Color photo taken by Laura Pica August 2011

River Vue Apartments

Laura Pica – Mechanical Option

Adviser – Stephen Treado

Senior Thesis Program 2011-2012

Department of Architectural Engineering

Color photo taken by Laura Pica August 2011

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Photo taken by Laura Pica August 2011

Photo taken by Laura Pica August 2011

Photo courtesy www.wikipedia.com

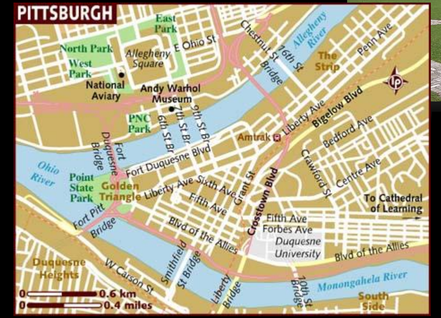

Photo courtesy: www.lonelyplanet.com

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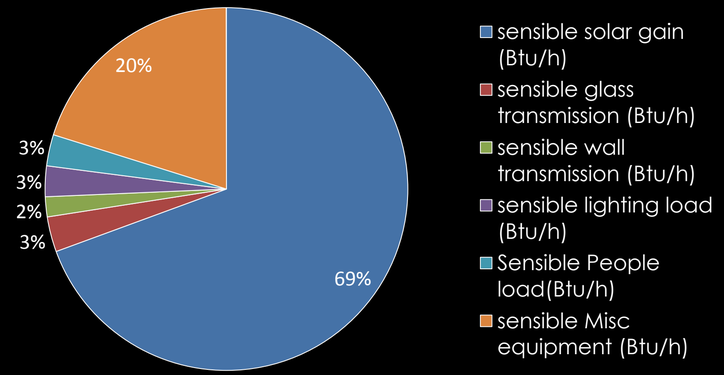
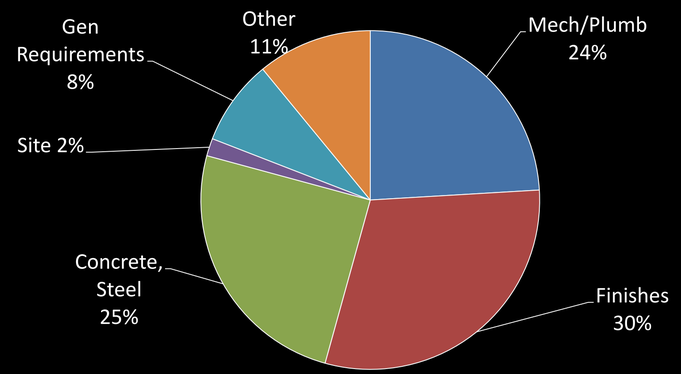
Building Loads



Project Cost Breakdown



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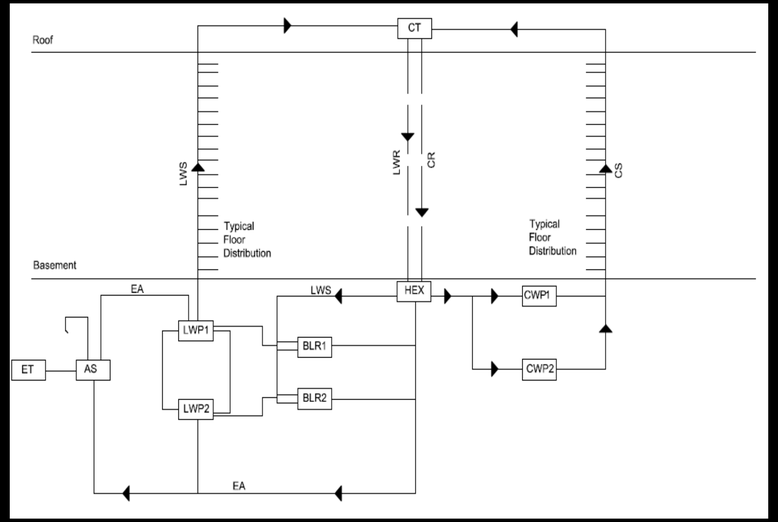

Space	ASHRAE Outdoor Airflow (cfm)	As Designed Outdoor Airflow (cfm)	Requires Redesign
Common Corridor	933	5250	
Stairwells	346	3200	
Main Entry Lobby	42	570	
Stair Lobby	81	150	
Elect Equip Room	48	0	YES
Bsmt Machine Room	96	0	YES
Elevator Machine Room	150	0	YES
Boiler Room	96	0	YES
Fire Pump Room	96	0	YES
Generator Room	96	0	YES
Dwelling Units 2nd Floor	1641	1156	YES
Dwelling Units 3-14 Floors	17504	8580	YES
Dwelling Units 15-16 Floors	2217	3107	
Fitness Center	516	500	YES
Retail Sales	365	500	
Parking Garage	2070	0	YES

