Assessment of Load and Energy Reduction Techniques (ALERT) Retrocommissioning Case Study of Two National Renewable Energy Laboratory (NREL) Sites

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ABSTRACT

Portland Energy Conservation Incorporated (PECI) in conjunction with the National Renewable Energy Laboratory (NREL) staff performed an Assessment of Load and Energy Reduction Techniques (ALERT) retrocommissioning evaluation on several buildings located at the South Table Mountain site and National Wind Technology Center site located in Golden, Colorado. The retrocommissioning process involved a coordinated effort between PECI and NREL staff and was completed in November of 2002.

Retrocommissioning (RCx), 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 energy-using equipment such as the HVAC and other mechanical equipment, lighting equipment, and related controls. The investigation phase for this project identified 33 findings. This paper gives an overview of the project and discusses a few of the operations and maintenance (O&M) findings as well as capital improvement recommendations that have the greatest potential for energy savings. An update on the progress of implementation will also be discussed.

The combined measures recommended for implementation result in an estimated total annual savings of 572,444 kWh, 54,114 therms, and a total utility cost savings of $44,040, which correspond to a 7.0% reduction in annual energy usage and 4.4% reduction in annual utility costs. With the measures already implemented, and those in the process thus far, the total estimated savings are 231,924 kWh, 51,550 therms, and $28,920 annual energy savings. Implementation costs were estimated at $56,380, which would result in a 1.9 year average payback. It cost approximately $0.09 per square foot to perform the ALERT RCx assessment.

Of the 33 measures identified, energy savings were not calculated for 14 of them due to insufficient data at the time or they are very general and difficult to estimate. Most of the measures focus on O&M improvements, and many of these measures have been implemented, or under evaluation for implementation. It is not unreasonable to assume that the measures under evaluation, if selected for implementation, could account for an additional 1% energy and cost savings.

INTRODUCTION

This report presents the draft results of the ALERT RCx evaluation performed on several of the NREL buildings located at the South Table Mountain (STM) site and the National Wind Technology Center (NWTC) site, located in Golden, Colorado. This ALERT RCx evaluation was completed as part of the ALERT program funded by the Department of Energy through the Federal Energy Management Program (FEMP). PECI and NREL staff completed the retrocommissioning study as the ALERT team. The NREL facilities staff personnel are very energy conscious and have already implemented many energy conservation measures over the years. Prior to performing the ALERT RCx study in 2002, NREL staff performed an in-house energy audits in 1996 and 2000 to achieve energy savings on measures with a less than 10-year payback. The measures implemented from the 1996 study and those selected for implementation from the 2000 study are listed in Appendix A. Their knowledge and expertise have greatly improved the ALERT team's ability to identify the savings opportunities outlined in this study.

The ALERT evaluation program was established by the Federal Energy Management Program (FEMP) and designed to identify energy-savings measures in existing buildings. ALERT teams focus on no- to low-cost measures by working with site personnel to perform energy use assessments. The process involves assessing operational energy efficiency measures, finding public benefit funds for the proposed measures, and working with on-site personnel to develop an implementation plan.

Retrocommissioning is an excellent way to obtain energy savings through low cost improvements that optimize building systems to operate efficiently and effectively. NREL continually evaluates and implements cost effective energy conservation measures as a normal course of

business. For this project, retrocommissioning created significant energy savings beyond the measures implemented by facility staff. For example, prior to the ALERT RCx study, NREL staff implemented 10 O&M and capital improvement measures identified in the 1996 study and selected additional measures from the 2000 study for implementation, which resulted in an estimated annual energy savings of $115,315, with an average payback of 4.1 years. After implementing just four of the O&M measures from the ALERT RCx study, the owners will see an estimated additional $22,610 per year in energy savings.

The retrocommissioning process also identifies potential capital improvements that can be made at the facility to further reduce energy usage and utility costs. Often, the savings associated with the low cost improvements can be used to "buy down" the implementation costs associated with the capital-intensive measures and make the overall package more economically viable. The ALERT team was specifically asked to evaluate potential capital improvements on this project as well as all low cost improvements.

