Technical Assignment #2

Building and Plant Energy Analysis Report

Photo by Fred Martin

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Anderson, SC

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Mechanical Option

Friday, October 27, 2006

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Executive Summary

The following report explains the energy analysis of the Clemson University Advanced Material Research Laboratory. Many different approaches were used to evaluate the energy of the building. Calculating the fenestration and the lighting densities were a few of the approaches used.

A checklist from the U.S. Green Building Council's LEED for New Construction was used to evaluate the building in all aspects. Clemson University ARML proposed 38 out of 62 credits. The certification goal for this project is Silver. The project proposed credits in the following categories: Sustainable Sites – 9, Water Efficiency – 4, Energy and Atmosphere – 4, Materials and Resources – 4, Indoor Environmental Quality – 12, and Innovation and Design – 5. These will be expanded later in the LEED-NC Certification section.

ASHRAE Standard 90.1 is a tool which evaluates the building envelope and lighting systems used in the building, not the mechanical energy performance. This standard requires no more than 50% of the building envelope to be glass. Clemson ARML meets this requirement with only 15.9% fenestration. ASHRAE also requires a lighting density less than 1.1 W/sq ft in order to save energy. After running the calculations using the Space-by-Space method, most of the spaces comply with this requirement.

The total amount of lost rentable space was calculated to be 30.4%. Since Clemson University ARML is mostly research laboratories, there is a gross amount of equipment for this type of building. After this, the mechanical first cost was calculated to be $3,024,000, with a cost of $25.85/sq ft.

Carrier's Hourly Analysis Program (HAP) was used to calculate the loads on the building and also to perform an energy analysis on the building. With this program, the annual energy consumption and operating costs were found, along with the yearly energy utilization data. The annual energy consumption, calculated to the best of my knowledge, is 1,266,030 kWh for the electric and 4,522 Therm for natural gas.

LEED – NC Certification

The Leadership in Energy and Environmental Design (LEED) rating system was created by the U.S. Green Building Council to determine the sustainability of buildings. Due to the recent rise in the cost of energy and resources, "green building" design is becoming more popular. LEED allows one to define a "green building" along with its sustainability in design.

The LEED Rating system consists of six major categories including sustainable sites, water efficiency, energy & atmosphere, materials & resources, indoor environmental air quality, and innovation & design. Of these six categories, 69 possible points are able to be achieved according to the LEED checklist. Based on the number of points obtained, one could earn a LEED certification rating of the following: Certified, Silver, Gold, and Platinum. Table 1 below shows the points for certification. Clemson University's AMRL was given Silver Certification after review. Refer to Appendix A for the preliminary credits prior to certification. Appendix B shows the accepted credits of 33 out of 69 points to earn silver certification.

Table 1: Points for certification

At least 26 points are required for LEED certification. Silver, gold, and platinum levels are also available.	
Credit Category	***Points Available***
Sustainable Sites	14
Water Efficiency	5
Energy and Atmosphere	17
Materials and Resources	13
Indoor Environmental Quality	17
Total Core Points	**64**
Innovation and Design Process	5
LEED Certification Levels	
Certified	26 - 32 Points
Silver	33 - 38 Points
Gold	39 - 51 Points
Platinum	52 - 69 Points

ASHRAE Standard 90.1-2004 Procedure

Section 5 – Building Envelope

Step 1: Fenestration Areas

In order to determine which method to use, such as the Prescriptive Building Envelope Option or the Building Envelope Trade – Off Option, we must analyze two critical points.

> The total vertical fenestration area shall be less than 50% of the gross wall area. The total skylight area shall be less than 5% of the gross roof area.

If the total area is as follows, then the steps for the Prescriptive Building Envelope Option will be followed. If one or more of the previous areas are greater than the allowed, then the Building Envelope Trade – Off Option must be followed.