Schedule

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Monthly Utility Usage			
Month	Electric (kW)	Gas (therms)	Water (gal)
1	722	36776	16
2	717	35939	13
3	722	26060	17
4	849	15040	104
5	839	4558	263
6	845	1307	411
7	846	46	509
8	844	1717	350
9	839	4782	238
10	842	17417	96
11	749	20845	83
12	726	33222	17
TOTAL	9540	197709	2117

Typical High Rise Apartment				River Vue Apartments
occupancy sqft/person				occupancy sqft/person
Lo	Av	Hi		
325	175	100		200
lights watts/sqft				lights watts/sqft
Lo	Av	Hi		
1	2	4		1
refrigeration sqft/ton				refrigeration sqft/ton
Lo	Av	Hi		
450	400	350		90
supply air rate (east-south-west) cfm/sqft				supply air rate (east-south-west) cfm/sqft
Lo	Av	Hi		
0.8	1.2	1.7		0.63
supply air rate (north) cfm/sqft				supply air rate (north) cfm/sqft
Lo	Av	Hi		
0.5	0.8	1.3		0.63

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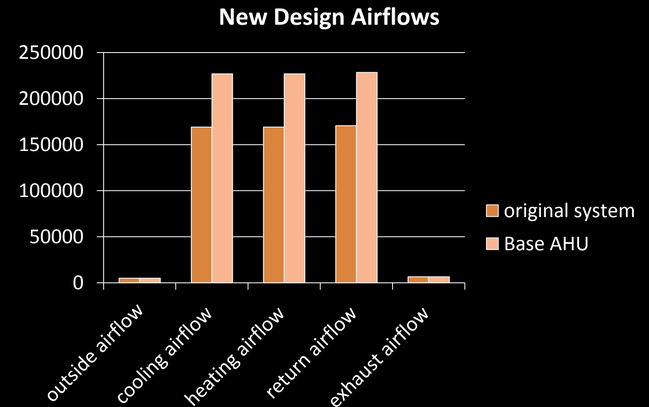
AHU Sizing Load Calculations

Lighting
Equipment
Occupancy
Solar Gain

LOADS (Btu/h)					
lighting	equipment	occupancy	solar	TOTAL Btu/h	TOTAL cfm
318096	7278258	352800	948365	8.90E+06	411922



Need for energy conservation

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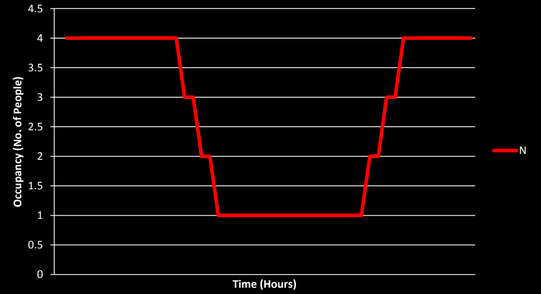
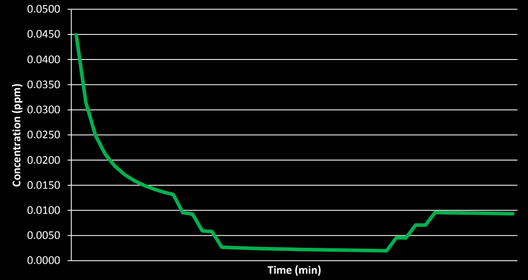
Demand Control Ventilation

