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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

American Recovery and Reinvestment Act (ARRA) FEMP Technical Assistance U.S. General Services Administration – Project 195 John Seiberling Federal Office Building and U.S. Courthouse, Akron, Ohio

J Arends
WF Sandusky

May 2010

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Pacific Northwest National Laboratory
Richland, Washington 99352

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Executive Summary

This report documents the findings from an onsite audit of the John Seiberling Federal building located in Akron, Ohio. The Federal landlord for this building is the General Services Administration (GSA). The focus of the audit was to identify various no-cost or low-cost energy efficiency opportunities that, once implemented, would either reduce electrical and gas consumption or increase the operational efficiency of the building. This audit also provided an opportunity to identify potential capital cost projects that should be considered in the interim to acquire additional energy (electric and gas) and water savings to further increase the operational efficiency of the building.

The audit identified six measures that could be implemented immediately resulting in a total savings of 2,343 MBtu of electrical and thermal energy that would result in an annual cost savings of $47,628. The estimated cost to implement the measures is $116,341, so the payback for such an investment would be 2.4 years.

Two capital item projects were identified related to utilization of the available solar resource. This would result in saving an additional 311 MBtu of energy, resulting in a cost savings of $8,486 annually. At this point in time, the economics for implementation of these measures is not cost-effective unless required for increasing the amount of onsite power generation from renewable resources.

Implementation of both the no-cost or low-cost measures would decrease greenhouse gas (GHG) emissions to the atmosphere as well as create job opportunities. For the no-cost or low-cost measures, it was estimated that 267 metric tons of GHG emissions to the atmosphere would be avoided and 1.3 jobs would be created. If the capital projects were implemented, 7.7 jobs would be created and 56 metric tons of GHG emissions to the atmosphere would be avoided.

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Acronyms and Abbreviations

AHU	Air handling unit
ALERT	Assessment of Load and Energy Reduction Techniques
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating & Air Conditioning Engineers
BAS	Building automation system
Btu	British thermal unit
CDD	Cooling degree days
DC	Direct current
DDC	Direct digital control
DOE	U.S. Department of Energy
DX	Direct expansion
E4	Energy efficiency expert evaluations
ECM	Energy conservation measure
EPA	Environmental Protection Agency
ESET	Energy savings expert teams
ESPC	Energy savings performance contracts
ft^2	Square feet
FEMP	Federal Energy Management Program
GHG	Greenhouse gas emissions
GSA	General Services Administration
HDD	Heating degree days
HVAC	Heating, ventilation and air conditioning
kBtu	10^3 Btu
kW	kilowatt
kWh	kilowatt hour (1 kWh = 3412 Btu)
LBNL	Lawrence Berkeley National Laboratory
Mcf	Million cubic feet (natural gas)
mm	millimeter
MMBtu	10^6 Btu
NOFA	Notice of funding available
NRC	Natural Resources Canada
ODOD	Ohio Department of Development
OEO	Ohio Energy Office
O&M	Operation and maintenance
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic
Retro-CX	Retro-commissioning
SHW	Solar hot water
SPV	Solar photovoltaic
UESC	Utility energy savings performance contracts
UV	Ultra violet
VAV	Variable air volume

1.0 Description of ARRA Program

The Federal Energy Management Program (FEMP) facilitates the Federal Government's implementation of sound, cost-effective energy management and investment practices to enhance the nation's energy security and environmental stewardship. Late in fiscal year 2009, FEMP received funds specific to the American Recovery and Reinvestment Act (ARRA) of 2009.

These funds were allocated to expand its laboratory and contractor support to agencies and to quickly provide technical advice and assistance to expand and accelerate project activities. FEMP requested that agencies submit projects in need of technical assistance in the following areas:

- Initial screenings or assessments of facility needs and/or feasibility of a particular technology
- Project prioritization
- Strategic energy planning and benchmarking
- Technical reviews of designs and proposals
- Energy audit training
- High-performance green building technical support
- Federal vehicle fleet technical support
- Operations and maintenance
- Detail of key lab staff to work within agencies for a limited duration (normally not more than 24 months)
- All of the above with special emphasis on particular technologies in the areas of the labs' expertise.

The General Services Administration (GSA) submitted a response to this call requesting that an energy audit be conducted at the John Seiberling Federal building in Columbus, OH with the goal of identifying energy conservation measures that could be implemented in a timely manner. This request was selected by FEMP and designated as Project 195.

1.1 Site Audit Activities

This energy and water audit was conducted December 2-3, 2009 using the protocols and guidance developed by Pacific Northwest National Laboratory (PNNL) to support previous Federal Energy Management Program (FEMP) activities related to assessment of load and energy reduction (ALERT), energy savings expert teams (ESET), and energy efficiency expert evaluations (E4) audits at federal sites. The primary focus of the protocols is to identify various no-cost and low-cost opportunities for major energy consuming equipment within the building. During the audit, however, other capital cost equipment opportunities were also considered with respect to future energy efficiency projects that could be undertaken by the sites to acquire additional energy, water, and cost savings.

An out-briefing of the preliminary audit results was provided to site personnel on December 3, 2009. A draft of this audit report was provided to the GSA point-of-contact for review and comment.

2.0 Background

2.1 Site Description

The John Seiberling Federal Building is located at 2 South Main Street, Akron, Ohio. The five-story office building was constructed in 1975 and has approximately 306,000 square feet (ft^2) with approximately 186,137 ft^2 of occupied space, mainly occupied by tenants with office suites. Each of the five floors has approximately 30,000 ft^2 of space. There is also a multi-floor parking garage and storage area underneath the building and a penthouse and upper level area that contains most of the building's mechanical and control systems. The cafeteria and other control systems are located on the B-3 level. The first floor has a unique layout, including a reception and security area. The parking garage is approximately 120,000 ft^2. This energy and water audit was focused on the office building, but also considered potential energy conservation measures (ECMs) for the garage area.

Most of the major building systems have been replaced or rebuilt in the past 10 years. Major upgrades to the building recently completed, ongoing, staged, or planned in the near future include a new building automation system (BAS), new windows, lighting system upgrades, and a new roof. (See Section 2.2 for additional details.) In addition, upgrades to reduce water use are planned, including low flow/no touch faucets and toilet fixtures. Figure 1 is a photograph of the building and parking garage.

Figure 1. Akron Seiberling Building and Garage

2.2 Major Building Energy Uses

Air Handling Systems

The building is heated and cooled by three variable air volume (VAV) air handling unit (AHU) systems. AHU-1 and 2 are located in the penthouse, and AHU-3 is located on B-3 near the cafeteria. These AHUs have BAC brand variable frequency drives controlling both supply and return fans. Outside air is tempered to 55°F by hot water heating coils in each of the air handlers. Mixed air is cooled by chilled water cooling coils in the air handlers. Both of the AHUs deliver 55°F supply air via ductwork to the building terminal boxes. Both of the air handlers are capable of using full outside air for economizer operation. No humidification or dehumidification is provided in the AHUs.

