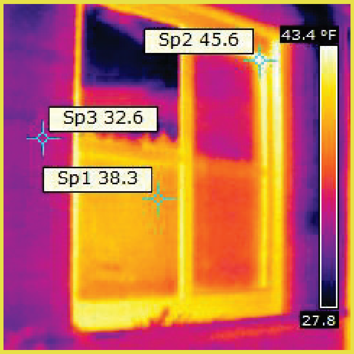

Facility Audit Report
New Hampshire Local Audit Exchange Program
Oyster River High School

FINAL R1

January 2012

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A. EXECUTIVE SUMMARY

Program Introduction

Figure 1 – Oyster River High School

The New Hampshire Local Audit Exchange (LAX) Program was developed by the NH Office of Energy and Planning (NHOEP) as a means to provide no-cost energy audits to New Hampshire municipalities and school districts. Phase one of the LAX Program involves conducting comprehensive energy audits of municipal buildings across New Hampshire. Phase two will include analyzing the results of the audits and posting summarized information on the program website (nhlocalenergyaudits.com). The information will be grouped by building type which will allow other interested municipalities to browse the site for building types that match their own. This will allow those not directly involved in the program to identify similar recommendations and energy efficiency upgrade opportunities (as well as the associated costs and paybacks).

The objective of the audit completed at the Oyster River High School (Figure 1) is to identify energy conservation measures that reduce the net energy consumption thereby reducing operating costs and the consumption of non-renewable fossil fuel energies. In addition to energy conservation, the evaluations and recommendations presented herein consider occupant comfort and holistic building performance consistent with its intended use and function. The information obtained as part of this audit has been used to develop Energy Efficiency Measures (EEM's). These EEM's provide the basis for future building improvements and modifying the manner in which the building is operated.

Disclaimer

This material is based upon work supported by the Department of Energy, American Recovery and Reinvestment Act of 2009 and the New Hampshire State Energy Program, under Award Number DE-EE0000228. This material was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of its employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Procedure

The NHLAX program provides an ASHRAE Level 2 audit of selected municipal buildings and schools. The energy audits identify all appropriate energy efficiency measures for a facility, and a financial analysis based on implementation costs, operating costs, and attainable savings. The ultimate goal is to identify the amount to be saved, the amount the measure will cost, and the estimated payback period for each EEM. In addition, the audit identifies any changes to operations and maintenance procedures.

Each municipal facility will have an in-depth field survey consisting of a site-visit that takes into consideration the following:

- Building Characteristics
- Building Use and Function
- Envelope Systems
- Heating and Cooling Systems
- Ventilation Systems
- Domestic Hot Water Systems

Following completion of the field evaluation, the data and information are reviewed to develop proposed recommendations or Energy Efficiency Measures (EEMs) for the building(s). All information, data, and recommendations are then compiled into a comprehensive report. The final report is then distributed to the municipality or school to assist with implementation and budgeting of the proposed EEMs. The reports will then be shared on the public website where they can be accessed by other NH municipalities and schools. The information provided in the reports will assist these municipalities and schools with determining the best value EEMs for their facilities. In addition to the facility information, the reports will identify potential financial resources available to help fund the EEMs.

Between the dates of November 21st 2011 and January 5th 2012, AEC personnel completed building site reviews at the Oyster River High School (ORHS) to obtain the information necessary to complete an assessment of overall building performance. All building systems that impact energy consumption were evaluated including the building envelope, heating and cooling, ventilation, electrical, plumbing, and mechanical. Secondary observations are also reported herein and include building code compliance, life safety, structural systems, and roofing systems. This evaluation also considers whole building performance that measures how well the integrated building systems in the ORHS function as a composite system.

AEC completed a desktop review of the data provided by the Oyster River Cooperative School District (ORCSD) including historical energy consumption data. The field review included evaluation of all building systems and measurements including an infra-red thermal imaging survey, indoor air quality measurements, and metering of lighting fixtures. A series of energy efficiency measures (EEMs) were then developed that provide a reduction to energy consumption. Capital investment costs for each EEM were developed, and based upon the predicted cost savings associated with the energy efficiency measure, the payback term is calculated. Other noted recommendations relate to indoor air quality, occupant comfort, code compliance, and life safety.

Summary of Findings

The building performance evaluation at the ORHS revealed three significant technical findings: 1) the ORHS consumes an extraordinarily high amount of energy; 2) indoor air quality and occupant comfort are below industry standards; and, 3) the district Facilities Operation and Maintenance budget is significantly higher than expected. Factors attributing to these findings include:

1. The 2004 mechanical engineering design did not provide systems optimization, efficiency, and durability.
2. Inferior construction quality and incomplete work (2004).
3. A deficient Facilities Operations and Maintenance organization.

Staff in the ORCSD Administrative Office and the ORHS (administration and teaching staff) exhibited a keen awareness and sincere interest in energy conservation. ORHS staff were genuinely cooperative and willingly offered anecdotal information during the audit process.

Notable Observations

The following notable observations were made during the desktop data review and/or the building evaluation. Notable observations may be related to data that is outside the normal or expected range, irregularities in building use or function, or problematic systems.

- Energy costs for the ORHS are substantially higher than regional high schools and national averages. The energy use intensity (total energy used per square foot) is notably higher than regional and national schools.
- Based on the high energy consumption and a very low rating, the ORHS does not qualify for ENERGY STAR® certification. This is rather unusual for a modern facility with an automated building controls system.
- Since the ORHS was entered into the USEPA ENERGY STAR® Portfolio Manager program two years ago, energy consumption is trending upward and the score / rating for the facility is trending downward.
- A major building addition and renovation project was completed in 2004. According to district personnel and as evidenced during the evaluation, the building systems were never commissioned.
- Repairs to correct identified issues have been largely ineffective and systems that have been previously repaired (e.g., roofing and HVAC equipment) remain dysfunctional.
- The quality of construction workmanship is inferior to standard industry practice. It is apparent that an adequate construction quality or assurance management plan was not implemented during construction.
- Based upon review of the design drawings and as evidenced during the site evaluation, the quantity, capacity, and operation of ventilation equipment exceeds industry standards resulting in increased energy consumption. A significant volume of air moves through the building including above ceiling spaces.
- Design configuration of the supply and return air ducting systems is inefficient. It provides limited control and balancing of the system is complicated.
- Several building code compliance issues were noted during the assessment including fire safety, mechanical, and electrical.
- As a result of poor design configuration, integration, and control of mechanical equipment by facilities management, systems efficiency is low. Examples include:
    - A rooftop air conditioning unit and a coil fan heater operating simultaneously in the main electric room (January).
    - Three (3) suspended fan-coil heating units operating in the boiler room when the ambient temperature exceeds 90°F.
    - Fresh-air intake dampers on air handling units consistently operating at 100% open.
    - No demand control of ventilation and exhaust equipment.
    - Unmanaged automated building controls system.
- Although ORHS has an automated controls system to improve the efficiency of heating, cooling, and ventilation, the system is not adequately managed or optimized. Equipment operation is not consistent with occupancy schedules resulting in increased operating time and reduced equipment life (e.g., systems were operating in occupied mode during Thanksgiving and New Years Day holidays). A competent understanding of the controls systems operation and function by facilities management personnel is not evident.

- Two mechanical and controls firms (Siemens and Aramark) are under long-term service contracts to rectify HVAC equipment and controls systems issues and to complete repairs however function of systems remains incomplete and inefficient. The scope and duties within their current services contracts could not be clearly established (requested service contracts were not provided by the Facilities Manager).
- Lighting in many common spaces remains on during unoccupied periods. Generally, artificial lighting densities exceed industry standards and yard lighting density is significantly higher than recommended.
- Roof leaks have been a persistent problem in the building since it was constructed. Several repairs have been made however leaks continue to occur. Evidence of leaks includes numerous water stains on ceiling tiles, corroded equipment, and moisture damage to building materials.
- Interviews with building occupants indicated that they are generally dissatisfied with building conditions, untimely response to work requests, and languishing repairs spanning several years. Evidence of the unresponsiveness observed by AEC includes:
  - A recent mechanical inspection provided to the facilities manager in December 2011 identified clogged and failed air filters in air handling units. A follow-up inspection in January 2012 also revealed failed and clogged filters that require replacement.
  - In a preliminary data presentation in early December 2011, AEC informed the Facilities Manager that the automated controls system is not properly scheduled and that HVAC systems are operating during non-occupied periods including Thanksgiving break. Equipment was observed to continue operating during the Christmas/New Year holiday break.
  - Persistent and significant roof leaks that were reported to Facilities Management two years ago.
- A sufficient facilities preventive maintenance program is not apparent. This results in: 1) reduced service life of mechanical equipment; 2) inefficient operation and increased energy consumption; 3) reduced indoor air quality; 4) reduced reliability of equipment; and, 5) increased repair frequency and costs. This observation was also noted in an independent facilities program review report (DGA, December 2011). Examples of some noted maintenance issues include:
  - On the inspection date of 01/05/2012, it was noticed that the NH Department of Labor regulated boiler inspections (RSA-157 A) expired on all three boilers on 10/22/2011. Other vessels with expired certifications include the two (2) hot water tank heaters and the DHW storage tank.
  - A burning rubber odor is emanating from at least two of the three boiler units (and into the corridors). Facilities personnel were aware of this when it was brought to their attention. Immediate replacement was recommended as it is most likely a result of failing combustion flange gaskets.
  - Air filters in most air-handling units are fouled with dirt and debris and some have disintegrated entirely. This was also noted in a recently completed inspection report prepared by Peterson Engineering (December 2011).
  - Maintenance of several air handling units has been neglected as evidenced by worn fan belts, “squeaking” fan units indicating failing of bearing assemblies, and mold formation inside of units. Pieces of shredded fan belts were observed inside of several units and some double-motor pulleys only have a single belt installed. Energy recovery wheels are covered with debris and do not appear to have been cleaned or maintained since installation.
  - Roof leaks have persisted since the 2004 construction and many reported leaks (by ORHS staff) remain unrepaired.

- The ORCSD facilities and maintenance group was generally unresponsive to requests for information by AEC. Some information conveyed by facilities personnel during interviews was inconsistent with AECs findings in the field.
- The Facility Operation and Maintenance budget for the ORCSD is high relative to local and national averages for comparable school district facilities.

Summary of Recommendations

Following is a summary table identifying the proposed recommendations, EEM costs, predicted annual energy cost savings, and simple payback period. Part E provides a more detailed explanation of these recommendations.

EEM No.	EEM Description	Capital Cost	Annual Cost Savings	Payback (yrs.)
TI-1	Optimize the existing DDC systems schedule consistent with occupancy schedules. Schedule setback temperatures and shut-down ventilation equipment during low and non-occupied periods *(this can be completed as part of the retro-commissioning program)*.	$0	$42,000	0
TI-2	Control lighting systems in all common spaces (corridors, lobbies, etc.) consistent with occupancy.	$0	$5,240	0
T1-3	Increase thermostat setpoint to 85°F for air-conditioning unit in electrical room. Inspect regularly to ensure that it is not operating during heating periods.	$0	$2,700	0
T1-4	Reduce exterior/yard lighting density per IESNA standards and optimize schedule based on zone requirements *(this can be completed as part of the retro-commissioning program)*.	$0	$2,600	0
T1-5	Reduce heating setpoint on thermostatically controlled valve for suspended fan coil heater in main electrical room to 55°F.	$0	$2,500	0
T1-6	Many entry doors are propped open during heating months (January), by students for after-school programs including athletics. Unlock utilized entry doors or provide access (key cards) to after-school program coordinators for student access.	$0	$1,820	0
T1-7	The domestic hot water systems provide over 1,000 gallons of supply (2-375 gallon heater tanks and 1-375 gallon storage). Reduce occupied capacity to a single 375 gallon unit and valve off storage tank.	$0	$1,700	0
T1-8	Shut off the 3 suspended fan coil heater and the AHU fan coil heating supplies in boiler room.	$0	$1,500	0
T1-9	Inspect and replace filters on all air-handling units as needed (2-3 months) to prevent filter clogging, fan motor strain, and reduced service life. This is also an IAQ measure.	$0	$1,200	0
T1-10	Inspect all supply and return vents to ensure that they are open to improve distribution of conditioned air.	$0	$1,000	0
T1-11	Remove all unutilized electronic equipment including computers, printers, overhead projectors, and small appliances.	$0	$950	0
T1-12	Control operation of the air compressor for the laboratory rooms. Capacity appears to exceed demand and compressors should be shut-down in summer.	$0	$650	0
T1-13	Power off overhead LCD projectors (SmartBoards) when not in use.	$0	$320	0
T1-14	Remove window air-conditioning unit during heating season to prevent air leakage.	$0	$285	0
T1-15	Determine control logic for the boiler AHU and optimize. Unit should only operate in transitional seasons (fall and spring) *(this can be completed as part of the retro-commissioning program)*.	$750	$2,300	0.3
T1-16	Balance the combustion air intake louvers so the supplied air equals the boiler demand *(this can be completed as part of the retro-commissioning program)*.	$1,000	$3,000	0.3
T1-17	Implement a standard facilities preventative maintenance and energy management program. Utilize a facilities management software program with scheduled PM events and repair logs.	$2,000	$5,000	0.4

T1-18	Install smart power strips (occupancy or time controlled) to power off computer systems (CPU and monitors) when not in use. This could also be software scheduled by the IT manager.	$1,600	$3,110	0.5
T1-19	Install weather-stripping on all entry door jambs, headers, and thresholds.	$900	$1,780	0.5
T1-20	Replace deteriorated piping insulation on rooftop condensing equipment with min. R-10 outdoor rated insulation.	$750	$1,340	0.6
T1-21	Seal all roof penetrations with caulking or fire-stopping.	$800	$1,200	0.7
T1-22	Clean all energy recovery wheels in AHUs (10) to remove debris and mineral scale. Unless a chemical treatment system is installed, this should be completed every 2-4 years depending on use frequency and mineral content in water. Inspection should be completed as part of a routine PM program.	$3,500	$1,500	2.3
T1-23	Consolidate compact refrigerators and replace with ENERGY STAR rated units (3).	$2,400	$610	3.9
T1-24	Seal roofs on all exterior AHU units to mitigate leaks (PM action).	$500	$100	5.0
T1-25	Remove compact refrigerators and replace with three (3) full-size ENERGY STAR rated units.	$1,800	$350	5.1
T1-26	Replace recessed lighting fixtures in main entrance vestibule and gymnasium lobby with lower wattage fluorescent fixtures. Reduce lighting density consistent with IESNA standards (5-10 FCs).	$3,200	$380	8.4
T2-1	Complete DDC systems evaluation by a mechanical controls engineer to optimize current system and to determine feasibility for repair and software update versus whole system replacement with non-proprietary system (BACnet) *(this can be completed as part of the retro-commissioning program).*	$6,500	$24,000	0.3
T2-2	Install demand or time programmable controllers on all exhaust fans and optimize runtime based on use and occupancy (ASHRAE 62.1) *(this can be completed as part of the retro-commissioning program)*.	$6,600	$3,800	1.7
T2-3	Measure supply and return air flow and balance all ventilation zones *(this can be completed as part of the retro-commissioning program)*.	$5,400	$2,700	2.0
T2-4	Replace condensing units (2) for walk-in freezer and refrigerator with high-efficiency units (SEER >18) and add economizer units.	$5,300	$2,100	2.5
T3-1	Install DDC demand controllers on all AHUs except boiler room (19) *(this can be completed as part of the retro-commissioning program)*.	$40,000	$28,000	1.4
T3-2	Retro-commission and optimize all building systems (this incorporates many other EEMs).	$185,000	$70,000	2.6
T3-3	Install stack economizer energy recovery units on boiler exhausts (3).	$75,000	$18,000	4.2
T3-4	Pressure test all supply ducting and seal leaking joints per ASHRAE standards *(this can be completed as part of the retro-commissioning program)*.	$23,000	$4,900	4.7
T3-5	Install VFD controllers on all AHU fan and hydronic pump motors greater than 5 HP.	$35,000	$6,300	5.6
T3-6	Inspect all mechanical and passive exhaust ducting and install positive pressure actuated dampers to reduce air leakage (lavatories, laboratories, locker rooms, kiln room) *(this can be completed as part of the retro-commissioning program)*.	$12,300	$2,100	5.6
T3-7	Replace gymnasium metal halide lighting fixtures (42) with super T-5 lamp fixtures (PSNH SmartSTART Program).	$25,000	$4,300	5.8
T3-8	Replace one of the existing boiler units with a condensing gas fired boiler (98% AFUE). Configure the remaining two units to provide supplementary heating and to serve as backup units.	$170,000	$28,000	6.1
T3-9	Install multi-controllers for lighting in common areas including corridors. Time programmable controls operate lighting during normal occupancy schedules and occupancy sensors control reduced lighting fixtures during non-occupied periods.	$12,200	$1,900	6.4
T3-10	Replace library lighting fixtures (PSNH SmartSTART Program). Add task lighting to reduce overhead lighting density/wattage.	$22,000	$2,900	7.6
T3-11	Install insulation on all uninsulated sections of supply ducting per ASHRAE standards. Repair all damaged and poorly installed insulation sections.	$25,000	$3,200	7.8
T3-12	Replace exterior wallpack lighting fixtures (27) with LED units (PSNH SmartSTART Program).	$18,500	$1,800	10.3

The energy cost savings and resulting payback are based upon each independent measure implemented for the building in its current condition and function. There are interdependencies among measures that will affect the realized energy savings. Capital costs are provided for budgetary planning only. They are estimated based on current industry pricing. A detailed cost estimate should be developed prior to appropriating capital funds for the more costly measures.

B. HISTORIC ENERGY CONSUMPTION

Utility Data

Utility data for the ORHS was provided by the District. Table 1 summarizes the total energy consumption for the year including electric and oil usage. Energy consumption and cost for electricity per pay period is shown in Table 2 and Figure 2. The regional electric utility supplier is Public Service Company of New Hampshire (PSNH) and natural gas is provided by Unitil.

Table 1 – Annual Energy Consumption (2010-2011)

Energy	Period	Consumption	Units	Cost
Electric	July 2010 – June 2011	1,674,000	Kilowatt hours	$229,964
Natural Gas	July 2010 – June 2011	90,200	Therms	$126,322
			Total Annual Energy Cost:	**$356,286**

The monthly electrical usage (Figure 2) reveals that the use is unusually consistent throughout the year. Over the twelve (12) month period (2010-2011), January was the peak demand month, consuming 152,400 kWh of electricity. Electricity demand in K-12 school facilities typically decreases significantly during summer break periods when the school occupancy is well below normal occupancy levels. Figure 2 indicates that electrical consumption is relatively constant throughout the year suggesting that HVAC systems are operating at full-occupancy capacity and schedule.

Table 2 – Monthly Electric Consumption (2010-2011)

Period	Year	Electric Use (kWh)	Cost
July	2010	142,400	$19,689
August	2010	148,000	$21,230
September	2010	140,800	$20,287
October	2010	131,200	$19,230
November	2010	145,200	$20,574
December	2010	132,000	$18,724
January	2011	152,400	$20,986
February	2011	138,400	$18,062
March	2011	139,600	$18,233
April	2011	138,000	$18,245
May	2011	146,400	$19,202
June	2011	119,600	$15,502
	Totals:	**1,674,000**	**$229,964**

Annual electric usage for the ORHS based on the most recent data provided by ORCSD (July 2010 through June 2011) is 1,674,000 kWh at a cost of $229,964. Based on the building size and function, this usage is extraordinarily high relative to similar use K-12 facilities. As comparison, the Londonderry High School is 16% larger in area, has a higher student (FTE) population, and a higher student density (FTE/SF) however their annual electric consumption is 77,947 kWh less ($11,000) than ORHS.