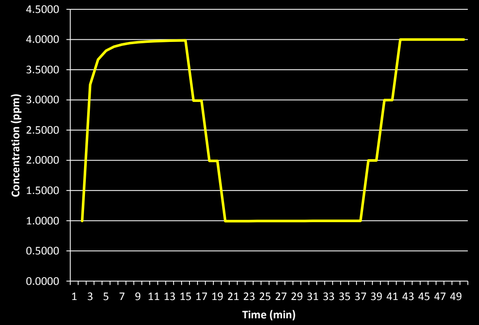
Occupancy Over 24 Hour Period



Natural Ventilation with Constant Air Changes

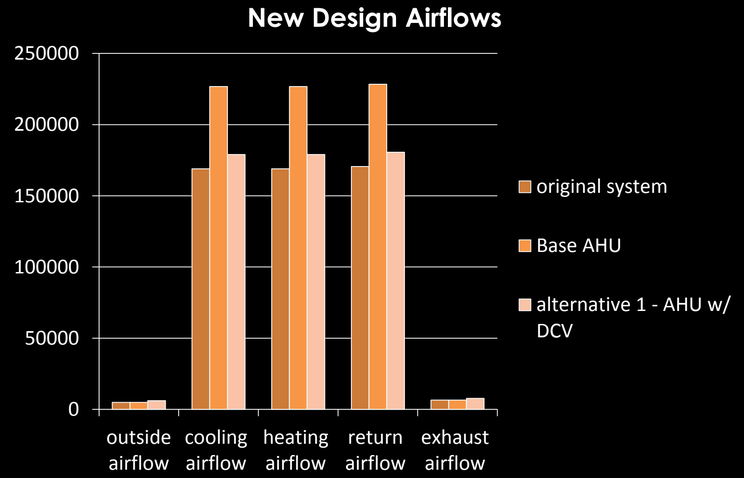


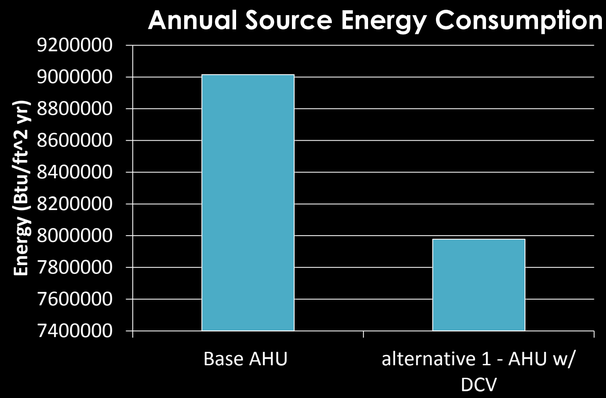
Demand Control Ventilation



$$c(t+\Delta t) = c(t) * e^{(-n*\Delta t)} + (cb + (N*q)/(n*V)) * (1-e^{(-n*\Delta t)})$$

Schedule





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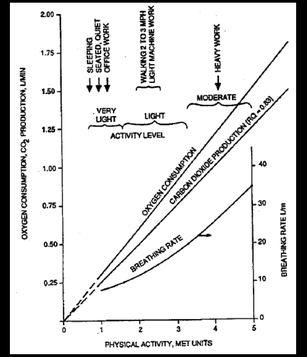
Contaminant Calculations

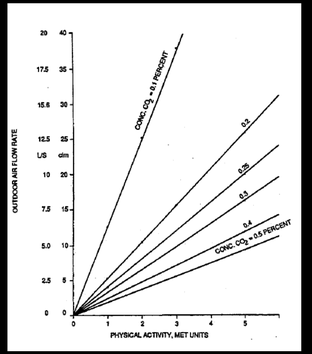
Contaminant Differential (Ceq) = Co + (N/Vo)

Vo = outdoor airflow rate per person
N = CO2 rate per person
Co = CO2 concentration outside

Assumptions:
15 cfm/person
700 ppm
1.2 MET level means N= 0.0106 cfm
Co = 400 ppm

Ceq = 1107 ppm differential





MET =1.2 and 15 cfm of outside airflow, the expected CO2 concentration will be about 0.13 percent

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Telair Ventostate 8000 series sensors

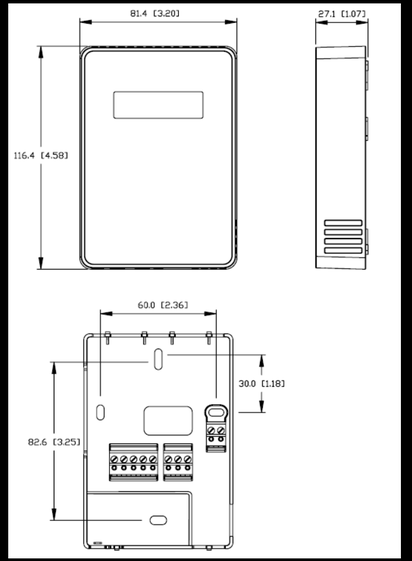
accurate within 3% and can detect 400-1250 ppm of CO_2
CO_2 detection between 2-3 minutes

Control Logic

one sensor per floor located in return air duct

supply air fan VFD to start when CO_2 concentration reaches 1170 ppm or more

*See final report for full descriptions of control logic and sequence of operation



