ANGIER ELEMENTARY SCHOOL
Newton, MA

Analysis for LEED for Schools Credit EA 1
Initial Report for Schematic Design Phase

Updated Draft Report
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PREPARED FOR

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EXECUTIVE SUMMARY

DiNisco Design commissioned Andelman and Lelek Engineering (ALE) to perform a preliminary analysis for LEED for Schools (3.0) Energy and Atmosphere (EA) credit #1, Optimized Energy Performance, for the new Angier Elementary School building that will be located in Newton, MA. The main objective of the study was to create eQUEST models of the *baseline* and *as currently proposed* building and to quantify the difference in annual energy consumption.

This report presents a simplified LEED energy analysis generated based on available project documents, currently at the Schematic Design (SD) phase. Major assumptions are listed and explained in subsequent sections of this report. The results are highly dependent on these assumptions and will change in subsequent iterations of this analysis as the building design evolves and more design details become available. Even the energy conservation measures listed below are based on *assumed* characteristics as outlined in the SD phase Building Systems Narrative and other input assumptions made by ALE. Major energy conservation measures that contribute to the currently reported savings include:

- Interior lighting – reduced power density, occupancy sensors, and daylight harvesting
- Reduced exterior lighting power
- High efficiency condensing boilers for space heating
- High efficiency condensing domestic hot water heaters
- High efficiency packaged rooftop air conditioning unit for admin area
- Exhaust air energy recovery that is above the minimum requirement
- Variable speed pumps and fans
- Automatic variable flow kitchen exhaust system
- Variable speed chiller for improved part-load performance
- Radiant hot water heat in perimeter spaces except gymnasium
- Envelope improvements
    - Enhanced wall insulation
    - Enhanced roof insulation
    - Enhanced window systems
    - Fixed window shades

The *as currently proposed* building achieves 18.6% energy cost savings (22.0% site energy savings) over a comparable *baseline* building that meets the requirements of the ASHRAE 90.1-2007 standard. The approximate energy use intensity (EUI) of the *as currently proposed* building is 34 kBtu/sf/yr. With more typical elementary school use (limited night and summer use) the consumption of this building likely would be in the 25-30 kBtu/sf/yr range.

Table 1 on the next page lists energy use and energy savings broken down by end use, as well as overall energy costs and cost savings. The Facility Description describes the features of the building used in this report iteration, the Analysis Methodology section describes the modeling approach used, and a section on Energy Efficiency Options outlines additional energy conservation measures and their impact to the overall savings. Finally, an appendix includes a side-by-side comparison of the *baseline* and *as currently proposed* building features and operating schedule information provided by the City of Newton.

Table 1: Results Summary

End Use	Regulated Load ? (Y/N)	Baseline Design Energy Type	Units of Annual Energy & Peak Demand		Baseline Building Results	As Designed	Percent Savings
Area Lights	Y	Electric	Energy Use	kWh	162,689	90,115	44.6 %
			Demand	kW	77	42	45.1 %
Misc Equip	N	Electric	Energy Use	kWh	144,748	144,748	0.0 %
			Demand	kW	49	49	0.0 %
Space Heating	Y	Electric	Energy Use	kWh	0	1,213	0.0 %
			Demand	kW	0	1	0.0 %
Space Cooling	Y	Electric	Energy Use	kWh	89,010	83,602	6.1 %
			Demand	kW	146	92	36.9 %
Pump & Aux	Y	Electric	Energy Use	kWh	2,709	27,797	-926.1 %
			Demand	kW	1	9	-974.4 %
Vent Fans	Y	Electric	Energy Use	kWh	100,189	76,229	23.9 %
			Demand	kW	36	38	-6.2 %
Dom. Hot Water	Y	Gas	Energy Use	Therms	1,084	881	18.7 %
			Demand	MBH	0.0	0	25.0 %
Exterior Usage	Y	Electric	Energy Use	kWh	14,551	8,731	40.0 %
			Demand	kW	3	2	40.0 %
Misc Equip 2	N	Gas	Energy Use	Therms	1,552	1,552	0.0 %
			Demand	MBH	0	0	0.0 %
Space Heating 2	Y	Gas	Energy Use	Therms	12,731	8,479	33.4 %
			Demand	MBH	2	1	41.1 %
Total Energy Use (kBtu/year)					3,290,611	2,567,087	22.0 %
Annual Process Energy (kBtu/year)					649,220	649,220	0.0 %

