Des Places Residence Hall Senior Thesis Presentation



Peter Edwards – Mechanical Option Advisor - Dustin Eplee





Des Places Residence Hall

Duquesne University Pittsburgh, PA

Project Team

Owner: Architect: Mechanical/Electrical Engineer: Structural Engineer: **Civil Engineer: Construction Management Agency:** Regency Construction

Duquesne University WTW Architects CJL Engineering Barber and Hoffman Inc. Gateway Engineers Services Inc.

- **Building Overview**
 - Building Information
 - Building Location and Site
- Thesis Overview
- **Existing Mechanical System**
- **Mechanical System Redesign Objectives**
- Analysis I Dedicated Outdoor Air System
- Analysis II Solar Thermal System
- Analysis III Building Envelope Redesign
 - Daylighting Breadth
- Conclusion \bullet

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Basic Information Size: **Stories Above Grade: Estimated Project Cost: Dates of Construction: Project Delivery Method: Occupancy Type:** LEED:

Building Information

LaQuatra Bonci Associates



131, 438 ft² 11 \$27,535,000 March 1, 2010 – August 7, 2012 Design-Bid-Build **Student Dormitory** Minimum of LEED Certification





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Peter Edwards – Mechanical Option

Location

- Pittsburgh, Pennsylvania
- \bullet • Surrounded by an urban environment

Building Location and Site



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Location

- Pittsburgh, Pennsylvania
- Surrounded by an urban environment

Site

- Square building footprint
- Building is oriented so that it faces almost exactly true north
 Surrounded by Seitz Street to the south and Stevenson Street to
- Surrounded b the east

Building Location and Site

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2. IN THE PREPARATION OF THIS PLAN, THE CUTS AND/OR FILLS WERE SET WITHOUT KNOW, EDGE OF THE CAPABILITIES OF THE SOLS LOCATED ON THE SITE THE GATEWAY PROINCERS, INC. MARKS NO REPRESENTATION BY THIS PLAN OF THE STABILITY OF THE CUTS AND/OR FILLS SHOWN.

CONSTRUCTION NOTES AND TYPICAL MAY ONLY APPEAR ONCE ON TH DRAWINGS, BUT APPLY TO ALL SIMILAR CONDITIONS.

4. CONTRACTOR SHALL CONTACT UTLITY COMPANES TO COORDINATE CONNECTION TO EXISTING PUBLIC UTLITES ALL PROPOSED UTLITY CONDUITS UTLITY, INES, PIPES, FITTINOS, COUPLERS, VALL'S, AND MOUNTING PAOS ETC. SHALL BIE INSTALLED IN ACCORDANCE WITH THE RESPECTIVE UTLITY COMPANY REGULTEMENTS AND REGULATIONS. THIS SHALL INCLUDE ALL MATERIALS FOR INSTALLATION AND CONSTRUCTION ETC.

5. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO ASCERTAIN THE EXACT LOCATION AND SIZE OF THE UTILITIES PRIOR TO CONSTRUCTION AND COORDINAT THE THE IN POINTS WITH THE ARCHITECT AND THE APPROPRIATE UTILITY COMPANY.

 ALL WORK WITHIN CITY RIGHT-OF-WAY MUST CONFORM TO CITY OF PITTSBURGH AND PITTSBURGH WATER AND SEWER AUTHORITY STANDARDS.

7. SEE ARCHITECTURAL DRAWINGS FOR BUILDING INFORMATION



- Building Overview
- Thesis Overview
 - Proposal
 - Results
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Proposal

- Replace fan coil units in existing dedicated outdoor air system with radiant ceilings and baseboard radiators
- Install a solar in Des Places
- Redesign the building envelope of Des Places to allow more natural daylight into the perimeter bedrooms and living rooms

• Install a solar thermal system to preheat the domestic hot water

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Proposal

- Replace fan coil units in existing dedicated outdoor air system with radiant ceilings and baseboard radiators
- Install a solar thermal system to preheat domestic hot water \bullet
- Redesign the building envelope by doubling the size of every bedroom and living room window

Thesis Overview

Results

- **Redesigned Dedicated Outdoor Air System**
 - \$7,370 increase in yearly operational costs
 - Cost \$186,500 less than original system
 - New system will increase the comfort of occupants
- Solar Thermal System •

 - Payback period under 11 years with government incentives
 - **Building Envelope Redesign**
 - throughout the year
 - adequate amount of daylight
 - Cost \$203,312 more than the original building envelope
 - \$2,137 increase in yearly operational costs

• Saves the central steam plant approximately 2,350 therms/year

Larger windows allow significantly more natural light into the rooms

Daylighting analysis showed that some of the rooms already had an

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Existing Mechanical System

Key Facts

- Total estimated cost = \$2,827,770
- System complies with ASHRAE Standards 62.1 and 90.1
- Steam supply comes from central steam plant on campus
- Chilled water supply comes from central chiller plant on campus
- Electricity is supplied by Duquesne Light

Utility Rates

	Utility	Costs
Energy Type		
Electricity		0.
Natural Gas		1.2



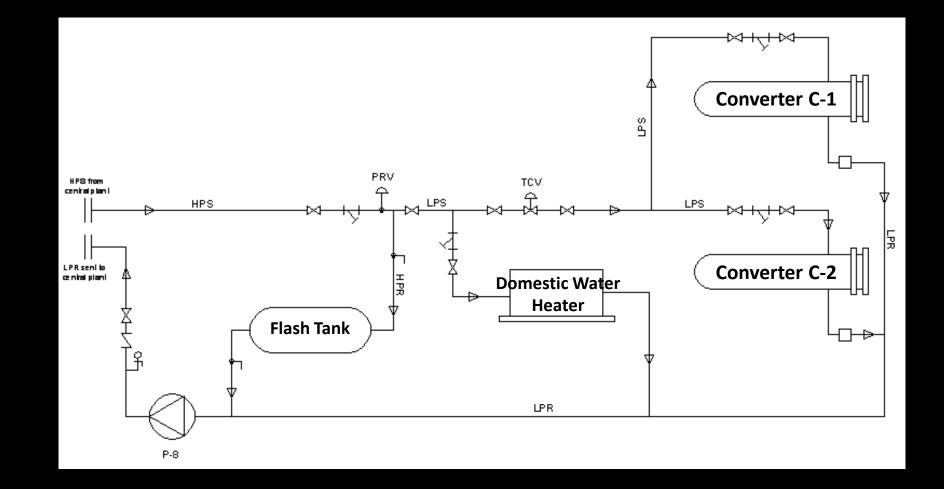
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Steam

