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MEMORANDUM

TO: Kevin J. Murphy, City Manager

FROM: Katherine Moses, Energy Manager

SUBJECT: INFORMATIONAL COMMUNICATION LOWELL HIGH SCHOOL FEASIBILITY PHASE ENERGY ANALYSIS

I have reviewed the Energy Analysis for the different design options for Lowell High School. Because energy-related issues can be complex and because they can impact ongoing operational costs in the built environment, I thought it would be helpful to summarize the major findings in the study and highlight points to consider in weighing this component of the design options.

A whole building analysis was performed by Thornton Tomesetti, Inc. to evaluate the relative energy performance of the different proposed design options. The firm utilized a sophisticated energy modeling software (eQUEST ® v3.65) to compare building performance for the different site options. This software allows users to simulate energy usage for a building and integrate energy conservation measures into the design. Existing building energy use intensity and cost measures were calculated from current LHS utility bills provided by the Department of Planning and Development.

The consultant's primary comparative tool utilized is a metric known as Energy Use Intensity (EUI). EUI is a metric that is used to express a building's energy use as a function of its size. It is typically used when benchmarking buildings to compare them to buildings with similar functions (e.g. different schools). EUI is measured in energy use per square foot annually (kBtu/sf-yr).

Results:
The results of energy modeling demonstrate:

- Each design option can significantly reduce the overall EUI and energy cost per square foot over the existing building.
- EUI reduction by design option:
  - 28.3% EUI reduction for Full Renovation
  - 32.2% EUI reduction for Addition/Renovation Option 2
  - 32.7% EUI reduction for Addition/Renovation Option 3
  - 36.8% EUI reduction for Cawley – 4 Story Option
  - 37.0% EUI reduction for Cawley – 5 Story Option
- Energy cost reduction per area by design option:
  - 21.5% reduction for Full Renovation
  - 26.2% reduction for Addition/Renovation Option 2
  - 26.2% reduction for Addition/Renovation Option 3
  - 27.5% reduction for Cawley – 4 Story Option
  - 28.2% reduction for Cawley – 5 Story Option
- The Cawley site with the 5 Story Option is projected to produce the greatest reduction in EUI and cost due to the more efficient space layout and higher performance envelope.

Considerations:

- The report states that the limited scope for envelope upgrades does not allow for significant reduction in energy use in any of the downtown options. However, even the full renovation option would likely result in a 28.3% reduction in EUI, which is significant. As a point of reference, since 2008, energy efficiency upgrades have resulted in a 24.4% EUI reduction in the high school complex.
- It should be noted that the numbers are for comparison purposes only, and are not predictive of actual energy use/building performance.
- Other sustainability issues were beyond the scope of the energy study, including the issue of embedded carbon (the carbon/emissions involved in material creation, delivery, and operation of a building) and renewable resource energy potential.

The feasibility study shows that any site chosen will have positive impacts on energy use intensity and cost. Once a site is selected, City representatives will work with the sustainability design team to connect them with resources to implement cost-effective sustainable solutions for the benefit of the students, community, and City.

KAM/ns
06/1/17
cc: Diane Tradd, Assistant City Manager/DPD Director
Philip Ferreira, Housing and Energy Programs Manager

LOWELL HIGH SCHOOL

FEASIBILITY PHASE ENERGY ANALYSIS

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01 ANALYSIS DESCRIPTION & SUMMARY

Thornton Tomasetti, Inc. (TT) has performed whole building energy analysis for Lowell High School. This intent of this report is to provide a baseline analysis of the existing high school and to evaluate only the relative energy performance of the proposed design cases. This information should be used for comparative analysis rather than predicting actual energy use. A more detailed analysis will be developed at subsequent design stages to optimize the building systems to improve the energy performance further. The energy models were created using eQuest v3.65.

The five different design options analyzed in this study are listed below:

DESIGN OPTIONS:
- Full Renovation (Full Reno)
- Addition/Renovation - Option 2 (Add/Reno 2)
- Addition/Renovation - Option 3 (Add/Reno 3)
- New Construction on Cawley Site 4 Story (Cawley 4 Story)
- New Construction on Cawley Site 5 Story (Cawley 5 Story)

The results demonstrate that each design option can reduce the overall EUI of Lowell High School from existing conditions with careful selection of Energy Conservation Measures (ECMs). The savings can be achieved with ECMs such as improved envelope, LED lighting fixtures, and high efficiency HVAC systems. New Construction at Cawley site shows the greatest Energy Use Intensity (EUI) savings from the existing building. This is due to the more efficient space layout, and a higher performance envelope than the renovation design options.

