Energy Study

DRC 4236 Warren Correctional Institution 5787 State Route 63 Lebanon, Ohio 45036

Prepared For:
Ohio Department of Administrative Services Columbus, Ohio

March 9, 2010 (Revision A – Final)
Ohio DAS Project No. DAS-097108
FTC&H Project No. G090545PS

ftc&h
Fishbeck, Thompson, Carr & Huber
engineers • scientists • architects • constructors

ENERGY STUDY

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LEBANON, OHIO 45036

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11353 Reed Hartman Highway, Suite 500, Cincinnati, OH 45241 Telephone: 513-469-2370

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LIST OF ABBREVIATIONS/ACRONYMS

AEP	Advanced Energy Program
AHU	Air Handling Unit
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
BTU	British Thermal Unit
CBECS	Commercial Buildings Energy Consumption Survey
CCF	One Hundred Cubic Feet
CCTV	Closed Circuit Television
CF	Cubic Feet
CFM	Cubic Feet Per Minute
CFC	Chlorofluorocarbon
CO_2	Carbon Dioxide
DAS	Department of Administrative Services
DDC	Direct Digital Control
DRC	Department of Rehabilitation and Correction
DX	Direct Expansion
ECM	Energy Conservation Measure
EMS	Energy Management System
FTC&H	Fishbeck, Thompson, Carr & Huber, Inc.
HP	Horsepower
HVAC	Heating, Ventilating, and Air Conditioning
kBTU	One Thousand British Thermal Units
kVA	Kilovolt Ampere
kW	Kilowatt
kWh	Kilowatt Hour
MEEA	Midwest Energy Efficiency Alliance
O&M	Operation and Maintenance
sf	Square Feet
USDOE	United States Department of Energy
VAV	Variable Air Volume
VFD	Variable Frequency Drive
VOCs	Volatile Organic Compounds
yr	Year

EXECUTIVE SUMMARY

Fishbeck, Thompson, Carr & Huber, Inc. (FTC&H) completed a technical energy analysis at the Department of Rehabilitation and Correction (DRC) Warren Correctional Institution, located at 5787 State Route 63, Lebanon, Ohio 45036, for the State of Ohio Department of Administrative Services (DAS). The energy analysis requested from the Ohio DAS included ASHRAE Levels 1 and 2 tasks, therefore, the project scope was defined as ASHRAE 1.5. The ASHRAE Level 1.5 audit consists of an analysis of a facility energy use analysis, a walk-through of the facility to visually assess and analyze the mechanical and electrical systems, and development of recommendations to implement that reduce energy usage.

This report includes a facility overview, an analysis of the campus facilities' energy usage, a description of observations made during the audit, and energy conservation measure (ECM) recommendations. Photos are included as Appendix 5 to present a visual description of noted conditions.

The following tables provide current annual energy cost data, and savings on an annual basis if all ECMs are considered. The summary is based on three years of average utility use and cost data and an overall square footage of 270,658.

Table 1 – Executive Summary of Suggested Capital Improvement ECMs (10 years payback or lower)

Agency Code	Facility Name	Current Facility Energy Use Intensity Kbtu/sf	Current Facility Utility Cost $/sf	Suggested ECMs To Be Implemented Now	Total Cost of Suggested ECMs	Total Calculated Savings ($)	Calculated Facility Energy Intensity After Implementation Kbtu/sf	Calculated Facility Utility Cost After Implementation $/sf
DRC 4236	Warren Correctional Facility	243	$3.62	1,3,4,5,7,8,11	$1,501,716	$469,901	132	$1.88

Table 2 – Executive Summary of Suggested Capital Improvement ECMs (all ECMs)

Agency Code	Facility Name	Current Facility Energy Use Intensity Kbtu/sf	Current Facility Utility Cost $/sf	Suggested ECMs To Be Implemented Now	Total Cost of Suggested ECMs	Total Calculated Savings ($)	Calculated Facility Energy Intensity After Implementation Kbtu/sf	Calculated Facility Utility Cost After Implementation $/sf
DRC 4236	Warren Correctional Facility	243	$3.62	1 - 12	$4,379,363	$642,447	91	$1.25

The listed estimated cost for each ECM is based on preliminary information and not on system-specific, engineered, design documents. These costs should be used for understanding ECM "order of magnitude" within the overall list and for general budget purposes only. Costs will need to be updated once system selection and designs are completed.

FACILITY OVERVIEW

1. Audit Location:
   Ohio DRC Warren Correctional Institution
   5787 State Route 63
   Lebanon, Ohio 45036

2. Audit Team:
   a. Mike Abbott, Air Quality Technician – DRC Warren Correctional Institution
   b. Don Huntsberger, Maintenance Superintendent – DRC Warren Correctional Institution
   c. William M. Hurst – FTC&H
   d. Robert H. Langerak – FTC&H

3. Audit Date: October 28 and 29, 2009

4. Facility Information:

The DRC Warren Correctional Institution is a 270,658 square foot (sf) building complex that is comprised of 12 buildings. All of the buildings are conditioned with heating and ventilation and some are partly or completely mechanically cooled. The entire prison complex was constructed in 1986. There have been no additions or additional buildings added since the original construction. However, according to Mr. Abbott and Mr. Huntsberger, a campus-wide interior lighting retrofit occurred in 2001 that provided a calculated energy savings of $35,000. This involved the replacement of T-12 florescent lamps with T-8 lamps and electronic ballasts. Similarly, a campus-wide lighting retrofit of exterior building security light fixtures occurred in 2007 that provided a calculated energy savings of $23,000. Timed switches were installed in mechanical and electrical rooms to automatically turn off lights after a set time.

This report will refer to the following building numbers and names. These names are taken from the drawings given to us for gathering information. Once on site, it was discovered that some buildings had a different numbering label.

Building 1 – Entry	3,567 sf	100% cooled
Building 2 – Administration/Medical/Segregation	24,547 sf	100% cooled
Building 3 – Custody/Visitation	11,413 sf	100% cooled
Building 4 – Reception Housing	16,617 sf	5% cooled
Building 5 – Reception Classification	19,939 sf	30% cooled
Building 6 – Programs and Services	84,412 sf	40% cooled

Building 7 – Recreation and Chapel	18,625 sf		30% cooled
Building 8 – General Housing (4 identical)	20,457 sf	each	5% cooled
Building 9 – Guard House	125 sf		100% cooled

5. Audit Process:

The audit started with an introductory overview of the campus where we discussed the original construction, design intent, utility infrastructure, general maintenance issues, and staffing. We learned that there is a large number of similar heating, ventilating, and air conditioning (HVAC), and electrical systems throughout the various buildings. We reviewed the accuracy of the building information submitted prior to our visit and there was still some energy usage data necessary to obtain. We reviewed the site utility metering system for gas and electric services. Parts of the electric system are shared with the adjacent Lebanon Correctional Facility. Some of the gas and electric utility usage data that we were given provides service to buildings outside the campus enclosure and beyond the scope of this audit.

Our audit process included a building facility staff interview where we reviewed:

a. Building operation data and occupancy schedules.
b. Heating and cooling equipment operation and maintenance concerns.
c. HVAC control system operation.
d. Lighting systems and controls.
e. Comfort problems and complaints.
f. Operation and maintenance (O&M) procedures.
g. Energy management or conservation efforts.

The remainder of the time on site was spent gathering data throughout the various building areas. FTC&H personnel were accompanied by Mr. Abbott.

UTILITY ANALYSIS

The utility analysis was completed with energy data received from the Ohio DAS for the DRC Warren Correctional Institution. The data was compared to the Public Order and Safety Building type in the 2003 Commercial Buildings Energy Consumption Survey (CBECS) compiled by the United States Department of Energy (USDOE), Energy Information Administration. The 1995 database was used for energy utilization index (EUI) comparison, as 1999 and 2003 data was not available for Public Order and Safety Building type.

The following table provides a summary of energy usage and cost data from the past three years.

Table 3 – Utility Data Summary – DRC Warren Correctional Institution

	Electricity				Natural Gas						
	Usage		Cost		Usage		Cost		Total Cost		EUI
Year	(kWh/yr)	(kWh /sf)	($/yr)	($/sf)	(CCF)	(CCF /sf)	($/yr)	($/sf)	($/yr)	($/sf)	(kBTU/ sf/yr)
2006	6,664,076	24.6	$451,209	$1.67	348,962	1.29	$420,173	$1.55	$871,382	3.22	217
2007	7,126,825	26.3	$512,172	$1.89	410,114	1.52	$463,270	$1.71	$975,442	3.60	246
2008	6,960,144	25.7	$507,731	$1.88	468,331	1.73	$584,733	$2.16	$1,092,464	4.04	266
Avg	6,917,015	25.6	$490,371	$1.81	409,136	1.51	$489,392	$1.81	$979,763	3.62	243

Based on 270,658 sf

An EUI allows building energy consumption comparisons to be made between similarly used buildings. Electricity and natural gas usage is converted to BTUs and total annual energy BTUs consumed is divided by gross building square footage. Each building's 3 year average EUI, electricity, and natural gas consumption is calculated and compared to the appropriate USDOE database in Appendices 2, 3, and 4.

The three year average annual energy cost is $979,763. Electricity accounted for 50% of the total cost at $490,371 and natural gas for 50% at $489,392. The average electricity cost was $0.071/kWh. The average natural gas cost was $1.20/CCF.

The DRC Warren Correctional Institution EUI was calculated from the past three years of consumption data and was 243 kBTU/sf/yr. Appendix 2 shows average energy consumption for buildings in different U.S. regions. The average consumption for a Midwest Public Order and Safety building is 99.5 kBTU/sf/yr. The DRC Warren Correctional Institution energy consumption is 144% greater than average.

Appendix 3 shows the 25th, 50th, and 75th percentile and corresponding average electrical consumption. The DRC Warren Correctional Institution uses 25.6 kWh/sf/yr, which corresponds to the 95th percentile. This indicates only 5% of Midwest Public Order and Safety buildings use more electricity than the DRC Warren Institution on a square foot basis.

Appendix 4 shows the 25th, 50th, and 75th percentile and corresponding average natural gas consumption. The DRC Warren Correctional Institution uses 151 CF/sf/yr, which exceed the 100th percentile. This indicates that on a square foot basis, the DRC Warren Correctional Institution uses more natural gas than all other Midwest Public Order and Safety buildings in the USDOE sample database.

The 2003 CBECS data provides average energy consumption for the following end uses. The DRC Warren Correctional Institution Energy Consumption values of the gas and electric usage for this site were determined by comparing summer versus winter utility usage and estimating specific equipment energy usage. These values were then compared to the CBECS data as follows. The data associated with the CBECS as published by the US DOE can be found at http://www.eia.doe.gov/emeu/cbecs/.