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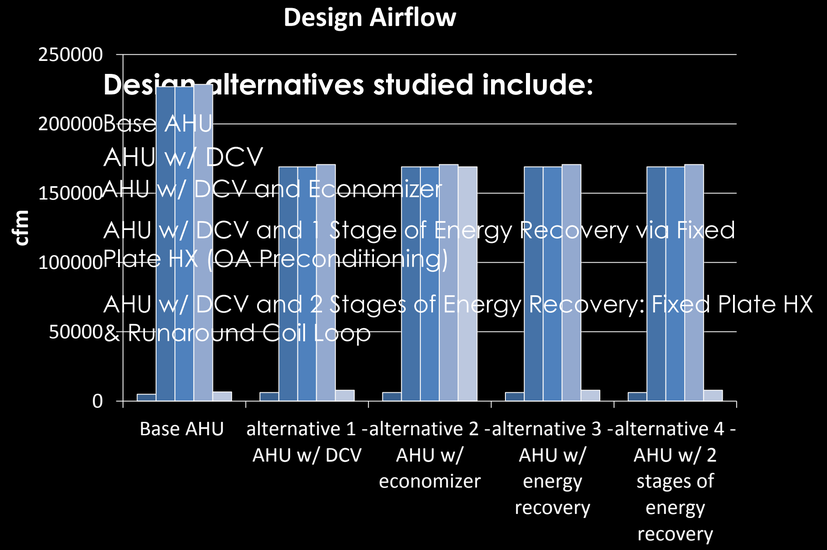
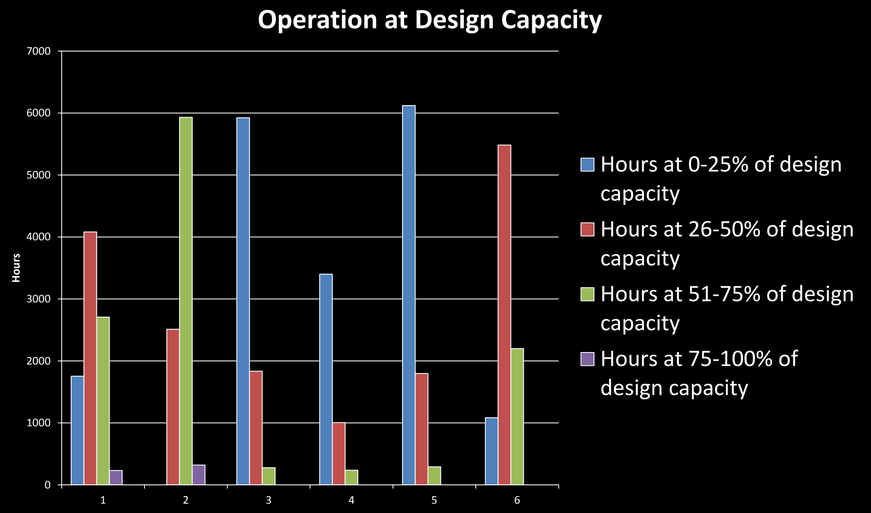
Design alternatives studied include:

- Base AHU
- AHU w/ DCV
- AHU w/ DCV and Economizer
- AHU w/ DCV and 1 Stage of Energy Recovery via Fixed Plate HX (OA Preconditioning)
- AHU w/ DCV and 2 Stages of Energy Recovery: Fixed Plate HX & Runaround Coil Loop





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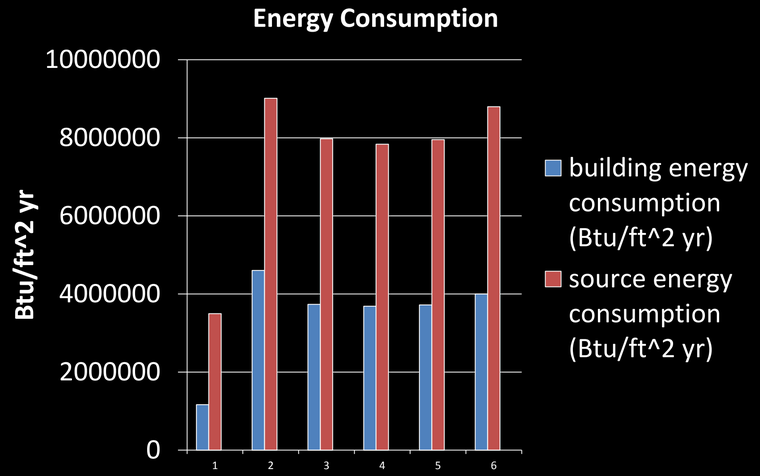

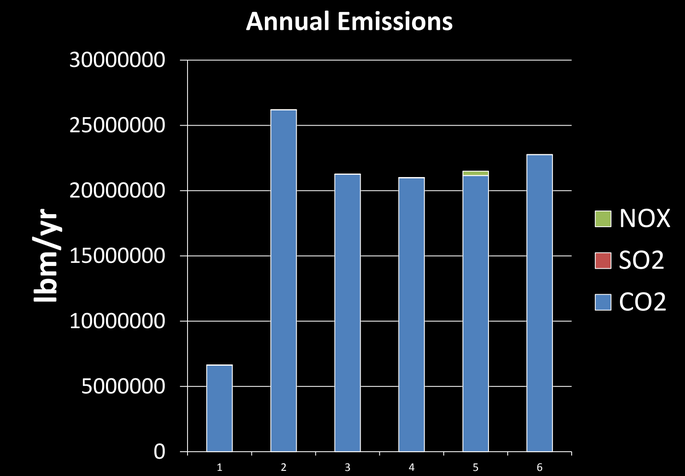

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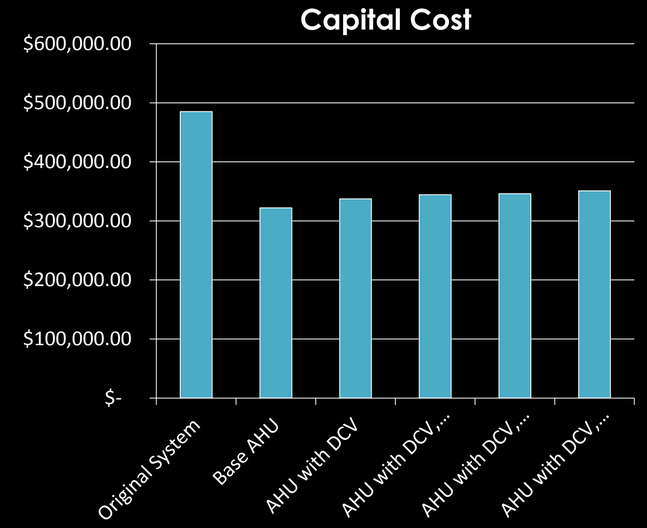

