Mechanical Breadth

Breadth Overview

My mechanical depth was designed to explore the affect of the architectural implications of the new façade designs in the capital market classroom, the designs that can be found on the cd attached to this book. The addition of the light shelf and the use of more efficient solar glazing windows will affect the mechanical design to the room. Solar gains through the windows can potentially cause significant loses and gains to the systems serving the room, and through these gains will directly affect the operation cost of the system. To explore how the design will affect the mechanical system in the capital market classroom, a program called Hourly Analysis Program was used.

The primary goal of this depth study is to examine the affect the solar heat gains or loses have on the mechanical systems, and to determine if the existing system is adequate. The secondary goal of the study is to analyze emissions and energy gains or loses.

Existing System Narrative –

The existing design utilizes two blower coil units, which are located on floor P1 below the classroom on floor. These two units only supply the capital market classroom. The existing system and the inputs placed into the HAP analysis are contained below.

1. General Details:				
Air System Name	**BCU1**		**BCU2**	
Equipment Class	**Chilled Water AHU**		**Chilled Water AHU**	
Air System Type	**Single Zone CAV**		**Single Zone CAV**	
Number of zones	**1**		**1**	
2. System Components:				
Ventilation Air Data:				
Airflow Control	**Constant Ventilation Airflow**		**Constant Ventilation Airflow**	
Ventilation Sizing Method	**ASHRAE Std 62-2001**		**ASHRAE Std 62-2001**	
Unocc. Damper Position	**Closed**		**Closed**	
Damper Leak Rate	**0**	%	**0**	%
Outdoor Air CO2 Level	**400**	ppm	**400**	ppm
Preheat Coil Data:				
Setpoint	**56.0**	°F	**56.0**	°F
Heating Source	**Hot Water**		**Hot Water**	
Schedule	**JFMAMJJASOND**		**JFMAMJJASOND**	
Coil position	**Downstream of Mixing Point**		**Downstream of Mixing Point**	
Central Cooling Data:				
Supply Airflow Rate	**2700.0**	CFM	**1200.0**	CFM
Coil Bypass Factor	**0.100**		**0.100**	
Cooling Source	**Chilled Water**		**Chilled Water**	
Schedule	**JFMAMJJASOND**		**JFMAMJJASOND**	
Capacity Control	**Constant Temperature - Fan Cycled**		**Constant Temperature - Fan Cycled**	
Supply Fan Data:				
Fan Type	**Forward Curved**		**Forward Curved**	
Configuration	**Draw-thru**		**Draw-thru**	
Fan Performance	**3.00**	in wg	**2.70**	in wg
Overall Efficiency	**54**	%	**54**	%

3. Zone Components:
Space Assignments:

Zone 1: Zone 1	
Capital Market	x1

Thermostats and Zone Data:

Zone	All	
Cooling T-stat: Occ.	75.0	°F
Cooling T-stat: Unocc.	85.0	°F
Heating T-stat: Occ.	70.0	°F
Heating T-stat: Unocc.	60.0	°F
T-stat Throttling Range	3.00	°F
Diversity Factor	100	%
Direct Exhaust Airflow	0.0	CFM
Direct Exhaust Fan kW	0.0	kW

Supply Terminals Data:

Zone	All	
Terminal Type	Diffuser	
Minimum Airflow	2700.0	CFM

Zone Heating Units:

Zone	All
Zone Heating Unit Type	Baseboard, room T-stat control

4. Sizing Data (Computer-Generated):
System Sizing Data:

Cooling Supply Temperature	61.2	°F
Supply Fan Airflow	2700.0	CFM
Ventilation Fan Airflow	495.0	CFM

Hydronic Sizing Specifications:

Chilled Water Delta-T	10.0	°F
Hot Water Delta-T	20.0	°F

Supply Terminals Data:

Zone	All	
Terminal Type	Diffuser	
Minimum Airflow	1200.0	CFM

Zone Heating Units:

Zone	All
Zone Heating Unit Type	Baseboard, room T-stat control

4. Sizing Data (Computer-Generated):
System Sizing Data:

Cooling Supply Temperature	43.9	°F
Supply Fan Airflow	1200.0	CFM
Ventilation Fan Airflow	495.0	CFM

Hydronic Sizing Specifications:

Chilled Water Delta-T	10.0	°F
Hot Water Delta-T	20.0	°F

Input data for the chiller plant and the boiler plant are contained in the appendix. Data for the chiller and boiler plants was taken from the existing mechanical plans, but sized down. The two plants were sized down to eliminate any portion of the system not feeding the room. With that portion of the system eliminate, it was easier to compare the systems that were just serving the classroom. All other results were placed with the HAP files with the CD contained.

System Analysis

The existing design of the two blowing coil units has already been included in this report; however, with the changes made to the exterior portion of the room, the system will operate at a separate design level. After running an analysis of the room with the addition of a light shelf, and then again with different windows, the system operated under different design loads each time. Displayed below is a comparison of the blowing coil unit one in its existing condition, with the light shelf added to the space, and with the addition of the light shelf and the new glass.

Information on blowing coil unit 2 can be found on the CD attached with the book.

BCU1 - Central Cooling Coil Size Data – Existing Data

Total coil load	7.3	Tons	Load occurs at	Jul 1100	
Total coil load	88.2	MBH	OA DB / WB	88.5 / 74.3	°F
Sensible coil load	68.5	MBH	Entering DB / WB	79.9 / 66.0	°F
Coil CFM at Jul 1100	2700	CFM	Leaving DB / WB	56.4 / 55.1	°F
Max block CFM	2700	CFM	Coil ADP	53.8	°F
Sum of peak zone CFM	2700	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.778		Resulting RH	46	%
ft²/Ton	195.1		Design supply temp.	58.5	°F
BTU/(hr-ft²)	61.5		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	17.64	gpm	Max zone temperature deviation	0.0	°F

BCU1 - Central Cooling Coil Size Data – Lightshelf only

Total coil load	7.4	Tons	Load occurs at	Jul 1100	
Total coil load	89.2	MBH	OA DB / WB	88.5 / 74.3	°F
Sensible coil load	69.4	MBH	Entering DB / WB	80.0 / 65.9	°F
Coil CFM at Jul 1100	2700	CFM	Leaving DB / WB	56.1 / 54.9	°F
Max block CFM	2700	CFM	Coil ADP	53.5	°F
Sum of peak zone CFM	2700	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.778		Resulting RH	46	%
ft²/Ton	192.7		Design supply temp.	58.2	°F
BTU/(hr-ft²)	62.3		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	17.86	gpm	Max zone temperature deviation	0.1	°F

BCU1 - Central Cooling Coil Size Data – Lightshelf with new glass

Total coil load	6.0	Tons	Load occurs at	Jul 1100	
Total coil load	72.2	MBH	OA DB / WB	88.5 / 74.3	°F
Sensible coil load	56.3	MBH	Entering DB / WB	79.9 / 67.8	°F
Coil CFM at Jul 1100	2685	CFM	Leaving DB / WB	60.4 / 59.3	°F
Max block CFM	2700	CFM	Coil ADP	58.3	°F
Sum of peak zone CFM	2700	CFM	Bypass Factor	0.100	
Sensible heat ratio	0.780		Resulting RH	54	%
ft²/Ton	238.0		Design supply temp.	62.5	°F
BTU/(hr-ft²)	50.4		Zone T-stat Check	1 of 1	OK
Water flow @ 10.0 °F rise	14.46	gpm	Max zone temperature deviation	0.0	°F

As expected, total coil loads and the sensible coil load decreased as the changes were made to the space, and the BTU value and water flow rate also lowered in the final situation. The glazing on the window blocks a solid portion of the heat gain from solar means. Making changes to an isolated system such as this one would not necessarily produce savings that would be noticeable among the costs of an entire building. However, if these changes were to be implemented throughout the building, cost savings would be more significant, and it would be easy to replace the existing system with a smaller, less expensive system.