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 to function together efficiently and effectively, although retrocommissioning may also recommend capital improvements. The three fundamental procedures are discussed in detail below.

- Investigation and data collection
- Analysis of data
- Implementation of recommendations

BASELINE FACILITY DESCRIPTIONS

The following buildings were evaluated for energy saving measures:

- STM – Field Test Laboratory Building (FTLB): 117,800 SF. Consists of laboratory spaces and office spaces.
- STM – Solar Energy Research Facility (SERF): 117,200 SF. Consists of laboratory spaces and office spaces.
- STM – Shipping & Receiving: 13,500 SF.
- STM – Visitor Center: 5,000 SF
- NWTC – Building 251: 21,700 SF. Primarily an office facility with small computer room.
- NWTC – Data Sheds: total square footage unknown
- NWTC – Trailers: total square footage unknown

Investigation and Data Collection

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

Documentation Review.

The investigative process consists of first obtaining as much building documentation as possible to allow the ALERT team to become familiar with the building and its systems. For this project, all control drawings and utility billing data for the past three years were provided. Control drawings and original sequence of operations were reviewed prior to visiting the site.

Initial Site Assessment.

The next step was to conduct an initial site assessment. The initial site assessment consisted of spending five days total in selected buildings at the STM and NWTC sites during July 2002 interviewing staff, reviewing control sequences and equipment operating schedules programmed into the central building automation system (BAS), inspecting and testing equipment, and performing an analysis of the site-gathered data. The assessment identified several significant findings, as well as identifying areas for monitoring and testing

Manual Testing.

Some systems were manually tested to determine system operation. For example, pre-filters were removed from a rooftop air handling unit to determine the pressure drop associated with the filters and evaluate the energy savings associated with permanently removing the pre-filters from the air stream.

Trend Analysis.

Additional data points were programmed into the BAS for trend collection. This trend data helped identify energy conservation opportunities and develop energy savings calculations. For example, trending compressor operation and outside air temperature for a rooftop HVAC unit at the NWTC site allowed a correlation to be developed between energy use and outside air temperature.

Analysis of Data

The ALERT team then analyzed the site interview, trend, monitored, and manual test data, and written documentation. From this work, the team formulated findings and developed estimates for the associated energy savings and costs to implement . The results are presented below.

Energy Use Analysis.

At the time of the ALERT RCx study, all of the buildings located at both the STM site and NWTC site were connected to one central electrical meter at each site, which made it difficult to determine the actual energy used by individual buildings. Several of the larger buildings located at each site were evaluated for energy conservation opportunities several years ago, with savings estimates based on DOE2 simulations. The ALERT team used the previously developed end use breakdowns to gage the reasonableness of the savings calculations, but a detailed end use breakdown for all buildings was not performed. Table 1 outlines the total energy usage for each site for 2001.

Table 1. 2001 Site Energy Usage

	STM	NWTC*
kWh	13,785,990	3,139,258
Therms	468,437	NA
Utility Cost	$840,511	$170,424

**Note: NWTC is an all-electric site*

Energy Savings Calculations.

Energy savings can be calculated in a variety of ways. For most of the measures presented in the study, customized spreadsheets based on standard engineering practices were used to estimate savings. Most cost savings were calculated using a blended unit cost per utility. For example, the blended cost of electricity is calculated by dividing the total monthly cost, which includes energy as well as on peak and off-peak demand costs, by the monthly consumption. However, some measures may only impact energy or possibly off-peak demand usage. Therefore, cost savings associated with these measures were calculated using the individual rates for electrical energy and off-peak demand as applicable. Utility costs used to estimate energy cost savings are tabulated below.

Table 2. Utility Costs

	STM Site	NWTC Site
Blended Energy Cost	$0.043/kWh	$0.052/kWh
Electrical Energy Cost	$0.01612/kWh	$0.01612/kWh
On-peak Demand Cost	$7.71/kW	$12.80/kW
Off-peak Demand Cost	$5.36/kW	NA

Project Costs.