The building is at 25.4% process load by cost. This passes LEED NC Requirements

Table 1.8.2 (b) Energy Cost and Consumption by Energy Type - Performance Rating Method Compliance

Energy Type			Baseline Design	As Designed	Percent Savings
Electric	Usage	kWh	513,896	432,435	15.9 %
Electric	Cost	$	$ 94,104	$ 78,411	16.7 %
Gas	Usage	Therms	15,367	10,912	29.0 %
Gas	Cost	$	$ 17,665	$ 12,529	29.1 %
Total Energy Use (kBtu/year)			3,290,611	2,567,087	**22.0 %**
Total Energy Cost ($)			$ 111,769	$ 90,940	**18.6 %**

FACILITY DESCRIPTION ASSUMED IN THIS ANALYSIS

The new building will have a total area of approximately 75,000 square feet. The building shape and layout are based on architectural plans.

Building occupancy schedules were based on typical primary school use with extended weekday hours as provided by the Newton Public Buildings Department. The schedule provided includes summer use of the building and Saturday gym use. A total of about one month of breaks are assumed per year. Occupant densities are based loosely on ASHRAE 62.1 default densities by space type. Ventilation rates are based on ASHRAE 62.1 combined[1] default rates. The total number of occupants is based on 456 students and 80 staff.

The building envelope is assumed to consist of steel framed walls with either masonry veneer or metal wall panels. Both wall constructions are expected to include 3" of rigid continuous insulation (R-4.2/inch), 1" of spray foam cavity insulation (R-6/inch) on metal studs, and 5/8" gypsum board. The roof has 6" of rigid polyisocyanurate insulation (R-36) on a sloped metal[2] deck. The first floor is a 5" concrete slab on grade with R-10 rigid insulation. Windows are assumed to be double glazed with a low-e coating on the second surface. Framing systems consist of thermally broken aluminum. The estimated average overall U-value of all exterior windows is 0.43.[3] The solar heat gain coefficient (SHGC) and visible transmittance (VT) vary depending on building face, with higher VT (0.76) and SHGC (0.54) on the north and east elevations than on the south and west (VT of 0.47 and SHGC of 0.37). Gymnasium clerestory windows will be translucent insulating glazing units. Overall the windows constitute approximately 26% of the total wall area. Fixed horizontal solar shades are expected to be installed on windows on the southwest and southeast faces of the building. Fixed vertical shades are expected to be installed on large classroom windows on the northwest face of the building.

Mechanical systems mostly consist of variable air volume (VAV) rooftop units. The classrooms are served by energy recovery units with chilled water (CHW) and hot water (HW) coils and variable speed fans. VAV terminal boxes include HW reheat coils. The cafeteria and gymnasium are served by single zone VAV rooftop units with CHW and HW coils. The administration area is served by a separate packaged direct expansion (DX) rooftop VAV unit with an assumed full-load energy efficiency ratio (EER) of 11.5 and a variable-speed supply fan. The kitchen is served by a gas-fired heating-only makeup air unit, which is assumed to be variable-volume, responsive to cooking activity. Mechanical spaces, vestibules, and exterior stairs are heated by unit heaters or convectors with HW coils. Most perimeter areas include hot water radiant heat. The assumed full-load energy efficiency ratios (EERs) of the packaged DX equipment is based on the Massachusetts "stretch" code requirements under the Efficient Mechanical Equipment compliance option. The efficiencies of *baseline* DX equipment are based on the minimums allowed by ASHRAE 90.1-2007. Thermal zones for both models and zone assignment for the *as currently proposed* case is based on SD phase mechanical drawings. Demand control ventilation (DCV) is included in the gymnasium, cafeteria, and offices. Typically spaces like the gymnasiums and cafeterias are required by code to have DCV; accordingly, the *baseline* also has DCV for these spaces.