- High pressure steam comes from central plant at a pressure of 50 lbs and a velocity of 6,000 fpm
- HPS passes through a pressure reducing valve
- Low pressure steam is used for the domestic water heater
- Remaining LPS is converted to hot water

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Existing Mechanical System



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Existing Mechanical System

Steam

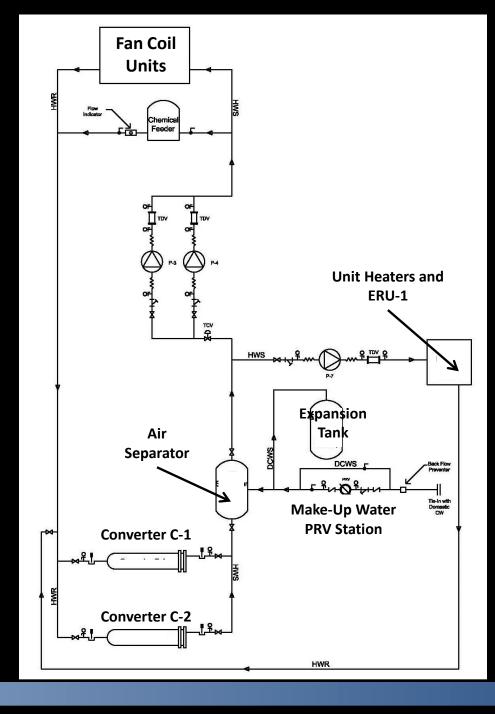
- High pressure steam comes from central plant at a pressure of 50 lbs and a velocity of 6,000 fpm
- HPS passes through a pressure reducing valve first
- Low pressure steam is used for the domestic water heater
- Remaining steam is converted to hot water

Hot Water

- converters
- 140 °F supply temperature
- ERU-1

Hot water supply starts at the two steam to hot water

Hot water supply feeds coils in unit heaters, fan coil units and



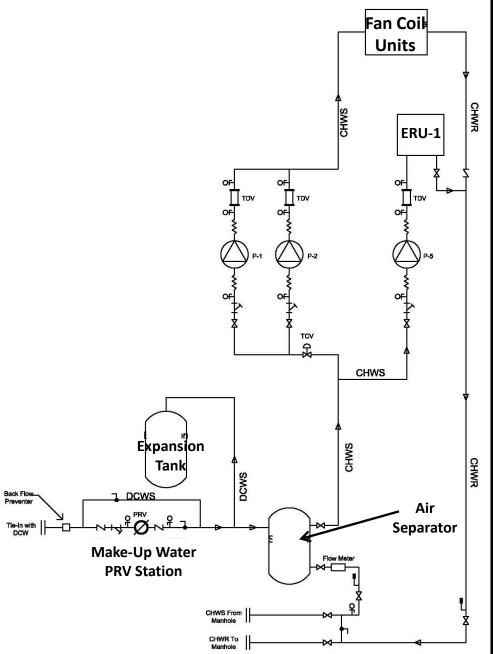
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Chilled Water

- Chilled water supply comes directly from central chiller plant
- 45 °F supply temperature
- Chilled water supply feeds coils in fan coil units and ERU-1

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Existing Mechanical System



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Existing Mechanical System

Chilled Water

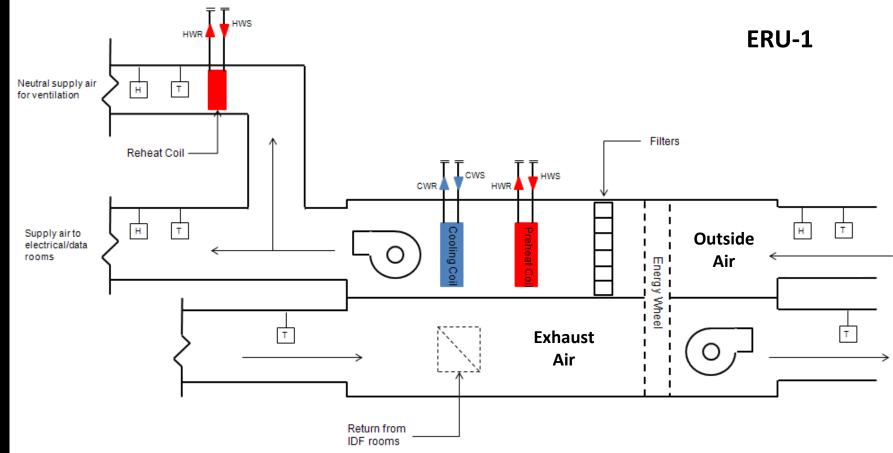
- Chilled water supply comes directly from central chiller plant 45 °F supply temperature
- Chilled water supply feeds fan coil units and ERU-1

Dedicated Outdoor Air System

- Energy recovery unit uses 100% outdoor air • Outdoor air is delivered to every room at a constant flow
- rate

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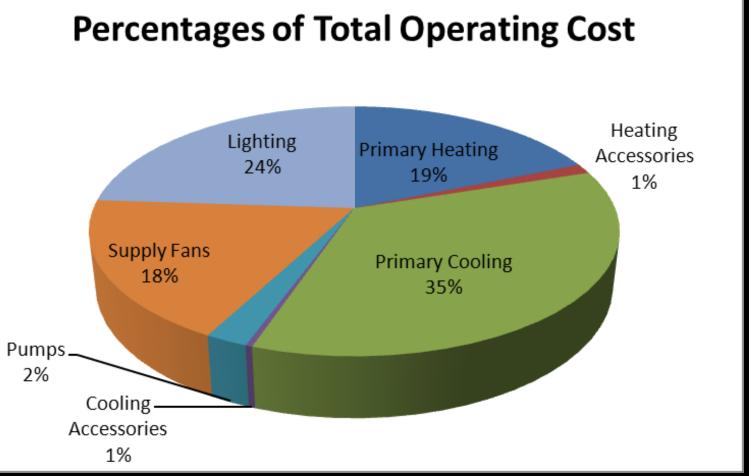
Annual Energy Cost

