

# 123 Alpha Drive

Pittsburgh,  
Pennsylvania



<https://www.google.com/maps/place/150+Gamma+Dr/@40.4997521,-79.8681269,18z/data=!4m2!3m1!1s0x8834ecdbc348bd5f:0xd10a14f6b42509a0>



## Alexander Radkoff

Mechanical Option | Spring 2014  
Advisor: Dr. Stephen Treado

# 123 Alpha Drive

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Pennsylvania

Introduction

Existing Mechanical System

Variable Refrigerant Flow System

Cost Analysis

Emissions Analysis

Acoustical Design

Conclusion

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## Background

**Location:** Pittsburgh, Pennsylvania

**Building Use:**

- Warehouse Storage
- Laboratory Space
- Offices

**Footprint:** 74,900 square feet

**Ceiling Height:**

- Offices: 9'
- Warehouse: 22' 6"

**Renovated:** 2012



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## Design Conditions

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### Outdoor Design Conditions

	Summer Design Cooling	Winter Design Heating
OA Dry Bulb (°F)	89 °F	2.0 °F
OA Wet Bulb (°F)	72 °F	.3 °F

### Indoor Design Conditions

	Offices & Lab	Warehouse & Packaging	Storage & Maintenance
Cooling Set Point	70 °F	85 °F	95 °F
Heating Set Point	55 °F	55 °F	60 °F
Relative Humidity	45%	-	-

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## Existing Mechanical System

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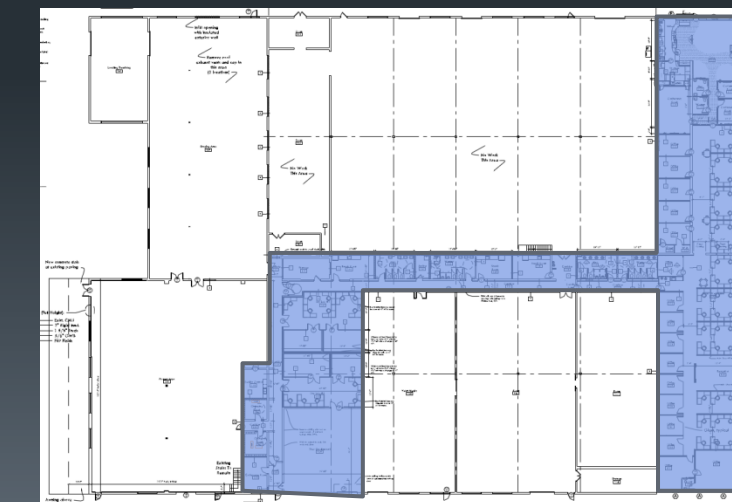
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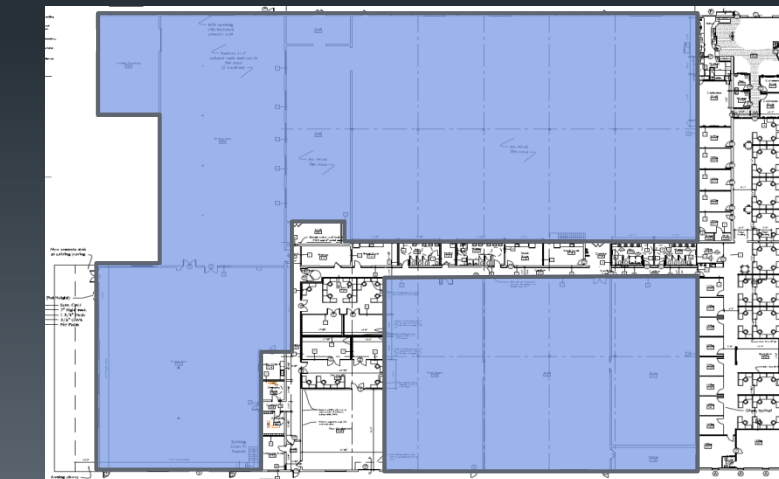
### Office/Lab Space

- 6 single zone CAV rooftop units (RTUs)
- CO2 preheat conditioning option available
- CO2 radiant floor cooling and heating



### Warehouse and Storage

- Primarily electric resistance heat
- 8 air handling units (AHUs)
- Makeup air handling unit



