Technical Assignment 2

ASHRAE Standard 90.1/ LEED – NC 2.2

Building & Energy Evaluation

CITY HOSPITAL – PHASE I
S.E. Pennsylvania

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Executive Summary

City Hospital – Phase I is the first phase of a multiphase development. The entire project will eventually result in the construction of approximately one million square feet of research space, one million square feet of ambulatory care and clinical office space, and one million square feet of parking and support services.

The 117,383 square feet, three-level sub-grade Research Facility is a part of City Hospital – Phase I construction. LEED certification and ASHRAE Standard 90.1 – 2004 compliance are used as basis of evaluation on the Research Facility.

City Hospital Campus Development has the ability to attain 34 point using LEED-NC Version 2.2 Checklist. The project achieves LEED Silver Certification (33 – 38 points) as intended.

Analysis of the Research Facility's building material, equipment efficiency, and lighting power density results in one category failed to comply with the standard.

	Building Envelope		**HVAC Equipment**			**Lighting**
	Wall	Roof	Chiller	Heat Rejection	Boiler	Lighting
Std 90.1 Compliance	Yes	Yes	Yes	No	Yes	Yes

Major mechanical equipments supporting the Research Facility are located in the Central Utility Plant that services the entire campus. Therefore, only space occupied by ventilation distribution system is accounted for lost rentable space. Even so, the distribution system alone occupied 22% of floor space of the research Facility. The first cost for the mechanical system is approximately $15 million, or $86 per square foot.

Trane Trace 700 was utilized to perform energy analysis and simulate the cost to operate the building. The ventilation rate and cooling load of the computer simulation reports 70% of the design document. The difference can be accounted by an additional 30% of the airflow rate exhausted by fume hoods which was not included by the program. Based on the design document, Trace calculated the annual cost of energy approximately $3.7 million or $21 per square foot for the Research Facility alone.

Project Background

City Hospital – Phase I is the first phase of a multiphase development. The entire project will eventually result in the construction of approximately one million square feet of research space, one million square feet of ambulatory care and clinical office space, and one million square feet of parking and support services.

City Hospital – Phase I in essence consisted of three buildings, a three-level sub grade Research Facility, a three-level sub grade Central Utility Plant (CUP), and a Support Services at street level. The mechanical, electrical, and plumbing system of the Research Facility is supported by the CUP, and its occupants gain access to the street through Support Services above.

Mechanical System Synopsis

The Research Facility of Phase I services by HVAC equipments contained in the CUP. The ventilation system for the research facility comprised of four 100,000 CFM air handling units (AHU) equipped with variable frequency drives (VFD). They deliver 100% outdoor air to three of the four fitted out levels by the means of variable air volume (VAV) system. The four AHU are demand based, and supply airflow can be reduced to 50% of the design airflow. Two 120,000 CFM exhaust air handlers with heat recovery remove majority of the indoor air, and preheat the supply air. Other exhaust systems compensate for the remaining indoor air removal.

The chiller plant, one 2,000 ton steam turbine chiller and one 2,000 ton electric centrifugal chiller, produces 42°F chilled water. They reject heat by means of four 1,000 cooling towers with VFDs, and act as siphon in winter time for water side “free” cooling. These chillers provide chilled water to the AHUs, as well as process chilled water (PCHW) loads.

The boiler plant included four 800 hp duel fuel boilers with VFDs and stack economizer. The boilers produce high pressure steam at 125 psig for high efficiency distribution, and drive a steam turbine chiller at 120 psig. High pressure steam is reduced to 70 psig medium pressure steam for process equipments and domestic hot water heating. Steam pressure is further reduced to 2 psig low pressure steam for humidification and building hot water loop re-heat.

LEED-NC Certification

The Leadership in Energy and Environmental Design (LEED) Green Building Rating system is a benchmark developed by the US Green Building Council (USGBC), for design, construction, and operation of green buildings. LEED-NC Version 2.2 is a point system used with the intent to make a positive impact on human health, lessen impact on the environment, reduce operating cost for the building, and potentially increasing occupant productivity.

City Hospital – Phase I is currently under construction, and is intended to achieve LEED Silver Certification. LEED – NC for new construction is used to determine the certification level for the building.