- **Primary Heating** \$17,914/year • **Primary Cooling** – \$33,725/year
- Total \$95,663/year

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Existing Mechanical System





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Mechanical System Redesign Objectives

Dedicated Outdoor Air System with Radiant Ceilings

- Reduce yearly energy consumption of building • Reduce the cost of the dedicated outdoor air system
- Improve comfort of occupants

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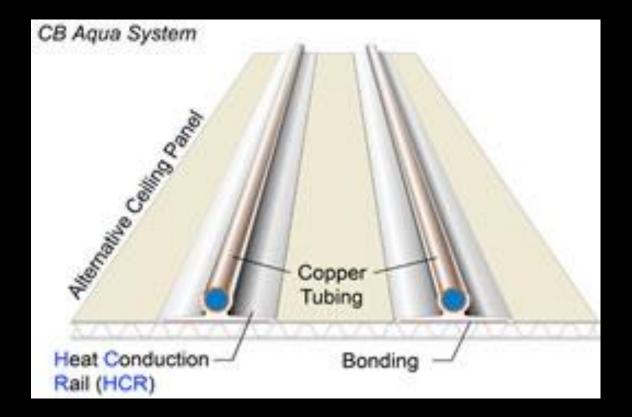


Diagram of a radiant ceiling produced by Barcol-Air



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Mechanical System Redesign Objectives

Dedicated Outdoor Air System with Radiant Ceilings

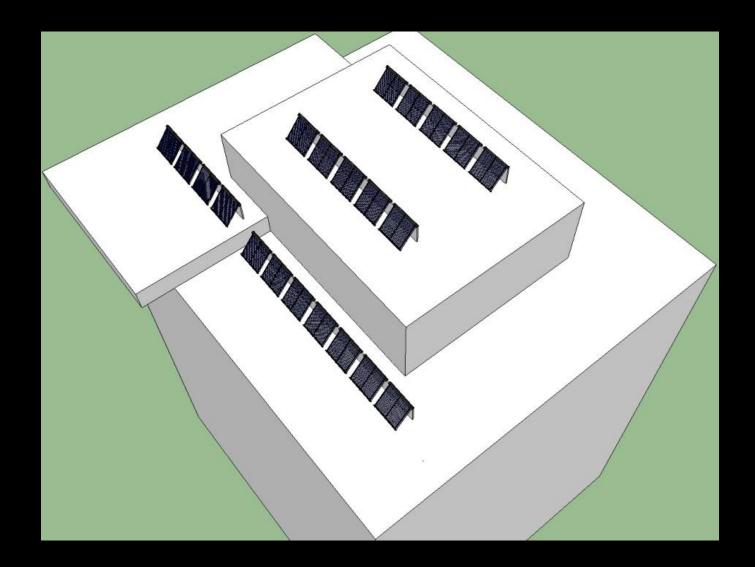
- Reduce yearly energy consumption
- Reduce the cost of the dedicated outdoor air system
- Improve comfort of occupants

Solar Thermal System

- Add renewable energy source to Des Places
- Reduce energy consumption of steam domestic water heater
- Produce a reasonable payback period

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Mechanical System Redesign Objectives

Dedicated Outdoor Air System with Radiant Ceilings

- Reduce yearly energy consumption
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Solar Thermal System

- Add renewable energy source to Des Places
- Reduce energy consumption of steam domestic water heater • Produce a reasonable payback period

Building Envelope Redesign

- Increase natural daylight in bedrooms and living rooms • Eliminate the need for artificial light in perimeter rooms during
- the day







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Analysis I - Dedicated Outdoor Air System

Design Overview

- radiators
- Energy recovery unit remains the same
- Thermostat and dew point sensor in each room
- Reduce fan energy consumption
- Eliminate fan noise in rooms

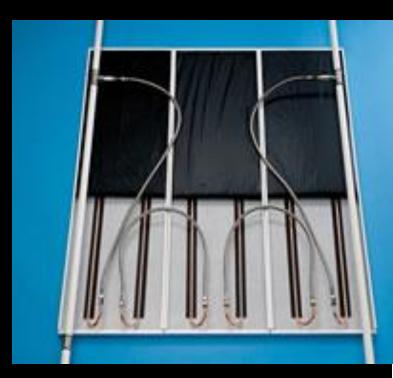
Chosen Manufacturers

- CB Aqua radiant ceilings produced by Barcol-Air Baseboard radiators produced by Slantfin

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• Replace all fan coil units with radiant ceilings and baseboard