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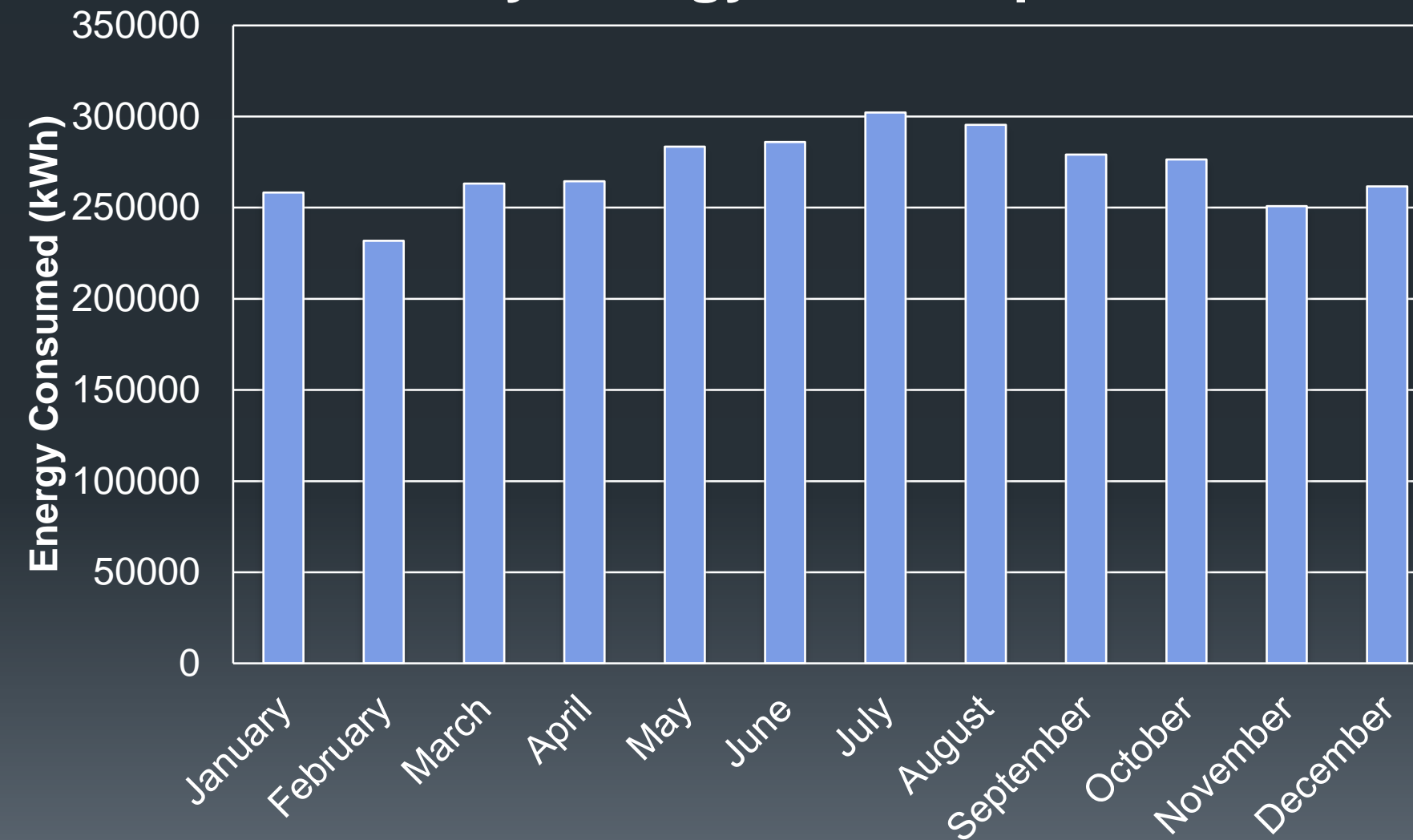
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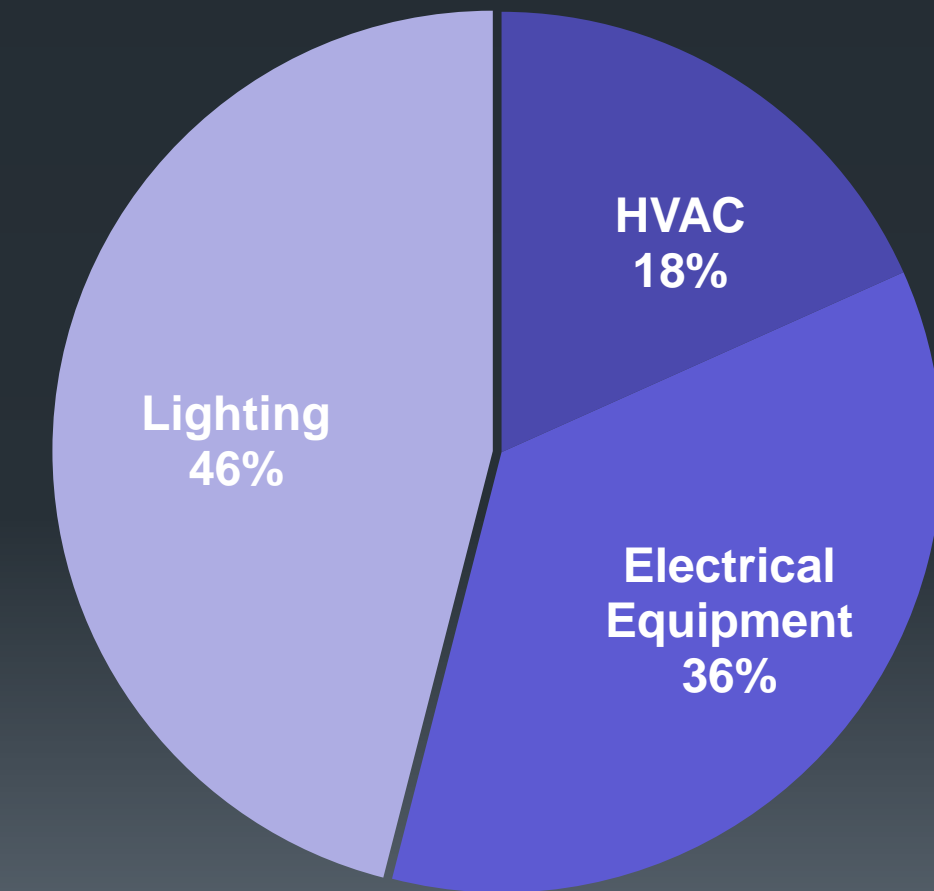
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# Annual Load Simulation