	Sustainable Sites	Water Efficiency	Energy & Atmosphere	Materials & Resources	Indoor Environmental Quality	LEED Innovation Credits	Project Total
Confirmed	4	1	2	0	6	1	14
Verification Needed	7	0	3	3	7	0	20
Total	11	1	5	3	13	1	**34**

Certified: 26 – 32 points
Silver: 33 – 38 points
Gold: 39 – 51 points
Platinum: 52 – 69 points

Based on Construction documents, City Hospital Campus Development (entire project) has the potential to achieve at least 34 points. It satisfied the minimum requirement for LEED Silver Certification. Of the 34 points, 14 points in four categories are confirmed by the MEP designers. The additional 20 points await verification from the project architect and construction manager.

Building Envelope Compliance

Standard 90.1 Section 5 specified requirements for an energy efficient building envelope and is used as the basis for evaluation.

Assumptions

The Research Facility is a three-level sub grade building, and serves as a base for future construction above. The walls of the Research Facility consisted of three 24 inches foundation walls with insulations on the first 4 feet, and a concrete masonry unit (CMU) cavity wall (4" concrete, 2" air space, 2" rigid insulation, and 8" CMU). Its occupants gain access to the street through Support Services constructed directly above.

- vertical and skylight fenestration will not be considered
- wall U-value are average of foundation wall and CMU cavity wall
- floor of Level D locates 48' below grade
- roof of the Facility will be enclosed by future phases

Procedure

Section 5.2.1 outlined two compliance paths, (a) the Prescriptive Building Envelope Option and (b) the Building Trade-Off Option. In order to use the Prescriptive Building Envelope Option, the vertical fenestration area does not exceed 50% of the gross wall area for each space conditioning category and the skylight fenestration area does not exceed 5% of the gross roof area for each space conditioning category. The research facility of Phase I has no vertical or skylight fenestration. Therefore the Prescriptive Building Envelope Option is acceptable.

City hospital – Phase I located in southeast Pennsylvania, falls under the climate zone 4A according to ASHRAE Standard 90.1 Figure B-1. Nonresidential column in table 5.5-4 in the Standard is used to determine building envelope compliance. Maximum assembly U-vales and minimum insulated R-values provided by ASHRAE are compared with the actual values. Product information is obtained from construction specifications.

		ASHRAE 90.1 – Nonresidential		**Actual**		**ASHRAE**
Opaque Elements		Maximum U-value	Minimum R-value	Assembly U-value	Insulation R-value	**Std 90.1 Compliant**
Roof	Insulated Entirely Above Deck	U-0.063	R - 15.0 ci	U-0.051	R-19.5	Yes
Walls, Below Grade	Mass	C-1.140	NR	C-0.165	-	Yes
Slab-On-Grade Floors	Unheated	F-0.730	NR	F-0.758	-	No*

Discussion

The floor of Level D locates 48’ below grade is not a true slab-on-grade. The 12” slab with vapor membrane complies if it is categorized as a sub grade wall instead of slab-on-grade. With such amendment, the building envelope of the Research Facility meets the terms of ASHRAE Standard 90.1 Section 5.

HVAC System Compliance

Standard 90.1 Section 6 illustrated minimum efficiency requirements for mechanical equipment in new buildings, and is used as basis of comparison.

Procedure

Section 6 outlined two compliance paths, a) Simplified Approach, and b) Mandatory Provision. In order to use Simplified Approach, the building must be less than two stories, and smaller than 25,000 square feet. Phase I did not qualify, thus Mandatory Provision compliance method in section 6 is used for the compliance check.

	Centrifugal Chiller, > 300 tons		Heat Rejection Equipment	Steam Boiler, > 2.5 Mbtuh	
	Condenser Flow: 2.5 gpm/ton 42°F LCHWT, 85°F ECDWT		Cooling Tower, Propeller/Axial Fan 95°F EWT, 85°F LWT	Gas-Fired	Oil-Fired
	COP	IPLV	gpm/hp	Efficiency	
Standard 90.1 Minimum	5.60	5.88	38.2	80%	83%
Installed	5.88	6.98	33.1	83.5%	83.5%
Compliance	Yes		No	Yes	

Discussion

Research facility's thermal load is supported one 2,000 ton steam turbine chiller, one 2,000 ton electric centrifugal chiller, and four 32,565 Mbtuh duel fuel steam boilers. Natural gas is the primary choice of fuel for the boilers installed. Nevertheless, the boilers have to meet the more stringent oil-fired boiler efficiency due to its flexibility of burning both fuels. Both boilers and chillers complied with minimum equipment efficiency found in Table 6.8.1F and 6.8.1J. The four 1,000 ton cool towers which support the two chillers, however, did not meet requirement found in Table 6.8.1G.