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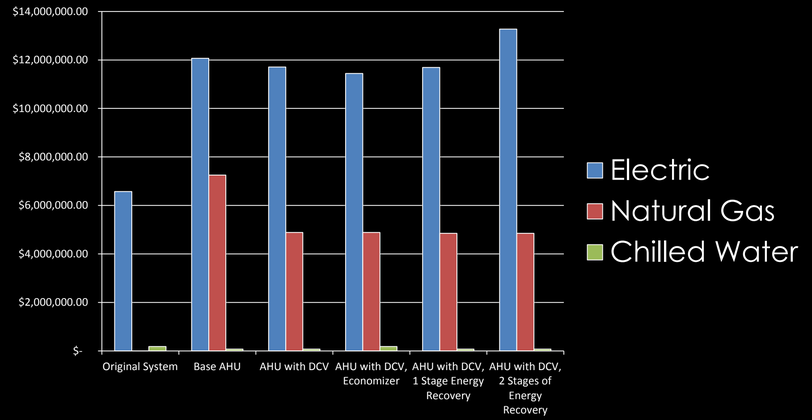
20 Year Utility Cost



System Selection

Airflow	**169,033 cfm**
Coil Size	434 tons
Total Btu/h	8.9MBtu/h
Annual CO2 Emissions	20,981,096 lbm/yr
Capital Cost	$363,600
20 Year Life Cycle Cost	$16.9 Million

AHU with DCV and Economizer

Success measured with:

Occupant comfort

Reduced energy use and emissions with control strategy

Minimum ventilation requirements met

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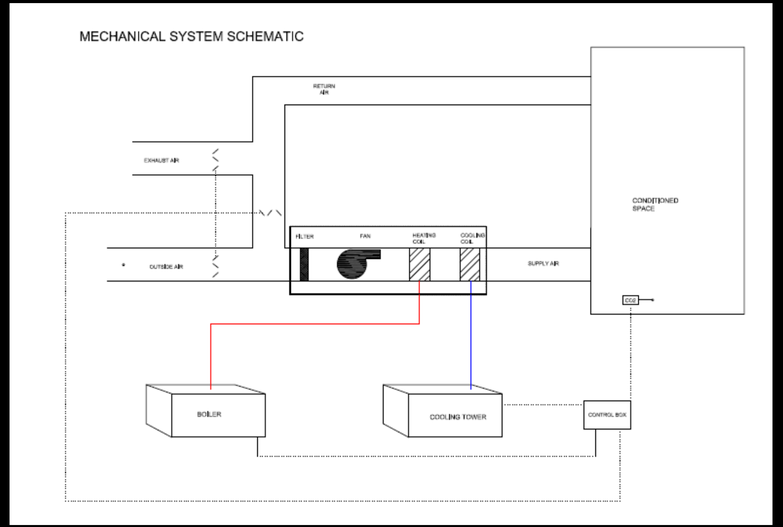

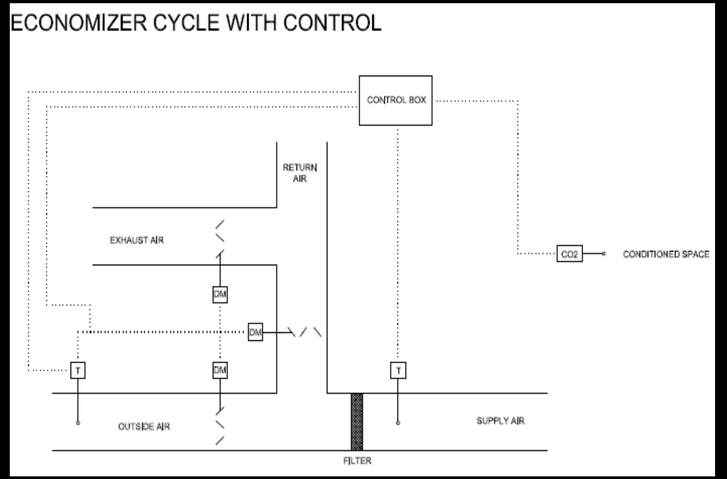

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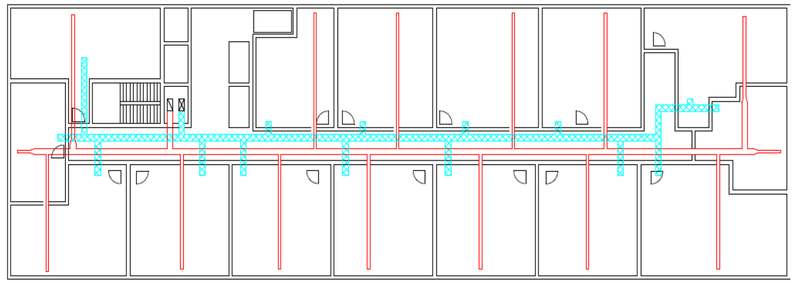
Typical Floor Duct Layout