Hot Water Heating Boilers

Hot water delivered to the air handler heating coils is produced by two water heating boilers located in the penthouse. Heating water is also distributed to the VAV terminal boxes located in the perimeter zones of the building. The Cleaver Brooks boilers have a capacity of 5 million British thermal units (MMBtus). The boilers are set up to operate on a standard schedule if outside air temperatures are below 60°F, and they are shut off nightly by the BAS. A third natural gas water tube boiler serves the B-3 level.

Heating Water Reset Schedule

When the outside air is less than or equal to 0°F, the heating water temperature setpoint is 180°F. The heating water temperature is proportionately adjusted downward as the outside air temperature rises, and the setpoint is 130°F when the outside air temperature is 60°F.

Chillers and Cooling Units

Chilled water delivered to the AHU cooling coils is produced by two Trane chillers located in the penthouse. Heat from the chillers is rejected by cooling towers located on the roof of the penthouse. The chilled water supply setpoint is currently maintained at 45°F.

Several computer server rooms also have dedicated direct expansion (DX) cooling units to handle the additional cooling loads.

Terminal Unit Distribution Boxes

The perimeter zones of the building are served by VAV terminal boxes equipped with hot water reheat coils. Supply air for the perimeter zones is provided by VAV AHU-2 located in the penthouse. Space setpoints are maintained by modulating the air volume to cool the space. If a space requires heating, the VAV box air flow is modulated to its minimum position and the heating coil hot water control valve modulates to maintain space temperatures. No simultaneous heating and cooling is permitted.

The core zones of the building are also served by VAV terminal boxes. However, these VAV terminal boxes do not have reheat coils. Supply air for the core zone is provided by VAV AHU-1, located in the penthouse. Space setpoints are maintained by modulating the air volume when necessary to cool the space.

Capital Projects in Progress

Lighting in both the office building and the parking garage will be replaced in 2010. Occupancy sensors will be installed throughout the building to control lighting. These occupancy sensors will also provide status for the VAV box controller. Occupied and unoccupied setpoints for the space temperature will also be triggered by the lighting occupancy sensors.

The BAS for the building is being upgraded to direct digital control (DDC). The pneumatic VAV terminal boxes are also being replaced with DDC VAV boxes. Completion is scheduled for October 2010.

All windows, water faucets, and toilet fixtures in the office building are scheduled for replacement in 2010. The roof is also being replaced and will have a highly reflective surface and double the current R-value of insulation.

2.3 Climate, Facility Type, and Operations

The climate for the site is humid continental and is influenced by its close proximity to Lake Erie. Based on data available from the National Climatic Data Center, the maximum mean monthly temperature occurs in July (74.1°F), with the minimum mean monthly temperature occurring in January (27.2°F). The highest recorded temperature during the period from1971 through 2000 was 103°F on July 7, 1988, while the lowest reported temperature during the period was -22°F on January 17, 1982. Based on the most recent mean data available (1971-2000), the site should experience 10 days with a maximum temperature exceeding or equal to 90°F, while the minimum temperature should be at 32°F or below for 112 days. Annually, the site should anticipate 5,752 heating degree days (HDD) and 856 cooling degree days (CDD).

Mean annual precipitation for the site is 36.07 inches. The highest daily reported precipitation was 6.78 inches for June 30, 1989. The highest reported monthly precipitation, 10.82 inches, occurred in November 1985. The daily precipitation should be at or greater than 0.01 inch for 136 days during the year. Mean annual snow fall for the site is 41.3 inches, but the highest monthly snowfall was reported in January 1974 (29.4 inches). The highest daily snow fall was 19.7 inches on April 4, 1987.

The facility is a standard commercial office facility. At the time of the site audit, the building was approximately 90% occupied (estimated 300 persons). The office building occupancy hours are approximately 7 a.m. to 5 p.m., Monday through Friday, with some additional hours for the courts, Internal Revenue Service, and Social Security offices. Tenants are charged for utility costs outside of the normal occupancy hours. One electric meter serves the office building and parking garage, with no electrical sub-metering. There is a natural gas sub-meter for the cafeteria. Electrical “live” meters have been requested from Ohio Edison.

3.0 Energy Use

The Akron Seiberling Federal building electrical usage is metered by Ohio Edison. One meter serves the entire building and parking garage. The building will receive advanced metering capabilities. Dominion East Ohio provides natural gas service.

3.1 Current Energy, Gas, and Water Use

Figures 2, 3, and 4 represent the energy usage by federal fiscal year. The fiscal years showing higher-than-average electrical usage may be attributable to construction.

