MORTON HOSPITAL EXPANSION

COURTNEY MILLETT

Mechanical Option
Class of 2015

The Pennsylvania State University

April 14, 2015

(Image courtesy of Steffian Bradley Architects)

Taunton, MA

Advisor: Dr. Bahnfleth

MORTON HOSPITAL EXPANSION

- Introduction
- Building Overview
- Overall Goals
- Mechanical Analysis
- CFD Analysis
- Electrical Breadth
- Conclusions

MORTON HOSPITAL EXPANSION

General Information:

Owner:
Steward Healthcare

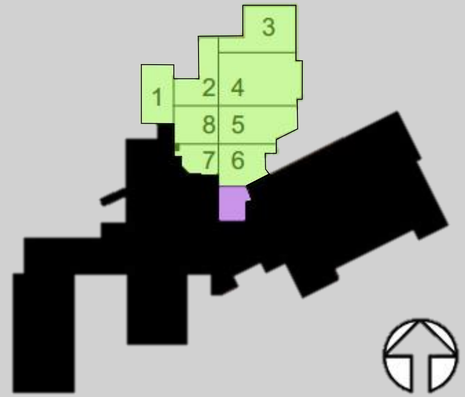
Occupancy:
Hospital

Location:
Taunton, MA

Existing Building Area:
100,000 SF

Expansion Area:
40,000 SF

Building Overview



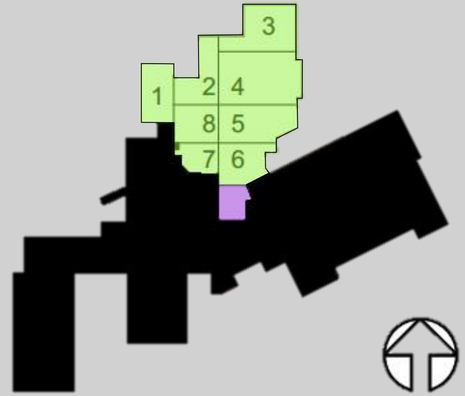
MORTON HOSPITAL EXPANSION

General Information:

Phase 1:

MRI

Building Overview



MORTON HOSPITAL EXPANSION

General Information:

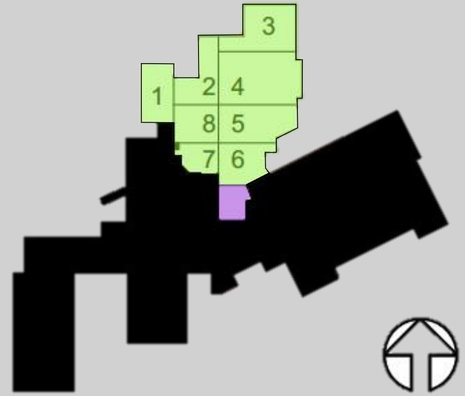
Phase 1:

MRI

Phase 2:

Emergency Department
Patient Treatment Rooms
Psychiatric Ward
Isolation Rooms

Building Overview



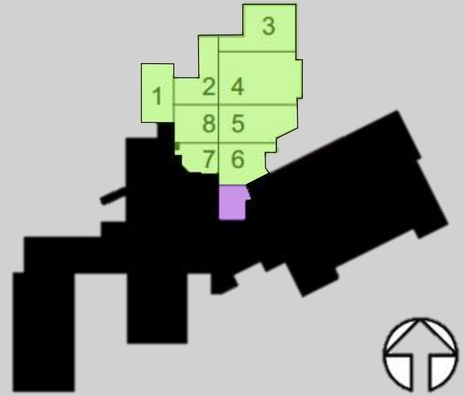
MORTON HOSPITAL EXPANSION

Building Overview

Current System:

Phase 1:

AHU-1: 2500 CFM
Steam Preheat Coil
DX Cooling Coil
Electric Reheat



Current System:

Phase 1:

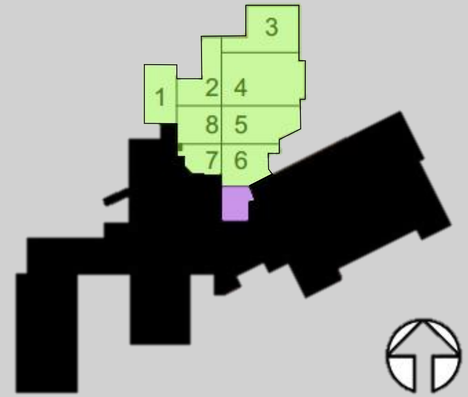
AHU-1: 2500 CFM
Steam Preheat Coil
DX Cooling Coil

Electric Reheat

Phase 2:

AHU-2: 35,000 CFM
Hot Water Preheat Coil
Chilled Water Cooling Coil

VAV Box – Hot Water Reheat



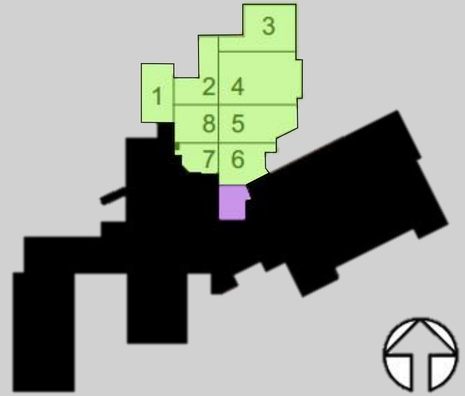
Current Heating System:

Existing Building Steam Plant

LPS to Steam to HW Heat Exchangers

180° F HW Supply

140° F HW Return



MORTON HOSPITAL EXPANSION

Building Overview

Current Heating System:

Existing Building Steam Plant

LPS to Steam to HW Heat Exchangers

180° F HW Supply

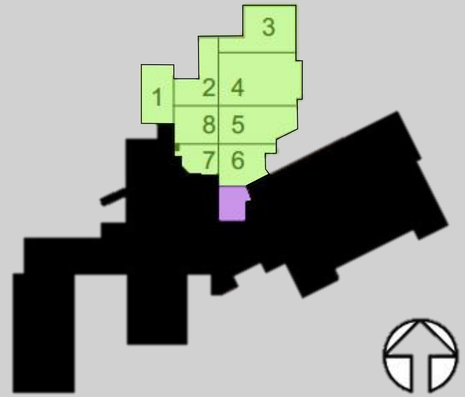
140° F HW Return

Current Cooling System:

New 155 Ton Air Cooled Chiller

55° F CHW Supply

43° F CHW Return



MORTON HOSPITAL EXPANSION

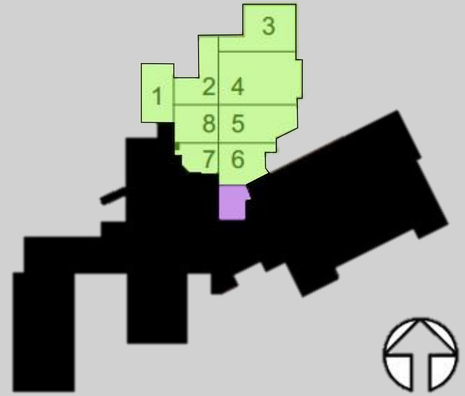
ASHRAE 90.1 - 2010:

TABLE 6.5.6.1 Exhaust Air Energy Recovery Requirements

Zone	% *Outdoor Air* at Full Design Airflow Rate					
	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000
1B, 2B,5C	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7,8	≥2500	≥1000	>0	>0	>0	>0