Slantfin baseboard radiator

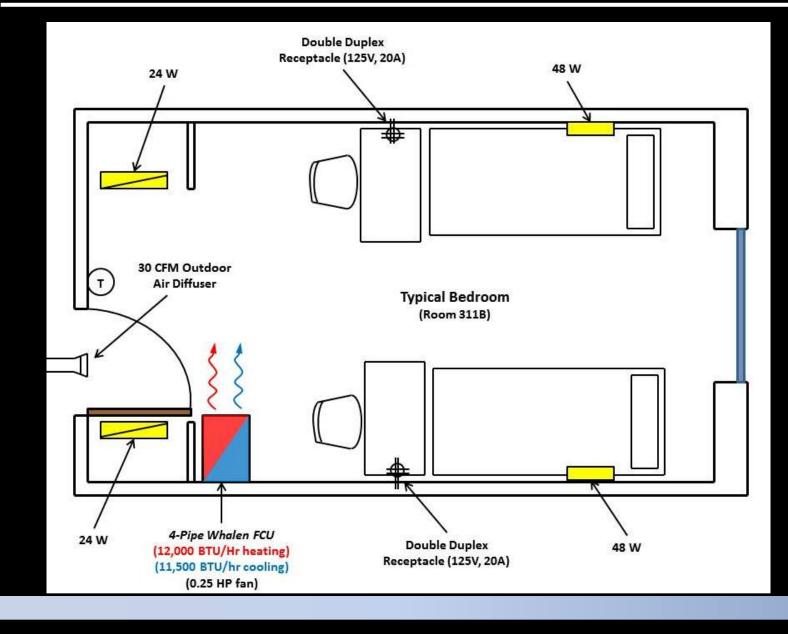
Barcol-Air radiant ceiling panel



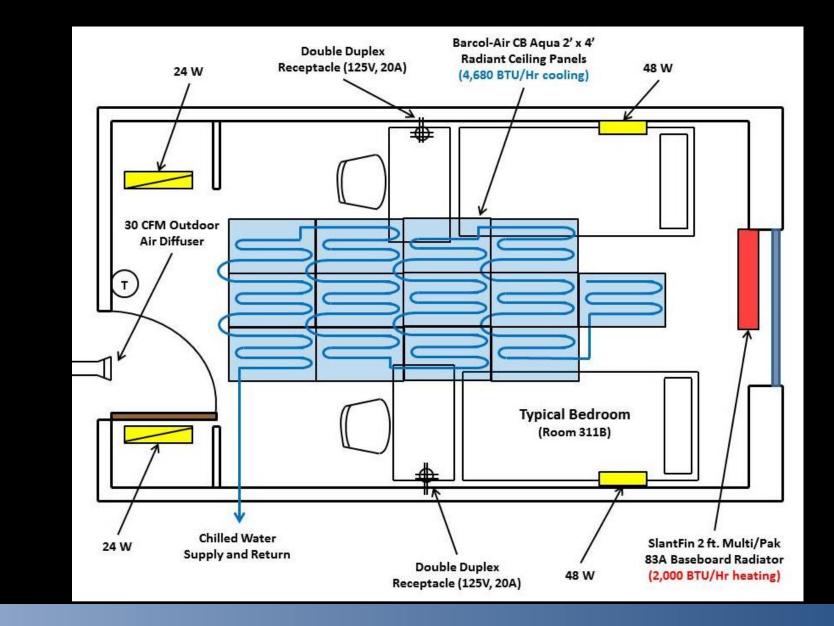


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Analysis 1 - Dedicated Outdoor Air System



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Analysis I - Dedicated Outdoor Air System

Computational Fluid Dynamics Analysis

- Accurate models of a typical bedroom with a fan coil unit and a radiant ceiling were created in Phoenics Cooling performance of each system was analyzed and
- compared

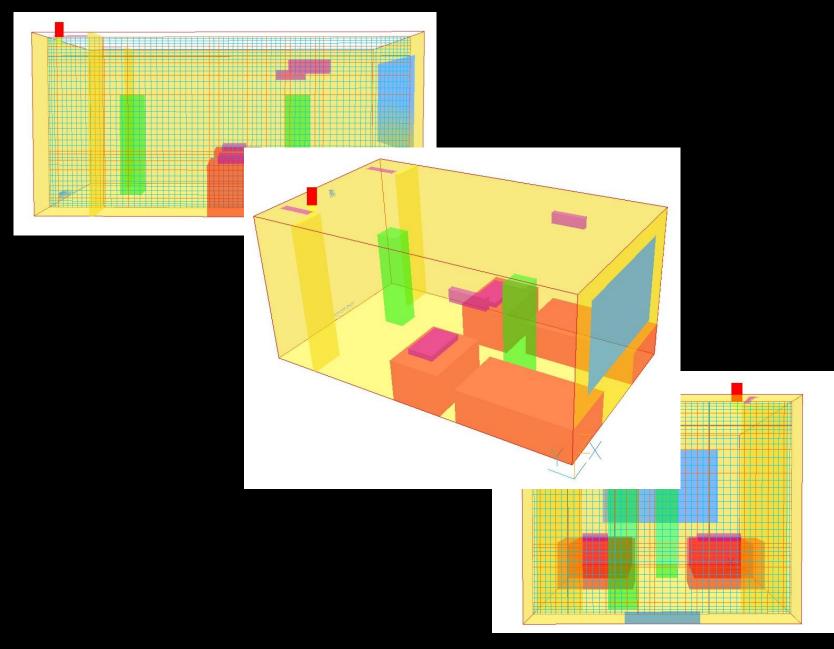
Results

- distribution throughout the space
- Radiant ceiling produced a lower average temperature in the
 - space by 1 °F

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• Radiant ceiling produced a more uniform temperature



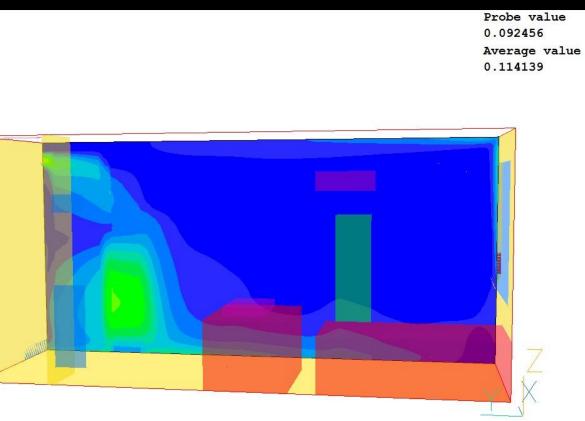
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Velocity Profiles in a Typical Bedroom

7	Velocity,	m/s
-	1.105217	
	1.036142	
-	0.967067	
	0.897992	
-	0.828917	
-	0.759842	
-	0.690767	
-	0.621692	
	0.552617	
	0.483541	
-	0.414466	
- 14	0.345391	
	0.276316	
	0.207241	
	0.138166	
	0.069091	
	1.562E-5	
		1912

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Analysis I - Dedicated Outdoor Air System

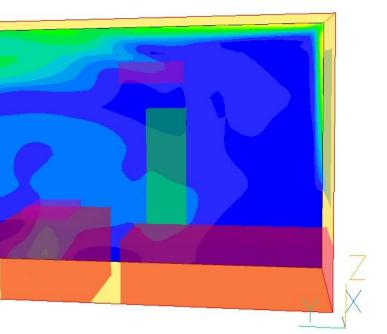


Velocity, m/s 0.600179 0.562670 0.525162 0.487653 0.450145 0.412636 0.375128 0.337620 0.300111 0.262603 0.225094 0.187586 0.150078 0.112569 0.075061 0.037552 4.397E-5