Lighting Compliance

Standard 90.1 Section 9 outlined maximum power density allowance for lighting system in new buildings, and is used as basis of comparison.

Procedure

Section 9 provided two methods for calculating lighting power allowance for buildings, a) Building Area Method, and b) Space-by-space Method. Building Area Method is a more simplified approach while Space-by-space Method allotted greater flexibility.

Assumptions

The Research Facility contained 117,383 square feet of laboratory space on three levels. Level B, C, and D shared similar layout, with Level C completed fit-out. Thus, Level C has been chosen as a typical floor for lighting compliance analysis.

- exterior lighting is not part of Phase I
- used Hospital building type as equivalent
- assumed 1.10 ballast factor

Procedure

No prerequisites are defined for either a) Building Area Method or b) Space-by-space Method. Thus, Building Area Method is chosen for analysis. Since laboratory space is not listed in Standard 90.1, Table 9.5.1, Hospital building type with lighting power density of 1.2 watts per spare foot has been chosen as equivalent. An inventory of lighting fixtures from the floor is summed and divided by the total square footage of the floor. The value is acceptable if it is less than or equal to 1.2 watts per square feet.

Fixture ID	Lamp Description Wattage Per Lamp	Ballast Factor	Lamps Per Fixture	Fixture Wattage	Number of Fixtures	Wattage Per Type
RA	24" T8U 32W	1.10	2	70	58	4,083
RB	48" T8 32W	1.10	3	106	84	8,870
RC	24" T8U 32W	1.10	2	70	34	2,394
RE	48" T8 32W	1.10	3	106	16	1,690
RF	CF 13W	1.10	2	29	8	229
RG	T5 40W	1.10	1	44	23	1,012
RK	A21 150W	-	1	150	14	2,100
RN	CF 26W	1.10	2	57	12	686
SA	48" T8 32W	1.10	2	70	89	6,266
SB	48" T8 32W	1.10	2	70	1	70
SC	48" T8 32W	1.10	3	106	350	36,960
WC	48" Super T8 25W	1.10	1	28	6	165
					Total Wattage	**64,525**
					Floor Area	53,675
					W/SF	**1.20**

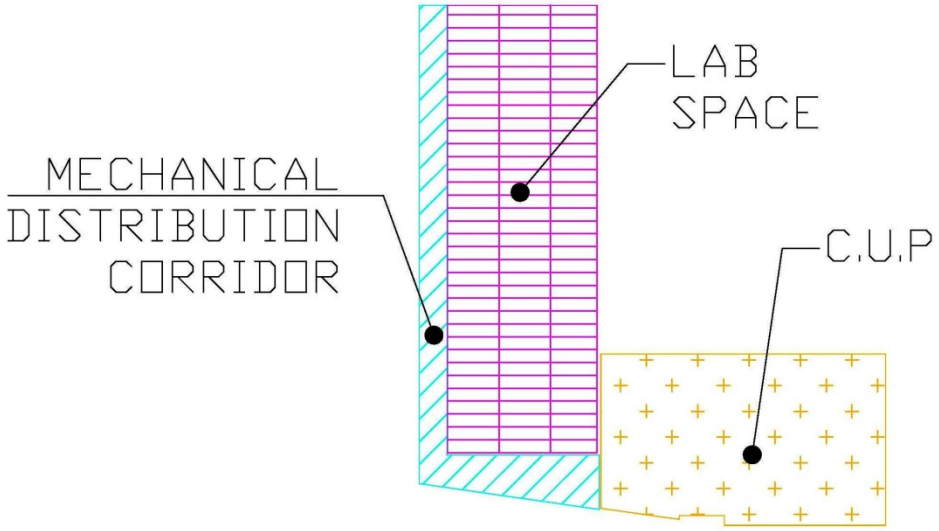
Discussion

The Research Facility meets the requirement of 1.2 watts per square foot for Hospital building type. Space-by-space method is also used to examine the Research Facility. Although the restroom/locker space went over the prescribed limit by 37% with Space-by-space method, the average lighting power density for the entire space is actually 16% lower than the allowance. The lighting power density reduction is made possible with low lighting power intensity, - 67%, in the mechanical

distribution space (Refer results to ComCheck attachments). The Research Facility complies with ASHRAE Standard 90.1 lighting compliance with either method.