Table 4 – CBECS and End Use Energy Consumption Data

End Use	2003 CBECS Data		DRC		
	kBTU/sf	%	kBTU/sf	%	% EBECS Value
Space Heating	49.9	42.8%	75.8	31.8%	152%
Cooling	8.9	7.6%	11.3	4.7%	127%
Ventilation	9.5	8.1%	42.7	17.9%	449%
Water Heating	14.0	12.0%	64.8	27.2%	463%
Lighting	16.5	14.1%	22.7	9.5%	137%
Cooking	4.2	3.6%	14.9	6.3%	355%
Other	13.7	11.8%	6.1	2.6%	44%
Total	116.7	100%	238.3	100%	

The DRC Warren Correctional Institution space heating energy consumption is 1.5 times the average CBECS value. The HVAC ventilation and domestic water heating are 4.5 times the average CBECS value. This high value is reflective of the equipment condition observed during the visit and excessive operation with little or no unoccupied schedule.

The following graphs show the monthly electric and gas usage and cost for the DRC Warren Correctional Institution for the past three years.

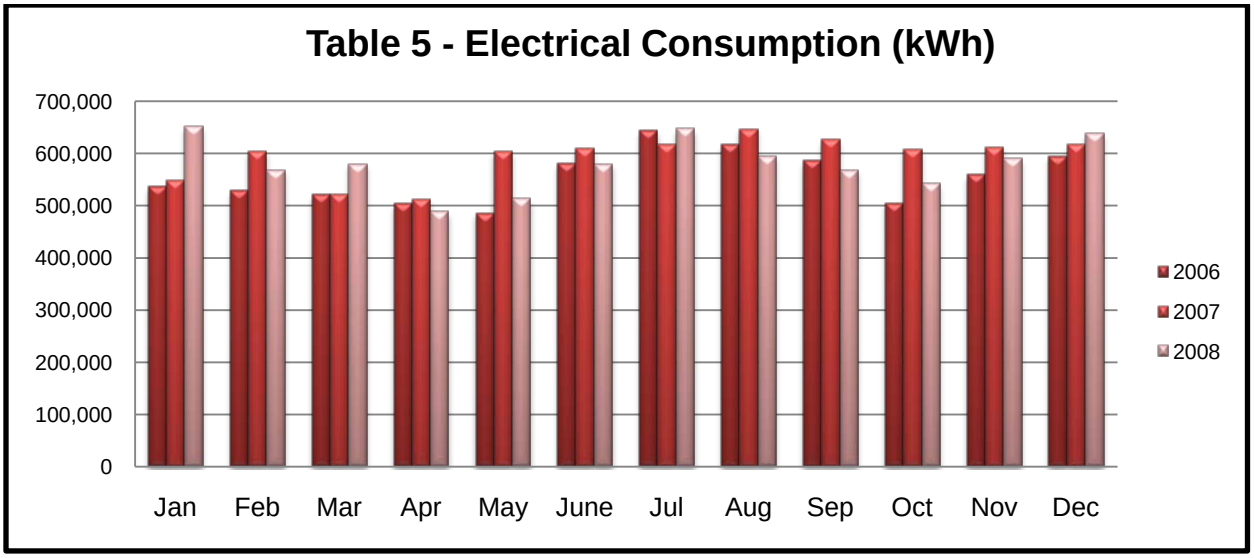
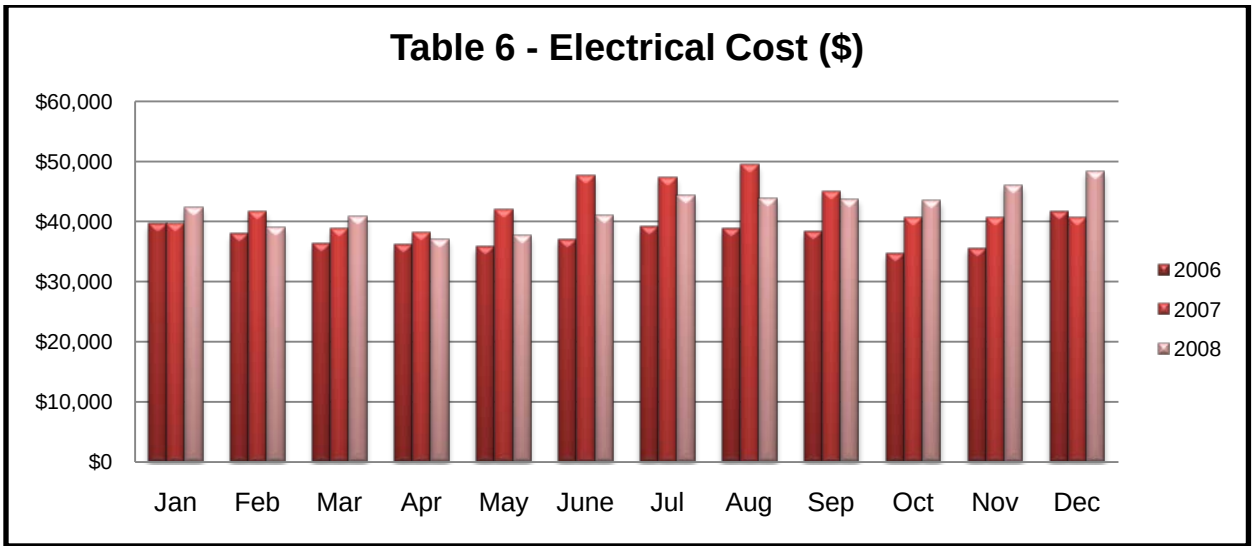
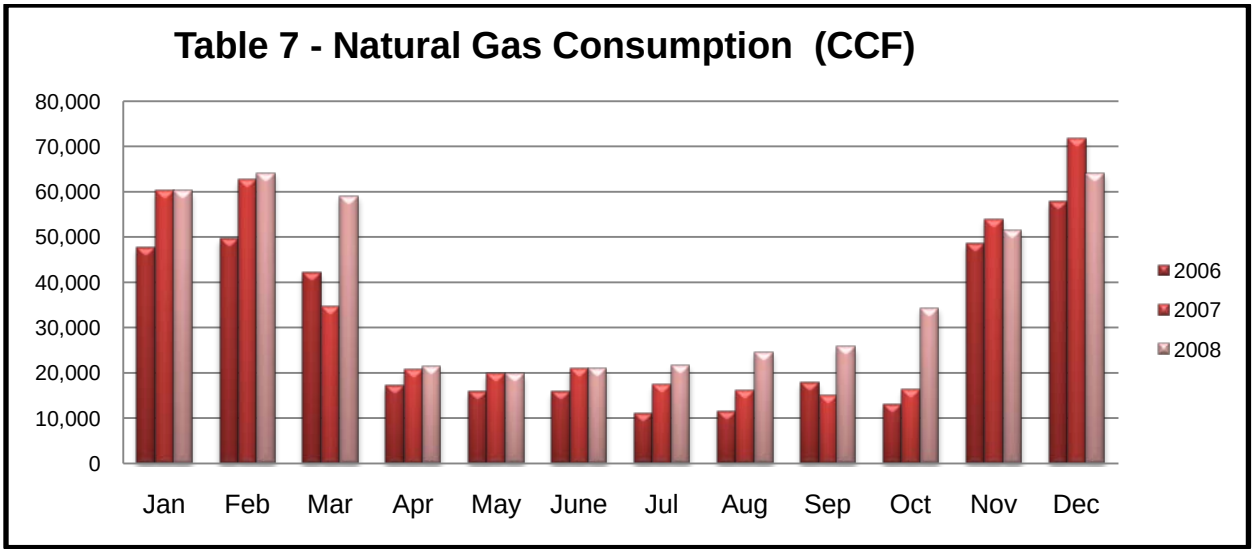


Table 5 indicates the electrical consumption is relatively stable and, as indicated in the preceding tables, the consumption for 2007 and 2008 increased slightly when compared to 2006. Cost and usage reduction is feasible if the recommended ECMs are implemented and preventive maintenance procedures are followed to maintain optimal operation of HVAC equipment and lighting throughout the facilities.

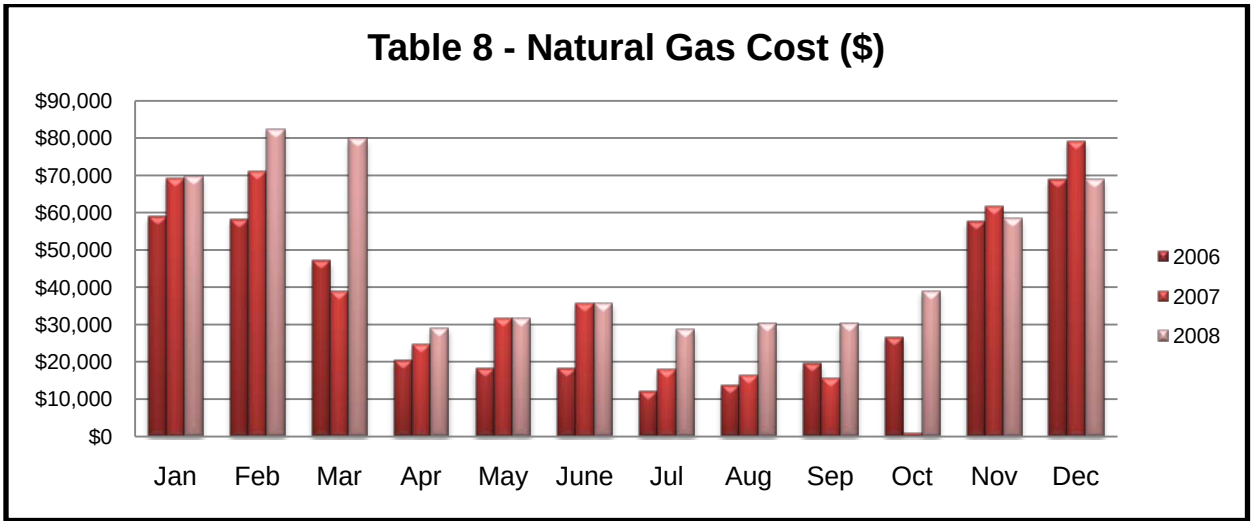


The electrical costs shown in Table 6 are very similar and follow the same pattern as indicated in Table 5. However, the goal with electrical energy usage is to keep usage linear and stable to avoid excessive peak demand and low power factor (level of electrical efficiency) charges. While these are assumed to be additional charges for this facility, this fact could not be verified, given the utility information provided. However, varying monthly costs associated with the past three years of data reviewed, does indicate

probable additional charges. Electric utility invoices should be monitored and recorded for potential cost savings related to peak demand and low power factor charges.



As indicated in the End Use Energy Consumption Data in Table 4, 43% of the energy consumed by Public Order and Safety buildings is used for space heating. This campus consumes an estimated 32% for space heating. As shown in Table 7, gas consumption increases during the fall and winter months as heating demands increase. The heating equipment within these facilities is at or near the end of its useful life and is operating inefficiently. Upgrading heating controls and equipment throughout the campus will provide greater operating efficiency and reduce gas consumption.