Room with Fan Coil Unit Maximum Velocity = 1.1 m/s

Probe value 0.297630 Average value 0.101923

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Room with Radiant Ceiling Maximum Velocity = 0.6 m/s

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Analysis I - Dedicated Outdoor Air System

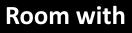
Temperature Profiles in a Typical Bedroom

1.6	emperature,	ø
	48.11644	
H	46.11234	
	44.10825	
	42.10415	
-	40.10005	
H	38.09595	
H	36.09186	
-	34.08776	
	32.08366	
-	30.07957	
	28.07547	
	26.07137	
-	24.06728	
	22.06318	
-	20.05908	
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	16.05089	

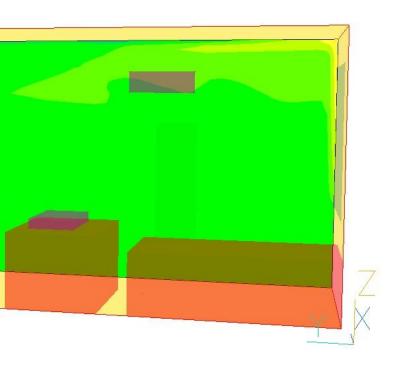
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Room with Fan Coil Unit



Probe value 22.64155 Average value 28.53883



Room with Radiant Ceiling



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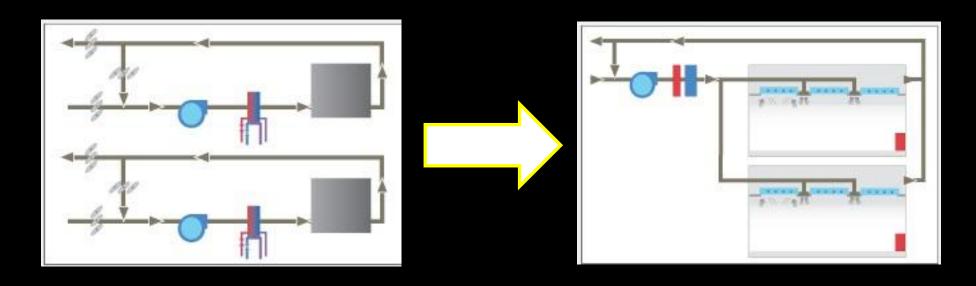
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Analysis I - Dedicated Outdoor Air System

Energy Analysis

- In comparison to the original design, DOAS with radiant ceilings and baseboard radiators:
 - Consumes 12,545 kW-hr LESS per year
 - Consumes 6,611 therms MORE per year
 - Costs \$7,370 MORE per year to operate



	Annual Energy Costs					
	Fan Coil Unit Model	Radiant Ceiling Model				
Total Annual KW-hr						
Used	169, 472 kW-hr	156,927 kW-hr				
Annual Cost of kW-hr						
Consumption	\$14,744	\$13,653				
Total Annual therms						
used	6,624 therms	13,235 therms				
Annual Cost of therm						
Consumption	\$8,479	\$16,941				
Total Annual Energy						
Cost	\$23,223	\$30,594				



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DOAS with radiant ceilings and baseboard radiators costs \$186,528 LESS than DOAS with fan coil units

Fan Coil Unit Dedicated Outdoor Air System Cost							
Component of System Quantity Unit Cost/Unit Total							
Energy Recovery Unit (20,000 cfm)	1	Each	\$150,570	\$150,570			
Supporting ductwork and mechanical equipment	1	Each	\$796,676	\$796,676			
4-Pipe Whalen Fan Coil Unit	257	Each	\$3,240	\$832,680			
			TOTAL:	\$1,779,926			

Analysis I - Dedicated Outdoor Air System

System Cost Comparison

Radiant Ceiling D	edicated O	utdoor A	Air System	Cost
Component of System	Quantity	Unit	Cost/Unit	Total Cost
Energy Recovery Unit				
(20,000 cfm)	1	Each	\$150,570	\$150,570
Supporting ductwork and				
mechanical equipment	1	Each	\$796,676	\$796,676
SlantFin Multi/Pak 83A		Linear		
Baseboard Radiator	689	Foot	\$18	\$12,402
Barcol-Air CB Aqua 2' x 4'				
radiant ceilng panel	4482	Each	\$86	\$385,452
Setup cost of radiant ceiling	1	Each	\$650	\$650
Barcol-Air nipple connector	1794	Each	\$6	\$10,764
Barcol-Air flexible hose with				
quick connector	5379	Each	\$18	\$96,822
Steel Ceilings Inc. 2' x 4'				
steel ceiling panel	4482	Each	\$31.25	\$140,062
			TOTAL:	\$1,593,398



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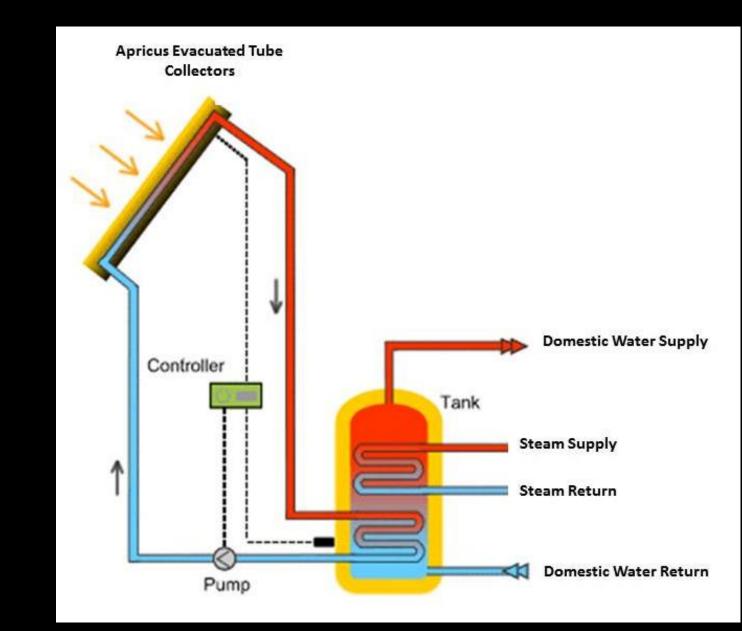
Analysis II - Solar Thermal System