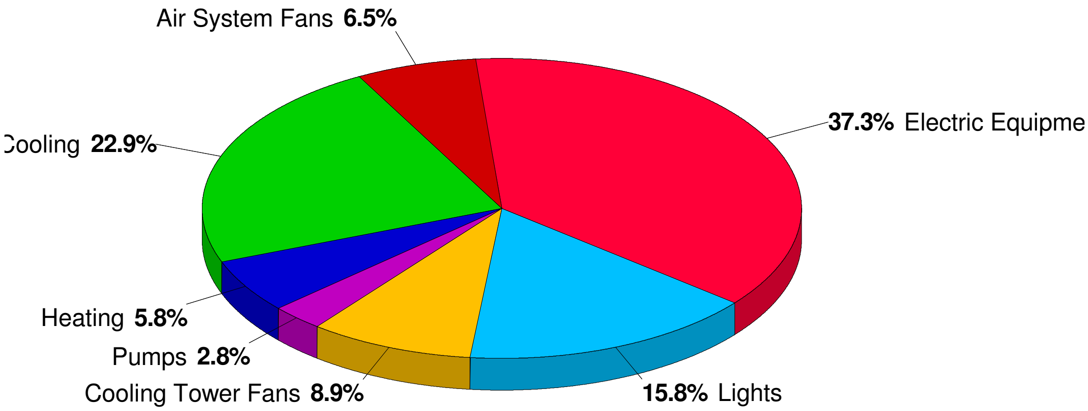
System Analysis

The advantages to the changes in the façade design are not limited to sizing down the blower coils units to a cheaper system. With the elimination of a portion of the solar loads, the mechanical equipment in the room will operate in a different way. In some cases there will be a decrease in certain cooling because a portion of the direct gains will be eliminated, and it will also affect heating loads in the opposite manner. Design for the capital market room was made with three different systems; however, due to the length of the study and the amount of data contained in each of the studies, only the data from two situations is contained below. An analysis of the existing condition has been run for comparison purposes, and then a direct indirect lighting system with a light shelf added to the space and a lighting system with a light shelf and new glass. The cases for the remaining lighting systems and blower coil units can be found in on the CD with the rest of the HAP files.

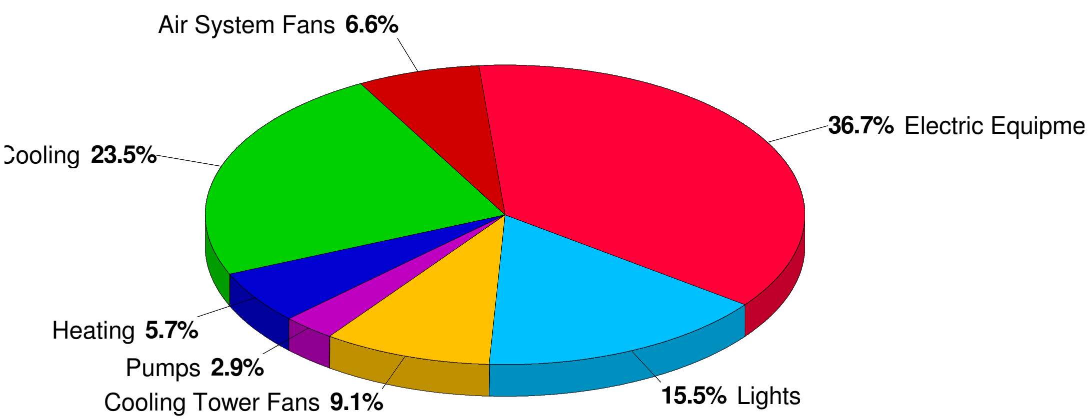
Component Costs Analysis

The pie charts that on the next page give a breakdown of how the total cost is divided between the varying system components. The charts show that the cost of the varying system components is spread in a uniform fashion for the different situations. Changes between the existing system and the system with the light shelf is not very different, but when the low-e windows are added, the system changes dramatically. By adding the windows, a very large portion of the cooling cost is eliminated. The other systems vary in only one and two percent increments. Small changes in the data are hard to judge however, as the values can remain the same, but the data can be affected by the other changes to the system. The pie charts showing these changes are shown on the next page, followed by the actual cost break down of each of the components.