In the design options, it is assumed that cooling will be provided to all regularly occupied spaces, while the existing building has limited cooling and ventilation air (provided by poorly performing and aging systems) which does not meet the requirements for new construction. Thus, the cooling energy use is increased from the existing building to the design option.

Utility bills of the existing high school were provided by the the city of Lowell, Department of Planning & Development. The existing building EUI was determined from the bills. The energy use associated with the pool in the building is included in this study, which has an impact on energy use. No renewable energy system is considered in this exercise but will be considered in future studies once a preffered option is selected.

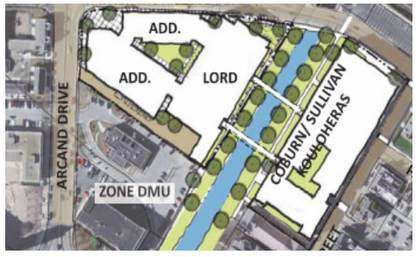
The new construction at Cawley Site 5 stories performs best among all options with an EUI of 39.7 kBtu/sf-yr. The renovation options can achieve better performance than the existing building. However, the limited scope to envelope upgrades does not allow for a significant reduction in energy use. For the renovation options moisture issues must be considered for envelope upgrades in conjunction with energy performance. The goal is to improve these preliminary baseline EUIs as the design evolves and more detailed information is available.

Another metric that is not part of this analysis but should be considered in selection of these options is the embodied carbon of new construction versus renovation and addition.

Figure 01. Lowell High School (Existing)

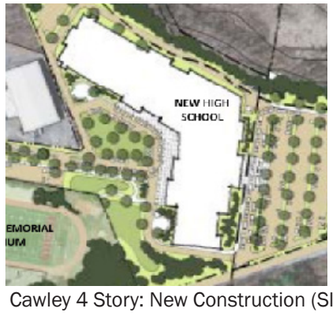
Photo Credit: Panoramo.com

Full Reno



Add/Reno 2

Add/Reno 3



Cawley 4 Story: New Construction (Slightily smaller footprint for 5 Story)

02 ENERGY END USE PROFILES BY SECTOR

Figure 02. shows the annual aggregate energy end-use breakdown for each of the design options. Each color in the pie charts denotes various end-uses. The largest end-use for each options is heating, followed by internal loads and cooling energy use. Although the new option has heating as the predominant load, it is smaller than the renovation options.