## Monthly Energy Consumption



## Energy Consumption By Use



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## Annual Energy Consumption By Use

HVAC: **595,045 kWh**

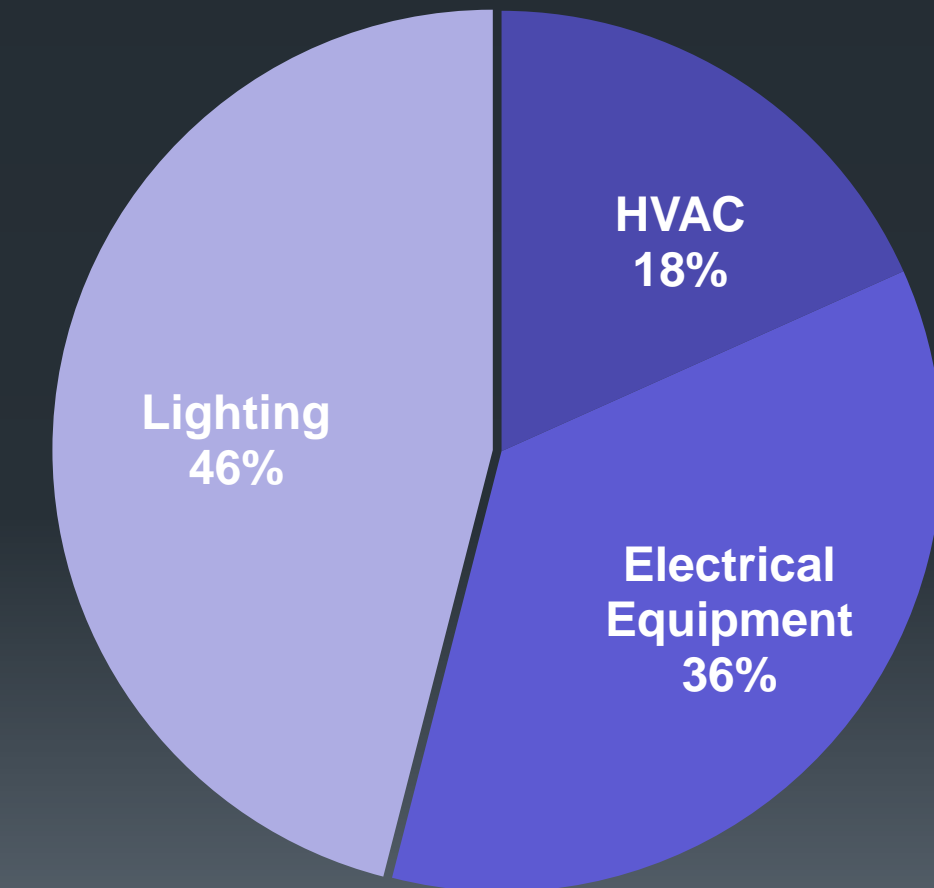
Lighting: **2,657,011 kWh**

Electrical Equipment: **3,252,057 kWh**

Total Annual Energy Consumption:

**6,5041,143 kWh**

## Energy Consumption By Use



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# Energy Cost and Consumption