Preliminary implementation costs are estimated for each measure based on a variety of methods: contractor budgetary cost estimates; R.S. Means cost estimation guidebooks; and manufacturer price lists. The cost projections assume that facility staff will complete the installation or be available to assist a contractor with the implementation. Costs include materials, labor and taxes, as well as the contractor's industry-standard overhead and profit mark-up, engineering design and construction-phase service fees, contingencies, and project management fees, if applicable. 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 capital-intensive projects.

Measure Selection.

Energy and cost savings and implementation costs were first determined for each measure on an individual basis. All measures were entered into a summary spreadsheet and prioritized based on payback. The ALERT team then recommended specific measures for installation at the facility and the spreadsheet figures energy savings, cost savings, and implementation cost for only these measures. The total energy and cost savings for these measures are then decreased by a factor of 5% to account for minor interactive effects between measures that reduce the savings from one measure when another is implemented.

There are various reasons for not recommending a measure. For example, in some cases, measures are mutually exclusive with others and a selection must be made. With regards to the current project, the owners implemented measures that were not recommended after performing their own calculations and evaluations. Many other reliability issues were implemented without performing energy calculations.

Implementation of Recommendations

The ALERT team presented the draft report to the owner describing the findings identified for the facility and which measures were recommended for implementation. The owner reviewed the report and selected which measures were to be implemented. We recommended the owner perform as much work as possible using in-house staff. To date, three of the fifteen recommended O&M measures have been implemented, and two more are in progress. The owner is evaluating several more of the recommended measures. Of the 14 measures without savings estimates, eight have been implemented, with one more in progress. These are mostly O&M and control programming issues, that could result in significant energy savings.

FINDINGS

Nineteen findings with associated energy savings were identified between all of the facilities evaluated and an additional fourteen findings were identified but energy savings calculations were not performed. The measures and findings identified by the ALERT team and recommended for implementation are summarized below, and listed in Appendix B. The following discussion only highlights measures with the highest energy savings and quickest simple payback.

Operation and Maintenance Measures / Low Cost Measures

Fifteen O&M measures were recommended. The total estimated annual savings for all of the O&M measures are 298,871 kWh, 54,114 therms, and a total cost savings of $31,934 in annual utility costs. Estimates of energy savings have been reduced by 5% to account for minor interactive effects between measures that reduce the savings from one measure when another is implemented. The total cost to implement these measures was estimated at $9,655, with approximately a four-month payback. A few of the O&M low-cost measures are discussed in detail below.

FLTB-01: Reduce Fan-coil Supply Fan Operating Hours.

Facility personnel stated that the supply fans associated with each of the 113 fan-coil units (FCU) were operating 24 hours per day in order to minimize belt replacements. The recommendation was to turn off the FCU supply fans during unoccupied hours, with an energy savings of 154,160 kWh/yr. To alleviate facility personnel concerns about increased maintenance, PECI suggested an experiment in which 50% of the FCU supply fans are turned off during unoccupied hours and the frequency of belt replacement compared to those units left running 24 hours per day are tracked. Table 3 outlines the estimated savings and simple payback for this measure.

Table 3. Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	154,160 kWh/yr
Estimated Off-peak Demand Savings	41.0 KW/mo
Estimated Annual Cost Savings	$5,122
Estimated Implementation Cost	$960
Simple Payback (years)	0.2

Implementation costs are based on 24 hours of labor at $40 per hour to make the necessary programming changes. This example illustrates a very high amount of energy savings relative to the implementation costs, with a simple payback of only 0.2 years.

After performing the experiment, facility personnel decided against implementation. In various areas within the building, some odors were noticed when the fans were turned off. To maintain pressurization and eliminate odors from the labs, the fans will continue to run 24 hours a day. Another factor weighing against the measure was an increased incidence of belt breakage, and associated maintenance costs, due to fan start/stop operation compared to continuous operation. This recommendation may merit further investigation since the energy saving potential is significant.

FTLB-03: Reset Condenser Water Temperature.