As shown in Table 8, the gas cost matches the usage. Considering the usage and cost patterns for natural gas, utility bills should be looked at closely and current rate schedules analyzed for any surcharges or capacity charges. Understanding the natural gas utility bill may help reduce monthly natural gas costs and help influence future natural gas purchase decisions.

GENERAL OBSERVATIONS

The walk-through analysis took us into most areas of every building. A special focus was placed on the mechanical and electrical equipment rooms, including roof areas. The following general and building specific observations will be used to support the various recommendations.

1. There has been very little replacement of HVAC equipment or components since originally installed at construction. All equipment, with few exceptions, is 24 years old.

2. There is a common design and system's installation from building to building with little variance. The two exceptions are HVAC systems in Buildings 2 and 6.

3. All HVAC equipment located on the campus has been inadequately maintained. Many equipment items are not operable due to failure. Whether due to lack of money in the maintenance repair budget or lack of staff to perform the repair tasks, the equipment and systems are in very poor operating condition.

4. Light fixtures throughout the facility appear to be in fair condition, but a significant number of lamps are burned out and the maintenance staff indicated that they have not received replacement lamps.

5. Lighting throughout the facility is controlled by standard wall switches with exception to the timed switches in the mechanical and electrical rooms. Mechanical time clocks control perimeter exterior building lighting, compound security lighting, and the lighting control panel relays for inmate rooms.

6. A fiber optic network serves each building on the campus. This is reportedly in use for the security system. This may be able to be used as the infrastructure for an EMS (energy management system) communication network, providing a lower cost to upgrade existing inoperable controls.

BUILDING SPECIFIC OBSERVATIONS

BUILDING 1 – ENTRY

This building's HVAC system consists of an air handler with a packaged cooling system and separate gas-fired duct furnace. The automatic damper operation has been disabled. For the most part, the unit maintains a fixed discharge temperature that varies whether in the heat or cool mode. There is no economizer operation. There are large leaks in the return ductwork. The filters and nearby coils are caked with dirt.

BUILDING 2 – ADMINISTRATION/MEDICAL/SEGREGATION

This set of four buildings has a variety of HVAC systems:

1. The Control Center has an air handler with a packaged electric heat assembly and two condensing units. The unit does not operate effectively. One of the cooling condensing units has failed. The space houses the campus security data hub and is often overheated due to lack of cooling capacity.

2. The Administration Building and Medical Center are both served by a variable air volume (VAV) air handler that provides tempered make-up air to a large number of terminal units. The terminal units are each controlled by thermostats located within the building spaces. There are some areas with reheat coils and others with perimeter finned tube. The mechanical room has a large amount of corroded piping that has rusted due to water leakage. There is missing pipe insulation. The filters within this area's air handler are very dirty and the fresh air inlet damper assembly is caked with dirt. Two special medical cells are supposed to be under negative pressure with respect to their entrance air lock and the adjacent building areas. This pressure difference is difficult to ensure given the inadequate ventilation provided by the associated AHU. The VAV operation of this AHU does not function. There is no control of the air volume being supplied to the boxes. The designed operating cost savings of VAV are not able to occur. Ventilation for the building is not adequate.

3. The Segregation Building has a separate multi-zone air handler. Four out of its ten control dampers and pneumatic branch lines are disconnected and inoperable. The piping serving the unit appears rusted and is missing or has damaged insulation. (Refer to Appendix 5, Photos 5, 6, and 7.)

4. A hot water boiler and roof-mounted air cooled chiller serve Building 2. The boiler has a maximum 80% efficiency. The chiller is approximately 2 years old and has the ability to be capacity-staged for efficient operation.

5. The two domestic gas hot water heating boilers serving Building 2 each have a nameplate 79% efficiency. They are coupled with a 500 gallon storage tank, circulating pump, and water softener system. This domestic water system is similar to what is found in most of the other buildings on campus. There is a large amount of labor and expense related to maintaining the water softener systems. Most tanks were low or empty of salt.

BUILDING 3 – CUSTODY/VISITATION

This building has two separate mechanical rooms, each with an air handler and packaged cooling unit. A separate gas-fired boiler serves both HVAC systems.

1. One of the air handlers has a leaking hot water coil that needs repair or replacement.

2. There was dirt caked on the surface of the building supply air diffusers.

3. The domestic hot water circulating pump is inoperable.

4. A noisy air compressor needs repair.

5. One of the units has a very large hole in the side of its mixing box. It is poorly covered with a piece of louver assembly. There is another open hole in the side of the fresh air inlet duct. (Refer to Appendix 5, Photo 8.)

BUILDING 4 – RECEPTION HOUSING

This building has two air handlers with associated gas-fired duct furnace heating units. There are two supply fans for summer building ventilation. A series of exhaust fans are designed to operate in sequence with the supply fans to provide general building exhaust, as well as assist in summer ventilation. A packaged air conditioning cooling unit with electric heat assembly serves the small administrative area. There are two domestic hot water heating boilers with associated pump, tank, and water softener system, similar to other buildings. The following are observed problems:

1. One of the domestic water boilers is not operable due to excessive flame roll-out and a damaged firebox frame assembly.

2. The discharge dampers that control the AHU and supply fan operation are not connected.

3. The supply fan is electrically disconnected from Auto-Summer operation. According to staff, it has not been used for some time to ventilate and cool the building in the summer.

4. The outside air dampers providing ventilation air to the supply fan are wired shut and the controls disconnected.

5. The filter assemblies for all three units are very dirty. There is dirt caked on the mixing box chamber duct insulation liner and dampers. The air conditioning unit has large amounts of dirt on the surface of the finned condenser coil.

BUILDING 5 – RECEPTION/CLASSIFICATION

This building has four air handlers. The inmate living areas are served by two air handlers, each with a gas-fired duct furnace heating unit and associated supply and exhaust fans, for summer building ventilation. The other two air handlers serve administrative office areas. One has a gas-fired duct heater assembly and the other an electric heat coil assembly. These two units also provide cooling through roof-mounted condensing units. As in other buildings, there are two domestic hot water heating boilers with associated pump, tank, and water softener systems. The following are observed problems:

1. One of the two condensing units that serve the majority of the office areas does not operate. It has a failed compressor.

2. Both supply fans serving the inmate living area are electrically disconnected to be off and dampers have been disconnected at both linkage and control points.

3. There are no air filters in the heating/ventilating units.

4. There is caked dirt on the surface of the evaporator coil.

5. By design, the electric heat coil assembly in one of the four AHUs consumes a large amount of energy when called to provide space heating.

BUILDING 6 – PROGRAMS AND SERVICES

This set of five buildings has a variety of HVAC systems.

1. The Cafeteria receives HVAC air by way of a large multi-zone air handler, with hot and chilled water coils. This unit has water ponding on the top due to a roof leak above.

2. The Kitchen receives heat and ventilation air from a dedicated AHU with a hot water heating coil. The Kitchen has a variety of makeup air and exhaust systems serving various areas.

3. The Maintenance Office area is served by an AHU with a hot water heating coil and a separate associated direct expansion (DX) cooling coil piped to a roof-mounted condensing unit.

4. The Vocational Building is served by an AHU with a hot water heating coil and a separate associated DX cooling coil piped to a roof-mounted condensing unit.

5. The Commissary receives HVAC air by way of a separate AHU, with hot and chilled water coils. The unit has very dirty filters with dirt caked on its coil surfaces. There was a large build-up of dirt on the surface of the supply air diffusers in the Commissary area.

6. The OPI/Furniture Manufacturing shop and office areas have a separate AHU with a hot water heating coil and DX cooling coil piped to a roof-mounted condensing unit. The general shop area has its own heating/ventilating unit. There are also roof mounted exhaust fans for summer cooling and added ventilation.

The following are observed problems:

1. The building's 80 ton, roof-mounted chiller is inoperable. All of its compressors have failed. The building has had no cooling for over a year.

2. One of the 5 refrigeration condensing units was inoperative at the time of this audit.

3. The roof membrane is detached from the roof edge in many areas. There is a large amount of water entering the building due to this condition. The exposed insulation is getting saturated.

4. There are areas at the roof's edge where the metal coping is detached, exposing parts of the roof parapet wall cavity. Water entering this area will do damage within the wall; especially, if exposed to freezing temperatures in winter.

BUILDING 7 – RECREATION AND CHAPEL

This building's Gymnasium area has a roof-mounted makeup air unit with associated exhaust and relief fans. At the time of the audit, the unit was not operable due to burner control problems. In addition, it was noted that the fans and vents in the gymnasium are very dirty with dirt caked on most surfaces visible from the gymnasium floor area. Other rooms associated with the Gymnasium are served by two separate heating and ventilating units. The Gymnasium office was designed to be served by a through-the-wall self-contained electric heat and cooling unit. It failed and has not been replaced. The Chapel has an air handler with an electric heat assembly and DX cooling coil piped to a roof-mounted condensing unit. By design, the electric heat assembly uses considerable power for space heating.

BUILDING 8 – HOUSING

There are four of these buildings, each identical in size, operation, and mechanical/electrical equipment. Each building has two air handlers with associated gas-fired duct furnace heating units. There are two supply fans for summer building ventilation. A series of exhaust fans are designed to operate in sequence with the supply fans to provide general building exhaust, as well as assist in summer ventilation. A packaged air conditioning cooling unit with its separate gas-fired duct heater serves the small administrative area. Similar to other buildings, there are two domestic hot water heating boilers with associated pump, tank, and water softener systems. The following are observed problems:

1. One of the domestic water boilers is not operable due to a leaking heat exchanger and a damaged firebox frame assembly.

2. The mixing dampers that control the AHU and supply fan operation are physically not connected. (Refer to Appendix 5, Photo 4.)

3. The supply fan is electrically disconnected from Auto-Summer operation. According to staff, it has not been used for some time to summer ventilate and cool the building. (Refer to Appendix 5, Photo 2.)

4. The outside air dampers feeding into the supply fan are wired shut and the controls disconnected.

5. According to staff, the Reliance variable speed controller for the supply and exhaust fans has been inoperable for a prolonged period.

6. The filter assemblies for all three units are very dirty. There is dirt caked on the mixing box chamber duct insulation liner and dampers. The air conditioning unit has large amounts of dirt on the surface of the finned condenser coil. (Refer to Appendix 5, Photo 1.)

7. Many of the inmate rooms have some type of cardboard or paper blocking the supply air inlet diffuser. It was reported that since original occupancy, there has never been an acceptable balance of air flow to the inmate rooms. On the day of our visit, there was a 20°F difference of space temperature between the upper and lower levels of the building. It was reported that most air quality complaints come from the four inmate Housing buildings and that the winter building temperatures are too cold. It was also reported that in winter, there can be a 20°F temperature difference between the floor and the top bunk within a room. The perception of the Facilities Staff is that the building heating/ventilating units are undersized. They have had to reduce the outside air quantities to supply adequate heat.