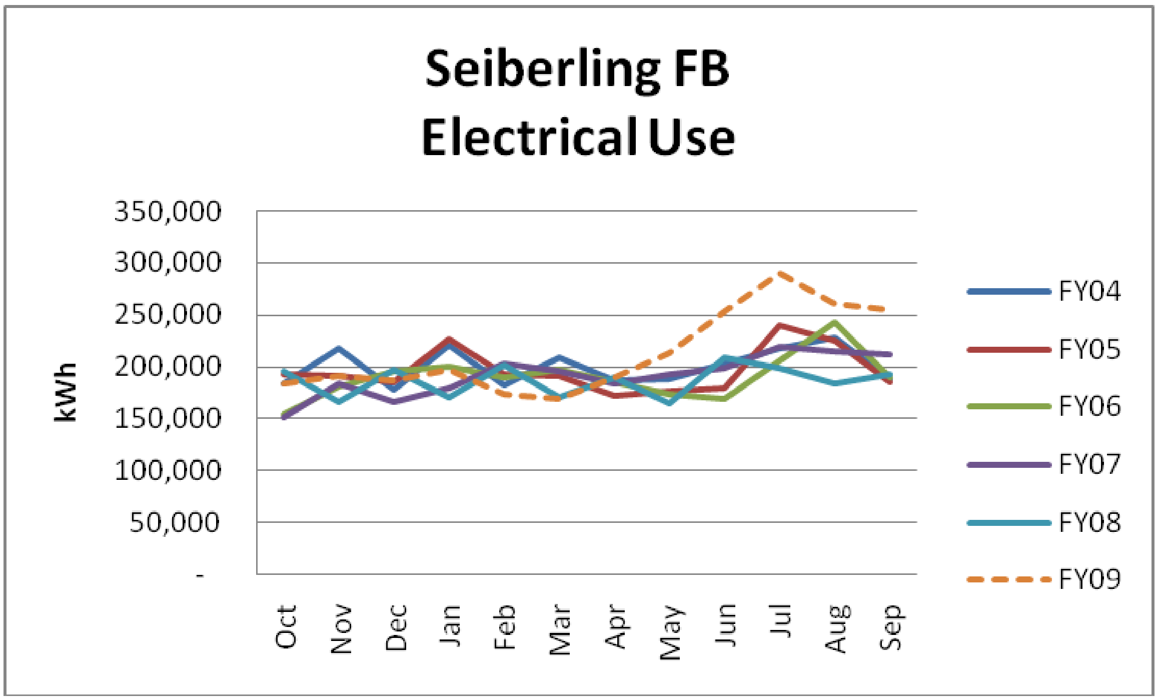

Figure 2. Akron Seiberling Federal Building Electrical Use

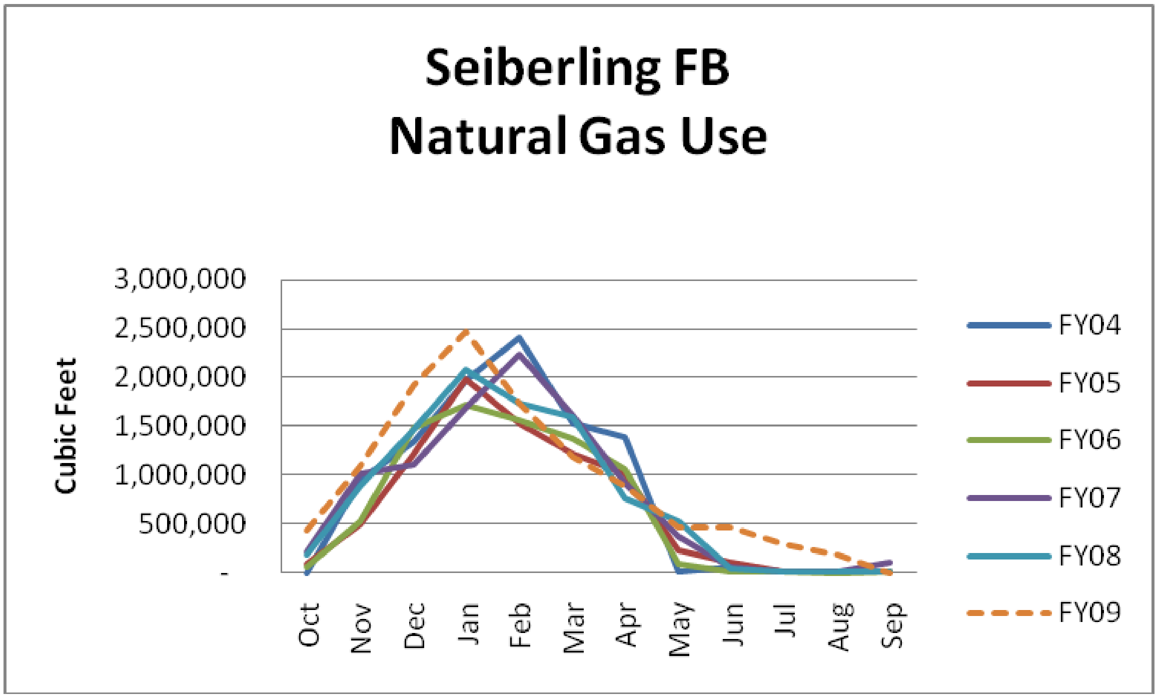

Figure 3. Akron Seiberling Federal Building Natural Gas Use

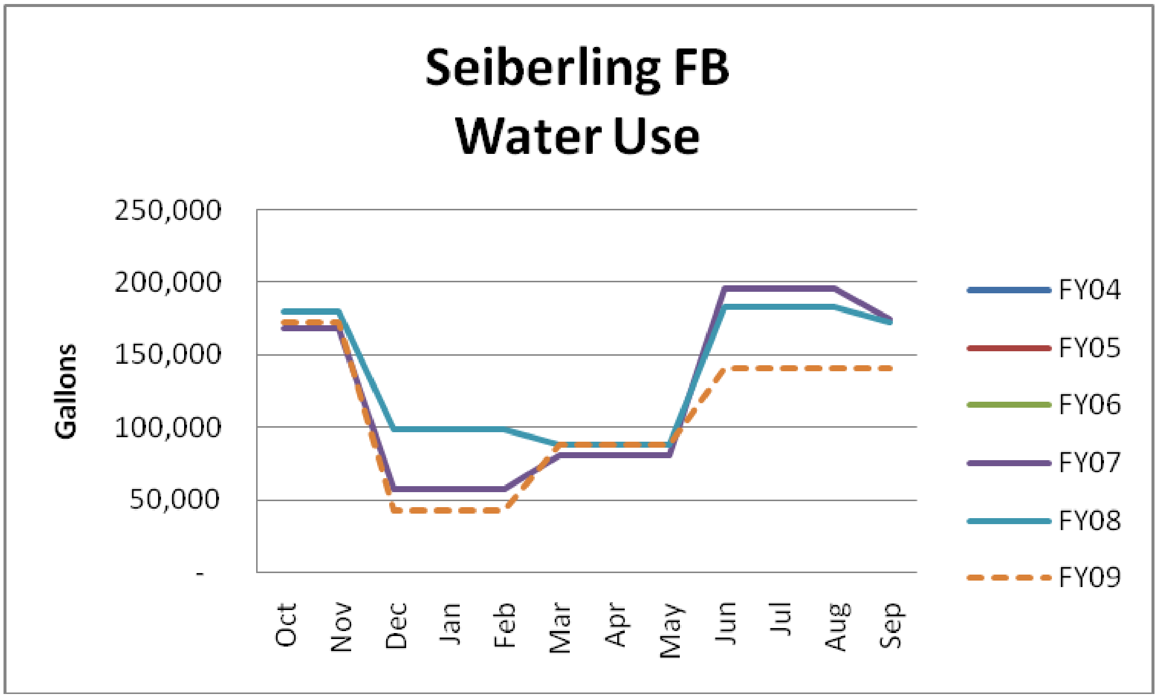

Figure 4. Akron Seiberling Federal Building Water Use

3.2 Current Rate Structure

Ohio Edison provides service under a General Service Secondary OE-GSF. Rate schedule OE-GSF is a general service tariff that is available for non-residential customers.

Dominion East Ohio transports and delivers natural gas, which GSA purchases from Delta Energy under a commercial fixed price rate schedule. Dominion delivers and transports under a general transportation rate schedule.

The City of Akron provides water under a commercial service rate.

4.0 Energy Conservation Measures Identified

4.1 Summary of Proposed Measures

Four main areas were identified where ECMs are recommended for immediate implementation. These ECMs were evaluated in reference to annual energy and cost savings, using a simple payback method. A detailed savings summary is included in Table 1. Energy savings estimates are based on individual results and do not represent the interactive effect they have on each other. Savings in Table 1 are estimated reductions in energy use compared with the baseline or existing building energy usage model. The four areas identified were:

1. Building automation system (BAS) - optimum start and stop of AHUs, chillers, and boilers
2. Air handling units (AHUs) - static pressure reset
3. Boilers — oxygen trim controllers; exhaust stack dampers
4. Building retro-commissioning
    a. BAS temperature sensors calibration
    b. Occupancy sensors calibration (used for both lighting and heating, ventilation and air conditioning [HVAC] setpoint control).

Several renewable energy projects were also identified for the building, including installation of a solar hot water (SHW) system and photovoltaic (PV) generation. The evaluation did not include the impact of obtaining rebates or incentives.

The team identified (but did not evaluate in detail) the following additional possible recommendations during the visit:

1. Web-based access for BAS
2. Lighting retrofits and sensors
3. AHU heat recovery
4. Condensing boiler (keep one dual-fuel boiler)
5. Ultraviolet (UV) lights for cooling coils
6. Wind turbine power generation
7. Training for the Akron ARRA team on the new BAS system, operations and maintenance (O&M), energy efficient operation, and troubleshooting of building systems is also recommended. Everyone on the team will certainly benefit from additional training, such as the web-based FEMP training on recommissioning.