During the site visit, the ALERT team noted that the condenser water return temperature was being controlled at 75°F. Spot measurements of chilled water supply and return temperature, chiller input power, and condenser water supply temperature indicated that the chiller was operating at approximately 50% load and 0.72 kW/ton efficiency with the 75°F condenser water temperature. Manufacturer's data indicates the chiller would operate at approximately 0.5 kW/ton at 50% load with 67°F condenser water temperature. The spot measurements observed during the site visit were validated using trend data that has been collecting since the initial site visit occurred.

The recommendation was to lower the condenser water temperature set point to be 10°F above current outside air wet-bulb temperature (Twb), with a minimum temperature of 67°F. The chiller would operate more efficiently with lower condenser water

temperature, however the cooling tower fans would operate more frequently to satisfy the new temperature setpoint. However, the minimal increase in fan energy will be offset by the reduction in chiller energy. The Twb+ 10°F control strategy is recommended to minimize the additional cooling tower fan operation necessary to achieve the lower set point. Adequate time delays also had to be programmed in to prevent the system from short cycling and hunting as the outside air conditions vary. Chiller energy savings have been calculated using local bin weather data for the hours the chiller is actually operating (6:00 am to 6:00 pm 7 days per week based on the current schedule), data gathered during the site visit, and through trending. The team recommended that the condenser water temperature sensor be calibrated prior to implementing the measure to maximize the savings potential.. Table 4 outlines the estimated savings and simple payback for this measure.

Table 4. Estimated Economic Impact **Summary**

Estimated Annual Electrical Energy Savings	48,769 kWh/yr
Estimated On-Peak Demand Savings	18.2 KW/mo
Estimated Annual Cost Savings	$2,097
Estimated Implementation Cost	$80
Simple Payback (years)	0.0

Implementation costs are based on two hours of labor at $40 per hour to make programming changes to the Delta building automation system. This example illustrates high energy savings relative to the costs to implement the measure. This measure has been implemented by NREL staff.

FTLB-07: Heat Recovery Control Modifications.

All four of the fan systems serving the FTLB have the capability to recover thermal energy from the exhaust air stream using a glycol-loop recovery system to pre-treat the respective incoming outside air stream of each unit prior to entering the evaporative cooling section and the heating/cooling coils. It was noted during the site visit that the thermal recovery control sequences for the Penthouse and Center fan systems were not programmed to enable the system to recover energy during heating conditions (below 50°F outside air temperature). In addition, the control sequences for the East and West fan systems were not programmed to enable the system to recover energy during cooling conditions (above 75°F outside air temperature).

The recommendation was to modify the control sequences so that thermal energy can be recovered from the exhaust air stream for all systems throughout the year. For the calculations, it is assumed that each thermal recovery system will have constant effectiveness and energy savings are based on actual system flow rates for both the "occupied" and "unoccupied" hours. The thermal recovery control strategy should not allow the leaving air temperature of the exhaust stream to drop below approximately 40ºF to prevent moisture and possible frost build-up on the coil (40ºF is the approximate dew point temperature of exhaust air at 74ºF and 30% relative humidity). Based on the analysis, a 40ºF leaving air temperature would occur when the outside air temperature was approximately 0ºF. Note that the actual on-peak demand savings for this measure will vary depending on outside air temperature. For example, the demand savings will be larger during the summer months when the energy recovery has the greatest impact on chiller savings. Table 5 outlines savings and implementation costs for this measure.

Table 5. Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	6,181 kWh/yr
Minimum On-peak Demand Savings	2.9 KW/mo
Estimated Annual Natural Gas Savings	54,263 Therm/yr
Estimated Annual Cost Savings	$19,800
Estimated Implementation Cost	$160
Simple Payback (years)	0.0

Implementation costs are based on four hours of labor at $40 per hour to make the necessary changes to the control sequences. This measure has been implemented by NREL staff.

VC-01: Lockout Compressor Operation.

The Visitor's Center is served by three DX air-handling units, each fitted with a direct evaporative cooling section on the outside air intake. The team noted during the site visit that when the air handling units transition between the unoccupied and the occupied cooling set point in the morning, mechanical cooling is enabled because the economizer and evaporative cooling sections are not given adequate time to meet the space temperature set point.