NR—Not required

Building Overview



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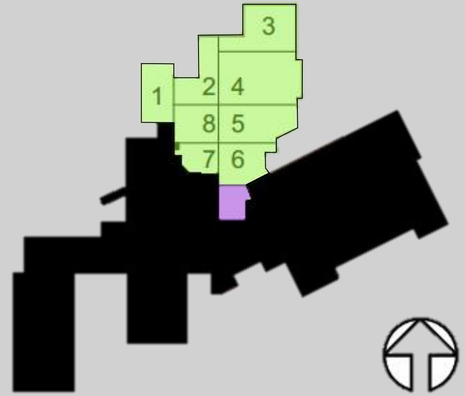
NR—Not required

27% Outdoor Air

Building Overview



MORTON HOSPITAL EXPANSION

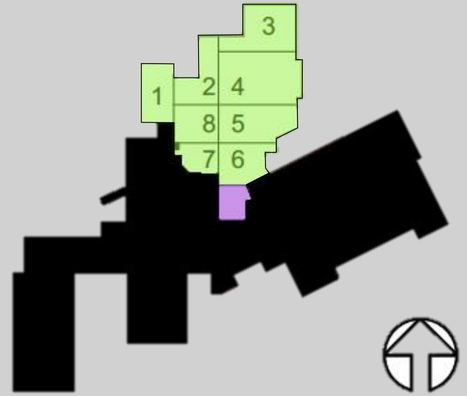
ASHRAE 90.1 - 2013:

TABLE 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year

Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate, cfm							
3C	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	>0
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0

NR—Not required

Building Overview



MORTON HOSPITAL EXPANSION

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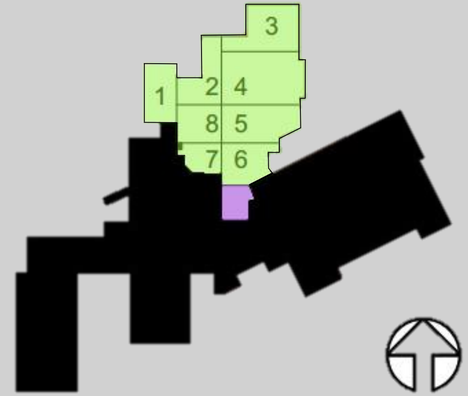
3C	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	>0
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0

NR—Not required

27% Outdoor Air

Building Overview



System Feasibility

OVERALL GOALS

System Feasibility

Energy Consciousness

OVERALL GOALS

System Feasibility

Energy Consciousness

$ Economically Practical

OVERALL GOALS

System Feasibility

Energy Consciousness

$ Economically Practical

Thermal Comfort

MECHANICAL SYSTEM ANALYSIS

Key Considerations:

Equipment First Cost
System Feasibility
Life Cycle Cost
Energy Consumption

ALTERNATIVE 1: Water-Cooled Chiller & Air-to-Air Heat Recovery

Key Considerations:

Equipment First Cost
System Feasibility
Life Cycle Cost
Energy Consumption

ALTERNATIVE 2: Variable Refrigerant Flow

ALTERNATIVE 1: Water-Cooled Chiller & Air-to-Air Heat Recovery

MECHANICAL SYSTEM ANALYSIS

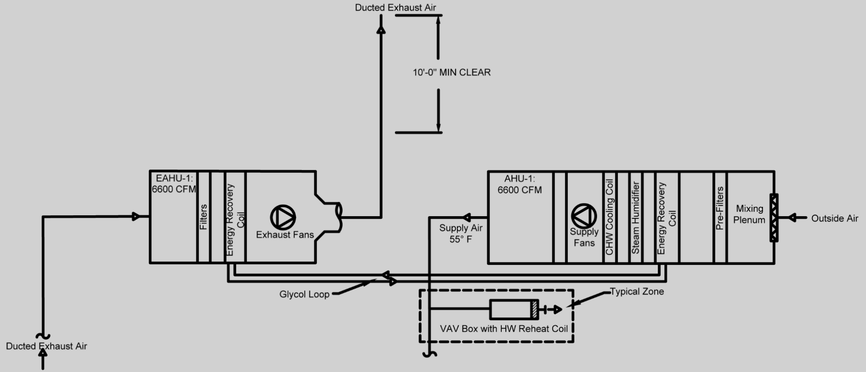
Key Considerations:

Equipment First Cost
System Feasibility
Life Cycle Cost
Energy Consumption

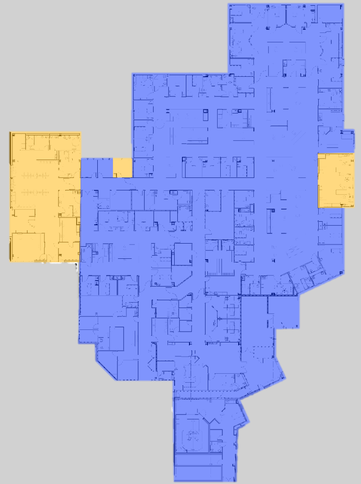
ALTERNATIVE 1: Water-Cooled Chiller & Air-to-Air Heat Recovery

Air-to-Air Energy Recovery

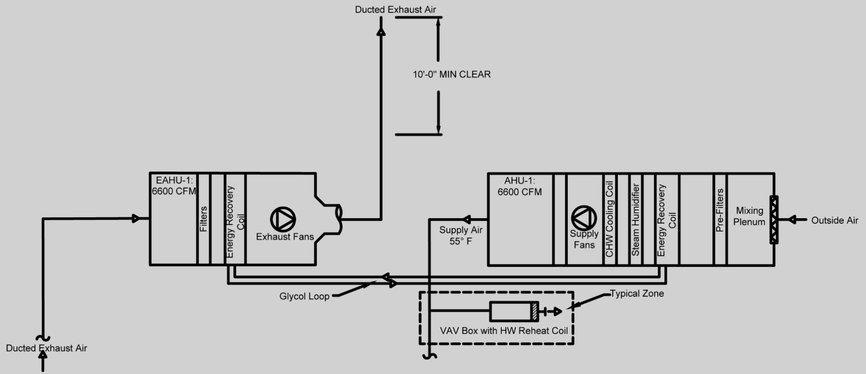
Air-to-Air Energy Recovery



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1



Air-to-Air Energy Recovery



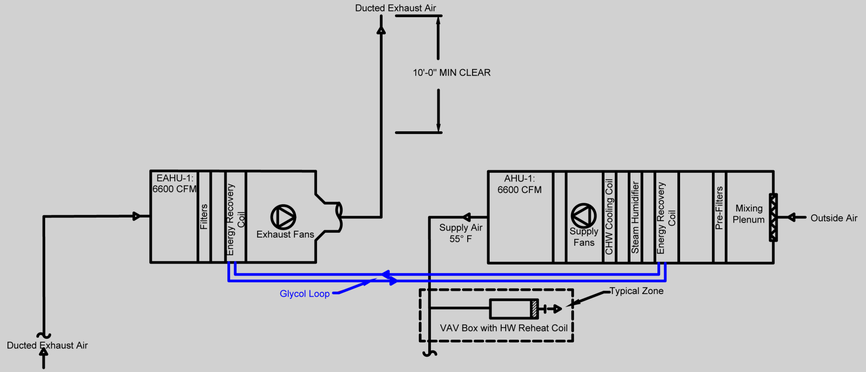
AHU-1 System Features:

100% Outside Air
AHU-1: 6600 CFM
EAHU-1: 6600 CFM
Glycol Solution Loop

Considerations:

Additional Equipment Cost
ASHRAE 90.1 – 2013 Compliance
Cross-Contamination

Air-to-Air Energy Recovery



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AHU-1: 6600 CFM
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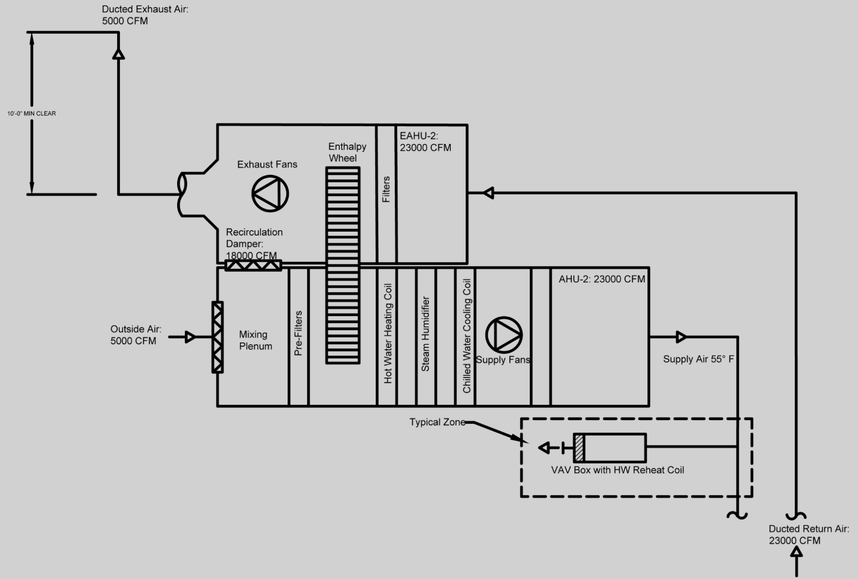
Glycol Solution Loop

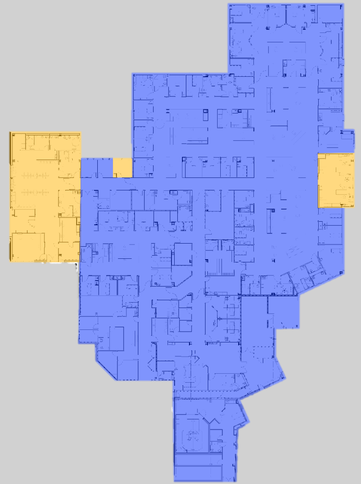
Considerations:

Additional Equipment Cost
ASHRAE 90.1 – 2013 Compliance
Cross-Contamination

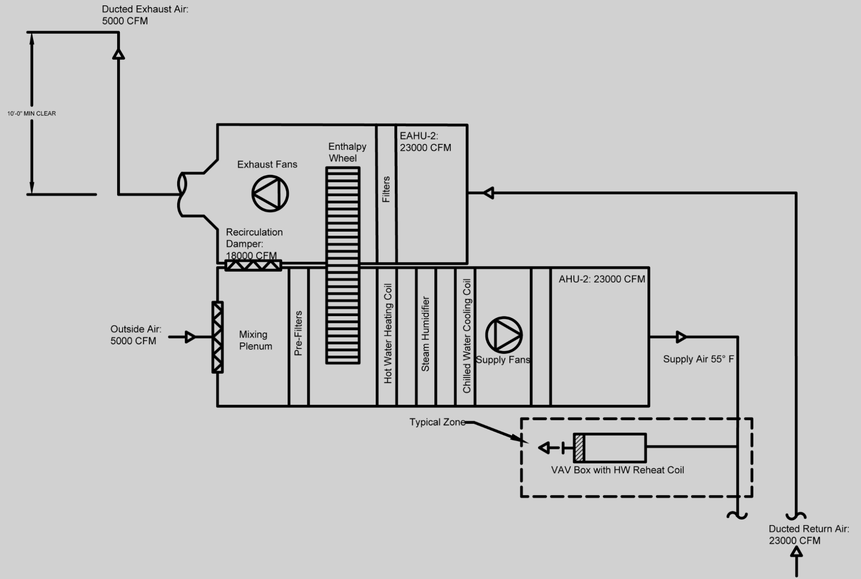
Air-to-Air Energy Recovery



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1



Air-to-Air Energy Recovery



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1

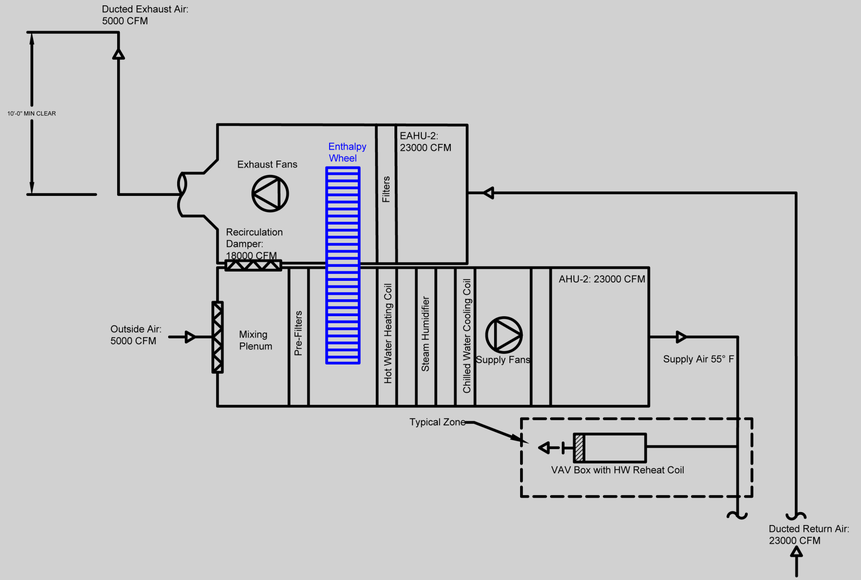
AHU-2 System Features:

AHU-2: 23,000 CFM
EAHU-2: 23,000 CFM
Enthalpy Wheel

Considerations:

Additional Equipment Cost
ASHRAE 90.1 – 2013 Compliance

Air-to-Air Energy Recovery



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1

AHU-2 System Features:

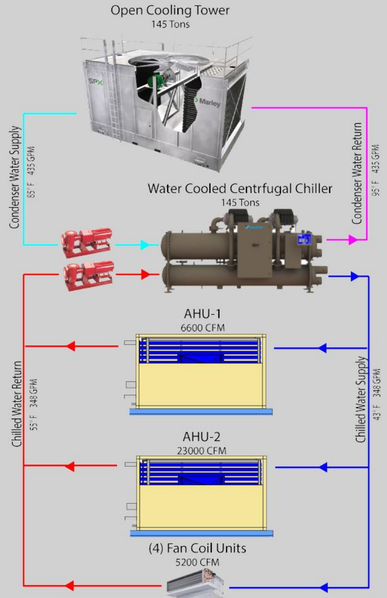
AHU-2: 23,000 CFM
EAHU-2: 23,000 CFM
Enthalpy Wheel

Considerations:

Additional Equipment Cost
ASHRAE 90.1 – 2013 Compliance

Chilled Water and Condenser Water Loop

Chilled Water and Condenser Water Loop



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1

System Features:

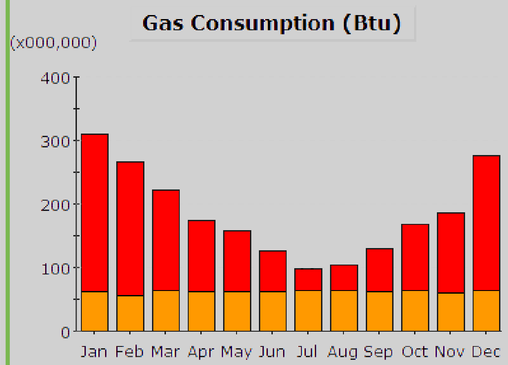
145 Ton Water Cooled Centrifugal Chiller
1,726,200 Btu/hr Open Cooling Tower
43° F Chilled Water Supply
85° F Condenser Water Supply