Size	Capacity	Throw	NC	Pressure Drop
2x12 sill grille	62 cfm	9.45 feet	20	0.073 in wg

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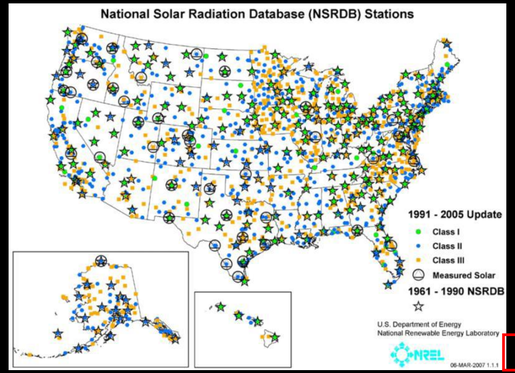
Available Solar Radiation



www.rredc.nrel.gov/solar_data

β	Monthly Electric Output
0	1.401E+18
5	1.389E+22
10	9.904E+20
15	4.487E+20
20	1.722E+20
25	3.564E+20
30	1.177E+24
35	1.044E+21
40	6.104E+20
45	3.497E+20

5500 sq. ft. of available space

http://gerardribas.com/wp-content/uploads/2011/05/Photovoltaic-Pannles6.jpg

Photo taken by Laura Pica August 2011

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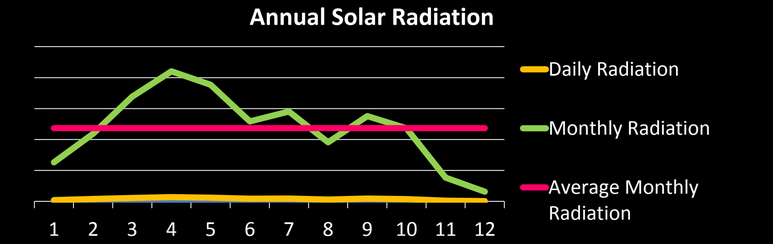

Energy Analysis

Windows modeled with improved U-value to represent shading

Sensible solar gain reduction of 243,549 Btu/h

(10% of total sensible load)

Schedule

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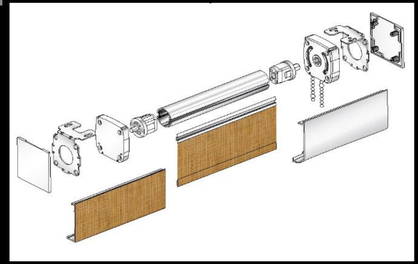
Internal Shading Analysis						
# Shades	volts	amps	VA	PF	Watts	Full load amps
1	120	20	2400	1	2400	12
400	120	8000	960000	1	960000	4624

# Shades	Shade (kW) requirement per year	Annual PV Array (kW) output	Δ (PV Output-Shading Requirement)	Annual Mechanical System Requirement (kW)	Mech Syst Need - PV Power Available	
1	2102.4	30872	28770	9491826	9460954	
					0	
400	840960		-810088	9491826	9460954	0.33%

http://mechosystems.com/UrbanShade/



http://mechosystems.com/UrbanShade/

Schedule

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		Original Photovoltaic TOTAL	**$ 712,273.54**
Solar Funding	PA Federal Investment Tax Credit	30% of total installation cost	$ 213,682.06
	West Penn Power Sustainable Energy Fund	one time grant	$ 25,000.00
		New Photovoltaic TOTAL	**$ 473,591.48**

simple payback period = 26.6 years

Photovoltaic Array Study					
Date	Year	Capital	Other Mat.	Elect. Escalation	Elect. Value
2011	1	$ 1,473,591	$ 100	1.00	**$ 64,461**
2012	2	$ -	$ 100	0.96	$ 61,883
2013	3	$ -	$ 100	0.93	$ 59,949
2014	4	$ -	$ 100	0.91	$ 58,660
2015	5	$ -	$ 100	0.91	$ 58,660
2016	6	$ -	$ 100	0.90	$ 58,015
2017	7	$ -	$ 100	0.90	$ 58,015
2018	8	$ -	$ 100	0.90	$ 58,015
2019	9	$ -	$ 100	0.91	$ 58,660
2020	10	$ -	$ 100	0.92	$ 59,304
2021	11	$ -	$ 100	0.93	$ 59,949
2022	12	$ -	$ 100	0.94	$ 60,594
2023	13	$ -	$ 100	0.94	$ 60,594
2024	14	$ -	$ 100	0.94	$ 60,594
2025	15	$ -	$ 100	0.94	$ 60,594
2026	16	$ -	$ 100	0.94	$ 60,594
2027	17	$ -	$ 100	0.94	$ 60,594
2028	18	$ -	$ 100	0.94	$ 60,594
2029	19	$ -	$ 100	0.93	$ 59,949
2030	20	$ -	$ 100	0.93	$ 59,949
			Net Present Value		$ 953,086