8. It was reported that many windows are found open throughout the winter to provide cooling and ventilation to some areas, while vigorous efforts are being taken to get the supply air temperature high enough to provide adequate heat in other areas.

BUILDING 9 – GUARD HOUSE

This small structure has a through-the-wall self contained electric heat and cooling unit.

ASSESSMENT OF OPERATION AND MAINTENANCE PRACTICES

ENERGY MANAGEMENT PROCEDURES

The Correctional Facility campus has an EMS (energy management system) that controls the various HVAC systems. It can best be described as a pneumatic control system with some interface of electric components. Buildings 2 and 6 have an addition of a direct digital control (DDC) controller in each of their main control panels to handle the added building control of more equipment and the rooftop chillers. There is no central control of the entire campus or EMS communication among the buildings. Each building stands alone. The following comments regarding the control system's operation are based on observations during the building walk through and the discussions that occurred in the Facility Staff Interview:

1. Most of the automatic temperature controls are now operated manually. Discharge air setpoints for heating and cooling are fixed and adjusted up or down depending on temperatures inside or complaints. There is no reset of these temperatures as the internal space or the outside air temperature varies. The internal space temperatures vary significantly.

2. There is damage due to the presence of moisture throughout the pneumatic control system. It results in device failure by plugging small control ports.

3. Each building's control system is not utilized to operate HVAC equipment according to a building occupancy schedule. The multiple pieces of heating and cooling equipment operate 24/7 continuously, with no setup or setback in temperature setpoint.

4. Most of the buildings have at least one, if not two, large volume supply air fans that originally were controlled, along with roof-mounted exhaust fans, to ventilate and cool the building throughout the year, but especially in the summer. The air volume of these fans varied by operation of a variable speed controller. They were designed with the ability to introduce more ventilation air into the inmate and day rooms during the occupied day and then reduce that amount at night. That function has been made inoperable. In fact, almost all of the large volume supply air and exhaust fan systems have been disconnected at both their control and damper linkage points.

5. Many outside air inlet damper assemblies providing ventilation and cooling air for the general use air handlers and the cooling systems were observed as disconnected and blocked shut. This is a separate system from the supply fans noted in Item 4 above.

6. There is no schedule to reset supply air temperature setpoints depending on time of day, space temperatures, or space occupancy needs. Fixed discharge air temperatures and air volumes are often warmer or cooler than needed. Energy is wasted and space temperatures are not comfortable.

7. There is no schedule to reset water system heating or cooling temperature setpoints depending on outside or inside air temperatures or space occupancy needs. Fixed water temperatures are often warmer or cooler than needed. Energy is wasted and space temperatures are not comfortable.

ENERGY MANAGEMENT RECOMMENDATIONS

1. Provide complete replacement of the building temperature control systems. Replace pneumatic systems with electronic. Provide the ability to control lighting, temperature, on/off operation, and ventilation where it currently has been removed either through disconnect, lack of maintenance, or the system was not originally designed for that ability of control.

2. Provide the ability to monitor the campus-facility HVAC and electrical lighting systems from multiple locations, but primarily supervised from a central location. This provision will allow operating control of systems, provide ability to monitor actual conditions, allow remote response to trouble concerns and allow trend data to be gathered. If possible, use the fiber optic network that is currently serving the campus security system as the communication network for an upgraded EMS.

3. Upgrade to provide local control of timed over-ride at the following locations:
   a. Day Room areas
   b. Classrooms
   c. Gymnasium
   d. Chapel
   e. Cafeteria
   f. Vocational Shops
   g. Administrative Offices in Buildings 2 and 6
   h. Any other large room or zone area with occasional unscheduled usage

   This upgrade will allow schedules to be put in place for off operation at times of no or low occupancy and the reset down or up of temperature setpoints. This will significantly reduce both electric and natural gas consumption. It will allow unscheduled use of the various space types to be reset to an occupied mode by use of the local timed over-ride control in the space. Added supervision or labor to maintain schedule adjustments will be minimal.

4. Rewrite a Sequence of Operation for each unique system.
   a. Among these are:
      1) Inmate and Dayroom areas (a common sequence to several buildings)
      2) Classrooms
      3) Gymnasium
      4) Chapel
      5) Cafeteria
      6) Kitchen
      7) Vocational shops
      8) Administrative Offices
      9) High volume supply air/exhaust air systems
      10) General purpose exhaust air systems
      11) Boilers used for building heating
      12) Boilers used for domestic how water heating
      13) Chillers
      14) Other unique areas or systems not included in the above
   b. This measure will include, but is not limited to the following:
      1) Establish setup and setback control setpoints
      2) Provide for morning warm-up with minimal ventilation
      3) Reset ventilation by monitoring CO_2 levels for many of the above spaces
      4) Reset heating hot water and chilled water loop temperatures based on space and outside air temperatures, and space occupancy.

5. Establish control of the domestic hot water pumps and boilers at all locations. This measure will allow pumps to be turned OFF that currently operate continuously.

6. Establish and communicate a documented campus facility Energy Management Program, which would consist of the following:
   a. Post the policy, its goals, temperature guidelines, and instructions on how to report air quality/HVAC concerns.
   b. Remind building users of the need to turn off lights and other equipment when not in use. Use “stickers” at light switches, etc., to remind occupants of their role in energy conservation at the facility.
   c. Train staff in use of the installed local over-ride controls located at the sensor in each building space.
   d. Reduce plug loads by removing personal appliances and heaters. Consolidate appliance use where possible.
   e. Specify and purchase Energy Star rated appliances.

f. Monitor energy usage for the facility. Track monthly energy consumption and costs. Compare usage with other similar facilities. (i.e., gas btu or electric kWh per square foot)
g. Provide consumption information to the building occupants and create incentives to further reduce usage.

7. Provide EMS operator training. Give a trained system operator the resources needed to monitor and maintain the upgraded EMS. It is important to keep the building operating schedules current and to use trend data to track HVAC system performance. This training should minimize air quality complaints, reduce reactive repairs, and continue an on-going reduction of energy usage.

8. Install an electric meter at the electrical service entrance to the campus to trend and monitor power consumption, demand, power factor, and possible voltage unbalance. This will allow for monthly analysis of usage patterns and may allow the maintenance staff to identify potential energy savings. In addition, this power meter could be hard wired via Ethernet to the fiber optic network on campus, which could allow personnel to remotely review this data for campus billing and usage information.

NO COST AND LOW COST RECOMMENDATIONS

1. Repair the roof membrane and roof edge coping at multiple locations on Building 6. At present, the membrane is pulled loose from the roof edge. There is exposed insulation getting water saturated. The wall cavities are also exposed, allowing water to enter. There are multiple leaks where water is entering the building. This problem will continue to worsen if not addressed. Structural damage is possibly already occurring. Further membrane movement may result in a complete roof replacement. When repairs are made, any identified wet insulation and building materials should be discarded to remove nutrient source for mold. (Refer to Appendix 5, Photos 34 to 41.)

2. Purchase and install low-flow shower heads at all shower locations. This measure will reduce water usage by up to 40% per shower location.

3. Initiate an active Skilled Trades Maintenance training program. Hold training sessions with select inmates to teach HVAC and electrical repair skills. Given training and testing, provide the necessary tools and supervision to enable on-site resources to perform a growing variety of maintenance services – repairs and preventive. If successful, this should provide a better level of maintenance than current resources allow.

4. Initiate an active schedule of regular preventive maintenance. At present, preventive maintenance involving filter changes and lubrication does not occur often enough on most of the HVAC systems. If this cannot be a skilled service provided by trained inmates, then take proposals from local contractors to perform a recommended level of service. In addition, request a reduced, fixed rate of regular time and over time services. Ideally, the same contractor can perform your preventive and routine service, but this is not necessarily a requirement for a successful preventive maintenance program. There are also benefits to having the preventive maintenance contractor be separate from your regular service contractor.

5. Recycle Kitchen waste food oils. This waste product can be sold rather than paying for disposal. It can be recycled for use as a fuel in a variety of fuel burning appliances.

ENERGY CONSERVATION MEASURES

The listed estimated cost for each ECM is based on preliminary information and not on system-specific, engineered, design documents. These costs should be used for understanding ECM “order of magnitude” within the overall list and for general budget purposes only. Costs will need to be updated once system selection and designs are completed.

ECM NO. 1: EMS UPGRADE

Complete the control revisions recommended and described earlier in this report. This recommendation, assuming complete replacement of existing HVAC equipment, will remove all of the existing pneumatic control devices and associated control air systems. A temperature control specification would be written to meet the operating expectations of the proposed HVAC systems. Some control devices may be provided, as indicated in this report, by the HVAC equipment manufacturers. A specification should be written to ensure one control system and consistency of components will be provided for the entire remodeled campus facility.

Estimated Cost:	$475,020
Estimated Savings:	$220,460/year
Simple Payback:	2.15 years

ECM NO. 2: HEATING AND VENTILATING SYSTEM REPLACEMENT

This recommendation replaces the heating and ventilating equipment in every building, including the supply and exhaust air systems and ductwork, heating boilers, and associated pumps. Demolition and removal of the existing systems is included. Test, adjust, and balance of the replaced systems is included. To allow proper sizing, it is recommended to calculate correct heating, cooling, and ventilation loads prior to replacing equipment and duct systems. If downsizing occurs, there is a lower first cost, reduced on-going operating costs, and reduced equipment on/off cycling, which extends equipment life. A specification should be written to meet the equipment and operating expectations of the proposed HVAC systems. It may be appropriate that some air or water systems be variable volume flow, while others constant volume. Consider the use of low temperature heating water systems with condensing boilers to provide an efficient source of heat for both space heating and domestic water heating in each building. Design the systems to correct existing building operating constraints, to improve air temperature and ventilation quality, and be simple to maintain. The intent of this specification would be to provide a consistency of system, major equipment, and components for the entire remodeled campus facility. (Refer to Appendix 5, Photos 1 to 18, 20 to 23, and 25 to 29.)

Estimated Cost:	$3,915,000
Estimated Savings:	$152,111/year
Simple Payback:	26 years (Equipment is nearly at end of its useful life and needs replacement regardless of calculated payback.)

ECM NO. 3: BUILDING 6 CHILLER REPLACEMENT

The existing 80 ton chiller is not operable due to compressor failure. In addition, the refrigerant is not chlorofluorocarbon (CFC) free and is becoming obsolete. The unit is not able to operate as efficiently as similar sized units with newer technology and control. Building cooling load calculations should be determined to allow replacement with a properly sized unit. If downsizing occurs, there is a lower first cost, as well as on-going operating cost. (Refer to Appendix 5, Photos 19 and 24.)

