Biobehavioral Health Building, University Park, PA
Jake Copley – Mechanical Option
April 9th, 2012

Presentation Outline

- Project Team
- Project Overview
- Existing Mechanical Systems
- Proposed Redesign
- Mechanical Depth
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Biobehavioral Health Building, University Park, PA
Jake Copley – Mechanical Option
April 9th, 2012

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Biobehavioral Health Building, University Park, PA
Jake Copley – Mechanical Option
April 9th, 2012

Project Team

Owner: The Pennsylvania State University
Architect: Bohlin Cywinski Jackson
CM: Massaro Corporation Inc.
MEP/Fire Protection: Bruce E. Brooks Assoc.
Structural Engineer: Robert Silman Assoc.
Civil Engineer: Gannett Fleming, Inc.
Landscape Architect: Michael Vergason

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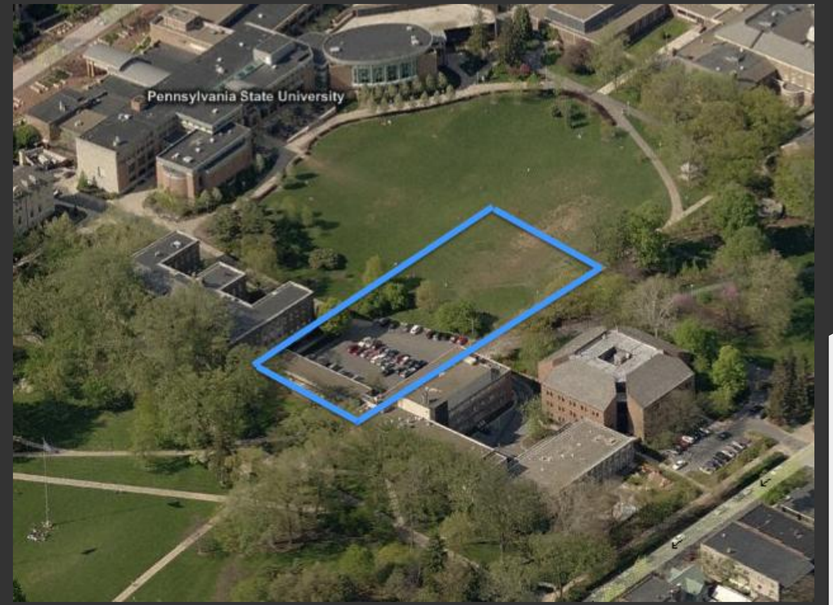
Project Overview

- Project Site
  - HUB Lawn



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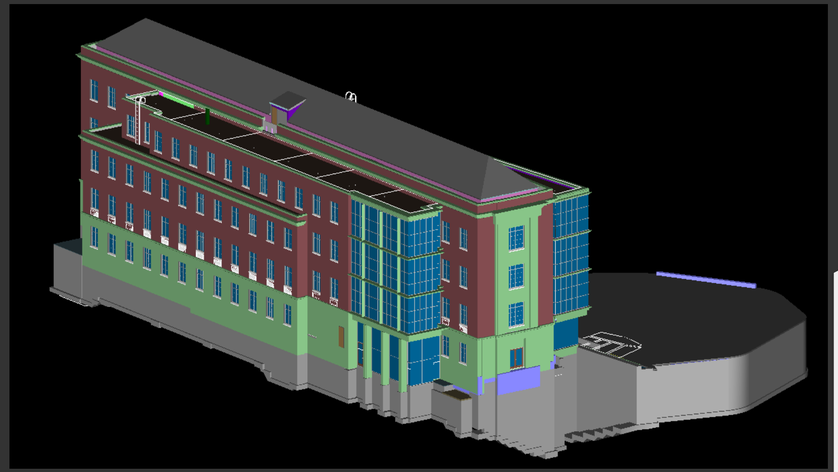
Project Overview

- Project Site
  - HUB Lawn
- Architecture
  - 93,500 SF for BBH Department
  - 4 Stories Above, 1 Below + Penthouse
  - Similar to Henderson North
  - Goal of LEED Silver
  - $48.1 Million



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Existing Mechanical System

- Air Side
  - 6 Variable Air Volume AHUs
    - All multi-zone with Economizers

Table P1.4.1: Existing Air Handling Units

AHU	Unit Location	Areas Served	Cooling Capacity (Tons)	Heating Capacity (kBTU/h)
1	M004	Core Offices	41	392.7
2	M021	Classrooms	34	236.7
3	Penthouse	South Offices	23	335.8
4	Penthouse	North Offices	16	179.8
5	Penthouse	Core	37	386.3
6	Penthouse	Conference	25	226.3

