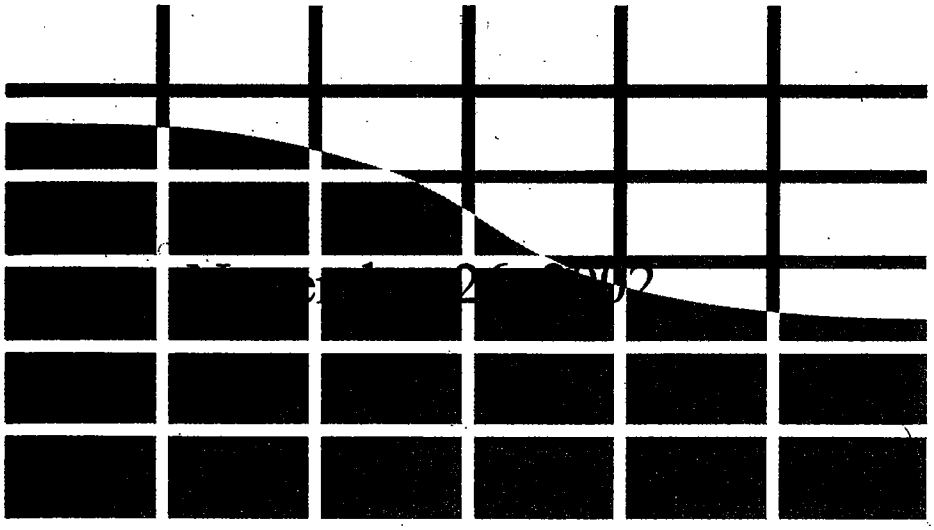

New Carlton Elementary School
Salem, MA
Energy Study

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Carlton Elementary School
Salem, Massachusetts

Energy Study
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Introduction and Summary of Findings

Flansburgh Associates, Inc (FAI) of Boston, Massachusetts commissioned DMI to study energy efficiency opportunities for the proposed Carlton Elementary School on Skerry Street in Salem, Massachusetts. TMP Consulting Engineers of Boston, Massachusetts is the MEP engineer. This study will be used as part of the Massachusetts Technology Collaborative's (MTC) Green Schools program and also may form the basis for efficiency rebates from Massachusetts Electric Company and KeySpan Energy.

The MTC Green Schools program presents a target of 20% reduction in facility energy consumption. This requirement can be met by either on-site generation using renewable technologies or efficient design. The proposed 30- kW DC photovoltaic array mounted on the school roof, the 1-kW DC array on the greenhouse will have an annual production of approximately 32,388 kWh AC, while the proposed 1,000-Watt pole-mounted Bergey wind turbine is expected to produce 1,394 kWh annually. The total amount of electricity generated on-site is expected to supply 8.7% of the facility's estimated total annual base case electrical consumption of 387,907 kWh.

The table on the following page presents a summary of the results of the energy conservation analyses. The simple total is based on energy savings of the listed individual custom and prescriptive measures for the entire building. A different consultant estimated the savings associated with the prescriptive lighting and efficient motor measures. The interactive total reflects the likely savings that would result if all of the custom and prescriptive measures were implemented.

The base case building energy consumption was estimated to be 6,886 million Btu (MMBtu) per year. If the selected conservation opportunities were implemented, preliminary results indicate an annual energy savings of 53,654 kWh and 4,171 therms of natural gas would reduce facility energy consumption by 15.1% (as measured in source MMBtu). The net annual energy savings from energy conservation measures will be worth $6,839. The incremental cost to implement these measures is $45,290. The Owner may be eligible to receive incentives from MECo and KeySpan Energy totaling $21,273.

The facility can reduce its source energy consumption by 20.8% if all of the recommended energy efficiency measures are implemented in addition to the installation of the two PV arrays and wind generator.

DMI takes this opportunity to thank Vince Dube (FAI), Bruce Dyas (MECo) and Joanne Schepis-Stone (MECo) for their assistance during the course of this study. This report is the work of Peter J. Barrer P.E, Olivier Dosiere, Wade McLaughlin, and Eric Studer of Demand Management Institute, Inc.

