

Introduction

Existing Systems

Mechanical Depth

Structural Breadth

Conclusion

# The Ed Roberts Campus

Berkeley, CA

Anderson Clemenceau  
Mechanical Option

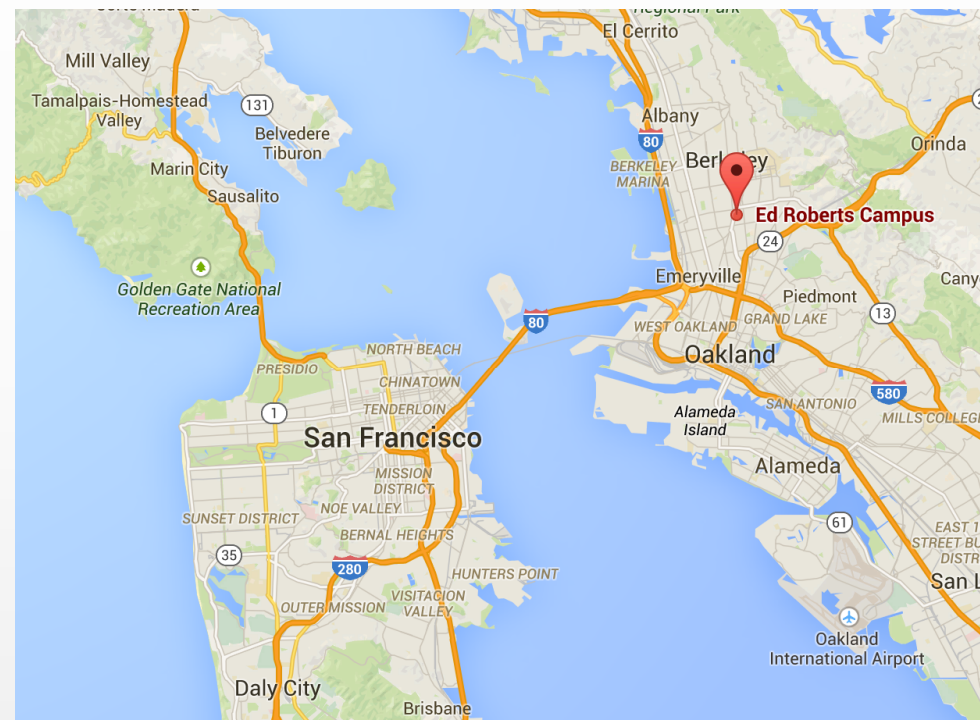
Penn State A.E. Senior Thesis  
April 14, 2015



Leddy Maytum Stacy Architects, Photo by Tim Griffith

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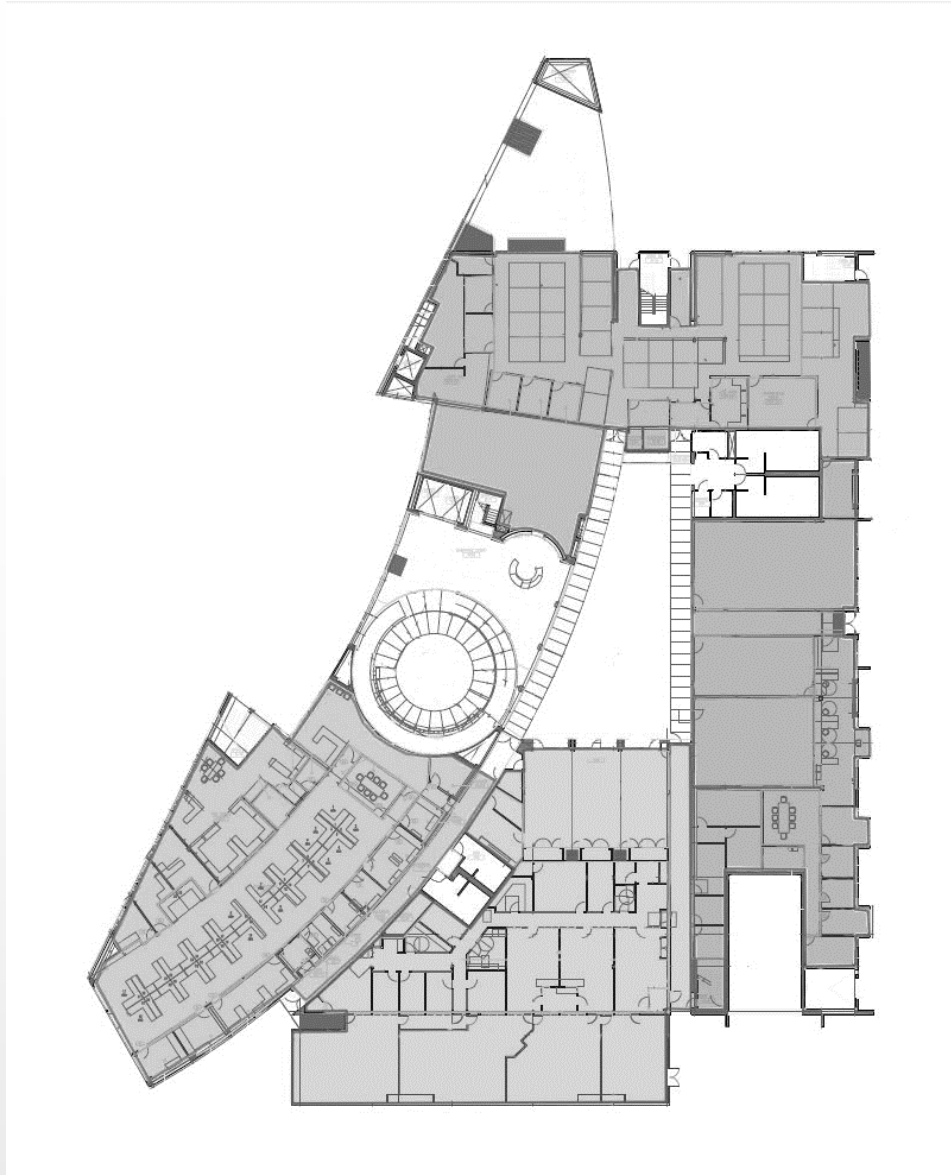


Google Maps

ASHRAE Climate Zone 3C

99.6% Heating DB: 37°F

0.4% Cooling DB: 81.8°F  
MCWB: 65°F



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- Equipment
  - Cooling and Heating
  - 100% OA System
  - Radiant Floor
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## **Water Source Heat Pump System With 100% Outdoor Air**

2 Gas-fired Boilers Provide Hot  
Water

- 900 MBH (Each)
- 98% Efficiency

2 Cooling Towers Provide Chilled  
Water

- 100 Ton Capacity (Each)