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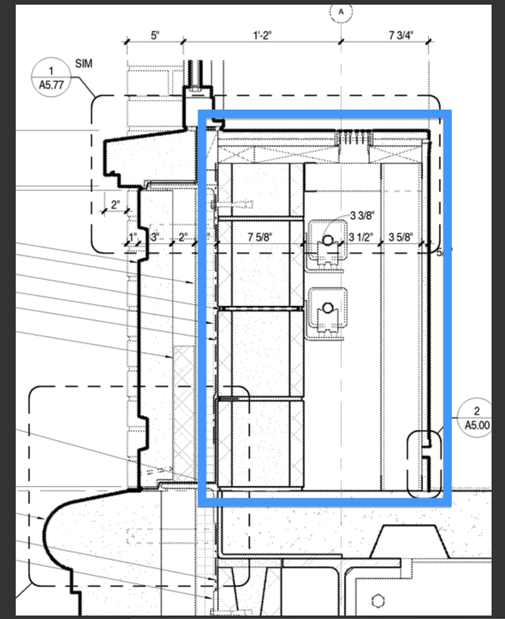
Existing Mechanical System

- Air Side
  - 6 Variable Air Volume AHUs
    - All multi-zone with Economizers
- Water Side
  - Perimeter Fin Tube Heating
  - Steam
  - Chilled Water



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- Project Team
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- Questions

Existing Mechanical System

- Air Side
  - 6 Variable Air Volume AHUs
    - All multi-zone with Economizers
- Water Side
  - Perimeter Fin Tube Heating
  - Steam
  - Chilled Water
- Energy Usage
  - Mechanical System: 52 kBTU/SF

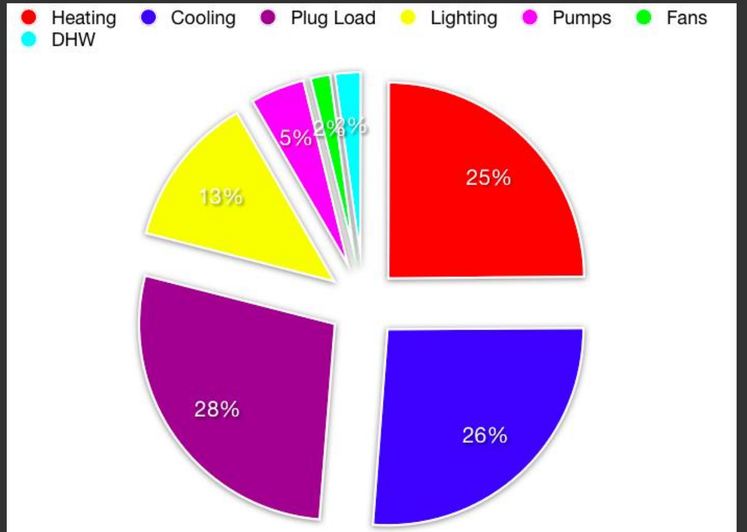

Figure 2.3.1: *Energy Consumption Breakdown (% of Total)*

Presentation Outline

- Project Team
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- Conclusion and Recommendation
- Questions

Proposed Redesign

- Design Objective
  - Reduce Building Energy Consumption

Presentation Outline

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Proposed Redesign

- Design Objective
  - Reduce Building Energy Consumption
- Design Components
  - Internal Thermal Mass
  - Radiant Heating and Cooling
  - Energy Recovery
  - Solar Thermal System

Presentation Outline

- Project Team
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Proposed Redesign

- Design Objective
  - Reduce Building Energy Consumption
- Design Components
  - Internal Thermal Mass
  - Radiant Heating and Cooling
  - Energy Recovery
  - Solar Thermal System
- Alternative Configurations

Table 4.1.1: System Alternatives				
Variable	Alternatives			
	1 (Existing)	2	3	4
Mechanical System	Full VAV	Full VAV	New AHU + Radiant Heating and Cooling	New AHU + Radiant Heating and Cooling
Economizer	X	X	X	X
Heat Recovery			X	X
Thermal Mass	Existing	Option 1	Option 1	Option 1
Solar Thermal System				X
Sorption Cooling				X

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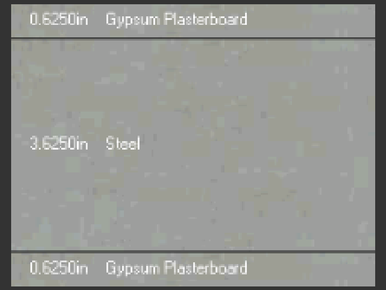
  - Radiant Heating and Cooling
  - Energy Recovery
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Thermal Mass