Carlton Elementary School

Summary of Energy Conservation Measures

ECM No.	Item	Savings/year			Incre-mental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu	Pro-gram Code
		Electricity kWh	Gas therms	Value $						
1	Efficient Glazing	*Measure Not Recommended*								
2	Gym Daylight Dimming	5,159	(162)	$326	$5,007	$1,760	$3,247	10.0	44	E/P
3	Demand Controlled Ventilation	1,681	472	$500	$2,445	$1,834	$611	1.2	67	E/C
4	Optimized RTU Controls	11,161	353	$1,232	$9,653	$7,240	$2,413	2.0	165	E/C
5	VSD on Gym RTU[4]	13,217	(21)	$1,130	$4,182	$2,463	$1,719	1.5	151	E/C
6	VSD on DTW Pumps	13,633	(1,221)	$266	$5,212	$3,439	$1,773	6.7	36	E/C
7	Condensing Boilers	929	5,913	$4,515	$22,974	$7,000	$15,974	3.5	602	G
Simple Total Savings[4]		32,563	5,355	$6,839	$45,290	$21,273	$24,017	3.5	1,064	
MECo Presciptive Rebates						$1,760				
MECo Custom Rebates						$14,976				
KeySpan Rebates						$7,000				
Base Case Consumption		387,907	23,862	$51,528					6,886	
Interactive Total Savings[4]		53,654	4,171	$7,780	$45,290	$21,273	$24,017	3.1	1,039	
On-site Generation		33,782	-	$2,929					392	
Total Savings		87,436	4,171	$10,709					1,431	
Percent Savings		23%	17%	21%					20.8%	

Notes:

1. Energy savings based on $0.0867/kWh and $0.750/therm
2. Source savings based on 11,600 Btu/kWh and 100,000 Btu/therm; reported in millions of Btu (MMBtu)
3. Program Codes: E/C - Electric Custom Measure, E/P - Electric Prescriptive Measure, G - Gas Measure
4. ECM 5 is not included in the Simple or Interactive Totals, nor is it going to be installed per the designer's decision
5. Interactive savings include efficient lighting design and premium-efficient motors

Methodology for Calculating Savings

Information for the study of the proposed facility was gathered through review of project schematic drawings and discussions with the designers. The building was modeled using the project drawings dated February 15, 2002. The gym skylight design was updated in late August 2002. The various systems addressed in this report were modeled using PowerDOE. The interactive energy savings for the individual measures were calculated by comparing the facility energy consumption of the proposed case measures to a base case model meeting standard practice and code. The PowerDOE model is based on weather data for Boston, Massachusetts.

This study can be used to support utility rebate applications for all custom measures. Prescriptive applications for lighting and motors will be prepared by others. The savings indicated for each of the individual measures assumes that the prescriptive lighting and efficient motor upgrades have not been implemented. DMI evaluated one prescriptive measure associated with the gymnasium daylight dimming/lighting measure (ECM 2). For purposes of calculating the MTC grant, the interactive total savings assume that all of the prescriptive and custom measures have been implemented and are compared to a base case with standard lighting and motor efficiencies.

An estimate of annual energy yield for the 30-kW and 1.0-kW photovoltaic arrays was obtained using the National Renewable Energy Lab's on-line PV calculator, PVWatts v.1 (rredc.nrel.gov). Energy yield for the 1,000-Watt wind turbine was calculated using Bergey's WindCADD program using a hub height of 55 feet and assuming a site with more turbulence than average.

Our analysis utilizes $0.0867 per kWh for electricity, which is MECo's 2002 average rate for industrial and commercial customers, including demand and customer service charges. The unit cost for natural gas used in this report is $0.75 per therm. Source energy savings are based on 11,600 Btu per kWh and 100,000 Btu per therm.

MECo *Design 2000plus* custom measure incentive values were estimated based upon the 2002 MECo screening tool. MECo *Design 2000plus* prescriptive incentives were estimated based on 2002 guidelines. The KeySpan incentives are based on 2002 program guidelines. All incentive amounts will be reviewed by the energy provider and are subject to change.

Description of Facility

The proposed 59,500 ft^2 Carlton Elementary School is located near the North River between Skerry and Burnside Streets in Salem Massachusetts. Seven classrooms, offices, cafeteria, gym, and a kindergarten room are located on the first floor, while the second floor contains seven classrooms, the library, faculty, choir and art rooms. The cafeteria, gym, and atrium at the main entrance extend upwards through the second floor to the roof.