Step 1a: Calculated Fenestration Areas

Table 2. Fenestration

	Elevation	Area	(sf)		
Material	North	South	East	West	Total
Total Windows	3104	3133	279	740	7256
Gross Exterior Wall Total	20942	22053	4659	5151	52805
Net Exterior Wall	17838	18920	4386	4411	45555
% Windows	17.4	16.5	6.3	16.8	15.9

Total Fenestration area = 15.9% < 50%

Skylight area = 0% < 5%

The Prescriptive Building Envelope Option will be used.

Step 2: Space – Conditioning Categories

Residential conditioned, non – residential conditioned, and semi – heated spaces must be separated according to their exterior building envelope. Since no spaces in the ARML were designated as unconditioned or semi – heated, only non – residential and residential conditioned requirements will be used. See Appendix C for requirements.

Step 3: Climate

Taken from figure B-1. South Carolina is located in Zone 3a.

Step 4: Compliance

Total vertical fenestration area = 15.9% < 50%

Skylight area = 0% < 5%

Step 5: Prescriptive Building Envelope Option

Using table 5.5-3 – Requirements for Zone 3A

At time of report, the Architectural data including U-values for the windows, walls and roof assembly have not been obtained. The comparison and compliance will be calculated upon document arrival.

Lighting Compliance

Maximum lighting power densities are suggested by Standard 90.1. Not only does lighting consume energy, but it also creates heat in the space, which in return increases cooling loads. Table 9.5.1 makes suggestions on the maximum lighting density according to each space. Appendix D shows this table.

According to the lighting calculations given by IDC, the calculated W/ft^2 are as follows:

Table 3. W/sq. ft. calculations

Area	W/sq. ft.
Office	1.10
	1.32
	1.50
	1.68
Prep Lab	1.44
Lab	1.68
Lab open	1.85
Corridors	0.82
	0.83

Area	W/sq. ft.
High Bay	0.65
Haz Mat	1.08
Waste Storage	1.95
Mech	0.39
	0.40
	0.43
	0.49
	0.55

By the space by space calculations and in accordance to Appendix D, all spaces comply except the mechanical rooms.

Mechanical System Lost Rentable Space

Clemson University ARML, due to its many laboratories, requires a lot of mechanical equipment. In design, they used mostly an entire floor to house the mechanical equipment. With this, the total area of the mechanical space on the second floor is 31,841 sq. ft. After calculating the areas other than the mechanical floor space, such as the draw tower and first floor mechanical room, there is a total of 35, 626 sq. ft. of lost rentable space. Out of 117,000 sq. ft, 30.4 % of this area is given to the mechanical equipment.

Mechanical System First Cost

The following information for system first cost was provided my IDC Architects through the master bid summary. The following break down includes all costs associated with the HVAC installation in dollars. Once the total first cost is calculated, the price per square foot can be determined.

Table 4. Total HVAC cost

SHV 1003 HVAC		**3,024,000**
SHV 1010 heat/cooling equipment	700,000	
SHV 1020 AHU/MAU	300,000	
SHV 1030 reheat coils	110,000	
SHV 1040 dehumidification	100,000	
SHV 1050 exhaust fans	70,000	
SHV 1060 ductwork	400,000	
SHV 1070 piping and supports	520,000	
SHV 1080 pumps	24,000	
SHV 1090 Phoenix Control System	400,000	
SHV 1100 insulation	350,000	
SHV 1200 LEED Commissioning	50,000	

The price/sf is calculated to be $25.85 based on 117,000 sq. ft.

Design Load and Energy Estimate:

The design load and energy estimate for the Clemson University ARML was done using Carrier's Hourly Analysis Program (HAP). A comparison was done after computing all loads.

Table 5. Total Supply Air Comparison:

System	Design SA (cfm/sf)	Supply Air (cfm/sf)
AHU-1	1.56	1.56
AHU-2	1.52	1.52
AHU-3	1.77	1.77
AHU-4	1.81	1.81
AHU-5	3.45	3.45
AHU-6	1.41	1.41
AHU-7	1.03	1.03
AHU-8	1.04	1.04
AHU-9	2.13	2.13
AHU-10	0.62	0.62
AHU-11	0.55	0.55
AHU-12	1.7	1.7
AHU-13	4.55	4.55
AHU-14	1.89	1.89
AHU-15	5.52	5.52
MAH-1	1	1
MAH-2	1	1
MAH-3	1	1
MAH-4	1	1

For the calculations of the central cooling, the supply air was used versus the supply temperature. Due to the calculation in HAP, I used the design SA as one of the conditions from the bid bid documents. That is why I suspect the identical numbers in this table.