Table 1 Akron Seiberling Federal Building Recommended ECMs

Table 1: Recommended Energy Conservation Measures (ECMs)											
ECM #	Energy Saving Recommendations	Electrical Savings (kWH)	Natural Gas Savings (Therms)	Energy Savings (Millions of Btus)	Water Savings (Gallons)	Electrical Savings ($)	Natural Gas Savings ($)	Water Savings ($)	Total Annual Savings ($)	Cost to Implement ($)	Simple Payback (Years)
1	Optimum Start/Stop	7,600	900	116		$ 782	$ 1,212		$ 1,995	$ 300	0.2
2	Static Pressure Reset	145,200	-2,900	206		$ 14,941	$ (3,907)		$ 11,034	$ 1,200	0.1
3a	Boilers (oxygen trim controller)	0	5,800	580		$ -	$ 7,814		$ 7,814	$ 20,000	2.6
3b	Boilers (exhaust stack damper)	0	4,400	440		$ -	$ 5,928		$ 5,928	$ 3,000	0.5
4	Building Retro-commissioning	129,510	5,590	1,001		$ 13,327	$ 7,531		$ 20,857	$ 91,841	4.4
	Total (Non-interactive)	**282,310**	**13,790**	**2,343**		**$ 29,050**	**$ 18,578**		**$ 47,628**	**$ 116,341**	**2.4**
	Percent Savings (Non-interactive)	**11%**	**12%**	**12%**							
	Renewable Energy										
SHW	Solar Domestic Hot Water	-100	456	45		$ (135)	$ 614		$ 479	$ 6,000	12.5
SPV	Solar Power Generation (70 kW)	77,815		266		$ 8,007	$ -		$ 8,007	$ 700,000	87.4
	Total Renewable Energy	**77,715**	**456**	**311**		**$ 7,872**	**$ 614**		**$ 8,486**	**$ 706,000**	**83.2**
2009 Reference Data											
		Annual Electrical Use (kWH)	**Annual Natural Gas Use (Therms)**	**Annual Energy Use (Millions of Btus)**	**Annual Water Use (Gallons)**	**Electrical Cost**	**Natural Gas Cost**	**Water Cost**	**Total Annual Utility Use ($)**	**Total Annual Energy Use ($)**	
	Cost Per Unit 2009					**0.1029**	**1.3472**	**0.00851**			
	eQUEST Baseline 2009	2,590,200	111,800	20,020	NA	$266,532	$150,617	NA	NA	$ 417,149	
	eQUEST / Actual Use Ratio	**101.0%**	**100.1%**	**100.5%**	Modeling estimates should fall within 5% of actual usage.						
	Actual Baseline Usage 2009	2,564,400	111,730	19,925	1,299,276	$263,877	$150,523	$ 11,057	$425,456	$ 414,399	
	Actual Energy Use Intensity (EUI) - (BTU/SF-YR)	28,589	36,497	65,086							

ECM1 - *Optimum Start/Stop of AHUs, Chillers and Boilers*

Optimum start/stop is a standard option provided in the BAS control strategies. This control strategy starts the building systems in advance of the building occupancy to bring space comfort temperatures to occupied setpoints before the building is occupied. Each day, the start of systems is calculated by the control system to determine how much time is needed to bring the space temperatures to the desired setpoint. Currently, the building systems are started at the same time each day on a set time schedule. Energy savings can be gained by automatically adjusting the daily start time to just meet the requirements of the building.

An eQUEST energy model was developed (Appendix A), and the estimated annual energy savings are summarized in Table 1.

ECM2 - *AHU Static Pressure Reset*

Air static pressure in a VAV air handling system is normally maintained by modulating the speed of the fan. Air is distributed throughout the building by ductwork, and VAV terminal boxes control the flow of cool air delivered to the spaces they serve. As the space cooling load increases, the flow of cold air increases to maintain the space temperature. If space cooling loads decrease, the requirements for cold air flow to cool the space decrease. The air flow to the VAV terminal boxes is delivered at a system static pressure. The static pressure level is established by the minimum pressure required for the terminal boxes to deliver full cooling flows. During the winter, air flow requirements drop to their minimum levels and the static pressure required at terminal boxes decreases. This reduced air flow requirement brings about an opportunity to reduce the system static pressure levels along with reducing energy usage. Static pressure reset control strategies have been in use for more than 20 years and have been proven to provide significant levels of energy savings.

An eQUEST energy model was developed (Appendix A), and the estimated annual energy savings are summarized in Table 1. The energy efficiency measure wizard option to model static pressure reset is not included in the current version of eQUEST. The magnitude of energy savings was estimated by modeling the baseline VAV system as a forward-curved fan system with inlet vane dampers, and the static pressure reset option was modeled as a standard VAV system with variable speed drives.

Implementation of the improved air static pressure reset control can greatly increase the energy savings. Since 1999, American Society of Heating, Refrigerating & Air Conditioning Engineers (ASHRAE) 90.1 has required that static air pressure be reset for systems with DDCs "i.e., the setpoint is reset lower until one zone damper is nearly wide open." However, system design deficiencies often limit the potential energy savings. These design deficiencies create problem zones that cause the reset scheme to underperform because they frequently or constantly generate zone pressure increase requests.

Common causes are:

- Undersized VAV box because of improper selection in the design phase, or because unexpectedly high zone loads are added to the space after construction

- Cooling thermostat setpoint below design condition

- Thermostats with heat releasing equipment under them (typically microwaves and coffee pots)

- Air distribution design problems — high-pressure drop fittings or duct sections.

The first three items cause the zone to frequently demand maximum or near-maximum zone air flow rates. Depending on zone location relative to the fan, a constant demand for high air flow rates indirectly causes the zone to generate frequent or constant pressure requests. The fourth problem directly results in pressure requests: for example, a zone with a fire/smoke damper installed in the 6-inch (150-millimeter [mm]) high-pressure duct at the box inlet. Small smoke dampers have little free area, so pressure drop will be very high.

Ways to mitigate the impact of problem zones on static pressure reset control sequences include:

- Exclude the problem zones from the reset control sequence. They can be excluded by ignoring the problem zone's pressure requests or including logic that ignores the first few pressure requests. Of course, ignoring the zone results in failure to meet zone air flow and temperature setpoints. This failure may be acceptable if the zone is a problem because the temperature setpoint is too low, but it clearly can be an issue if the zone is more critical.

- Limit thermostat setpoint adjustments to a range that is close to space design temperatures. DDC systems typically have the ability to limit the range; occupants can adjust setpoints from the thermostat. This means of mitigation can prevent cooling setpoints that are well below design conditions.

- Request that all thermostats are free of impact from heat producing appliances directly under them.

- Fix duct restrictions and sizing issues. This choice is clearly better than ignoring the zone and letting it overheat, but the cost to make revisions may be higher than the owner is willing to invest. It is best, of course, to avoid these restrictions in the first place. For instance, building design should avoid using flexible duct at VAV box inlets, oversized inlet ducts when they extend a long way from the duct main, and small fire/smoke dampers in VAV box inlet ducts.

- Add auxiliary cooling to augment the VAV zone. If the problem results from an undersized zone or unexpectedly high loads, a second cooling system, such as a split air conditioning (AC) system, can be added to supplement the VAV zone capacity. However, this solution is also expensive.