The HW sources are three 94.5% efficient (assumed; based on 80°F return water and full load), condensing boilers, each designed for 1/3 of the design heating load. HW design supply temperature is assumed to be 140°F with a 30°F differential; supply temperature is assumed to be reset to as low as 110°F based on outside air temperature. The minimum flow ratio assumed for the HW loop is 0.25, using a variable-speed, primary-only pump.

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1 ASHRAE 62.1 requires ventilation air per square foot plus per occupant; "combined" values are average quantities accounting for both components.

2 A minority of roof areas have tapered flat roofs and/or concrete decks.

3 Note that the specification listed a window system performance of R-0.56. Performance assumed in this analysis assumes a slightly higher-performing window system based on the understanding that the building will meet Advanced Buildings requirements.

The CHW source for rooftop air handling equipment is a 250-ton[4] air-cooled chiller with an assumed full-load coefficient of performance of 3.0. The chiller is assumed to be equipped with a variable speed screw compressor for improved part-load performance. CHW supply temperature is assumed to be fixed at 45°F with a 10°F differential. The minimum flow ratio assumed for the CHW loop is 0.7, using a variable-speed, primary-only pump.

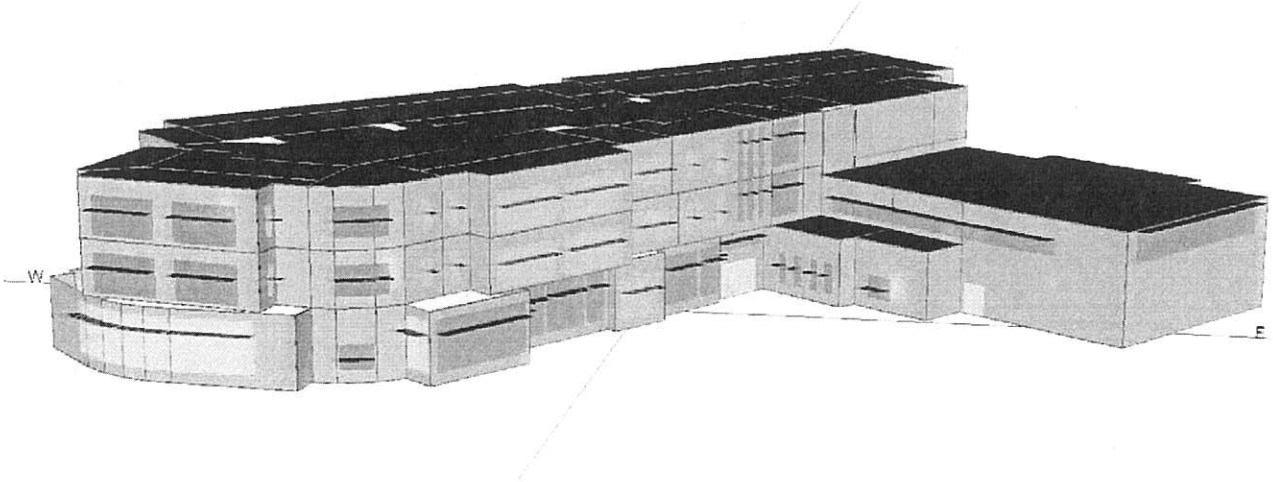
Lighting power density of 0.8 W/sf is assumed for the entire building. Occupancy sensors are used in offices, conference and break rooms, classrooms, the gymnasium, and restrooms. Daylight harvesting is used in most perimeter areas. Assumed proportion of lights controlled are as follows, with the controlled lighting dimmed based on the available daylight:

- In typical perimeter classrooms and the library, 30% of the lighting in those spaces dimmed based on the available daylight.
- In small perimeter classrooms, 50%.
- In the cafeteria and music classroom, 15%.
- In the gymnasium, 50%.