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5 Air Handling Units

- 3 Constant Air Volume Units
- 2 Variable Air Volume Units
  
- Paired with Exhaust Fans

Water Source Heat Pumps

- Total of 63 Units

Range of Capacity: 0.75 – 3.25 tons

- COP: 4.1 – 4.4
- EER: 13.7 - 16.0

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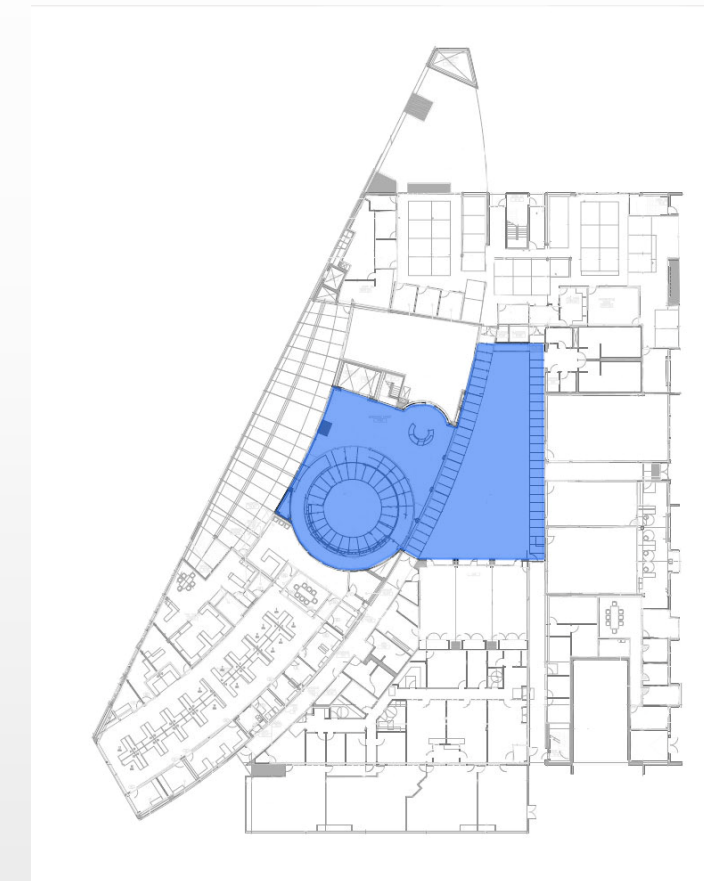
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Radiant Floor



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Radiant Floor

- Heating and Cooling Capacity
- Serves Lobby and Courtyard Areas – 7,150 sq. ft.

	Area Served	Coverage Area (sqft)	Cooling Cap. (MBH)	Heating Cap. (MBH)
Zone 1	Courtyard North	1800	27	18
Zone 2	Courtyard South	2000	30	20
Zone 3	Lobby	3350	58	30

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## Trace 700 Model vs. Real Building

---

	<b>Modeled</b>	<b>Building Capacity</b>
Cooling	146 Tons	200 Tons
Heating	2,200 MBH	1800 MBH

---

## Energy Use

- ~30% Less Electricity Use
- ~30% More Gas Use



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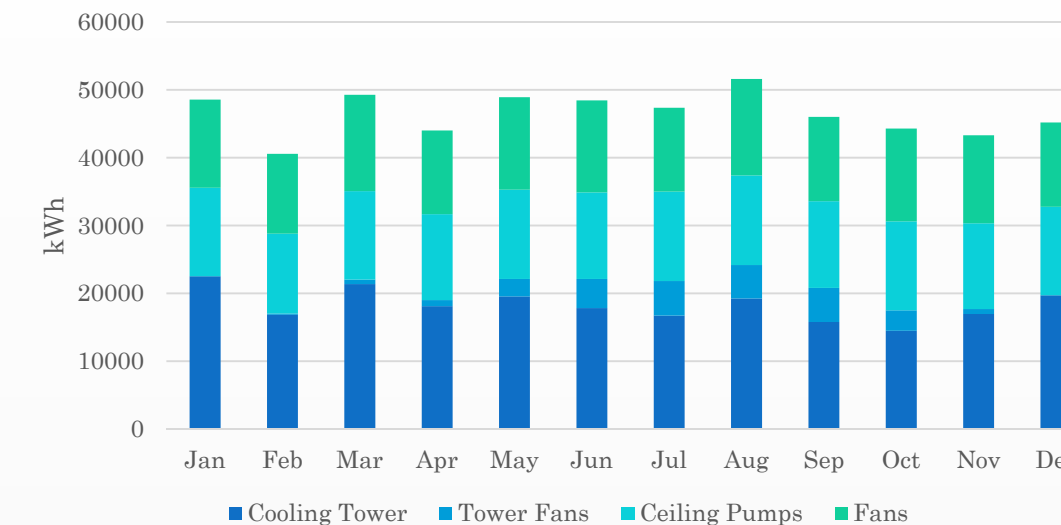
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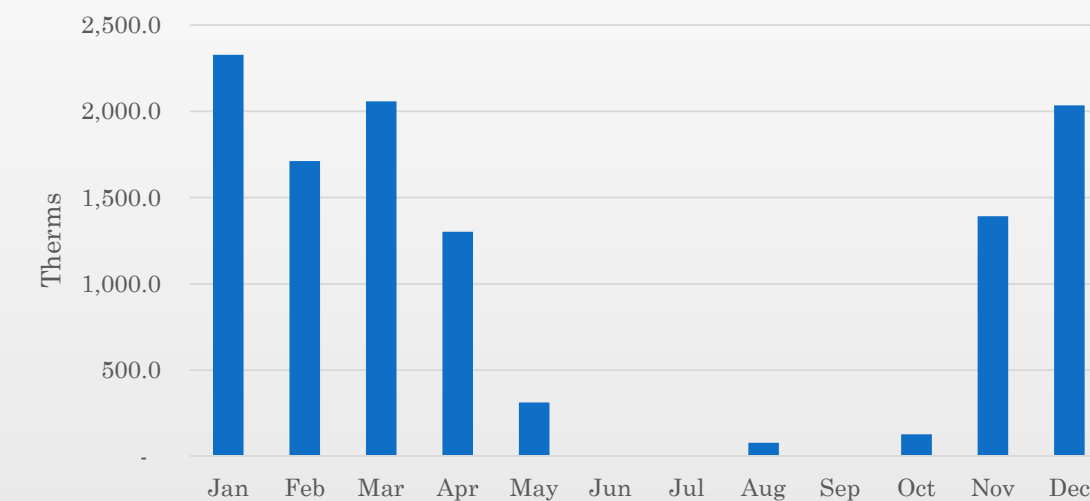
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Energy Use by HVAC Equipment Type