Estimated Cost:	$75,000
Estimated Savings:	$9,190/year
Simple Payback:	8.16 years

ECM NO. 4: DOMESTIC HOT WATER HEATING SYSTEM REPLACEMENT

This recommendation includes the domestic hot water boilers and pump equipment in every building. Demolition and removal of existing systems is included. Further evaluation will need to occur to determine if the existing water storage tanks are properly sized and can be re-used. At a minimum, these tanks should be insulated to reduce surface temperature heat losses. Further evaluation also needs to occur to determine if the water softening systems are properly sized and can be reused. In addition, investigation should occur to learn if newer domestic hot water heating technology can heat the volume of water needed without a storage tank and without the need for softeners. As stated in ECM No. 2, consideration should be given to use low temperature, condensing boilers for both water and space heating. A lower temperature water heating system may allow the complete removal of the existing softener systems. Water usage load calculations should first occur to allow replacement equipment and piping to be properly sized. If downsizing occurs, there is a lower first cost as well as reduced on-going operating costs. A specification should be written to meet the equipment and operating expectations of the proposed system per each building's requirements. The intent of this specification would be to provide a consistency of system, major equipment, and components for the entire remodeled campus facility. (Refer to Appendix 5, Photos 29 to 33.)

Estimated Cost:	$522,000
Estimated Savings:	$76,969/year
Simple Payback:	6.8 years

ECM NO. 5: DHW SOLAR WATER HEATING INSTALLATION

Install a DHW solar water heating system as an add-on to the building domestic water heating system in the inmate housing areas. This recommendation is for the seven building locations where inmates are housed and there is consistent hot water usage for showers. This add-on system will use a heat exchanger and glycol/water mixture as the heat transfer medium.

Estimated Cost:	$82,000
Estimated Savings:	$20,672/year
Simple Payback:	4 years

ECM NO. 6: CCTV INSTALLATION

At present, a very large number of television antennas fasten to the outside of the inmate room windows providing a television signal. The result is hundreds of slightly open windows throughout the winter months, while the heating system is in operation. An installed closed circuit television (CCTV) system would provide the requested television signal with better quality to the inmates without opening windows. The inmate rooms would be warmer and consume less heating energy. The use of individual metal antennas could be disallowed. (Refer to Appendix 5, Photo 42.)

This estimate is based on an installation in all buildings with inmate rooms.

Estimated Cost:	$101,250
Estimated Savings:	$5,114/year
Simple Payback:	20 years

ECM NO. 7: BUILDING COMMISSIONING TO SUPPORT REMODEL PROCESS

The remodeling of existing HVAC and control systems in a campus facility, such as the DRC Warren Correctional Institution, will benefit from the support of commissioning services throughout the construction process. Commissioning services can verify the quality of the proposed specifications, sequences of operation, and bid documents before bidding occurs. Commissioning will also verify the proper installation and operation of the HVAC and electrical systems in an effort to reduce construction mistakes, get best value for the facility, assure proper operation in accordance with specifications, and assure optimal energy performance.

Estimated Cost:	$195,750
Estimated Savings:	$76,226/year
Simple Payback:	2.57 years

ECM NO. 8: AIR HANDLING UNITS VFDS

This ECM provides a VFD controller on all HVAC air handling equipment motors that are 5 HP or larger. This includes supply, return, and exhaust fans, air conditioning unit fans, and heating and ventilation unit fans.

Table 9 – ECM 8 – Install VFDs on HVAC Air Handler Motors

Unit Description	Initial Cost	Controlled Hours of Operation Per Year	kWh/Savings/yr	Annual Cost Savings	Simple Payback (Years)
RF-2-1	$2,430	4,368	13,288	$930	2.61
RF-6-1	$2,230	4,368	5,344	$374	5.96
RF-6-2	$2,430	4,368	13,288	$930	2.61
EF-6-2	$2,430	4,368	13,288	$930	2.61
EF-6-3	$2,430	4,368	13,288	$930	2.61
EF-7-7	$2,230	4,368	10,476	$733	3.04
Ef-7-8	$2,230	4,368	10,476	$733	3.04
SF-4-1	$2,975	4,368	20,967	$1,468	2.03
SF-4-2	$2,375	4,368	5,598	$392	6.06
SF-5-1	$2,375	4,368	5,598	$392	6.06
SF-5-2	$2,500	4,368	9,329	$653	3.83
SF-6-2	$2,375	4,368	5,598	$392	6.06
SF-8X-1	$3,725	4,368	27,988	$1,959	1.90
SF-8X-2	$3,725	4,368	27,988	$1,959	1.90
RF-10-1	$2,430	4,368	13,288	$930	2.61
ACU-2-1	$4,950	4,368	45,166	$3,162	1.57
ACU-2-2	$2,975	4,368	13,077	$915	3.25
ACU-2-3	$2,375	4,368	4,366	$305	7.79
ACU-6-1	$3,725	4,368	32,749	$2,292	1.63
ACU-6-2	$4,950	4,368	40,070	$2,805	1.76
HVU-4-1	$2,975	4,368	16,671	$1,167	2.55
HVU-4-2	$2,500	4,368	11,114	$778	3.21
HVU-5-1	$2,500	4,368	11,114	$778	3.21
HVU-5-2	$2,500	4,368	11,114	$778	3.21
HVU-6-1	$2,975	4,368	19,031	$1,332	2.23
HVU-6-2	$2,500	4,368	11,114	$778	3.21
HVU-7-1	$2,375	4,368	6,286	$440	5.40
HVU-7-2	$2,375	4,368	6,286	$440	5.40
HVU-7-3	$2,975	4,368	19,031	$1,332	2.23
HVU-8X-1	$2,975	4,368	16,671	$1,167	2.55
HVU-8X-2	$2,975	4,368	16,671	$1,167	2.55
HVU-10-1	$2,375	4,368	3,108	$218	10.89
HVU-10-2	$2,375	4,368	4,166	$292	8.13
AHU-10-3	$2,375	4,368	4,166	$292	8.13
AHU-10-4	$2,375	4,368	2,083	$146	16.27
HVU-6-3	$6,900	4,368	59,521	$4,166	1.66
Totals	$103,890	157,248	549,377	$38,455	2.70

ECM NO. 9: HYDRONIC PUMP VFDS

This ECM provides a VFD controller on all HVAC hydronic pump motors that are 5 HP or larger. This includes the primary chilled water pumps in Buildings 2 and 6 and the primary heating water pumps in Building 6. Cost savings for this ECM were calculated on the basis that the current HVAC hydronic pumps could have controlled hours of operation. Currently the equipment runs continuously without adequate controls. The upgrades of ECMs No. 1 and 2 will allow control of this equipment and reduce operating times. Initial costs were calculated using RS Means Electrical Cost Data 2008.

Table 10 – ECM 9 – Install VFDs on HVAC Hydronic Pumps

Unit Description	Initial Cost	Controlled Hours of Operation Per Year	kWh/Savings/yr	Annual Cost Savings	Simple Payback (Years)
CHP-2-1	$1,980	1,680	2,387	$167	11.86
CHP-2-2	$1,980	1,680	2,387	$167	11.86
CHP-6-1	$1,980	1,680	2,387	$167	11.86
CHP-6-2	$1,980	1,680	2,387	$167	11.86
HWP-6-1	$1,980	1,680	2,387	$167	11.86
HWP-6-2	$1,980	1,680	2,387	$167	11.86
Totals	$11,880	10,080	14,322	$1,002	11.86

ECM NO. 10: METAL HALIDE WALL PACK FIXTURE REPLACEMENT

Existing metal halide wall packs are 100 watt fixtures, which have an input wattage of approximately 125 watts. The proposed twin tube compact fluorescent wall pack fixtures have an input wattage of approximately 38 watts. A total count of 78 building wall packs was used for this ECM.

Estimated Cost: $26,598
Estimated Savings: $2,251/year
Simple Payback: 11.82 years

ECM NO. 11: LIGHT FIXTURES IN INMATE CELL AREAS RETROFIT

Retrofit 1-foot x 4-foot fluorescent three lamp light fixtures within cell inmate areas to two lamp fixtures. According to maintenance personnel, the current fixtures are three lamp fixtures, but because of a short supply of lamps, they are only running one lamp within these fixtures. Reducing the number of lamps would improve the efficiency, which is indicated in the savings, and also reduce maintenance cost. A total count of 1,256 fixtures was used for this ECM.

Estimated Cost:	$141,049
Estimated Savings:	$12,708/year
Simple Payback:	11.10 years

ECM NO. 12: METAL HALIDE LIGHT FIXTURES REPLACEMENT

This ECM was based on 10 operating hours per day within the OPI area. 320 watt metal halide light fixtures within the OPI area should be replaced with high-bay 6 lamp fluorescent fixtures. The maintenance personnel indicated that the entire roof on Building 6 is being replaced in the near future. That would allow installation of skylights within this space, which, when combined with dimmable fluorescent fixtures, could save an additional 35% in energy cost and reduce maintenance cost. This is based on a lighting study conducted by the Midwest Energy Efficiency Alliance (MEEA).

Estimated Cost:	$36,016
Estimated Savings:	$3,831/year
Simple Payback:	9.40 years

ADDITIONAL CONSIDERATIONS

SUSTAINABLE AND ENERGY EFFICIENT CLEANING MEASURES

1. Implement a building cleaning program that utilizes products and procedures promoting minimal waste and that are less harmful to the building atmosphere and occupants. It is recommended to use:
   a. Products of greater concentration, thus requiring less volume of purchase, less packaging waste, and lower unit of use cost.
   b. Products with lower concentration of volatile organic compounds and other materials. This would promote user health and improved building air quality.
   c. Cleaning equipment that utilizes internal filtration to minimize re-introduction of air contaminants.

2. Provide walk-off mats at entrance areas to minimize the introduction of dirt into the building by catching it before it can get airborne and contaminate other building parts. This dirt affects air quality, the air filtration system, and does damage to carpet and other surfaces.

3. Establish a daytime cleaning routine which will reduce energy use by not having to utilize the lights and HVAC systems.