The building is to have load-bearing concrete block walls, pre-cast concrete plank floors, and an insulated deck membrane roof. The building will have aluminum framed, double-paned low-E glazing. The gym will have reflective tube 4-foot by 4-foot skylights spaced evenly across the roof.

Classrooms will be conditioned using unit ventilators, while rooftop units and perimeter fin tube baseboard heat will serve the corridors (RTU1 and RTU-5), offices (RTU-2), cafeteria (RTU-3), kitchen (RTU-4), and gym (RTU-6). Chilled water is supplied to the entire building by a 55-ton, air-cooled, roof-mounted scroll chiller. Two 1,110-MBH natural gas-fired boilers provide hot water for the unit ventilators and baseboard heaters; each RTU has its own gas-fired burner. The building is to operate on a two-pipe dual temperature system. Two sets of 5-hp pumps provide circulation through the dual temperature water (DTW) loop.

The building will be occupied from 7:00 AM until 4:30 PM during the school year, with full occupancy from 8:00 AM until 2:30 PM. Mechanical systems are to be setback from approximately 4:30 PM until 6 AM. The gym will be used on Saturdays from approximately 9:00 AM until noon during the winter for basketball; otherwise the school is unoccupied on weekends. The school will be unoccupied during three one-week long vacations in the fall, winter, and spring. Custodial staff and administrators will work in the building over the summer. There will be a two-week summer science camp during July. It is assumed that air conditioning will be used all summer from 6:00 AM until 2:00 PM.

Energy Conservation Measures:

ECM 1: Efficient Glazing

This measure proposed to install energy efficient glazing throughout the building similar to Viracon VE-1-2M. The measure was evaluated using the base and proposed glazing characteristics shown below. Unfortunately, the loss of winter solar heat gain was found to offset the summer cooling savings due to limited summer heat gain. This measure is not recommended for implementation.

Glazing Characteristic	Base Case	Proposed Case
Color	Clear	Clear
Shading Coefficient	0.67	0.43
U-Value	0.33	0.29
Visible Transmittance	0.74	0.70
Outside Emissivity	0.84	0.84

ECM 2: Gym Daylight Dimming

The design of the gymnasium includes eight reflective tube skylights to allow for natural illumination of the space. The base case lighting design would install sixteen 250-Watt metal halide fixtures. It is assumed in the base and proposed cases that the gym lights would operate during normally scheduled occupied hours.

This measure proposes to install sixteen 8-lamp T8 fluorescent fixtures equipped with dimmable ballasts. The ballasts would be controlled using electronic daylight harvesting controllers. Each controller would contain a photosensor and would control half of the fixtures in the gym. The minimum and maximum light levels in the space would be programmed in accordance with the lighting designer's intent. As natural light fades to zero, the fixtures would ramp up to operate at full brightness. Reducing the light power draw will reduce annual lighting energy consumption.

Costs of this measure include fixture, ballast, photocontroller, and programming. The lighting fixtures qualify for a prescriptive *Design 2000plus* lighting rebate from MECo of $30 per fixture for new fluorescent fixtures for high and low bay applications with a fixture wattage greater than 220-Watts. The photocontrol systems qualify for a prescriptive *Design 2000plus* lighting rebate from MECo of $40 per ballast. Prescriptive program guidelines for daylight dimming systems require that each controller be in command of at least 224 Watts of fluorescent lighting.

ECM No.	Item	Savings/year			Incre-mental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu
		Electricity kWh	Gas therms	Value $					
2	Gym Daylight Dimming	5,159	(162)	$326	$5,007	$1,760	$3,247	10.0	43.6

ECM 3: Demand Controlled Ventilation

RTU-3, serving the cafeteria, was selected for 4,145 cfm total supply air. When the unit serving the kitchen (RTU-4) is operating, the ventilation volume would remain at 3,000 cfm. When RTU-4 is off, the ventilation volume would be set at a constant 1,530 cfm during the cafeteria's occupied hours. The cafeteria will operate on an occupied schedule of 7:00 AM until 3:00 PM, while the kitchen will be occupied from 7:00 AM until 1:30 PM.