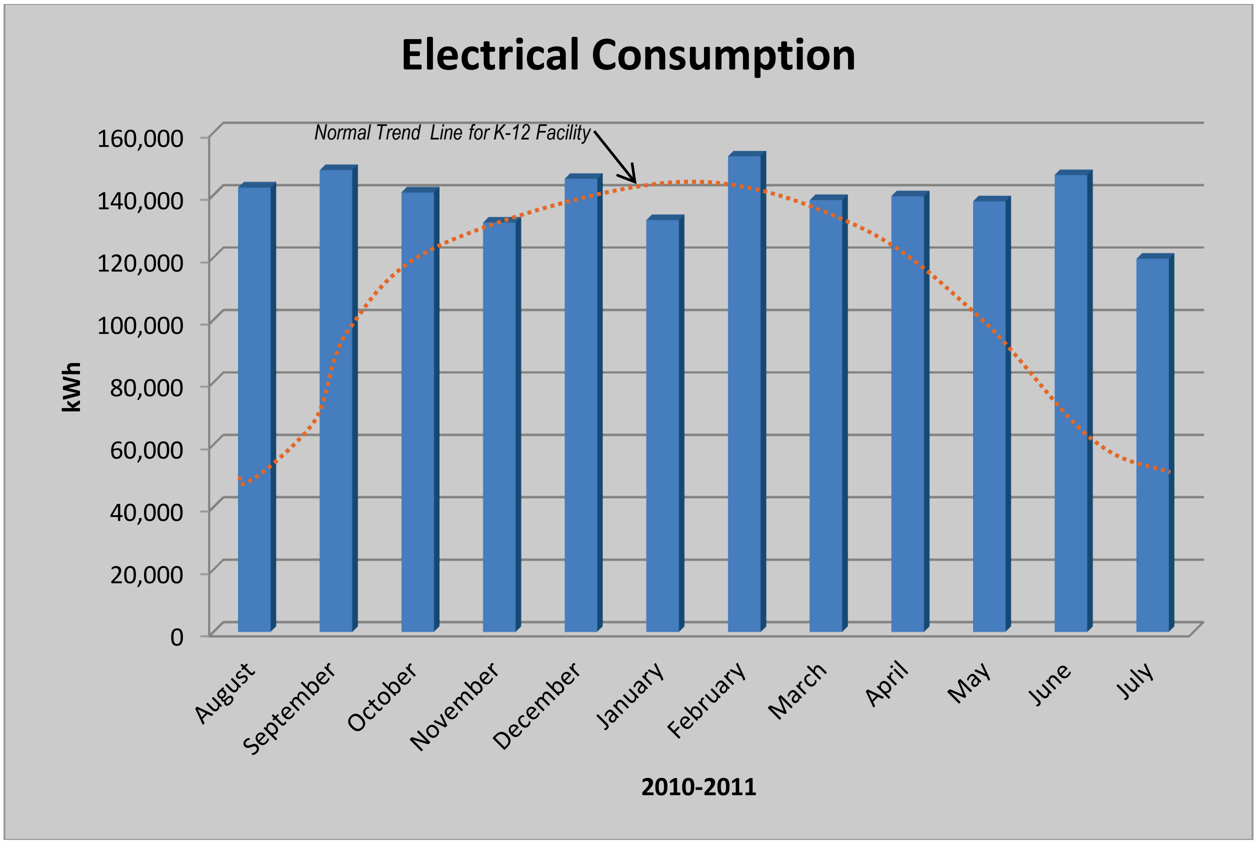


Figure 2 – Electric Consumption (2010-2011)

To provide the most accurate recommendations for energy conservation, the energy consumption based on end use was determined. Table 3 presents the estimated electrical usage for each category including lighting, plug loads, and mechanical. Mechanical equipment includes all hard-wired, permanently installed equipment including ventilation, exhaust, heating, cooling, pumps, etc. These values were determined using observations from the field audit and typical energy consumption data for appliances observed throughout the building. A more detailed accounting of all electrical equipment by end-use is presented in Part C of this Report.

Table 3 – Categorized Electrical Consumption (2010-2011)

Equipment Type	Annual Consumption (kWh/yr)	% of Total Consumption	Annual Cost
Plug Loads	232,047	14%	$32,487
Lighting Fixtures	392,362	23%	$54,931
Mechanical Equipment	1,050,463	63%	$147,065
Totals	**1,674,873**	**100%**	**$234,483**

Mechanical loads consume the greatest amount of electricity at the ORHS accounting for 63% of the electrical energy for the building. This is largely a result of poorly controlled heating, cooling, and ventilation systems. Lighting systems represent 23% of the annual electrical energy or 392,362 kWh. At 232,047 kWh per year, plug loads account for 14% of the electrical demand in the building. Figure 3 presents the relative energy use for each of the three categories.

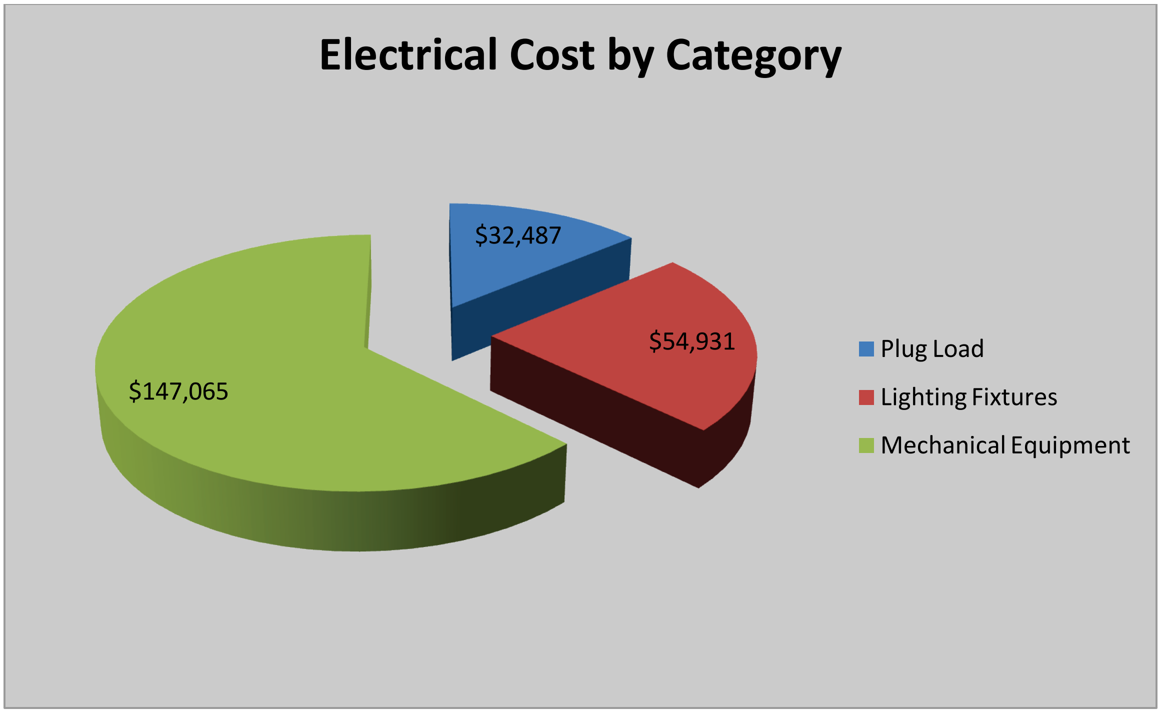


Figure 3 – ORHS Electrical Cost by Category (2010-2011)

Mechanical equipment accounts for an unexpectedly high amount of electric usage with an annual cost of $147,065 (2010-2011). This usage is higher than expected considering the building characteristics and use. Lighting fixtures consume a moderate amount of electricity however consumption can be reduced with simple measures. Plug loads are limited to office equipment, electronics, and appliances.

Table 4 – Monthly Heating Fuel Consumption (2010-2011)

Month	Year	Fuel Consumption (therms)	Cost
August	2010	165	$407
September	2010	280	$463
October	2010	801	$957
November	2010	6,685	$7,241
December	2010	10,449	$13,946
January	2011	16,235	$21,601
February	2011	22,108	$30,458
March	2011	14,406	$20,182
April	2011	10,770	$15,152
May	2011	5,316	$6,222
June	2011	1,790	$7,988
July	2011	249	$456
	Totals:	**90,200**	**$126,322**

Heating fuel for space heating and domestic hot water heating at the ORHS is provided by Unitil (Table 4, Figure 4). The building consumed an annual total of 90,200 therms of natural gas (July 2010 to June 2011). Notably, the fuel consumption for domestic hot water during unoccupied summer months is considerably high based on expected demand. The total annual heating fuel cost for the ORHS is $126,322 (2010-2011).

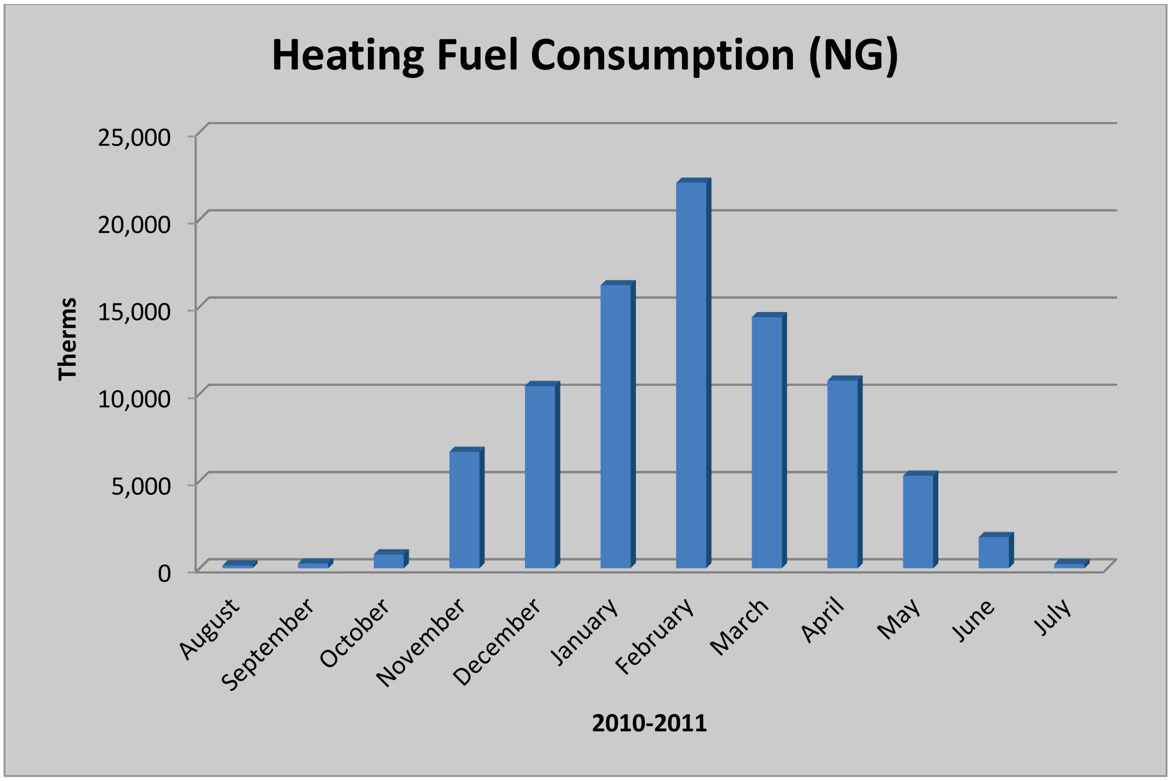


Figure 4 – Heating Fuel Consumption (2010-2011)

Considering the ORHS building systems including the envelope integrity (insulation and air leakage), modern mechanical equipment, and an automated controls system, the heating fuel usage is extraordinarily higher compared than expected. This is mostly attributable to poorly controlled air exhaust and ventilation systems resulting in increased exchange of interior conditioned air and outdoor air. The boiler units have a relatively low combustion efficiency and when installed had a maximum efficiency (AFUE) of 82% which decreases over the life of the system. Based on the unit condition and age (8 years) the de-rated efficiency is 79% or less. New commercial gas-fired condensing boilers can operate at efficiencies as high as 98%. Other explanations for the high usage include heating setpoints that are higher than recommended and poor heating distribution throughout the building. For example, several areas exceeded 73°F and the average recorded temperature was 71.5°F. The recommended heating setpoint for a high school facility is between 68°F and 70°F.

C. FACILITY INFORMATION / EXISTING CONDITIONS

Setting

The Oyster River High School (ORHS) is located in Durham, NH within a semi-rural suburban setting. The building and facilities are located on a land parcel owned by the Oyster River Cooperative School District (ORCSD). ORCSD is comprised of three abutting towns including Durham, Lee, and Madbury. The school building is located on Coe Drive immediately southwest of State Route 4. Bagdad Road defines the northern boundary of the parcel and Coe Drive bounds the parcel to the northeast and east. Athletic fields occupy the southwestern portion of the parcel with a small field house further southwest. School Administrative Unit Number 5 (SAU-5) office buildings (2) are located at the southwest limit of the district owned parcel. Parking for the ORHS is provided by three discrete paved parking areas located to the south (2) and to the northeast extending along the front building elevation and the gymnasium. The gross area of the ORHS is 198,000 square feet.

Figure 5 – Aerial Photograph of ORHS (2009)

History

According to archive records, the original high school building was constructed in the mid 1960's. In 2004, a major addition and total renovation of the original building was completed. The newly constructed building increased the building area by more than 100% (Figure 6). The 2004 renovation included whole replacement of existing HVAC equipment and systems. The architect of record for the renovation was TEAM Architects of Londonderry, NH (now part of Harriman Associates in Manchester, NH) and the mechanical engineer was Rist-Frost-Shumway (RTS) of Laconia, NH. The general contractor for the construction was Gilbane Building Company of Bedford, NH. MacMillin of Bedford, NH provided construction management services.


Figure 6 – Aerial Photograph of ORHS (1998)

Use, Function & Occupancy Schedule

The ORHS and the land it occupies are owned by the ORCSD. The building is a multi-level structure with single floor sections, two-story sections, and a smaller three-story section. Spatial configuration and functional use of the building is typical of regional high schools. Spaces include classrooms, video and media facilities, a library, a cafeteria, a gymnasium, an auditorium, mechanical rooms, and several administrative offices. A small childcare facility is also supported at the ORHS. The current full-time enrollment (FTE) for the ORHS is approximately 675 students yielding a density of 293 square feet (SF) per FTE. For comparison, densities at the Portsmouth High School and Londonderry High School are 324 SF/FTE and 157 SF/FTE, respectively. Overall, building facilities and spatial configuration appear to adequately support the current use and functions and provide some capacity for increased FTE and staff.

Table 5 – ORHS Operating Schedule (2011-2012)

Month	No. School Days	Breaks
August	1	Start 8/31
September	21	Labor Day (9/5)
October	19	Columbus Day (10/10) Teacher Workshop Day (10/31)
November	19	Veterans Day (11/11) Thanksgiving Recess (11/24-11/25)
December	17	Holiday Recess (12/24-01/02)
January	19	Holiday Recess (12/24-01/02) Martin Luther King Day (01/16) Teacher Workshop Day (01/23)
February	18	Winter Recess (02/27-03/02)
March	19	Winter Recess (02/27-03/02) Teacher Workshop Day (3/16)
April	16	Spring Recess (04/23-04/27)
May	22	Memorial Day (05/28)
June	14	End 6/20

Anecdotal Information

Anecdotal information includes all relevant information collected during the desktop review, as part of occupant interviews, or general observations noted during the site evaluation. Generally, anecdotal information corresponds to issues or concerns that may not be apparent during the building evaluation. It includes complaints about seasonal occupant comfort, maintenance issues, systems or equipment performance issues, recent improvements or changes in use, and previous reports prepared by others. Anecdotal information obtained during the ORHS evaluation includes the following:

- Occupants stated that the building is inefficiently controlled and operated resulting in increased energy consumption and reduced occupant comfort.
- Occupants indicated that rooms are not evenly conditioned. Some rooms are consistently cold while most are consistently too warm. Space heaters are used in some classrooms while windows in other classrooms are opened in winter months to maintain comfortable temperatures (open windows were observed in January). A significant number of portable fans were noted throughout the building –this is also indicative of low occupant comfort.
- Occupants indicated that air flow in some rooms is very high creating nuisance drafts and noise.
- Occupants indicated that facility repair work requests are not addressed in a timely manner. Some expressed frustration with regard to issues that remain unresolved after numerous requests and attempted repairs.
- Occupants indicated that they have to make service requests to the facilities group each spring and fall to have the hot water coil in the Administration Area manually shut off / turned on.
- Occupants expressed concerns over persistent and unrepaired roof leaks and the potential for mold formation.
- Facilities personnel indicated that the automated building controls system (Siemens®) does not function as intended. Aramark is contracted to make system adjustments on a quarterly basis.
- Facilities personnel indicated that a section of the roof system was replaced in 2010 to repair damaged insulation board from the original installation.

- Facilities personnel stated that sections of the roof continue to leak on a regular basis including the north wing corridor beneath the mechanical penthouse and in the principal's office. It is noted that leaks in several other areas were identified during the survey.
- Facilities personnel indicated that the air-handling units require frequent repair. Some units (notably the unit in the penthouse) have reoccurring repair issues. One of the energy recovery units was repaired at significant cost by Siemens® under a service contract but it remains inoperative. Facilities personnel allege that Siemens® has refused to return and repair the unit. It is noted that this unit was observed to be operating upon inspection.
- Administrative office personnel indicated that there was no independent quality assurance management for the 2004 construction project and that the district elected not to fund commissioning of the facility. Allegedly there were disputes between the district and the general contractor and between the general contractor and their subcontractors.
- A *Facilities and Program Analysis* was recently (December 2011) completed by Davis-Goudreau Architects (DGA) of Portsmouth, NH. The analysis including a limited review of building mechanical systems by Petersen Engineers of Portsmouth, NH. Notable mechanical issues identified in the final report include: 1) a lacking preventative maintenance program has resulted in reduced service life of mechanical equipment; 2) unreliable operation of the combustion air ventilating unit for the boiler room is a code compliance concern; 3) demand ventilation controls (CO_2) are not utilized (as required by code) to control building ventilation and to prevent over-ventilation of the building; 4) the direct digital controls system is not functioning as intended; and 5) several code violations exist in the building. In summary, the report indicated that retro-commissioning of all building mechanical systems and the DDC systems is required to correct known deficiencies and to ensure systems are functioning efficiently. The report also identified several fire and life safety code issues.

Building Envelope

The following sections present the building envelope systems and insulation values for each assembly. Assembly values are compared to the *International Energy Conservation Code (IECC), 2009* for commercial buildings located in Climate Zone 5. A complete set of design plans (2003) were available and used to verify the building envelope sections.

Floor Systems

The concrete floor in the basement is four (4) inches in thickness with a laminate floor covering or carpeting. The floor system has an installed assembly insulation R value of 1.2, as shown in Table 6. Although the IECC does not specify an insulation requirement for unheated slab on grade floors in Climate Zone 5, a minimum value of R-10 is generally recommended.

Table 6 – Floor Insulation Values

Material	Thickness (in.)	R-value	Integrity Factor	Installed R-value
Concrete slab	4.0	0.3	1.0	0.3
Floor Tile	0.1	0.1	1.0	0.2
Interior air film	NA	0.7	NA	0.7
			Installed Assembly	**1.2**
			2009 IECC Requirement:	**NR**

Wall Systems

The building is a multi-level steel framed structure with elevated ceilings in the gymnasium, cafeteria, and library. The below grade foundation walls are steel reinforced cast-in-place concrete with two inches of exterior rigid insulation along the frost wall. All walls are above grade systems supported by structural steel members and concrete masonry units (CMU). The front exterior of the building is clad in split-face concrete block (lower sections) and full brick (upper sections). The gymnasium and rear elevations are clad entirely in split-face concrete block. There are seven (7) unique exterior wall sections depending on the wall location and interior function (Table 7). Mass walls (CMU construction) are insulated with polystyrene insulation board and metal framed walls are insulated with fiberglass batts. Table 7 presents wall insulation values for all wall systems. None of the wall systems comply with current energy code standards (IEC, 2009) however they are presumed to comply with the building code in effect at the time of construction (2004). Inspection of the walls with an infra-red thermal imaging camera did not reveal any notable issues and overall thermal integrity is consistent with the construction methods.

