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under Contract DE-AC05-76RL01830

American Recovery and Reinvestment Act Federal Energy Management Program Technical Assistance Project 184

U.S. Customs and Border Protection Administrative and Laboratory Building, Springfield, Virginia

J Arends
WF Sandusky

September 2010

Pacific Northwest
NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

This report documents the findings of an on-site energy audit of the U.S. Customs and Border Protection (CBP) Laboratory in Springfield, Virginia. The landlord for this building is Boston Properties, and the facility is leased by CBP. The focus of the audit was to identify various no-cost or low-cost energy efficiency opportunities that, once implemented, would reduce electrical consumption and increase the operational efficiency of the building. This audit also provided an opportunity to identify potential renewable energy projects that should be considered in the future to acquire additional electrical energy to further increase the operational efficiency of the building.

The audit identified four measures that could be implemented immediately and the two capital projects, resulting in a total estimated savings of 1,605 million British thermal units (MMBtu) of electrical energy that in turn would result in an annual cost savings of $35,280. The estimated cost to implement the measures is $82,050, so the payback for such an investment would be 2.3 years.

Two renewable energy projects were identified related to use of the available solar resource. These projects would save an additional 343 MMBtu of energy, resulting in a cost savings of $7,531 annually. At this point, implementation of these measures is not cost-effective unless they are required for increasing the amount of on-site power generation from renewable resources.

Implementation of the four no-cost and low-cost energy conservation measures (ECMs) and the two capital projects would decrease greenhouse gas (GHG) emissions to the atmosphere as well as create job opportunities. For the no-cost and low-cost ECMs and two capital projects, it was estimated that 318 metric tons of GHG emissions to the atmosphere would be avoided and 0.9 job would be created. If the renewable energy projects were implemented, 7.7 jobs would be created and 70 metric tons of GHG emissions to the atmosphere would be avoided.

List of 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
BCS	Building control system
BLCC	Building life cycle cost
Btu	British thermal unit
USCBP	U.S. Customs and Border Protection
CF	Cubic feet (ft^3)
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
EISA	Energy Independence and Security Act
ESET	Energy savings expert teams
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act
EUI	Energy Use Intensity
ft^2	Square feet
FEMP	Federal Energy Management Program
GSA	General Services Administration
IR	Infrared
kBtu	10^3 Btu
kW	Kilowatt
kWh	Kilowatt hour (1 kWh = 3412 Btu)

LBNL	Lawrence Berkeley National Laboratory
LED	Light emitting diode
LEED	Leadership in Energy and Environmental Design
Mcf	Million cubic feet (natural gas)
MMBtu	10^6 Btu
NII	Non-invasive inspection
NOFA	Notice of funding available
O&M	Operation and maintenance
PM	Preventive maintenance
PNNL	Pacific Northwest National Laboratory
PV	Photovoltaic
Retro-CX	Retro-commissioning
RTU	Rooftop unit
SHW	Solar domestic hot water
SPV	Solar photovoltaic
UV	Ultraviolet
VAV	Variable air volume
Yr	year

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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. To advance that goal and help accelerate agencies' progress, FEMP works to foster collaboration between its Federal agency customers and the U.S. Department of Energy (DOE) national laboratories.

In 2009 and 2010, FEMP has utilized funding from the American Recovery and Reinvestment Act of 2009 (ARRA) to facilitate Federal agency access to the broad range of capabilities expertise at the National Laboratories. Funds were directed to the Laboratories to assist agencies in making their internal management decisions for investments in energy efficiency and deployment of renewable energy sources, with particular emphasis on assisting with the mandates of the Energy Independence and Security Act of 2007 related to Federal facilities and fleets.

FEMP provided major DOE laboratories with funding that will allow them to respond quickly to provide technical advice and assistance. FEMP applied a simple vetting and approval system to quickly allocate work to each of the laboratories in accordance with FEMP allocated funding. All assistance provided by the laboratories was in accordance with the requirements of Federal Acquisition Regulation (FAR) Subpart 35.017 and the laboratories' designation as “Federal Funded Research and Development Center” (FFRDC) facilities.

The CBP submitted a response to this call requesting that energy audits be conducted at a laboratory building and a data center building in Springfield Virginia, and a laboratory building in Houston Texas, with the goal of identifying energy conservation measures that could be implemented in a timely manner. This request was selected by FEMP and designated Project 184. This report provides results of the audit for the Springfield laboratory building.

1.1 Site Audit Activities

This energy and water audit was conducted using the protocols and guidance developed by Pacific Northwest National Laboratory (PNNL) to support previous FEMP activities related to assessment of load and energy reduction techniques (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.

2.0 Background

2.1 Site Description

The CBP National Distribution Center (NDC) 2 Laboratory is located at 7501 Boston Boulevard in Springfield, Virginia. The two-story building of 83,460 square feet (ft^2) was originally constructed in 1997. Total occupancy for the building is just over 400 people, with a 10 to 20% reduction in occupancy during non peak periods after 10 PM until 5 AM. The building is owned by Boston Properties and has been leased by CBP since its construction.

The activities of the Springfield laboratory are varied in supporting CBP commercial and enforcement mission. The laboratory conducts programs to ensure analytical uniformity among the field laboratories and maintains technical and scientific exchange with other Federal enforcement agencies, technological branches of foreign customs agencies and the military.

The laboratory is well equipped to meet its analytical objectives with a staff of scientists and state-of-the art instrumentation including a Fourier-transform infrared spectrophotometer (FTIR), high-resolution inductively coupled plasma mass spectrometer (HR-ICP-MS), scanning electron microscope (SEM), and capillary electrophoresis equipment.

Major upgrades to the laboratory building planned in the near future include replacing the laboratory area rooftop air handling unit. Figure 1 is a photograph of the laboratory building.