Design Overview

- Antifreeze loop with internal heat exchanger in existing domestic hot water tank
- Solar hot wa series with e

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- Solar hot water heat exchanger will preheat domestic water in
 - series with existing steam heat exchanger





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Design Overview

- Antifreeze loop with internal heat exchanger in existing domestic hot water tank
- Solar hot water heat exchanger will preheat domestic water in series with existing steam heat exchanger

Chosen Manufacturers

- Apricus would supply the solar collectors
 - Evacuated tube collectors
- Sunmaxx Solar would supply the piping, pump station, accessories and controls

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Analysis II - Solar Thermal System







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Analysis II - Solar Thermal System

Solar Collector Array

- Apricus evacuated tube collectors
 - Better performance in cloudy and cold weather
 - 10 year warranty
- 21 AP-30 collectors in array
- accordance with OSHA regulations
- Array faces south
- All collectors positioned at 45° from horizontal

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• All collectors are at least 10 ft. from the edge of the roof in

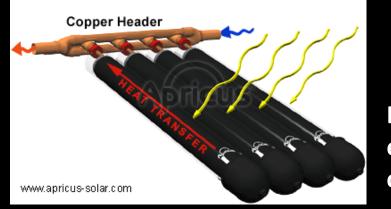
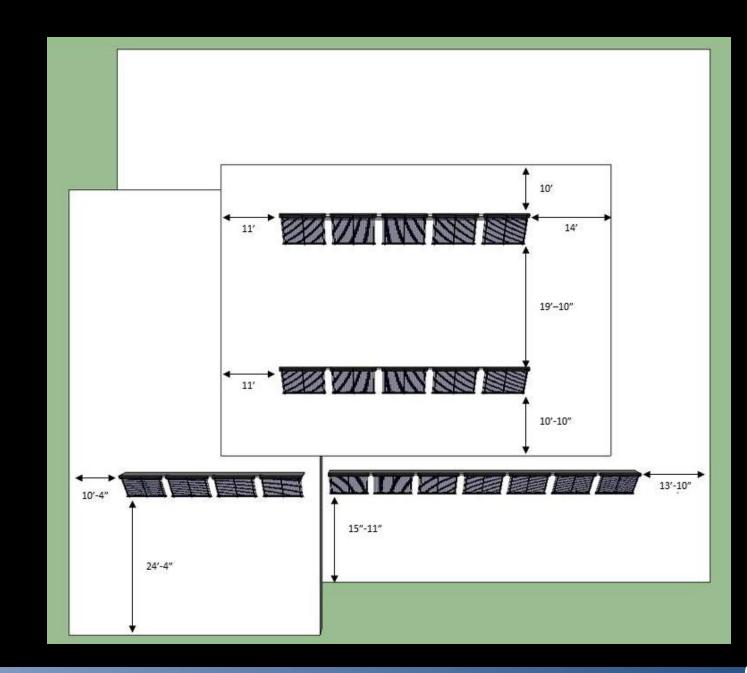


Diagram of an Apricus evacuated tube solar collector





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Energy Output

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• Solar thermal system produces 1,551 therms per year • Net efficiency of central steam plant and distribution network is 66% Therefore system saves the central steam plant **2,350 therms** per year

Insolation Level

Absorber Area/Collector

Number of Collectors

Total Absorber Area

Average Energy Output Per Day

Average Energy Outpu

Per Month

Energy Output Per Yea

Equivalent Steam Ene

Output per Year

Energy Output For Solar Thermal Array 3.53 kWh/m²/day 2.4 m² 50.4 m²

	2350 therms
ergy	
ar	1551 therms
	127.5 therms
ut	
	4.25 therms
ut	



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Energy Output

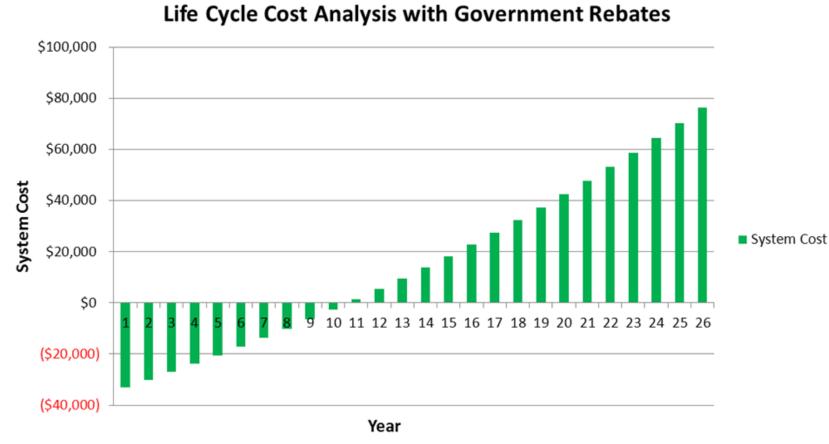
- Solar thermal system produces 1551 therms per year • Net efficiency of central steam plant and distribution network is 66% Therefore system saves the central steam plant **2350 therms** per year

Life Cycle Cost Analysis

- Total cost of system = \$94,500
- Applicable Government Financial Incentives
 - Business Energy Investment Tax Credit: 30% of total system cost
 - PA Sunshine Solar Rebate Program: 35% of total system cost
- Payback period between 10 and 11 years with government incentives

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Daylighting Analysis

- analyzed

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• A typical east facing bedroom and west facing bedroom was

 Models of both rooms were created and analyzed using AGI • According to IESNA Lighting Handbook there should be at least 30 footcandles of light in each room