Table 6. Ventilation Supply Air Comparison:

System	Design Vent (cfm/sf)	Ventilation (cfm/sf)
AHU-1	0.71	0.23
AHU-2	0.61	0.18
AHU-3	0.56	0.24
AHU-4	0.63	0.2
AHU-5	1.53	0.22
AHU-6	1.34	0.003
AHU-7	0.08	0.17
AHU-8	0.2	1.04
AHU-9	0.63	0.18
AHU-10	0.16	0.14
AHU-11	0.1	0.55
AHU-12	1.39	0.13
AHU-13	0.63	13.2
AHU-14	0.57	0.23
AHU-15	1.62	0.07
MAH-1	1	0.05
MAH-2	1	0.05
MAH-3	1	0.05
MAH-4	1	0.05

The building was assumed to have a schedule of people during normal business hours. Equipment heat gains were assumed per space. The ventilation for AHU-7, 8, 10, 11, and 13 worried me since it was close or greater than the design ventilation.

Annual Energy Consumption and Operating Costs

Clemson University ARML's energy utilization data was estimated from Carrier's Hourly Analysis Program (HAP). The building uses both electric power and fossil-fuels. The electric service is provided by Duke Power. The rates can be seen in Appendix E. The fossil-fuel service is provided by Piedmont Natural Gas. These rates can be seen in Appendix F.

The yearly utilization data can be seen below, which was calculated through HAP.

Annual Energy Consumption

Component	Clemson ARML
HVAC Components	
Electric (kWh)	1,266,030
Natural Gas (Therm)	4,522

The annual energy consumption and operating costs were performed with HAP. The fuel costs for both electric and natural gas are given below.

RATE:

I.	Basic Facilities Charge	$33.54	
II.	Demand Charge	Summer Months	Winter Months
	A. On-Peak Demand Charge per month	June 1 – September 30	October 1 – May 31
	For the first 2000 KW of Billing Demand per month	$13.16 per KW	$7.69 per KW
	For the next 3000 KW of Billing Demand per month	$11.67 per KW	$6.40 per KW
	For all over 5000 KW of Billing Demand per month	$ 9.40 per KW	$4.74 per KW
	B. Economy Demand Charge per month	$1.01 per KW	$1.01 per KW
III.	Energy Charge		
	A. All On-Peak Energy per month	4.3937 cents per kWh	4.3937 cents per kWh
	B. All Off-Peak Energy per month	1.7336 cents per kWh	1.7336 cents per kWh

DETERMINATION OF ON-PEAK AND OFF-PEAK HOURS

	Summer Months	Winter Months
	June 1 – September 30	October 1 – May 31
On-Peak Period Hours	1:00 p.m. – 9:00 p.m. Monday – Friday	6:00 a.m. – 1:00 p.m. Monday – Friday
Off-Peak Period Hours	All other weekday hours and all Saturday and Sunday hours.	

Figure 1. Electric rate

Rate Classification	Facility Charge		Rate/Therm November/March		Rate/Therm April/October
	250.00	First 15,000	1.19349	First 15,000	1.12654
Demand (Therm)	1.90	Next 15,000	1.13290	Next 15,000	1.08143
		Next 75,000	1.08558	Next 75,000	1.05278
		Next 165,000	1.04020	Next 165,000	1.02163
		Next 330,000	0.99909	Next 330,000	0.99409
		Over 600,000	0.97052	Over 600,000	0.97052

Figure 2. Natural Gas

The following charts will give a break down of the mechanical equipment. These charts were produced by HAP and only include the electric and natural gas.