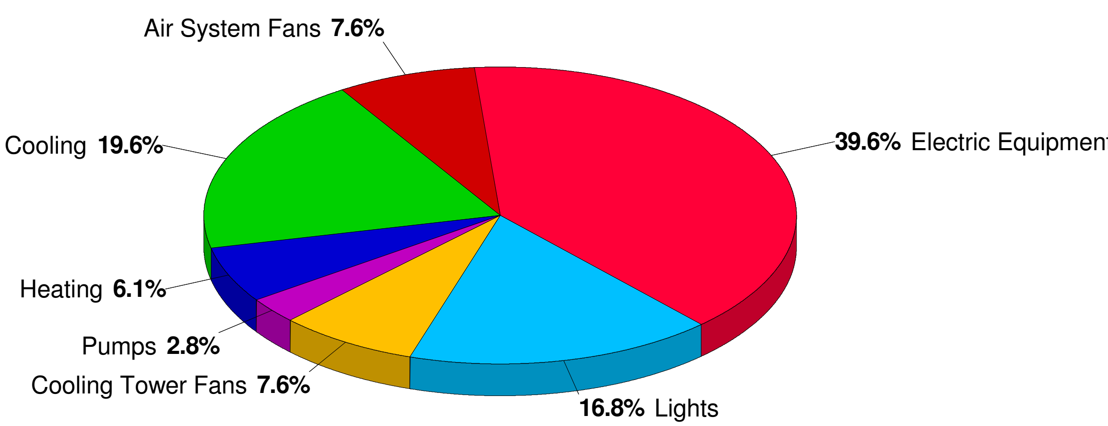
Existing System



Light Shelf Design



Light Shelf and Window Design



Component Cost Analysis

Existing System

Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	514	0.179	6.5
Cooling	1,810	0.632	22.9
Heating	458	0.160	5.8
Pumps	223	0.078	2.8
Cooling Tower Fans	702	0.245	8.9
HVAC Sub-Total	**3,707**	**1.293**	**46.9**
Lights	1,248	0.436	15.8
Electric Equipment	2,947	1.028	37.3
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**4,195**	**1.464**	**53.1**
Grand Total	**7,902**	**2.757**	**100.0**

Light Shelf

Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	530	0.185	6.6
Cooling	1,880	0.656	23.5
Heating	457	0.160	5.7
Pumps	230	0.080	2.9
Cooling Tower Fans	729	0.255	9.1
HVAC Sub-Total	**3,826**	**1.335**	**47.8**
Lights	1,245	0.434	15.5
Electric Equipment	2,939	1.025	36.7
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**4,184**	**1.460**	**52.2**
Grand Total	**8,009**	**2.795**	**100.0**