• The area of most concern in both rooms is the two desks



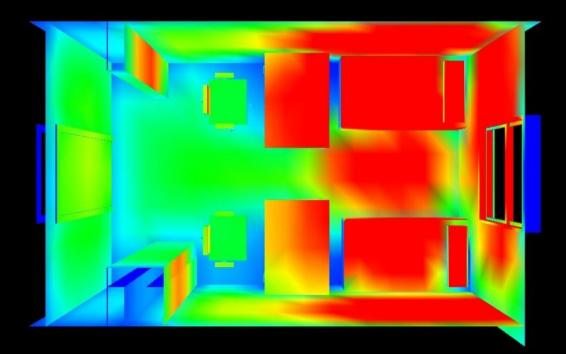
•	Building Overview	Illuminance
•	Thesis Överview	
•	Existing Mechanical System	
•	Mechanical System Redesign Objectives	50.00
•	Analysis I – Dedicated Outdoor Air System	43.75
•	Analysis II – Solar Thermal System	37.50
•	Analysis III – Building Envelope Redesign	31.25
	 Daylighting Breadth 	25.00
•	Conclusion	18.75
		12.50
		6.25
		0.00
		Illuminance (F

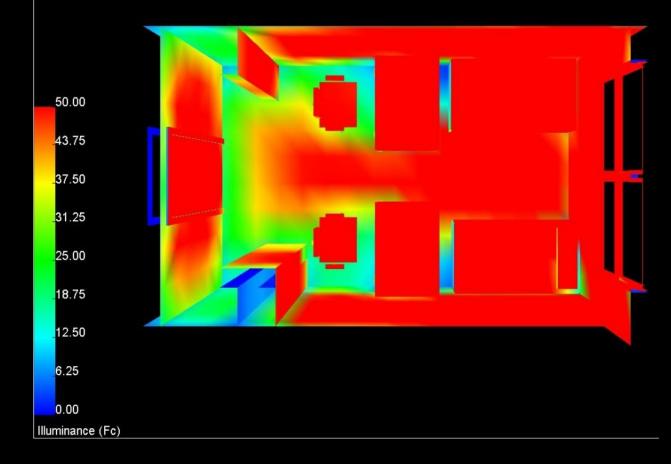
Des Places Residence Hall Peter Edwards – Mechanical Option

East facing room with 4 ft. by 5 ft. window at 10 AM on September 23rd

Daylighting Breadth

Distribution in a Typical East Facing Bedroom





East facing room with 8 ft. by 5 ft. window at 10 AM on September 23rd



•	Building Overview	Illuminance	
	Thesis Overview		
•	Existing Mechanical System		
•	Mechanical System Redesign Objectives	50.00	
•	Analysis I – Dedicated Outdoor Air System	43.75	
•	Analysis II – Solar Thermal System	.37.50	
•	Analysis III – Building Envelope Redesign	_31.25	
	 Daylighting Breadth 		
•	Conclusion	18.75	
		12.50	
		6.25	
		0.00	

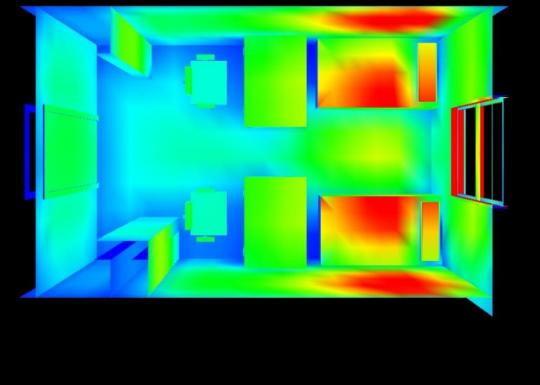
Des Places Residence Hall

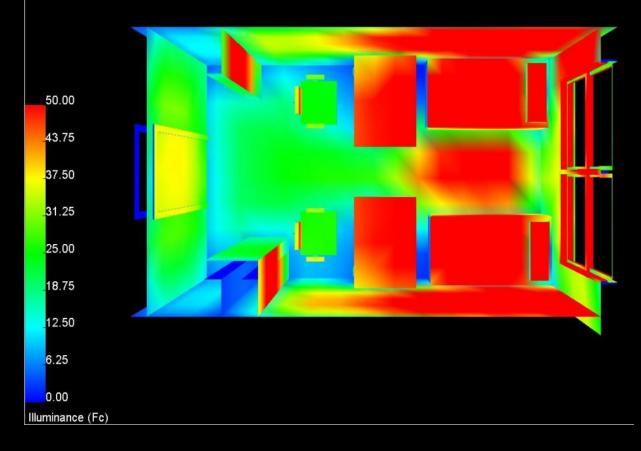
Peter Edwards – Mechanical Option

West facing room with 4 ft. by 5 ft. window at 1 PM on September 23rd

Daylighting Breadth

Distribution in a Typical West Facing Bedroom





West facing room with 8 ft. by 5 ft. window at 1 PM on September 23rd



- **Building Overview**
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Results

- bedroom

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• Larger windows were more beneficial for the west facing

• East facing bedroom had an average illuminance value well over 30 footcandles with the smaller window



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Cost Analysis

Installation Cost of Building Envelope Redesign							
Floor 2 Floors 3-11 Floor 12 TC							
Item Description	Cost/SF	Cost/Unit	Cost	Cost	Cost	Cost	
PPG Solarban 60							
window w/NX-3500							
aluminum frame		\$1,211	\$21,798	\$272,475	\$23,009	\$317,282	
Brick wall w/ 6"							
metal stud back-up	\$21.75		(\$7,830)	(\$97,875)	(\$8,265)	(\$113,970)	
TOTAL			\$13,968	\$174,600	\$14,744	\$203,312	

Building envelope cost will increase by **\$203,312**

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uilding Envelope Redesign

Yearly Energy Cost For Des Places Residence Hall						
	Yearly Gas		Yearly Electricity	Electricity		
	Consumption (therms)	Gas Cost	Consumption (KW-Hr)	Cost	Total Cost	
Building with 4 x 5						
windows	10,988	\$14,099	622,456	\$54,153	\$68,252	
Building with 8 x 5						
windows	12,467	\$15,983	625,360	\$54,406	\$70,389	
Difference	1,479	\$1,884	2,904	\$253	\$2,137	