Appendix 1

Summary Table of Energy Conservation Measures

Energy Conservation Measure (ECM) Summary (all possible ECM's payback up to 20 years)

Facility Name DRC 4236 Warren Correctional Institution
Address 5787 State Route 63, Lebanon, Ohio 45036
Building Name All

ECM No.	ECM Description	Implementation Cost	Calculated KWH Reduction	Calculated KW Reduction	Calculated Elec. Savings	Calculated CCF gas Reduction	Calculated Gas Cost Savings	Calculated Water CCF	Calculated Water Cost Savings	Calculated Total Savings	Simple Payback
1	EMS upgrade	$475,020	2,144,274	24,478	$156,532	51,142	$63,928			$220,460	2.15
2	HVAC system replacement	$3,915,000	857,710	9,791	$62,612	71,600	$89,500			$152,112	25.74
3	Chiller replacement	$75,000	125,889	35,927	$9,190					$9,190	8.16
4	Domestic HW system replacment	$522,000				61,575	$76,969			$76,969	6.78
5	DHW solar water heating	$82,000				16,538	$20,672			$20,672	3.97
6	CCTV	$101,250				4,091	$5,114			$5,114	19.80
7	Commissioning services	$195,750	518,776	59,221	$37,870	30,685	$38,356			$76,226	2.57
8	Install VFDs on HVAC air handler motors	$103,890	549,377		$38,455					$38,455	2.70
9	Install VFDs on HVAC hydronic pumps	$11,880	14,322		$1,002					$1,002	11.86
10	Replace Wall Packs	$26,598	32159	6,786	$2,251					$2,251	11.82
11	Retrofit Light Fixtures	$141,049	181,542	45,216	$12,708					$12,708	11.10
12	Replace OPI Fixtures	$36,016	54728	14,994	$3,831					$3,831	9.40
Totals		$5,685,453	4,478,777	196,413	$324,451	235,631	$294,539	0	0	$618,990	9.19

Appendix 2

Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels, 1995

Table 5. Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels, 1995

Building Characteristics	Sum of Major Fuel Consumption (trillion Btu)				Total Floorspace of Buildings (million square feet)				Energy Intensity for Sum of Major Fuels (thousand Btu/sq. ft.)				RSE Row Factor
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	
RSE Column Factor:	1.1	1.1	1.0	1.4	1.0	0.8	0.8	1.0	1.0	0.9	0.8	1.2	
All Buildings	1,035	1,497	1,684	1,106	11,883	14,322	20,830	11,736	87.1	104.5	80.8	94.2	7.61
Building Floorspace (square feet)													
1,001 to 5,000	125	189	251	143	995	1,772	2,428	1,144	125.9	106.7	103.4	124.9	13.15
5,001 to 10,000	82	161	185	196	1,223	1,678	2,786	1,842	66.6	96.1	66.3	106.5	21.55
10,001 to 25,000	140	233	315	136	2,118	2,701	4,481	2,317	66.0	86.2	70.3	58.8	15.98
25,001 to 50,000	123	169	189	149	1,380	1,726	2,664	1,905	89.3	98.0	70.8	78.1	11.30
50,001 to 100,000	113	199	213	173	1,371	1,920	2,980	1,697	82.7	103.5	71.6	101.9	12.57
100,001 to 200,000	134	205	254	95	1,377	1,896	2,428	1,075	97.2	108.0	104.5	88.2	17.20
200,001 to 500,000	155	179	156	147	1,389	1,520	1,679	965	111.3	117.8	92.7	152.4	15.75
Over 500,000	164	162	122	67	2,029	1,110	1,384	791	80.7	145.9	88.0	84.4	20.94
Principal Building Activity													
Education	161	173	146	134	1,930	1,997	2,315	1,498	83.4	86.8	62.9	89.3	13.07
Food Sales	Q	Q	56	32	Q	Q	287	209	Q	Q	196.4	151.3	17.06
Food Service	Q	82	133	69	166	474	443	271	Q	172.9	299.9	253.5	26.57
Health Care	113	144	193	110	408	466	916	543	278.4	308.6	211.2	202.6	18.50
Lodging	62	136	147	115	350	909	1,313	1,047	178.0	150.0	111.8	110.2	16.79
Mercantile and Service	173	322	354	123	2,838	3,203	4,864	1,822	61.0	100.7	72.9	67.4	15.91
Office	188	261	304	265	2,154	2,338	3,483	2,503	87.4	111.7	87.4	105.9	12.63
Public Assembly	75	108	118	Q	694	957	1,367	930	108.2	113.3	86.3	Q	19.85
Public Order and Safety	51	30	25	Q	548	300	308	Q	92.6	99.5	81.8	Q	32.29
Religious Worship	19	33	24	28	442	633	1,006	711	42.7	52.1	24.0	39.8	21.56
Warehouse and Storage	68	105	113	38	1,480	2,044	3,436	1,522	46.0	51.3	33.0	25.2	19.81
Other	Q	Q	57	Q	Q	402	289	Q	Q	145.7	197.8	Q	35.58
Vacant	7	Q	12	11	627	531	804	422	Q	Q	15.1	25.9	32.87
Year Constructed													
1919 or Before	79	135	32	46	1,226	1,529	514	404	64.1	88.2	62.1	114.6	26.35
1920 to 1945	129	201	111	67	1,794	2,314	1,709	893	71.9	87.0	64.8	75.3	18.32
1946 to 1959	192	267	197	171	1,944	2,268	3,192	1,894	98.7	117.6	61.6	90.3	15.40
1960 to 1969	199	265	336	224	2,344	2,356	3,856	2,302	84.8	112.5	87.1	97.4	12.11
1970 to 1979	189	266	410	260	1,658	2,435	4,344	2,895	114.0	109.4	94.4	89.7	12.95
1980 to 1989	157	265	397	241	2,128	2,324	5,371	2,429	73.6	113.9	73.9	99.3	15.34
1990 to 1992	51	53	129	63	443	545	1,094	509	116.1	97.6	118.2	123.6	23.27
1993 to 1995	40	45	72	33	347	552	750	410	115.3	81.1	96.0	80.6	26.86
Floors													
One	224	461	756	405	3,337	5,298	11,019	4,897	67.1	86.9	68.7	82.7	12.68
Two	211	315	363	233	2,738	3,537	4,788	3,059	77.0	89.0	75.8	76.2	12.40
Three	168	241	134	132	2,103	2,306	1,644	1,282	80.0	104.3	81.4	103.0	14.77
Four to Nine	284	381	302	262	2,347	2,461	2,165	1,816	121.1	154.6	139.3	144.5	14.52
Ten or More	148	100	129	73	1,359	720	1,214	682	109.0	139.3	106.3	107.3	18.50
Climate Zone: 45-Year Average													
Fewer than 2,000 CDD and --													
More than 7,000 HDD	87	357	Q	54	1,094	3,598	Q	406	79.7	99.3	Q	Q	17.65
5,500-7,000 HDD	472	835	Q	284	4,956	7,615	Q	2,026	95.3	109.6	Q	140.3	15.37
4,000-5,499 HDD	476	304	435	192	5,833	3,109	4,342	1,872	81.6	97.9	100.1	102.4	16.88
Fewer than 4,000 HDD	Q	Q	635	443	Q	Q	7,778	5,713	Q	Q	81.6	77.6	10.66
More than 2,000 CDD and --													
Fewer than 4,000 HDD	Q	Q	614	132	Q	Q	8,711	1,719	Q	Q	70.5	76.8	17.05
Workers (main shift)													
Fewer than 5	128	204	248	209	2,430	3,584	5,345	2,526	52.7	56.9	46.4	82.8	15.34
5 to 9	61	207	138	102	1,057	1,764	2,082	1,387	57.9	117.5	66.1	73.7	18.15
10 to 19	109	148	252	105	1,317	1,511	2,701	1,572	82.8	97.9	93.4	66.7	18.26
20 to 49	181	247	286	154	1,807	2,390	3,212	1,723	100.4	103.3	88.9	89.7	12.62
50 to 99	101	176	209	144	1,264	1,504	2,733	1,430	80.0	116.7	76.4	101.0	13.12
100 to 249	138	193	182	136	1,429	1,579	1,755	1,224	96.9	121.9	103.5	111.0	14.30
250 or More	316	323	369	254	2,577	1,990	3,001	1,875	122.6	162.2	123.1	135.7	14.70

See footnotes at end of table.

Appendix 3

Electricity Consumption and Expenditure Intensities for Non-Mall Buildings, 2003

Table C14. Electricity Consumption and Expenditure Intensities for Non-Mall Buildings, 2003

	Electricity Consumption						Electricity Expenditures		
				Distribution of Building-Level Intensities (kWh/square foot)					
	per Building (thousand kWh)	per Square Foot (kWh)	per Worker (thousand kWh)	25th Per-centile	Median	75th Per-centile	per Building (thousand dollars)	per Square Foot (dollars)	per kWh (dollars)
All Buildings*	202	14.1	12.2	3.6	8.2	17.1	15.7	1.09	0.078
Building Floorspace (Square Feet)									
1,001 to 5,000	47	17.8	11.4	3.8	8.9	20.3	4.3	1.63	0.092
5,001 to 10,000	92	12.4	10.3	3.8	7.4	14.5	8.7	1.18	0.095
10,001 to 25,000	164	10.5	11.1	2.9	6.3	13.4	13.8	0.88	0.084
25,001 to 50,000	439	12.2	11.6	3.8	8.8	16.2	33.6	0.94	0.077
50,001 to 100,000	927	13.1	14.1	4.5	9.9	17.0	68.0	0.97	0.073
100,001 to 200,000	2,181	15.7	12.2	5.3	13.0	23.4	146.4	1.05	0.067
200,001 to 500,000	4,347	15.0	15.4	5.8	12.1	20.7	301.0	1.04	0.069
Over 500,000	17,034	19.0	12.8	10.0	16.6	25.2	1209.8	1.35	0.071
Principal Building Activity									
Education	283	11.0	8.7	4.9	8.9	13.6	21.1	0.82	0.075
Food Sales	276	49.4	43.0	33.4	48.0	77.0	20.9	3.74	0.076
Food Service	213	38.4	20.3	18.8	37.4	70.3	17.4	3.13	0.082
Health Care	564	22.9	11.5	6.1	12.0	18.4	37.9	1.54	0.067
Inpatient	6,628	27.5	14.1	21.8	24.0	35.6	405.3	1.68	0.061
Outpatient	168	16.1	7.8	5.8	11.3	16.5	13.9	1.34	0.083
Lodging	483	13.5	28.0	6.7	11.9	17.7	37.1	1.04	0.077
Retail (Other Than Mall)	139	14.3	17.8	4.3	9.4	18.4	11.6	1.19	0.083
Office	256	17.3	7.5	6.5	11.5	17.6	20.7	1.40	0.081
Public Assembly	179	12.5	20.5	2.2	5.1	11.3	14.4	1.00	0.080
Public Order and Safety	237	15.3	12.4	4.0	7.9	17.6	17.2	1.12	0.073
Religious Worship	49	4.9	10.7	1.9	3.3	6.0	4.4	0.43	0.089
Service	73	11.0	12.0	3.0	6.3	11.8	5.8	0.88	0.080
Warehouse and Storage	154	7.6	16.7	1.4	3.1	6.2	10.8	0.53	0.070
Other	510	22.5	21.4	3.5	7.2	20.3	40.0	1.76	0.078
Vacant	42	2.4	Q	0.4	1.7	3.8	3.9	0.22	0.092
Year Constructed									
Before 1920	83	7.1	8.7	1.6	3.9	9.6	7.3	0.62	0.088
1920 to 1945	122	9.2	9.9	3.2	6.9	13.9	10.3	0.78	0.084
1946 to 1959	125	9.9	10.2	3.1	6.4	14.3	10.6	0.84	0.085
1960 to 1969	168	11.9	11.0	3.4	7.4	14.7	13.5	0.96	0.080
1970 to 1979	239	15.9	13.3	4.4	9.5	21.4	18.1	1.20	0.075
1980 to 1989	275	18.1	12.2	4.8	10.1	20.5	20.8	1.37	0.076
1990 to 1999	250	16.7	12.5	4.7	10.5	22.6	18.8	1.26	0.075
2000 to 2003	288	16.2	19.2	3.1	7.8	18.3	21.4	1.20	0.074
Census Region and Division									
Northeast	208	11.5	9.9	2.4	6.1	14.2	20.1	1.11	0.097
New England	139	10.8	10.0	1.8	4.3	13.2	13.7	1.06	0.099
Middle Atlantic	240	11.7	9.8	2.9	6.9	15.2	23.1	1.13	0.096
Midwest	182	12.9	13.2	3.5	7.9	15.9	11.9	0.85	0.066
East North Central	233	13.5	13.4	4.2	8.3	19.1	15.5	0.90	0.067
West North Central	118	11.7	12.8	3.0	7.2	13.6	7.4	0.74	0.063
South	226	16.5	13.9	4.1	9.2	19.7	15.4	1.12	0.068
South Atlantic	252	17.4	12.6	4.2	9.7	19.7	17.0	1.17	0.067
East South Central	160	15.5	16.4	3.8	8.4	19.8	10.7	1.04	0.067
West South Central	226	15.3	15.8	4.0	9.0	19.3	15.9	1.08	0.070
West	179	13.8	10.6	4.0	9.2	15.2	17.7	1.37	0.099
Mountain	196	15.4	13.1	4.3	8.6	14.4	15.0	1.18	0.076
Pacific	170	13.0	9.5	3.8	9.3	15.7	19.1	1.46	0.112