Figure 1. U.S. Customs and Border Protection Laboratory in Springfield, Virginia

2.2 Major Building Energy Uses

Air Handling Systems

The building office areas are heated and cooled by three variable air volume (VAV) air handling unit (AHU) systems with electric resistance heating elements and direct expansion (DX) cooling. AHU systems 1, 2, and 3 are located on the roof, serving the office areas, and operate continuously because the building is occupied at all times. Total occupancy for the building is just over 400 people, with a 10 to 20% reduction in occupancy during non-peak periods after 10 PM until 5 AM. These rooftop units (RTUs) have variable frequency drives that control both supply and return fans. Outside air is tempered in each of the air handlers by electric resistance heating elements in the winter and by DX cooling coils in the summer. During the site visit, it was determined the AHUs deliver 55°F supply air via ductwork to the building terminal boxes. No humidification is provided in the AHUs.

The laboratory area of the building is served by a separate AHU with dedicated laboratory exhaust fans. This unit serves the laboratory area of the building as a

100% outside air system with variable frequency drives; variable frequency drive exhaust fans pull the exhaust air from the laboratory areas.

Terminal Unit Distribution Boxes

The perimeter zones of the building are served by VAV terminal boxes equipped with electric resistance reheat elements. Supply air for the perimeter zones is provided by VAV RTUs. 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 electric resistance heating elements reheat the supply air 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 capability. Supply air for the core zone is provided by VAV RTUs. Space setpoints are maintained by modulating the air volume when necessary to cool the space.

Laboratory Equipment

Laboratory equipment used in the lab includes lasers, mass spectrometers, fume hoods, and other testing apparatus.

Office Equipment and Lighting

Office equipment is found throughout the laboratory with computers and related equipment in offices. Lighting throughout the building is provided by T-8 fluorescent fixtures in most areas and compact fluorescent fixtures in lobby areas.

2.3 Climate, Facility Type, and Operations

The climate for the site is considered humid subtropical. Based on data available from the National Climatic Data Center, the maximum mean monthly temperature occurs in July (87.4°F), with the minimum mean monthly temperature occurring in January (21.9°F). The highest recorded temperature during the period from1971 through 2000 was 104°F on two occasions, while the lowest reported temperature during the period was -18°F on January 22, 1984. Based on the most recent mean data available (1971 to 2000), the site should experience 29.9 days with a maximum temperature exceeding or equal to 90°F, while the minimum temperature should be at 32°F or below for 112.5 days.

Annually, the site should anticipate 4,925 heating-degree-days and 1,075 cooling-degree-days.

Mean annual precipitation for the site is 41.8 inches. The highest daily reported precipitation was 10.67 inches on June 21, 1972. The highest reported monthly precipitation, 18.19 inches, occurred in June 1972. The daily precipitation should be at or greater than 0.01 inch for 120.1 days during the year. Mean annual snow fall for the site is 21.2 inches, but the highest monthly snowfall was reported in January 1996 (30.9 inches). The highest daily snow fall was 22.5 inches on February 11, 1983.

3.0 Energy Use

The electrical usage is metered by Dominion Virginia Power. Two electric meters serve the building. No natural gas is used for heating or cooling in the building; however, natural gas is used for laboratory bunsen burners.

3.1 Current Electricity Use

The building includes laboratory and office space. The building is occupied continuously; typical occupancy is just over 400 people, although staffing levels decrease by 10 to 15% during non-peak times (10 PM until 5 AM). Figure 2 represents the electrical energy usage estimated by an eQUEST building energy simulation. Utility data for the building were not provided. The default inputs were used in the modeling process, and could have been adjusted if utility data would have been provided. Lighting loads were input to match the existing intensity per square foot. The manufacturers' efficiencies for RTUs were input for the cooling efficiencies.