- Composition of Mass Alternatives



Existing Internal Mass

Presentation Outline

- Project Team
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- **Mechanical Depth**
  - **Thermal Mass**
  - Radiant Heating and Cooling
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  - Solar Thermal System
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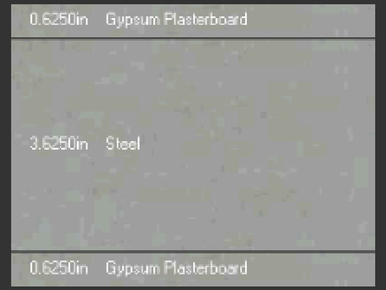
Mechanical Depth – Thermal Mass

- Composition of Mass Alternatives



Existing Internal Mass

Internal Mass Option 1

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- Project Team
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- **Mechanical Depth**
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  - Solar Thermal System
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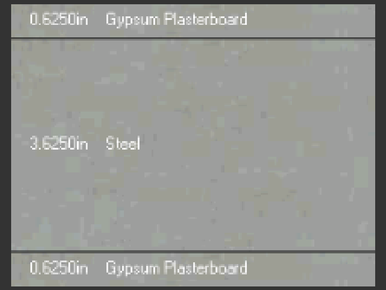
Mechanical Depth – Thermal Mass

- Composition of Mass Alternatives



Existing Internal Mass

Internal Mass Option 1

Internal Mass Option 2

Presentation Outline

- Project Team
- Project Overview
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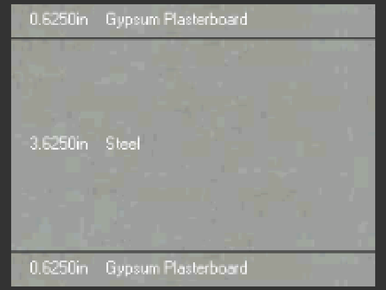
- Proposed Redesign
- **Mechanical Depth**
  - **Thermal Mass**
  - Radiant Heating and Cooling
  - Energy Recovery
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Thermal Mass

- Composition of Mass Alternatives
- Performance Comparison
  - 1.3 kBTU/SF or 2.5%



Existing Internal Mass

Internal Mass Option 1

Internal Mass Option 2

Presentation Outline

- Project Team
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- **Mechanical Depth**
  - Thermal Mass
  - **Radiant Heating and Cooling**
  - Energy Recovery
  - Solar Thermal System
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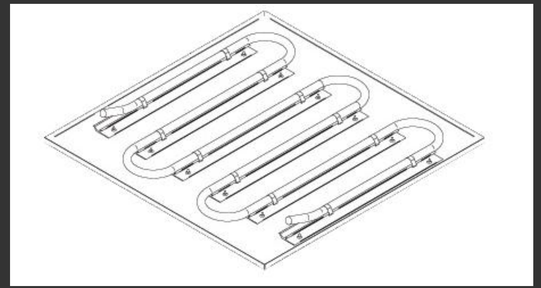
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Radiant System

- Panel Design Parameters
  - Air: Latent + Sensible Load
  - Radiant: Sensible Load
  - CHW and HW Temperatures
  - Replace Acoustical Ceiling Tiles



Presentation Outline

- Project Team
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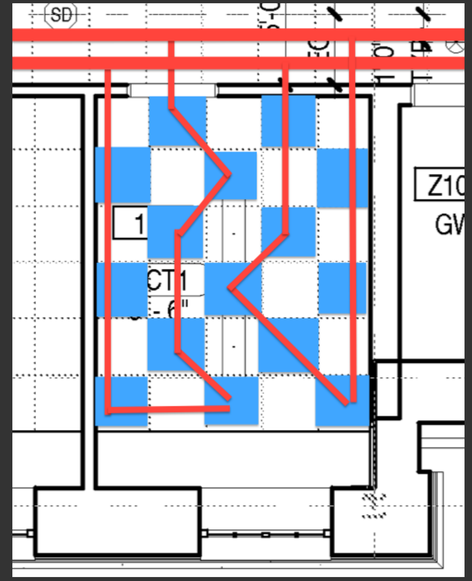
- **Mechanical Depth**
  - Thermal Mass
  - **Radiant Heating and Cooling**
  - Energy Recovery
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Radiant System

- Panel Design Parameters
  - Air: Latent + Sensible Load
  - Radiant: Sensible Load
  - CHW and HW Temperatures
  - Replace Acoustical Ceiling Tiles
- Panel Layout
  - Typical Office