Appendix 4

Natural Gas Consumption and Expenditure Intensities for Non-Mall Buildings, 2003

Released: October 2006
Next CBECS will be conducted in 2007

Table C24. Natural Gas Consumption and Expenditure Intensities for Non-Mall Buildings, 2003

	Natural Gas Consumption						Natural Gas Expenditures		
				Distribution of Building-Level Intensities (cubic feet/square foot)					
	per Building (thousand cubic feet)	per Square Foot (cubic feet)	per Worker (thousand cubic feet)	25th Per-centile	Median	75th Per-centile	per Building (thousand dollars)	per Square Foot (dollars)	per Thousand Cubic Feet (dollars)
All Buildings*	782	43.0	36.0	17.6	37.1	70.9	6.1	0.33	7.77
Building Floorspace (Square Feet)									
1,001 to 5,000	219	78.7	42.6	23.7	46.3	92.0	1.9	0.70	8.88
5,001 to 10,000	408	54.8	42.5	13.9	28.8	65.7	3.4	0.46	8.34
10,001 to 25,000	667	42.5	40.8	14.4	29.2	52.1	5.6	0.36	8.41
25,001 to 50,000	1,483	41.5	39.1	16.0	31.5	55.3	11.1	0.31	7.46
50,001 to 100,000	2,498	35.4	39.1	10.1	27.6	48.8	19.7	0.28	7.90
100,001 to 200,000	5,029	36.3	26.1	6.1	23.6	55.2	36.2	0.26	7.19
200,001 to 500,000	10,234	35.0	35.5	10.0	22.7	47.2	69.2	0.24	6.76
Over 500,000	39,551	43.0	28.8	2.8	20.0	71.9	268.2	0.29	6.78
Principal Building Activity									
Education	1,223	36.9	28.0	14.9	31.9	60.8	8.9	0.27	7.27
Food Sales	383	50.2	38.0	18.9	39.8	69.4	3.4	0.44	8.85
Food Service	870	141.2	72.0	77.0	150.3	301.8	7.1	1.16	8.20
Health Care	3,283	92.5	44.1	19.1	40.1	65.7	21.5	0.60	6.54
Inpatient	28,222	109.8	56.2	77.1	112.3	145.1	176.8	0.69	6.26
Outpatient	574	50.2	20.6	16.2	34.2	56.0	4.6	0.40	8.01
Lodging	2,432	48.9	101.2	19.8	36.7	76.4	18.5	0.37	7.59
Retail (Other Than Mall)	362	30.9	41.3	16.5	28.7	66.8	2.9	0.25	8.11
Office	535	31.8	13.8	17.2	35.7	56.9	4.5	0.27	8.42
Public Assembly	678	36.4	63.0	13.0	28.9	53.5	5.3	0.28	7.83
Public Order and Safety	771	43.7	39.8	26.6	49.8	76.8	6.5	0.37	8.43
Religious Worship	362	30.3	70.2	12.9	23.5	53.0	3.0	0.25	8.33
Service	481	54.1	52.2	22.9	44.5	82.6	3.9	0.44	8.12
Warehouse and Storage	687	23.4	42.1	9.3	22.1	37.5	5.2	0.18	7.60
Other	1,885	67.6	59.7	22.6	46.3	82.8	15.3	0.55	8.09
Vacant	557	23.0	Q	7.4	21.7	44.6	4.5	0.19	8.14
Year Constructed									
Before 1920	693	50.3	58.8	24.6	46.8	70.7	5.7	0.41	8.16
1920 to 1945	659	47.6	44.5	17.5	36.0	68.2	5.1	0.37	7.67
1946 to 1959	670	45.1	47.2	21.9	39.0	76.8	5.1	0.35	7.67
1960 to 1969	802	44.0	41.1	18.2	38.0	70.9	6.1	0.33	7.56
1970 to 1979	872	44.5	35.9	19.4	36.3	71.7	6.3	0.32	7.24
1980 to 1989	931	43.7	30.2	15.2	30.3	71.8	7.5	0.35	8.04
1990 to 1999	727	37.2	25.1	15.1	32.0	69.7	5.9	0.30	8.05
2000 to 2003	1,042	35.8	38.7	14.5	35.0	69.1	8.6	0.30	8.25
Census Region and Division									
Northeast	1,047	45.2	36.7	22.5	46.2	80.8	9.0	0.39	8.56
New England	981	49.5	38.4	15.9	41.1	61.7	9.1	0.46	9.27
Middle Atlantic	1,062	44.4	36.3	25.1	48.4	82.9	8.9	0.37	8.41
Midwest	853	51.9	49.5	25.6	45.4	81.2	6.0	0.37	7.09
East North Central	938	53.5	49.8	27.4	47.7	85.0	6.7	0.38	7.12
West North Central	671	47.6	48.7	23.4	43.9	74.1	4.7	0.33	6.98
South	644	34.6	27.4	12.5	26.3	52.8	5.4	0.29	8.40
South Atlantic	683	33.2	20.8	12.7	30.1	55.7	6.3	0.31	9.20
East South Central	635	43.3	45.9	14.4	25.1	45.9	5.3	0.36	8.28
West South Central	603	32.2	33.5	9.6	24.0	58.9	4.4	0.24	7.37
West	649	39.8	30.9	11.5	27.2	58.4	4.7	0.29	7.28
Mountain	853	57.9	51.1	28.3	49.8	92.0	5.7	0.39	6.72
Pacific	516	29.7	21.6	7.1	17.2	37.7	4.1	0.23	7.88

Appendix 5

Photo Log

Photo 1 – Building 8: HVAC System Conditions: Dirt on coil.

Photo 2 – Building 8: HVAC System Conditions: Typical ventilation supply fan.

Photo 3 – Building 8: HVAC System Conditions: Typical heating ventilating unit.

Photo 4 – Building 8: HVAC System Conditions: Disconnected HVU damper.

Photo 5 – Building 2: HVAC System Conditions: Multi-zone unit dampers disconnected.

Photo 6 – Building 2: HVAC System Conditions: Multi-zone unit dampers disconnected.

Photo 7 – Building 2: HVAC System Conditions: Corroded heating water piping at AHU.

Photo 8 – Building 3: HVAC System Conditions: Holes in mixing box side ductwork.

Photo 9 – Building 2: HVAC System Conditions: Open heating boiler.

Photo 10 – Building 2: HVAC System Conditions: Primary heating pumps.

Photo 11 – Building 2: HVAC System Conditions: Chemical feeder for heating hot water system.

Photo 12 – Building 5: HVAC System Conditions: Uninsulated duct connector between AHU and heater.