Boiler - Natural Gas Use



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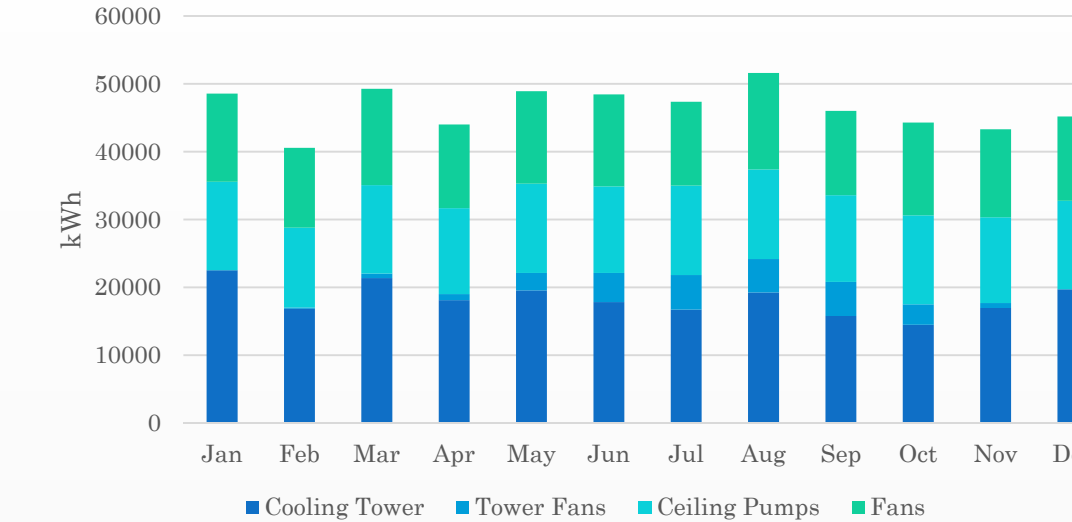
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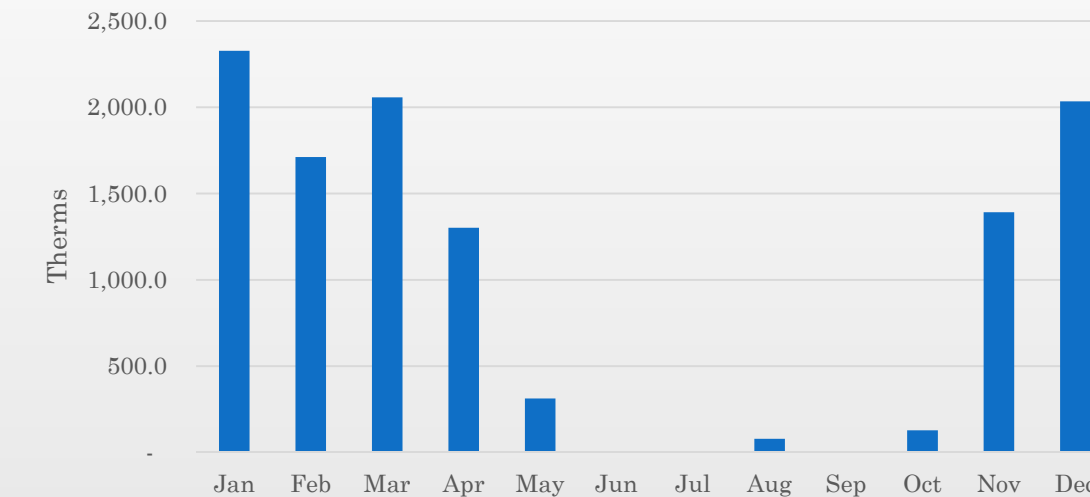
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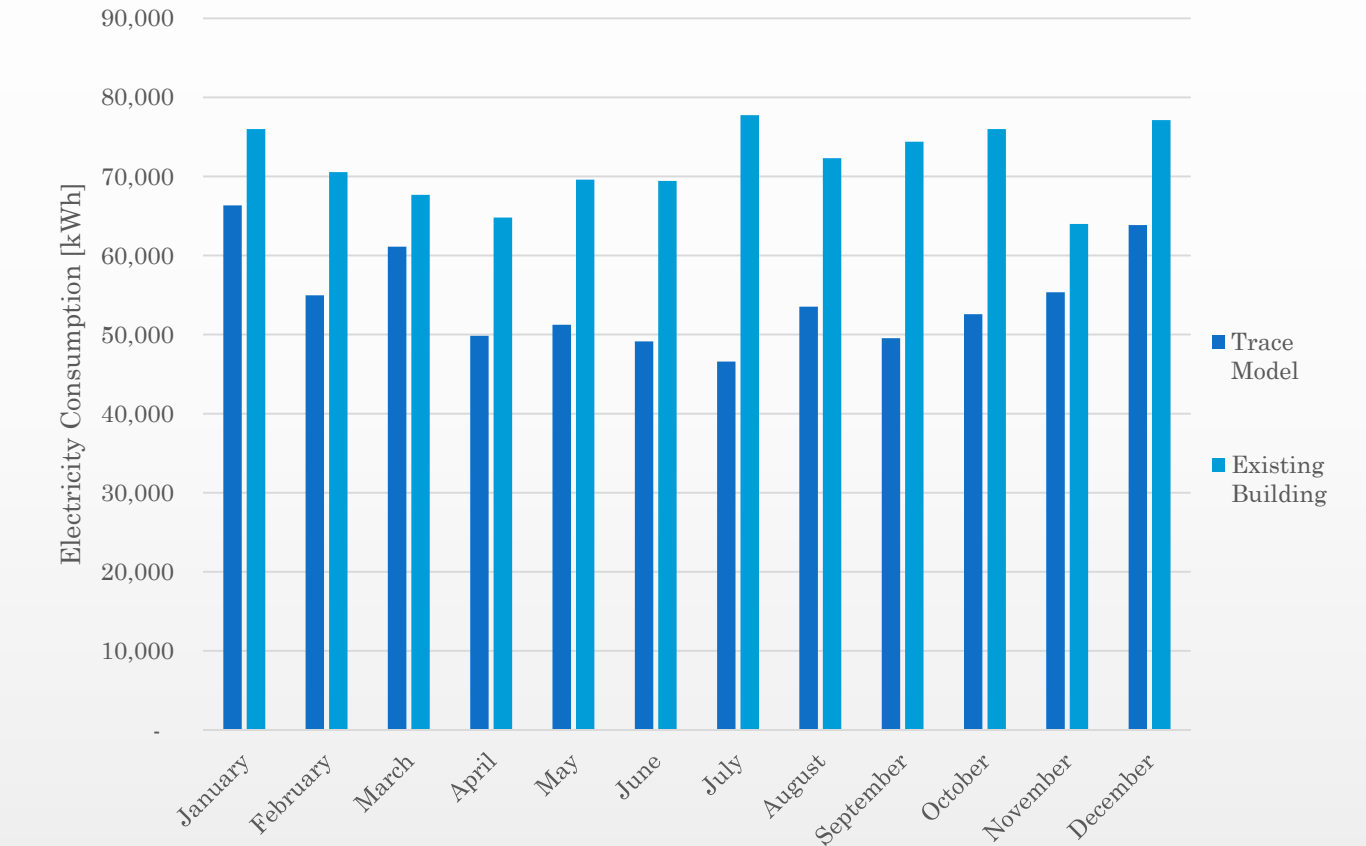
## Energy Use by HVAC Equipment Type