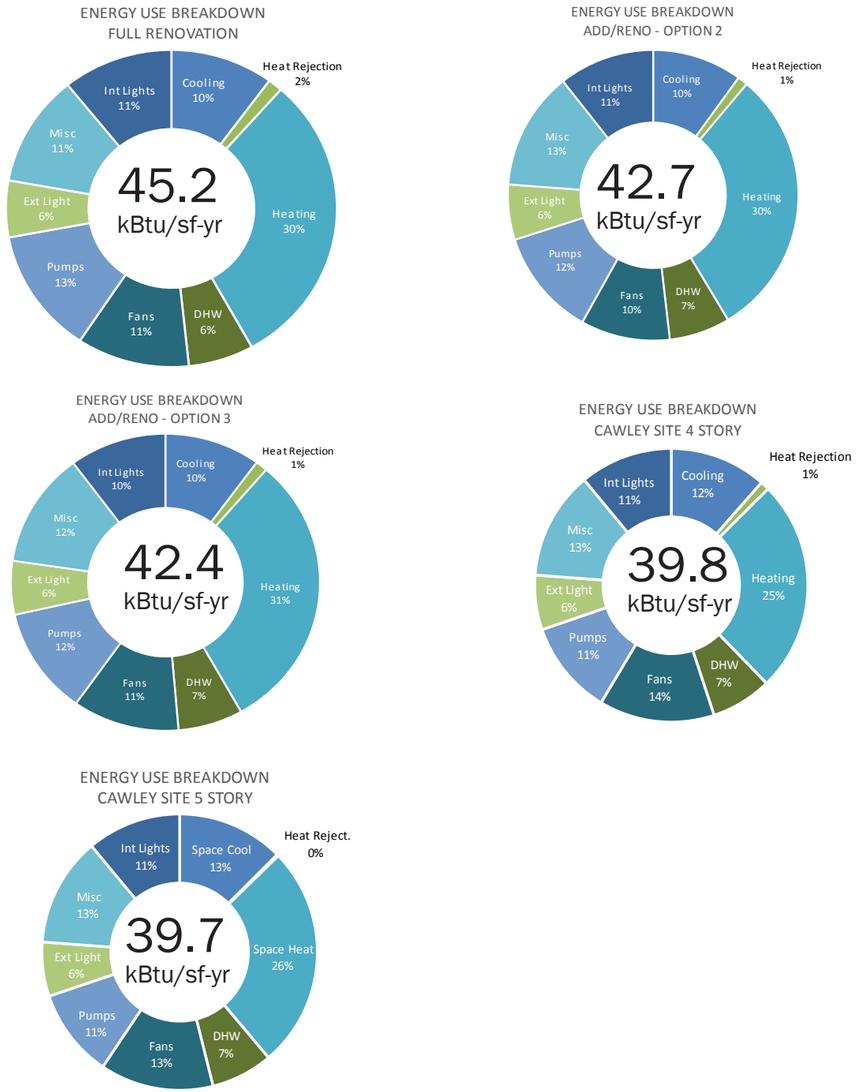


Figure 02. EUI Comparison by Design Options

03 ENERGY END USE PROFILE

Figure 03. shows the annual aggregate energy end-use breakdown for each design case. Each color in the bar chart denotes various end-uses.

The results illustrate that all the design options have a lower EUI than the existing building. The Full Reno has the least total savings, and Cawley Site 5 Story has the most compared to the existing building. The Add/Reno 2 and Add/Reno 3 options have a negligable difference in their EUI. Likewise the Cawley Site 4 and 5 Story options also have a negligable difference.

Note that the energy use associated with the pool is included in each case, causing the total EUI to be larger then comparable buildings. The percent EUI savings shown in Figure 03 do not linearly convert to percent cost savings shown in Figure 04. This is because gas is approximately 4-5 times cheaper than electricity in terms of cost per BTU. More BTUs saved in electricity returns higher cost savings compared to the same BTUs saved in natural gas.