Table 8. Annual Energy Costs

Component	Clemson ARML ($)
HVAC Components	
Electric	4,241,147
Natural Gas	9,545
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Remote CW	0
HVAC Sub-Total	**4,250,692**
Non-HVAC Components	
Electric	2,047,133
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Non-HVAC Sub-Total	**2,047,133**
Grand Total	**6,297,825**

Table 9. Annual Energy Consumption

Component	Clemson ARML
HVAC Components	
Electric (kWh)	1,266,030
Natural Gas (Therm)	4,522
Non-HVAC Components	
Electric (kWh)	599,443
Totals	
Electric (kWh)	1,865,474
Natural Gas (Therm)	4,522

Table 10. Annual Cost per Unit Floor Area

Component	Clemson ARML ($/ft²)
Air System Fans	18.189
Cooling	15.382
Heating	0.098
Pumps	3.250
Cooling Tower Fans	6.632
HVAC Sub-Total	**43.552**
Lights	15.104
Electric Equipment	5.870
Misc. Electric	0.000
Misc. Fuel Use	0.000
Non-HVAC Sub-Total	**20.975**
Grand Total	**64.526**
Gross Floor Area (ft²)	97600.0
Conditioned Floor Area (ft²)	97600.0

Note: Values in this table are calculated using the Gross Floor Area.

Table 11. Component Cost as a Percentage of Total Cost

Component	Clemson ARML (%)
Air System Fans	28.2
Cooling	23.8
Heating	0.2
Pumps	5.0
Cooling Tower Fans	10.3
HVAC Sub-Total	**67.5**
Lights	23.4
Electric Equipment	9.1
Misc. Electric	0.0
Misc. Fuel Use	0.0
Non-HVAC Sub-Total	**32.5**
Grand Total	**100.0**

Appendix A:

Proposed LEED Checklist

LEED-NC Version 2.1 Registered Project Checklist

Clemson University ARML

Anderson, SC

Yes	?	No			
9	-	5	**Sustainable Sites**		14 Points
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
Y			Credit 1	**Site Selection**	1
		N	Credit 2	**Development Density**	1
		N	Credit 3	**Brownfield Redevelopment**	1
Y			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
Y			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
		N	Credit 4.3	**Alternative Transportation**, Alternative Fuel Vehicles	1
Y			Credit 4.4	**Alternative Transportation**, Parking Capacity and Carpooling	1
Y			Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
Y			Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
Y			Credit 6.1	**Stormwater Management**, Rate and Quantity	1
		N	Credit 6.2	**Stormwater Management**, Treatment	1
Y			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
		N	Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
Y			Credit 8	**Light Pollution Reduction**	1

Yes	?	No			
4	-	1	**Water Efficiency**		5 Points
Y			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
Y			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		N	Credit 2	**Innovative Wastewater Technologies**	1
Y			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
Y			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes	?	No			
4	2	2	**Energy & Atmosphere**		17 Points
Y			Prereq 1	Fundamental Building Systems Commissioning	Required
Y			Prereq 2	Minimum Energy Performance	Required
Y			Prereq 3	CFC Reduction in HVAC&R Equipment	Required
Y			Credit 1	Optimize Energy Performance	1 to 10
Y			Credit 2.1	Renewable Energy, 5%	1
	?		Credit 2.2	Renewable Energy, 10%	1
	?		Credit 2.3	Renewable Energy, 20%	1
		N	Credit 3	Additional Commissioning	1
Y			Credit 4	Ozone Depletion	1
Y			Credit 5	Measurement & Verification	1
		N	Credit 6	Green Power	1

continued...