Presentation Outline

- Project Team
- Project Overview
- Existing Mechanical Systems
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- **Mechanical Depth**
  - Thermal Mass
  - **Radiant Heating and Cooling**
  - Energy Recovery
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Radiant System

- Panel Design Parameters
  - Air: Latent + Sensible Load
  - Radiant: Sensible Load
  - CHW and HW Temperatures
  - Replace Acoustical Ceiling Tiles
- Panel Layout
  - Typical Office
  - Typical Classroom

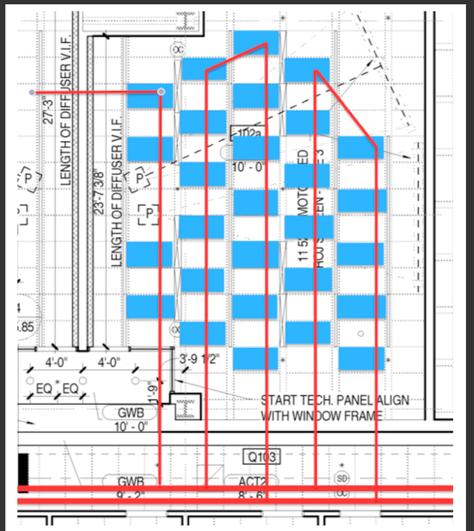

Figure 6.1.2: *Typical Classroom Radiant Panel Layout*

Presentation Outline

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  - Energy Recovery
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Radiant System

- Panel Design Parameters
  - Air: Latent + Sensible Load
  - Radiant: Sensible Load
  - CHW and HW Temperatures
  - Replace Acoustical Ceiling Tiles
- Panel Layout
  - Typical Office
  - Typical Classroom
- Acoustical Effects

Location	Recommended Reverb Time (S)	Existing Reverb Time (S)	New Reverb Time (S)
Typical Office	0.6-1	0.67	0.76
Typical Classroom	0.6-1	0.73	0.97

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  - Energy Recovery
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Radiant System

- Panel Design Parameters
  - Air: Latent + Sensible Load
  - Radiant: Sensible Load
  - CHW and HW Temperatures
  - Replace Acoustical Ceiling Tiles
- Panel Layout
  - Typical Office
  - Typical Classroom
- Acoustical Effects
- Performance
  - 1 kBTU/SF or 2%

Presentation Outline

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  - Thermal Mass
  - Radiant Heating and Cooling
  - **Energy Recovery**
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Energy Recovery

- AHU Resizing
  - 50% Size Reduction
- Unit Selection

Face Velocity	Efficiency (%)
400	86
600	80.5
800	77
1000	74.5

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  - Thermal Mass
  - Radiant Heating and Cooling
  - **Energy Recovery**
  - Solar Thermal System
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Energy Recovery

- AHU Resizing
  - 50% Size Reduction
- Unit Selection
- Performance
  - 4 kBTU/SF or 7.6%

Face Velocity	Efficiency (%)
400	86
600	80.5
800	77
1000	74.5

Presentation Outline

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  - Thermal Mass
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  - Energy Recovery
  - **Solar Thermal System**
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Solar System

- Design Parameters

Table 8.2.1: Solar Thermal System Design Constraints	
Chiller Heat Input	195 F HW at 40 GPM
Available Roof Area	4921 SF

Presentation Outline

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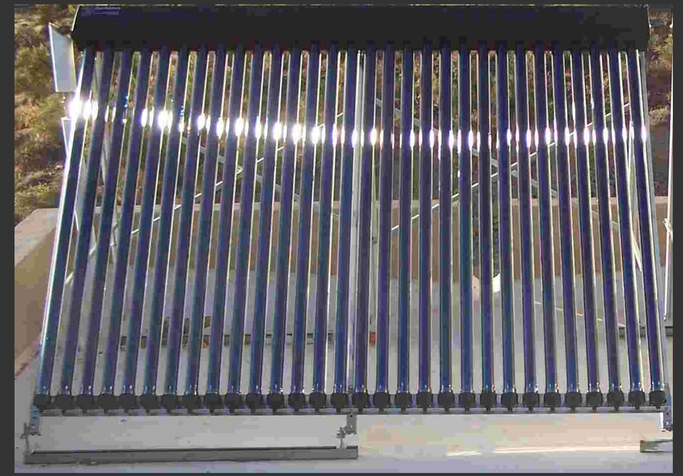
  - **Solar Thermal System**
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors



http://asolarheater.net/1959-sunmaxx-solar-collectors-best-solar-water-heater.html