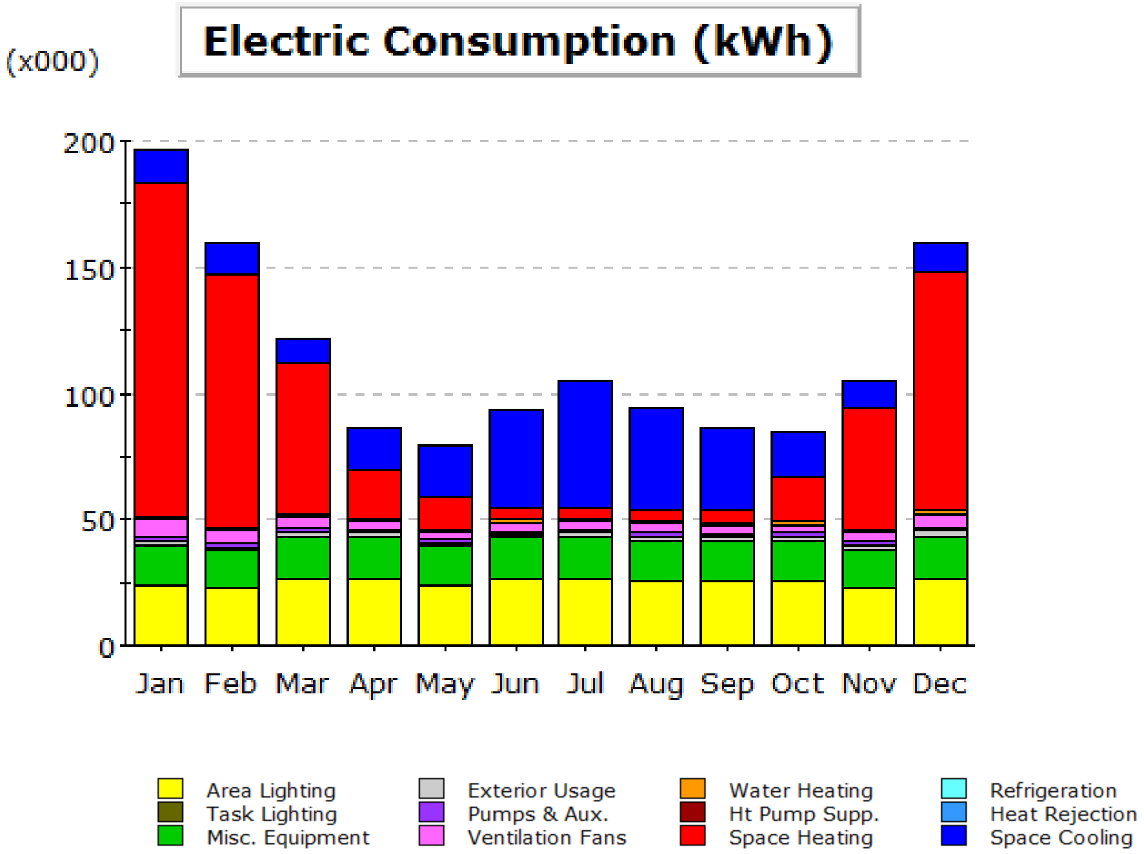


Figure 2. U.S. CBP Springfield, Virginia, Laboratory Electrical Use (Simulated by eQUEST)

3.2 Current Rate Structure

Dominion Virginia Power provides electric service under a commercial service rate. The current rate schedule for the adjacent data center is GS-3, a large general service secondary voltage tariff, which is a rate available for general service business customers with a maximum demand that exceed 500 kilowatts (kW) during three billing cycles. CBP currently pays an average of $0.075 per kilowatt hour (kWh) for the Springfield data center. This rate was used for laboratory building calculations in this report.

Information on the water rate was not provided for the building.

4.0 Energy Conservation Measures Identified

4.1 Summary of Proposed Measures

Four areas were identified where energy conservation measures (ECMs) are recommended for immediate implementation along with two capital projects. In addition, two renewable energy projects were investigated. 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 below. Energy saving estimates are based on individual results and do not represent any interactive effect. Savings in Table 1 are estimated reductions in energy use compared with the baseline or existing building energy usage model. The areas identified for immediate implementation were:

(1) VAV air handling unit static pressure reset
(2) AHU supply air temperature reset
(3) Ventilation air reduction – CO_2 sensors
(4) AHU night setback of temperatures
(5) Heating, ventilation, and air conditioning (HVAC) occupancy controls
(6) Laboratory RTU4 chiller replacement

The following renewable energy projects were also evaluated:

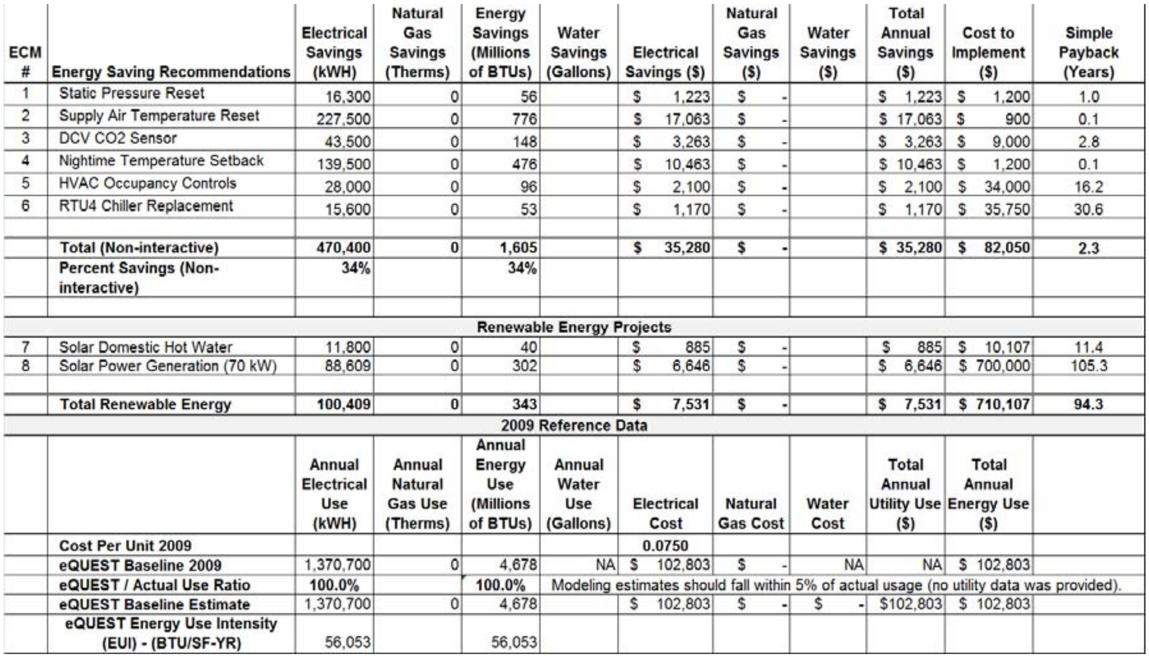
(1) Solar power generation
(2) Solar domestic hot water heating

The evaluation of the solar options did not include the impact of obtaining rebates or incentives.

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

(1) Exhaust air heat recovery

Table 1. U.S. CBP Laboratory 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	Static Pressure Reset	16,300	0	56		$ 1,223	$ -		$ 1,223	$ 1,200	1.0
2	Supply Air Temperature Reset	227,500	0	776		$ 17,063	$ -		$ 17,063	$ 900	0.1
3	DCV CO2 Sensor	43,500	0	148		$ 3,263	$ -		$ 3,263	$ 9,000	2.8
4	Nightime Temperature Setback	139,500	0	476		$ 10,463	$ -		$ 10,463	$ 1,200	0.1
5	HVAC Occupancy Controls	28,000	0	96		$ 2,100	$ -		$ 2,100	$ 34,000	16.2
6	RTU4 Chiller Replacement	15,600	0	53		$ 1,170	$ -		$ 1,170	$ 35,750	30.6
	Total (Non-interactive)	**470,400**	**0**	**1,605**		**$ 35,280**	**$ -**		**$ 35,280**	**$ 82,050**	**2.3**
	Percent Savings (Non-interactive)	**34%**		**34%**							
Renewable Energy Projects											
7	Solar Domestic Hot Water	11,800	0	40		$ 885	$ -		$ 885	$ 10,107	11.4
8	Solar Power Generation (70 kW)	88,609	0	302		$ 6,646	$ -		$ 6,646	$ 700,000	105.3
	Total Renewable Energy	**100,409**	**0**	**343**		**$ 7,531**	**$ -**		**$ 7,531**	**$ 710,107**	**94.3**
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					**0.0750**					
	eQUEST Baseline 2009	1,370,700	0	4,678	NA	$ 102,803	$ -	NA	NA	$ 102,803	
	eQUEST / Actual Use Ratio	**100.0%**		**100.0%**	Modeling estimates should fall within 5% of actual usage (no utility data was provided).						
	eQUEST Baseline Estimate	1,370,700	0	4,678		$ 102,803	$ -	$ -	$102,803	$ 102,803	
	eQUEST Energy Use Intensity (EUI) - (BTU/SF-YR)	56,053		56,053							