Exterior lighting consists of building security lighting and driveway/parking lot lighting. All are assumed to be on from dusk to dawn 365 days a year. A placeholder value of 2 kW is assumed for all exterior lighting in the proposed case, and it is assumed to be 40% less than the lighting power allowed by code.

Equipment loads are assumed as follows: 1.0 W/sf for classrooms and the library, 1.5 W/sf for offices and conference rooms, 5 W/sf in the kitchen and the network room, 0.5 W/sf in the cafeteria, and 0.2 W/sf in miscellaneous spaces such as corridors and mechanical rooms. Equipment loads comprise all non-HVAC electrical equipment loads plugged into convenience outlets including computers and displays, printers, kitchen equipment, etc. In addition, 500 MBH of gas-fired cooking equipment is assumed in the kitchen.

Domestic hot water (DHW) heaters are to be two 130 gallon, 94% efficient, condensing units. The *baseline* DHW load is based on 456 students plus 80 staff using an average of 0.6 gallons per person per day. The *as currently proposed* DHW load is reduced by 10% based on the assumption that water efficient fixtures can be shown to reduce the DHW load by at least as much.



4 Based on equipment and occupancy assumptions used in this report, the chiller is oversized by more than 100%, which has a detrimental effect on energy performance. While some degree of oversizing is expected (the assumptions in the energy model are intended to be *typical* rather than *conservative*), improved building energy performance may result to if the chiller size is reduced as the design develops.

ANALYSIS METHODOLOGY

The comparison of the *baseline* and *as currently proposed* buildings was performed using a simplified version of a LEED NC 3.0 energy savings calculation protocol which generally follows analysis methodology described in informative Appendix G to ASHRAE Standard 90.1-2007. A computer model of the facility was developed and building energy consumption simulations were performed using the eQUEST building energy analysis program. eQUEST uses the latest DOE-2.2 building energy analysis software as its calculating engine. This very flexible program permits modeling of a variety of building types and components including complex building geometry, lighting systems, HVAC systems, central plant equipment, and utility rate structure.

Boston typical meteorological year (TMY2) weather data was used in the analysis. Electric utility cost and cost savings were calculated using the NSTAR G-3 rate. The thermal energy cost and cost savings were calculated using the National Grid Gas G-43 rate.

ENERGY EFFICIENCY OPTIONS

A series of optional energy conservation measures are outlined below for value engineering purposes, to provide a path to the 6 EAc1 points expected (corresponding to 22% energy cost savings). Below the brief description of each measure is a summary table. The savings reported are relative to the baseline.

Measure 1: The effective insulation component of the wall assembly is increased from R-15.6 to R-22.

Measure 2: The effective insulation component of the wall assembly is increased from R-15.6 to R-28.

Measure 3: The lighting power density is reduced to an average of 0.7 throughout the building.

Measure 4: Fan power for all packaged air handling units is reduced by 20% from the baseline values.

Measure 5: The static pressure drop of the energy recovery units in AHU-1 and AHU-2 is reduced from 1.0" to 0.6".

Measure 6: Combines measures 2 through 5.

Table 2 - Energy Efficiency Options Summary

No.	Measure Name	Energy Savings				Total Cost Reduction	Energy Cost Savings	increas in % savings
		Electric Energy Savings						
		kWh	$	Gas (Therms)	$	$	%	%
-	As currently proposed	81461	$ 16,192	4456	$ 4,901	$21,093	18.8%	-
#1	R-22	81296	$ 16,149	4845	$ 5,324	$21,473	19.2%	0.3%
#2	R-28	81091	$ 16,106	5063	$ 5,561	$21,667	19.3%	0.5%
#3	LPD = 0.7	92701	$ 18,296	4230	$ 4,674	$22,970	20.5%	1.7%
#4	Fan 20% reduction	94772	$ 18,286	4405	$ 4,847	$23,133	20.6%	1.8%
#5	Wheel p.d. reduction	87502	$ 17,186	4424	$ 4,870	$22,056	19.7%	0.9%
#6	ECMs combined	111913	$ 21,372	4754	$ 5,249	$26,621	23.8%	4.9%