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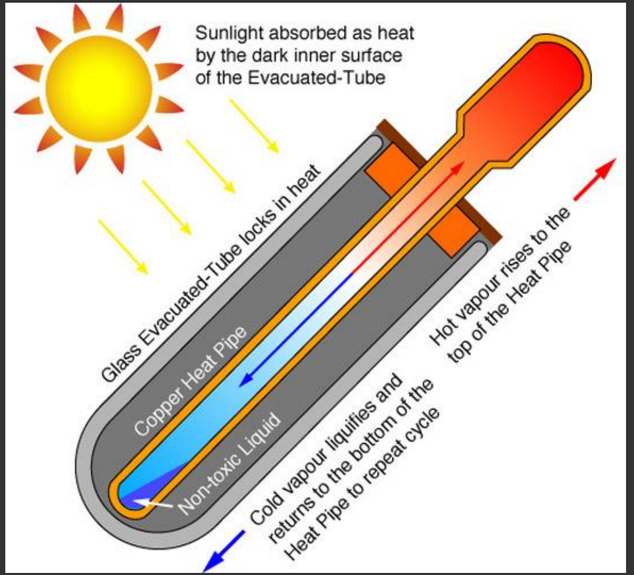
  - Energy Recovery
  - **Solar Thermal System**
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance



http://www.sunmaxxsolar.com/how-evacuated-tube-solar-collectors-work.php

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  - Energy Recovery
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- Cost and Energy Savings
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- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout

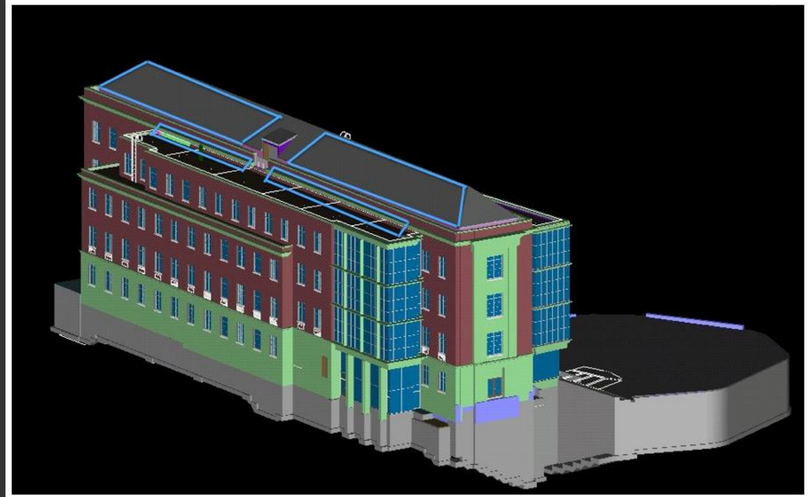

Figure 8.2.1: *Solar Panel Locations*

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  - Energy Recovery
  - **Solar Thermal System**
- Electrical Breadth
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- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout
- Chiller Selection

http://www.prweb.com/releases/2011/02/prweb5075134.htm

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  - **Solar Thermal System**
- Electrical Breadth
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout
- Chiller Selection
- Cooling Tower
  - Selection

Table 8.3.1: Cooling Tower Sizing Conditions	
Tower Water Flow	72 GPM
Hot Water Temperature	95 F
Cold Water Temperature	76 F
Wet-Bulb Temperature	71 F

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  - **Solar Thermal System**
- Electrical Breadth
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- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout
- Chiller Selection
- Cooling Tower
  - Selection

http://www.evap-technmtc.com/Marley_Aquatower_en.html

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  - Energy Recovery
  - **Solar Thermal System**
- Electrical Breadth
- Cost and Energy Savings
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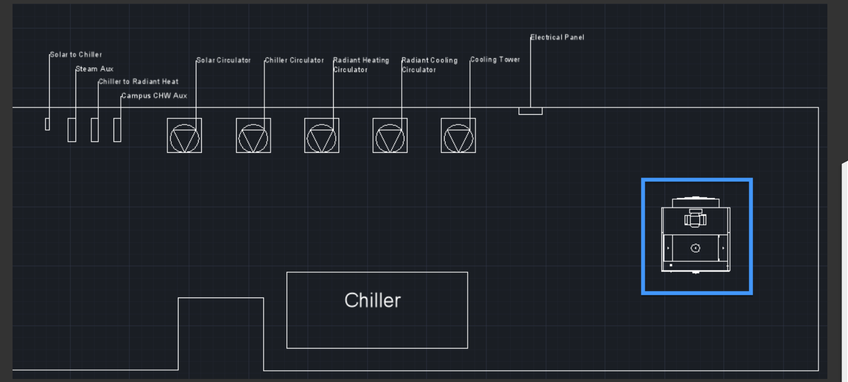
- Questions

Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout
- Chiller Selection
- Cooling Tower
  - Selection
  - Location



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  - **Solar Thermal System**
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Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout
- Chiller Selection
- Cooling Tower
  - Selection
  - Location
- System Performance

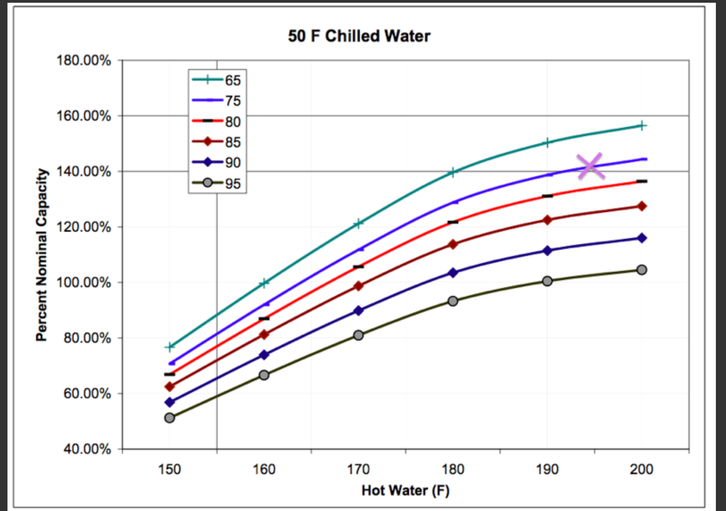

Figure 8.3.1: *Chiller Performance Curve at 50 F CHW (Provided by PowerPartners, Inc.)*

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Mechanical Depth – Solar System

- Design Parameters
- Panel Selection
  - Evacuated Tube Collectors
  - Heat Pipes
  - Ease of Maintenance
- Array Location and Layout
- Chiller Selection
- Cooling Tower
  - Selection
  - Location
- System Performance
- Performance

13% Reduction in Heating

4% Reduction in Cooling

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- Questions

Electrical Breadth

- Calculations
  - Motor HP
  - Equipment FLA

Table P9.2.1: New Equipment Requirements			
Equipment	**HP**	**V/PH/HZ**	**FLA**
Solar Circulator Pump	0.25	120/1/60	5.8
Radiant Heating Pump	0.75	208/3/60	3.5
Radiant Cooling Pump	1	208/3/60	4.6
Condenser Water Pump	0.5	208/3/60	2.4
Chiller Pump	1	208/3/60	4.6
Cooling Tower Fan	2	208/3/60	7.5
Chiller	-	208/3/60	4.72

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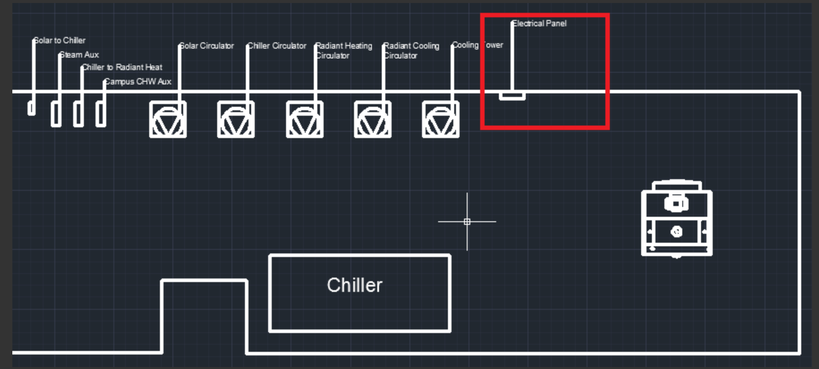
Electrical Breadth

- Calculations
  - Motor HP
  - Equipment FLA
- Scheduling
  - Additional Lighting Panel Relocation



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- **Electrical Breadth**
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Electrical Breadth

- Calculations
  - Motor HP
  - Equipment FLA
- Scheduling
  - Additional Lighting Panel Relocation
- Sizing
  - Branch Circuits
  - Breakers