The recommendation was made to lockout cooling for the first two hours in the morning (5:30 am to 7:30 am) in order to give the economizer/direct evaporative cooling an opportunity to satisfy space temperature requirements. Energy savings will result from utilizing "free" cooling during the morning cool-down cycled. However, energy used by the

water circulation pump will increase but this should be minimal compared to compressor energy savings. For the calculations, it is estimated that the compressors would typically cycle on and off approximately 75% of the time during the morning cool-down period and the water circulation pump energy increase will be approximately 1% of compressor energy savings. Table 6 outlines savings and implementation costs for this measure.

Table 6. Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	11,694 kWh/yr
Estimated Off-Peak Demand Savings	21.6 KW/mo
Estimated Annual Cost Savings	$1,116
Estimated Implementation Cost	$120
Simple Payback (years)	0.1

Implementation costs are based on three hours of labor at $40 per hour to make the necessary changes to the control sequences. This measure has been implemented by NREL staff.

Capital Improvement Measures

The ALERT team identified four capital improvement measures and recommended three for implementation. Total energy savings for the recommended measures is 273,573 kWh/yr, with an annual cost savings of $12,106. Total implementation cost is estimated at $103,868 with approximately and 8.6 year simple payback.

One measure, *SERF-02 Reduce Process Chilled Water Flow* was not recommended for immediate implementation due to the long payback, however, NREL is evaluating the feasibility of implementing the measure as major additions/renovations occur. The three recommended measures are detailed below.

SERF-01: Install Indirect Evaporative Cooling.

The direct evaporative cooling section of each air handling unit (AHU) serving the SERF building was controlled to maintain space relative humidity and not to minimize the cooling load. An indirect evaporative process cools the air sensibly and does not add moisture to the air stream. The recommendation was to investigate the possibility of designing and installing an indirect evaporative cooling system to pre-cool all of the outside air supplied to each AHU. Using indirect evaporative cooling would remove a significant amount of energy from the outside air stream and reduce the load on the chillers, with an annual energy savings of 93,524 kWh/yr. In addition, the two VAV units serving the office spaces could operate for extended periods at 100% outside air since the pre-cooled air temperature was estimated to be less than return air temperature, thereby reducing he chiller load even further.

Bin weather data was used to estimate energy savings associated with the measure. The current reduction in cooling load due to operation of the existing direct evaporative cooling process on each AHU has been accounted for in the calculations. Note actual on peak and off-peak demand savings for this measure will vary depending on outside air temperature. Table 7 outlines savings and associated costs.

Table 7. Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	93,524 kWh/yr
Minimum On-Peak Demand Savings	33.6 KW/mo
Estimated Annual Cost Savings	$4,022
Estimated Implementation Cost	$40,000
Simple Payback (years)	9.9

Due to the unique nature of the outside airshaft and plenum, installing a pre-fabricated indirect evaporative cooler section on each AHU is not applicable. A custom indirect system will have to be designed and installed at the facility. Based on energy savings, the total project cost must be around $40,000 in order to receive a 10-year payback. To date, NREL staff is evaluating this measure for feasibility, but it is unlikely that the project could be implemented for less than $40,000.

SERF-03: Exhaust Fan VFD.

The SERF building is served by four central exhaust fan systems that operate at constant flow 24 hours per day. Each fan system has two motors to achieve 100% redundancy but only one fan operates at a time. The East exhaust system is currently under control but the West and Central exhaust systems were not operating as intended. The total connected load for the fan motors that are running at any given time is 130 horsepower. The exhaust fans operate at constant volume and dilution dampers are modulated open to maintain constant static pressure and system air flow. However, facility personnel stated that even with the dilution dampers, the static pressure within the exhaust system is much more negative than the desired setpoint (-2.2 inch w.c. typical operating point and -1.8 inch w.c. setpoint). This indicated that too much air was being drawn through the system and the fans were running faster than required.