ECM1 - 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 space 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 likewise 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 the 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 is 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) Standard 90.1 (ASHRAE 2007a) has required that static air pressure be reset for systems with direct digital controls (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); and
- 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 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 that the owner is willing to invest. It is best, of course, to avoid these restrictions in the first place. For instance, avoid using flexible duct at VAV box inlets, avoid oversized inlet ducts when they extend a long way from the duct main, and avoid 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.

ECM2 – Supply Air Reset

The supply air temperature for a single-duct VAV system is usually set at a constant 55°F. This setpoint is used in the design of air handling systems to calculate the maximum air flow to satisfy the maximum cooling load conditions. If the setpoint is left at 55°F, significant reheat will occur in the winter when air flows reach their minimums and the heating load increases. The system is in a heating mode, and the supply air temperature is often reset upward to minimize simultaneous cooling and heating. The reset schedule can be based on either return air temperature or outside air temperature. Resetting the supply air temperature not only affects the cooling and heating energy consumption, but also the fan power consumption. If the supply air is reset too high, it may result in a fan power consumption penalty.

An eQUEST energy model was performed (Appendix A), and the estimated annual energy savings are summarized in Table 1. The energy efficiency measure wizard option for supply air reset (55/65°F) based on zone loads was used for these estimates.

Air handling systems that serve both the core areas of the building and the perimeter areas of the building have limited opportunities to use supply air reset control strategies. This limitation is most evident in the winter when the perimeter zones are in heating and the core areas of the building continue to require cooling. If the supply air temperature is reset upwards, the core area VAV terminal boxes will increase air flows to maintain space temperature. This increase in air flow will cause an increase in fan energy. For a net energy savings, this increase in fan energy use would have to be offset by the energy savings in the perimeter zones that would be required for less reheating at the terminal boxes. The optimal supply air temperature needs to take into account the thermal and electrical energy costs to achieve the minimum total operating costs. Generally, the amount of reset is limited by the percent of building area included in the core areas of the building; perimeter areas are affected by the weather and present greater opportunities for temperature reset. Significant energy saving opportunities can be gained if the building perimeter and core zones are served by separate VAV air handling systems.

During the winter, occupants of the building will complain about cold drafty airflows from a VAV system if the supply air temperature is left at 55°F. These complaints are justified as the VAV boxes throttle back to minimum flows in the winter during heating and the supply air diffusers do not distribute the air as effectively with low air flow velocities. This cold air tends to drop down around the occupants, and many complaints will be registered with the operations staff. Resetting the supply air upwards will reduce comfort complaints. The most common supply air reset schedules vary the supply temperature between 55°F and 65°F.

ECM3– Demand Controlled Ventilation (DCV) Using Carbon Dioxide (CO_2) Sensors

The American Society of Heating, Refrigeration and Air Conditioning Entineers (ASHRAE) recommends a ventilation rate of 15 to 20 cubic feet per minute (cfm) per person in ASHRAE Standard 62-1999 (ASHRAE 2007 b) to ensure adequate air quality in buildings. To meet the standard, many ventilation systems are designed to admit air at the maximum level whenever a building is occupied, as if every area were always at full occupancy. The result, in many cases, has been buildings that are highly over-ventilated. The development of CO_2-based DCV was driven in part by the need to satisfy ASHRAE 62 without over-ventilating.

When CO_2 sensors are used to maintain indoor air quality (IAQ), they continuously monitor the air in a conditioned space. Because people constantly exhale CO_2, the difference between the indoor CO_2 concentration and the outdoor concentration indicates the occupancy or activity level in a space and thus its ventilation requirements. An indoor/outdoor CO_2 differential of 700 parts per million (ppm) is usually assumed to indicate a ventilation rate of 15 cfm/person; a differential of 500 ppm indicates a 20 cfm/person ventilation rate. The CO_2 sensor readings are monitored at the air handling system control panel, which automatically increases ventilation when the CO_2 concentration in a zone rises above a specified level.

The highest payback can be expected in high-density spaces where occupancy is variable and unpredictable (such as auditoriums, some school buildings, meeting areas, and retail establishments), in locations with high heating or cooling demand (or both), and in areas with high utility rates. Case studies (DOE 2004) show DCV offers greater savings for heating than for cooling. In areas where peak power demand and peak prices are an issue, DCV can be used to control loads in response to real-time prices. DCV may result in significant cost savings even with little or no energy savings in those locations. Energy savings can be as high as 10%. The potential energy cost savings for CO_2-based DCV is estimated to range from \$0.05 to more than \$1 per ft^2 annually.

The reliability of CO_2 sensors has improved in recent years, and they should be considered for use in the modern energy efficient office. Opportunities in this building to use CO_2 sensors are limited to the non-laboratory areas because the laboratory areas always operate using 100 percent outside air. The DCV control option in the eQUEST was selected for all non-laboratory areas. An eQUEST energy model was performed (Appendix A), and the estimated annual energy savings are summarized in Table 1.