## Annual Cost per Unit Floor Area

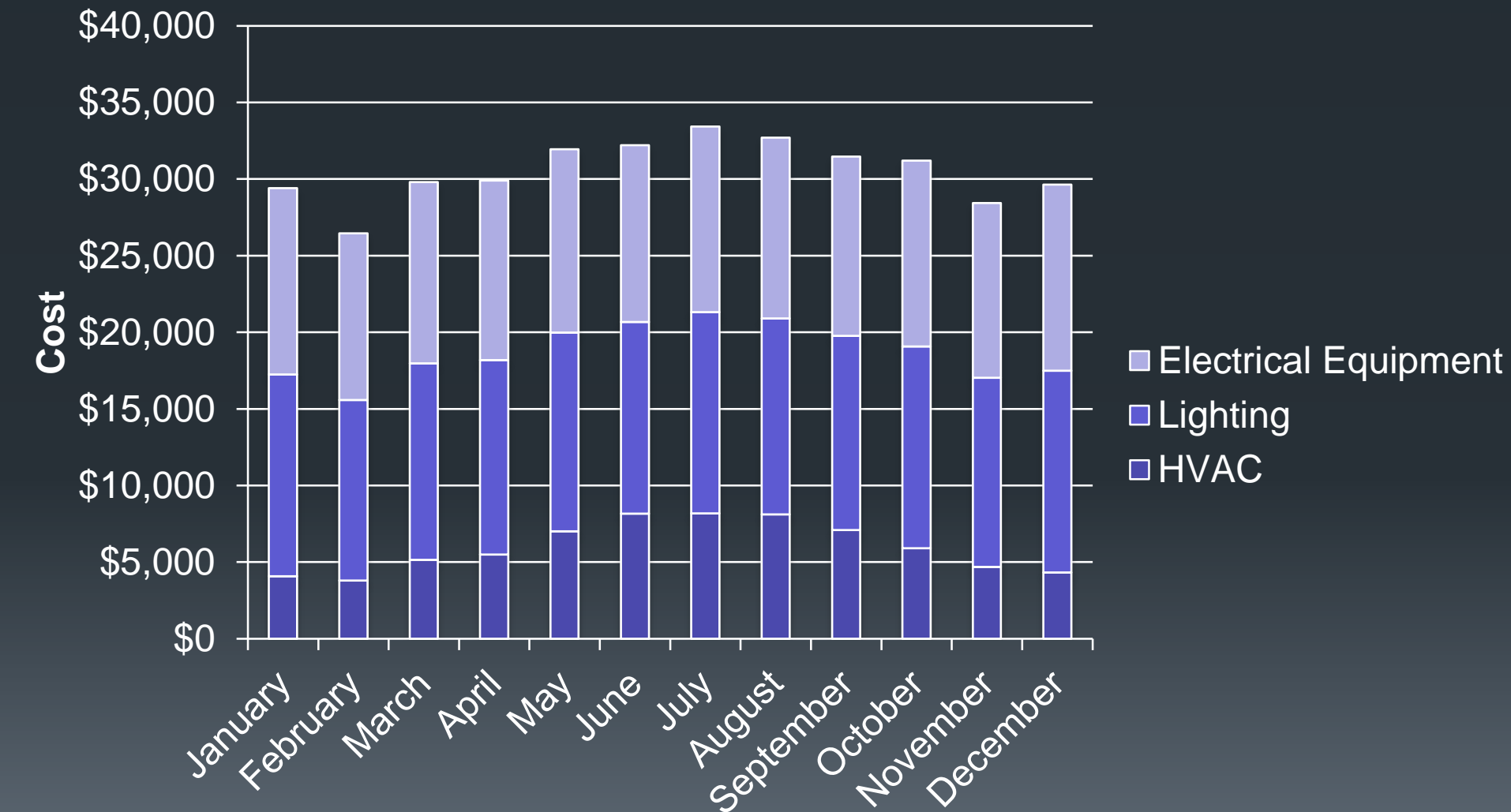
HVAC: **\$0.96/ft<sup>2</sup>**

Lighting: **\$2.04/ft<sup>2</sup>**

Electrical Equipment: **\$1.89/ft<sup>2</sup>**

Total Annual Energy Cost: **\$366,744**

## Electrical Cost by Use



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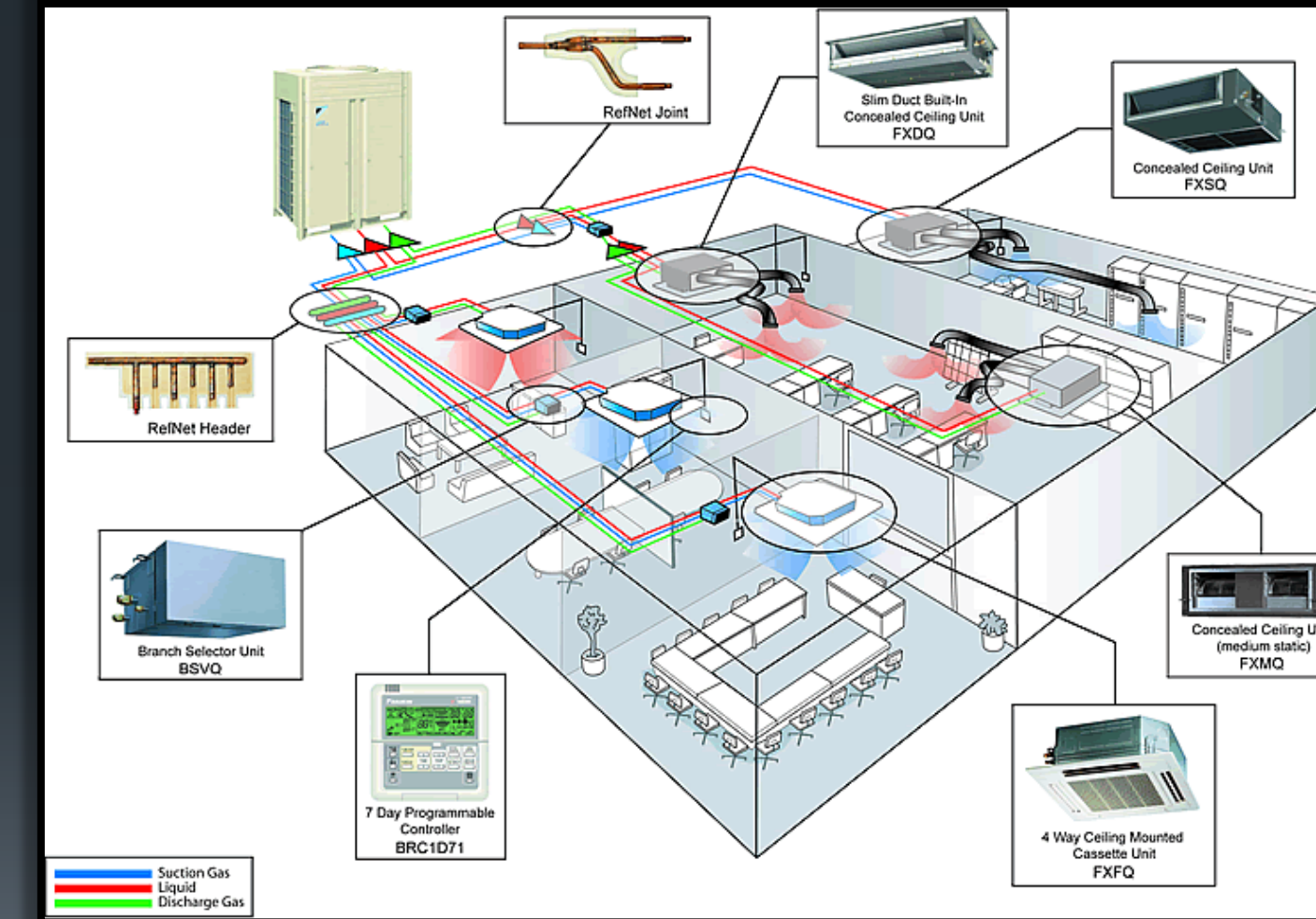
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# Variable Refrigerant Flow System