Table 9.2.1: New Equipment Power Requirements

Equipment	HP	V/PH/HZ	FLA	Branch Circuit Wire	Breaker Size
Solar Circulator Pump	0.25	120/1/60	5.8	#12 AWG	20
Radiant Heating Pump	0.75	208/3/60	3.5	#12 AWG	20
Radiant Cooling Pump	1	208/3/60	4.6	#12 AWG	20
Condenser Water Pump	0.5	208/3/60	2.4	#12 AWG	20
Chiller Pump	1	208/3/60	4.6	#12 AWG	20
Cooling Tower Fan	2	208/3/60	7.5	#12 AWG	20
Chiller	-	208/3/60	4.72	#12 AWG	20

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- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Electrical Breadth

- Calculations
  - Motor HP
  - Equipment FLA
- Scheduling
  - Additional Lighting Panel Relocation
- Sizing
  - Branch Circuits
  - Breakers
  - Motor Starters
  - VFDs

Table 9.2.2: Schedule of VFD/Single Speed Motors	
Solar Circulator Pump	Single Speed
Radiant Heating Pump	VFD
Radiant Cooling Pump	VFD
Condenser Water Pump	Single Speed
Chiller Pump	VFD
Cooling Tower Fan	Single Speed

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- Mechanical Depth
- **Electrical Breadth**
- Cost and Energy Savings
- Conclusion and Recommendation
- Questions

Electrical Breadth

- Calculations
  - Motor HP
  - Equipment FLA
- Scheduling
  - Additional Lighting Panel Relocation
- Sizing
  - Branch Circuits
  - Breakers
  - Motor Starters
  - VFDs
  - Feeder
- Conclusion

Panel Voltage	Panel Ampacity	Feeder Size
208/120	400	2 Sets (4) 4/0 AWG + (1) #3 AWG G in 2.5" C

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  - **First and Operating Cost**
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First and Operating Cost

Table P11.1.2: System Cost		
System	**First Cost**	**Estimate Operating Cost**
Heat Recovery	$104,458.00	-
Radiant Heating/Cooling	$1,100,923.00	-
Solar Thermal	$160,544.00	-
Combined Systems	$1,365,925.00	$6,500.00

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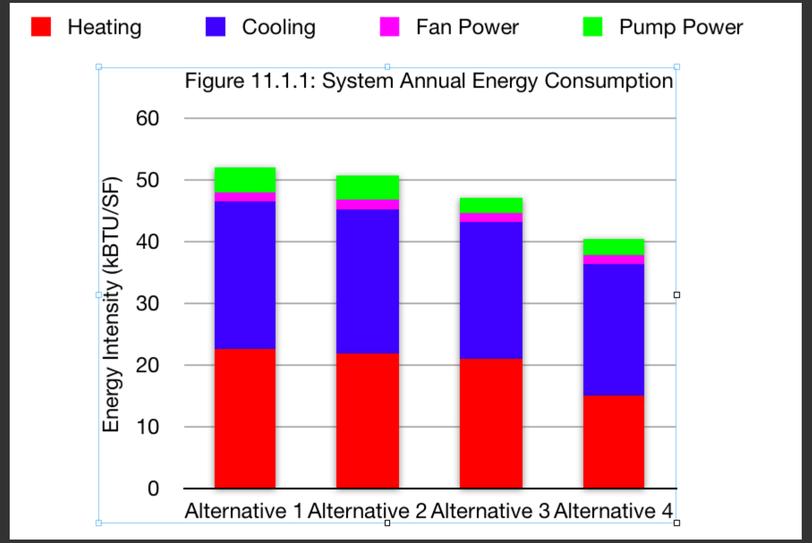
Energy Savings



12kBTU/SF or 23% Reduction

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  - Energy Savings
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Payback Period

	Annual Savings	Life Savings	Payback Period (Years)
Alternative 4	$15,933.00	$1,390,000.00	77

Economic Factor	Rate
Interest Rate (2011)	3.90%
Solar System Degradation	0.50%
Fuel Escalation Cost	3.80%
Maintenance Escalation Cost	1.00%

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  - **New System Configuration**
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Conclusion and Recommendation

- New System
  - Keep Existing AHUs
  - Include Heat Recovery System
  - Include Solar Thermal System
  - Space Constraint

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- Questions

Conclusion and Recommendation

- New System
  - Keep Existing AHUs
  - Include Heat Recovery System
  - Include Solar Thermal System
  - Space Constraint
- Estimated Cost

System	First Cost
Heat Recovery	$104,458.00
Solar Thermal System	$170,838.00
Combined	$275,296.00