Light Shelf and Windows

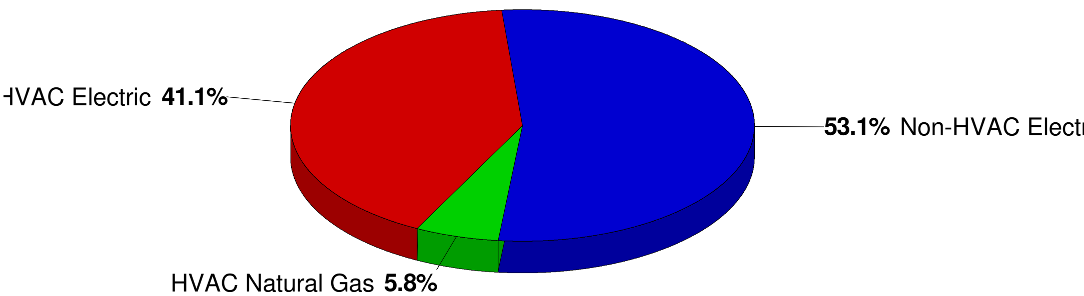
Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	568	0.198	7.6
Cooling	1,467	0.512	19.6
Heating	457	0.160	6.1
Pumps	213	0.074	2.8
Cooling Tower Fans	571	0.199	7.6
HVAC Sub-Total	**3,276**	**1.143**	**43.7**
Lights	1,257	0.439	16.8
Electric Equipment	2,967	1.035	39.6
Misc. Electric	0	0.000	0.0
Misc. Fuel Use	0	0.000	0.0
Non-HVAC Sub-Total	**4,224**	**1.474**	**56.3**
Grand Total	**7,500**	**2.617**	**100.0**

As you can see from viewing the charts above, the cost of the system components increases slightly with the addition of the light shelf, and then decreases significantly when the glazing windows are added to the façade. The savings found in this room may seem to be significant, but the savings of five hundred dollars in a single room can be very small compared to the cost of the upkeep of the entire building. However, if the new windows are placed throughout the entire building, the savings would multiply and the building would see substantial savings.

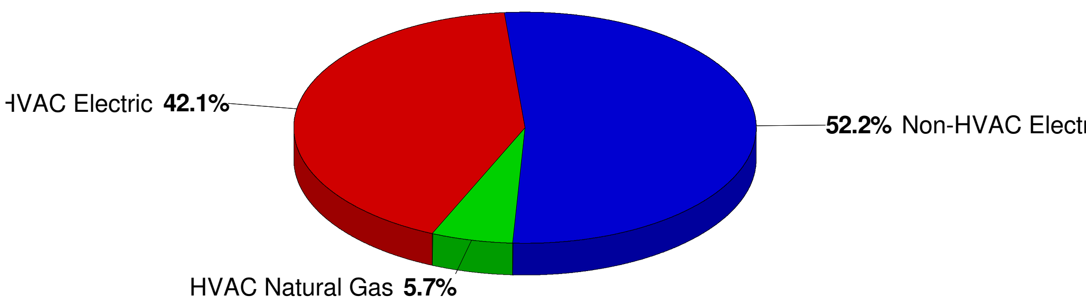
Annual Energy Costs

The annual energy cost utilized the information from the system components and applied it to the cost of the system as opposed to the singular components. The data is displayed in the same manner as the previous section. H.A.P. provided a pie chart to show the breakdown of the cost on the entire system, and then numerical charts to give raw cost data on the systems.

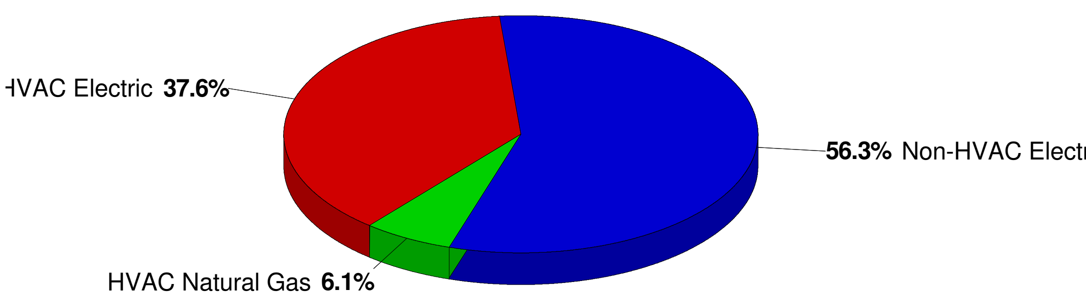
Existing System



Light Shelf



Light Shelf and Windows



Annual Energy Costs

Existing System

Component	Annual Cost ($/yr)	($/ft²)	Percent of Total (%)
HVAC Components			
Electric	3,249	1.134	41.1
Natural Gas	458	0.160	5.8
HVAC Sub-Total	**3,707**	**1.293**	**46.9**
Non-HVAC Components			
Electric	4,195	1.464	53.1
Natural Gas	0	0.000	0.0
Non-HVAC Sub-Total	**4,195**	**1.464**	**53.1**
Grand Total	**7,902**	**2.757**	**100.0**