## Boiler - Natural Gas Use



## Electricity Use



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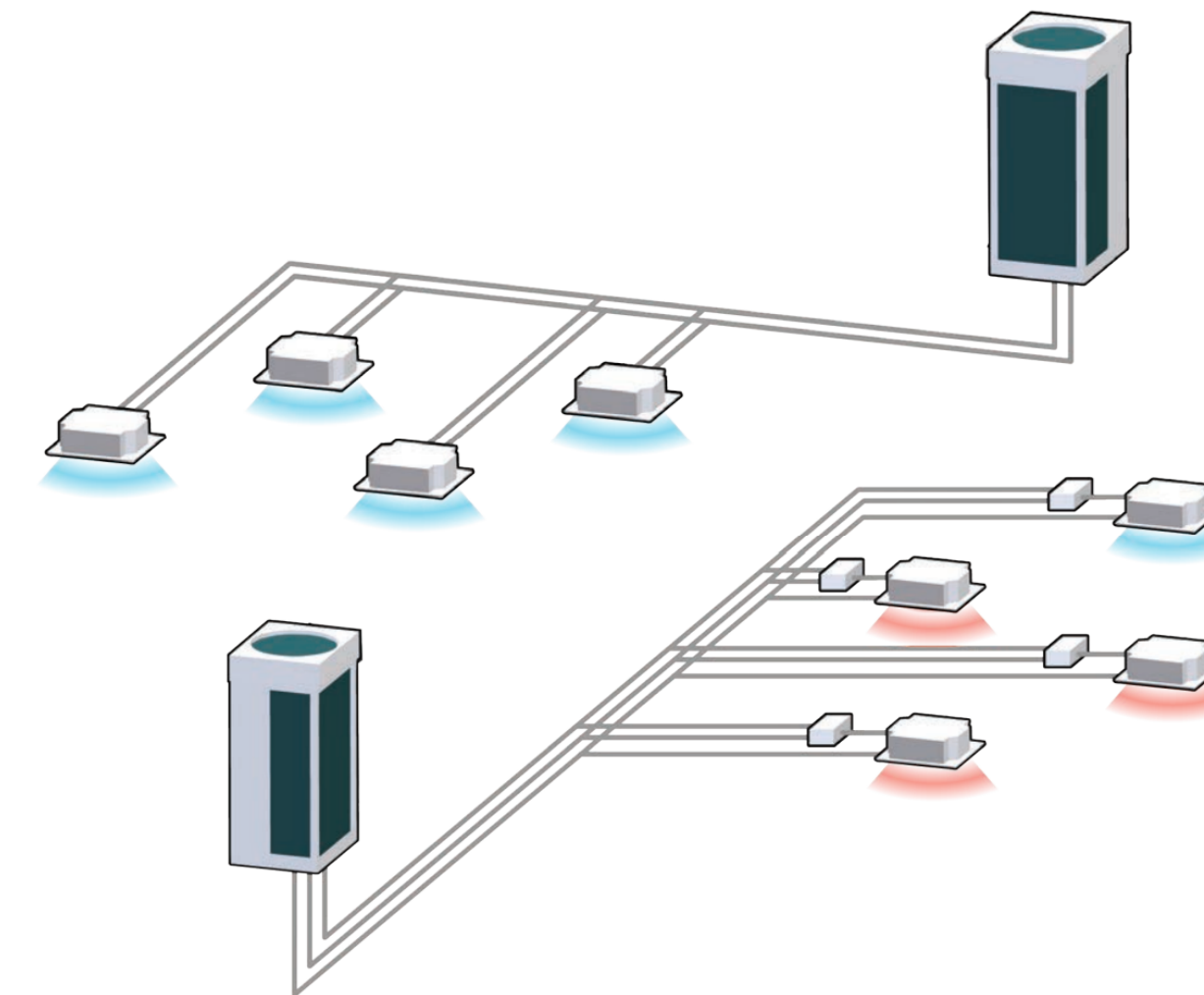
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## VRF Heat Recovery System

- Air-cooled Condenser (Outdoor) Unit
- Variable-Speed Scroll Compressor
- Simultaneous Cooling And Heating
- Heat Recovery Between Indoor Units



Johnson Controls

## Ceiling-Mounted, Ducted Indoor Units

- 6,000-48,000 Btu/h Capacities
- .32 in wg Static Pressure



Johnson Controls

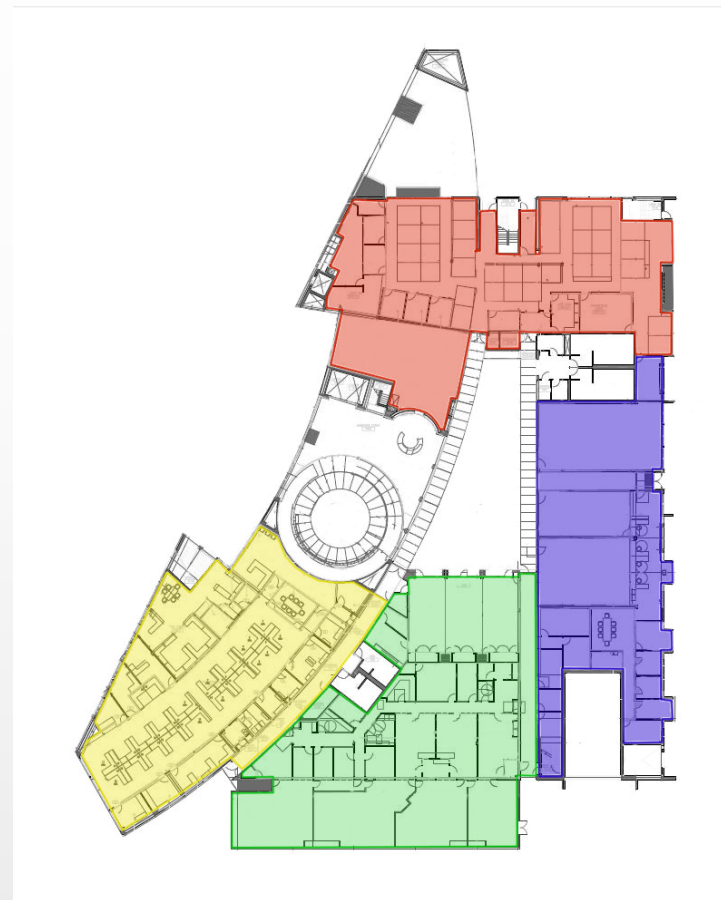
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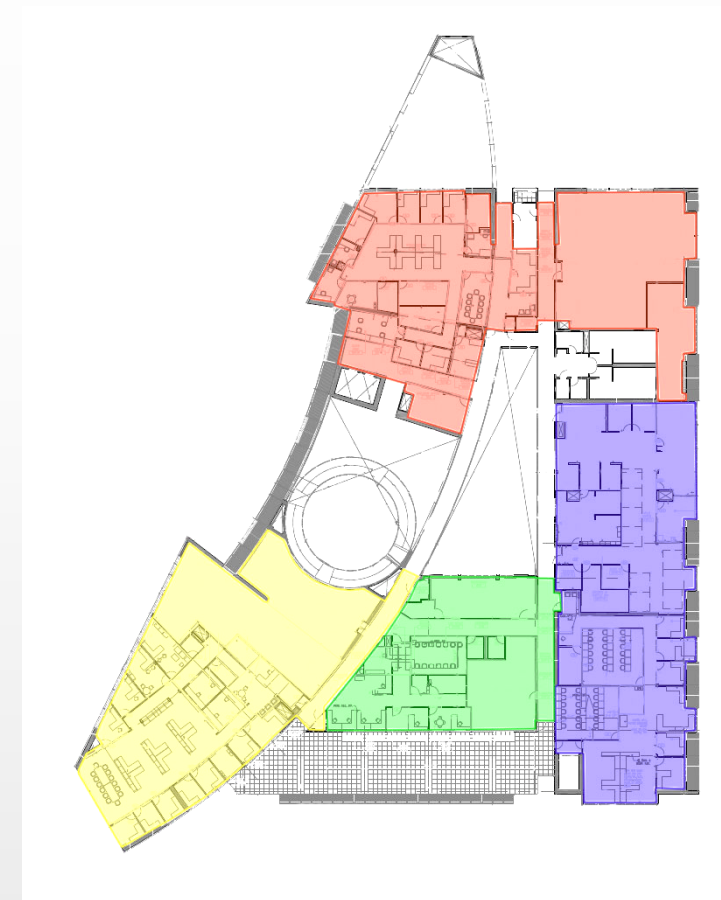
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## VRF Mechanical Zoning Plan