This measure proposes to reset the ventilation volume to maintain a CO_2 setpoint of 600 ppm as measured by CO_2 sensors in the return air stream of RTU-3. When RTU-4 is not operating, the minimum air volume will be reset from 600 cfm up to a maximum of 1,530 cfm to maintain the CO_2 concentration setpoint. The 1,530 cfm limit will increase to 100% outside air during economizer operation. When RTU-4 is operating, the CO_2 controls will become inactive and RTU-3 will operate with constant 3,000 cfm outside air.

RTU-6, serving the gym, was selected for 4,000 cfm total supply air. In the base case, the ventilation volume would be balanced at 800 cfm during all occupied hours. The gym will be occupied from 8:00 AM until 4:30 PM on weekdays and from 9:00 AM until 12:00 PM on Saturdays from December through March for basketball practice.

This measure proposes to reset the ventilation volume to maintain a CO_2 setpoint of 600 ppm as measured by CO_2 sensors in the return air stream of RTU-6. The minimum air volume will be reset from 375 cfm up to a maximum of 800 cfm to maintain the CO_2 concentration setpoint. The 800 cfm limit will increase to 100% outside air during economizer operation.

This measure will reduce heating and cooling energy as the amount of exhausted conditioned air decreases. This measure may qualify for a *Design 2000plus* incentive from MECo.

ECM No.	Item	Savings/year			Incre-mental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu
		Electricity kWh	Gas therms	Value $					
3	Demand Controlled Ventilation	1,681	472	$500	$2,445	$1,834	$611	1.2	66.7

ECM 4: Optimized RTU Controls

Three of the six packaged rooftop units serve variable volume distribution systems in the corridors and classrooms (RTU-1 and RTU-5), and the administrative offices (RTU-2). Each of these units is equipped in the base case with a VSD on the supply fan and DX cooling and a gas-fired heating section. In the base case, a constant supply temperature of 53°F would be maintained during the cooling season. Space temperatures would be maintained using reheat coils located in the variable air volume (VAV) boxes. The VSDs on the fans would modulate fan speed to maintain a fixed static pressure setpoint. The outside damper would be controlled to be at minimum position during mechanical cooling regardless of outside air conditions.

Discharge Air Temperature Reset Control: This measure proposes a discharge air temperature (DAT) reset sequence that would incrementally increase or decrease the DAT setpoint based upon the number of VAV boxes fully open to primary air. The building EMS would poll all of

the VAV boxes in each unit's distribution system. If all of the boxes were modulating less than 100% open, the DAT setpoint would be reset upward by 1°F increments in 15-minute intervals up to a maximum of 60°F until at least one VAV box is fully open to primary air. If any of the spaces served by a fully open VAV box cannot meet the space temperature setpoint, the DAT setpoint would be reduced in 1°F increments every 15 minutes until all of the space temperature setpoints are satisfied.

Discharge air temperature reset control saves cooling energy by allowing economizer free cooling to be engaged at a higher outside air temperature. Measure costs are primarily for programming.

Static Pressure Reset Control: This measure also proposes to implement a static pressure reset sequence on RTU-1, RTU-2, and RTU-5 whereby the static pressure setpoints for the VAV systems are adjusted to minimize draw of the supply fans. This sequence is similar to DAT reset in that all of the VAV box damper positions are polled on each system to determine whether any of the boxes are fully open to primary air. The static pressure setpoint would be decreased in 1" w.g. increments in 15-minute intervals until one VAV box is fully open to primary air. If any zone served by a fully open VAV box cannot maintain its temperature setpoint, the static pressure setpoint would be increased upward in 1" w.g. increments in 15-minute intervals until the space temperature setpoint is satisfied or the maximum static pressure setpoint of 1" w.g. is met.

Static pressure reset control saves energy by minimizing the pressure developed by the operating fans via VSD modulation of the fan speed. SP reset control is used when DAT reset is not available (during mechanical cooling or heating). Measure costs include programming.

Mechanical cooling should only be used when outside air cannot meet the cooling loads of the building or when dehumidification is required. Mechanical cooling is generally required when the outside air drybulb temperature rises within 3°F of the discharge air temperature setpoint or when the dewpoint rises above 60°F.

Outside Air Damper Control: Finally, this measure proposes to implement comparative enthalpy economizer on RTU-1 and RTU-5. This sequence controls the outside air damper to fully open when the unit is in cooling mode and the return enthalpy is greater than the outdoor enthalpy. The sequence saves energy by cooling air with the lowest enthalpy when possible, thus reducing the cooling load on the DX cooling systems. Measure costs include a control point for a return air humidity sensor on each unit, a control point for measuring outside air humidity, and programming. RTU-2 is too small to be cost effective and was not studied as part of this measure.