Table 7 – Wall Assembly Insulation Values

Wall Type 1 & 16 (metal stud framed)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Split Face Block	4	0.6	1.0	0.6
Air Gap	2	1.0	1.0	1.0
Dens Glass Sheathing	5/8	0.7	0.9	0.6
Fiberglass Batt	6	19.0	0.8	15.2
FF Gypsum Wallboard	5/8	0.6	0.9	0.5
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**18.8**
			2009 IECC Requirement:	**13.0 + 7.5 c.i.**
			Code Compliant?	**NO**
Wall Type 2 (mass)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Split Face Block	4	0.6	1.0	0.6
Air Gap	2	1.0	1.0	1.0
Polystyrene Insulation Board	2	10.0	0.9	9.0
CMU	8	1.1	1.0	1.1
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**3.6 + 9.0 c.i.**
			2009 IECC Requirement :	**11.4 c.i.**
			Code Compliant?	**NO**
Wall Type 7 (metal stud framed)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Split Face Block	4	0.6	1.0	0.6
Air Gap	2	1.0	1.0	1.0
Dens Glass Sheathing	5/8	0.7	0.9	0.6
Fiberglass Batt	8	25.0	0.8	20.0
FF Gypsum Wallboard	5/8	0.6	0.9	0.5
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**23.6**
			2009 IECC Requirement:	**13.0 + 7.5 c.i.**
			Code Compliant?	**NO**
Wall Type 9 (mass)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Split Face Block	4	0.6	1.0	0.6

Air Gap	2	1.0	1.0	1.0
Polystyrene Insulation Board	2	10.0	0.9	9.0
CMU	12	1.3	1.0	1.3
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**3.8 + 9.0 c.i.**
			2009 IECC Requirement:	**11.4 c.i.**
			Code Compliant?	**NO**
Wall Type 15 (metal stud framed)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Split Face Block	4	0.6	1.0	0.6
Air Gap	2	1.0	1.0	1.0
Dens Glass Sheathing	5/8	0.7	0.9	0.6
Fiberglass Batt	6	19.0	0.8	15.2
Air Gap (chase)	4	1.0	NA	1.0
FF Gypsum Wallboard	5/8	0.6	0.9	0.5
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**19.8**
			2009 IECC Requirement:	**13.0 + 7.5 c.i.**
			Code Compliant?	**NO**
Wall Type 21 (mass)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Split Face Block	4	0.6	1.0	0.6
Air Gap	2	1.0	1.0	1.0
Polystyrene Insulation Board	2	10.0	0.9	9.0
CMU	4	0.8	1.0	0.8
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**12.3 + 9.0 c.i.**
			2009 IECC Requirement:	**11.4 c.i.**
			Code Compliant?	**NO**
Wall Type 22 (mass)				
Material	**Thickness (in.)**	**R-value**	**Integrity Factor**	**Installed R-value**
Exterior Air Film	NA	0.2	NA	0.2
4" Brick	4	0.6	1.0	0.6
Air Gap	1	1.0	1.0	1.0
CMU	8	1.1	1.0	1.1
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**3.6**
			2009 IECC Requirement:	**11.4 c.i.**
			Code Compliant?	**NO**

Ceiling Systems

Ceilings throughout the building are suspended acoustical tile (SAT) systems. The above ceiling plenum space is used for routing of ducting, piping, conduit, and cable. Numerous water stains were evident on the tiles and many have been painted over. It was also observed that most of the tiles are sagging which is an indication of moisture intrusion in the above-ceiling space (Figure 7).

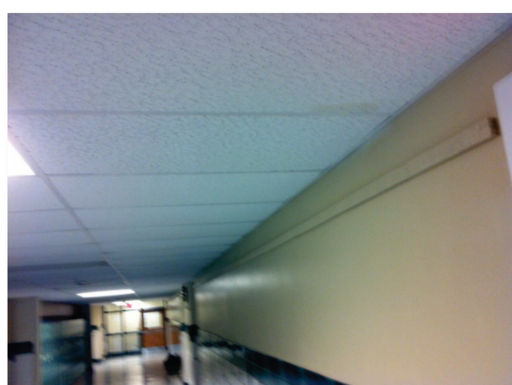


Figure 7 – Sagging Ceiling Tiles & Water Stains

Roofing Systems

The roofing system on the ORHS consists of an adhered polyurethane membrane (EPDM) with the exception of the original building which has a built-up ballasted system. The membrane system has 3 inches of polystyrene rigid insulating board. Roofing insulation values are presented in Table 8. The insulation does not comply with current code standards.

Table 8 – Roof Systems Insulation

Material	Thickness (in.)	R-value	Integrity Factor	Installed R-value
Exterior Air Film	NA	0.2	NA	0.2
EPDM	NA	0.3	1.0	0.3
Polystyrene Insulation Board	3	15.0	0.9	13.5
Interior Air Film	NA	0.7	NA	0.7
			Installed Assembly:	**1.2 + 13.5 c.i.**
			2009 IECC Requirement (roof):	**20.0 c.i.**
			Code Compliant?	**NO**

Noted issues with the roofing system include persistent leaks, ponding water (Figures 9 and 10), scupper drain inverts set too high (Figure 10), and unsealed fasteners on pipe penetrations (Figure 8). Ponding on membrane roofing systems will reduce the service life of the system due to the mechanical forces created by freeze-thaw action. Recommended repairs include opening sections of membrane where significant ponding occurs, shimming the substrate with polystyrene insulation board and recovering the section. Scupper drain inverts should be set at a minimum of 1 inch below the roof deck. Many previous repairs and patches are evident on the membrane roof and ongoing repairs by a roofing contractor were observed during the evaluation.

Figure 9 – Ponding Water

Figure 8 – Vent Penetration (note untightened band clamp)

Figure 10 – Scupper Drain (note drain pipe invert is 2” above deck)

Other recommendations include inspecting all edge and parapet wall flashing. Degraded caulking should be removed and replaced by a qualified roofing contractor. Holes and gaps in flashing should be sealed. Annual inspection of roofing systems is recommended as part of a standard preventative maintenance program.

Fenestration Systems

Fenestration systems on the ORHS building include operable windows, fixed window units, glazed entry doors, and fixed storefront entry units. Window units in the building are aluminum framed units with double-pane glass. Based on the thermal infra-red imaging, the window and door frames are not insulated. Consistent with IECC requirements, fenestration performance is measured by the U-factor, the solar heat gain coefficient (SHGC), and air leakage as determined by the unit manufacturer. No manufacturer information was available for the windows or doors in the

ORHS and therefore compliance with IECC standards for commercial buildings located in Climate Zone 5 cannot be established. The south facing storefront units on the library do have tinted glazing and interior shades to reduce solar heat gain in warmer months. Use of the shades is recommended.

In general, the glazed units perform reasonably well based on visual inspection and survey with the infra-red thermal camera. Typical of modern units, most thermal transfer and air leakage occurs at the seals of operable windows and the interface between the window and the wall opening (Figure 11). Recommendations include exterior and interior inspection and re-caulking of window jambs, headers, and sills as needed. If the operable double-hung and sliding window units have adjustable jambs, they should be inspected and adjusted as necessary to maintain a complete air seal.

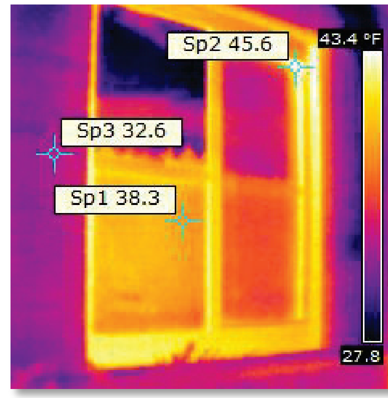


Figure 11 – Infra-Red Image of Window

Doors

The door units in ORHS are hollow metal units with thermal breaks. Units include double doors and with full glazed sections (entry doors) and solid doors (utility areas). Glazed door units appear to be uninsulated providing high thermal transfer through the frame. Solid doors appear be insulated. Based on visual observations and thermal imaging, the seals on door jambs, partings, and thresholds are incomplete allowing substantial air leakage. Daylight can be seen through many door thresholds and double-door partings. On several occasions, front and rear entry doors were observed to be propped open with waste containers and other objects (Figure 12). Most notably students prop rear locked doors open to maintain access to and from athletic fields and awaiting buses in the rear driveway. This results in significant heat loss and air infiltration during heating months. Recommendations include unlocking the door or providing access (key card) to the after school program coordinators (e.g., athletic coaches).

Figure 12 – Propped Open Rear Entry Door

Air Sealing

Based on the thermal imaging survey and visual observations, air leakage occurs through windows and entry doors. Although this is typical even for a modern school building, simple measures can significantly reduce air leakage. Recommended measures for windows include: 1) adjusting jamb seals on operating windows; 2) adding weather-stripping; 3) caulking interior frames and moldings; and 4) locking/clasping windows to maintain a complete seal.

Figure 13 – Window A/C Unit (January)

Air sealing of all door units can be improved with weather-stripping. All door and window units should be regularly inspected (every 2 to 3 years) to ensure proper operation, identify faulty seals, and to identify any deteriorated caulking requiring replacement.

A window air-conditioning unit remains in place year round in Room C135 (Figure 13). As evidenced by thermal imaging, this results in substantial air leakage and thermal transfer. Standard procedure should be to remove all window units during winter months.

Other air sealing recommendations include inspecting all exhaust and ventilation ducts to determine if they have a positive pressure actuated damper. Dampers are recommended on all exterior ducting to prevent passive air leakage.

Thermal Imaging Survey

The thermal imaging survey was completed on the morning of November 22nd, 2011 and on January 5th, 2012. Outdoor ambient temperature ranged between 28°F and 42°F. The survey was conducted using a FLIR© B-CAM infra-red (IR) camera. The building exterior and interior envelope and major mechanical and electrical equipment were surveyed with the IR camera. IR camera surveys not only identify heat transfer through building envelopes, they also identify trapped moisture, electrical system overloading, heat loss through ducting and piping, high energy lighting fixtures, and energy intensive plug load equipment. Appendix B presents the survey report.

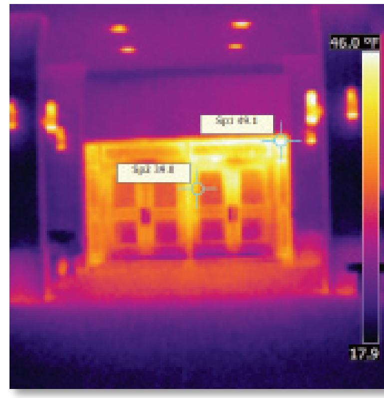


Figure 14 – Main Entry Doors

The IR surveys revealed the following notable observations at the ORHS:

- The thermal integrity of the envelope (walls and roof) is relatively good. However, thermal bridging of interior metal wall studs is evident (Figure 15).
- A large amount of rooftop mechanical equipment including air handling units, exhaust fans, and passive ventilation ducts release interior conditioned air (65°F to 72°F) to the atmosphere in winter months.
- Rooftop air conditioning condensers are operating at very high temperatures (100°F) during cold winter temperatures (Figure 16).
- Poorly sealed windows and doors provide a significant amount of thermal transfer and air leakage (Figure 14).
- Cold air is being drawn into the building at door openings indicating the building interior is under negative pressure (vacuum).
- The concrete foundation wall extending above grade provides substantial thermal transfer.
- The exterior wallpack lighting fixtures operate at very high temperatures (87°F) indicating that they are inefficient units.
- Ballasts on the metal halide lighting fixtures in the gymnasium operate at very high temperatures (+155°F) (Figure 19).
- Uninsulated ducting and piping above the ceiling results in heat loss to a semi-conditioned space. Recorded temperatures above the suspended ceiling ranged from 68°F to 74°F which is higher than expected.

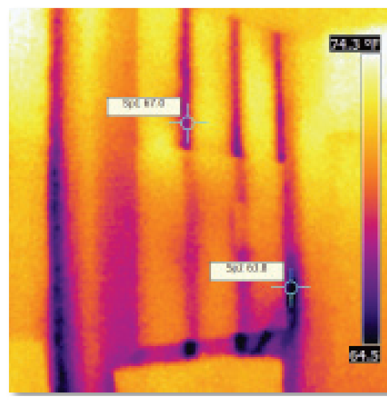


Figure 15 – Thermal Bridging of Metal Wall Studs (interior)

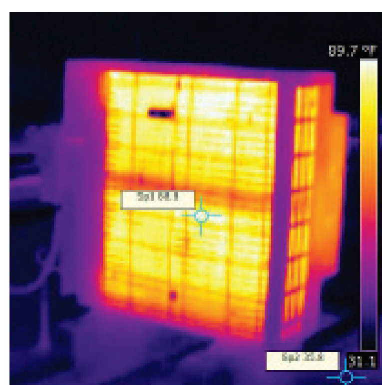


Figure 16 – Operating Rooftop A/C Condenser (January)

- Electronic equipment including photocopiers, overhead LCD projectors, and computers/monitors operate at high temperatures and increase heat loading of the building.

Electrical Systems

Supply & Distribution

Grid electricity is supplied to ORHS in the main electrical room located on the southwest side of the building adjacent to the boiler room. Several sub-distribution electrical rooms are located in the building. Minor code compliance issues noted during the inspection include open junction boxes (missing covers), potentially overloaded circuit breakers, and water stains on the ceiling above a main circuit panel presumably a result of roof leaks (Figure 17).

Figure 17 – Water Stains around Electrical Panel Conduit

Lighting Systems

As presented in Table 9, there are a variety of lighting fixtures and lamp types in the ORHS. Lighting fixtures in the building consist mainly of recessed mounted T8 fluorescent fixtures and surface mounted compact fluorescent lighting (CFL) fixtures. All exterior lights are metal halide fixtures. Exit signs are LED units.

In general, lighting densities in the building exceed recommended standards. Overall lighting control can be improved to reduce energy consumption. Control of lighting during unoccupied periods is poor. Lighting was observed to remain on during unoccupied periods including common areas such as corridors, cafeteria, gymnasium, and auditorium. According to facility personnel, lighting remains on for custodial staff and for security reasons.

Table 9 – Lighting Fixture Schedule

Fixture Lamp Type	Location(s)	Control	No. Lamps	Watts	Qty.	Total Watts
T8	Throughout	Switch, OS	2, 4, 8	32	1,647	135,744
CFL	Lobbies, Cafeteria, Library	Switch	1, 2, 6	17	55	19,920
Metal Halide	Gymnasium	Switch	1	465	42	19,530
Metal halide	Exterior (pole mounted)	Time-clock, photo-eye	1, 2	580	48	15,559
Incandescent	Auditorium	Switch	1	150	38	5,700
Metal halide	Exterior (wallpacks)	Time-clock, photo-eye	1	94	27	2,538
LED	Exit Signs	Constant on	1	5	46	230
				Totals:	**1,824**	**192,291**

Table 10 presents the energy consumption by lighting fixture type. The T8 fluorescent fixtures are the main source of lighting and account for 69% of all lighting energy consumption annually. Metal halide fixtures in the gymnasium and on the exterior poles are the other main sources of lighting each accounting for 10% of lighting energy consumption. CFL lamps are used in the two lobbies (recessed cans), the cafeteria, and in the library accounting for 7% of lighting use. Incandescent fixtures in the auditorium account for 3% and the twenty-seven (27) exterior metal halide wallpack fixtures account for 2% of lighting energy consumption.

Table 10 – Lighting Fixture Energy Consumption

Fixture Lamp Type	Location(s)	Est. Usage (kWh/year)	% of Total
T8	Throughout	271,488	69%
Metal Halide	Gymnasium	39,060	10%
Metal halide	Exterior (pole mounted)	37,342	10%
CFL	Lobbies, Cafeteria, Library	25,840	7%
Incandescent	Auditorium	11,400	2.9%
Metal halide	Exterior (wallpacks)	6,091	1.6%
LED	Exit Signs	1,546	<1%
	Totals:	**392,766**	**100%**

Lighting density measurements in ORHS were obtained to establish if building illumination is consistent with the *Illuminating Engineer Society of North America* (IESNA) standards for the prescribed use. These measurements were obtained during normal operating conditions on November 21st, 2011 between the hours of 0945 and 1146. Table 11 presents the lighting density measurements obtained in units of foot-candles (FCs).

Figure 18 – Library Light Fixtures

Lighting data logger instruments were used to determine lighting operation schedules in representative areas of the building including classrooms, the administration office, the library, and common spaces including corridors, student gathering areas (core), and the cafeteria. The lighting logging data graphs are presented in Appendix C. In summary, the logging data indicates:

Figure 19 – Suspended T-8 Fixture

- Lighting is well controlled in classrooms and operation is consistent with occupancy schedules. It was also observed that many teachers use the single-lamp switch setting and task lighting (desk and floor lamps) which reduces energy consumption.
- Lighting control in the administration offices and the library are consistent with occupancy schedules.
- Custodial staff turn lighting on and off while they are servicing rooms thereby limiting lighting operation (it is noted that school custodial staff often leave lighting on for extended periods but that was not evident at ORHS).
- Common area lighting remains on for extended periods and operates when the building is not occupied including evenings, holidays, and weekends. For example, the lighting logger was installed in the Junior Core area on 11/22/2011 at 1230 and the lights remained on until the logger was removed on 12/2/2011 (more than 10 days). Lighting in the corridor outside of the cafeteria consistently operates from 0700 to 0200 (19 hours per day). Other corridors were also observed to have lighting on during non-occupied periods including nights and weekends.

The T-8 lamp fixtures are relatively efficient units. While replacement of the fixtures would not provide a reasonable payback on investment, adding controls to reduce the frequency of operation is recommended especially in common spaces such as corridors where lighting is poorly controlled. Time and motion controllers can be used in combination where the timer is the primary control device and the motion sensor is the secondary control –this also provides a security alert function where operating lights would indicate occupancy when the school is closed (facility personnel indicated that they leave common area lighting on for security).

Reduced operating frequency of the exterior pole mounted fixtures is also recommended. This is best achieved with zone control of lighting. For example, lighting for the adjacent parking areas could be turned off at 10:00pm when they are typically empty (a few fixtures could remain on for security purposes). There are a significant number of fixtures along the rear of the building which could be reduced while maintaining security lighting.

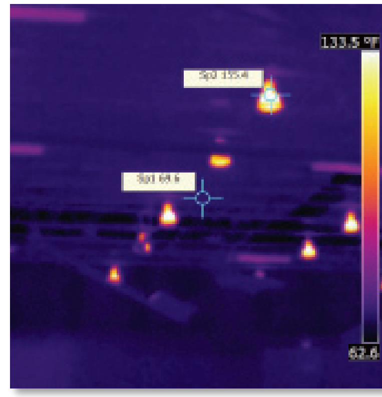


Figure 20 – Gymnasium Light Fixtures

The library and cafeteria fixtures are inefficient based on the net illumination that they deliver. These fixtures use multiple CFL bulbs with a combined wattage of 306. As shown in Figure 18, the fixture is designed to disperse lighting toward the ceiling. Approximately 20% of the fixture illumination is delivered at the working surface. Replacing these with high efficiency suspended decorative fluorescent (T-8) fixtures (Figure 19) that are lowered toward the working surface would reduce the lighting consumption by nearly 70% in these spaces. Other options include removing some bulbs from the fixtures and adding task lighting including desk lamps, floor lamps, and wall mounted fixtures at the reading surface.

The high intensity metal halide fixtures in the gymnasium are high wattage units that operate at very high temperatures (Figure 20). Replacing the existing fixtures with super T-5 lamp fixtures will significantly reduce energy consumption and improve lighting density and quality in the gymnasium (Figure 21).