APPENDIX

Comparison of a*s currently proposed* to *baseline*

Item	*As Currently Proposed ("proposed case")*	*Baseline*
Building Envelope		
Building Shape	Per design documents, with self shading	Same as proposed case, no self shading
Building Orientation	Actual orientation	Average of four runs: actual, and rotated 90, 180, and 270 degrees
Wall Construction/ Insulation	Masonry veneer / metal panel exterior, 3" of semi-rigid fiberglass continuous insulation (R-4.2/inch), steel framing with 1" spray foam cavity insulation (R-6), and 5/8" gypsum board.	Based on ASHRAE std 90.1-2007, A3.3: steel framed building with R-13 between framing + R-7.5 continuous insulation - exterior finish same as proposed
Roof Insulation	Average of 6" of continuous polyisocyanurate insulation (R-36) on metal deck	Based on ASHRAE 90.1-2007 Table 5.5-4, R-20 continuous insulation
Roof Albedo	White roof with reflectivity of 0.45 based on assumed SRI ≥ 82	All roofs modeled as dark roofs with reflectivity of 0.3
Vertical Glazing % of Wall	Approximately 26%	Same as proposed case
Window Distribution	As specified in drawings	Same as proposed case
Overhangs/fins	3 foot overhangs on all windows except on NE and NW faces. 3 foot fins on large NW classroom windows.	No overhangs or fins on any windows
Glass Selection	Curtainwall: North and east: based on Viracon VE 1-85, SC=0.62, VT=0.76, overall system U-value of 0.39 South and west: based on Viracon VE 1-48, SC=0.43, VT=0.47, overall system U-value of 0.37.	From ASHRAE std 90.1-2007 Table 5.5-5, U-value = 0.45, SHGC= 0.4 (equivalent to SC of 0.46)
	Punched: North and east: based on Viracon VE 1-85, SC=0.62, VT=0.76, overall system U-value approximately 0.5 South and west: based on Viracon VE 1-48, SC=0.43, VT=0.47, overall system U-value approximately 0.5	From ASHRAE std 90.1-2007 Table 5.5-5, U-value = 0.55, SHGC= 0.4 (equivalent to SC of 0.46)
	Gym clerestory: based on Viracon VE 3-55, SC=0.3, VT=0.3, overall system U-value of 0.5	From ASHRAE std 90.1-2007 Table 5.5-5, U-value = 0.55, SHGC= 0.4 (equivalent to SC of 0.46)
Skylights % of roof	No skylights	Same as proposed case
Building HVAC System		
HVAC System Types	As described in body of report. All HW coils have two-way valves. All equipment is self-sized except MAU-1 which is assumed to be 3,400 cfm. Unit heaters are identical to base case but with hot water as the heat source.	Per ASHRAE 90.1-2007 Table G3.1.1A "Baseline HVAC System Type" and Table G3.1.1B "Baseline System Descriptions". One System 5 per floor except as noted below. All systems are self sized with heating coils oversized by 25% and cooling coils oversized by 15%. All HW coils have two-way valves.
		System 5 - VAV with DX cooling, hot water heat & reheat.
		Admin offices - System 3 - single zone constant volume systems with gas heating and DX cooling
		Cafeteria - System 3 with demand control ventilation
		Gymnasium - System 3 with demand control ventilation
		Kitchen - MAU-1 same as proposed case except constant volume rather than responsive to cooking activity
		Utility, vestibule, storage, etc. - System 9 - gas fired unit heaters.
Unitary Equipment Capacities	Self-sized	Same as proposed case
Unitary Equipment Efficiencies (COP, EER, etc)	As described in body of report	Based on ASHRAE 90.1-2007 minimum efficiencies for air conditioners. Vary from 13 SEER for small units to 9.8 EER for large units.
Fan System Operation	On when occupied; off all other times except to maintain unoccupied setback temperatures	Same as proposed case
Fan Capacity Control for VAV units	Variable speed	Same as proposed case
Fan Power (kW) (supply, return, and exhaust fans)	0.8 W/cfm for VAV systems and MUA-1, 1.0 W/cfm for kitchen exhaust fan, 0.3 W/cfm for unit heaters; eQUEST defaults for other systems	0.8 W/cfm for VAV systems and MUA-1, 1.0 W/cfm for kitchen exhaust fan, 0.3 W/cfm for unit heaters; eQUEST defaults for other systems
Baseboards and Radiant Panels	In all perimeter spaces served by AHUs 1, 2, and 3. (note: radiant heat not shown on drawings for some of these spaces)	No baseboards
Ventilation (minimum outside air)	Based on combined default values in ASHRAE 62.1-2010. Zero at night.	Same as proposed case
Heat Recovery	On AHU-1 and AHU-2 only; assumed overall (sensible/latent) effectiveness of 75%; adds 1.0" of static pressure each on supply and exhaust	In cafeteria core zone because auto-sized system is 100% OA. Effectiveness of 50%.