First Floor  
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Second Floor  
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	Nominal Size of Outdoor Unit [tons]	IEER	COP
VRF Zone 1	26 (10+10+6)	18.8	3.56
VRF Zone 2	22 (10+6+6)	18.8	3.61
VRF Zone 3	18 (6+6+6)	19.2	3.49
VRF Zone 4	28 (8+8+6+6)	21.2	3.87

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## Dedicated Outside Air System (DOAS)

- Supplies Filtered, Dehumidified Ventilation Air
- Variable-Speed Fan Operation
- DX Cooling, Electric Heating

	Required Airflow [cfm]	Model	DOAS Unit Nominal Airflow [cfm]
VRF Zone 1	4,426.47	JDHA-210	2250-5500
VRF Zone 2	5,480.2	JDHA-300	3750-8700
VRF Zone 3	3,808.54	JDHA-210	2250-5500
VRF Zone 4	5,867.72	JDHA-300	3750-8700
Lobby/Reception	2,503.64	JDHA-120	1500-3550

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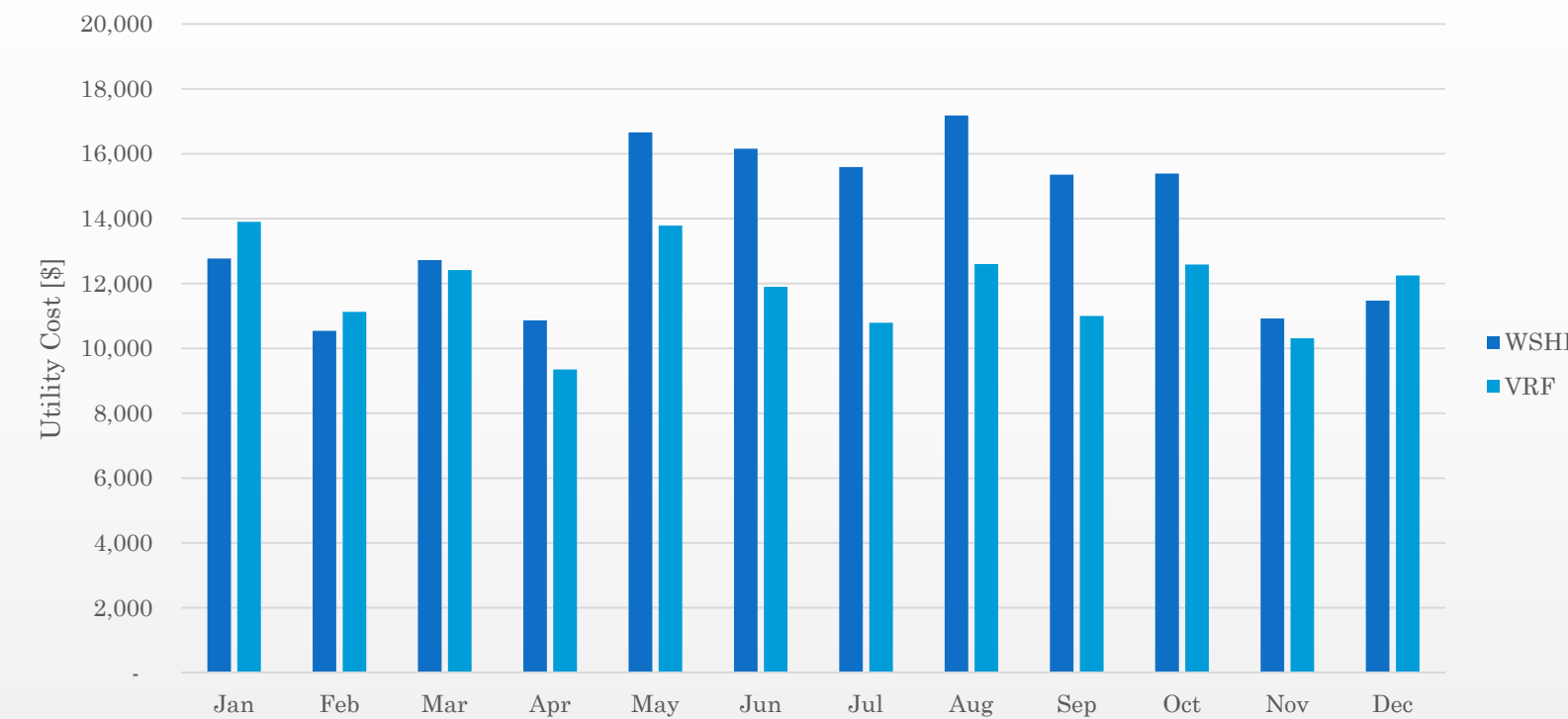
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Utility Costs: WSHP vs. VRF



% Change in Utility Cost - WSHP vs. VRF

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
8.86%	5.55%	-2.40%	-13.90%	-17.26%	-26.34%	-30.78%	-26.67%	-28.40%	-18.22%	-5.59%	6.78%

Yearly Utility Cost Change: 14.3%

Yearly Savings: \$23,200

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## Life Cycle Cost Analysis

- 2014 Supplement to NIST Manual 135
- Discount Rate: 3%

Existing System Energy Costs	VRF Energy Costs	Net Savings	Investment	Discounted Payback Period
\$4,336,036.32	\$3,718,476.30	\$617,560.02	\$364,300.00	20 Years