ECM3.a - *Boilers — Oxygen Trim Controllers*

All combustion requires oxygen; too much or too little can cause undesirable effects. However, the error is almost always intentionally on the high side (too much oxygen) because the main effect on the high side is low efficiency. Too little air results in carbon monoxide formation, as well as sooting and even explosion if accumulated soot and other non-combusted gases suddenly receive enough oxygen to rapidly burn.

When boiler burners are manually tuned on a periodic basis, they are typically adjusted to about 3% excess oxygen, which is about 15% excess air. These levels are used because there are many ambient and atmospheric conditions that can affect oxygen and air supply. For example, colder air is denser and contains more oxygen by volume than warm air; wind speed affects every chimney, flue, and stack differently; and barometric pressure further affects draft. Therefore, an excess oxygen and air setting at the time of tuning assumes there will still be enough oxygen available for complete combustion when conditions worsen.

From an efficiency standpoint, the excess oxygen means there is more air in the combustion stream than necessary. The amount of excess oxygen is roughly proportional to the efficiency lost.

Although it may be possible to monitor and adjust the burner on a daily basis, it is not practical. Automatic oxygen systems (Figure 5) continuously monitor the flue gases and adjust the burner air supply. They are generically called “Oxygen Trim Systems.”

Figure 5. Components of Automatic Oxygen Monitoring System

An electronic sensor is inserted into the boiler flue, near the boiler, ahead of dampers or other sources of air leakage into the boiler or flue. The sensor is connected to a control panel that measures oxygen and sends a signal to a control damper on the burner air supply.

An eQUEST energy model was performed (Appendix A), and the estimated annual energy savings are summarized in Table 1. The energy conservation measure wizard was used to model the energy savings by adjusting the overall combustion efficiency by 4 percent.

ECM3.b - *Boilers — Exhaust Stack Dampers*

Gas-fired furnaces, small boilers, and water heaters require a flue that has a good draft to eliminate the products of combustion after most of the heat has been removed. Newer appliances have fans and are called “forced” or “induced” draft venting. Older equipment and most small boilers still rely on natural draft. Figure 6 shows a picture of a typical exhaust stack damper. Figure 7 is a picture of a typical installation on two boilers.

Figure 6. Exhaust Stack Dampers

Figure 7. Exhaust Dampers Installed

The problem arises when the draft is occurring all of the time, drawing air out of the facility, even when it is not necessary to remove flue gases (when the burner is off). A vent damper is an automatic device that shuts off the flue pipe when the burner is not running, saving off-cycle losses of heated air. Therefore, if the appliance is in an unheated space, there is no benefit to a vent damper. The Akron Seiberling building boilers are located in a heated space, and exhaust vent dampers will reduce heated air energy loss.

An eQUEST energy model was performed (Appendix A) and the estimated annual energy savings are summarized in Table 1. The energy conservation measure wizard was used to model the energy savings by adjusting the overall combustion efficiency by 3 percent.

ECM4 - ***Building Retro-commissioning***

Retro-commissioning (or Retro-Cx) is a form of commissioning. Commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs. Retro-commissioning is the same systematic process applied to existing buildings that have never been commissioned to ensure that their systems can be operated and maintained according to the owner's needs. It is recommended that the practices of recommissioning or ongoing commissioning be applied for buildings that have already been commissioned or retro-commissioned.

Recommissioning is the term for applying the commissioning process to a building that has been commissioned previously (either during construction or as an existing building); it is normally done every 3 to 5 years to maintain top levels of building performance or after upgrades to identify new opportunities for improvement.

Researchers at Lawrence Berkeley National Laboratory, Portland Energy Conservation, Inc., and the Energy Systems Laboratory at Texas A&M University concluded in a study published in December 2004 (Mills et al. 2004) that retro-commissioning is one of the most cost-effective means of improving energy efficiency in commercial buildings. The researchers statistically analyzed more than 224 new and existing buildings that had been commissioned, totaling more than 30 million ft^2 of commissioned floorspace (73% existing buildings and 27% new construction). The results revealed the most common problem areas and showed that both energy and non-energy benefits were achieved. Analysis of commissioning projects for existing buildings showed a median commissioning cost of $0.27 per ft^2, an energy savings of 15%, and a simple payback period of 0.7 year.

The Retro-commissioning Process

Retro-commissioning should follow a four-step approach of planning, investigation, implementation, and continuation.

Step 1 is the planning step, which includes assembling the Retro-Cx core team that will work with the Retro-Cx provider and is composed of building management staff with skills in equipment operation, energy management, and engineering. The overall objectives and strategy are established during this step.

Step 2, the investigation step, includes several significant activities. During a typical Retro-Cx effort, the providers become familiar with the building and its systems via walk-throughs, gathering and reviewing equipment and design documentation, and evaluating O&M practices. As part of the investigation step, a list of potential ECMs for the building is developed. The Department of Energy's (DOE's) Industrial Assessment Center maintains an exhaustive data base of 2,300 potential ECMs, most of which are no cost / low cost (less than $500). The Retro-Cx provider identifies applicable ECMs, develops cost estimates, and prioritizes the opportunities.

Step 3 is implementation of ECMs. ECMs determined to be easy to complete, measure, and most likely to succeed are the first to be addressed. The results of these ECMs are then used to build up credibility for the Retro-Cx approach and gain support to accomplish the full range of ECMs. Completed ECMs are tested and monitored for results with readjustments made as necessary.

Step 4 in the Retro-Cx effort is that of continuing the onsite efforts with activities such as monitoring building energy data, periodic review of operational changes, occupant and operator feedback, and monthly update reports. Ongoing monitoring of building performance helps to ensure that the retro-commissioned building systems continue to operate in their optimized state and that energy savings continue to be realized.

4.2 Renewable Energy Measures Evaluated

Solar Hot Water

The Akron Seiberling building is occupied by about 300 people, and the needs for hot water are primarily the cafeteria kitchen area, other small kitchen areas, and bathroom faucets. Solar hot water is a viable renewable energy system in Ohio. The State of Ohio encourages the use of solar hot water and offers partial incentive funding on a first–come, first-served basis (see below). The Akron Seiberling building has rooftop space that would be suitable for a solar photovoltaic collector field. Solar collector areas of the roof should not be shaded to allow for direct solar absorption on the collector surface. The system proposed for the Akron Seiberling building would require almost 1,000 square feet of roof area for the solar collector field.

The annual production of solar heated water was estimated using a solar hot water heating estimator from RETScreen (NRC 2010) that uses solar data for Akron, Ohio.

Photovoltaic Power Generation

Photovoltaic power production is also a viable renewable energy producer in Ohio. The State of Ohio encourages the use of solar power generation and offers partial incentive funding on a first come first served basis (see below). As noted in the discussion of solar hot water, the roof area of the Akron Seiberling building has areas that are suitable for optimum solar collector placement. The collector field area needed to produce 70 kilowatts (kW) of solar power is equal to 7,000 ft^2 of roof area.

The annual production of electricity was estimated using a PV Watts solar production estimator using solar data for Akron, Ohio. The power produced is used by the building and no power is transferred to the grid. Solar PV rebates and incentives may be available, but they have not been factored into the cost of implementing the project, as found in Table 1.