Lost Rentable Space

The Research Facility, an 117,383 square feet three-level sub-grade structure, is a part of City Hospital – Phase I construction. Mechanical equipments, AHUs, chillers, and boilers, utilized to support the Facility are located in the CUP. Since these HVAC equipments are centralized in a separate building adjacent to the research facility, they will not be considered in the lost rentable space calculation. The air distribution system, however, are situated in a 12,443 square feet mechanical distribution corridor along the west and south sides of the laboratory on each floor. The mechanical distribution corridor, housed a 144x60 supply duct, a 96x74 exhaust duct, and VAV boxes for individual zones. It occupied 22% of totally floor space, a considerable amount of lost rentable space for distribution only.



Mechanical System First Cost

The mechanical system first cost for the Research Facility is an estimated value provided by Turner Construction Company. The cost per square foot is higher than typical construction due to the fact that the research facility contains advance laboratory spaces, and the utilization of energy saving equipments.

Trade	Cost	Dollars/SF
Automatic Controls	$ 1,950,000	$ 11.00
HVAC Equipment	$ 2,240,000	$ 12.50
HVAC Piping	$ 5,530,000	$ 31.20
Sheet Metal	$ 5,640,000	$ 31.80
Total	**$ 15,360,000**	**$ 86.50**

Design Load & Energy Analysis

In order to estimate design loads, annual energy consumption, and operating cost for the Research Facility, Trane's Trace 700 is utilized for building energy simulation.

Assumptions

- the nearest location to City Hospital – Phase I is Philadelphia, PA
  weather data for Philadelphia is adequate for simulating heating and cooling loads with exception: 95°F DB/78°F WB summer, 0°F winter
- all exterior walls for the research facility are modeled as partition with constant soil temperature of 65°F
- research facility has no heat gain/loss through the roof due to future constructions above
- medium building weight of 100 lbm/sf
- no infiltration due to positive pressurized building design to keep contaminated air from entering
- indoor temperature set point of 72°F at all time for all spaces
- see Appendix C for internal loads and corresponding schedules

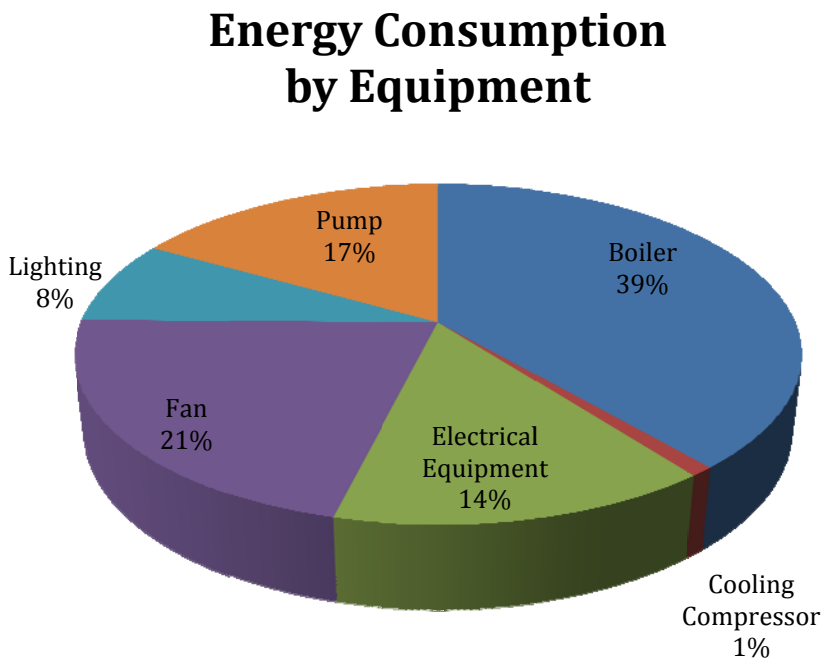
Simulation Results

The computed cooling ventilation rate and cooling loads are 70% of design document. The energy simulation program Trace does not have a category for airflow rate through fume hood exhaust. It accounts for approximately 24,000 cfm of exhaust air each floor at maximum capacity, 28% of design flow rate. Thus, the simulation is 30% less than design ventilation rate and cooling load. The MEP designer did not perform an energy analysis for Phase I due to numerous unknowns in this multiphase development. The calculation however showed the MEP designer used a simple rule of thumb of 1.5 cfm/sf for laboratory space design.