IESNA Standards

Most spaces in the building, including common areas and meeting rooms exceed IESNA standards. Methods to reduce lighting densities include reducing the quantity of fixtures, replacing them with lower-wattage fixtures, and installing lower wattage bulbs in the existing fixtures. Other methods to reduce lighting density include replacing overhead lighting with task lighting, adding multiple control zones, adding daylighting controls and adding dimming controls. Newer technology fixtures provide higher lighting density per watt than the existing older fixtures and provide improved lighting quality. The lighting density data is included in Appendix C.

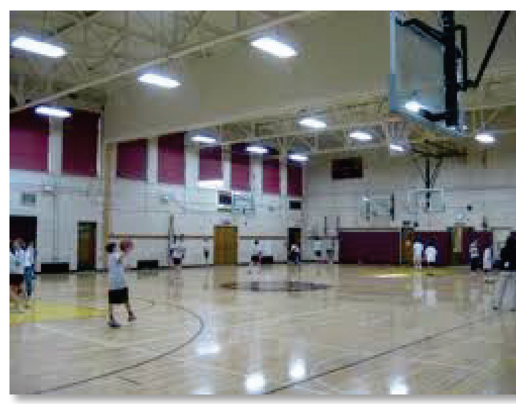


Figure 21 – Super T-5 Fixtures (typ.)

In general, lighting densities in the ORHS consistently exceed IESNA and recommended standards resulting in increased electrical energy consumption. The most significant increased lighting densities were measured in common spaces including lobbies, corridors, stairwells, and student gathering areas (core). Lighting densities in some classrooms and offices are two and three times higher than the recommended density (e.g., T101, T102, T106, T110, C226, and the main office). The classrooms with lower lighting densities (~30 FC) had the single setting lamp (1 lamp) on and the higher density rooms had both light switches on (3 lamps). Recommendations include completing a comprehensive lighting density study and reducing lighting densities throughout the building. The gymnasium is the only space where lighting density is significantly lower that recommended. These metal halide units are recommended for replacement with high-efficiency super T-5 fixtures which will provide higher lighting density than the existing fixtures.

Table 11 – Illumination Densities

Location	Lighting Density (FC)	Recommended Density (FC) (1)
Library	30	30
L1 South corridor	27	5
C137	38	30
C132	24	30
C126 guidance	26	30
C127 computer	29	30
Senior core	23	5
T101	102	30
T102	75	30
West T corridor	48	5
T106	62	30
T110	59	30
T112	27	30
Learning lab	27	30
L151	68	50
L150	29	50
C120 conference	64	30
Main office	78	30
1a classroom	55	30
Teachers room	30	30
Gymnasium	26	75
Art	46	50
Music	51	30
Cafeteria	27	10
West stairwell	36	5
C221 computer	24	30
Junior core	32	5
Corridor to core	43	5
2nd fl special education	56	30
L253 lab	70	50
C226	95	30
L252 lab	34	50
C223	33	30
T206	36	30
T207	28	30
T202	33	30
3rd floor north stairwell	21	5
3rd floor hallway	71	5
3rd floor south stairwell	37	5
North hallway	43	5
Gym lobby	46	5
Library	30	30
South corridor L1	27	5

(1) Based upon IESNA standards and AEC recommendations.

Plug Loads

Plug loads for the ORHS were determined based on equipment nameplate information. The operating time for each item is based on observations, occupant loading, schedule, and typical operating time for the equipment. Plug loads are categorized as appliances, electronics and office equipment. Appendix F presents an inventory of all plug load equipment.

Based on this analysis, the total annual plug load is 232,047 kWh. Office equipment, computers and electronics account for the majority of plug load energy consumption (53%). Appliances account for an estimated 47% of total energy consumption.

Table 12 – Plug Load Energy Consumption

Category	Location(s)	Est. Usage (kWh/year)	% of Total
Office Equipment, Computers, Electronics	Throughout	122,466	53%
Appliances	Throughout	109,581	47%
	Subtotals:	**232,047**	**100%**

A total of eight (8) display refrigerators and vending machines are located in the building. These are energy intensive appliances consuming a substantial amount of energy annually. Six (6) compact refrigerators and nine (9) standard refrigerators were inventoried (excluding commercial units in kitchen). Recommendations include consolidating these units with standard size ENERGY STAR® rated units. A total of fifty-four (54) overhead LCD projectors were inventoried including older units and ceiling mounted units (SmartBoards). An overhead projector was observed to remain on when the classroom was unoccupied (Figure 22). Forty-five (45) computer printers were observed and older units that are not used should be unplugged.

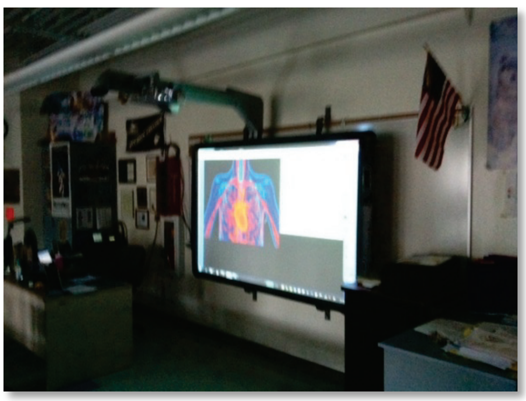


Figure 22 – Operating SmartBoard in Unoccupied Classroom

A total of 279 desktop computers and 170 notebook computers were inventoried which provides approximately one computer for every 1.6 occupants (students and staff). Additionally, many of the staff utilize iPads®. Recommendations include removing older and unused computer systems.

Motors

Electrical motors are used for the elevator, air handling unit (AHU) fan motors, and hydronic pump units. Variable frequency drive (VFD) controllers are typically recommended for larger motors (over 5 horsepower). Most of the larger motors have older VFDs installed. Recommendations include verifying function of the existing VFDs and installing new digital programmable VFDs on all pumps greater than 5-HP in size. Replacement of failed motors with premium efficiency NEMA rated motors is recommended.

Emergency Power Systems

An on-site diesel powered generator supplies the building with electricity during grid outages.

Plumbing Systems

Domestic Water Supply

Domestic water supply for the ORHS is provided by the Town of Durham. Water demand for the building is expected to be moderate and includes lavatory facilities (toilets and sinks), laundry facilities, and kitchen uses (cooking and dish washing). Shower facilities in the locker rooms do not appear to be frequently used.

Domestic Water Pump Systems

Domestic water pump systems were not identified in the facility.

Domestic Water Treatment Systems

Domestic water treatment systems were not identified in the facility. Considering the large amount of hydronic piping and heating equipment, a chemical treatment system should have been included in the 2004 mechanical design. Water quality as measured by alkalinity, pH, and mineral content significantly affects hydronic systems and equipment service life, performance efficiency, and maintenance and repair costs. For example, high mineral content will result in the formation of scale on the energy recovery wheels thereby reducing the performance efficiency due to reduced capacity of the fins to accept energy from the water.

Water quality testing is recommended and a chemical treatment system should be installed on the hydronic system based on the measured parameters.

Domestic Hot Water Systems

Figure 23 – Domestic Hot Water System

Domestic hot water is provided by two (2) 375-gallon natural gas fire tank heating units and an insulated 375-gallon tank provides storage for high demand events. The DHW distribution piping in the building appears to be well insulated. The system capacity appears to exceed occupant demand requirements. Recommendations include turning one of the heaters off and closing the valve to the storage tank and monitoring DHW capacity to ensure that the single tank will provide adequate capacity (this is a standard practice). The systems remain operating during summer break consuming a considerable amount of natural gas. Recommendations include installing a gas fired demand controlled tankless unit sized to accommodate the low demand during the summer.

Hydronic Systems

Space conditioning is provided by heat pumps and hot water coils connected to a hydronic loop. Water is circulated by two (2) 30 horsepower circulation pumps located in the mechanical room. Sections of piping insulation in the attic is missing resulting in heat transfer to the unconditioned attic space. Recommendations include replacing the missing insulation. Heat losses from the hydronic system into the attic space increase heating fuel consumption and contribute to ice damming by warming the roof and melting accumulated snow.

Mechanical Systems

Heating Systems

Heating systems are relatively inefficient. Low boiler combustion efficiencies, poor envelope insulation, uncontrolled combustion makeup air, and the lack of energy recovery capacity results in a substantial amount of heat loss and total system inefficiency. Based on accounts by building occupants and as evidenced during the evaluation, heating distribution throughout the building is poor. Occupants indicated that some rooms are consistently overheated requiring open windows in winter months while other rooms remain consistently colder than thermostat set point temperatures resulting in reduced occupant comfort. Over-heating and inconsistent temperatures of interior spaces was confirmed by IAQ measurements.

Figure 24 – Cleaver-Brooks® Boilers (3)

Three natural gas fired hydronic boilers provide heating for the building. The Cleaver-Brooks® units are approximately 9 years old (manufacture date of 2003) and are relatively inefficient compared to available boiler units.

Table 13 – Heating Supply Systems

Heating Unit	Unit Description	Area(s) Served	Output (MBH)	Age (yrs.)	AFUE (new)	Control Type
Boiler No. 1	Cleaver-Brooks 150 LE	Whole Building	6,124	9	82%	DDC
Boiler No. 2	Cleaver-Brooks 150 LE	Whole Building	6,124	9	82%	DDC
Boiler No. 3	Cleaver-Brooks 150 LE	Whole Building	6,124	9	82%	DDC

They are rated at 82% combustion efficiency when new and considering the age of the units, the de-rated combustion efficiency is less than 79%. Modern natural gas fired commercial condensing boiler units can achieve efficiencies as high as 98%.

Current operation of the boilers is a lead-lag scenario where only one boiler is operating under standard load conditions. Several issues were noted during the inspection including:

- The posted boiler inspection certificates (NHDOL) expired on 10/22/2011 (noted on 01/07/2012).
- Boiler service and inspection records are not maintained in the boiler room.
- An odor of burning rubber was notable emanating from the combustion head gasket. This was detected in the adjacent corridors as well.
- There is no energy recovery system on the dedicated rooftop air handling unit (AHU-15) providing combustion air to the boiler room.
- AHU-15 has an internal heating coil and provides hot air to the boiler room when the ambient temperature in the boiler room was in excess of 90°F.
- The AHU-15 heating coils and three (3) suspended coil-fan heaters were supplying heat to the boiler room when the ambient room temperature was in excess of 90°F.
- A thermostatically controlled gravity vent above the boilers appears to remain 100% open while AHU-15 and the suspended unit heaters are supplying heat to the space.
- A significant amount of heat is lost through the boiler exhaust stacks.

Recommendations include retro-commissioning of the entire heating supply systems including combustion air supply. Other recommendations include installing heat recovery systems such as stack economizers and/or energy recovery ventilators in the boiler room. Replacing one of the boiler units with a single or multiple high-efficiency condensing unit(s) and making it the primary unit would provide considerable cost savings. This primary unit could be sized to accommodate 80% to 90% of the annual heating load and the existing boilers would be controlled to provide secondary / reserve heating capacity during peak heating periods.

Cooling Systems

Cooling of the ORHS is limited to the administration offices, library, auditorium, computer classrooms, the video production room, the main electrical room, and several smaller electrical and data equipment rooms. Total cooling capacity for the building exceeds 155 tons which appears excessive for the served spaces. Condensers are charged with R-22 refrigerant. It is noted that the use of refrigerant R-22 is no longer permitted (per USEPA) based on its high ozone depletion potential.

Figure 27 – Shoelace Tied to Condensate Pipe as Electrical Conduit Support

The Energy Efficiency Ratio (EER) for the larger condensing units is 11.5 or less. The smaller mini-split units are rated at a Seasonal Energy Efficiency Ratio (SEER) SEER of 11 or less. Operating efficiency tends to decrease with system age. As cooling condensing units fail, they should be replaced with the highest rated equipment available. The condenser piping insulation on the rooftop units is not outdoor exposure rated. Most of it has deteriorated and some sections have entirely fallen off of piping sections (Figure 25). On one condenser, maintenance personnel repaired the deteriorated insulation with duct tape (Figure 26) instead of replacing it (recommended best practice). All condenser piping insulation should be replaced with outdoor exposure rated insulation.

Figure 26 – Duct Tape on Deteriorated Pipe Insulation

Figure 25 – Deteriorated Condenser Pipe Insulation

As prescribed by the 2009 IECC, the current minimum SEER for smaller cooling systems is 13 and larger units are rated at a minimum EER of 11.2. Modern cooling systems can achieve SEERs up to 24. As example, replacing a unit with a SEER rating of 8 with a new unit rated at 16 would reduce energy consumption by 50% and provide an equivalent cooling capacity.

Pumps

A total of forty-four (44) hydronic pumps exist in the building with motors ranging from 1/3 horsepower (HP) to 30 HP. Older style variable frequency drive (VFD) controllers are installed on most of the larger pumps. Several of the pumps are leaking and corroded (Figure 28). Maintenance personnel have placed buckets beneath them or installed a drain hose leading to a floor drain. Maintenance of all pumps is recommended to eliminate leaks, increase service life, and to prevent catastrophic failure resulting from a ruptured pressure relief valve or failed valve packing.

Figure 28 – Leaking Hydronic Pumps with Buckets

Recommendations include installing new digital programmable VFD controllers on the main heating system pumps in the boiler room (HWP-1 and HWP-2) and adding VFDs to all pumps larger than 5-HP.

Controls Systems

A proprietary Siemens® direct digital controls (DDC) system was installed during the 2004 construction. It was designed to control all of the heating, cooling, and ventilation equipment. The DDC system was never commissioned and operation is not optimized. Facilities management staff and subcontracted controls firms do not have a competent understanding of the DDC system.

Heating and ventilation systems are scheduled to operate on a very high frequency and are not consistent with occupancy schedules. Equipment was observed to be operating during unoccupied periods including evenings, holiday periods, and weekends. Based on the large number of ventilation equipment and the operating schedules, ventilation equipment accounts for a substantial portion of electrical consumption at the ORHS. Data logging of several air handling units verifies the excessive runtime (Appendix F). Measured runtimes vary from 82.5 to 116.0 hours per week. Typical AHU runtime durations for similar use spaces in a K-12 facility with modern ventilation equipment and an optimized DDC system (occupancy and event scheduled) are 25 to 35 hours per week. The summary logging data presented in Table 14 is indicative of a poorly controlled operating schedule. Notably, AHU-4 that serves the southwest wing (classrooms) operated non-stop from Friday through Sunday when the building was unoccupied. Comparison between actual AHU runtime (100% outdoor air) and typical runtime (based on the space use) indicates an increased runtime of 3 to 4 times. According to the monthly electrical consumption data, this operating schedule continues 12 months out of the year including summer break.

Table 14 – AHU Data Logging Summary

AHU No.	Area Served	Daily Schedule	Time Schedule	Runtime (hrs/day)	Runtime (hrs/week) Actual	Runtime (hrs/week) Typical	Actual v. Typical
AHU-4	Southwest Wing (Area B)	Fr/Sa/Su	0000-2400	24.0	72	-	-
		Mo-Th	0500-1600	11.0	44	-	-
				Subtotal:	116	35	331%
AHU-13	Gymnasium	Su-Sa	0600-2200	16.0	112	30	373%
AHU-18	Stage Area	Mo-Fr	0600-2230	16.5	83	25	332%

Although a current service contract was not provided by the Facilities Manager, Aramark is apparently under contract to provide services including controls repair and schedule optimization on a quarterly schedule. Based on the current operating condition of the DDC systems, the services provided by Aramark are unclear.

Recommendations include an independent evaluation of the controls system by a Controls Engineer. This assessment should determine the operation of the current system and identify any necessary repairs. Additionally, the report should provide a feasibility assessment for replacing the proprietary Siemens® DDC system with a non-proprietary BACnet® compatible system with remote web-based access.

Mechanical Equipment Energy Consumption

The electrical energy consumption for mechanical equipment was determined according to nameplate information and building function and occupancy schedules. Table 14 presents a summary of the mechanical equipment and annual energy usage. Appendix E presents the detailed inventory and the associated energy consumption for each piece of mechanical equipment. Mechanical equipment represents the highest usage among the three categories including lighting and plug loads. Total mechanical consumption is 1,050,463 kWh per year compared to 392,766 kWh for lighting and 232,047 kWh for plug loads.

Table 15 – Mechanical Equipment Energy Consumption

Equipment Type	Qty.	Item Manufacturer	Consumption (kWh/yr)	% of Total
Air Handling Units	20	Trane	556,661	53%
Air Cooled Condensing Units	7	Trane	406,214	39%
Hydronic Circulating Pumps	22	Bell & Gossett	47,904	5%
Mini-Split Air Conditioners	10	Mitsubishi	32,835	3%
Exhaust Fans	46	Greenheck	5,623	<1%
Unit Fan Heaters	28	Vulcan	1,134	<1%
Blower Coil Unit	1	Trane	94	<1%
		Totals:	**1,050,463**	**100%**

Ventilation Systems

Exhaust Ventilation Systems

Exhaust ventilation systems in the ORHS include numerous rooftop mounted fan units (Greenheck®). According to facility personnel, the units are controlled by time scheduled controllers. This could not be verified and as part of the recommended retro-commissioning of the automated controls system, operation and schedules of all exhaust ventilators should be optimized. This includes limiting control of the units to reduce energy consumption and the exhaust of interior conditioned air.

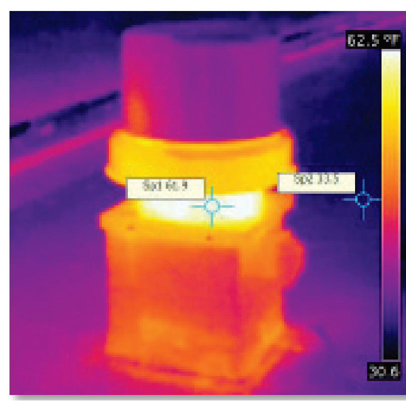


Figure 29 – Operating Rooftop Exhaust Fan (typ.)

Exhaust fan units provide several functions including humidity control, odor control, venting of VOC containing materials (e.g., cleaning solvents), chemical gas venting in laboratories, and venting of cooking fumes. Operation frequency and schedules for the fans units should be consistent with the use type and intensity of the vented space. For example, lavatories may be demand ventilated (interlocked with light switch) or they may operate constantly at a low rate during occupied periods. Spaces equipped with exhaust fans are commonly over-ventilated resulting in increased energy consumption. All exhaust controls and rates should be consistent with ASHRAE Standard 62.1. Fan ducting should have pressure actuated dampers to restrict air flow and heat loss when the units are not operating.

As evidenced by the infra-red thermal imaging survey (Figure 29), most of the exhaust fans were observed to be operating at full capacity resulting in the exhaust of heated air in January.

Figure 30 – Lab Exhaust Ventilator w/ no Guard

Other exhaust ventilator units include laboratory fan units for the chemical exhaust hoods. These fans are controlled by a manual switch at the hood unit. The fans do not have a guard for safety and to prevent bird nesting inside the units – installation of guards is recommended.

Exchange Air Ventilation Systems

Distribution and balancing of ventilation air throughout the building is poor. Some supply duct vents were observed to be completely closed and are under very high pressure. Supply vents in some areas have little flow while others operate at high flow rates resulting in nuisance drafts and noise. When the gymnasium air-handling unit is operating a significant pressure differential is evidenced by doors that are difficult to open due to the negative pressure (vacuum) forces. Poor distribution of ventilation is evidenced by inconsistent and highly variable CO_2 concentrations throughout the building.

Figure 31 – Air Flow Rate Above Ceiling

The above-ceiling plenum space is under substantial pressure. Measured airflow rates in the space exceeded 1,482 CFM (level 1, west corridor). Over-pressurization of plenum spaces increases the fire hazard due to the oxygen enriched atmosphere ("supercharge" effect) and airflow which promotes the propagation and uncontrolled spread of fire throughout the building.