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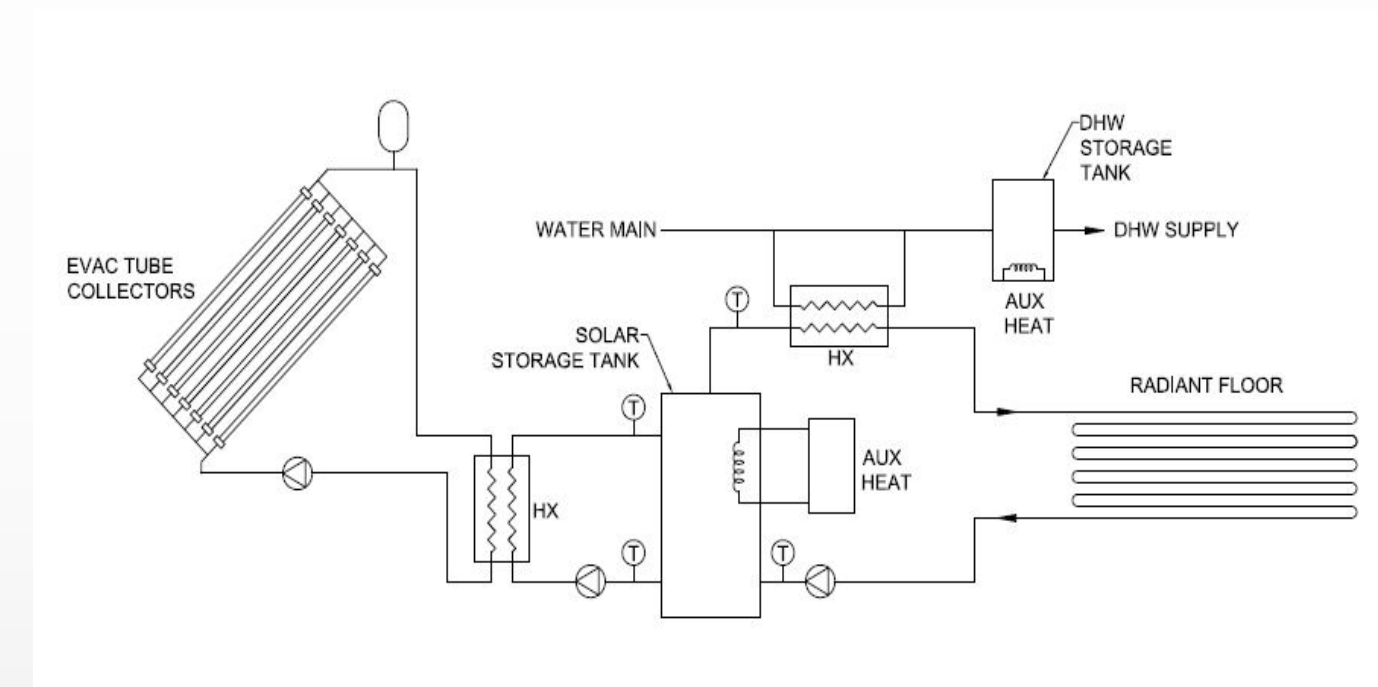
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## Solar Thermal Water Heating System

- Domestic Water Heating
- Radiant Floor Space Heating

## Analysis: CombiSys

- Solar Thermal Water Heating Simulation



Solar Thermal Schematic

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Solar Thermal Water Heating System

- Domestic Water Heating
- Radiant Floor Space Heating

Analysis: CombiSys

- Solar Thermal Water Heating Simulation

Model Inputs:

- Collector Area: 90 m<sup>2</sup> (970 ft<sup>2</sup>)
- Collector Performance Characteristics:  $\eta_0=0.687$ ,  $a_1=1.505$  [W/m<sup>2</sup>-K],  $a_2=0.011$  [W/m<sup>2</sup>-K]
- Dom. Hot Water Load: 3 gal/d per occupant, 50 occupants
- Space Loss Coefficient: 500 W/K (~1700 Btu/h/°F)

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### Solar Thermal Water Heating System

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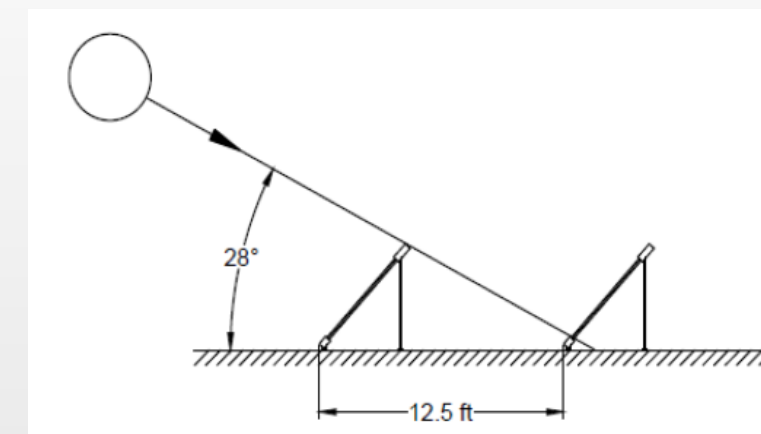
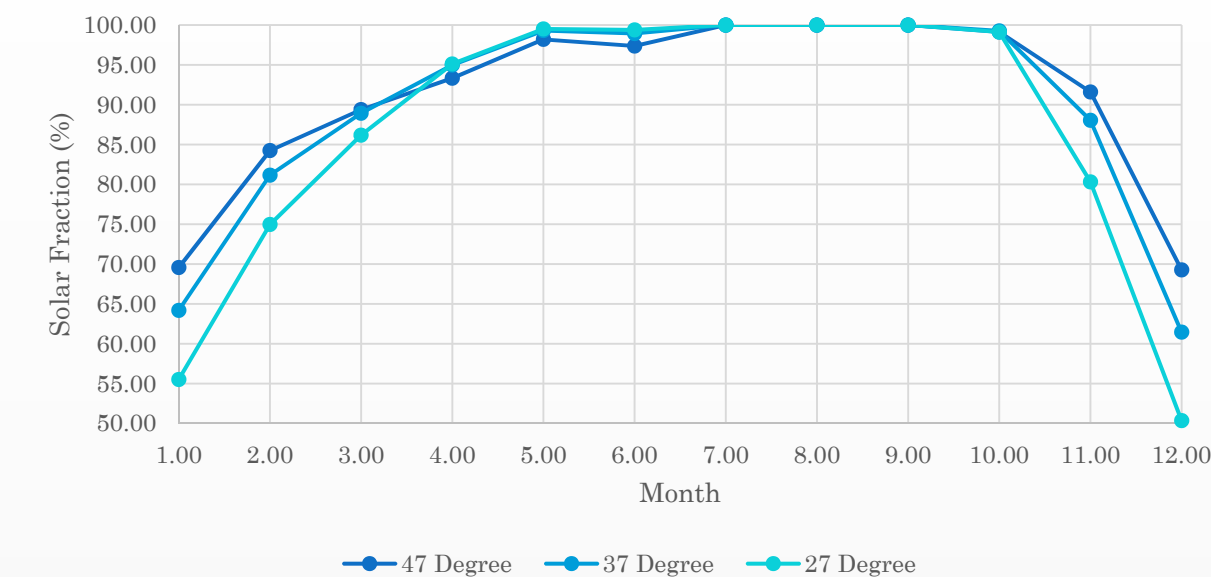
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Comparison of Collector Angles



Gross Roof Area:  
~2,500 sq. ft.