5.0 Potential Green House Gas Reduction

The proposed ECMs will reduce greenhouse gas (GHG) emissions. All reported calculations in Table 2 below are based on the Environmental Protection Agency (EPA) GHG emissions calculator and are reported as carbon dioxide equivalent (CO_2e). The EPA calculator estimates for kWh savings are based on CO_2 only. If the recommended ECMs are implemented, the actual kWh savings can be used to determine GHG emissions reductions using the EPA eGRID model (Pechan 2008), using actual data from the specific electricity provider, which takes into consideration complex factors such as utility generation mix from coal, natural gas, nuclear and renewable energy sources.

Table 2 Estimated GHG Emissions Reductions for each Proposed ECM

ECM#	kWh savings estimated	therm savings estimated	metric tons GHG avoided (kWh estimated) in CO_2e	metric tons GHG avoided (therms estimated) in CO_2e	estimated total metric tons GHG avoided in CO_2e
1	7,600	900	5	5	10
2	145,000	-2,900	102	-15	87
3a	0	5,800	0	29	29
3b	0	4,400	0	22	22
4	129,510	5,590	91	28	119
Solar Hot Water	-100	456	0	2	2
Solar Power Generation	77,815	0	54	0	54
TOTALS	**360,025**	**14,246**	**252**	**71**	**323**

Reference: http://www.epa.gov/rdee/energy-resources/calculator.html

To calculate jobs created/retained, we assume one job for every $92,000 in funds expended. The baseline non-interactive energy efficiency retrofits ($116,341) will result in 1.3 jobs created and 267 tons of carbon dioxide equivalent (CO_2) emissions avoided. If the proposed renewable energy projects are implemented, the estimated investment would be $706,000. This would result in 7.7 jobs created and 56 tons of carbon dioxide equivalent (CO_2) emissions avoided.

6.0 Action Plan for Implementation of ECMs

6.1 Priorities and Next Steps

There are three ways to implement the recommended measures:

1. Use the audit report findings to immediately implement the no-cost and low-cost ECMs identified.

2. Further analyze ECMs with moderate cost or longer simple payback times

3. Conduct a more comprehensive audit or recommissioning to identify ECMs that may be less desirable now because of implementation obstacles or capital cost considerations.

   - The first action item should focus on implementing the no-cost/low-cost recommendations. To implement these measures, GSA can request a proposal to implement the measures from the operations contractor.

   - Building retro-commissioning implementation is a four-step process, and the planning stage is the first step once funding is secured.

   - The solar energy projects need further study and require the services of an engineering consultant to design these systems.

   - Replacing the natural gas boilers and upgrading lighting systems are capital projects that require an engineering consultant to begin project development.

   - Recommended resources for Akron Seiberling building operations staff:
     ✓ FEMP Retro-commissioning
     http://www1.eere.energy.gov/femp/pdf.om retrocs.pdf
     ✓ FEMP Best Practices Operations and Maintenance
     http:///www1.eere.energy.gove/femp/operations maintenance/om bpguide.html

6.2 Funding Assistance Available

Ohio Edison a FirstEnergy Company currently does not offer any incentives for non-residential projects. Ohio Edison offers energy and water efficient products through an on-line store. The store is available for customers of FirstEnergy's operating companies. Additional information can be found at the following web site: http://www.energyfederation.org/firstenergy/default.php

Renewable energy funding may be available through the State of Ohio. The Ohio Department of Development's (ODOD) Ohio Energy Office (OEO) is seeking applications to implement renewable energy projects limited to solar electric, wind electric, and solar thermal systems for commercial, industrial, institutional and governmental entities in Ohio. In accordance with the authority provided the Director of the ODOD under Ohio Revised Code §4928.61-63, qualifying applicants will be eligible to apply for grant assistance to cover a portion of the costs of eligible projects located in the service territories of the four investor-owned electric distribution companies. Grant funds are limited, but qualifying applications will be funded until all the funds for this Notice of Funding Available (NOFA) are awarded or the OEO concludes the program no longer suits the best interest of Ohio's energy plan. Additional information can be found at the following web site:
http://www.development.ohio.gov/cdd/oee/ELFGrant.htm#NOFA_08-09

Solar electric system incentives are available at a rate of $3.50/watt for systems that are at least 10 kW direct current (DC) in size. The maximum incentive cannot exceed 50% of eligible system costs, and the maximum incentive as a total of eligible system costs is $150,000.

Solar thermal system incentives are available at a rate of $30 per thousand British thermal units (kBtu)/day for systems that are at least 200 kBtu/day in size. The maximum incentive cannot exceed 50% of eligible system costs, and the maximum incentive as a total of eligible system costs is $150,000.

Federal projects can be financed by various means. The most readily available funding source would be ARRA funds at the agency level. An alternative approach for Federal projects is the use of either energy savings performance contracts (ESPC) or utility energy savings performance contracts (UESC) that provide up-front funding to install systems and make modifications with repayment made from the resulting energy and cost savings.

7.0 Assessment Team Members and Site Team

The Redhorse ARRA assessment team for the audit included Jim Arends, PE, CEM, Redhorse Corporation Energy Audit Team Technical Lead; and Darcy Anderson, CEM, Redhorse Corporation Energy Audit Team Member. Site support was provided by John Bolovan, GSA Supervisory Property Manager; Joseph Blake, GSA Assistant Property Manager; and Angela Jayjack, GSA Property Manager handling the regional lighting projects. Additional interviews were conducted with Dave Mosser, supervisor, HVAC technician (onsite contract operator) with CMC & Maintenance, Inc.; Harry Smith, maintenance mechanic with CMC & Maintenance, Inc.; and Daniel Blasko, lead systems specialist with Johnson Controls.

8.0 References

Mills, E, H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M. Piette. December 2004. *The Cost-Effectiveness of Commercial-Building Commissioning: A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States*. LBNL-56637. Lawrence Berkeley National Laboratory, Berkeley, California. *Can be accessed at http://eetd.lbl.gov/emills/PUBS/PDF/Cx-Costs-Benefits.pdf*.

National Resources of Canda (NRC) 2010. *RETScreen® Clean Energy Project Analysis Software from RETScreen International*. *Can be accessed at http://www.retscreen.net/ang/t_software.php.*

E.H. Pechan & Associates (Pechan). September 2008. *The Emissions & Generation Resource Integrated Database for 2007 (eGRID 2007).* Report Number 08.09.006/9011.239. Springfield, Virginia.