The supply and return systems designed as part of the 2004 construction appear to be inefficiently configured. Long supply ducting runs provide inefficient distribution of air and increased pressurization of ducting resulting in greater leakage. There is limited return ducting and most return air travels through the above-ceiling space which results in very inefficient airflow. The configuration provides limited control and balancing of the air supply and return systems is complicated.

Specific issues noted with the ducting systems include:

- Leaking supply ducting due to: 1) missing joint sealant; and, 2) poorly connected supply ducting. Measured airflow leakage from a supply duct connected to AHU-4 was 2,570 CFM.
- Missing / uninstalled and damaged insulation on supply ducting.
- Damage of ducting (dents and crushing) incurred during installation.
- Incorrect support of main ducting (steel rebar and electrical conduit supported by the suspended ceiling grid) (Figure 32).

Figure 32 – Rebar & Wire Used for Duct Support

Recommendations include retro-commissioning of all exchange air ventilation systems. Inspection of the ducting should include a visual inspection, pressure testing and leak identification, and airflow measurements at supply vents. Recommended repairs include leak sealing, installing / repairing insulation, and balancing the entire supply system.

Table 15 presents a summary of the ventilation systems evaluation completed by Petersen Engineering (December 2011). It presents the total required supply and exhaust ventilation rates (IMC 2009) for each level in the ORHS based on space use and occupancy. The design ventilation rates are based on the schedules provided in the 2004 design. Comparison of the required and actual rates indicates that the design rates for the first level are 565% higher than required.

Table 16 – Ventilation Rates Comparison

Level	Required (IMC 2009)		Designed		Difference		Supply/Exchange Ratio
	Supply (CFM)	Exhaust (CFM)	Supply (CFM)	Exhaust (CFM)	Supply (CFM)	Exhaust (CFM)	
1	37,250	11,377	93,564	64,250	251%	565%	146%
2	9,168	6,004	16,525	7,700	180%	128%	215%
3	4,520	735	4,610	1,050	102%	143%	439%

Further analysis indicates that the ratio of supply ventilation to exchange ventilation capacity varies significantly by level. These ratios are unusually high and inconsistent by level. Figure 33 presents a graphical illustration of the required versus designed ventilation rates. It is expected that actual ventilation rates vary from the design rates.

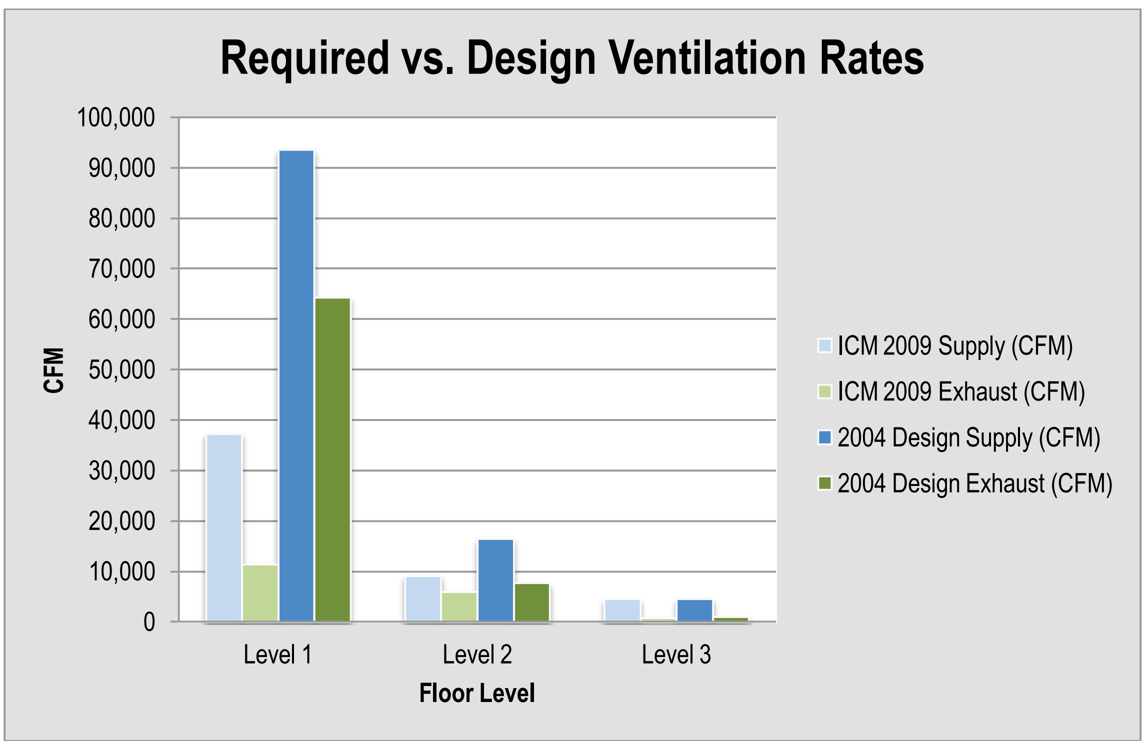


Figure 33 – Required vs. Designed Ventilation Rates (Petersen Engineering, Dec 2011)

Energy Recovery Ventilation Systems

Ten (10) of the twenty (20) AHUs have enthalpy energy recovery wheels. As evidenced by debris and scale on the recovery wheels, they are not being maintained by the facilities personnel (Figure 34). This results in fouling of the wheel fins and reduced performance efficiency and service life of the units. Annual inspection and cleaning of the wheels is recommended. Cleaning frequency depends upon water quality (mineral content) but every 2 to 4 years is generally recommended.

An energy recovery system is recommended for the boiler room. In its current operation, a substantial amount of heat is lost through the boiler room envelope and exhaust. Recovery systems include exhaust stack economizers and air to water exchange units. Recovered heat can be utilized for the building heating or DHW systems.

Indoor Air Quality

Indoor air quality (IAQ) is established based upon temperature (°F), relative humidity (%), and carbon dioxide (CO_2); measured in parts per million (ppm). This data provides the best representation of building ventilation performance and occupant comfort. They are also indicative of conditions that are detrimental to building systems including moisture intrusion and the potential for fungi growth (mold and mildew) and related damage of building materials.

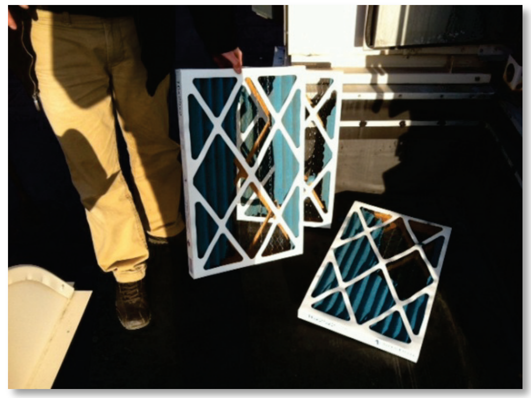


Figure 34 - Deteriorated AHU Air Filters

Recommended temperatures vary based on the season, occupant activity, and relative humidity levels. Generally, recommended setpoint heating temperatures in northern New England range between 67°F and 70°F and recommended cooling setpoint temperatures range between 73°F and 76°F. Relative humidity (RH) levels fluctuate consistent with seasonal atmospheric conditions. A range between 30% and 65% is recommended (ASHRAE). While there are no known adverse health effects related to elevated CO_2 concentrations, it can cause acute illness including headaches, drowsiness, lethargy, and nausea. For this reason, the U.S. Environmental Protection Agency (EPA) has established a recommended threshold concentration of 1,000 ppm.

Figure 35 – AHU Energy Recovery Wheel

The IAQ in the ORHS was measured on November 21st, 2011 between the hours of 0945 and 1146. The building was lightly occupied when the measurements were obtained. Forty-seven (47) IAQ measurements were obtained at representative locations throughout the building. Appendix C presents all of the measurements. Results of the IAQ measurements are summarized as follows:

- Temperatures in the building ranged from 68.7°F in the cafeteria, to 74.3°F in Classroom L253. The average recorded temperature was 71.5°F.
- Relative humidity levels varied substantially throughout the building from 15.7% in Classroom C223 to 27.3% in the library. The average relative humidity was 21.1%.
- CO_2 concentrations ranged from 432 ppm in Classroom C223 to 2,633 ppm in the west stairwell. Eight (8) CO_2 levels exceeded the EPA recommended threshold of 1,000 ppm.

IAQ data varies considerably throughout the building. This is indicative of poor distribution of conditioned air and unbalanced ventilation systems. Considering the relatively high capacity and frequency of ventilation systems in the ORHS, the elevated CO_2 concentrations are unexpected. Some areas of the building are over-ventilated while other areas do not have adequate ventilation. Other IAQ related concerns include inadequate maintenance of ventilation equipment including air handling units where fouled and deteriorated air filters were identified (Figure 34) and mold was observed inside AHU-4 due to a leaking rooftop. A high potential for fungal growth (mold and mildew) exists in the above ceiling spaces where roof leaks provide a source of moisture. Additionally, the energy recovery wheels on the air handling units are not being maintained / cleaned further increasing the potential for fungal formation (Figure 35). Recommendations include improved preventative maintenance of ventilation equipment and retro-commissioning of all supply and ventilation systems.

Secondary Observations

Observations noted herein are not directly related to the objective of the energy audit. Investigation of these items is beyond the defined scope of services and these observations are not intended to be inclusive of all building issues and code infractions. They are provided as anecdotal information for the ORCSD's consideration and may warrant further investigation.


Figure 36 – Structural Beam with Loose Bolted Flange Connection and no Fireproofing

Many of the provided secondary observations for ORHS relate to quality issues, incomplete work, and missing equipment. These items were either required by building code or where identified on the design drawings.

Structural Systems

It is noted that a comprehensive structural evaluation of the ORHS is beyond the intent and scope of this evaluation. The issues presented herein are secondary observations noted during the course of the energy systems assessment.

Structural issues identified during the building assessment include loose and missing bolted connections on structural steel members. On a steel structural member providing header support at the west gymnasium lobby and corridor the nut is does not appear to be torqued to the rated tension and the washer is not adequately seated on the flange. In the same vicinity, there are steel plates seated on the top of the CMU wall with protruding threaded rod. Uninstalled washers and bolts are resting on the plates. The function of the plates and bolted connections is unknown and a review of the design drawings should be completed to determine such. If the plates function as a structural element then the bolted connections should be completed.


Figure 37 – CMU Wall Plate with Missing Bolted Connections

A vertically descending crack in the interior west corridor wall was observed. This is most likely attributable to minor differential settlement of foundation bearing soils. Considering the age of the facility, settlement of bearing soils should be complete. Recommendations include periodic monitoring of the crack and if it continues to propagate in width or distance then evaluation by a NH licensed Professional Structural Engineer is recommended.

Structural steel framing for AHU-4 is poorly installed. It appears that the roof mounted column supports were installed at incorrect dimensions along the width of the framing assembly. The horizontal steel cross members are shorter than the distance between the columns and the installer inserted steel clips that are butt welded to the member bolt clip and to the accepting bolt clips on the frame. It is presumed that the strength of this field-engineered and fabricated connection does not provide adequate strength. Quality and workmanship of welds on all AHU steel framed assemblies are generally below industry standards. Bolted fan and motor damping frame connections (2) for the AHU-4 unit are incomplete. Bolts are not tightened which increases the potential for propagation of vibration thereby increasing forces exerted upon the unit and the main structural framing system. Recommendations include inspection of all framed assemblies by NH licensed Professional Structural Engineer to identify issues and to provide recommended repairs.

Considering the identified issues and consistently reduced level of workmanship and quality, a structural systems evaluation by a NH licensed Professional Structural Engineer is recommended. This would include a review of the structural design drawings and a focused field inspection to verify that installation meets the intent of the design and all building code requirements. Identified issues and recommended corrective actions should be provided in a findings report.

Roofing Systems

As noted herein, roof leaks are evident in several locations of the building. Previous attempts to repair the roofing systems have proved unsuccessful. Significant ponding in several areas of the roof is evident. Left unrepaired, this condition will reduce the service life of the roofing membrane and may result in damage to the building interior. The inlet invert elevation on several scupper drains is too high to sufficiently drain the roof (one drain pipe is set 1 inch higher than the roof deck). All scupper drain inlets should be a minimum of 2 inches below the roof deck. Some of the scupper screens are not secured and may become dislodged. The scupper drain beneath AHU-4 is clogged with debris and moss is growing around in the inlet. Location of the drain is poorly designed (directly beneath the AHU) making access difficult. Unsupported ducting for AHU-4 is lying directly on the roof membrane which will damage the membrane and conceal leaks (this condition will void the manufacturer warranty). Ducting should be raised and properly supported. All wall flashing and membrane terminations should be inspected. Deteriorated caulking should be replaced and all holes and gaps should be sealed with membrane manufacturer approved caulking compound.

Figure 38 – Clogged Scupper under AHU-4

Figure 39 – Gap in Masonry Wall Flashing Joint

Recommendations include implementing a roofing systems preventative maintenance program. In addition to repairing the existing issues (persistent leaks, ponding, and scupper drain elevations) this should include: 1) annual roof systems inspection by a qualified engineer, roofing consultant, or membrane manufacturer technical representative; 2) inspection, cleaning, and securing of all scupper drains; 3) inspection of poorly drained areas where ponding is evident; 4) inspection and repair of gaps in flashing joints and unsealed perforations (Figure 38); and 5) inspection and re-pointing of masonry wall mortar joints (wind-blown rain will permeate mortar joints cracks resulting in leaks).

Considering the repair history and persisting roof leaks, the ORCSD should verify that they have the original manufacturer warranty. If the warranty is not available then the manufacturer should be contacted. It is recommended that a membrane manufacturer representative inspect the current roof conditions and advise on necessary repairs to extend the service life of the membrane and to ensure that the warranty is not voided due to installation quality issues or a lacking maintenance program.

Building Code

Several building code issues were identified during the building assessment. Noted electrical issues include lighting and data wiring junction boxes with missing covers. Water staining was observed on some electrical circuit panel conduit and the source of the leaks should be identified and repaired. As evidenced by the IR thermal imaging, circuits in one of the panels located in the second floor electrical room was very warm (+95°F) which may indicate an overloaded circuit (Figure 39). Recommendations include completing a thorough IR review of electrical systems (transformers, distribution panels, and wiring) to identify potential overloading issues. Identified issues should be inspected by a licensed electrician for IEE and NFPA code compliance. Mechanical code issues include no demand controls for ventilation equipment. Inadequate control of combustion air supply for the boiler room was also noted. These issues were also identified in the *Facilities and Program Analysis Report* (DGA, December 2011).

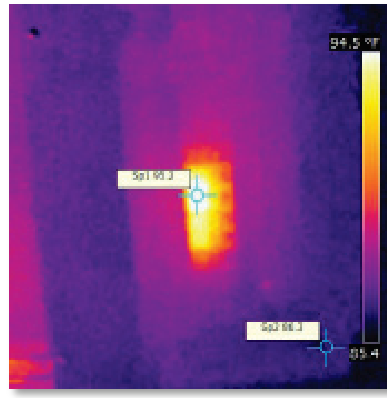


Figure 40 – Potentially Overloaded Electrical Circuit

Life Safety Code

Identified life safety code issues at ORHS include fire barrier wall penetrations without adequate sealing and fire proofing (Figure 40). Many penetrations are sealed with "blue" colored caulking which is typically used for joint sealing (not penetration sealing) and it has a lower fire rating. Fire dampers inside ducting through a fire barrier wall do not appear to be adequately sealed and operation of the units could not be verified.

A structural steel header beam in the west (gymnasium) lobby and corridor is not protected with fire-proofing (Figure 35). Fire-proofing of steel structural members is required by building code. Installation of fire-proofing material to all unprotected structural steel members is recommended. Fireproofing material installation should be inspected to ensure the integrity complies with code standards including composition, thickness, cohesion, and substrate adhesion.

Figure 41 – Unsealed Conduit in Fire Barrier Wall

Measured air flow in the above-ceiling space is excessively high. This condition promotes the propagation of fire due to the oxygen enriched atmosphere and high rate of air movement. Noted concerns include the fire rating of building materials inside the space including wiring, cabling, steel members, and wall assemblies.

Review of the as-built electrical building plan set revealed a note by the electrician. A hand written note by the electrician in the drawings questioned why smoke detection devices were not specified in the design drawings for the library. Installation and operation of the devices should be verified for code compliance.

Recommendations include completing a whole facility inspection by a NH licensed Professional Fire Safety Engineer (http://www.nh.gov/safety/divisions/firesafety/documents/FireProtectionEngineers.pdf). In addition to a thorough visual code compliance review, testing of all equipment is recommended including fire detection devices, notification devices, fire suppression systems, and smoke damper actuators. A findings report should be prepared providing corrective actions for all identified fire code issues. A copy of the report should be provided to the local Fire Department.

ADA Accessibility

No gross ADA accessibility standards compliance issues were identified during the building assessment. A *Facilities and Program Analysis* was recently (December 2011) completed by Davis-Goudreau Architects (DGA) of Portsmouth, NH. This report identifies several minor ADA compliance issues for the District's consideration.

Hazardous Building Materials

Based upon the construction date of the original ORHS building, hazardous building materials may be present. No evidence of hazardous materials was identified during the building assessment however all painted surfaces on original portions of the building should be presumed to contain regulated levels of lead. Based on the construction date of the addition and renovation portions of the building (c. 2004) it is presumed that there are no hazardous building materials present in those sections of the building.

D. FACILITY BENCHMARKING

ENERGY STAR for Commercial Buildings

The ORHS was benchmarked using the EPA's ENERGY STAR® Portfolio Manager for Commercial Buildings. This benchmarking program accounts for building characteristics, regional climatic data, and user function. It then ranks a building within its defined category amongst all other buildings entered in the program to date. The defining metric is the building Energy Use Intensity (EUI). If a building scores at or above the 75th percentile within its category then it becomes eligible for ENERGY STAR® certification pending an on-site validation review by a licensed Professional Engineer. Currently the program does not have categories for every commercial building type but they can still be entered into the program and checked against similar buildings to determine where the building ranks compared to the current national average. The average energy intensity for every building type category is constantly changing and theoretically is it reducing as more efficient buildings are constructed and existing buildings implement energy efficiency measures. Therefore, buildings that currently meet the eligibility requirements may not be eligible next year when they apply for annual re-certification.

The ORHS is defined as a "K-12 School" use building and it is not currently certified in the Commercial Building ENERGY STAR® program. Utility data for electric and heating fuel for the preceding twelve (12) months was input into the benchmarking program. Table 16 presents the annual energy use (through July 2011) and Table 17 presents a summary of the Statement of Energy Performance (SEP) benchmarking results. The SEP is presented in Appendix G.

Table 17 – Annual Energy Consumption

Energy	Site Usage (kBtu)
Electric – Grid	5,711,688
Natural Gas	8,925,563
Total Energy:	**14,637,251**

Table 18 – SEP Benchmarking Summary

Location	Site EUI (kBtu/ft²/yr)	Source EUI (kBtu/ft²/yr)
ORHS	74	144
National Median (K-12 School)	84	164
	% Difference:	**-12%**
	Portfolio Manager Score:	**64**

Compared to the high school facilities that have entered data into Portfolio Manager to date, the ORHS energy use is above the national average. The source EUI for the ORHS is 144 kBtu/ft^2/yr while the national average is 164 kBtu/ft^2/yr, meaning the ORHA uses 12% less energy than the average high school facility. Considering that the median age of high school facilities in the national database is much older than the ORHS, a significantly lower than average EUI is expected. With a score (64) below the minimum threshold of 75, the ORHS does not currently qualify for ENERGY STAR® certification.