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## CombiSys Solar Thermal Simulation

### Model Inputs:

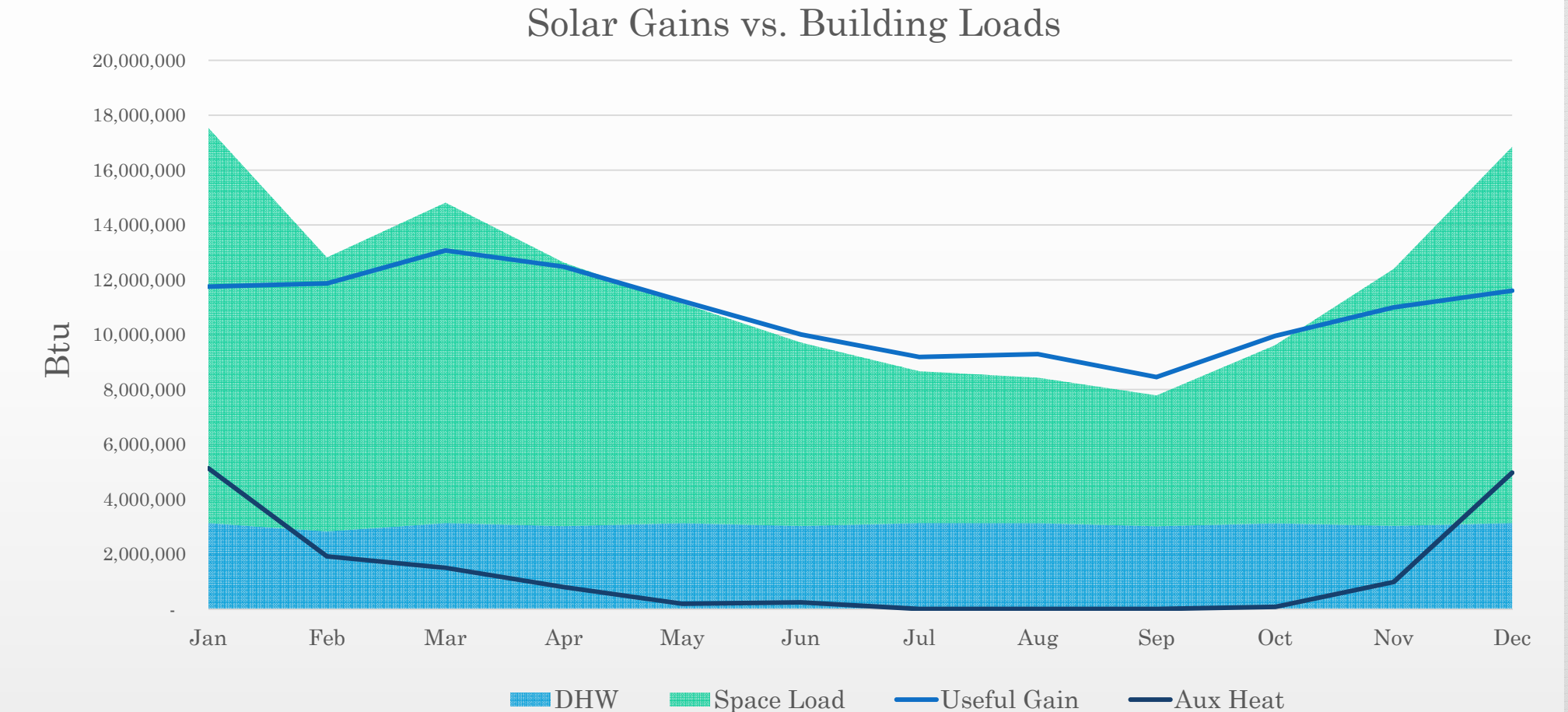
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### Avg. Solar Fraction

- 91%

### Avg. Collector Efficiency

- 24%



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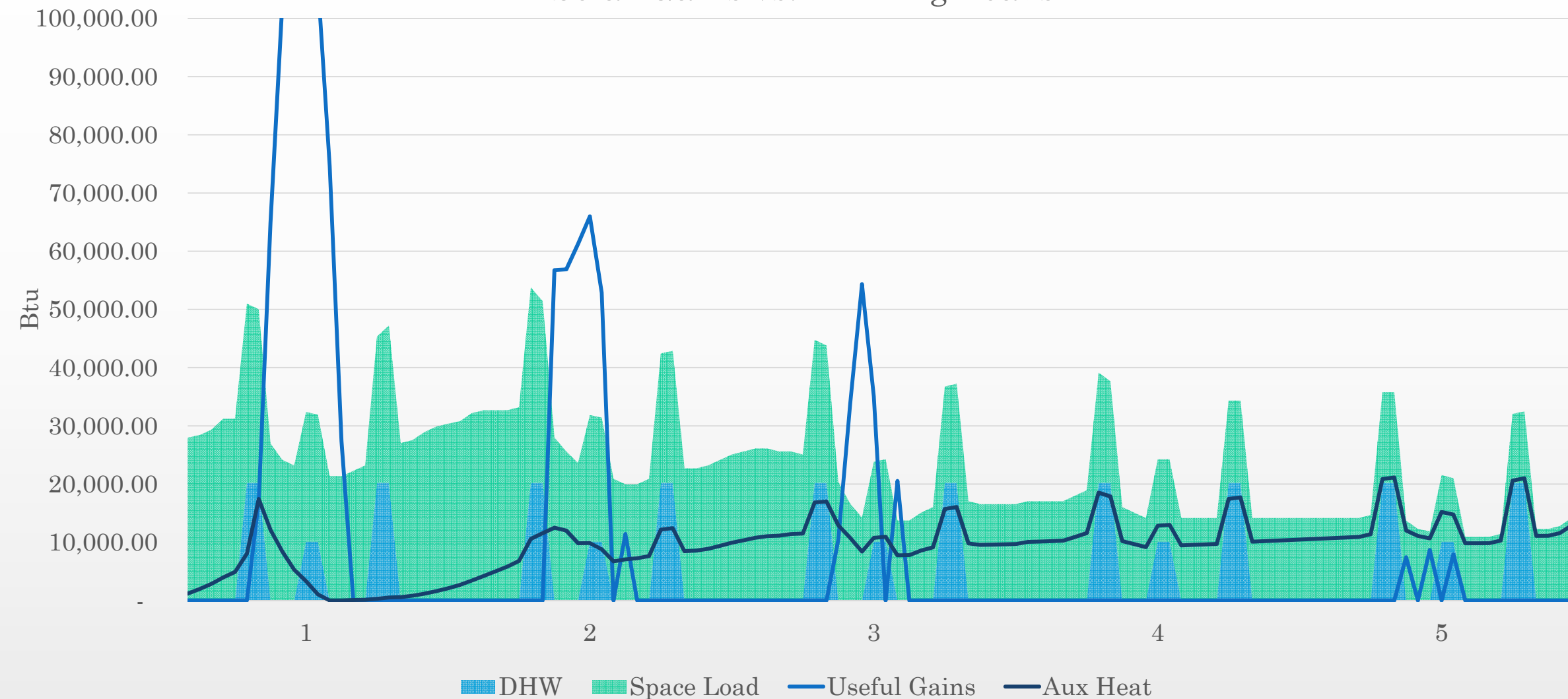
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Solar Gains vs. Building Loads