ECM4 – Night Setback of Temperatures

The nighttime temperatures in the building are currently the same as the daytime temperatures. Just more than 6 months ago, temperatures in the non-laboratory areas of the building were set back at night. This setback strategy was somehow removed, however. The setback temperatures were 65°F in heating and 85°F in cooling during the night. Returning the setpoints to the prior setbacks will save a significant amount of energy. An eQUEST energy model was performed (Appendix A), and the estimated annual energy savings are summarized in Table 1.

ECM5 - Occupancy Sensor Controlled HVAC

Lighting occupancy sensors can be used to reduce the HVAC heating and cooling energy use in spaces that are not occupied. Temperatures in the unoccupied space are reset by the controls system to unoccupied setpoints of 65°F in heating and 85°F in cooling. The state of the occupancy sensor is tapped by the building energy management system to control the heating or cooling setpoint of the space. When the space is unoccupied, the occupancy sensor turns off the lights and the space setpoint is reset to unoccupied temperature settings.

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

ECM6 – Laboratory RTU4 Chiller Replacement

RTU4 serves the laboratory section of the building; it has a chiller unit that is oversized and cycles on and off under low loads. During startup, the unit often kicks off, and then maintenance staff must manually restart the unit. This unit is an air-cooled chiller with reciprocating compressor. Replacing the unit with an air-cooled chiller with a scroll chiller compressor will provide a greater operating range to handle low cooling load conditions. Although this opportunity is not low cost/no cost, operational issues should be greatly improved.

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

ECM7 – Solar Domestic Hot Water Heating

Domestic hot water is used in the bathrooms, the laboratory, and in the break area kitchens of the building. Solar collectors could be mounted on the roof of the building to provide solar heating of domestic hot water. Estimates of solar hot water heating were obtained using the RETScreen (NRC 2010) energy modeling spreadsheets (Appendix A), and the estimated annual energy savings are summarized in Table 1.

ECM8 – Solar Power Generation

Open space on the rooftop area of the building could be used to install photovoltaic panels to generate electricity. The space available is somewhat limited because of the presence of the RTUs. Photovoltaic (PV) panels should not be located in areas where the panels may be shaded. Estimated electrical production for a 70-kilowatt (kW) array was obtained using the online PV Watts calculator (Appendix A), and the estimated annual energy savings are summarized in Table 1. The size of the array is limited by the available roof area, as the minimum electrical demand in the building far exceeds 70 kW.

4.2 Summary of Other Measures Identified but not Evaluated

Exhaust Air Energy Recovery

The laboratory RTU supplies 100% outside air 24 hours a day year round, and this air is subsequently exhausted out the building. Energy in the exhaust air could be recovered by a set of coils — one in the exhaust air stream and one in the RTU supply air stream. In the cooling season, the energy in the cool air leaving the laboratory areas of the building could be recovered and used to pre-cool the supply air for the laboratory. This system must be properly engineered to select coils of the proper material to handle the corrosive chemical vapors that are in the exhaust air stream. This RTU would remain a 100% outside air system; however, energy leaving the exhaust stream would be recovered.

5.0 Potential Greenhouse Gas Reduction

The proposed ECMs will reduce greenhouse gas (GHG) emissions. All reported calculations in Table 2 below are based on the U.S. 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 estimate 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 Greenhouse Gas Reductions for Each Proposed ECM (http://www.epa.gov/rdee/energy-resources/calculator.html)

ECM #	Estimated Electrical Savings (kWH)	Estimated Natural Gas Savings (Therms)	GHG Avoided (Est. Electrical Use Reduction) (metric tons CO2e)	GHG Avoided (Est. Natural Gas Use Reduction) (metric tons CO2e)	Total GHG Avoided (metric tons CO2e)
1	16,300	-	11.41	-	11.41
2	227,500	-	159.25	-	159.25
3	43,500	-	30.45	-	30.45
4	139,500	-	97.65	-	97.65
5	28,000	-	19.60	-	19.60
6					
TOTALS	**454,800**	**0**	**318**	**0**	**318**
Estimated Green House Gas Reductions (Renewable Energy Projects)					
7	11,800	0	8.3	0.0	8.3
8	88,609	0	62.0	0.0	62.0
TOTALS	**100,409**	**0**	**70**	**0**	**70**

One job for every $92,000 in funds expended was assumed to calculate jobs created and retained. The baseline non-interactive energy efficiency retrofits ($82,050) will result in 0.9 job created and 318 metric tons of CO_2e emissions avoided. If the proposed renewable energy projects are implemented, the estimated investment would be $710,107. This amount would result in 7.7 jobs created and 70 metric tons of CO_2e 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:

- Use the audit report findings to immediately implement the no-cost and low-cost ECMs identified.
- Further analyze ECMs with moderate cost or longer simple payback times.
- 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, CBP can request a proposal to implement the measures from the operations contractor.

Replacing the laboratory zone RTU4 with an air-cooled chiller, and installing solar domestic hot water heating or power generation systems are capital projects that require an engineering consultant to begin project development. In addition, the owner of the building will have to agree to installation of the solar systems if incentives or rebates from the state or the utility are used because they involve multi-year operating requirements.

Recommended resources for Springfield laboratory 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

Dominion Power of Virginia and Washington Gas are the serving utilities (electric and gas) for the CBP facilities. Incentives may be available from Dominion via the commercial customer incentive program. All business (non-residential) customers in Dominion's service territory are eligible to participate in a prescriptive rebate program that applies to energy-efficient lighting and HVAC technologies. Customers will receive a financial incentive payment based on the rebate program's itemized lists at the time of application. For example, replacing T-12 lamps with more efficient T-8 lamps will result in a $6.00/fixture rebate incentive. Similarly, installing a new, energy efficient air-cooled chiller (1.008 kW/ton) yields incentive funds of $17/ton. The rebate program is available until fully subscribed, and rebate amounts are subject to regulatory modifications without notice. Additionally, an application and coordination with the utility for an inspection is required before these systems can be installed. Projects must be completed before rebates will be paid.