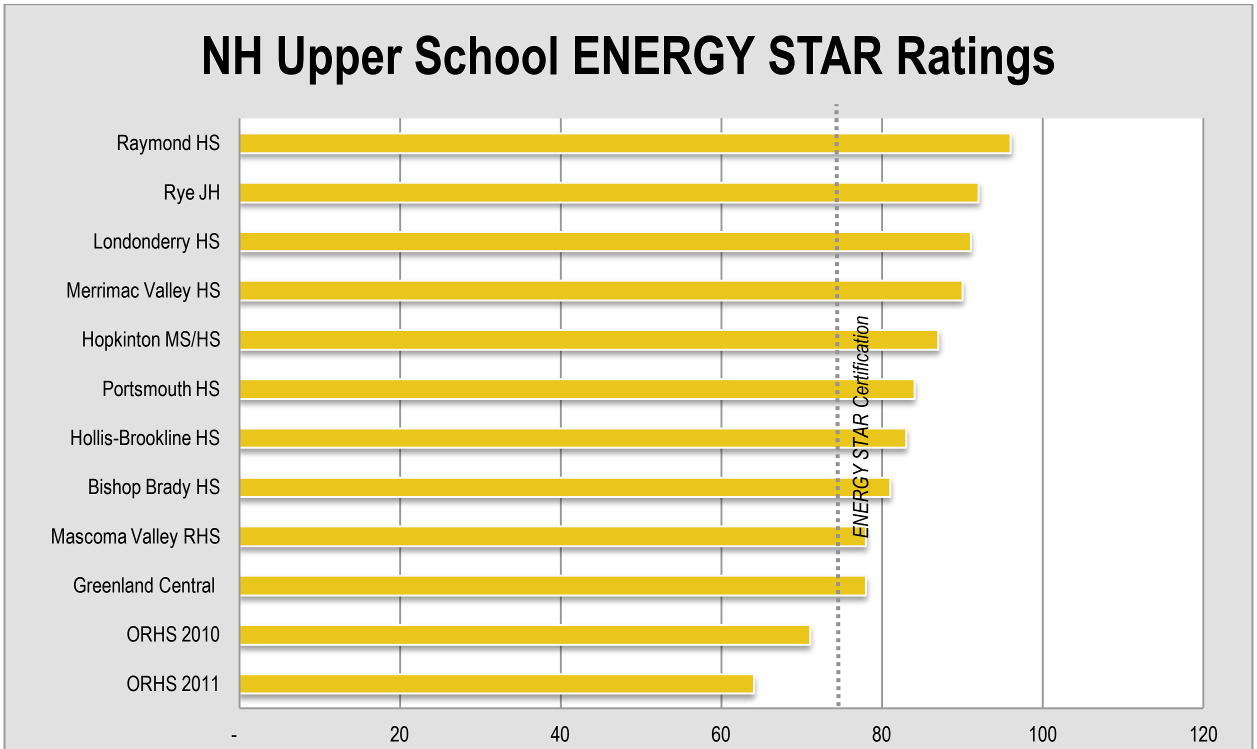
Regional Benchmarking

Regional benchmarking provides a valuable comparison of local facilities that are similar in use, function, and size. Three data groups were used to complete independent benchmark comparisons for:

1. ENERGY STAR Ratings and Energy Use Intensities (source and site)
2. Total Energy Costs by Student and Building Area

3. District Facilities Operations and Maintenance Budgets by Student and Building Area

As an initial comparison, the ENERGY STAR® ratings of ten (10) New Hampshire schools were compared to the ORHS. The selected schools provide a fair representation of regional junior and senior high school facilities located in the southern New Hampshire region. The selected schools and characteristics are presented in Table 18.



	ORHS 2011	ORHS 2010	Greenland Central	Mascoma Valley RHS	Bishop Brady HS	Hollis-Brookline HS	Portsmouth HS	Hopkinton MS/HS	Merrimac Valley HS	Londonderry HS	Rye JH	Raymond HS
ENERGY STAR Score	64	71	78	78	81	83	84	87	90	91	92	96

Figure 42 – Regional ENERGY STAR Ratings

As presented in Figure 41, of the eleven schools ORHS has the lowest ENERGY STAR® rating. The average score is 84 and with the exception of the ORHS, each building exceeds the minimum rating of 75 required for ENERGY STAR® certification. Considering that the ORHS facilities are relatively modern and efficient compared to the other schools, this low rating is unusual. It also is noted that the ORHS rating has declined from 71 since it was entered into the ENERGY STAR® program two years ago (2010).

The ratings consider use characteristics of the building to provide the most accurate comparison. For example, schools that have summer programs for students are expected to have a higher energy consumption than schools that operate nine months out of the year. The ENERGY STAR® program accounts for this higher use intensity so the school is not unfairly penalized.

Table 19 – ENERGY STAR Regional Schools

School	Location	Area (SF)	FTE	Density (SF/FTE)
Bishop Brady High School	Concord, NH	76,332	369	207
Greenland Central School	Greenland, NH	91,226	354	258
Hollis-Brookline High School	Hollis, NH	153,429	904	170
Hopkinton Middle/High School	Hopkinton, NH	74,589	329	227
Londonderry High School	Londonderry, NH	235,520	1,796	131
Mascoma Valley High School	Canaan, NH	57,740	439	132
Merrimack Valley High School	Penacook, NH	141,000	887	159
Oyster River High School	Durham, NH	198,000	675	293
Portsmouth High School	Portsmouth, NH	353,659	1,091	324
Raymond High School	Raymond, NH	106,000	444	239
Rye Junior High School	Rye, NH	67,891	216	314
			Average:	**223**

Figure 42 presents the source and site Energy Use Intensities (EUIs) for the eleven schools. EUIs are measured in units of energy per area or kBtu per square foot (kBtu/SF). Source EUIs consider all of the energy required to develop the energy and distribute the energy to the site location including inefficiency losses such as electrical distribution grids. Site energy is the energy consumed at the point of service or meter. Because natural gas (NG) requires a large amount of energy for extraction, refining, and distribution, the source EUI is higher than other heating fuels. This accounts for the relatively high source EUI for the ORHS of 144 kBtu/SF. At 74 kBtu/SF, ORHS also has the highest site EUI of the eleven schools. In contrast to the high source EUI for natural gas, the site EUI is less than other fuels because is burns more efficiently. Considering that the ORHS is a modern facility, the EUIs are unusually high. Notably, the Site EUI for ORHS increased 11% since 2010.

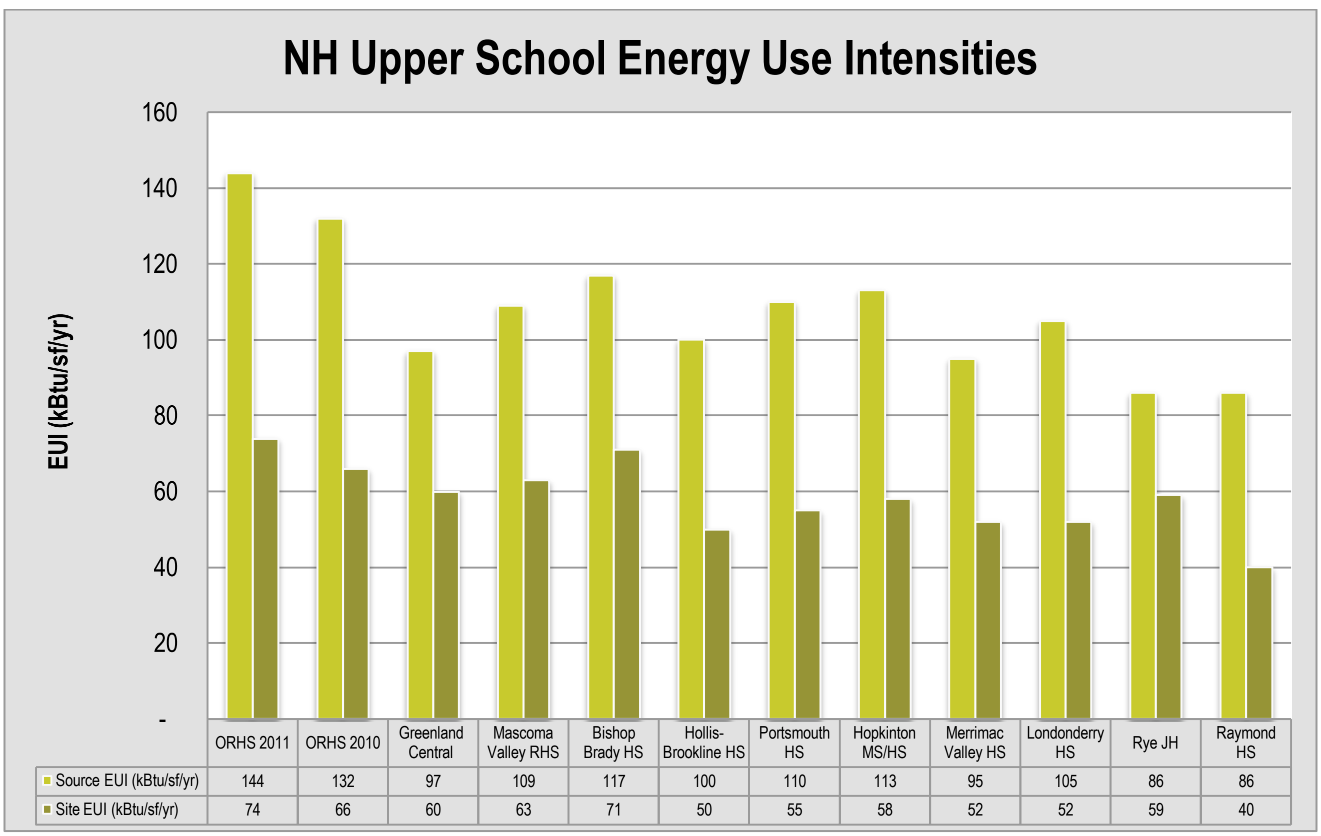
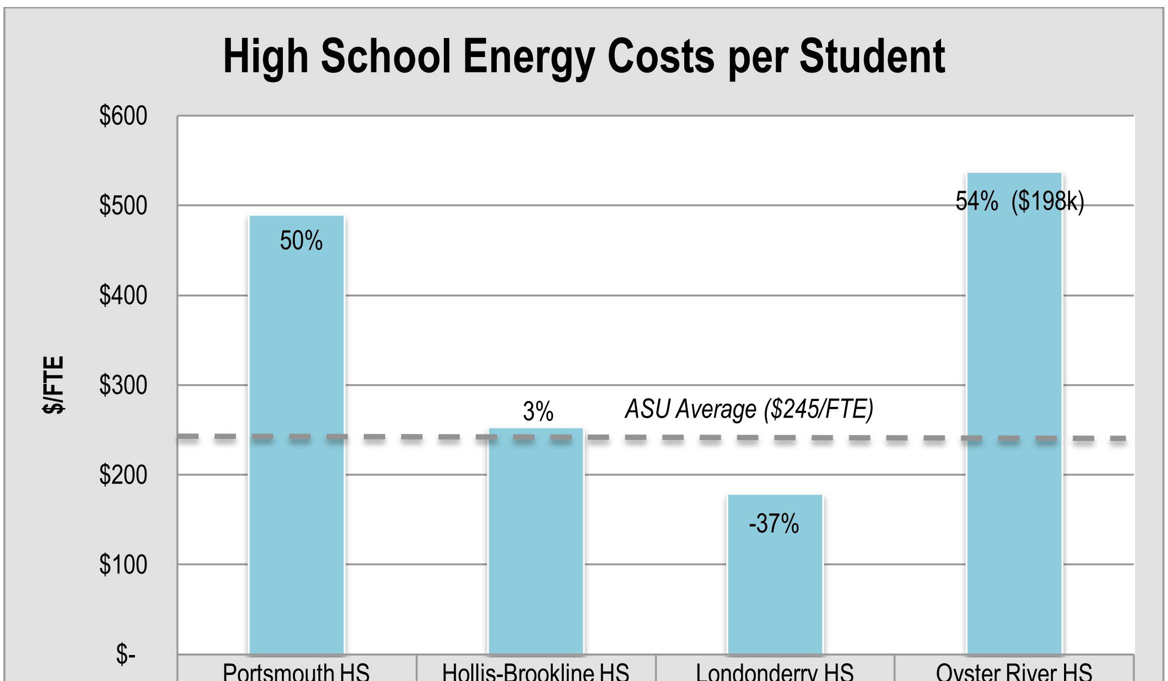


Figure 43 – NH Upper School Energy Use Intensities

The ORHS was compared to three (3) regional high schools that are very similar in use, area, and FTE. AEC has evaluated each of these facilities and we have an intimate understanding of how the building is being managed and operated by the Facilities Operations and Maintenance (FOM) groups. FOMs that have a more aggressive energy efficiency program in place show a clear and consistent reduction in energy consumption and costs such as Hollis-Brookline and Londonderry. Some FOMs are more focused on occupant comfort, such as Portsmouth High School where ventilation systems operate on a higher frequency than recommended and lighting densities are higher than required. The Portsmouth Facility Manager has made a conscious decision to over-ventilate and over-light the facility for the benefit of increased occupant comfort.

Figure 43 presents the energy costs per student (FTE) for each of the four High Schools. Londonderry has the lowest cost at $179/FTE and ORHS has the highest cost at $538/FTE. Comparing ORHS energy costs to the national average (American Schools and Universities, 2010), ORHS's annual energy costs are $198,000 higher. Comparing energy costs on a building area unit indicates that ORHS energy costs are $127,000 higher than the national average (Figure 44).

While both unit measurements of energy costs provide an indication of how well a building is being managed, energy costs per FTE is most indicative of building efficiency and performance. Providing adequate ventilation and conditioning is proportionate to the number of occupants. That is, as the number of building occupants or density increases, the ventilation rates should also increase proportionately. This requires increased electrical energy to operate the ventilation equipment and increased heating fuel to maintain a conditioned indoor environment.



	Portsmouth HS	Hollis-Brookline HS	Londonderry HS	Oyster River HS
Cost/FTE	$490	$253	$179	$538

Figure 44 – High School Energy Costs per Student

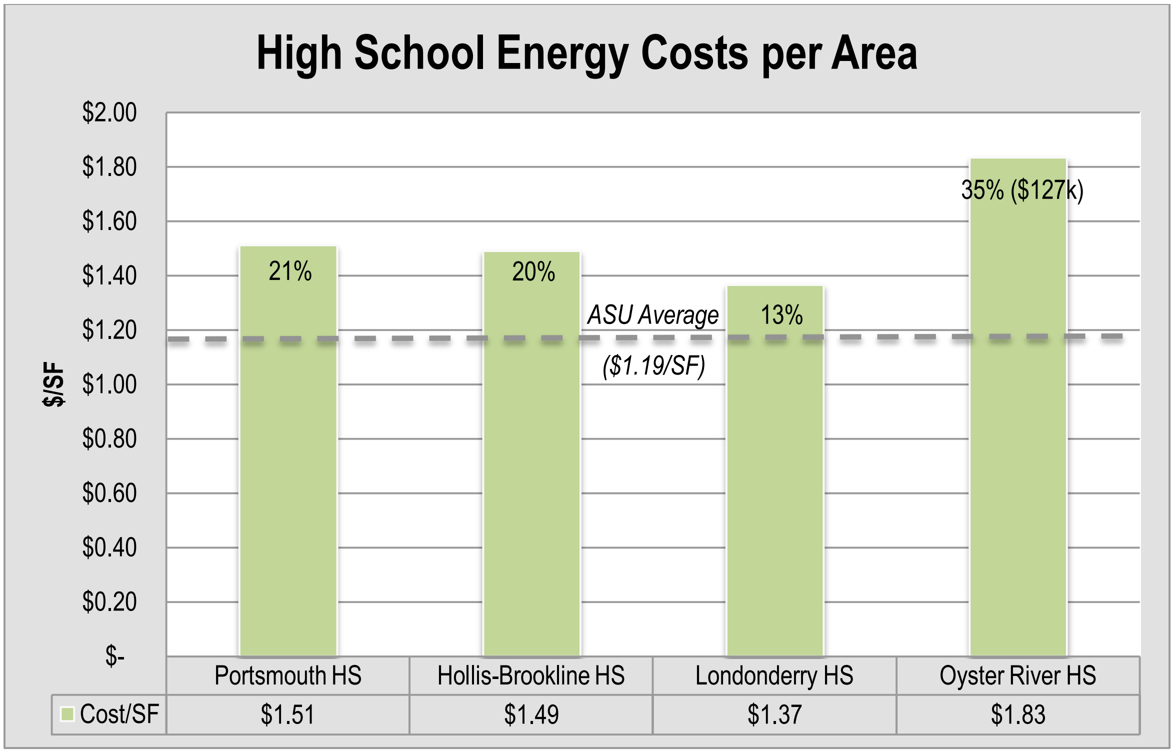


Figure 45 – High School Energy Costs per Area

As a final regional benchmark, school district FOM budgets (2010-2011) are compared to the national average. District comparisons provide an overall measurement of how efficiently FOM organizations manage and operate facilities. Budgets are more easily compared as district FOM budgets include all costs required for labor, subcontractors, materials and equipment, and energy costs to maintain and operate all K-12 facilities. District FOM costs also generally correlate to occupant comfort and satisfaction. Figures 45 and 46 present a graphical comparison of the five school districts for FOM costs by student (FTE) and by facility area, respectively.