Yes	?	No			
4	·	9	**Materials & Resources**		13 Points
Y			Prereq 1	Storage & Collection of Recyclables	Required
		N	Credit 1.1	Building Reuse, Maintain 75% of Existing Shell	1
		N	Credit 1.2	Building Reuse, Maintain 100% of Shell	1
		N	Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell	1
Y			Credit 2.1	Construction Waste Management, Divert 50%	1
		N	Credit 2.2	Construction Waste Management, Divert 75%	1
		N	Credit 3.1	Resource Reuse, Specify 5%	1
		N	Credit 3.2	Resource Reuse, Specify 10%	1
Y			Credit 4.1	Recycled Content, Specify 5% (post-consumer + ½ post-industrial)	1
		N	Credit 4.2	Recycled Content, Specify 10% (post-consumer + ½ post-industrial)	1
Y			Credit 5.1	Local/Regional Materials, 20% Manufactured Locally	1
Y			Credit 5.2	Local/Regional Materials, of 20% Above, 50% Harvested Locally	1
		N	Credit 6	Rapidly Renewable Materials	1
		N	Credit 7	Certified Wood	1

Yes	?	No			
12	**-**	**3**	**Indoor Environmental Quality**		**15 Points**
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke (ETS) Control**	Required
Y			Credit 1	**Carbon Dioxide (CO_2) Monitoring**	1
		N	Credit 2	**Ventilation Effectiveness**	1
Y			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
Y			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
Y			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
Y			Credit 4.2	**Low-Emitting Materials**, Paints	1
Y			Credit 4.3	**Low-Emitting Materials**, Carpet	1
Y			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber	1
Y			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
		N	Credit 6.1	**Controllability of Systems**, Perimeter	1
Y			Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
Y			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
Y			Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
Y			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
		N	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No			
5	**-**	**0**	**Innovation & Design Process**		**5 Points**
Y			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
Y			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
Y			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
Y			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
Y			Credit 2	**LEED™ Accredited Professional**	1

Yes	?	No		
38	**2**	**20**	**Project Totals**	**69 Points**

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

Appendix B:

LEED Certification:

Clemson University's Advanced Materials Research Laboratory

LEED® Project # 0909

LEED Version 2 Certification Level: SILVER

March 11, 2005

33 Points Achieved — Possible Points: 69

Certified 26 to 32 points Silver 33 to 38 points Gold 39 to 51 points Platinum 52 or more points

7 Sustainable Sites — Possible Points: 14

Y			
Y	Prereq 1	Erosion & Sedimentation Control	
1	Credit 1	Site Selection	1
	Credit 2	Urban Redevelopment	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
	Credit 4.3	Alternative Transportation, Alternative Fuel Refueling Stations	1
1	Credit 4.4	Alternative Transportation, Parking Capacity	1
1	Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space	1
1	Credit 5.2	Reduced Site Disturbance, Development Footprint	1
1	Credit 6.1	Stormwater Management, Rate and Quantity	1
	Credit 6.2	Stormwater Management, Treatment	1
	Credit 7.1	Landscape & Exterior Design to Reduce Heat Islands, Non-Roof	1
	Credit 7.2	Landscape & Exterior Design to Reduce Heat Islands, Roof	1
	Credit 8	Light Pollution Reduction	1

4 Water Efficiency — Possible Points: 5

Y			
1	Credit 1.1	Water Efficient Landscaping, Reduce by 50%	1
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
1	Credit 3.2	Water Use Reduction, 30% Reduction	1

5 Energy & Atmosphere — Possible Points: 17

Y			
Y	Prereq 1	Fundamental Building Systems Commissioning	
Y	Prereq 2	Minimum Energy Performance	
Y	Prereq 3	CFC Reduction in HVAC&R Equipment	
2	Credit 1.1	Optimize Energy Performance, 20% New / 10% Existing	2
2	Credit 1.2	Optimize Energy Performance, 30% New / 20% Existing	2
	Credit 1.3	Optimize Energy Performance, 40% New / 30% Existing	2
	Credit 1.4	Optimize Energy Performance, 50% New / 40% Existing	2
	Credit 1.5	Optimize Energy Performance, 60% New / 50% Existing	2
	Credit 2.1	Renewable Energy, 5%	1
	Credit 2.2	Renewable Energy, 10%	1
	Credit 2.3	Renewable Energy, 20%	1
	Credit 3	Additional Commissioning	1
1	Credit 4	Ozone Depletion	1
	Credit 5	Measurement & Verification	1
	Credit 6	Green Power	1