Unfortunately, renewable energy incentives have limited options in the State of Virginia relative to other neighboring state's grant, utility, and tax incentive programs. Currently, neither the State of Virginia nor Dominion Power offers any direct incentives for renewable technologies such as photovoltaic (PV), solar thermal hot water, wind power, or daylighting; however, there is a possibility of case-by-case incentives for these technologies. Projects containing bundled demand-side management capability and energy savings could be of interest with a local utility company. Thus, a utility energy service contract (UESC) could be pursued to arrange various energy savings initiatives such as efficient lighting and air conditioning and bundled with a renewable initiative such as PV. Incentives for the entire project could be evaluated based on the total planned energy and demand savings.

In addition, Virginia enacted legislation (H.B. 1416) in April 2007 that includes a provision that electricity customers in Virginia have the option to purchase 100% renewable energy from their utility. Dominion Power offers this service; however, customers are also permitted to purchase green power from any licensed retail supplier. For information about the green power utilities and suppliers in Virginia, see the Department of Energy, Energy Efficiency and Renewable Energy Green Power Network website: http://apps3.eere.energy.gov/greenpower/

Federal energy projects can be funded or financed by various means. Energy projects can be funded with operation and maintenance funding if the resulting payback period is acceptable. If no appropriated funding is available, an alternative approach for Federal projects is to pursue financing from a utility (UESC) or energy services company (ESCO) via an energy savings performance contract (ESPC). Both UESC and EPSC contract methods enable a customer to finance the construction costs of the project with the savings that will take place after installation. For more information on these programs, please visit the FEMP, Department of Energy website: http://www1.eere.energy.gov/femp/

7.0 Assessment Team Members and Site Team

The Redhorse ARRA assessment team for the audit included Jim Arends, PE, CEM, Energy Audit Team Technical Lead; Mike Savena, PE, Energy Audit Team Member; and Hani Geeso, CEM, Energy Audit Team Member. Site support was provided by Charlie Watts, CBP Operations and Maintenance; Vim Kumar, CBP Data Center Infrastructure Management; and Dr. Patricia Harrington, CBP Conservation & Energy. Additional interviews were conducted with Walter H. Horn, AMDEX Corporation Environmental Support Supervisor; and Luis Salazar, Boston Properties, Lead Engineer Property Management (contract operators). William Sandusky, PNNL Program Manager, provided technical review of the report.

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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.

Department of Energy (DOE). 2004. *Federal Technology Alert: Demand Controlled Ventilation Using CO2 Sensors*. DOE/EE-0293. Washington, DC. Can be accessed at: http:/www1.eere.energy.gov/femp/pdfs/fta_co2.pdf.

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APPENDIX A

Model Output Files

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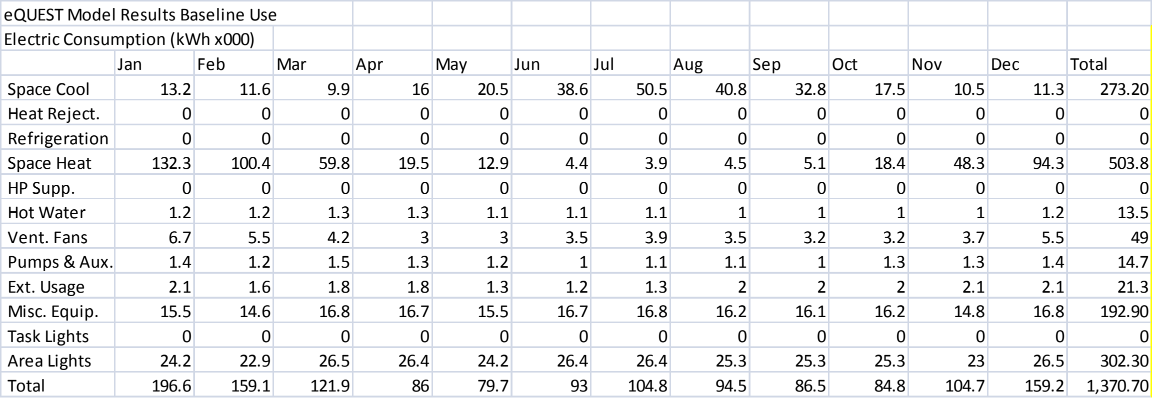
Appendix A – Model Output Files

Energy modeling developed for the annual energy savings estimates were developed in eQUEST version 3.63b. The schematic design model was used to develop the building footprint and input basic building systems. Basic model inputs include: 24 hours a day operation for 7 days a week, VAV RTU AHUs with DX cooling and electric resistance heating, T-8 and compact fluorescent lighting.