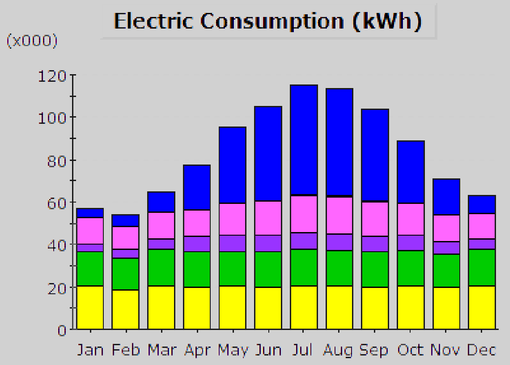
Considerations:

Additional Equipment Cost
Re-evaluation of Roof Structure

Electric & Natural Gas Consumption

Electric & Natural Gas Consumption





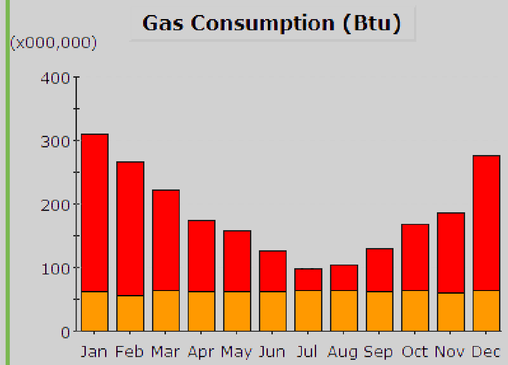
MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1

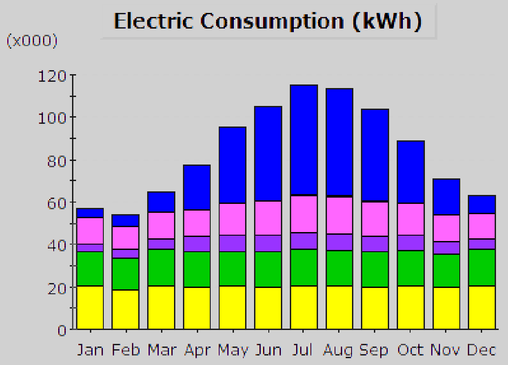
Total Energy Savings:

10% Savings in Electrical Consumption

34% Savings in Natural Gas Consumption

Electric & Natural Gas Consumption





MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 1

Reductions:

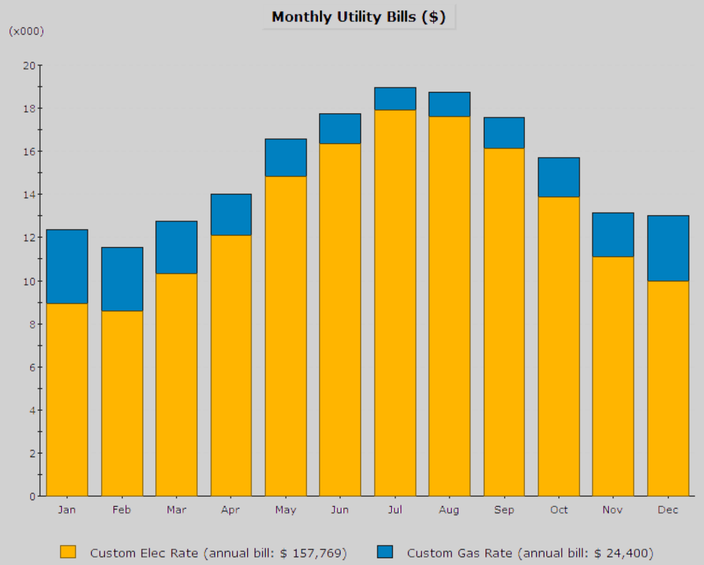
8.5% Reduction in Space Cooling
41% Reduction in Fan Energy
44% Reduction in Space Heating

Increases:

83% Increase in Pump Energy

Annual Operating Cost

Annual Operating Cost



Total Annual Bill Across All Rates: $ 182,169

Total Cost Savings:

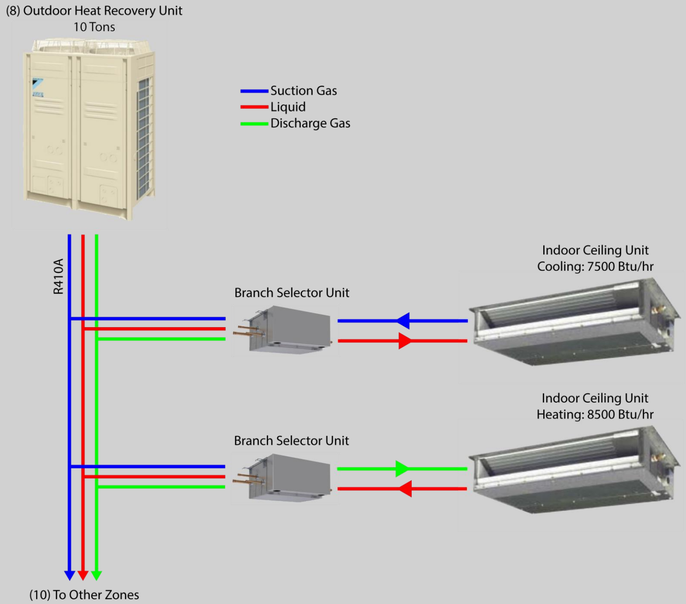
15% Total Annual Savings
10% Savings in Electrical Costs
34% Savings in Natural Gas Consumption
$4.47/SF

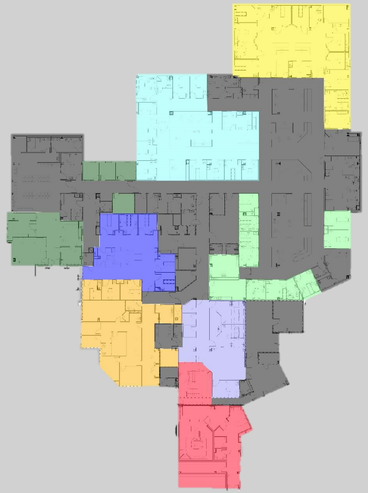
ALTERNATIVE 2:
Variable Refrigerant Flow

VRF Refrigerant Loop

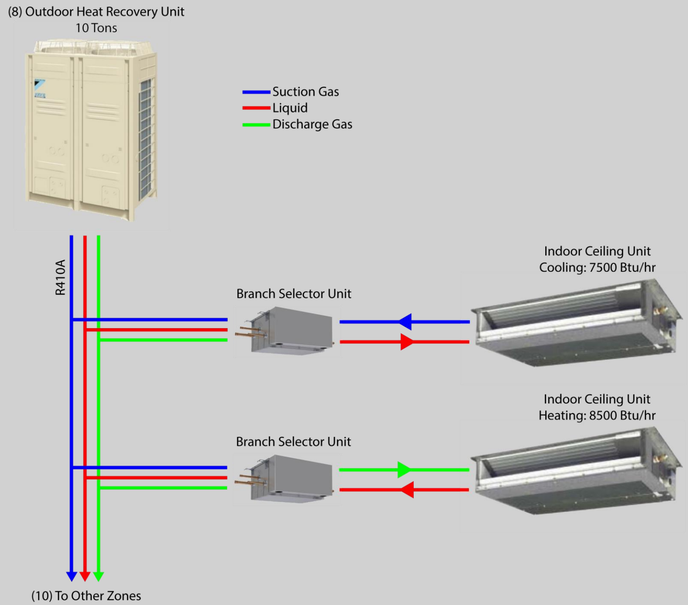
MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 2