APPENDIX A

Model Output Files

Appendix A –Model Output Files

Energy Simulation Output: Baseline Energy Use

eQUEST Model Results Baseline Use													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13.7	14.2	19.7	20.6	23.1	45.1	54.3	45.1	28.7	17.4	14.3	15.5	311.60
Heat Reject.	0	0	0.4	0.7	1.6	6.6	9.3	7.3	3.4	0.6	0.1	0	30
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	0
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	51.1	46.8	37.9	32.1	27.6	35.8	39.7	34	34.5	41.1	45.6	50.7	476.9
Pumps & Aux.	21.6	20.5	24.8	24.1	22.5	23.1	23.8	22	21.1	21.6	20.5	23.2	268.9
Ext. Usage	0.5	0.4	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	5.5
Misc. Equip.	41.5	39.1	47.4	47.1	44.1	44.8	44.9	43.2	43	43.2	39.5	45	522.80
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	76.9	72.8	88.4	88.3	81	84.2	84.1	80.6	80.4	80.5	73.1	84.1	974.50
Total	205.5	193.9	219.1	213.4	200.2	239.8	256.5	232.7	211.6	204.9	193.6	219.1	2,590.20
Gas Consumption (Btu x000,000,000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	2.29	1.93	1.31	0.72	0.41	0.14	0.1	0.14	0.22	0.65	1.12	1.97	11.01
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.17
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	0	0	0	0	0	0	0	0	0	0	0	0	0
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.31	1.94	1.33	0.74	0.42	0.15	0.12	0.15	0.24	0.67	1.13	1.98	11.18

Energy Simulation Output: Optimum Start / Stop

eQUEST Model Results Optimum Start/Stop													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13.7	14.2	19.6	20.3	22.6	44.7	54.3	45	28.2	17	14	15.4	309
Heat Reject.	0	0	0.3	0.6	1.5	6.5	9.3	7.3	3.3	0.5	0.1	0	29.5
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	0
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	51.1	46.8	37.7	31.7	26.7	35.3	39.7	33.9	33.5	40.4	45.1	50.5	472.5
Pumps & Aux.	21.6	20.5	24.8	24.1	22.5	23.1	23.8	22	21.1	21.6	20.5	23.2	268.7
Ext. Usage	0.5	0.4	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	5.5
Misc. Equip.	41.5	39.1	47.4	47.1	44.1	44.8	44.9	43.2	43	43.2	39.5	45	522.80
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	76.9	72.8	88.4	88.3	81	84.2	84.1	80.6	80.4	80.5	73.1	84.1	974.5
Total	205.4	193.9	218.7	212.7	198.8	239	256.4	232.5	210	203.7	192.8	218.7	2,582.60
Gas Consumption (Btu x000,000,000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	2.29	1.93	1.31	0.71	0.39	0.13	0.1	0.13	0.21	0.64	1.1	1.96	10.92
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.17
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	0	0	0	0	0	0	0	0	0	0	0	0	0
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.31	1.94	1.33	0.73	0.4	0.15	0.12	0.15	0.22	0.65	1.12	1.98	11.09

Energy Simulation Output: Static Pressure Reset

eQUEST Model Results Static Pressure Reset													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	12.9	13.1	18.4	19.6	22.3	43.9	53	43.8	27.8	16.5	13.3	14.3	298.9
Heat Reject	0	0	0.4	0.6	1.5	6.4	9.1	7.1	3.3	0.5	0.1	0	29.1
Refrigeratio	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	0
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	37	33.9	25.3	21.4	18.4	27.6	30.4	26.2	26.6	30.5	32.6	36.8	346.8
Pumps & Au	21.5	20.3	24.6	24	22.4	23.1	23.7	21.9	21	21.5	20.4	23	267.4
Ext. Usage	0.5	0.4	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	5.5
Misc. Equip.	41.5	39.1	47.4	47.1	44.1	44.8	44.9	43.2	43	43.2	39.5	45	522.80
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	76.9	72.8	88.4	88.3	81	84.2	84.1	80.6	80.4	80.5	73.1	84.1	974.5
Total	190.3	179.7	205	201.5	190.1	230.2	245.6	223.4	202.5	193.3	179.5	203.7	2,445.00
Gas Consumption (Btu x000,000,000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat Reject	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeratio	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	2.35	1.98	1.35	0.75	0.42	0.14	0.11	0.14	0.23	0.68	1.16	2.02	11.3
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.17
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps & Au	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	0	0	0	0	0	0	0	0	0	0	0	0	0
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.36	1.99	1.37	0.76	0.43	0.16	0.12	0.15	0.24	0.69	1.17	2.03	11.47

Energy Simulation Output: Boiler O_2 Trim Controller

eQUEST Model Results Boiler O2 Trim Controller													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13.7	14.2	19.7	20.6	23.1	45.1	54.3	45.1	28.7	17.4	14.3	15.5	311.6
Heat Reject.	0	0	0.4	0.7	1.6	6.6	9.3	7.3	3.4	0.6	0.1	0	30
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	0
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	51.1	46.8	37.9	32.1	27.6	35.8	39.7	34	34.5	41.1	45.6	50.7	476.9
Pumps & Aux.	21.6	20.5	24.8	24.1	22.5	23.1	23.8	22	21.1	21.6	20.5	23.2	268.9
Ext. Usage	0.5	0.4	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	5.5
Misc. Equip.	41.5	39.1	47.4	47.1	44.1	44.8	44.9	43.2	43	43.2	39.5	45	522.80
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	76.9	72.8	88.4	88.3	81	84.2	84.1	80.6	80.4	80.5	73.1	84.1	974.5
Total	205.5	193.9	219.1	213.4	200.2	239.8	256.5	232.7	211.6	204.9	193.6	219.1	2,590.20
Gas Consumption (Btu x000,000,000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	2.17	1.83	1.24	0.69	0.38	0.13	0.1	0.13	0.21	0.62	1.06	1.86	10.43
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.17
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	0	0	0	0	0	0	0	0	0	0	0	0	0
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.19	1.84	1.26	0.7	0.4	0.15	0.11	0.14	0.22	0.63	1.07	1.88	10.6

Energy Simulation Output: Boiler Exhaust Stack Damper

eQUEST Model Results Boiler Exhaust Stack Damper													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13.7	14.2	19.7	20.6	23.1	45.1	54.3	45.1	28.7	17.4	14.3	15.5	311.6
Heat Reject.	0	0	0.4	0.7	1.6	6.6	9.3	7.3	3.4	0.6	0.1	0	30
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	0	0	0	0	0	0	0	0	0	0	0	0	0
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	51.1	46.8	37.9	32.1	27.6	35.8	39.7	34	34.5	41.1	45.6	50.7	476.9
Pumps & Aux.	21.6	20.5	24.8	24.1	22.5	23.1	23.8	22	21.1	21.6	20.5	23.2	268.9
Ext. Usage	0.5	0.4	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	5.5
Misc. Equip.	41.5	39.1	47.4	47.1	44.1	44.8	44.9	43.2	43	43.2	39.5	45	522.80
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	76.9	72.8	88.4	88.3	81	84.2	84.1	80.6	80.4	80.5	73.1	84.1	974.5
Total	205.5	193.9	219.1	213.4	200.2	239.8	256.5	232.7	211.6	204.9	193.6	219.1	2,590.20
Gas Consumption (Btu x000,000,000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	0	0	0	0	0	0	0	0	0	0	0	0	0
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	2.2	1.85	1.26	0.7	0.39	0.13	0.1	0.13	0.22	0.63	1.07	1.89	10.57
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.17
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	0
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0
Misc. Equip.	0	0	0	0	0	0	0	0	0	0	0	0	0
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	2.22	1.87	1.28	0.71	0.4	0.15	0.11	0.14	0.23	0.64	1.08	1.91	10.74