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## Life Cycle Cost Analysis

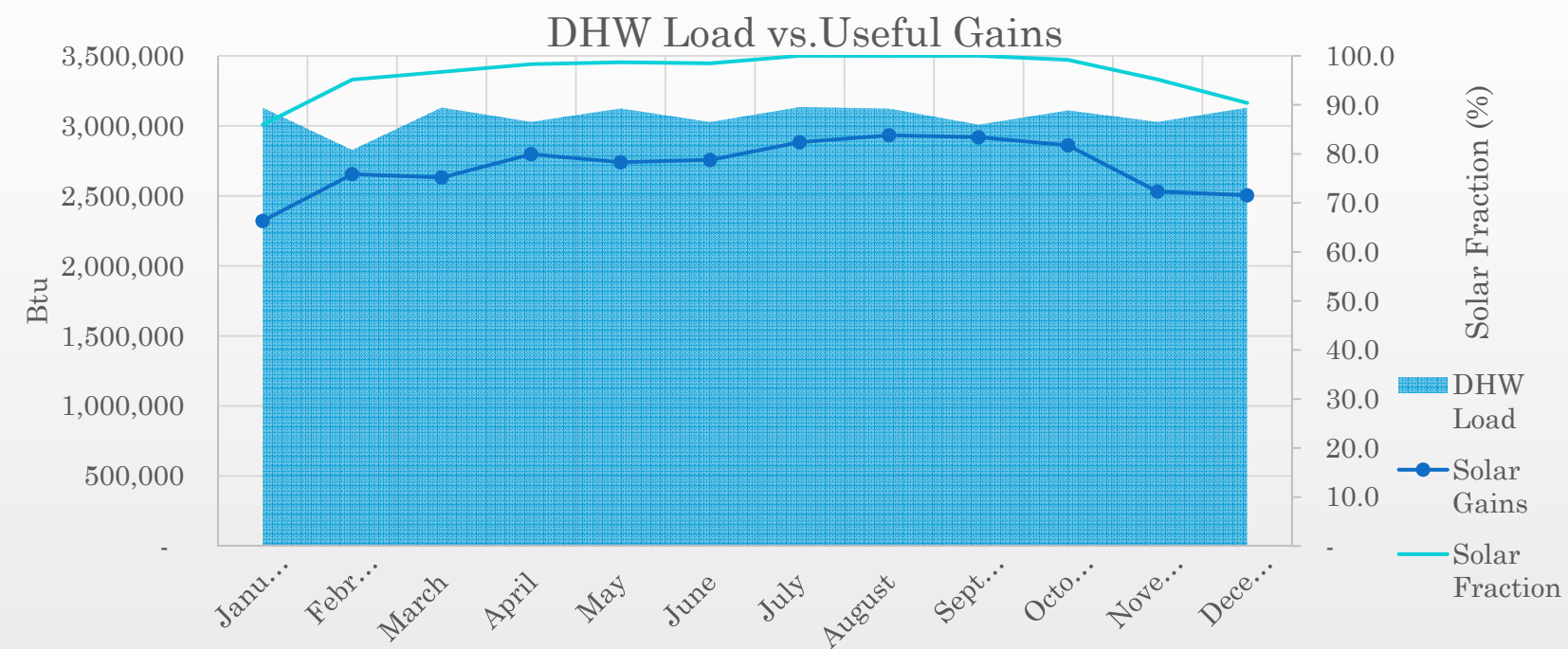
Yearly Cost Savings	Net Savings	Investment	Discounted Payback Period
\$3,058.63	\$80,074.93	~\$75,000	25+ Years

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## Alternative Application: Domestic Hot Water Only

- Peak 1-Hour Demand of 150 gal
- Constant, Year-Round Load



Solar Fraction	Collector Efficiency	Yearly Cost Savings	Investment	Payback Period
96%	23%	\$2,016	~\$25,000	18 Years

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- Roof Structure Redesign
  - Current Structure
  - New Design Criteria
  - Results

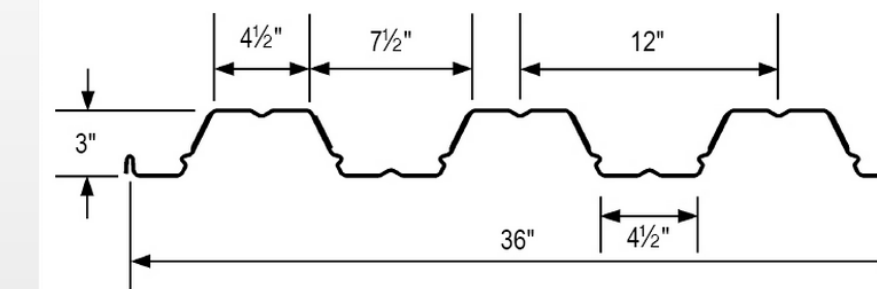
## Current Roof Structure

- Structural Steel Framing
- 18 Gage Verco W3 Metal Decking
- 3-1/2" LW Concrete Topping

PLW3™ FORMLOK™ or W3 FORMLOK™



Profile Dimensions



Verco Decking, Inc.

## Current Roof Structure

- Max Unshored Clear Span: 15'-7" @3-Span
- Allowable Superimposed Load for 11'-0" Span Condition: 207 psf

Typical Framing Plan for South East Roof:

3 Spans @10'-8"



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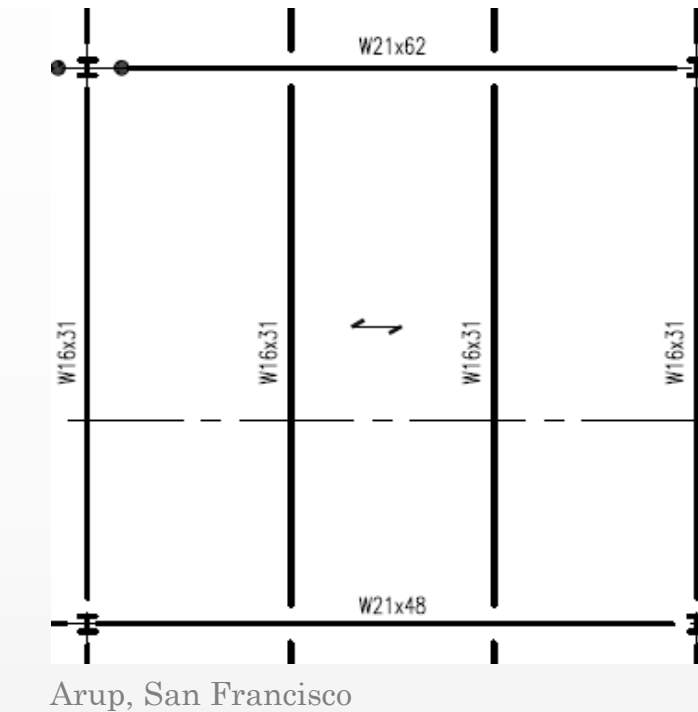
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## Solar Panel Array for DHW and Space Heating

- 30 Panels at 225 lb/panel
- Vertical Pull Force Due To Wind: ~610 lb
- Panel Area on Roof: 1,100 sq ft.

- Total Additional Load: ~55 psf



## Vulcraft Deck Manuals

### 3VLI Composite Deck, LW Concrete Topping

- 19 Gage, 2" Topping
- Self-Weight: 35 psf
- Maximum SLL @10'-8" Spans: 105 psf

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## Variable Refrigerant Flow System

- First Cost: \$364,300
- Yearly Energy Savings: \$23,200
- Payback Period: 20 Years

### Conclusion:

- Not Recommended For A Complete Renovation
- Could Be Considered For New Construction

## Solar Thermal Water Heating System

### Two Options:

- Space Heating and DHW
  - First Cost: \$75,000
  - Payback: 25+ Years
- DHW Only
  - First Cost: \$25,000
  - Payback: 18 Years

### Conclusion:

- Not Recommended
- Could More Economical In Different Climate Conditions