Light Shelf

Component	Annual Cost ($/yr)	($/ft²)	Percent of Total (%)
HVAC Components			
Electric	3,368	1.175	42.1
Natural Gas	457	0.160	5.7
HVAC Sub-Total	**3,826**	**1.335**	**47.8**
Non-HVAC Components			
Electric	4,184	1.460	52.2
Natural Gas	0	0.000	0.0
Non-HVAC Sub-Total	**4,184**	**1.460**	**52.2**
Grand Total	**8,009**	**2.795**	**100.0**

Light Shelf and Glass

Component	Annual Cost ($/yr)	($/ft²)	Percent of Total (%)
HVAC Components			
Electric	2,819	0.984	37.6
Natural Gas	457	0.160	6.1
HVAC Sub-Total	**3,276**	**1.143**	**43.7**
Non-HVAC Components			
Electric	4,224	1.474	56.3
Natural Gas	0	0.000	0.0
Non-HVAC Sub-Total	**4,224**	**1.474**	**56.3**
Grand Total	**7,500**	**2.617**	**100.0**

The results from the annual energy costs mirror the results from the component costs. As before, the cost of the system with the light shelf and the low-e glass windows provided the most cost saving. Although there was an increase in the cost of the non HVAC electrical equipment, there was a very large saving in the actual HVAC systems.

Energy Emissions

Existing System

Table 1. Annual Costs

Component	duques hall ($)
HVAC Components	
Electric	3,249
Natural Gas	458
HVAC Sub-Total	**3,707**
Non-HVAC Components	
Electric	4,195
Natural Gas	0
Non-HVAC Sub-Total	**4,195**
Grand Total	**7,902**

Light Shelf

Table 1. Annual Costs

Component	duques hall ($)
HVAC Components	
Electric	3,368
Natural Gas	457
HVAC Sub-Total	**3,826**
Non-HVAC Components	
Electric	4,184
Natural Gas	0
Non-HVAC Sub-Total	**4,184**
Grand Total	**8,009**

Light Shelf and Windows

Table 1. Annual Costs

Component	duques hall ($)
HVAC Components	
Electric	2,819
Natural Gas	457
HVAC Sub-Total	**3,276**
Non-HVAC Components	
Electric	4,224
Natural Gas	0
Non-HVAC Sub-Total	**4,224**
Grand Total	**7,500**

The annual savings for the space are shown in the tables above. The biggest savings is electrical savings for the HVAC components when the Solarban windows are utilized in the design. Overall totals do not differ very much between the existing system and the light shelf study, while the study with the glazing and the light shelf gives the biggest savings.

Existing System – Table 2. Annual Energy Consumption

Component	duques hall
HVAC Components	
Electric (kWh)	26,253
Natural Gas (Therm)	3
Non-HVAC Components	
Electric (kWh)	32,644
Natural Gas (Therm)	0
Totals	
Electric (kWh)	58,897
Natural Gas (Therm)	3

Light Shelf – Table 2. Annual Energy Consumption

Component	duques hall
HVAC Components	
Electric (kWh)	27,280
Natural Gas (Therm)	2
Non-HVAC Components	
Electric (kWh)	32,644
Natural Gas (Therm)	0
Totals	
Electric (kWh)	59,924
Natural Gas (Therm)	2

Light Shelf and Windows – Table 2. Annual Energy Consumption

Component	duques hall
HVAC Components	
Electric (kWh)	22,430
Natural Gas (Therm)	1
Non-HVAC Components	
Electric (kWh)	32,644
Natural Gas (Therm)	0
Totals	
Electric (kWh)	55,074
Natural Gas (Therm)	1

The energy consumption tables follow the same trend. Values for the existing system and the system with the light shelf are rather similar; however, cost savings occur in the HVAC components of the final study.