4 Materials & Resources — Possible Points: 13

Y			
Y	Prereq 1	Storage & Collection of Recyclables	
	Credit 1.1	Building Reuse, Maintain 75% of Existing Shell	1
	Credit 1.2	Building Reuse, Maintain 100% of Existing Shell	1
	Credit 1.3	Building Reuse, Maintain 100% Shell & 50% Non-Shell	1
1	Credit 2.1	Construction Waste Management, Divert 50%	1
1	Credit 2.2	Construction Waste Management, Divert 75%	1
	Credit 3.1	Resource Reuse, Specify 5%	1
	Credit 3.2	Resource Reuse, Specify 10%	1
1	Credit 4.1	Recycled Content	1
	Credit 4.2	Recycled Content	1
1	Credit 5.1	Local/Regional Materials, 20% Manufactured Locally	1
	Credit 5.2	Local/Regional Materials, of 20% Above, 50% Harvested Locally	1
	Credit 6	Rapidly Renewable Materials	1
	Credit 7	Certified Wood	1

10 Indoor Environmental Quality — Possible Points: 15

Y			
Y	Prereq 1	Minimum IAQ Performance	
Y	Prereq 2	Environmental Tobacco Smoke (ETS) Control	
	Credit 1	Carbon Dioxide (CO_2) Monitoring	1
1	Credit 2	Increase Ventilation Effectiveness	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
	Credit 4.2	Low-Emitting Materials, Paints	1
1	Credit 4.3	Low-Emitting Materials, Carpet	1
	Credit 4.4	Low-Emitting Materials, Composite Wood	1
1	Credit 5	Indoor Chemical & Pollutant Source Control	1
	Credit 6.1	Controllability of Systems, Perimeter	1
1	Credit 6.2	Controllability of Systems, Non-Perimeter	1
1	Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992	1
1	Credit 7.2	Thermal Comfort, Permanent Monitoring System	1
	Credit 8.1	Daylight & Views, Daylight 75% of Spaces	1
1	Credit 8.2	Daylight & Views, Views for 90% of Spaces	1

3 Innovation & Design Process — Possible Points: 5

Y			
1	Credit 1.1	Innovation in Design: Fume Hood Commissioning	1
1	Credit 1.2	Innovation in Design: Low-Emitting Furniture	1
	Credit 1.3	Innovation in Design:	1
	Credit 1.4	Innovation in Design:	1
1	Credit 2	LEED® Accredited Professional	1

Appendix C:

Building Envelope Requirements for Climate Zone 3

TABLE 5.5-3
Building Envelope Requirements For Climate Zone 3 (A,B,C)