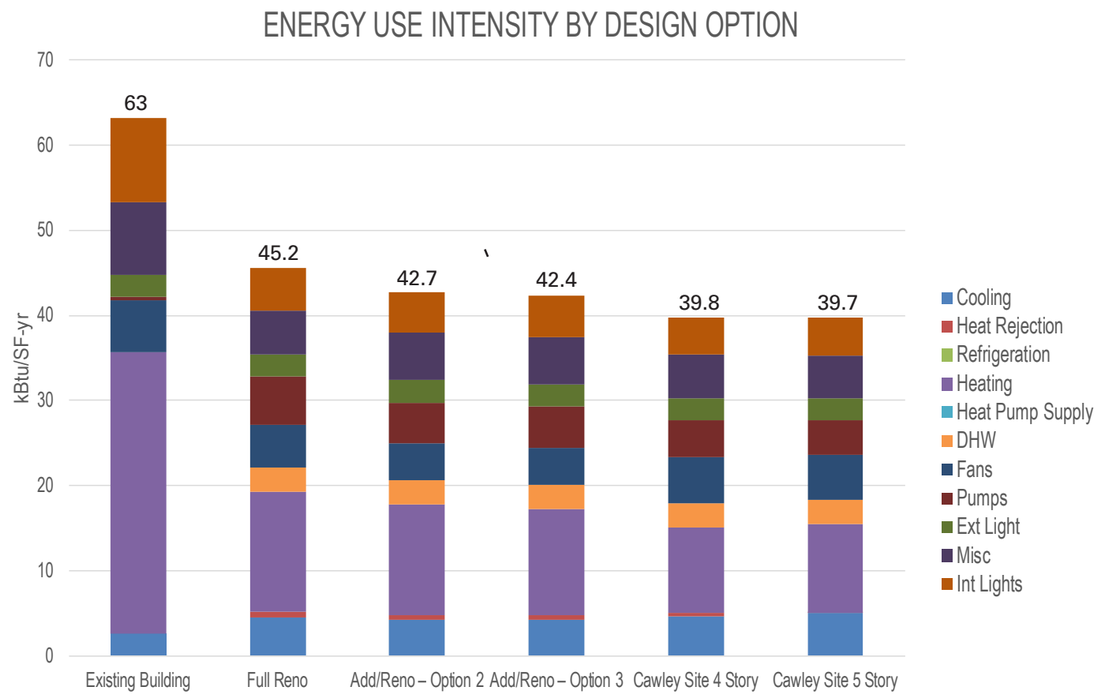


Figure 03. Annual Energy Use Profile by Design Options

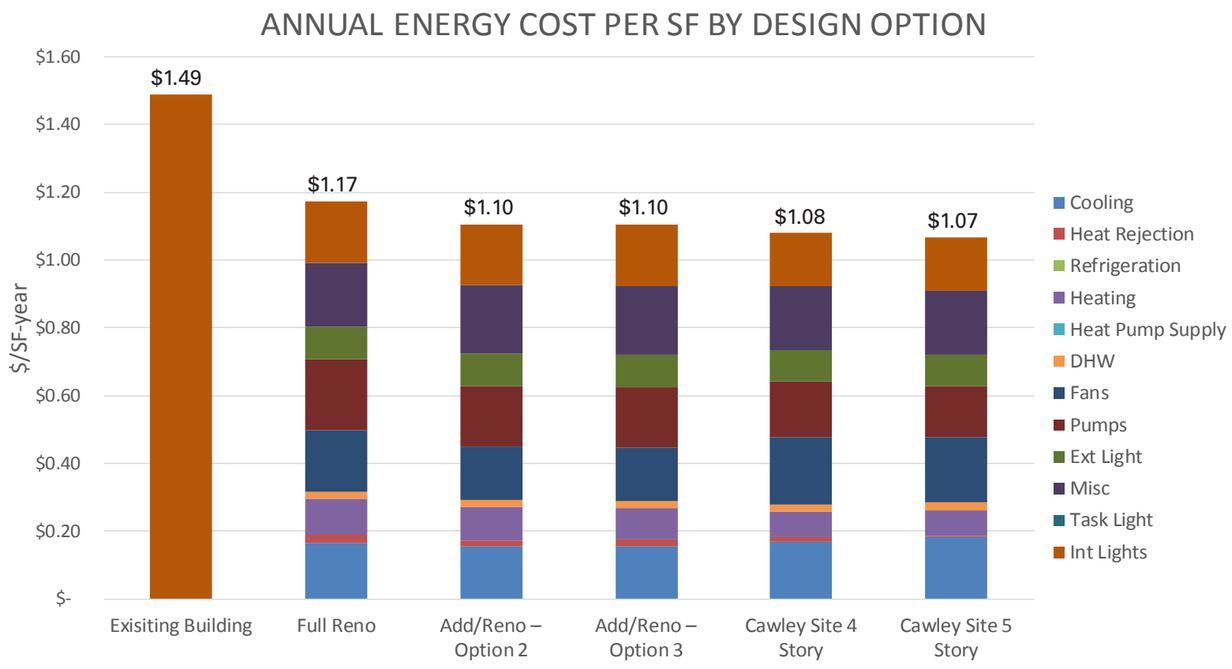


Figure 04. Annual Energy Cost Profile by Design Options

04 ENERGY COST PROFILE BY SYSTEM

The energy cost breakdown demonstrates the relative cost of energy per design option against the existing building. Figure 04. highlights the reduction of energy cost for each design option from the existing building. The Cawely Site 5 story design has the greatest savings, due to the improved envelope and space layout.

Note that the percent difference between the options in energy cost (Figure 03) is smaller than in energy use (Figure 04). This is primarily due to difference in energy cost rates for natural gas vs electricity. Electricity is more expensive per BTU than natural gas. Thus, energy use savings on electricity will return higher cost savings per BTU. Further studies will be conducted in subsequent design phases to further bring down the operating energy costs.

Note: All options include full window & door replacement and new sealant. Final U-values for existing wall components and insulation upgrades are to be determined during further studies.