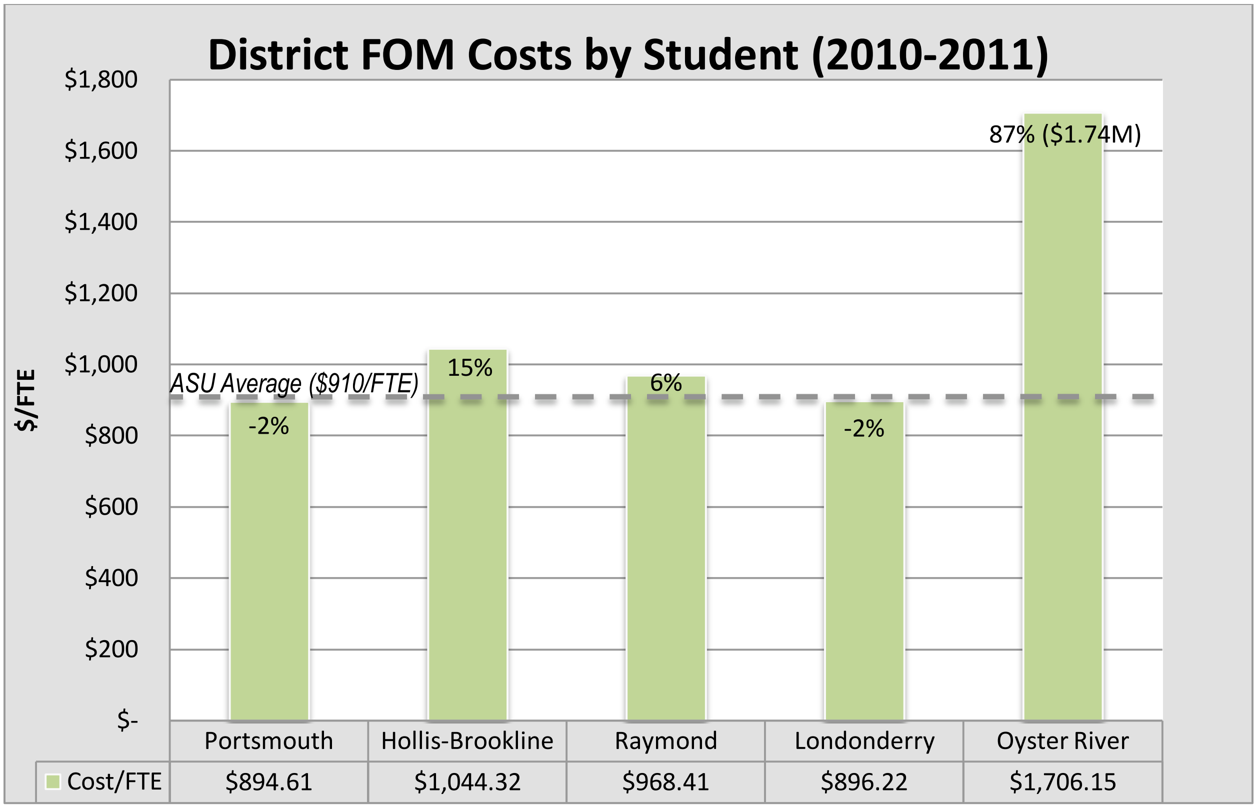


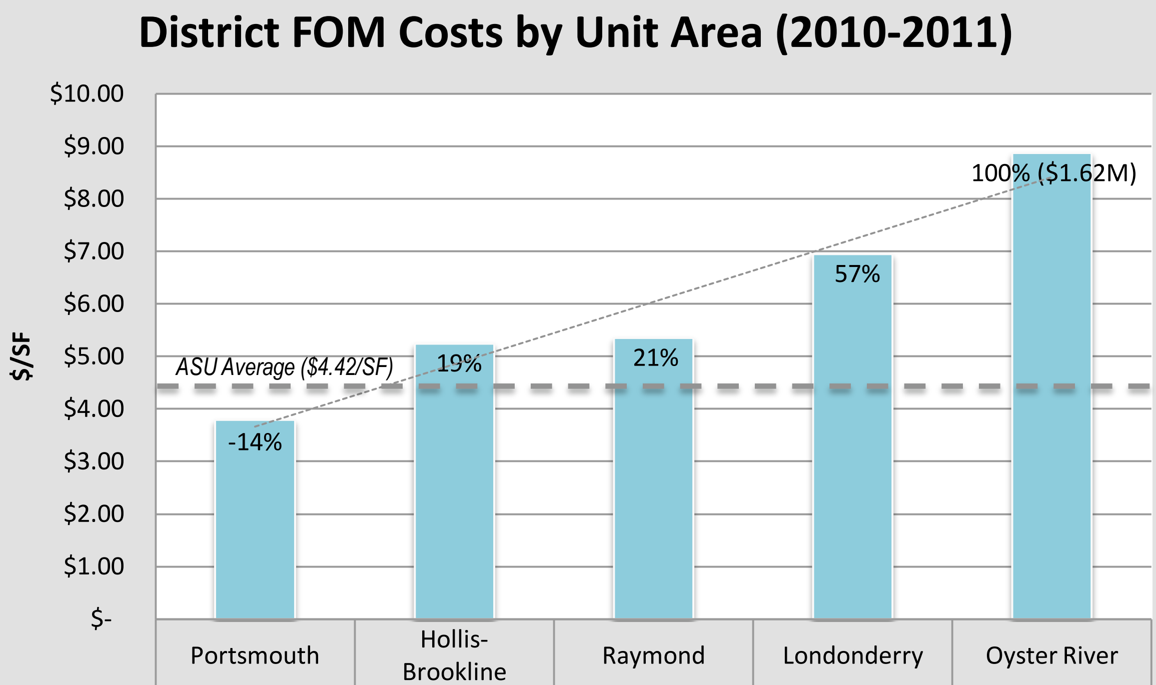
Figure 46 – District FOM Costs by Student (2010-2011)

ORHS is compared to four (4) regional school districts having a similar quantity and a size of K-12 school facilities (Table 19). At $1,706, the ORCSD FOM cost by student or FTE is the highest among the five districts and is nearly twice the national average. This results in a total annual budget that exceeds the national average by $1.74 million. The FOM budgets for the other four school districts are very consistent with the national average.

Table 20 – Regional School Districts

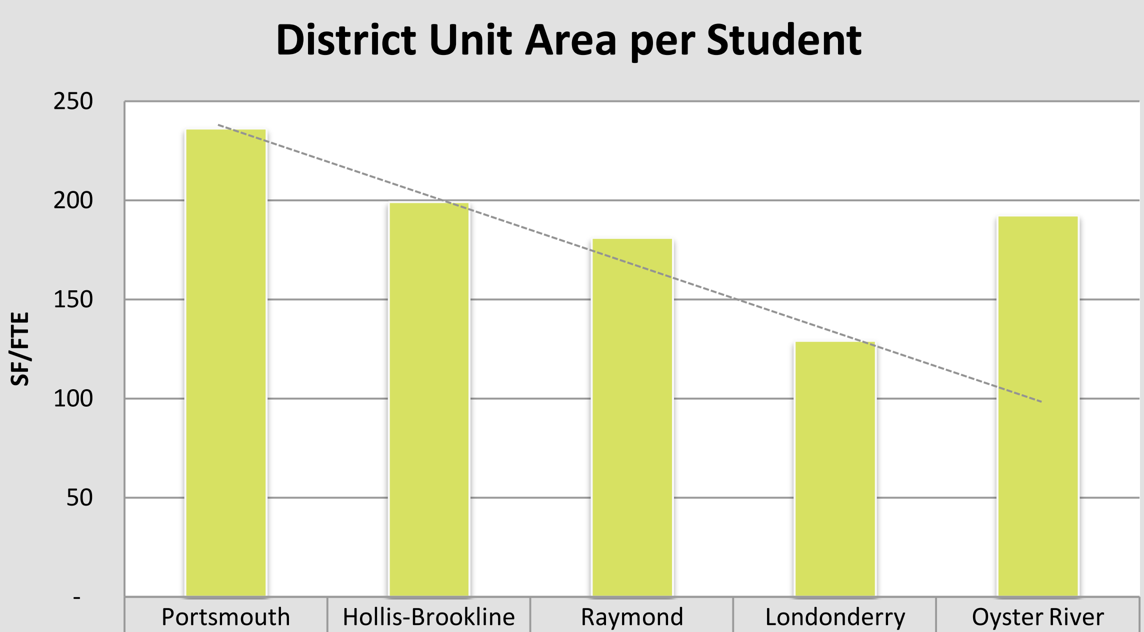
School District	No. of School Buildings	Total Area (SF)	FTE	Density (SF/FTE)
Hollis-Brookline	4	392,630	1,971	199
Londonderry	6	630,052	4,883	129
Oyster River	4	392,418	2,039	192
Portsmouth	6	632,584	2,679	236
Raymond	3	267,888	1,480	181
			Average:	**188**

Comparing district FOM costs by unit area suggests a similar trend with ORHS having the highest cost at $8.87/SF (Figure 46). Londonderry ranks as the second highest cost at $6.95/SF however this is partly attributable to a higher than average student density. That is, the Londonderry district yields 129 square feet per FTE and considering the higher than average student density, the FOM costs are expected to be higher. This trend is presented in Figure 47 which indicates a correlating increase in FOM costs to a decrease in area per FTE (increased density).



	Portsmouth	Hollis-Brookline	Raymond	Londonderry	Oyster River
Cost/SF	$3.79	$5.24	$5.35	$6.95	$8.87

Figure 47 – District FOM Costs by Unit Area (2010-2011)



	Portsmouth	Hollis-Brookline	Raymond	Londonderry	Oyster River
SF/FTE	236	199	181	129	192

Figure 48 – District Unit Area per Student

E. RECOMMENDATIONS

Energy Conservation Measures

Based on the observations and measurements of the ORHS, several energy conservation measures (EEMs) are proposed for consideration (Tables 20 to 22). These recommendations are grouped into three tiers based on the cost and effort required to implement the EEM. EEMs are ranked within each tier based on the capital cost for implementation versus the net estimated energy cost savings.

Tier I EEMs are measures that can be quickly implemented with little effort for no or little cost. They include routine maintenance items that can often be completed by facility maintenance personnel and changes in occupant behavior or building operation. Tier II items generally require contracted tradesmen to complete but can generally be implemented at low cost and within operating building maintenance budgets. EEMs that require large capital expenditure and budgetary planning (one year or greater) are categorized as Tier III measures.

Simple payback is calculated for the proposed EEMs. The cost to implement the measure is estimated based on current industry labor and equipment costs and the annual cost savings represents the reduced costs for energy savings. The net energy and cost savings for smaller EEMs is based on the estimated reduction of the associated energy consumption as defined in the model and equipment inventory. Using these costs, the payback period is then calculated as the number of years at which the capital cost of implementation equals the accumulated energy cost savings. Other qualitative considerations that do not influence the Simple Payback Method calculation but should be considered by the owner during the decision-making process include:

- Occupant comfort.
- Relative operation and maintenance requirements.
- Remaining useful life of equipment and systems to be replaced.

Energy cost savings are based on the current net electric utility charge of **$0.14** per kWh (PSNH) and a heating fuel cost of **$1.40** per therm (Unitil).

Many of the provided EEMs for ORHS relate to quality issues and incomplete work. These items were either required by building code or where identified on the design drawings. Other items relate to neglected maintenance and include establishing a formal preventative maintenance program.

Tier I Energy Efficiency Measures

Tier I EEMs are measures that can be quickly implemented with little effort for zero or little cost (Table 20). They include routine maintenance items that can often be completed by facility maintenance personnel, and changes to occupant behavior or building operation. Twenty-seven (27) Tier I EEMs are recommended.

Fourteen (14) of the Tier I EEMs are zero cost items. The majority of these items (12) are associated with recommended corrective actions for ORHS facilities operations. The subtotal annual cost savings for these zero cost changes in operation is $62,235.

Table 21 – Tier I Energy Efficiency Measures

No.	Description	Capital Cost	Annual Cost Savings	Payback (yrs.)
1	Optimize the existing DDC systems schedule consistent with occupancy schedules. Schedule setback temperatures and shut-down ventilation equipment during low and non-occupied periods *(this can be completed as part of the retro-commissioning program)*.	$0	$42,000	0
2	Control lighting systems in all common spaces (corridors, lobbies, etc.) consistent with occupancy.	$0	$5,240	0
3	Increase thermostat setpoint to 85°F for air-conditioning unit in electrical room. Inspect regularly to ensure that it is not operating during heating periods.	$0	$2,700	0
4	Reduce exterior/yard lighting density per IESNA standards and optimize schedule based on zone requirements *(this can be completed as part of the retro-commissioning program)*.	$0	$2,600	0
5	Reduce heating setpoint on thermostatically controlled valve for suspended fan coil heater in main electrical room to 55°F.	$0	$2,500	0
6	Many entry doors are propped open during heating months (January), by students for after-school programs including athletics. Unlock utilized entry doors or provide access (key cards) to after-school program coordinators for student access.	$0	$1,820	0
7	The domestic hot water systems provide over 1,000 gallons of supply (2-375 gallon heater tanks and 1-375 gallon storage). Reduce occupied capacity to a single 375 gallon unit and valve off storage tank.	$0	$1,700	0
8	Shut off the 3 suspended fan coil heater and the AHU fan coil heating supplies in boiler room.	$0	$1,500	0
9	Inspect and replace filters on all air-handling units as needed (2-3 months) to prevent filter clogging, fan motor strain, and reduced service life. This is also an IAQ measure.	$0	$1,200	0
10	Inspect all supply and return vents to ensure that they are open to improve distribution of conditioned air.	$0	$1,000	0
11	Remove all unutilized electronic equipment including computers, printers, overhead projectors, and small appliances.	$0	$950	0
12	Control operation of the air compressor for the laboratory rooms. Capacity appears to exceed demand and compressors should be shut-down in summer.	$0	$650	0
13	Power off overhead LCD projectors (SmartBoards) when not in use.	$0	$320	0
14	Remove window air-conditioning unit during heating season to prevent air leakage.	$0	$285	0
15	Determine control logic for the boiler AHU and optimize. Unit should only operate in transitional seasons (fall and spring) *(this can be completed as part of the retro-commissioning program)*.	$750	$2,300	0.3
16	Balance the combustion air intake louvers so the supplied air equals the boiler demand *(this can be completed as part of the retro-commissioning program)*.	$1,000	$3,000	0.3
17	Implement a standard facilities preventative maintenance and energy management program. Utilize a facilities management software program with scheduled PM events and repair logs.	$2,000	$5,000	0.4
18	Install smart power strips (occupancy or time controlled) to power off computer systems (CPU and monitors) when not in use. This could also be software scheduled by the IT manager.	$1,600	$3,110	0.5
19	Install weather-stripping on all entry door jambs, headers, and thresholds.	$900	$1,780	0.5
20	Replace deteriorated piping insulation on rooftop condensing equipment with min. R-10 outdoor rated insulation.	$750	$1,340	0.6
21	Seal all roof penetrations with caulking or fire-stopping.	$800	$1,200	0.7
22	Clean all energy recovery wheels in AHUs (10) to remove debris and	$3,500	$1,500	2.3

	mineral scale. Unless a chemical treatment system is installed, this should be completed every 2-4 years depending on use frequency and mineral content in water. Inspection should be completed as part of a routine PM program.			
23	Consolidate compact refrigerators and replace with ENERGY STAR rated units (3).	$2,400	$610	3.9
24	Seal roofs on all exterior AHU units to mitigate leaks (PM action).	$500	$100	5.0
25	Remove compact refrigerators and replace with three (3) full-size ENERGY STAR rated units.	$1,800	$350	5.1
26	Replace recessed lighting fixtures in main entrance vestibule and gymnasium lobby with lower wattage fluorescent fixtures. Reduce lighting density consistent with IESNA standards (5-10 FCs).	$3,200	$380	8.4

Tier II Energy Efficiency Measures

Tier II items generally require contracted tradesmen to complete but can be implemented at low cost and within operating building maintenance budgets. Four (4) Tier II EEMs are provided in Table 21 for the ORHS.

Table 22 – Tier II Energy Efficiency Measures

No.	Description	Capital Cost	Annual Energy Cost Savings	Payback (yrs.)
1	Complete DDC systems evaluation by a mechanical controls engineer to optimize current system and to determine feasibility for repair and software update versus whole system replacement with non-proprietary system (BACnet) *(this can be completed as part of the retro-commissioning program).*	$6,500	$24,000	0.3
2	Install demand or time programmable controllers on all exhaust fans and optimize runtime based on use and occupancy (ASHRAE 62.1) *(this can be completed as part of the retro-commissioning program)*.	$6,600	$3,800	1.7
3	Measure supply and return air flow and balance all ventilation zones *(this can be completed as part of the retro-commissioning program).*	$5,400	$2,700	2.0
4	Replace condensing units (2) for walk-in freezer and refrigerator with high-efficiency units (SEER >18) and add economizer units.	$5,300	$2,100	2.5

Tier III Energy Efficiency Measures

EEMs that require large capital expenditure and budgetary planning (one year or greater) are categorized as Tier III measures. Twelve (12) Tier III EEMs are provided in Table 22 for the ORHS. EEM number 2 includes total retro-commissioning of all mechanical and DDC systems. The costs assume a phased approach including a comprehensive engineering evaluation, developing a list of corrective actions that reduce energy consumption and improve occupant comfort, and implementation of the corrective actions.

Table 23 – Tier III Energy Efficiency Measures

No.	Description	Capital Cost	Annual Energy Cost Savings	Payback (yrs.)
1	Install DDC demand controllers on all AHUs except boiler room (19) *(this can be completed as part of the retro-commissioning program)*.	$40,000	$28,000	1.4
2	Retro-commission and optimize all building systems (this incorporates many other EEMs).	$185,000	$70,000	2.6
3	Install stack economizer energy recovery units on boiler exhausts (3).	$75,000	$18,000	4.2
4	Pressure test all supply ducting and seal leaking joints per ASHRAE standards *(this can be completed as part of the retro-commissioning program)*.	$23,000	$4,900	4.7
5	Install VFD controllers on all AHU fan and hydronic pump motors greater than 5 HP.	$35,000	$6,300	5.6
6	Inspect all mechanical and passive exhaust ducting and install positive pressure actuated dampers to reduce air leakage (lavatories, laboratories, locker rooms, kiln room) *(this can be completed as part of the retro-commissioning program)*.	$12,300	$2,100	5.6
7	Replace gymnasium metal halide lighting fixtures (42) with super T-5 lamp fixtures (PSNH SmartSTART Program).	$25,000	$4,300	5.8
8	Replace one of the existing boiler units with a condensing gas fired boiler (98% AFUE). Configure the remaining two units to provide supplementary heating and to serve as backup units.	$170,000	$28,000	6.1
9	Install multi-controllers for lighting in common areas including corridors. Time programmable controls operate lighting during normal occupancy schedules and occupancy sensors control reduced lighting fixtures during non-occupied periods.	$12,200	$1,900	6.4
10	Replace library lighting fixtures (PSNH SmartSTART Program). Add task lighting to reduce overhead lighting density/wattage.	$22,000	$2,900	7.6
11	Install insulation on all uninsulated sections of supply ducting per ASHRAE standards. Repair all damaged and poorly installed insulation sections.	$25,000	$3,200	7.8
12	Replace exterior wallpack lighting fixtures (27) with LED units (PSNH SmartSTART Program).	$18,500	$1,800	10.3

The energy cost savings and resulting payback are based upon each independent measure implemented for the building in its current condition and function. There are interdependencies among measures that will affect the realized energy savings. For example, replacing lighting fixtures with lower energy units reduces heat load to the building thereby requiring more heating fuel to compensate for the loss in heat from the inefficient light fixtures. Also, many of the larger capital Tier III EEM projects may include some of the smaller dependent EEMs.

Capital costs are provided for budgetary planning only. They are estimated based on current industry pricing for materials and labor. A detailed cost estimate should be developed prior to appropriating capital funds for the more costly measures.

Indoor Air Quality Measures

Based upon the measured indoor air quality in the ORHS, exhaust ventilation systems are not performing as designed. The highly variable CO_2 concentrations indicate that the ventilation systems are unbalanced resulting in over-ventilation of some spaces and inadequate ventilation of other spaces. Eight (8) measured spaces exceeded the EPA threshold of 1,000 parts per million of CO_2. Recommendations for evaluation and improvement of the ventilation systems are addressed in the recommended EEMs.

Periodic monitoring of IAQ conditions including temperature, relative humidity, and CO_2 concentrations is recommended to ensure that minimum IAQ standards are maintained as EEMs are implemented and the building systems are optimized. IAQ data also directly correlates to the performance efficiency of building conditioning and ventilation systems.

Renewable Energy Considerations

While renewable energy systems generally require a higher capital investment, they provide a significant reduction in the consumption of non-renewable fossil fuel energies. Other obvious benefits include a reduction in ozone depleting gas emissions (as measured by CO_2 equivalency), otherwise referred to as the "carbon footprint". Renewable energy systems also reduce the reliance upon fossil fuels derived from foreign nations and mitigate pricing fluctuations in a volatile and unpredictable market.

Evaluating the practicality of a renewable energy system for a specific facility should consider several facility specific variables including:

- Geographical location.
- Building orientation.
- Adjacent and abutting land features.
- Site footprint and open space.
- Building systems configuration and condition.
- Local zoning or permitting restrictions.
- Currently available financial resources (grants, utility provider rebates, tax incentives).

Table 23 provides a summary description of the more common and proven renewable energy technologies. The Table also provides a preliminary feasibility assessment for implementing each technology at the ORHS. Additionally, each renewable energy technology is scored and graded based on technology and facility specific characteristics. Appendix H presents the criteria used to develop the score and grade for each renewable energy technology. A more rigorous engineering evaluation should be completed if the ORCSD is considering implementing any renewable energy system.

Table 24 – Renewable Energy Considerations

Renewable Energy System	System Description & Site Feasibility
Roof-Mounted Solar Photovoltaic Systems	***System Description:*** Photovoltaic (PV) systems are composed of solar energy collector panels that are electrically connected to DC/AC inverter(s). The inverter(s) then distributes the AC current to the building electrical distribution system. Surplus energy is sent into the utility grid via net metering and reimbursed by the utility at a discounted rate. The capital investment cost for PV systems is high but the technology is becoming increasingly more efficient thereby lowering initial costs.
Score: 67%	***Site Feasibility:*** Based on the quantity of mechanical equipment on the ORHS roof and the history of roof leaks, a mid to large size rooftop mounted PV system may not be practical. A small system (5kW-10kW) could be sited on the building. This would require a design and permitting process with the local utility. Current utility incentives and renewable energy grants would help offset the capital cost for the system. A structural evaluation of the roof framing system would be required to ensure that it could accommodate the increased loading.
Ground-Mounted Solar Photovoltaic Systems	***System Description:*** A ground-mounted PV system composed of the same collector panels that are electrically connected to a DC/AC inverter(s). The collectors are mounted on a frame support system on the ground verses the roof. This is advantageous when roof framing can no accommodate the increased load of the collector panel and the ease of installation.