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Category	Cost for Equipment & Materials	Total installation hours	Total installation days
New Mech System	$ 865,728.62	18306	763
Old Mechanical System	$ 1,371,508.55	24812	1034
Mech System Cost Difference	**$ 505,779.92 savings**	**6506**	**271**

Category	Total Labor Cost
New Mech System	$ 15,610.64
Old Mechanical System	$ 3,323.81
Mech System Cost Difference	**$ (12,286.83)**

Schedule

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Category	Cost for Equipment & Materials	Total installation hours	Total Labor Cost
New Mech System with Photovoltaic and Shading Systems TOTAL	$ 2,578002.16	18911	$ 17,128.94
Old Mechanical System	$ 1,371,508.55	24812	$ 3,323.81
Overall System Difference	**$ (1,206,493.62)**	**5901**	**$ (13,805.13)**

Type of Certification	Points Range
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

www.usgbc.org

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Original Schedule		
Duration (days)	Start	Finish
840	7/25/2011	8/31/2012

Adjusted Schedule	
Duration	**Decrease in Time**
640	**24%**

Project Schedule					
	Original Schedule			Adjusted Schedule	
	Duration	Start	Finish	Duration	Decrease in Time
TOTAL	840	7/25/2011	8/31/2012	640	24%
MEP Rough In	465	7/25/2011	2/10/2012	340	27%
MEP Finishes	250	11/21/2011	7/27/2012	190	24%
Punch list & Inspections	125	2/27/2012	8/31/2012	110	12%

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Conclusions

Recommended larger AHU with Demand Control Ventilation
- Increased occupant comfort
- Minimum ventilation requirements met
- Decreased capital cost
- Decreased construction schedule

Photovoltaic array and internal shading not recommended

Next Analysis – the use of solar thermal collectors and storage to assist existing system

Photo taken by Laura Pica August 2011

Acknowledgements

- My adviser, Stephen Treado, for his help in editing my technical reports and providing professional consulting
- All other Department of Architectural Engineering faculty for their passion for teaching, continued support and encouragement
- All AE Mentors and Practitioners from the "Mentoring Center" for their valuable design advice
- Kevin Ludwick, Turner Project Manager for supplying design documents and construction data
- And most importantly, my friends and family for their support throughout my senior year. I could have never finished this project without you!

Thank You

Questions?

Appendix

Mechanical Depth Design

Load Calculations

LOADS (Btu/h)					
lighting	equipment	occupancy	solar	TOTAL Btu/h	TOTAL cfm
318096	7278258	352800	948365	8.90E+06	411922

Room No	Space Type	Area (Az)	OA Rate per person (Rp)	OA Rate (cfm)	OA Rate (cfm)	(CFM)	Btu/h
B-10	lobby	100	5	25	6	31	1.435

Room No	Space Type	Area (Az)	(Watts)	Density (W/sqft)	Btu/h
B-10	lobby	100	256	2.560	874

Equipment	Quantity	BTU/h per unit	Watts per unit		TOTAL Btu/h
dishwasher	199	800	234		159200

Room No	Space Type	Expected # of occupants	occupant load (Btu/h)	CFM
B-10	lobby	5	1750	81

Breadth 2 – CM Study

Mechanical System Takeoff

Category	Equipment	Quantity	Cost Per Item (Inc. O&P)	Total Cost
Mechanical System Design Alternative	AHU – VAV for 100,000 cfm, not incl duct & accessories	2	$ 161,000.00	$ 322,000.00
	DCV Direct-Digital CO2 Detector System, incl panel & sensor	1	$ 1,650.00	$ 1,650.00
	DCV sensor	200	$ 950.00	$ 190,000.00
	DCV Wiring (ft)	212	$ 50.00	$ 10,600.00
	Economizer Add-on	1	$ 25,000.00	$ 25,000.00
	supply duct (lb) – 20"	16299.75	$ 5.67	$ 92,338.08
	supply duct (lb) – 10"	16268.1	$ 2.83	$ 45,989.92
	return duct (lb) – 20"	24604	$ 5.67	$ 139,382.37
	supply elbows	225	$ 18.55	$4173.75
	return elbows	255	$ 37.00	$9435
	supply transitions	60	$35	$2100
	diffusers	225	$65.5	$14737.5
	modulating dampers for AHU	2	$161	$322
	TOTAL			$ 857,728.62