## System Components

- Outdoor/Indoor Condensing Unit
- 3 pipe system (suction, liquid, discharge gas)
- Mode Change Unit (MCU)
- 2 pipe system from MCU to fan coil unit
- Indoor fan coil units



## Advantages

- Lower energy costs
- Lower CO2e emissions
- Simultaneous heating and cooling
- Precise and occupant control capabilities

## Disadvantages

- Expensive first costs
- Requires DOAS system



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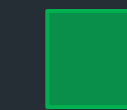
## System Layout Restrictions

- Piping Length – 656 feet maximum
- External Static Pressure – 1" maximum
- Condensing Unit Elevation – 360 feet maximum

## VRF System Layout



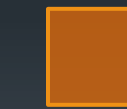
### Key



**VRF System 1**



**VRF System 2**



**VRF System 3**

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# Condensing Unit Quantity

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## Samsung DVM S Series Condensing Unit Requirements

Number of Condensing Units Needed	One	Two	Three
Size (tons)	6-12	14-24	26-36

VRF System	1	2	3
Size (tons)	11.5	17.2	12.5
Number of Condensing Units Needed	One	Two	Two

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## Indoor Fan Coil Unit Selection

### 1-Way Cassette Terminal Unit

- Located at edges of room ceiling
- Diffuses in one direction

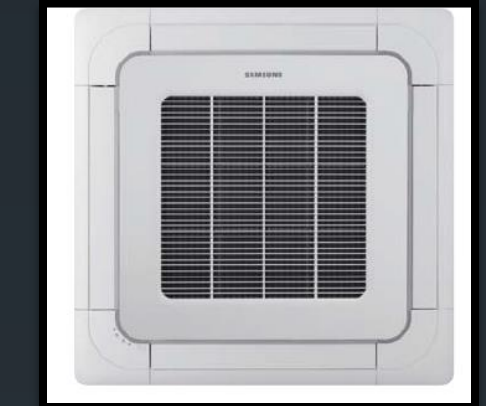


### 1 Way Cassette Terminal Unit

Source: Samsung DVM S Series Catalog

### 4-Way Cassette Terminal Unit

- Located in central area of ceiling
- Distributes air in four directions



### 4 Way Cassette Terminal Unit

Source: Samsung DVM S Series Catalog

### High Static Pressure Duct Unit

- Up to .99 in wg. external static pressure
- Can condition multiple spaces at a time



### High Static Pressure (HSP) Duct Unit

Source: Samsung DVM S Series Catalog

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## VRF System 1

12 ton Outdoor Condensing Unit (1)



Mode Change Units (3)