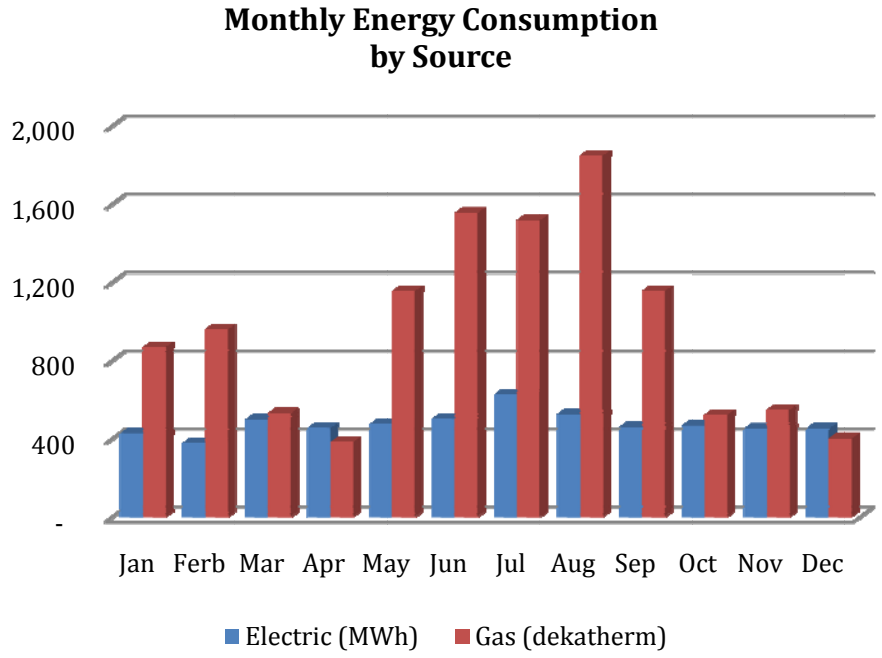
System	Design			Computed		
	Supply Air cfm/ft²	**Load** ft²/ton	cfm/ton	**Supply Air** cfm/ft²	**Load** ft²/ton	cfm/ton
AHU - C	1.50	74.2	111	1.03	96.9	99.8

Building Operation Cost

To calculate energy consumption and operating cost, design rather than computed ventilation rate and cooling load are used. The Energy Consumption by Equipment pie chart showed the percentage of total energy each major component consumes. HVAC equipments consume 70% of total energy by comparison. Trace assumed the 2,000 ton steam turbine chiller is the primary, and the electric centrifugal chiller as a standby. The electrical centrifugal chiller will operate when additional capacity is required during warm seasons. Hence, only 1% of the total energy consumption is counted toward cooling compressor. Cooling compressor energy consumption should include a portion of the boiler energy consumption since the steam turbine consumes 7,000 MMBtu of steam produced by the boiler.



The four 800 hp duel fuel steam boilers use both natural gas and #2 distillate oil. Since natural gas is their primary source of energy, it is used in the for energy consumption simulation. The Monthly Energy Consumption by Source bar chart showed electricity consumption in megawatt-hour, and natural consumption in dekatherm. Electricity consumption remained fairly consistent throughout the year, while gas consumption rate varies. This configuration is a possible operating cost reduction strategy when electric demand charge is minimized.



To calculate the energy cost for the Research Facility, electricity and natural gas tariff are obtained through corresponding providers' website.

	Consumption		Demand
	On Peak	Off Peak	
Electricity	0.58/kWh	0.21/kWh	11.81/KW
Natural Gas	1.31/therm		

From the tariffs, the Research Facility spends 3.6 million annually on energy, $21.50 a square foot. See Appendix C for operating cost by equipment type.

	Energy Consumption	Energy Cost	Cost per SF
Electricity	5,716,816 kWh	$ 3,523,386	$ 20.62 $/sf-yr
Natural Gas	9,537 therm	$ 149,900	$ 0.88 $/sf-yr
	Total	$ 3,673,286	$ 21.50 $/sf-yr

Reference

ASHRAE. 2005. 2005 ASHRAE handbook – Fundamentals. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2001.

ASHRAE. 2004, ANSI/ASHRAE, Standard 90.1 – 2004, Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2004.

LEED. 2005, LEED 2005 Green Building Rating System for New Construction & Major Renovations. Leadership in Energy & Environmental Design, Washington, DC. 2003.