Existing System – Table 3. Annual Emissions

Component	duques hall
CO_2 (lb)	81,282
SO_2 (kg)	201
NO_x (kg)	118

Light Shelf – Table 3. Annual Emissions

Component	duques hall
CO_2 (lb)	82,699
SO_2 (kg)	205
NO_x (kg)	120

Light Shelf and Windows – Table 3. Annual Emissions

Component	duques hall
CO_2 (lb)	76,004
SO_2 (kg)	188
NO_x (kg)	111

The savings in the HVAC systems carriers over into the emissions categories. This is clear because the light shelf and windows system has the least amount of emissions.

Table 4. Annual Cost per Unit Floor Area

Component	duques hall ($/ft²)
HVAC Components	
Electric	1.134
Natural Gas	0.160
HVAC Sub-Total	**1.293**
Non-HVAC Components	
Electric	1.464
Natural Gas	0.000
Non-HVAC Sub-Total	**1.464**
Grand Total	**2.757**
Gross Floor Area (ft²)	2866.0
Conditioned Floor Area (ft²)	2866.0

Table 4. Annual Cost per Unit Floor Area

Component	duques hall ($/ft²)
HVAC Components	
Electric	1.175
Natural Gas	0.160
HVAC Sub-Total	**1.335**
Non-HVAC Components	
Electric	1.460
Natural Gas	0.000
Non-HVAC Sub-Total	**1.460**
Grand Total	**2.795**
Gross Floor Area (ft²)	2866.0
Conditioned Floor Area (ft²)	2866.0

Table 4. Annual Cost per Unit Floor Area

Component	duques hall ($/ft²)
HVAC Components	
Electric	0.984
Natural Gas	0.160
HVAC Sub-Total	**1.143**
Non-HVAC Components	
Electric	1.474
Natural Gas	0.000
Non-HVAC Sub-Total	**1.474**
Grand Total	**2.617**
Gross Floor Area (ft²)	2866.0
Conditioned Floor Area (ft²)	2866.0

The same conclusions made in the other categories follow through to this one as well.

Table 5. Component Cost as a Percentage of Total Cost

Component	duques hall (%)
HVAC Components	
Electric	41.1
Natural Gas	5.8
HVAC Sub-Total	**46.9**
Non-HVAC Components	
Electric	53.1
Natural Gas	0.0
Non-HVAC Sub-Total	**53.1**
Grand Total	**100.0**

Table 5. Component Cost as a Percentage of Total Cost

Component	duques hall (%)
HVAC Components	
Electric	42.1
Natural Gas	5.7
HVAC Sub-Total	**47.8**
Non-HVAC Components	
Electric	52.2
Natural Gas	0.0
Non-HVAC Sub-Total	**52.2**
Grand Total	**100.0**

Table 5. Component Cost as a Percentage of Total Cost

Component	duques hall (%)
HVAC Components	
Electric	37.6
Natural Gas	6.1
HVAC Sub-Total	**43.7**
Non-HVAC Components	
Electric	56.3
Natural Gas	0.0
Non-HVAC Sub-Total	**56.3**
Grand Total	**100.0**

The break down of cost percentage varies so much across the three categories because of the difference in total cost.

Conclusion

From the breakdown of the different sections, it is quite apparent that the implementation of the solarban glass cuts significant portions out of the heating and cooling loads to the capital market classroom. The light shelf seems to have little affect on the room, and if anything, seems to cause higher heating costs to supplement the light it prevents from entering the space. More efficient glazing is an excellent addition to any space to aide of the HVAC systems. Cost data might not reach a pay back for a few years do to the smaller scale of this situation, but if implemented to an entire building, the money saved would slowly start adding up in the bank.