This measure may qualify for a *Design 2000plus* incentive from MECo.

ECM No.	Item	Savings/year			Incremental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu
		Electricity kWh	Gas therms	Value $					
4	Optimized RTU Controls	11,161	353	$1,232	$9,653	$7,240	$2,413	2.0	164.8

ECM 5: VSD on Gym RTU

RTU-6 is a 4,000 cfm constant-volume unit serving the gymnasium. In the base case, the unit would operate with constant airflow during all occupied hours.

This measure proposes to reduce air circulation within the gym by installing a single VSD to control both the 3-hp supply and 2-hp exhaust fans on RTU-6. The total air volume through the unit would be at design levels when the outside air drybulb temperature is above 75°F, and would be set back to 75% of design flow during cooler temperatures. Destratification fans in the current design will assure adequate air circulation during the heating season. Reducing the amount of air circulated through the gym will save fan energy during all hours below 75°F. This measure may qualify for a *Design 2000plus* incentive from MECo.

Although this measure saves energy and may be eligible for a utility rebate, the design team has chosen not to include the VSD on the gym RTU fans.

ECM No.	Item	Savings/year			Incre-mental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu
		Electricity kWh	Gas therms	Value $					
5	VSD on Gym RTU	13,217	(21)	$1,130	$4,182	$2,463	$1,719	1.5	151.2

ECM 6: VSD on Dual Temperature Water Pumps

One set of 5-hp Taco Model FE-2508 frame mounted end suction pumps circulates water through the dual temperature water loop. In the base case, one pump would operate at constant volume. This system serves a two-pipe system for unit ventilators, with a changeover three-way valve for summer and winter. A three-way bypass valve would be used to maintain adequate flow during periods of low heating/cooling demand.

This measure proposes to control the active DTW pump to maintain a differential pressure setpoint as measured across the most distant coil in the distribution system. In order to maintain proper system pressurization, the three-way bypass valve will be required to modulate during periods of low heating or cooling load. In cooling mode the bypass will begin modulating when the VSD is operating at or below 60% of full speed to maintain minimum flow through the chiller. During the heating season, the bypass valve shall modulate open when the VSD is operating between 50% of full speed and the minimum speed recommended by the manufacturer.

ECM No.	Item	Savings/year			Incre-mental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu
		Electricity kWh	Gas therms	Value $					
6	VSD on DTW Pumps	13,633	(1,221)	$266	$5,212	$3,439	$1,773	6.7	36.0

This measure saves energy by allowing the pumps to operate at a lower head. Measure costs include a VSD with bypass and controls programming. This measure may qualify for a *Design 2000plus* incentive from MECo.

ECM 7: Condensing Boilers

Two 1,110-MBH hot water boilers provide heat for the water loop at a full load temperature of 180°F. The supply temperature would be reset based upon the return water temperature down to a minimum of 120°F. The base case boilers would have an efficiency rating of 80% and would be similar to a Burnham model V-908A-W-G.

This measure proposes to install two Fulton model PHW-1400 PulsePak hydronic boilers that have a full load efficiency of 85% and a part load efficiency of 94% when the boilers are operating to produce 120°F hot water. The boiler operates by modulating butterfly valves in the gas and exhaust lines and allows for 5:1 turndown for precise load matching capability.

Implementation costs for this measure assume stainless steel boiler liners and the installation of AL-29-4C corrosion-resistant flue gas vents. This measure qualifies for a prescriptive rebate from KeySpan Energy of $3,500 per boiler.

ECM No.	Item	Savings/year			Incremental Cost	Utility Incentive	Net Cost	Net Payback years	Source Savings MMBtu
		Electricity kWh	Gas therms	Value $					
7	Condensing Boilers	925	5,913	$4,515	$22,974	$7,000	$15,974	3.5	602.0

Interactive Total Savings

The interactive total savings compares custom measures ECM 3, 4, 6, and 7 as well as prescriptive measures for gym daylight dimming (ECM 2), premium efficient motors, and efficient lighting design to a base case design meeting standard practice and code. The proposed case lighting design is based on FAI drawings dated February 15, 2002.