Score:71 %	***Site Feasibility:*** Based on the limited southern facing land area at the ORHS only a small sized PV system (5-10 kW) could be sited in the green space to the southeast of the building. This would require a design and permitting process with the local utility. Current utility incentives and renewable energy grants would help offset the capital cost for the system.
Solar Domestic Hot Water	***System Description:*** Solar domestic hot water (DHW) systems include a solar energy collector system which transfers the thermal energy to domestic water thereby heating the water. These are typically used in conjunction with an existing conventional DHW system as a supplemental water heating source. Because of the high capital cost, solar DHW systems are only feasible for facilities that have a relatively high demand for DHW.
Score: 80%	***Site Feasibility:*** Based on the low demand for domestic hot water, a solar hot-water system may be a practical consideration for the building. The capital cost could be offset with substantial utility rebates and incentives. The system could provide primary DHW during summer months when demand is low. In colder months, it would provide secondary heating.
Geothermal Heating & Cooling	***System Description:*** Geothermal heating systems utilize solar energy residing in the upper crust of the earth. Cooling is provided by transferring heat from the building to the ground. There are a variety of heating/cooling transfer systems but the most common consists of a deep well and piping loop network. All systems include a compressor and pumps which require electrical energy. Geothermal systems are a proven and accepted technology in the New England region. Site constraints and building HVAC characteristics define the practicality.
Score: 82%	***Site Feasibility:*** A geothermal heating and cooling system is a practical consideration for the building. The parcel provides adequate area for well installation and spacing. Considering the existing hydronic heating and cooling equipment is compatible with a ground-source water heat pump system, it is a practical technology for the building. Considering the high heating and cooling costs for the building, payback for the system is relatively low. Based on site constraints, the wells and pipe loop may have to be installed beneath the athletic fields.
Wind Turbine Generator	***System Description:*** Wind turbine generators (WTGs) simply convert wind energy into electrical energy via a turbine unit. WTGs may be pole mounted or rooftop mounted however system efficiency improves with increased elevation. Due to cost and site related constraints, WTG technology in New England is only practical for select sites. Constraints include local geographical and manmade features that alter wind direction, turbulence, or velocity. Other technology constraints include local variability of wind patterns and velocity. Additionally, WTGs require permitting (local, state, FAA) and local zoning that may restrict systems due to height limitations, and/or, visual detraction of the local landscape. Presently, WTG technology is not widely used in New England based on the relatively high capital cost compared to the energy savings.
Score: 62%	***Site Feasibility:*** Considering the small parcel that the building is sited on, a pole-mounted WTG unit may not be practical. However, a feasibility assessment should be completed as part of an evaluation. As described above, there are many constraints that determine if WTG is prudent for a particular site including: • Local zoning restrictions. • Detraction of the local landscape and abutter opinion. • Permitting requirements (local, state, FAA). • Local wind characteristics. Determining the local wind characteristics would require a wind study of the site.
Combined Heat & Power (CHP)	***System Description:*** Combined heat and power (CHP) systems are reliant on non-renewable energies. Systems are composed of a fossil-fuel powered combustion engine and electrical generator. Electrical current is distributed to the building distribution system to reduce reliance on grid supplied electricity. Byproduct thermal energy derived from the combustion engine is recovered and used to heat the building (this is generally considered to be renewable energy). Another benefit of CHP systems is that they provide electrical energy during power outages in buildings that do not have emergency power backup. Larger CHP units require a substantially large fuel supply and if natural gas is not available then a LPG tank must be sited.
Score: 67%	***Site Feasibility:*** Considering the availability of natural gas and high electric demand, a large (~75kW) CHP unit may be practical. The unit could be tied into the existing hydronic heating systems. Costs associated with the infrastructure development may not be practical.

Biomass Heating Systems	***System Description:*** Biomass heating systems include wood chip fueled furnaces and wood pellet fueled furnaces. For several reasons, wood chip systems are generally practical only in large scale applications. Wood pellet systems can be practical in any size. Wood chip systems are maintenance intensive based on the market availability and procurement of woodchip feedstock and variability of woodchip characteristics (specie, size, moisture content, bark content, Btu value) which affect the operating efficiency of the furnace and heating output. They require a constant feed via a hopper and conveyor system and feed rates must vary according to feedstock Btu value and heating demand. For these reasons they typically require full-time maintenance and are practical only in large scale applications. Wood pellet systems are much less maintenance intensive and feedstock availability and consistency is less of an issue. Both systems reduce the dependency on fossil-fuels and feedstock can be harvested locally.
Score: 69%	***Site Feasibility:*** Considering the constrained location of the building and site and area required for storing and managed woodchips, a woodchip furnace may not be practical. A pellet unit is a more practical heating system for the building however this requires additional effort for procurement of pellets, storing pellets, and periodic filling the pellet hopper during the heating season.

Other Energy Efficiency Measures

Measures Identified but not Recommended

The following measures were identified as part of the building evaluation but are not recommended as best-value EEMs. Considerations include the cost practicality and payback term and occupant comfort concerns.

1. Replacing the T8 lamp lighting fixtures with high-efficiency fixtures would reduce lighting energy consumption and improve lighting quality however the payback would not be significant unless there is a substantial incentive program to offset the capital cost.
2. As evidenced in the thermal imaging survey, the exposed concrete foundation walls have very low thermal performance resulting in significant heat loss. Typical methods to improve thermal integrity of foundation walls include adding rigid foam insulation to the wall. Because there are no below grade walls, insulation would have to installed on the exterior walls. Adding insulation would be a costly measure with a long payback term.

Existing Measures

Existing measures includes EEMs and initiatives that were observed during the evaluation. They identify the facilities commitment to reducing energy consumption, enhancing occupant comfort, and improving overall building performance.

1. The ORCSD has an established and well organized cooperative Sustainability Committee.
2. ORHS teachers and staff exhibit energy conservation awareness and behavior. This includes reduced lighting settings, turning off lights when rooms are unoccupied and identifying energy reducing initiatives for facilities personnel. They were extremely cooperative and helpful throughout the audit process.

O&M Considerations

O&M and considerations are provided for existing systems and for proposed EEMs. They are intended to provide best-value practices for the building manager and to identify any O&M requirements for the proposed EEMs.

1. Establishing a Preventative Maintenance program is recommended. This provides several benefits including energy efficiency, improved occupant comfort, and extending the service life of equipment and building systems.

2. Most regional school districts have a formalized Energy Reduction Program in place. These districts have shown a significant reduction in energy consumption while maintaining adequate occupant comfort.

F. ENERGY EFFICIENCY INCENTIVE AND FUNDING OPPORTUNITIES

The State of New Hampshire along with the utility companies offer multiple programs designed to improve the energy efficiency of municipal and school buildings through financial incentives and technical support. Some of the currently available programs are presented herein however building managers are encouraged to explore all funding and incentive opportunities as some programs end and new programs are developed. For a current listing of advertised programs and initiatives, visit www.dsireusa.org.

Northeast Energy Efficiency Partnerships

Northeast Collaborative for High Performance Schools (NE-CHPS)

NE-CHPS is a set of building and design standards for all schools from pre-K through community colleges tailored specifically for NH state code requirements, the New England climate, and the environmental priorities of the region. NH Department of Education offers up to a 3% reimbursement for New Construction School projects. To learn more about NE-CHPS and incentive programs please visit: http://neep.org/public-policy/hpse/hpse-nechps .

New Hampshire Public Utilities Commission

New Hampshire Pay for Performance

This program addresses the energy efficiency improvement needs of the commercial and industrial sector. The Program is implemented through a network of qualified Program Partners. Incentives will be paid out on the following three payment schedule: Incentive # 1: Is based on the area of conditioned space in square feet. Incentive #2: Per kWh saved and Per MMBTU saved based on projected savings and paid at construction completion. Incentive #3: Per kWh saved and Per MMBTU saved based on actual energy savings performance one year post construction. Total performance incentives (#2 and #3) will be capped at $300,000 or 50% of project cost on a per project basis. For more information visit http://nhp4p.com.

New Hampshire Public Utilities Commission's Renewable Energy Rebates

The Sustainable Energy Division provides an incentive program for solar electric (photovoltaic or PV) arrays and solar thermal systems for domestic hot water, space and process heat, with a capacity of 100 kW or equivalent thermal output or less. The rebate for PV systems as follows: $1.00 per Watt, capped at 25% of the costs of the system or $50,000, whichever is less. For solar hot water (SHW) systems, the base rebate is $0.07 per rated or modeled kBtu/year, capped at 25% of the cost of the facility or $50,000, whichever is less, as a one-time incentive payment. http://www.puc.state.nh.us/Sustainable%20Energy/RenewableEnergyRebates-CI.html.

New Hampshire Community Development Finance Authority

New Hampshire Community Development Finance Authority Revolving Loan Fund

The Enterprise Energy Fund is a low-interest loan and grant program available to businesses and nonprofit organizations to help finance energy improvements and renewable energy projects in their buildings. The loans will range from $10,000 to $500,000. Larger amounts will be considered on a case by case basis. The program is available to finance improvements to the overall energy efficiency performance of buildings owned by businesses and nonprofits, thereby lowering their overall energy costs and the associated carbon emissions. More information about the program can be found on their website www.nhcdfa.org. These activities may include:

- Improvements to the building's envelope, including air sealing and insulation in the walls, attics and foundations;
- Improvements to HVAC equipment and air exchange;
- Installation of renewable energy systems;
- Improvements to lighting, equipment, and other electrical systems; and
- Conduction of comprehensive, fuel-blind energy audits.

Public Service of New Hampshire (PSNH)

Commercial (Electric) Energy Efficiency Incentive Programs

This program targets any commercial/industrial member building a new facility, undergoing a major renovation, or replacing failed (end-of-life) equipment. The program offers prescriptive and custom rebates for lighting and lighting controls, motors, VFDs, HV AC systems, chillers and custom projects. http://www.psnh.com/SaveEnergyMoney/For-Business/Energy-Saving-Programsand-Incentives.aspx

SmartSTART

The SmartSTART (Savings Through Affordable Retrofit Technologies) advantage is simple – pay nothing out of pocket to have energy efficiency products and services installed in your building. The Smart Start program is limited to PSNH's municipal customers only and includes schools. The program is available on a first-come, first served basis to projects which have been pre-qualified by PSNH. The cost of the improvements is fronted by PSNH which is then repaid over time by the municipality or school using the savings generated by the products themselves. This program is for lighting and lighting controls, air sealing, insulation and other verifiable energy savings measures which have sufficient kilowatt-hour savings. For more information on this program visit: http://www.psnh.com/SaveEnergyMoney/For-BusinessIMunicipal-Smart-Start-Program.aspx

Schools Program

For major renovation or equipment replacement projects, this program offers prescriptive and custom rebates for energy efficient lighting, motors, HVAC, chillers, and variable frequency drives to towns or cities that install energy efficient equipment at their schools. Financial incentives are available for qualifying energy efficient equipment. Technical assistance is also offered through the Schools Program. http://w.Ytw.psnh.com/SaveEnergy MoneyILarge-Power/Schools-Program.aspx

Unitil

Unitil offers energy efficiency programs for commercial, industrial and multifamily gas customers, including the Small Commercial & Industrial Incentive and New Equipment & Construction Program. For more information, call 866-933-3820 or visit http://www.unitil.com/energy-efficiency/natural-gas-programs-rebates-assistance-for-businesses.

Small Commercial & Industrial Incentives (Natural Gas)

Small commercial and industrial customers using up to 40,000 therms per year qualify for an incentive of up to 50% of the qualified installed cost of identified energy efficiency upgrades, up to a maximum of $50,000 per master meter. Customers must be on a firm commercial rate.

New Equipment & Construction Program (Natural Gas)

This program offers incentives towards the installation of Energy Star-rated high efficiency gas furnaces, hot water boilers and water heaters, as well as controls and food service equipment in commercial and industrial applications.

The prescriptive and customer incentives offered can cover up to 75% of the incremental costs of qualifying energy efficiency measures. To qualify for this program: you must be a

commercial, industrial or multifamily Unitil customer on a qualifying rate code with a planned new construction, major renovation, or failed equipment replacement project. For more information on this Program, visit http://www.unitil.com/sites/default/files/Natural%20Gas%20Rebates%20%20lot%20a.pdf.

Clean Air - Cool Planet

Community Energy Efficiency

CA-CP works with communities throughout the Northeast to find solutions to climate change and build constituencies for effective climate policies and actions. Much of their work focuses on successful models for energy efficiency and renewable energy planning. They advise and partner with citizens, educators, faith groups, small businesses, municipal governments, and other local leaders. They explore cost-effective opportunities that exist for communities to reduce their emissions as well as their vulnerability to climate impacts. One such example is CA-CP's partnership with the University of NH, NH Sustainable Energy Association and UNH Cooperative Extension to create www.myenergypian.net . A groundbreaking suite of web and outreach tools for individual action used by households, schools and community groups around the northeast. http://www.cleanair-coolplanet.orglfor_communities/index.php .

Environmental Protection Agency (EPA)

ENERGY STAR Challenge for Schools

EPA is challenging school administrators and building managers to improve energy efficiency throughout their facilities. More than 500 school districts across the country are helping to fight climate change by committing to reducing their energy use with help from ENERGY STAR. Schools that take the ENERGY STAR Challenge can use energy tracking tools, technical guidance, case studies and other ENERGY STAR tools and resources to help them improve their energy efficiency. More information can be found at:
http://www.energystar.gov/index.cfm?c=challenge.bus_challenge

Cool School Challenge

The Cool School Challenge is a program of the Puget Sound Clean Air Agency, developed in collaboration with Redmond High School environmental science teacher Mike Town, and Puget Sound Energy's Powerful Choices for the Environment program.

Conceptually modeled after the U.S. Mayor's Climate Protection Agreement, the Cool School Challenge aims to motivate students, teachers, and school districts to reduce carbon dioxide and other greenhouse gas emissions schoolwide. At the heart of the Cool School Challenge is the philosophy that big changes start with small steps, and that taken together, simple individual actions create a world of difference.

The goals of the Cool School Challenge are to:

- Educate young people, and by proxy their families, about climate change and everyday actions they can take to reduce their impact locally and globally;
- Reduce carbon dioxide emissions and other greenhouse gas emissions in and around schools;
- Encourage student leadership and empowerment;
- Foster a community of teachers/students working together to reduce their greenhouse gas emissions; and

- Foster a new generation of environmental/air quality advocates.

Learn more about the Cool School Challenge at: http://www.coolschoolchallenge.org/.

G. PROCEDURES & METHODOLOGY

Standards and Protocol

The American Society for Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has developed the most widely accepted process for completing energy audits at commercial facilities. ASHRAE document RP-669, SP-56, *Procedures for Commercial Building Energy Audits* defines several levels of audits. The appropriate level of audit for a particular facility depends on the availability of existing data and information, owner objectives, and owner budget. Levels range from simple benchmarking to a comprehensive review of all building systems. The most common audit is a Level II which is typically conducted as an initial audit to identify ECMs and establish budgetary costs for implementation. Level II audits are commonly referred to as "Investment Grade Audits".

Basic elements of a Level II Investment Grade Audit include the following:

- A review of existing facility data including energy usage.
- Benchmarking the facilities energy usage relative to similar use facilities.
- An on-site inspection and survey of all building systems.
- On-site measurements and data collection.
- Informal owner and occupant interviews.
- Energy use analysis and development of conservation measures.
- Developing a simple payback cost estimate for each recommended measure.
- Development of a comprehensive report that clearly presents all findings and provides recommended energy conservation measures and the associated costs.

In addition to the ASHRAE standard for commercial audits, there are industry and code-based standards that must be considered when analyzing building systems and evaluating energy conservation measures. All recommendations must be consistent with the intent of these standards. For example, the US Environmental Protection Agency (EPA) has established a recommended carbon dioxide (CO_2) threshold concentration of 1,000 parts per million (ppm) to promote a healthy indoor air environment. ASHRAE defines recommended temperatures, relative humidity levels, minimum ventilation rates, and energy standards. The Illuminating Engineering Society of North America (IESNA) prescribes recommended lighting densities based on the designated space use. The International Code Council (ICC) is the adopted standard for all building and energy codes (2009) in the state of New Hampshire. New Hampshire has also adopted ASHRAE Standards 62.1 and 90.1.

Table 25 – Relevant Industry Codes and Standards

Standard	Description
28 CFR Part 36	ADA Standards for Accessible Design
ANSI/ASHRAE Standard 55	Thermal Environmental Conditions for Occupancy
ANSI/ASHRAE Standard 62.1	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE/IESNA Standard 90.1	Energy Standards for Buildings Except Low-Rise Residential Buildings
ICC 2009	International Building Code (IBC)
ICC 2009	International Existing Building Code (IEBC)
ICC 2009	International Energy Conservation Code (IECC)
IESNA Lighting Handbook	Reference and Application
NFPA 70	National Electrical Code (NEC)

While the primary objective of an energy audit is identify energy conservation measures, such measures cannot adversely affect occupant comfort and indoor air quality. For example, if a building ventilation system is inadequate then it would be recommended that additional ventilation capacity be added. The electrical power required to operate the added ventilation equipment would increase energy consumption. Typically, the net energy usage incorporating the sum of the recommended conservation measures would still be less than the current usage even with the added ventilation equipment.

It is noted that although there is a prescriptive approach to commercial building audits, that every building is unique in many ways. Buildings should be evaluated consistent with the characteristics that define its need and appropriate function. This includes the following:

- Building system characteristics, and more importantly, how each system integrates within the composite facility ultimately determining building function and energy usage.
- Current building use and occupant needs.
- The manner in which the operator controls the building systems.

Desktop Data Review

Ideally, the building owner provides all available information to the engineering firm prior to initiating the facility site review. Information such as utility bills, building plans, repair records, planned improvements, and occupant concerns will help the building engineer identify potential issues before initiating the site review. The Building Engineer can then focus the site review toward problematic and energy intensive building systems.

Facility Site Review

Following the desktop data review, the Engineer initiates the facility site review. This review includes all major building systems including the envelope, electrical, mechanical, heating, cooling, and ventilation. The Engineer not only determines the performance and operating characteristics of all building systems, they also evaluate how the users operate the systems and how they perceive building performance. Photographs of representative systems, major equipment, and any identified issues are obtained to help document existing conditions. Field notes are maintained by the Engineer to further document building and user characteristics.

Data Measurements

In addition to collecting equipment information, several data measurements are obtained as part of the facility site review. This data is necessary to identify potential building issues and to collect the information needed to develop an accurate energy analysis. Measurements include:

- Infra-red thermal imaging survey of the building envelope.
- Indoor air quality (IAQ) measurements (temperature, relative humidity, and CO_2).
- Lighting metering to determine energy use and operating schedules.
- Lighting output density.
- Metering of energy intensive electrical equipment (e.g., motors, compressors, heaters) to determine energy use and operating schedules.
- Metering of energy intensive plug-loads to determine energy use and operating schedules.

Data Gap Review

Once the facility site review and data measurements are substantially complete, the engineer begins reviewing and processing all of the collected data. Any data gaps discovered during this process are addressed prior to completing the audit report.

Cost Estimating and Payback

The cost for implementing each evaluated ECM is then estimated by the Engineer. This provides a net estimated energy savings per dollar invested. Simple payback calculations determine the number of years required for the capital investment cost to equal the present day cost savings realized from energy reductions.