Appendix A

LEED for New Construction v2.2
Registered Project Checklist

Project Name: **City Hospital – Phase I**
Project Address: **Southeast Pennsylvania**

Yes	?	No			
4	7		**Sustainable Sites**		**14** Points
Y			Prereq 1	**Construction Activity Pollution Prevention**	Required
	1		Credit 1	**Site Selection**	1
1			Credit 2	**Development Density & Community Connectivity**	1
			Credit 3	**Brownfield Redevelopment**	1
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
	1		Credit 4.3	**Alternative Transportation**, Low-Emitting & Fuel-Efficient Vehicles	1
	1		Credit 4.4	**Alternative Transportation**, Parking Capacity	1
			Credit 5.1	**Site Development,** Protect or Restore Habitat	1
	1		Credit 5.2	**Site Development,** Maximize Open Space	1
	1		Credit 6.1	**Stormwater Design,** Quantity Control	1
	1		Credit 6.2	**Stormwater Design,** Quality Control	1
			Credit 7.1	**Heat Island Effect,** Non-Roof	1
1			Credit 7.2	**Heat Island Effect,** Roof	1
	1		Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
1			**Water Efficiency**		**5** Points
			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2	**Innovative Wastewater Technologies**	1
1			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

2	3		Energy & Atmosphere	17 Points

Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**Fundamental Refrigerant Management**	Required

***Note for EAc1**: All LEED for New Construction projects registered after June 26th, 2007 are required to achieve at least two (2) points under EAc1.

1	1		Credit 1	**Optimize Energy Performance**	1 to 10
				1 10.5% New Buildings or 3.5% Existing Building Renovations	1
				14% New Buildings or 7% Existing Building Renovations	2
				17.5% New Buildings or 10.5% Existing Building Renovations	3
				21% New Buildings or 14% Existing Building Renovations	4
				24.5% New Buildings or 17.5% Existing Building Renovations	5
				28% New Buildings or 21% Existing Building Renovations	6
				31.5% New Buildings or 24.5% Existing Building Renovations	7
				35% New Buildings or 28% Existing Building Renovations	8
				38.5% New Buildings or 31.5% Existing Building Renovations	9
				42% New Buildings or 35% Existing Building Renovations	10
			Credit 2	**On-Site Renewable Energy**	1 to 3
				2.5% Renewable Energy	1
				7.5% Renewable Energy	2
				12.5% Renewable Energy	3
	1		Credit 3	**Enhanced Commissioning**	1
1			Credit 4	**Enhanced Refrigerant Management**	1
	1		Credit 5	**Measurement & Verification**	1
			Credit 6	**Green Power**	1

Yes ? No

	3		Materials & Resources	13 Points

Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
			Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
			Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
	1		Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
	1		Credit 3.1	**Materials Reuse**, 5%	1
			Credit 3.2	**Materials Reuse**,10%	1
	1		Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
			Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1
			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes	?	No			
6	7		**Indoor Environmental Quality**		15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
	1		Credit 1	**Outdoor Air Delivery Monitoring**	1
1			Credit 2	**Increased Ventilation**	1
	1		Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
	1		Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
	1		Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
	1		Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
	1		Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
	1		Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1			Credit 6.1	**Controllability of Systems**, Lighting	1
1			Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
1			Credit 7.1	**Thermal Comfort**, Design	1
1			Credit 7.2	**Thermal Comfort**, Verification	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No			
2			**Innovation & Design Process**		**5** Points
1			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
1			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No		
15	20		**Project Totals (pre-certification estimates)**	69 Points

Certified: 26-32 points, **Silver:** 33-38 points, **Gold:** 39-51 points, **Platinum:** 52-69 points

Appendix B

Assumptions - Internal Load

	Load	Schedule	Other
Electrical Equip	3.0 w/sf	Misc - Low rise office	-
Light 1	1.4 w/sf	Light - Low rise office	Lab space
Light 2	0.9 w/sf	Light - Low rise office	Mechanical distribution
Steam Equip	6.16 Mbh	Misc - Low rise office	-
People	Laboratory	People - Low rise office	33.5 sf/person
Test Subject	5 btu/sf	100% available	-

Operating Cost by Equipment Type

Equipment By Type	Annual Cost
Lighting System	$ 462,083
Electrical Equipment	$ 808,646
Pump	$ 658,215
Fan	$ 1,212,969
Cooling Compressor	$ 57,760
Boiler	$ 149,900
Total	$ 3,673,286