Yearly Energy costs for Des Places will increase by **\$2,137**



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Des Places Residence Hall

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Final Recommendations

- - \bullet

Solar Thermal System – RECOMMENDED

• Building Envelope Redesign – NOT RECOMMENDED

- Limited daylighting benefits
- Significantly higher construction cost and yearly energy cost

Conclusion

DOAS Redesign – RECOMMENDED

Higher yearly energy costs, but less expensive system Comfort of occupants will be increased

• Saves central steam plant 2,350 therms per year • Payback period under 11 years



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Peter Edwards – Mechanical Option

Acknowledgements

Special Thanks to:

- **CJL Engineering**
 - Craig Duda, Harry Hoover, Tony Valenza and Brad Allis
- WTW Architecture
 - Adam Stadt
- Duquesne University
- Barcol-Air
 - George Hoekstra
- Apricus
 - Eric Skiba

Conclusion

- Regency Construction Services
- Dustin Eplee
- AE Faculty
- Carl Hubben
- Jay Brognano



DUQUESNE Ð NIVFRSITY













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Peter Edwards – Mechanical Option

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Questions





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Inlet Boundary Conditions						
Fan Coil Unit Model						
Diffuser Type	Volume Flow Rate (m^3/s)	Gross Area (Agross)	Area Factor (A _o)	Σ (Ao/Agross)	Temp (°C)	Temp (°F)
Outdoor Air	0.014	0.15 m x 0.15 m	0.0225 m^2	100%	21	70
Fan Coil Unit	0.142	0.2 m x 0.36 m	0.0576 m^2	80%	12.8	55

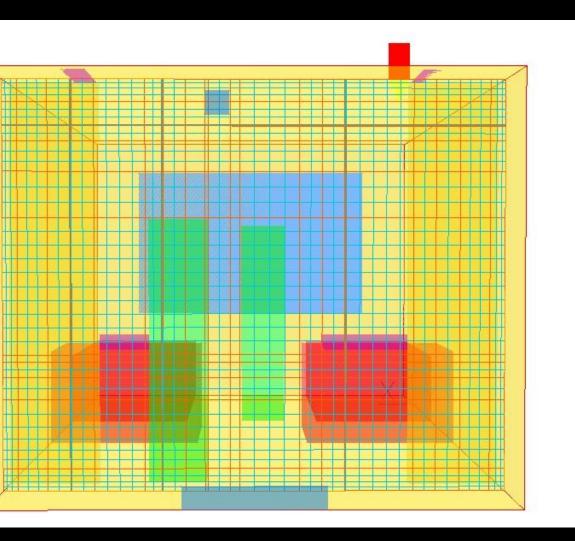
Conclusion

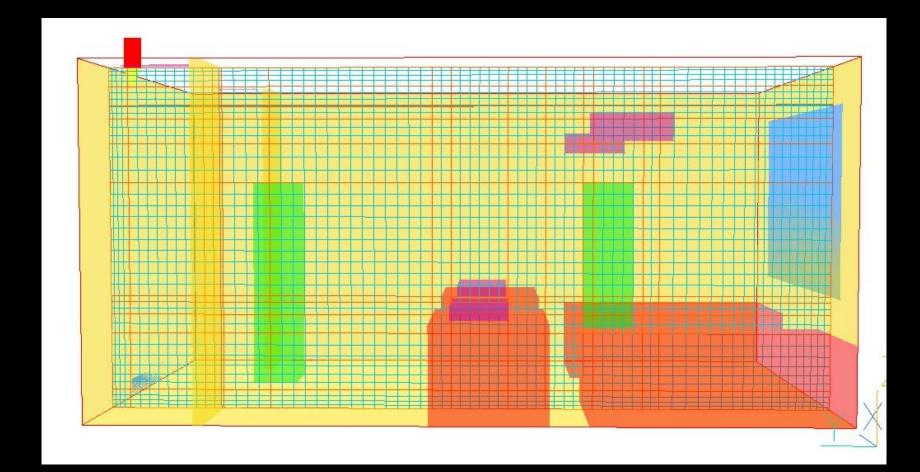
Properties of Different Phoenics Models								
	Turbulence Model	Differencing Scheme	Iterations	Computation Time	Grid Size (X)	Grid Size (Y)	Grid Size (Z)	Mass Residual
Room with Heat								
Sources Only	LVEL	Upwind	2000	2 hr, 1 min	66	75	44	2.70%
Room with Fan								
Coil Unit	KEMODL	Upwind	4000	3 hr, 15 min	48	63	47	0.30%
Room with								
Radiant Ceiling	LVEL	Upwind	8000	8hr, 10 min	66	75	44	1.26%

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Conclusion



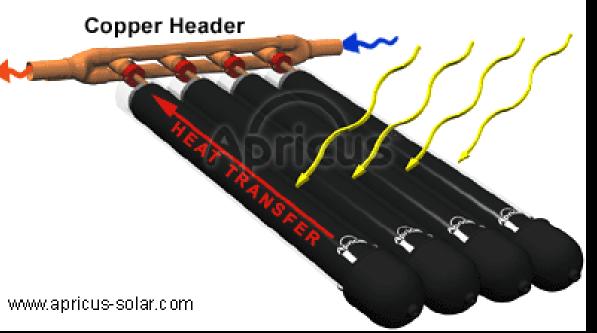


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Conclusion



Apricus Solar Colle	ecto			
Aanifold Casing Material	Alι			
rame Material	1.5			
landar Dina Matarial				
leader Pipe Material	silv			
nsulation	Со			
ubber Seals and Rings	ΗТ			
optimal installation angle				
Aaximum Operating Pressure	8ba			
ptimal flow rate	0.1			
erformance Data (SPF)				

or General Specifications

- uminium (grade 3A21)
- 5mm 304 Stainless Steel
- .93% pure Copper & lead free 45%
- ver brazing
- mpressed Glass Wool K = 0.043W/mK
- ∇ grade silicone rubber
- -70o Vertical, -5o to +5o Horizontal
- ar 116psi
- Ll/min/tube 0.026G/min/tube
- onversion Factor: ho = 0.717
- Loss Coefficients: a1 = 1.52, a2 = 0.0085

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