Baseline eQUEST Model Results

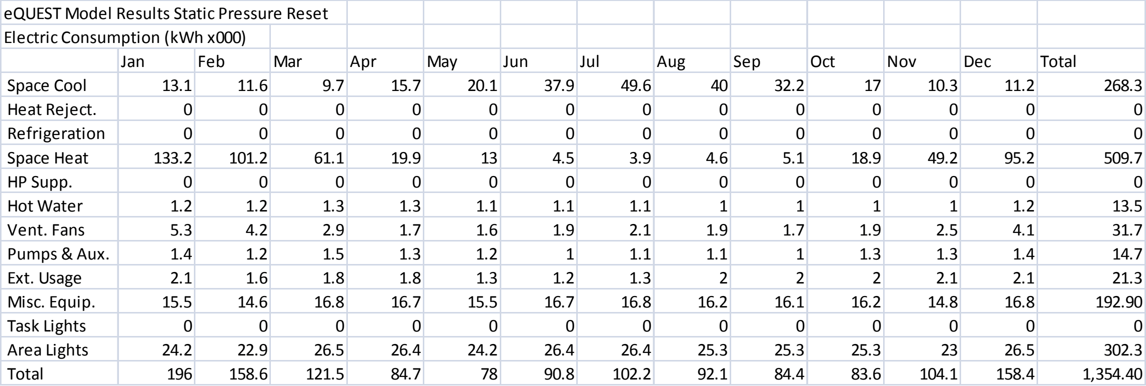


eQUEST Model Results Baseline Use

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13.2	11.6	9.9	16	20.5	38.6	50.5	40.8	32.8	17.5	10.5	11.3	273.20
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	132.3	100.4	59.8	19.5	12.9	4.4	3.9	4.5	5.1	18.4	48.3	94.3	503.8
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	1.2	1.2	1.3	1.3	1.1	1.1	1.1	1	1	1	1	1.2	13.5
Vent. Fans	6.7	5.5	4.2	3	3	3.5	3.9	3.5	3.2	3.2	3.7	5.5	49
Pumps & Aux.	1.4	1.2	1.5	1.3	1.2	1	1.1	1.1	1	1.3	1.3	1.4	14.7
Ext. Usage	2.1	1.6	1.8	1.8	1.3	1.2	1.3	2	2	2	2.1	2.1	21.3
Misc. Equip.	15.5	14.6	16.8	16.7	15.5	16.7	16.8	16.2	16.1	16.2	14.8	16.8	192.90
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	24.2	22.9	26.5	26.4	24.2	26.4	26.4	25.3	25.3	25.3	23	26.5	302.30
Total	196.6	159.1	121.9	86	79.7	93	104.8	94.5	86.5	84.8	104.7	159.2	1,370.70

Static Pressure Reset Model Results



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	13.1	11.6	9.7	15.7	20.1	37.9	49.6	40	32.2	17	10.3	11.2	268.3
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	133.2	101.2	61.1	19.9	13	4.5	3.9	4.6	5.1	18.9	49.2	95.2	509.7
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	1.2	1.2	1.3	1.3	1.1	1.1	1.1	1	1	1	1	1.2	13.5
Vent. Fans	5.3	4.2	2.9	1.7	1.6	1.9	2.1	1.9	1.7	1.9	2.5	4.1	31.7
Pumps & Aux.	1.4	1.2	1.5	1.3	1.2	1	1.1	1.1	1	1.3	1.3	1.4	14.7
Ext. Usage	2.1	1.6	1.8	1.8	1.3	1.2	1.3	2	2	2	2.1	2.1	21.3
Misc. Equip.	15.5	14.6	16.8	16.7	15.5	16.7	16.8	16.2	16.1	16.2	14.8	16.8	192.90
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	24.2	22.9	26.5	26.4	24.2	26.4	26.4	25.3	25.3	25.3	23	26.5	302.3
Total	196	158.6	121.5	84.7	78	90.8	102.2	92.1	84.4	83.6	104.1	158.4	1,354.40

Demand Control Ventilation CO_2 Model Results

eQUEST Model Results DCV CO2													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	15.6	14	8.2	14.6	19.8	36.9	47	38.6	31.5	16.3	9.2	11.8	263.7
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	128.4	101.2	49.5	13.4	10.6	4.4	3.9	4.5	5	15.7	42	89.4	468
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	1.2	1.2	1.3	1.3	1.1	1.1	1.1	1	1	1	1	1.2	13.5
Vent. Fans	6.9	5.7	4.2	3	3	3.7	4.1	3.8	3.4	3.2	3.7	5.6	50.3
Pumps & Aux.	1.5	1.3	1.6	1.3	1.2	1	1.1	1.1	1	1.3	1.4	1.5	15.2
Ext. Usage	2.1	1.6	1.8	1.8	1.3	1.2	1.3	2	2	2	2.1	2.1	21.3
Misc. Equip.	15.5	14.6	16.8	16.7	15.5	16.7	16.8	16.2	16.1	16.2	14.8	16.8	192.90
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	24.2	22.9	26.5	26.4	24.2	26.4	26.4	25.3	25.3	25.3	23	26.5	302.3
Total	195.5	162.6	109.9	78.5	76.7	91.5	101.6	92.5	85.3	81	97.2	155	1,327.20

Night Setback of Temperatures Model Results

eQUEST Model Results Night Setback													
Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	6.9	7.1	7.7	15.2	19.7	36.9	46.9	37.9	31.3	16.6	8.7	7.3	242.2
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	99.9	77	48.5	16.1	11.4	4.4	3.9	4.5	5.1	16.4	38.8	73.2	399.3
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	1.2	1.2	1.3	1.3	1.1	1.1	1.1	1	1	1	1	1.2	13.5
Vent. Fans	5.6	4.6	3.7	2.9	2.8	3.3	3.7	3.4	3.1	3	3.3	4.7	44
Pumps & Aux	1.7	1.5	1.6	1.3	1.2	1	1.1	1.1	1	1.3	1.4	1.6	15.7
Ext. Usage	2.1	1.6	1.8	1.8	1.3	1.2	1.3	2	2	2	2.1	2.1	21.3
Misc. Equip.	15.5	14.6	16.8	16.7	15.5	16.7	16.8	16.2	16.1	16.2	14.8	16.8	192.90
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	24.2	22.9	26.5	26.4	24.2	26.4	26.4	25.3	25.3	25.3	23	26.5	302.3
Total	157.1	130.5	107.9	81.7	77.2	91.1	101.1	91.4	84.8	81.9	93.1	133.4	1,231.20

Supply Air Temperature Reset Model Results

eQUEST Model Results Supply Air Reset												
Electric Consumption (kWh x000)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	1.6	2	2.6	11.1	16.4	37	48.9	38.1	29.4	11.5	2.8	1.8	203.3
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	97.4	73.5	38.7	9.1	5.7	0.5	0.1	0.5	0.9	11.1	31.1	67.2	335.9
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	1.2	1.2	1.3	1.3	1.1	1.1	1.1	1	1	1	1	1.2	13.5
Vent. Fans	6.2	5.2	4.2	3.8	4	5.3	5.9	5.4	4.8	4	3.8	5.3	57.7
Pumps & Aux.	1.8	1.5	1.7	1.3	1.2	1	1.1	1.1	1	1.3	1.5	1.8	16.2
Ext. Usage	2.1	1.6	1.8	1.8	1.3	1.2	1.3	2	2	2	2.1	2.1	21.3
Misc. Equip.	15.5	14.6	16.8	16.7	15.5	16.7	16.8	16.2	16.1	16.2	14.8	16.8	192.90
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	24.2	22.9	26.5	26.4	24.2	26.4	26.4	25.3	25.3	25.3	23	26.5	302.3
Total	150	122.6	93.6	71.4	69.5	89.3	101.5	89.6	80.5	72.5	80	122.7	1,143.20