Model Input Parameter	Full Renovation	Add/ Reno 2	Add/ Reno 3	Cawley Site 4 Story and 5 Story Options
Utility				
Electric Rates	0.125 $/KWH			
Natural Gas Rates	0.75 $/therm			
Number of Floors	1922 Building: 1 below grade Floors+3 above grade floors+attic, Lord: 3 Floors, Freshman Academy 1 below grade + 2 above grade	1922 Building: 1 below grade + 3 above grade Lord: 3 above grade + 2 additional floors of Freshman Academy	1922 Building: 1 below grade + 3 above grade Lord: 3 above grade + 2 additional floors of Freshman Academy	Cawley Option 4 Story: 4 floors Cawley Option 5 Story: 5 floors
Flr to Flr Height	14FT	14FT	14FT	14FT
Climate Zone	5A			
Model Input Parameter	**Full Renovation**	**Add/ Reno 2**	**Add/ Reno 3**	**Cawley Site 4 Story and 5 Story Options**
Building Envelope (Construction Assemblies)				
Roofs Construction/Exterior insulation/Additional insulation	Existing- Assembly: U-0.063	Existing- Assembly: U-0.063 Addition- Assembly: U-0.032 Insulation: R-30	Existing- Assembly: U-0.063 Addition- Assembly: U-0.032 Insulation: R-30	Assembly: U-0.032 Insulation: R-30
Walls (Above Grade) construction/Exterior insulation/Additional Insulation/Interior insulation	Existing- Assembly: U-0.109	Existing- Assembly: U-0.109 Addition- Assembly: U-0.064 Insulation: R-13 + R-7.5 c.i.	Existing- Assembly: U-0.109 Addition- Assembly: U-0.064 Insulation: R-13 + R-7.5 c.i.	Assembly: U-0.064 Insulation: R-13 + R-7.5 c.i.
Ground Floor construction/insulation	Unheated Assembly: F-0.520	Unheated Assembly: F-0.520	Unheated Assembly: F-0.520	Unheated Assembly: F-0.520
Perimeter Zone Infiltration	0.038 CFM/SF of exterior wall	0.038 CFM/SF of exterior wall	0.038 CFM/SF of exterior wall	0.038 CFM/SF of exterior wall
Core Zone Infiltration	0.001 CFM/SF	0.001 CFM/SF	0.001 CFM/SF	0.001 CFM/SF
Vertical fenestration Area (% of Wall area)	1922 Building/Lord/Freshman: 40% Gymnasium: 0%	1922 Building/Lord: 40% Gymnasium: 0%	1922 Building/Lord: 40% Gymnasium: 0%	40% Gymnasium: 0%
Vertical Glazing U-factor (Assembly)	U-0.5	U-0.5	U-0.5	U-0.5
Vertical Glazing SHGC	0.4	0.4	0.4	0.4
Shading Devices	No	No	No	No
Building Operation Schedule				
Occupancy	4,020 Students+ Staff	4,020 Students+ Staff	4,020 Students+ Staff	4,020 Students+ Staff
Schedule	Typical school year: 90% occupancy 8am-4pm Summer & Breaks: 15% occupancy 8am-4pm, 4 days/wk	Typical school year: 90% occupancy 8am-4pm Summer & Breaks: 15% occupancy 8am-4pm, 4 days/wk	Typical school year: 90% occupancy 8am-4pm Summer & Breaks: 15% occupancy 8am-4pm, 4 days/wk	Typical school year: 90% occupancy 8am-4pm Summer & Breaks: 15% occupancy 8am-4pm, 4 days/wk
Annual Days of Operation	365	365	365	365