The recommendation was to install variable frequency drives (VFDs) on each of the exhaust fans

so that system static pressure setpoint can be achieved. The team recommended setting the VFDs at a constant point and allow the dilution dampers to modulate in order to achieve the desired control as system load varies. Since pressure is a square function of flow and power is a cube function of flow, a significant reduction in power can be realized for moderate reductions in flow. For the calculations, it is estimated that system flow rate could be reduced to approximately 90% of total system flow to meet design static setpoint. This approximately equates to a 77% reduction in fan power. Table 8 outlines savings and associated costs.

Table 8. Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	154,462 kWh/yr
Estimated Electrical Peak Demand Savings	17.6 KW/mo
Estimated Annual Cost Savings	$6,642
Estimated Implementation Cost	$55,200
Simple Payback (years)	8.3

Implementation of this measure includes installation of VFDs, connection to the Delta building automation system, and miscellaneous material. Implementation of this measure has been completed.

NWTC-03: RTU-1 Supply and Return Fan VFD.

Building 251 is primarily served by RTU-1, a roof-top packaged HVAC system. The HVAC system is designed to be variable air volume since the VAV boxes located in the space vary the quantity of primary air from RTU-1 depending on space temperature conditions. However, it was noted during the site visit that the roof-top HVAC unit does not have any way to modulate air flow through the system (the unit was designed to utilize inlet guide vanes to vary the flow). As the primary air dampers close and the system duct pressure increases, the supply air flow rate decreases by pushing the supply fan back up on its performance curve, an extremely energy inefficient method of flow control. In addition, since the return fan continually runs at full flow, the building pressure could be negative at times since the amount of air being drawn from the space by the return fan could exceed the amount delivered by the supply fan, particularly in the winter time when the primary air dampers are most likely at minimum position. A negatively pressurized building can cause comfort complaints and increase energy usage because unconditioned air will be drawn into the building through doors, windows, and other perimeter cracks.

The recommendation was to install variable frequency drives (VFDs) on both the supply and return fans so that system static pressure setpoint can be achieved. Since the existing MicroTech controller measured system static pressure, the existing duct static pressure signal should be used to control the supply fan VFD and the return VFD should track the supply fan in order to control building pressurization. Table 9 outlines estimated savings and the associated costs.

Table 9. Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	39,986 kWh/yr
Estimated Annual Cost Savings	$2,079
Estimated Implementation Cost	$8,668
Simple Payback (years)	4.2

Implementation of this measure includes installation of each VFD, connection to the MircoTech controller, and miscellaneous material. To date, NREL staff is in the process of evaluating this measure for feasibility.

CONCLUSIONS

Retrocommissioning is an excellent way to obtain energy savings through low cost improvements that optimize building systems to operate efficiently and effectively. PECI and NREL staff performed an ALERT RCx evaluation in July 2002 on several buildings at both the South Table Mountain and National Wind Technology Center sites in Colorado, which identified 33 O&M and capitol improvement measures. The measures already implemented, and those in the process thus far, account for a total estimated energy savings of 231,924 kWh, 51,550 therms, and $28,920 annual cost savings. Implementation costs were estimated at $56,380, which would result in a 1.9 year average payback.

The project was a success due in part to the ALERT team's neutral and objective perspective, as well as NREL's commitment to energy conservation and developing a sustainable campus. The O&M staff has performed in-house audits and has implemented many cost effective energy efficiency measures as funding permits. But the ALERT RCx evaluation allowed NREL staff to dedicate time directly to facility retrocommissioning, time that is not currently built into periodic maintenance schedules.