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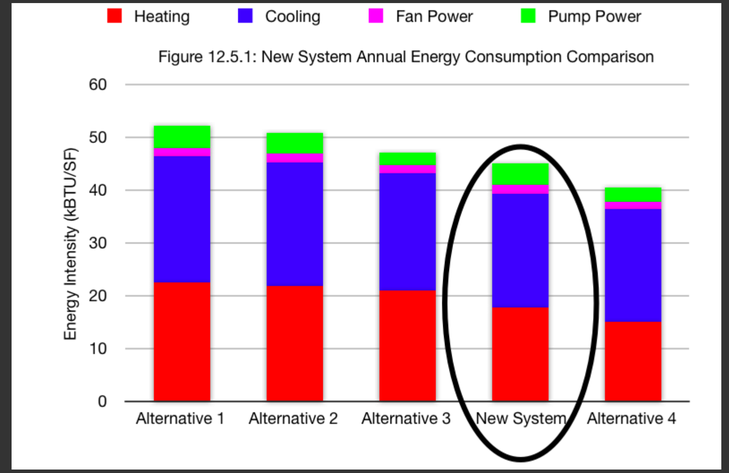
Conclusion and Recommendation

- New System
  - Keep Existing AHUs
  - Include Heat Recovery System
  - Include Solar Thermal System
  - Space Constraint
- Estimated Cost
- Energy Savings
  - 8.6 kBTU/SF or 16.5%
- Payback Period

	Annual Savings	Life Savings	Payback Period (Years)
Recommended System	$16,589.00	$1,450,000.00	16



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Special Thanks to:
PSU Office of Physical Plant
Massaro Corporation
Professors
Family and Friends

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Questions?

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Questions?

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Table 5.0.2: Thermal Mass Capacity					
Material	**C (BTU/lb F)**	***ρ (lb/ft³)***	***K (BTU/hr ft F)***	***B***	***Q_{stored} (BTU/SF F)***
8" Concrete	0.156	144	0.54	3.48	14.98
4" Brick	0.2	123	0.4	3.14	8.20
2 x 5/8" Gypsum	0.259	78	0.25	2.25	2.10
1/4" Cork Board	0.485	5.4	0.028	0.27	0.05

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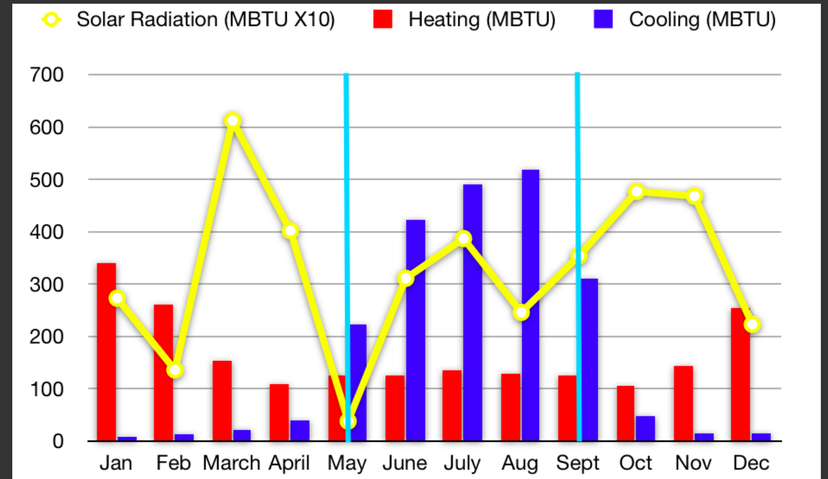

Figure 8.4.1: *Heating, Cooling and Solar Exposure Relationship*

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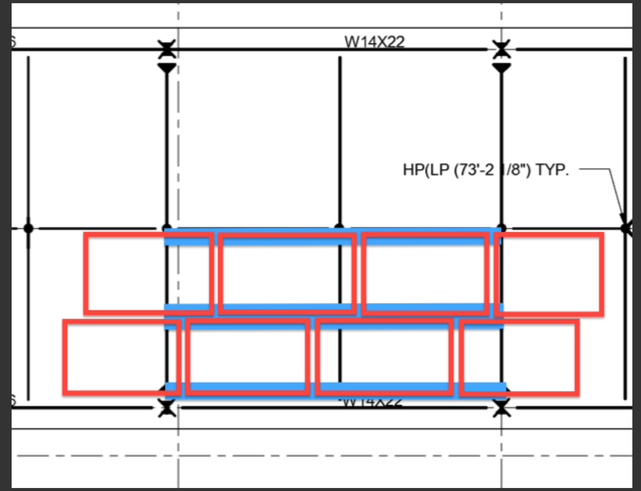

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