Model Input Parameter				
HVAC (Air-Side)	Full Renovation	Add/ Reno 1	Add/ Reno 1	Cawley Site 4 Story and 5 Story Options
Primary HVAC Type[1]	Full Air Conditioning Variable Air Volume Displacement System in classrooms Overhead ventilation system in: • Gym • Locker rooms • Auditorium and stage • Admin and media • Kitchen, Custodial Support, Receiving • Cafeteria • Studios • Pool • Corridors	Full Air Conditioning Variable Air Volume Displacement System in classrooms Overhead ventilation system in: • Gym • Locker rooms • Auditorium and stage • Admin and media • Kitchen, Custodial Support, Receiving • Cafeteria • Studios • Pool • Corridors	Full Air Conditioning Variable Air Volume Displacement System in classrooms Overhead ventilation system in: • Gym • Locker rooms • Auditorium and stage • Admin and media • Kitchen, Custodial Support, Receiving • Cafeteria • Studios • Pool • Corridors	Full Air Conditioning Variable Air Volume Displacement System in classrooms Overhead ventilation system in: • Gym • Locker rooms • Auditorium and stage • Admin and media • Kitchen, Custodial Support, Receiving • Cafeteria • Studios • Pool • Corridors
Cooling Source	1992: (2) 215 ton high efficiency water cooled chillers Lord: (2) 270 ton high efficiency water cooled chillers Freshman: DX cooling	1992: (2) 215 ton high efficiency water cooled chillers Lord: (2) 310 ton high efficiency water cooled chillers	1992: (2) 215 ton high efficiency water cooled chillers Lord: (2) 310 ton high efficiency water cooled chillers	High efficiency central chilled water cooling plant - (3) 310 ton water cooled chillers
Heating Source	1922 Building: High efficiency gas-fired condensing boiler plant (3) 5,000 MBH boiler Lord:(3) 5,000 MBH output boilers Freshman: (2) two gas fired 2,000 MBH boilers	1922 Building - High efficiency gas-fired condensing boiler plant (3) 5400 MBH Lord:(3) 5400 MBH output boilers	1922 Building - High efficiency gas-fired condensing boiler plant (3) 5400 MBH Lord:(3) 5400 MBH output boilers	High efficiency gas-fired condensing boiler plant (5) 4500 MBH
Seasonal Thermostat setpoints				
- Heating (occupied/unoccupied)	70 F ; 60 F	70 F ; 60 F	70 F ; 60 F	70 F ; 60 F
- Cooling (occupied/unoccupied)	75 F ; 85 F	75 F ; 85 F	75 F ; 85 F	75 F ; 85 F
Outside Air System				
Heat Recovery Device Type	Enthalpy Wheel	Enthalpy Wheel	Enthalpy Wheel	Enthalpy Wheel
Effectiveness	74%	74%	74%	74%
Domestic Water Heating	**Full Renovation**	**Add/ Reno 2**	**Add/ Reno 3**	**Cawley Site 4 Story and 5 Story Options**
Heater Fuel	Gas	Gas	Gas	Gas
Tank Volume	5,500 gal	5,500 gal	5,500 gal	5,500 gal
Supply water Temp	135F	135F	135F	135F
Lighting	**Full Renovation**	**Add/ Reno 2**	**Add/ Reno 3**	**Cawley Site 4 Story and 5 Story Options**
Lighting Power Density (LPD) for all activity areas	0.5 W/SF: Classroom 0.6 W/SF: Gymnasium 0.5 W/SF: Office 0.6 W/SF: Library 0.4 W/SF: Corridor 0.6 W/SF: Kitchen 0.65 W/SF: Dining 0.63 W/SF: Auditorium	0.5 W/SF: Classroom 0.6 W/SF: Gymnasium 0.5 W/SF: Office 0.6 W/SF: Library 0.4 W/SF: Corridor 0.6 W/SF: Kitchen 0.65 W/SF: Dining 0.63 W/SF: Auditorium	0.5 W/SF: Classroom 0.6 W/SF: Gymnasium 0.5 W/SF: Office 0.6 W/SF: Library 0.4 W/SF: Corridor 0.6 W/SF: Kitchen 0.65 W/SF: Dining 0.63 W/SF: Auditorium	0.5 W/SF: Classroom 0.6 W/SF: Gymnasium 0.5 W/SF: Office 0.6 W/SF: Library 0.4 W/SF: Corridor 0.6 W/SF: Kitchen 0.65 W/SF: Dining 0.63 W/SF: Auditorium
Daylighting Controls	Continuous dimming in classroom spaces	Continuous dimming in classroom spaces	Continuous dimming in classroom spaces	Continuous dimming in classroom spaces
Miscellaneous	**Full Renovation**	**Add/ Reno 2**	**Add/ Reno 3**	**Cawley Site 4 Story and 5 Story Options**
Miscellaneous equipment	Classrooms - 0.85 W/sf Core/transition spaces - 0.165 - 0.316 W/sf	Classrooms - 0.85 W/sf Core/transition spaces - 0.165 - 0.316 W/sf	Classrooms - 0.85 W/sf Core/transition spaces - 0.165 - 0.316 W/sf	Classrooms - 0.85 W/sf Core/transition spaces - 0.165 - 0.316 W/sf