Energy Simulation Output: Retro-commissioning

eQUEST Model Results	kWh	Therms
Baseline	2,581,500	111,000
Estimated Savings Percent	5%	5%
Estimated Savings Retrocommissioning	129,075	5,550

Energy Simulation Output: Solar Domestic Hot Water

Retrscreen Tool				
Technology		Solar water heater		
Load characteristics	**Unit**	**Base case**	**Proposed case**	
Load type		Office		
Number of units	Person	300		
Occupancy rate	%	80%		
Daily hot water use - estimated	gal/d	241		
Daily hot water use	gal/d	240	240	
Temperature	°F	130	130	
Operating days per week	d	5	5	
Supply temperature method		Formula		
Water temperature - minimum	°F	41.1	Akron City Water	
Water temperature - maximum	°F	57.5	Akron City Water	
Heating	million Btu	42.0	42.0	
Resource assessment				
Solar tracking mode		Fixed		
Slope	°	0.0		
Azimuth	°	0.0		
Solar water heater				
Type	Unglazed			
Manufacturer	Heliocol			
Model	HC-10			
Gross area per solar collector	ft²	10.37		
Aperture area per solar collector	ft²	10.37		
Fr (tau alpha) coefficient		0.87		
Wind correction for Fr (tau alpha)	s/ft			
Fr UL coefficient	(Btu/h)/ft²/°F	3.75		
Wind correction for Fr UL	(Btu/ft³)/°F			
Number of collectors		36	22	
Solar collector area	ft²	373.16		
Capacity	kW	24.27		
Miscellaneous losses	%			
Balance of system & miscellaneous				
Storage		Yes		
Storage capacity / solar collector area	gal/ft²	1		
Storage capacity	gal	373.2		
Heat exchanger	yes/no	Yes		
Heat exchanger efficiency	%	60.0%		
Miscellaneous losses	%	10.0%		
Pump power / solar collector area	W/ft²	0.10		
Electricity rate	$/kWh	0.103		
Summary				
Electricity - pump	MWh	0.1		
Heating delivered	million Btu	34.2		
Solar fraction	%	81%		
Heating system		**Base case**	**Proposed case**	**Proposed Savings**
Fuel type		Natural gas - therm	Natural gas - therm	Natural gas - therm
Seasonal efficiency		75%	75%	
Fuel consumption - annual	therm	560.4	104.7	455.7

Energy Simulation Output: Solar Power Generation

PV Watts AC Energy & Cost Savings

Station Identification		Results		
		Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)
City:	Akron			
State:	Ohio			
Latitude:	40.92° N	1	2.40	4148
Longitude:	81.43° W	2	3.38	5207
Elevation:	377 m	3	4.21	6964
PV System Specifications		4	4.76	7425
DC Rating:	70.0 kW	5	5.33	8334
DC to AC Derate Factor:	0.77	6	5.41	7874
AC Rating:	53.9 kW	7	5.53	8261
Array Type:	Fixed Tilt	8	5.40	8130
Array Tilt:	40.9°	9	5.15	7671
Array Azimuth:	180.0°	10	4.08	6555
		11	2.48	3852
		12	2.03	3394
		Year	4.18	77815

APPENDIX B

Photographs

Appendix B – Photographs

Photo 1: Joseph Blake, GSA Assistant Property Manager, collecting nameplate data from AHU-2 during FEMP audit site visit, December 2009.

Photo 2: Roof area with potential for solar panel installation, December 2009.

Photo 3: Harry Smith, maintenance mechanic with CMC & Maintenance, Inc.; Joseph Blake, GSA Assistant Property Manager; and Jim Arends, Redhorse Corporation CEM; climbing to collect data on rooftop BAC unit during FEMP audit site visit, December 2009.

Photo 4: Joseph Blake, GSA Assistant Property Manager, and Jim Arends, Redhorse Corporation CEM, collecting data in penthouse during FEMP audit site visit, December 2009.

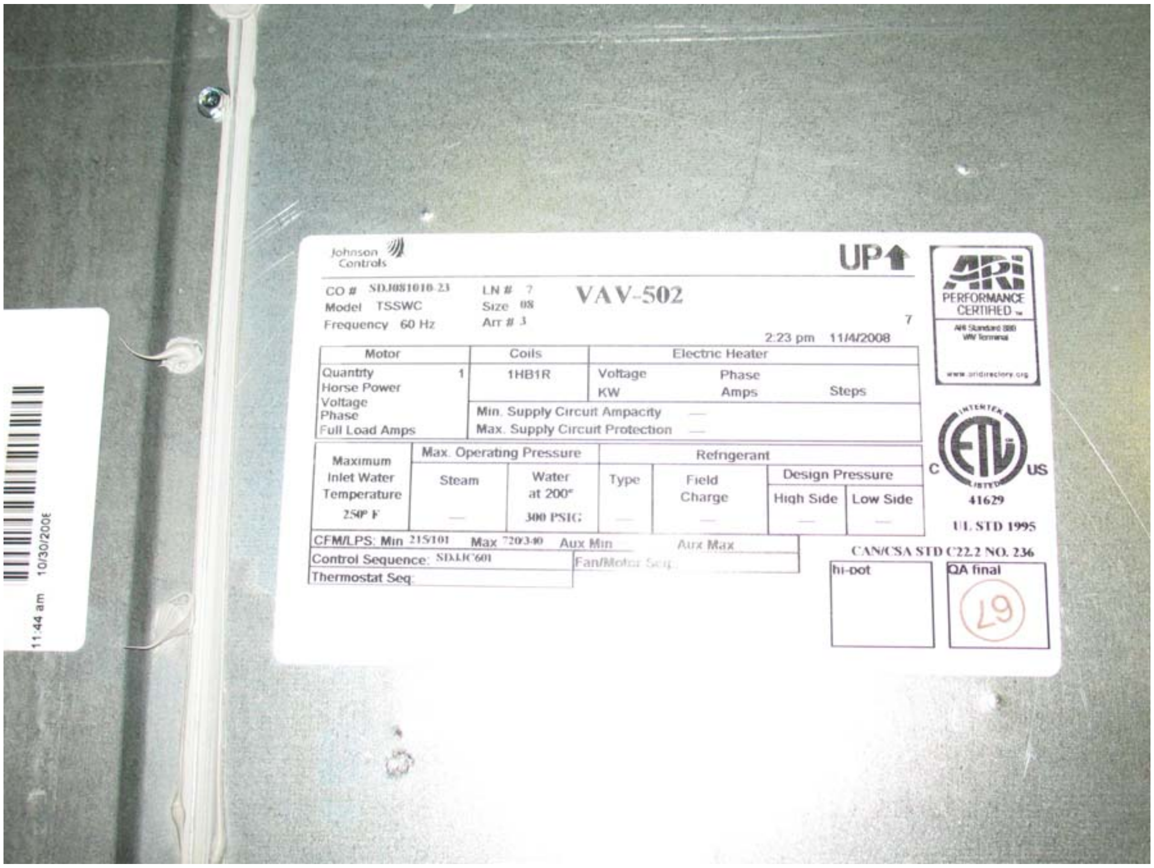

Photo 5: Johnson Controls VAV nameplate, December 2009.