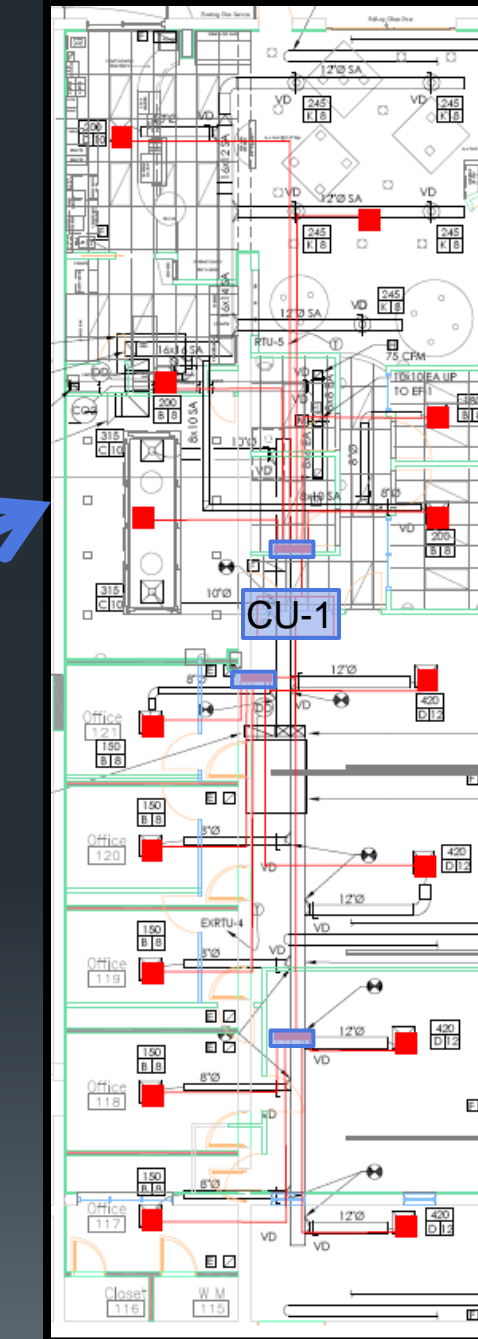
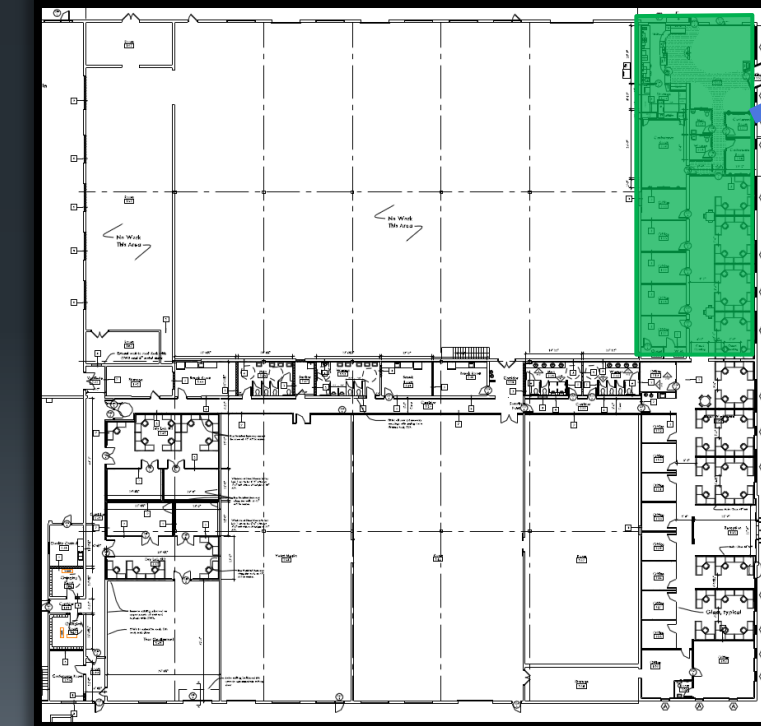


4 Way Cassette FCU (6)



1 Way Cassette FCU (9)

## VRF System Selection



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## VRF System 2

6 ton Outdoor Condensing Unit (1)  
10 ton Outdoor Condensing Unit (1)

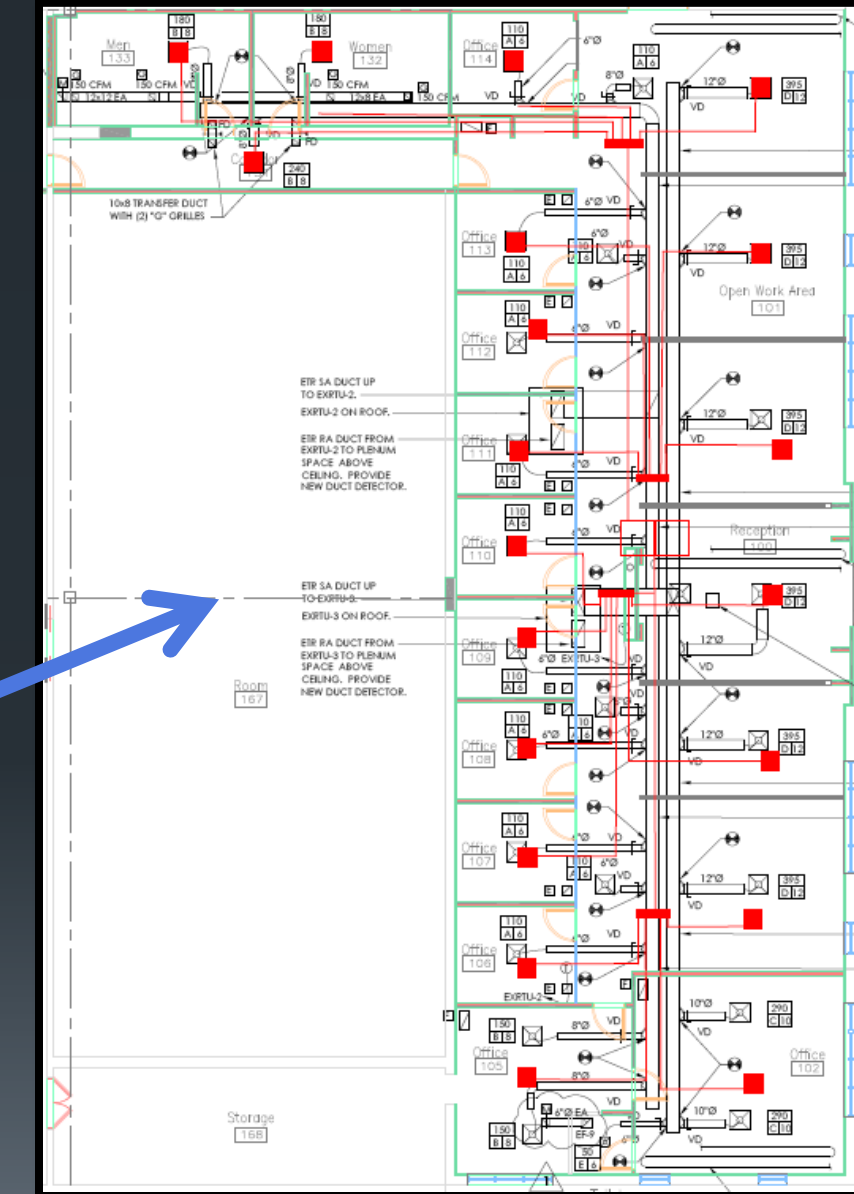


Mode Change Units (4)