Category	Equipment	Crew Size	$ Per crew member	Total Labor $	Labor Hours per unit	Total installation hours
Mechanical System Design Alternative	AHU – VAV for 100,000 cfm, not incl duct & accessories	1	$ 14,400.00	$ 14,400.00	290	580
	DCV Direct-Digital CO2 Detector System, incl panel & sensor	2	$ 104.00	$ 208.00	2	2
	DCV sensor	2	$ 57.00	$ 114.00	1.1	220
	DCV Wiring (ft)	1	$ 16.00	$ 16.00	0.2	42
	Economizer Add-on	1	$ 590.00	$ 590.00	13	13
	supply duct (lb) – 20"	2	$ 16.90	$ 33.80	0.369	6015
	supply duct (lb) – 10"	2	$ 4.42	$ 8.84	0.1	1627
	return duct (lb) – 20"	2	$ 16.90	$ 33.80	0.369	9079
	supply elbows	2	$ 10.00	$ 20.00	0.5	113
	return elbows	2	$ 10.00	$ 20.00	0.5	128
	supply transitions	2	$ 10.00	$ 20.00	0.5	30
	diffusers	4	$ 12.30	$ 49.20	0.25	56
	modulating dampers for AHU	1	$ 49.00	$ 49.00	1	2
	TOTAL			$ 15,562.64		17906

Breadth 2 – CM Study

Electrical Takeoff

Category	Equipment	Quantity	Cost Per Item (Inc O&P)	Total Cost
Photovoltaic Array	photovoltaic panel kit	94	$ 6,790.91	$ 638,345.54
	additional wiring (ft)	212	$ 140.00	$ 29,680.00
	conduit	212	$ 44.00	$ 9,328.00
	conduit cutting/drilling	64	$ 200.00	$ 12,800.00
	grounding electrode	1	$ 120.00	$ 120.00
	circiut breaker	1	$ 22,000.00	$ 22,000.00
	internal shade & motor	400	$ 2500	$ 1,000,000.00
	TOTAL			$ 1,712,273.54

Category	Equipment	Crew Size	$ Per crew member	Total Labor $	Labor Hours per unit	Total installation hours
Photovoltaic Array	photovoltaic panel kit	2	$ 25.00	$ 50.00	0.75	70.5
	additional wiring (ft)	2	$ 16.00	$ 32.00	1	212
	conduit	2	$ 9.40	$ 18.80	0.2	42.4
	conduit cutting/drilling	1	$ 114.00	$ 114.00	2.4	153.6
	grounding electrode	1	$ 68.50	$ 68.50	1.45	1.45
	circiut breaker	1	$ 1,175.00	$ 1,175.00	25	25
	internal shade	4	$ 15.00	$ 60.00	0.25	100
	shade motor	4	$ 15.00	$ 60.00	0.2	80
	TOTAL			$ 1,578.30		685

Breadth 2 – CM Study

Schedule Changes

Project Schedule					
	Original Schedule			Adjusted Schedule	
Zone	Duration	Start	Finish	Duration	Decrease in Time
TOTAL	840	7/25/2011	8/31/2012	640	24%
MEP Rough In	465	7/25/2011	2/10/2012	340	27%
Elevator Lobbies & Stair Towers Rough In	100	8/15/2011	12/9/2011	85	
Basement and Level 1 Underground Rough In	80	10/24/2011	2/10/2012	70	
Level 2, 3, 4, 5 Rough In	60	7/25/2011	10/14/2011	40	
Level 6 & 7 Rough In	30	8/1/2011	9/9/2011	15	
Level 8 & 9 Rough In	30	8/22/2011	9/30/2011	15	
Level 10 & 11 Rough In	30	9/12/2011	10/21/2011	15	
Level 12 & 13 Rough In	30	10/3/2011	11/11/2011	15	
Level 14, 15 & 16 Rough In	45	10/24/2011	12/23/2011	30	
Penthouse and Roof Rough In	60	8/8/2011	10/28/2011	55	
MEP Finishes	250	11/21/2011	7/27/2012	190	24%
Elevator Lobbies & Stair Towers	60	11/21/2011	2/10/2012	45	
Basement and Level 1 Underground	20	1/30/2012	2/24/2012	15	
Level 2, 3, 4, 5	60	11/28/2011	2/17/2012	45	
Level 6 & 7	20	2/27/2012	3/23/2012	15	
Level 8 & 9	20	3/19/2012	4/13/2012	15	
Level 10 & 11	20	4/30/2012	5/25/2012	15	
Level 12 & 13	20	5/28/2012	6/22/2012	15	
Level 14, 15 & 16	30	6/18/2012	7/27/2012	25	
Punch list & Inspections	125	2/27/2012	8/31/2012	110	12%
Basement and Level 1, 2, 3, 4, 5	20	2/27/2012	3/23/2012	18	
Level 6 & 7	20	3/26/2012	4/20/2012	18	
Level 8 & 9	20	4/23/2012	5/18/2012	18	
Level 10 & 11	20	5/28/2012	6/22/2012	18	
Level 12 & 13	20	7/2/2012	7/27/2012	18	
Level 14, 15 & 16	25	7/30/2012	8/31/2012	20	