage energy efficiency by giving rebates for items such as compact fluorescent and T-8 lamps, etc. The approval of this program by the Public Utility Commission is expected sometime in 2002.

Post Monitoring of Implemented Measures

Once the Owner has selected and implemented the retrocommissioning measures, retesting and/or observation will be used to confirm that the measures are working correctly.

MAINTENANCE OF SAVINGS

Implementation Persistence

Continued maintenance of savings is an essential factor in insuring the success over time of a particular project and of retrocommissioning in general. Retrocommissioning often involves the implementation of measures that can degrade over time if not maintained or managed properly, reducing the net positive cash flow the owner can realize.

Benchmarking & Continuous Monitoring Of Energy Use

To insure measure persistence over time and the overall success of the project, the building can be "benchmarked", then have the utility use tracked over time (normalized for weather data or other operating conditions). This continuous monitoring can be configured to notify the owner of any deviation from the savings plan in order to allow for active changes in the building's operation to stay within the savings plan.

Energy Reduction Targeting

Once the building is benchmarked, a target can be set to encourage further building operations improvements and energy awareness efforts. Many times building owners are unaware of the energy use of their own buildings. Having the tools to track and reduce energy usage is the first step toward being able to optimize a building's operations.

Recommissioning

Periodically the facility should be recommissioned to verify and ensure that changes made to the building's operations and equipment during the original retrocommissioning process are still applicable and maintained over time. Recommissioning helps to guard against degradation of savings and helps to ensure the net positive cash flow throughout the life of the project that result from the owner's investment. The optimum frequency of recommissioning may vary from every quarter to every five years depending on the size and nature of the project. For this project, annual recommissioning is recommended.

APPENDICES

- A. Photos, Floor Plan, Remodel Layout**
- B. Utility History and Analysis Figures**
- C. Data Logging Trend Analysis Figures**
- D. Metering Plan**
- E. Compare Original Operations Sequences with Current**
- F. Recommended Equipment**
- G. Lighting Survey, Temperature Survey, Maintenance Invoices, Equipment List, Comfort Survey Results,**
- H. Sequencing for Economy Cooling**
- I. Programmable Thermostat Setup**
- J. Filter Replacement Procedure**
- K. Boiler Procedures**
- L. Cost Estimate Memo and Client Response Memo**
- M. PECI Review Comments on Maintenance Service Contract Proposal**
- N. Post Implementation Inspection Report Memo, Ridgeway Mechanical and Client Response Memos, and Datalogging Summary Graphs**