4 Way Cassette FCU (12)  
+  
1 Way Cassette FCU (7)

## VRF System Selection



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## VRF System 3

6 ton Outdoor Condensing Unit (1)  
10 ton Outdoor Condensing Unit (1)



Mode Change Units (3)



4 Way Cassette FCU (3)

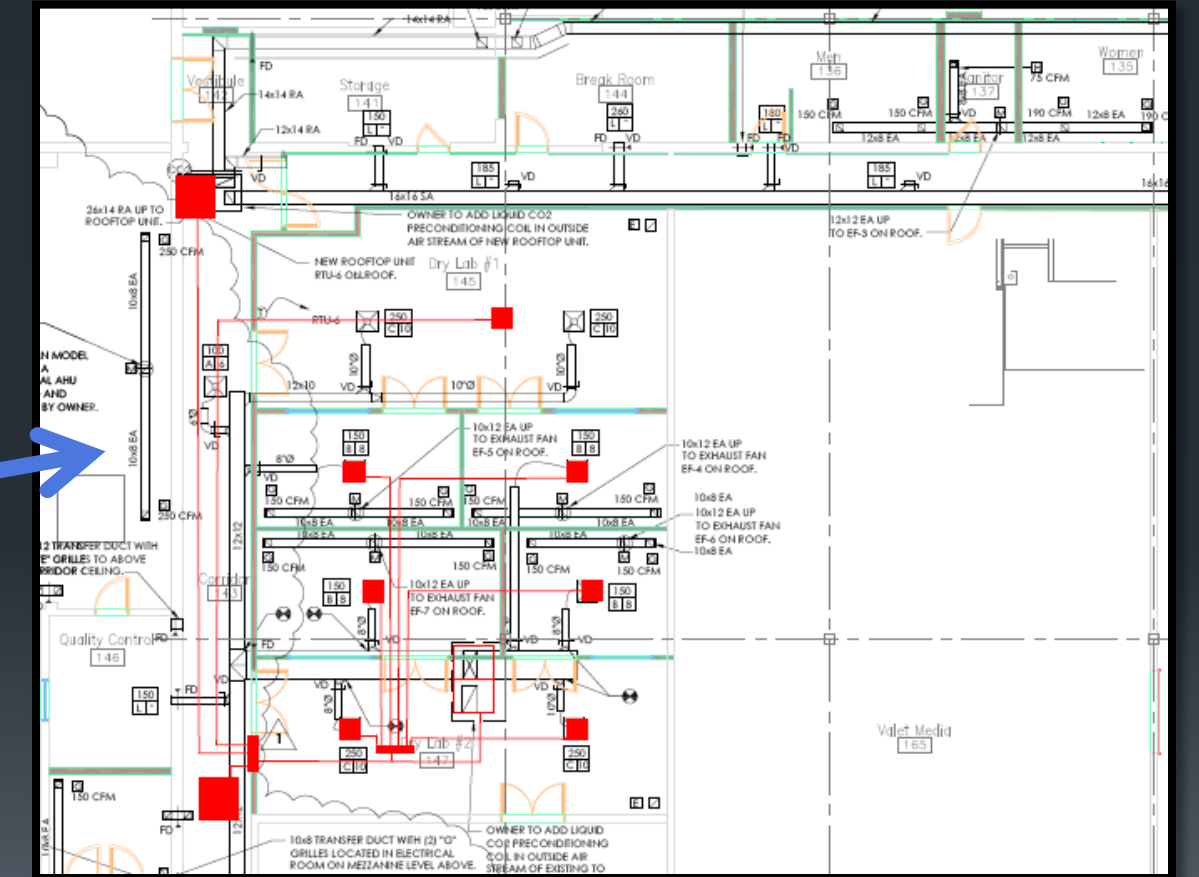
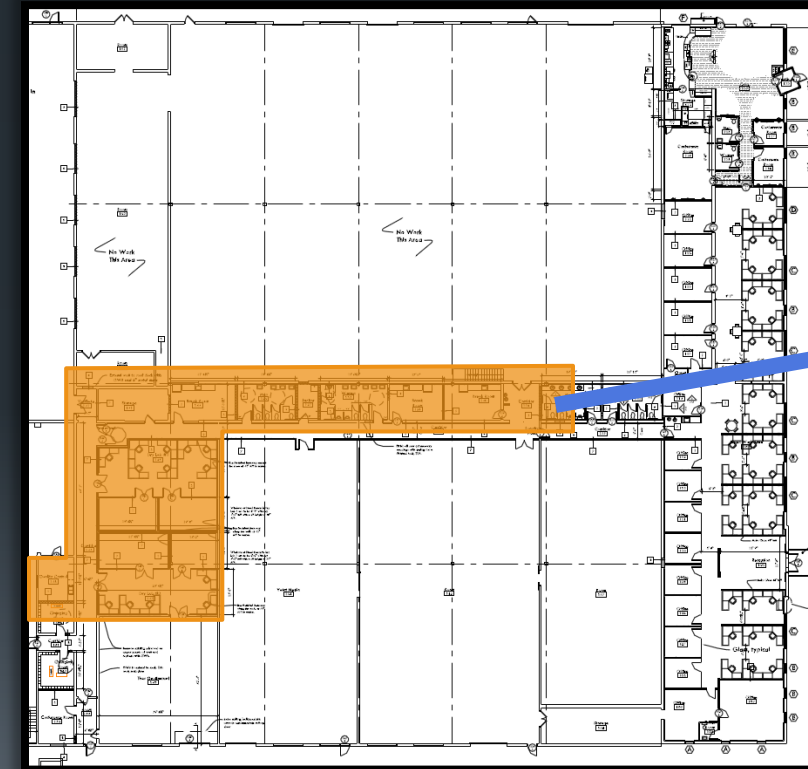