		Nonresidential		Residential		Semiheated	
	Opaque Elements	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
Roofs							
	Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.218	R-3.8 ci
	Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
	Attic and Other	U-0.034	R-30.0	U-0.027	R-38.0	U-0.081	R-13.0
Walls, Above Grade							
	Mass	U-0.151[a,b]	R-5.7 ci[a,b]	U-0.123	R-7.6 ci	U-0.580	NR
	Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.184	R-6.0
	Steel Framed	U-0.124	R-13.0	U-0.084	R-13.0 + R-3.8 ci	U-0.352	NR
	Wood Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.089	R-13.0
Wall, Below Grade							
	Below Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors							
	Mass	U-0.107	R-6.3 ci	U-0.087	R-8.3 ci	U-0.322	NR
	Steel Joist	U-0.052	R-19.0	U-0.052	R-19.0	U-0.069	R-13.0
	Wood Framed and Other	U-0.051	R-19.0	U-0.033	R-30.0	U-0.282	NR
Slab-On-Grade Floors							
	Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
	Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors							
	Swinging	U-0.700		U-0.700		U-0.700	
	Non-Swinging	U-1.450		U-0.500		U-1.450	
	Fenestration (for Zones 3A and 3B; see next page for Zone 3C)	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing,% of Wall							
	0-10.0%	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.39}$	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.39}$	$U_{fixed}^{-1.22}$	$SHGC_{all}^{-NR}$
		$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.49}$	$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.49}$	$U_{oper}^{-1.27}$	$SHGC_{north}^{-NR}$
	10.1-20.0%	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.25}$	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.39}$	$U_{fixed}^{-1.22}$	$SHGC_{all}^{-NR}$
		$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.49}$	$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.49}$	$U_{oper}^{-1.27}$	$SHGC_{north}^{-NR}$
	20.1-30.0%	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.25}$	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.25}$	$U_{fixed}^{-1.22}$	$SHGC_{all}^{-NR}$
		$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.39}$	$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.39}$	$U_{oper}^{-1.27}$	$SHGC_{north}^{-NR}$
	30.1-40.0%	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.25}$	$U_{fixed}^{-0.57}$	$SHGC_{all}^{-0.25}$	$U_{fixed}^{-1.22}$	$SHGC_{all}^{-NR}$
		$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.39}$	$U_{oper}^{-0.67}$	$SHGC_{north}^{-0.39}$	$U_{oper}^{-1.27}$	$SHGC_{north}^{-NR}$
	40.1-50.0%	$U_{fixed}^{-0.46}$	$SHGC_{all}^{-0.19}$	$U_{fixed}^{-0.46}$	$SHGC_{all}^{-0.19}$	$U_{fixed}^{-0.98}$	$SHGC_{all}^{-NR}$
		$U_{oper}^{-0.47}$	$SHGC_{north}^{-0.26}$	$U_{oper}^{-0.47}$	$SHGC_{north}^{-0.26}$	$U_{oper}^{-1.02}$	$SHGC_{north}^{-NR}$
Skylight with Curb, Glass,% of Roof							
	0-2.0%	$U_{all}^{-1.17}$	$SHGC_{all}^{-0.39}$	$U_{all}^{-1.17}$	$SHGC_{all}^{-0.36}$	$U_{all}^{-1.98}$	$SHGC_{all}^{-NR}$
	2.1-5.0%	$U_{all}^{-1.17}$	$SHGC_{all}^{-0.19}$	$U_{all}^{-1.17}$	$SHGC_{all}^{-0.19}$	$U_{all}^{-1.98}$	$SHGC_{all}^{-NR}$
Skylight with Curb, Plastic,% of Roof							
	0-2.0%	$U_{all}^{-1.30}$	$SHGC_{all}^{-0.65}$	$U_{all}^{-1.30}$	$SHGC_{all}^{-0.27}$	$U_{all}^{-1.90}$	$SHGC_{all}^{-NR}$
	2.1-5.0%	$U_{all}^{-1.30}$	$SHGC_{all}^{-0.34}$	$U_{all}^{-1.30}$	$SHGC_{all}^{-0.27}$	$U_{all}^{-1.90}$	$SHGC_{all}^{-NR}$
Skylight without Curb, All,% of Roof							
	0-2.0%	$U_{all}^{-0.69}$	$SHGC_{all}^{-0.39}$	$U_{all}^{-0.69}$	$SHGC_{all}^{-0.36}$	$U_{all}^{-1.36}$	$SHGC_{all}^{-NR}$
	2.1-5.0%	$U_{all}^{-0.69}$	$SHGC_{all}^{-0.19}$	$U_{all}^{-0.69}$	$SHGC_{all}^{-0.19}$	$U_{all}^{-1.36}$	$SHGC_{all}^{-NR}$
a.	Exception to A3.1.3.1 applies.						
b.	Insulation is not required for non-residential mass walls in Climate Zone 3A located below the "Warm-Humid" line, and in Zone 3B.						

Appendix D:

Table 9.5.1 Lighting Power Densities Using the Building Area Method

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	Lighting Power Density (W/ft2)
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Health Care-Clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theater	1.2
Multi-Family	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both general building area type and a specific building area type are listed, the specific building area type shall apply.

References:

"ANSI/ASHRAE/IESNA Standard 90.1-2004—Energy Standard for Buildings Except Low-Rise Residential Buildings." ASHRAE, Inc. Atlanta, GA. 2004.

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