VRF Refrigerant Loop





VRF Refrigerant Loop



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 2

System Features:

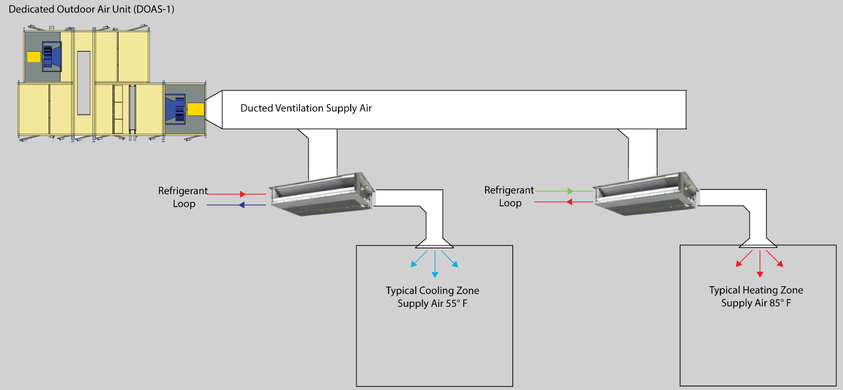
(8) 10 Ton Outdoor Units
Refrigerant R410A
Heat Recovery

Considerations:

Additional Equipment Cost
ASHRAE 15 – 2013 Compliance

DOAS Ventilation

DOAS Ventilation



System Features:

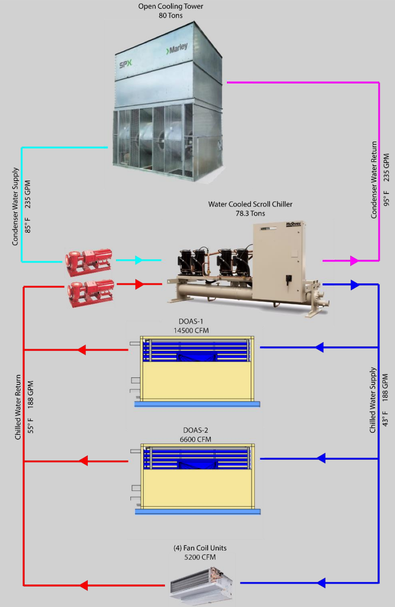
DOAS-1: 14,500 CFM
EAHU-1: 14,500 CFM
Enthalpy Wheel Heat Recovery

Considerations:

ASHRAE 170 – 2013 Ventilation Requirements

Chilled Water & Condenser Water Loop

Chilled Water & Condenser Water Loop



MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 2

System Features:

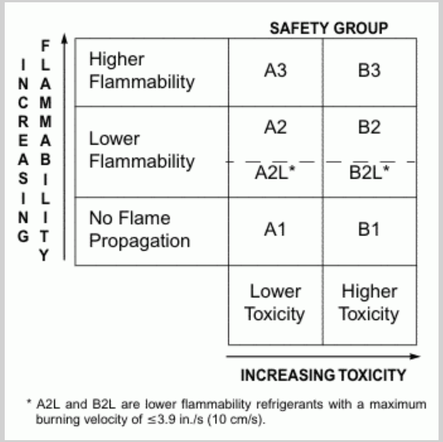
78 Ton Chiller
970,400 Btu/hr Cooling Tower
43° F Chilled Water Supply
85° F Condenser Water Supply

Considerations:

Reduced Equipment Sizes
Reduced Equipment Cost

ASHRAE 15: Safety Standard for Refrigeration Systems

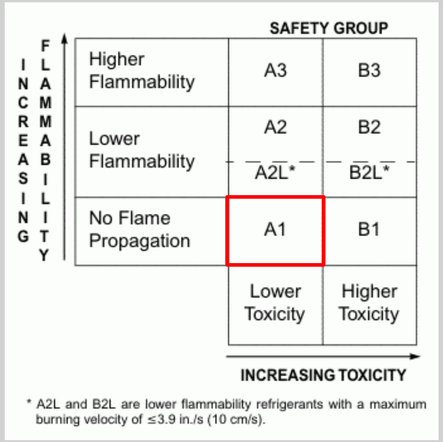
ASHRAE 15: Safety Standard for Refrigeration Systems



ASHRAE 34:

Refrigerant Safety Group Classifications

ASHRAE 15: Safety Standard for Refrigeration Systems



ASHRAE 34:

Refrigerant Safety Group Classifications

ASHRAE 15: Safety Standard for Refrigeration Systems

TABLE 4-2 Data and Safety Classifications for Refrigerant Blends

Refrigerant Number	Composition (Mass %)	Composition Tolerances	OEL[b], ppm v/v	Safety Group	RCL[a] (ppm v/v)	RCL[a] (lb/Mcf)	RCL[a] (g/m^3)	Highly Toxic or Toxic[f] Under Code Classification
Zeotropes								
409A	R-22/124/142b (60.0/25.0/15.0)	(±2.0/±2.0/±1.0)	1000	A1	29,000	7.1	110	Neither
409B	R-22/124/142b (65.0/25.0/10.0)	(±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120	Neither
410A[i]	R-32/125 (50.0/50.0)	(+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420	Neither
410B[i]	R-32/125 (45.0/55.0)	(±1.0/±1.0)		A1	140,000	27	430	Neither
411A[e]	R-1270/22/152a (1.5/87.5/11.0)	(+0.0, –1.0/+2.0, –0.0/+0.0, –1.0)	990	A2	14,000	2.9	46	Neither
411B[e]	R-1270/22/152a (3.0/94.0/3.0)	(+0.0, –1.0/+2.0, –0.0/+0.0, –1.0)	980	A2	13,000	2.8	45	Neither
412A	R-22/218/142b (70.0/5.0/25.0)	(±2.0/±2.0/±1.0)	1000	A2	22,000	5.1	82	Neither
413A	R-218/134a/600a (9.0/88.0/3.0)	(±1.0/±2.0/+0.0, –1.0)	1000	A2	22,000	5.8	94	Neither

ASHRAE 34:

Table 4-2 Data and Safety Classifications for Blends

Considerations:

Institutional Occupancy: Reduce RCL by 50%

ASHRAE 15: Safety Standard for Refrigeration Systems

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Zeotropes								
409A	R-22/124/142b (60.0/25.0/15.0)	(±2.0/±2.0/±1.0)	1000	A1	29,000	7.1	110	Neither
409B	R-22/124/142b (65.0/25.0/10.0)	(±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120	Neither
410A[i]	R-32/125 (50.0/50.0)	(+0.5, –1.5/+1.5, –0.5)	1000	A1	140,000	26	420	Neither
410B[i]	R-32/125 (45.0/55.0)	(±1.0/±1.0)		A1	140,000	27	430	Neither
411A[e]	R-1270/22/152a (1.5/87.5/11.0)	(+0.0, –1.0/+2.0, –0.0/+0.0, –1.0)	990	A2	14,000	2.9	46	Neither
411B[e]	R-1270/22/152a (3.0/94.0/3.0)	(+0.0, –1.0/+2.0, –0.0/+0.0, –1.0)	980	A2	13,000	2.8	45	Neither
412A	R-22/218/142b (70.0/5.0/25.0)	(±2.0/±2.0/±1.0)	1000	A2	22,000	5.1	82	Neither
413A	R-218/134a/600a (9.0/88.0/3.0)	(±1.0/±2.0/+0.0,–1.0)	1000	A2	22,000	5.8	94	Neither

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2

ASHRAE 34:

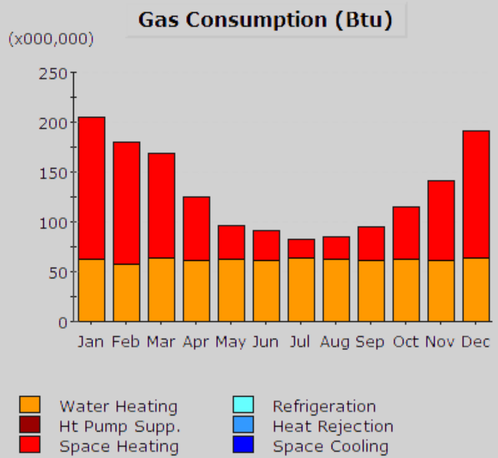
Table 4-2 Data and Safety Classifications for Blends

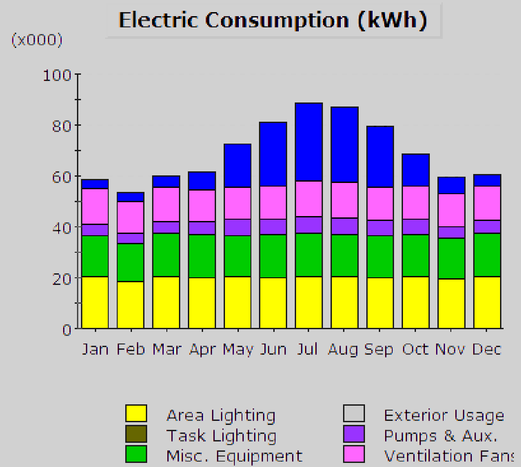
Considerations:

Institutional Occupancy: Reduce RCL by 50%

Electric & Natural Gas Consumption

Electric & Natural Gas Consumption





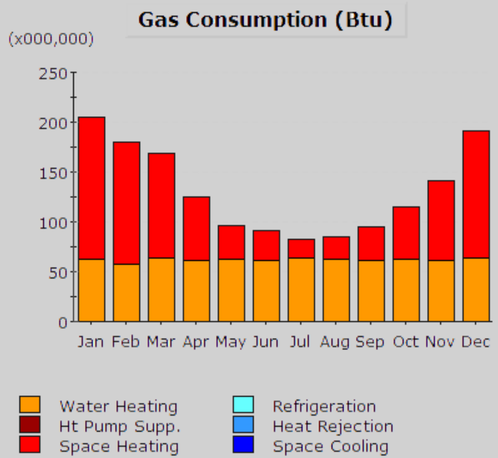
MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 2

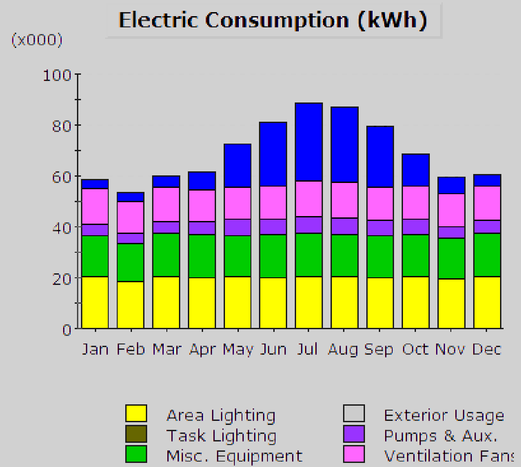
Total Energy Savings:

26% Savings in Electrical Consumption

50% Savings in Natural Gas Consumption

Electric & Natural Gas Consumption





MECHANICAL SYSTEM ANALYSIS
ALTERNATIVE 2

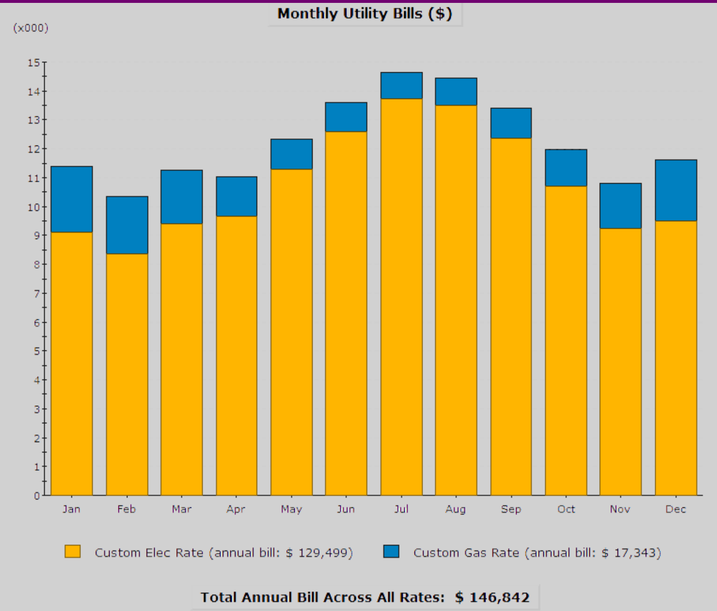
Reductions:

40% Reduction in Space Cooling

44% Reduction in Space Heating

Annual Operating Cost

Annual Operating Cost



Total Cost Savings:

32% Total Annual Savings
26% Savings in Electrical Costs
54% Savings in Natural Gas Consumption
$3.60/SF

MECHANICAL SYSTEM ANALYSIS
Overall Comparison

Life Cycle Cost and Payback Period

Life Cycle Cost			
	Total Life Cycle Cost	Savings	Payback Period
Base	$ 4,726,768.09		
Alternative 1	$ 4,157,240.30	12%	1.85
Alternative 2	$ 3,771,892.32	20%	4.98

Cost Basis:

25 Year Equipment Life

First Cost:

RS Means Mechanical Cost Data 2015

Maintenance Cost:

RS Means Facilities Maintenance & Repairs 2015

Utility Cost:

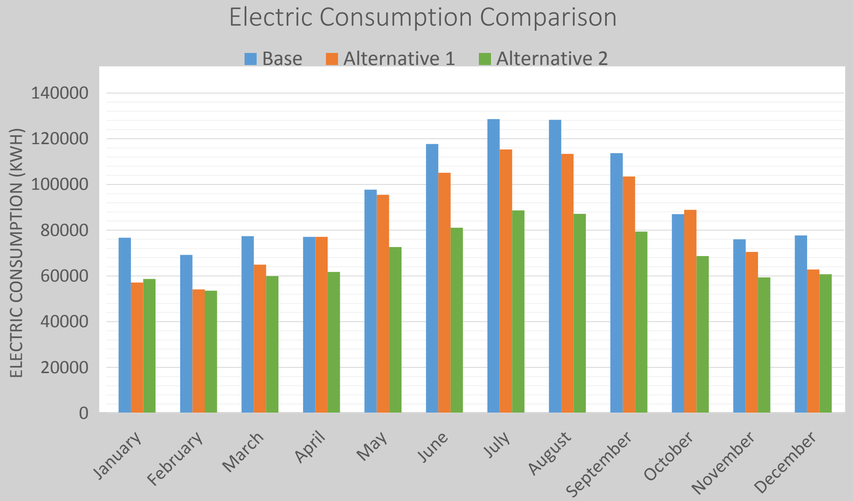
eQuest Energy Simulation

Escalation Factors:

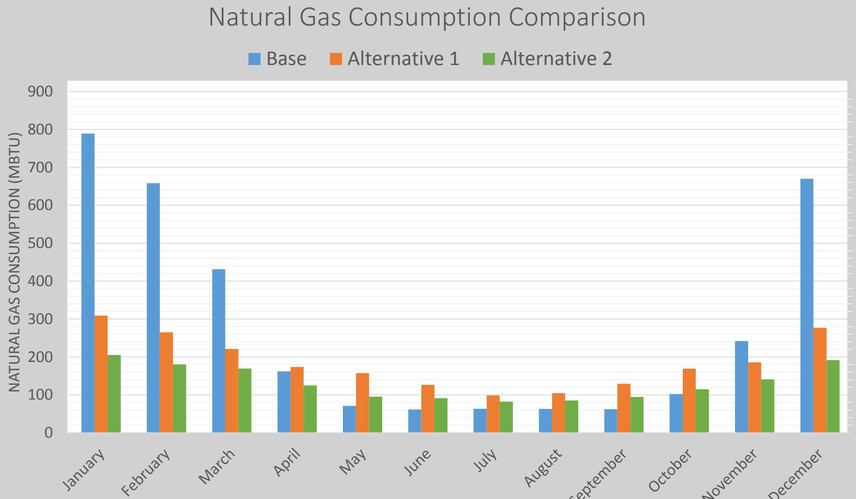
NIST Handbook 135

Energy Analysis

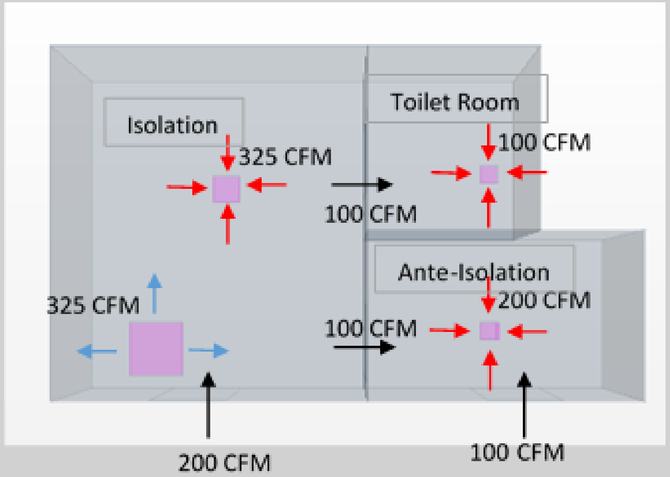
Overall Comparison



Energy Analysis



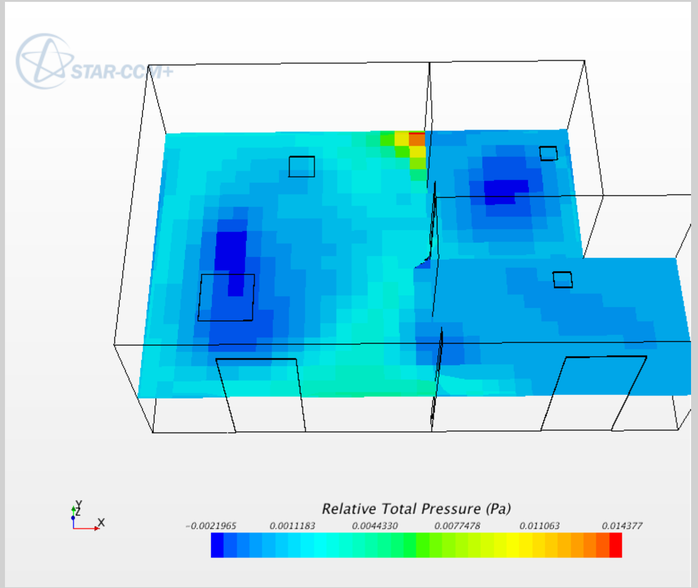
Isolation Room Geometry



Considerations:

ASHRAE 170 AII Room Requirements:
Negative Pressure Relationship
70-75° F Design Temperature
12 Total ACH

Pressure Gradient



Considerations:

ASHRAE 170 All Room Requirements:

Negative Pressure Relationship

70-75° F Design Temperature

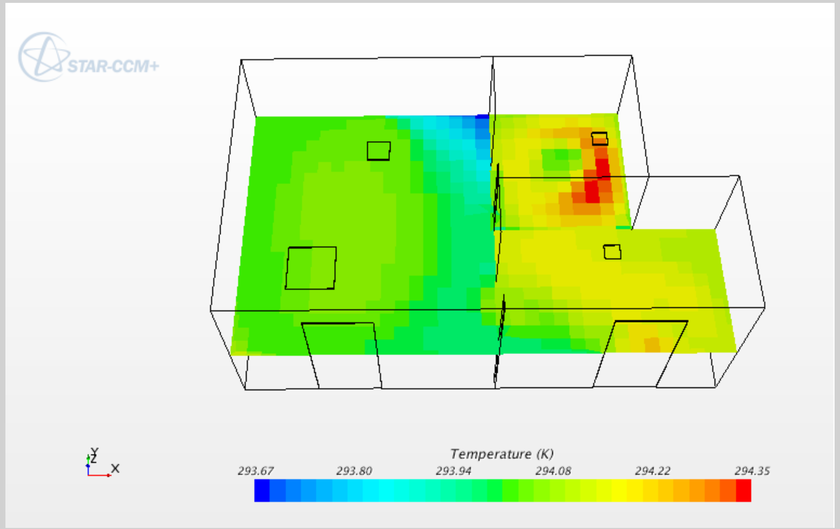
12 Total ACH

Pressure Gradient

Considerations:

ASHRAE 170 All Room Requirements:
Negative Pressure Relationship
70-75° F Design Temperature
12 Total ACH

Temperature Gradient



Considerations:

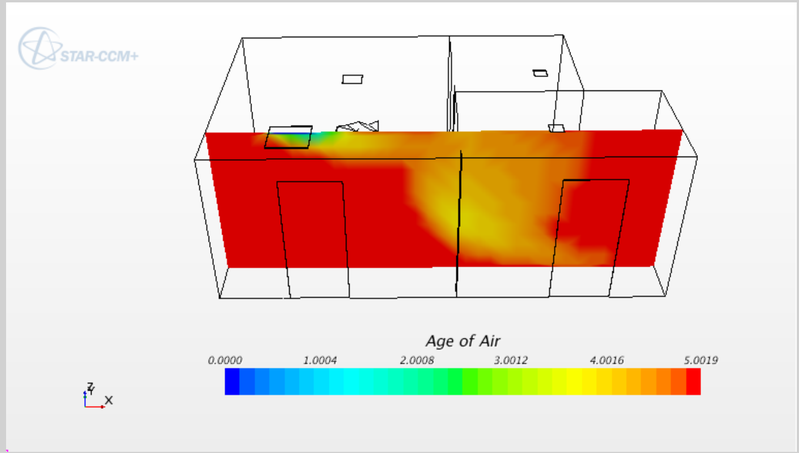
ASHRAE 170 All Room Requirements:
Negative Pressure Relationship
70-75° F Design Temperature
12 Total ACH

Temperature Gradient

Considerations:

ASHRAE 170 All Room Requirements:
Negative Pressure Relationship
70-75° F Design Temperature
12 Total ACH

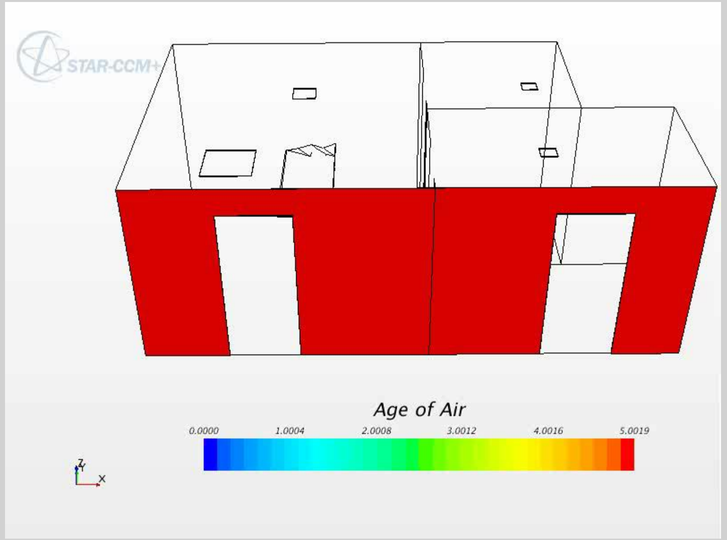
Age of Air



Considerations:

ASHRAE 170 AII Room Requirements:
Negative Pressure Relationship
70-75° F Design Temperature
12 Total ACH

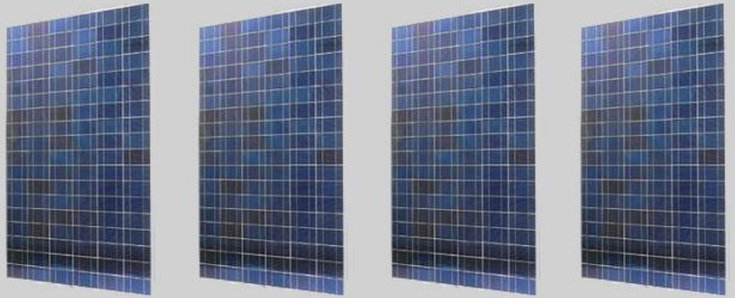
Age of Air



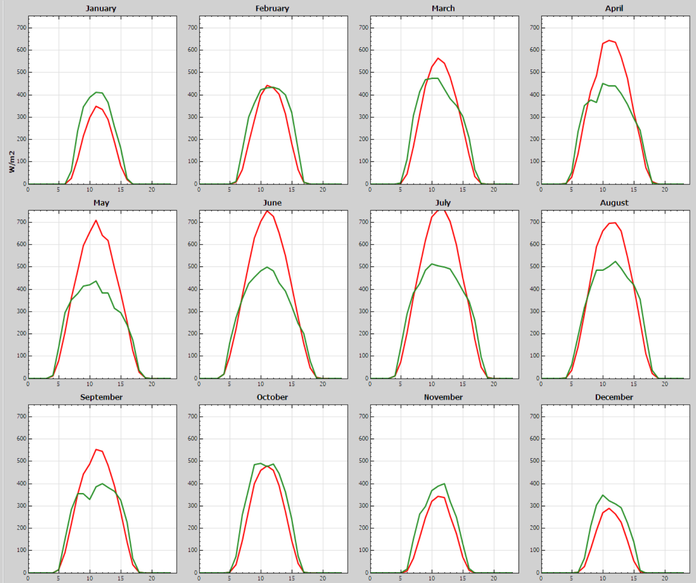
Considerations:

ASHRAE 170 All Room Requirements:
Negative Pressure Relationship
70-75° F Design Temperature
12 Total ACH

Electrical Breadth
Photovoltaic Array



Site Information

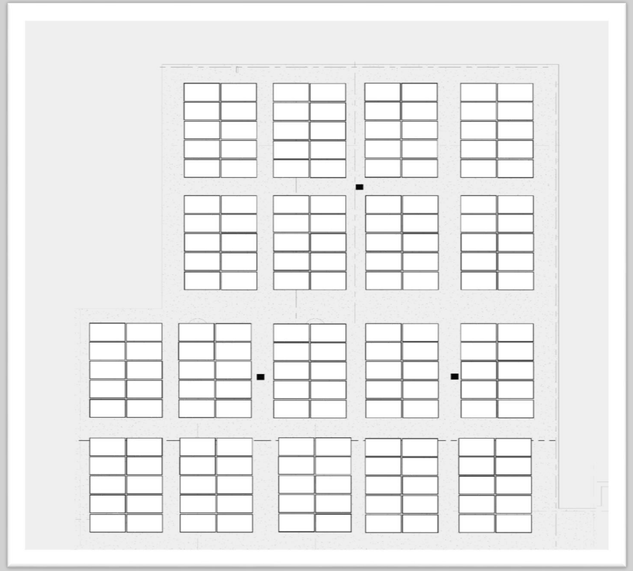


Considerations:

Annual Beam Normal Radiation: 1388.7 kWh/m^2

Annual Diffuse Radiation: 1454.4 kWh/m^2

Site Information

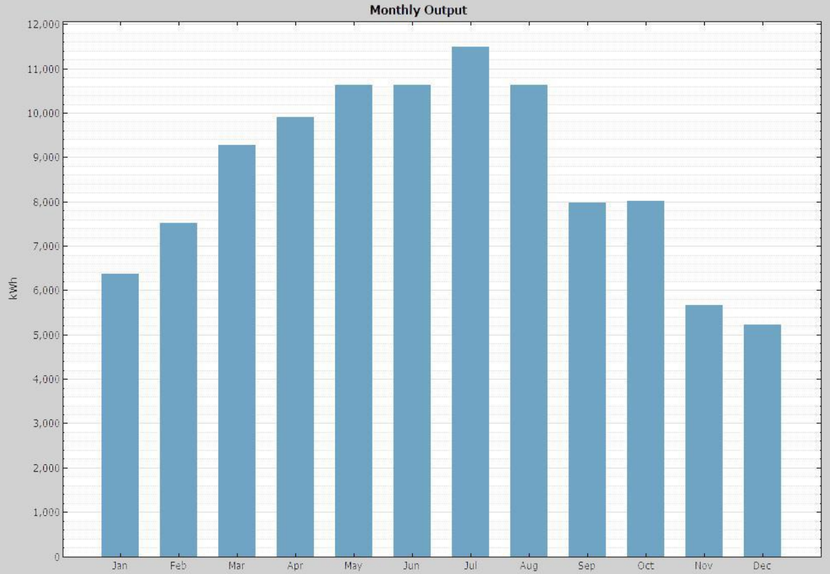


Considerations:

Latitude: 41.7°

Total Area: 3800 SF

Electric Generation



Considerations:

Total Site Electric Consumption: 831,450 kWh
Total Generated by Panels: 103,349 kWh
Remaining 88% produced by the grid

Economics

Photovoltaic Panels Payback			
First Cost	Annual Consumption Savings	Annual Consumption Savings	Payback Period (year)
$ 161,154.00	$ 11,022.58	9%	14.62

Payback Period:

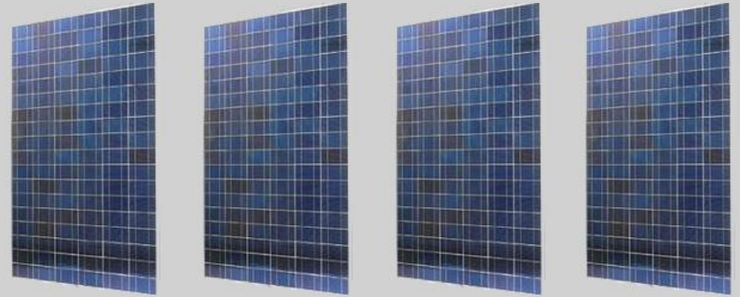
$$\frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

Alternative 2: VRF

26% Savings in Electrical Consumption
50% Savings in Natural Gas Consumption
32% Total Annual Utility Cost Savings
23% Cost Savings over the Equipment Life
4.5 Year Payback

Photovoltaic Array

12% Reduction in Electrical Grid Generation
9% Reduction in Annual Cost
14.5 Year Payback



Acknowledgments

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Dr. Donghyun Rim	Assistant Professor – Penn State AE Department

Conclusions

PSU Architectural Engineering Department Faculty and Staff
AE Class of 2015
Friends & Family

MORTON HOSPITAL EXPANSION

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