APPENDIX A – SUMMARY OF PRE-ALERT MEASURES

Measure Description	Disposition	Estimated Energy Savings	Estimated Implementation Cost	Payback (years)
FTLB				
Unoccupied fume hood exhaust reduction	Implemented	$1,029	$1,350	1.3
Decrease make-up air temperature to 62F	Implemented	$2,427	$450	0.2
Upgrade emergency exit signs to LED	Implemented	$635	$2,550	4.0
Reduce exhaust air volume via VAV controls	Selected	$40,164	$418,000	10.4
Modify setback and set-up temperature schedules	Selected	$27,813	$2,840	0.1
SERF				
Implement setback and set-up temperature with override controls	Implemented	$10,391	$1,980	0.2
Calibrate and fix occupancy sensors in labs	Implemented	$1,107	$2,245	2.0
Replace electric baseboard heating with hot water in offices	Implemented	$5,217	$6,000	1.2
Replace electric unit heater with hot water in shipping room	Implemented	$572	$1,450	2.5
Calibrate make-up air unit supply temperature	Selected	$17,937	$6,000	0.3
NWTC				
Implement new lighting schedule	Implemented	$4,349	$450	0.1
Install F32T8 lamps/electronic ballasts	Implemented	$3,674	$30,096	8.2
Install occupancy sensors in bathrooms*	Implemented	NA	NA	NA
Total O&M and ECM Savings and Costs		**$115,315**	**$473,411**	**4.1**
**Note original recommendation was to install occupancy sensors throughout the building but sensors were only installed in the bathrooms and energy savings were not calculated.*				

APPENDIX B – SAVINGS SUMMARY FOR ALL MEASURES

SAVINGS SUMMARY PROJECTION

National Renewable Energy Laboratory

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)
385,599	FY 2001 Total Energy Use	16,925,248	2,758	468,437	$1,010,935	271.3	$2.62

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

OPERATION AND MAINTENANCE / LOW COST 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)	%Total Cost Savings
No	Yes	FTLB-01	Reduce Fan-coil Supply Fan Operating Hours	154,160	0	$5,122	$960	0.2	0.5%
Yes	Yes	FTLB-02	Replace Exhaust Stream Filters	23,024	0	$787	$820	1.0	0.1%
Yes	Yes	FTLB-03	Reset Condenser Water Temperature	48,769	0	$2,097	$80	0.0	0.2%
No	Yes	FTLB-04	Reset Chilled Water Temperature	11,541	0	$496	$80	0.2	0.0%
*Eval	Yes	FTLB-05	Reduce Compressed Air System Pressure	8,309	0	$357	$20	0.1	0.0%
No	Yes	FTLB-06	Lower Heating Water Temperature	4,540	939	$411	$80	0.2	0.0%
Yes	Yes	FTLB-07	Heat Recovery Control Modifications	6,181	54,263	$19,800	$160	0.0	2.0%
No	Yes	NWTC-01	Recondition RTU-2 Economizer	11,278	0	$586	$1,660	2.8	0.1%
No	Yes	NWTC-02	Remove RTU-1 Pre-filters	1,677	0	$447	$220	0.5	0.0%
*Eval	Yes	NWTC-04	Data Shed Programmable Thermostats	24,996	0	$1,300	$4,400	3.4	0.1%
*Eval	Yes	S&R-01	Radiant Heater Programmable Thermostats	0	1,760	$827	$480	0.6	0.1%
*Eval	Yes	S&R-02	De-lamp Office Area Lights	3,130	0	$145	$80	0.6	0.0%
No	Yes	S&R-03	Lower Storage Area Occupancy Sensor	1,423	0	$23	$235	10.2	0.0%
Yes	Yes	VC-01	Lockout Compressor Operation	11,694	0	$1,116	$120	0.1	0.1%
*Eval	Yes	VC-02	Video Monitor Timeclocks	3,879	0	$101	$260	2.6	0.0%
Total Recommendation Package as Selected by PECI				314,601	56,962	$33,615	$9,655	0.3	3.3%
	5%	**Measure interaction of total package**		298,871	54,114	$31,934	$9,655	0.3	3.2%
Total Recommendation Package as Selected by Owner				89,668	54,263	$23,800	$1,180	0.0	2.4%
	5%	**Measure interaction of total package**		85,185	51,550	$22,610	$1,180	0.1	2.2%
Recommendations under Evaluation by Owner				40,314	1,760	$2,730	$5,240	1.9	0.3%
	5%	**Measure interaction of total package**		38,298	1,672	$2,594	$5,240	2.0	0.3%