Comparison, continued

Item	*As Currently Proposed ("proposed case")*	*Baseline*
Temperature and Humidity Requirements	Heating to 68°F when occupied; 60°F when unoccupied. Cooling to 76°F when occupied; 90°F when unoccupied. No humidity requirements.	Same as proposed case
Economizers	Based on outdoor dry bulb; available when below 70°F	Same as proposed case
Kitchen exhaust fan	Variable speed based on assumed kitchen schedule	Constant volume when on
VAV Unit Supply Air Temperature Control	55°F supply air temperature, reset to 60°F based on OAT	Same as proposed case
VAV Unit Minimum Flow Control	Same as baseline	0.4 cfm/sf for all zones unless more OA required
Type and Number of Boilers	Three equally sized 94.5% thermal efficiency condensing hot water boilers	Two equally sized 80% thermal efficiency natural draft boilers
Design HW Supply/Return Temp	Supply 140°F, return 110°F	Supply 180°F, return 130°F per ASHRAE 90.1-2007 G3.1.3.3
HW Supply Temp Reset	From 140°F to 110°F based on outside air temperature, corrensponding to 20°F and 60°F, respectively	From 180°F to 150°F per ASHRAE 90.1-2007 G.3.1.3.4
HW Pumps	Primary only pumping with one variable-speed pump; 19 W/gpm assumed	Primary only pumping with one constant-speed pump; 19 W/gpm
Design CHW Supply/Return Temp	Supply 45°F, return 55°F	n/a
CHW Supply Temp Reset	None	n/a
CHW Pumps	Primary only pumping with one variable speed pump	n/a
Chiller Plant	Single 250 ton air-cooled chiller with COP of 3.0 and VFD screw compressor	n/a
Building Lighting System		
Lighting Power Density	0.8 W/sf, whole building	1.2 W/sf, whole building
Occupancy Sensors	10% reduction from LPD, applies to all offices, classrooms, the cafeteria, the library, and restrooms (not teacher break rooms because sensors there are mandatory)	None modeled–lighting schedules are understood to reflect the mandatory control requirements
Daylight Controls	As described in body of report	None
Exterior Lights	2 kW total	3.33 kW total
Other Systems and Data		
Equipment (Plug) Loads	As described in body of report	Same as proposed case
Domestic Hot Water Heater	Two 130 gallon gas fired tank heaters, 94% efficient	Two 130 gallon gas fired tank heaters, 80% efficient
Domestic Hot Water Load	0.54 gallons per person per day	0.60 gallons per person per day
Rate Schedules	NSTAR Electric rate G-3; National Grid Gas rate G-43	Same as proposed case

Operating schedule information provided by the City of Newton

School year:

6:30am to 6pm 100% of the school M-F

6pm to 10pm 1st and 2nd floors M-F

8 hours on Saturdays in the gym, main hall lights, and 1st floor bathrooms(basically gym use)

Summer Months (9 weeks max):

8am to 5pm M-F