Laboratory RTU4 Chiller Replacement Model Results

eQUEST Model Results LAB Chiller Replacement												
Electric Consumption (kWh x000)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	13	11.4	9.6	15.2	19.1	35.8	46.1	37.3	30.2	16.3	10	11.1	255.1
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	132.3	100.4	59.8	19.5	12.9	4.4	3.9	4.5	5.1	18.4	48.3	94.3	503.8
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Hot Water	1.2	1.2	1.3	1.3	1.1	1.1	1.1	1	1	1	1	1.2	13.5
Vent. Fans	6.7	5.5	4.2	3	3	3.5	3.9	3.5	3.2	3.2	3.7	5.5	49
Pumps & Aux	1.6	1.4	1.7	1.5	1.4	1.2	1.3	1.3	1.2	1.5	1.5	1.6	17.3
Ext. Usage	2.1	1.6	1.8	1.8	1.3	1.2	1.3	2	2	2	2.1	2.1	21.3
Misc. Equip.	15.5	14.6	16.8	16.7	15.5	16.7	16.8	16.2	16.1	16.2	14.8	16.8	192.90
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	24.2	22.9	26.5	26.4	24.2	26.4	26.4	25.3	25.3	25.3	23	26.5	302.3
Total	196.7	159	121.8	85.4	78.4	90.4	100.7	91.1	84.1	83.8	104.4	159.2	1,355.10

Solar Domestic Hot Water Model Results

RETScreen Tool		www.retscreen.net		
Technology		**Solar water heater**		
Load characteristics	**Unit**	**Base case**	**Proposed case**	
Load type		Office		
Number of units	Person	432		
Occupancy rate	%	80%		
Daily hot water use - estimated	gal/d	347		
Daily hot water use	gal/d	320	320	
Temperature	°F	130	130	
Operating days per week	d	5	5	
Supply temperature method		Formula		
Water temperature - minimum	°F	49.9	Springfield City Water	
Water temperature - maximum	°F	64.4	Springfield City Water	
Heating	million Btu	50.6	50.6	
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	ft^2	10.37		
Aperture area per solar collector	ft^2	10.37		
Fr (tau alpha) coefficient		0.87		
Wind correction for Fr (tau alpha)	s/ft			
Fr UL coefficient	(Btu/h)/ft^2/°	3.75		
Wind correction for Fr UL	(Btu/ft^3)/°F			
Number of collectors		39		
Solar collector area	ft^2	404.26		
Solar collector cost	$	$ 10,107		
Capacity	kW	26.29		
Miscellaneous losses	%	0.0%		
Balance of system & miscellaneous				
Storage		Yes		
Storage capacity / solar collector area	gal/ft^2	1		
Storage capacity	gal	404.3		
Heat exchanger	yes/no	Yes		
Heat exchanger efficiency	%	60.0%		
Miscellaneous losses	%	10.0%		
Pump power / solar collector area	W/ft^2	0.10		
Summary				
Electricity - pump	MWh	0.1		
Heating delivered	million Btu	40.6		
Solar fraction	%	80%		
Heating system		**Base case**	**Proposed case**	**Proposed Savings**
Fuel type		Electric	Electric	Electric
Seasonal efficiency		100%	100%	
Fuel consumption - annual	MWh	14.8	2.9	11.9
Total electrical savings - annual	MWh			11.8

Solar Power Generation Model Results

PV Watts AC Energy & Cost Savings

Station Identification	
City:	Richmond
State:	Virginia
Latitude:	37.50° N
Longitude:	77.33° W
Elevation:	50 m
PV System Specifications	
DC Rating:	70.0 kW
DC to AC Derate Factor:	0.77
AC Rating:	53.9 kW
Array Type:	Fixed Tilt
Array Tilt:	37.5°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	7.5 ¢/kWh

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	3.99	6715	537.20
2	4.37	6549	523.92
3	4.96	8064	645.12
4	5.32	7971	637.68
5	5.49	8403	672.24
6	5.54	7908	632.64
7	5.55	8143	651.44
8	5.31	7920	633.60
9	5.30	7686	614.88
10	4.65	7230	578.40
11	3.95	6208	496.64
12	3.51	5812	464.96
Year	4.83	88609	7088.72

APPENDIX B

Photographs

Appendix B - Photographs

Photo 1. Jim Arends, PE, CEM, Redhorse; Charlie Watts and Dr. Pat Harrington, CBP; and Mike Savena, PE, Redhorse, inspecting RTU4 AC compressor during FEMP energy audit site visit, April 2010.

Photo 2: Jim Arends PE, CEM, Redhorse Corporation, and Charlie Watts, CBP, inspecting rooftop unit during FEMP energy audit site visit, April 2010.

Photo 3: Jim Arends, PE, CEM, Redhorse, reviewing control sequences on building automation system during FEMP energy audit site visit, April 2010.

Photo 4: Hani Geeso, CEM, Mike Savena, PE, and Jim Arends, PE, CEM, Redhorse, reviewing operation and maintenance data during FEMP energy audit site visit, April 2010.

Photo 5: Jim Arends, PE, CEM, Redhorse; Dr. Pat Harrington, CBP; Charlie Watts, CBP; Mike Savena, PE, Redhorse; and Vim Kumar, CBP; inspecting RTUs during FEMP energy audit site visit, April 2010.