Note: Measures marked by (*Eval) indicate the owner is evaluating whether to implement the measure

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)	%Total Cost Savings
*Eval	Yes	SERF-01	Install Indirect Evaporative Cooling	93,524	0	$4,022	$40,000	9.9	0.4%
*Eval	No	SERF-02	Reduce Process Chilled Water Flow	32,496	0	$1,397	$28,800	20.6	0.1%
Yes	Yes	SERF-03	Exhaust Fan VFD	154,462	0	$6,642	$55,200	8.3	0.7%
*Eval	Yes	NWTC-03	RTU-1 Supply and Return Fan VFDs	39,986	0	$2,079	$8,668	4.2	0.2%
Total Recommendation Package as Selected by PECI				287,972	0	$12,743	$103,868	8.2	1.3%
	5%	**Measure interaction of total package**		273,573	0	$12,106	$103,868	8.6	1.2%
Total Recommendation Package as Selected by Owner				154,462	0	$6,642	$55,200	8.3	0.7%
	5%	**Measure interaction of total package**		146,739	0	$6,310	$55,200	8.7	0.6%
Recommendations under Evaluation by Owner				166,006	0	$7,498	$77,468	10.3	0.7%
	5%	**Measure interaction of total package**		157,706	0	$7,123	$77,468	10.9	0.7%

Note: Measures marked by (*Eval) indicate the owner is evaluating whether to implement the measure

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)	%Total Cost Savings
Total Recommendation Package as Selected by PECI	602,573	56,962	$46,358	$113,523	2.4	4.6%
5% Overall measure interaction of total package	572,444	54,114	$44,040	$113,523	2.6	4.4%
Total Recommendation Package as Selected by Owner	244,130	54,263	$30,442	$56,380	1.9	3.0%
5% Overall measure interaction of total package	231,924	51,550	$28,920	$56,380	1.9	2.9%
Recommendations under Evaluation by Owner	206,320	1,760	$10,228	$82,708	8.1	1.0%
5% Overall measure interaction of total package	196,004	1,672	$9,717	$82,708	8.5	1.0%

OTHER MEASURES CONSIDERED (SAVINGS NOT CALCULATED)

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)	%Total Cost Savings
Yes	Yes	FTLB-08	Cooling Tower Water Distribution		NA		In-house O&M		
No	Yes	FTLB-09	Supply Fan S-8 Running Overloaded		NA		In-house O&M		
*Eval	Yes	SERF-04	VAV Box Pneumatic Controller Maintenance				In-house O&M		
Yes	Yes	SERF-05	Review Chilled Water Control Sequences		NA		In-house O&M		
Yes	Yes	SERF-06	Check Heat Recovery Programming				In-house O&M		
*Eval	Yes	NWTC-05	RTU-1 Control Settings				HVAC Tech Time		
Yes	Yes	NWTC-06	VAV Box Pneumatic Controller Maintenance				In-house O&M		
Yes	Yes	NWTC-07	Miscellaneous Findings in Trailer Buildings		NA		In-house O&M		
No	Yes	NWTC-08	Turn Off Harmonic Filter		NA		In-house O&M		
Yes	Yes	S&R-04	Repair Condensate Line on Roof-top Unit	NA	NA		In-house O&M		
Yes	Yes	S&R-05	Check Economizer Operation		NA		In-house O&M		
Yes	Yes	S&R-06	Adjust HVAC Unit Serving Office/Storage Area		NA		In-house O&M		
*Eval	Yes	VC-03	Implement Override Alarms				In-house O&M		
Yes	Yes	VC-04	Daylight Sensor May Have Failed		NA		New Sensor Cost		
Estimated Savings Impact of 1% Total Utility Usage				169,252	2,342	$10,109	$10,109	1.0	1.0%
	5%	**Measure interaction of total package**		160,790	2,225	$9,604	$10,109	1.1	1.0%

Note: Measures marked by (*Eval) indicate the owner is evaluating whether to implement the measure