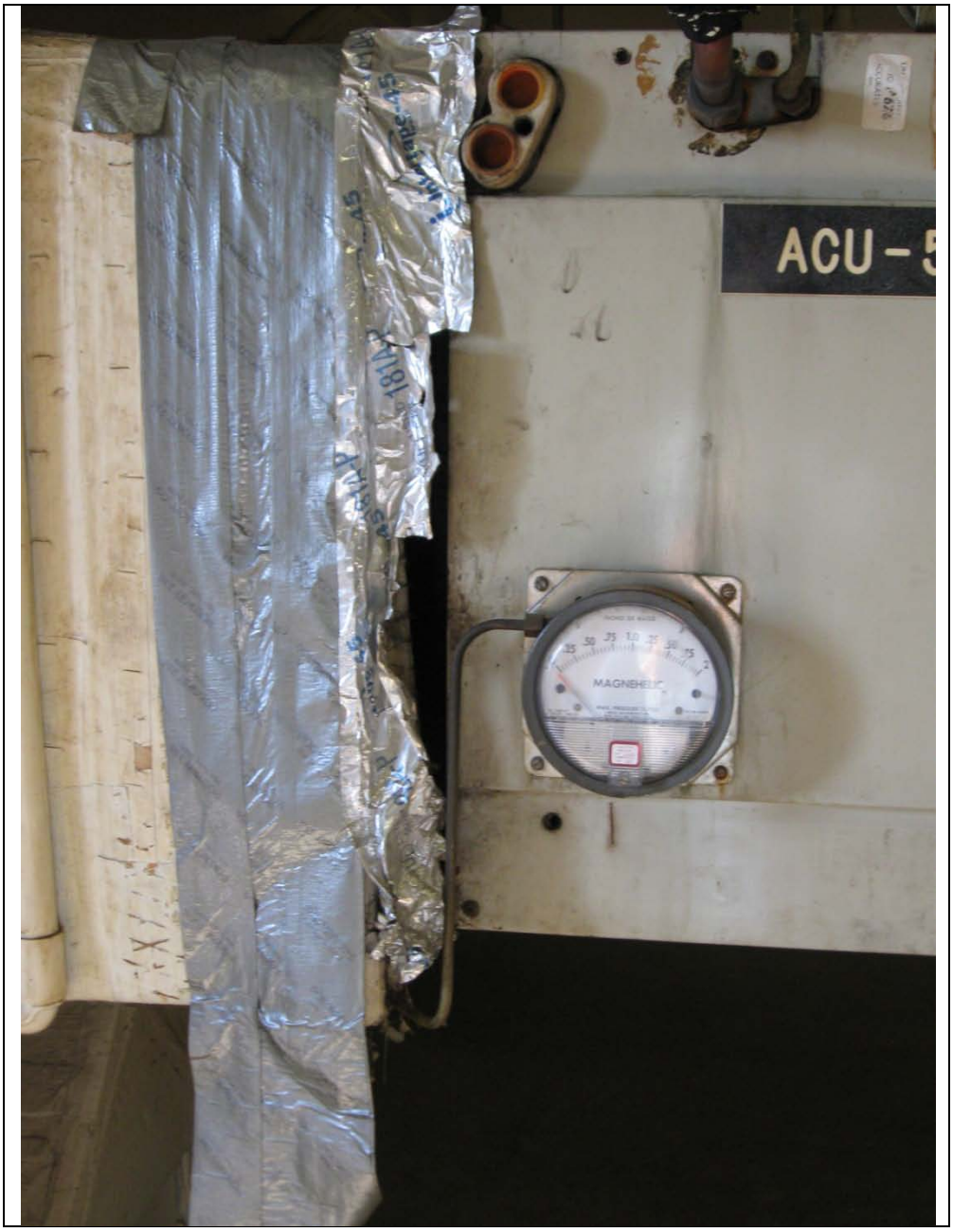


Photo 13 – Building 5: HVAC System Conditions: Missing air filter/taped over access.

Photo 14 – Building 6: HVAC System Conditions: Dirt on coils.

Photo 15 – Building 1: HVAC System Conditions: Corroded cooling unit base.

Photo 16 – Building 8: HVAC System Conditions: Debris at air inlet and exhaust louvers.

Photo 17 – Building 8: HVAC System Conditions: Typical heating and ventilating unit.

Photo 18 – Building 8: HVAC System Conditions: Holes at side of AHU.

Photo 19 – Building 6: HVAC System Conditions: Inoperable rooftop chiller unit.

Photo 20 – Building 8: HVAC System Conditions: Typical housing building HV unit.

Photo 21 – Building 8: HVAC System Conditions: Caked on dirt in mixing box.

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Photo 22 – Building 8: HVAC System Conditions: Supply air grille in inmate room.

Photo 23 – Building 8: HVAC System Conditions: Exhaust air grille in inmate room.

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Photo 24 – Building 2: HVAC System Conditions: Building No. 2 new Carrier unit.

Photo 25 – Building 5: HVAC System Conditions: Disconnected damper assembly.

Photo 26 – Building 5: HVAC System Conditions: Inoperable condensing unit.

Photo 27 – Building 7: HVAC System Conditions: Gym supply air ducts and exhaust fans.

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Photo 28 – Building 7: HVAC System Conditions: Duct covering Gym supply air ducts and exhaust fans.

Photo 29 – Multiple Buildings: Domestic Water Heating Conditions: Typical Raypak domestic hot water boiler.

Photo 30 – Building 8: Domestic Wtr Htg Conditions: Open inoperative boiler.

Photo 31 – Multiple Buildings: Domestic Wtr Htg Conditions: Typical water softener.

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Photo 32 – Multiple Buildings: Domestic Water Heating Conditions: Domestic water storage tank.

Photo 33 – Building 4: Domestic Water Heating Conditions: Water service inlet.

Photo 34 – Building 6: Roof Issues: Missing edge coping.

Photo 35 – Building 6: Roof Issues: Pulled membrane at edge.

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Photo 36 – Building 6: Roof Issues: Pulled membrane at edge.

Photo 37 – Building 6: Roof Issues: Pulled membrane at edge.

Photo 38 – Building 6: Roof Issues: Pulled membrane at edge.

Photo 39 – Building 6: Roof Issues: Pulled membrane at edge.

Photo 40 – Building No. 6: Roof Issues: Pulled membrane and missing edge metal.

Photo 41 – Building No. 6: Roof Issues: Pulled membrane and removed edge piece.

Photo 42 – Multiple Buildings: Antennas placed outside windows.

Appendix 6

ECM Detail

ECM calculations follow; electricity and natural gas savings are based on $0.073/kWh and $1.25/ccf, respectively.

ECM No. 1: EMS Upgrade

This ECM proposes to reduce electric and gas usage by de-energizing equipment. Other benefits include improved air quality due to more accurate control of air and water temperatures, ventilation, and air filtration. In addition, domestic hot water system performance will be improved, along with providing remote access for building diagnostics, and allowing trending for future operational improvements. This ECM is dependent on the implementation of ECM No. 2.

Total average electric usage is 6,917,015 kWh, of which an estimated 49% is consumed by the HVAC system and 13% by cooling compressor systems. It is estimated operation time would be reduced by 50%.

Total average gas usage is 409,136 ccf, of which an estimated 50% is consumed by the space heating system. It is estimated operation time would be reduced by 25%.

The controls upgrade is estimated to cost $1.82/sf.
Total building floor area is estimated to be 261,000 sf.

Implementation Cost	261,000 sf x $1.82/sf = $475,020
Gas Savings	409,136 ccf x 0.50 x 0.25 x $1.25/ccf = $63,928
Electric Savings	6,917,015 kWh x 0.49 x 0.50 x $0.073/kWh = $123,711
	6,917,015 kWh x 0.13 x 0.50 x $0.073/kWh = $32,821
Total	$220,460 /year
Simple Payback	2.15 years

ECM No. 2: Heating and Ventilating System Replacement

Given the condition of the existing HVAC equipment and systems, this ECM recommends complete replacement. It also includes replacement of temperature controls as provided in ECM No. 1.

Total average electric usage is 6,917,015 kWh, of which 49% is consumed by the HVAC system and 13% by cooling compressor systems. It is estimated operating efficiency would improve by 20%. .

Total average gas usage is 409,136 ccf, of which an estimated 50% is consumed by the space heating system. It is estimated burner operating efficiency would be improved by 25% and damper operation would improve by 10%.

The equipment replacement is based on $15.00/sf.
Total building floor area is estimated to be 261,000 sf.

Implementation Cost	261,000 x $15.00/sf = $3,915,000
Gas Savings	409,136 ccf x 0.50 x 0.25 x $1.25/sf = $63,928
	409,136 ccf x 0.50 x 0.10 x $1.25/sf = $25,571
Electric Savings	6,917,015 kWh x 0.49 x 0.20 x $0.073/kWh = $49,484
	6,917,015 kWh x 0.13 x 0.20 x $0.073/kWh = $13,128
Total	$152,111 /year
Simple Payback	26 years

ECM No. 3: Building 6 Chiller Replacement

A 0% operating efficiency improvement is used. An engineering fee is also included to accurately calculate the building cooling load.

Total average electric usage is 6,917,015 kWh, of which 49% is consumed by the HVAC system and 13% by cooling compressor systems. It is estimated operating efficiency would improve by 20%.

Total average electric usage is 6,917,015 kWh, of which 13% is consumed by all cooling compressor systems with an estimated 14% assigned to chiller cooling costs at Building 6. Chiller replacement costs are estimated to be $75,000.

Implementation Cost	$75,000
Electric Savings	6,917,015 x 0.13 x 0.14 x 0.073 = $9,190
Simple Payback	8.16 years

ECM No. 4: Domestic Hot Water Heating System Replacement

Total average gas usage is 409,136 ccf, of which 43% is estimated to be consumed by DHW heating systems. It is estimated that 30% improvement in boiler operating efficiency and 5% improvement due to added insulation of both the storage tanks and piping would result.

The equipment replacement is based on $2.00/sf.
Total building floor area is estimated to be 261,000 sf.

Implementation Cost	261,000 sf x $2.00/sf = $522,000
Gas Savings	409,136 ccf x 0.43 x 0.30 x $1.25/ccf = $65,973
	409,136 ccf x 0.43 x 0.05 x $1.25/ccf = $10,996
Total Savings	$76,969 /year
Simple Payback	6.8 years

NOTE: The concern for minimum domestic hot water system temperatures to maintain acceptable water quality is valid. If 140°F is needed to meet the building needs, that is still an acceptable low temperature to benefit from condensing boiler technology. The presence of biological growth in the water system may be indicative of inadequate circulation and/or excessive storage versus daily use. This should be taken into consideration at the time of system design to properly match system components to the actual load.

ECM No. 5: DHW Solar Water Heating Installation

Total average gas usage is 409,136 ccf, of which 43% is estimated to be consumed by the DHW heating system. It is calculated that Buildings 8A through 8D, 2, 4 and 5 total 126,384 sf or 47% of the total campus building floor area. An estimated 20% improvement would result.

The $82,000 equipment replacement cost is based on 8 building locations at $10,250 each.

Implementation Cost	8 x $10,250 = $82,000
Gas Savings	409,136 x 0.43 x 0.47 x 0.20 x 1.25 = $20,672
Simple Payback	4 years

ECM No. 6. CCTV Installation

Total average gas usage is 409,136 ccf, of which an estimated 50% is consumed by the space heating system. It is estimated that a 2% reduction would occur in gas usage associated with elimination of these openings.

The $100,000 equipment cost is based on installing a CCTV system serving 675 locations at $150/room.

Implementation Cost	675 x 150 = $101,250
Gas savings	409,136 x 0.50 x 0.02 x 1.25 = $5,114
Simple Payback	20 years

ECM No. 7: Building Commissioning to Support Remodel Process.

This ECM estimates the operating costs saved when commissioning occurs to support the building construction or remodel process. In the case of this facility, this ECM applies not only to the controls but includes the variety of HVAC air handlers, exhaust fans, pumps, VFD motor controllers, boilers, and domestic hot water heating systems that are being recommended in ECMs 1, 2, 3, 4, 5, 8, and 9. This ECM estimates a project commissioning cost for the items listed above at approximately $0.75/sf and estimates a 7.5% reduction in gas and electric usage.

Implementation Cost	261,000 sf x $0.75/sf = $195,750
Gas savings	409,136 ccf x 0.075 x $1.25/ccf = $38,356
Electric savings	6,917,015 kWh x 0.075 x $0.073/kWh = $37,870
Total Savings	$76,226/year
Simple Payback	2.57 years

ECM No. 11: Light Fixtures in Inmate Cell Areas Retrofit

Maintenance personnel informed us that generally they only have enough lamps in stock to put one lamp in each fixture within cells, even though they are 3-lamp fixtures. If they had enough lamps, they would put 3 lamps in each fixture because the inmates were complaining. However, if the fixture only takes 1-lamp and still puts out enough lumens of light; then there would be fewer lamps to stock/handle and less maintenance cost over time.