1 Way Cassette FCU (4)



High Static Pressure Unit (2)

## VRF System Selection



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# Dedicated Outside Air System

## Semco FV-2000 Fresh Air Preconditioner

- 3 Angstrom Total Energy Wheel
- Parallel system to VRF system
- Manages humidification and de-humidification

	Airflow (cfm)	Ext. Static Pressure (in wg.)	Motor Brake Horsepower	Fan Speed (RPM)
Supply Air	1,250	1.50	1.00	1723
Exhaust Air	1,175	.75	.64	1413

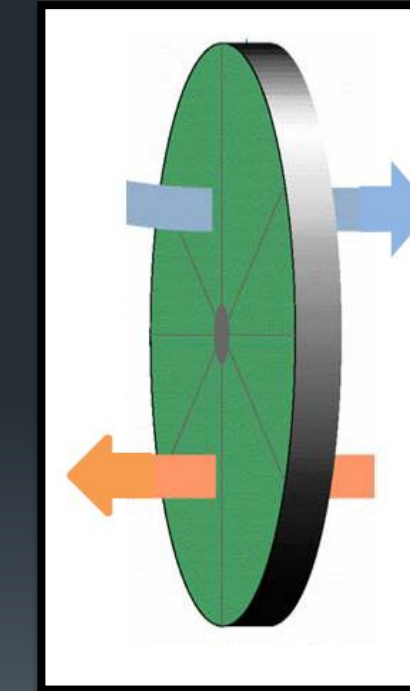
## Design Conditions: Cooling Season

### Outdoor Airstream

Dry Bulb (°F) : 95.0  
Wet Bulb (°F): 75.0  
Enthalpy (BTU/lb): 38.4

### Exhaust Airstream

Dry Bulb (°F) : 90.8  
Wet Bulb (°F): 72.5  
Enthalpy (BTU/lb): 36.1



### Supply Airstream

Dry Bulb (°F) : 80.2  
Wet Bulb (°F): 65.7  
Enthalpy (BTU/lb): 30.5  
Airflow (CFM): 1,250

### Return Airstream

Dry Bulb (°F) : 75.0  
Wet Bulb (°F): 62.0  
Enthalpy (BTU/lb): 27.8  
Airflow (CFM): 1,175

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## Dedicated Outside Air System

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### Efficiency and Static Pressure Loss

Sensible Supply Efficiency: 74%

Latent Supply Efficiency: 74%

Supply Air Pressure Loss: .36

Exhaust Air Pressure Loss: .33

### Design Conditions: Cooling Season

#### Outdoor Airstream

Dry Bulb (°F) : 95.0

Wet Bulb (°F): 75.0

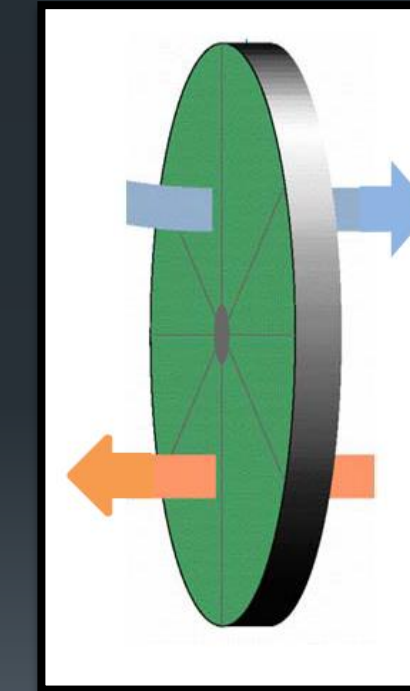
Enthalpy (BTU/lb): 38.4

#### Exhaust Airstream

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Enthalpy (BTU/lb): 30.5

Airflow (CFM): 1,250

#### Return Airstream

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Wet Bulb (°F): 62.0

Enthalpy (BTU/lb): 27.8

Airflow (CFM): 1,175

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## Controls

### BACnet Gateway Building Management System

- Can connect up to 256 indoor units/16 outdoor units
- Weekly/Daily Scheduling
- Temperature limitations
- ERV operation mode and fan speed
- Zone Management

### Occupant Controls

- MWR-WE10N Wired Remote Controller
- Can control up to 16 indoor units and ERV
- Operation mode
- Temperature setting (limited by BACnet)
- ERV operation and fan speed (limited by BACnet)

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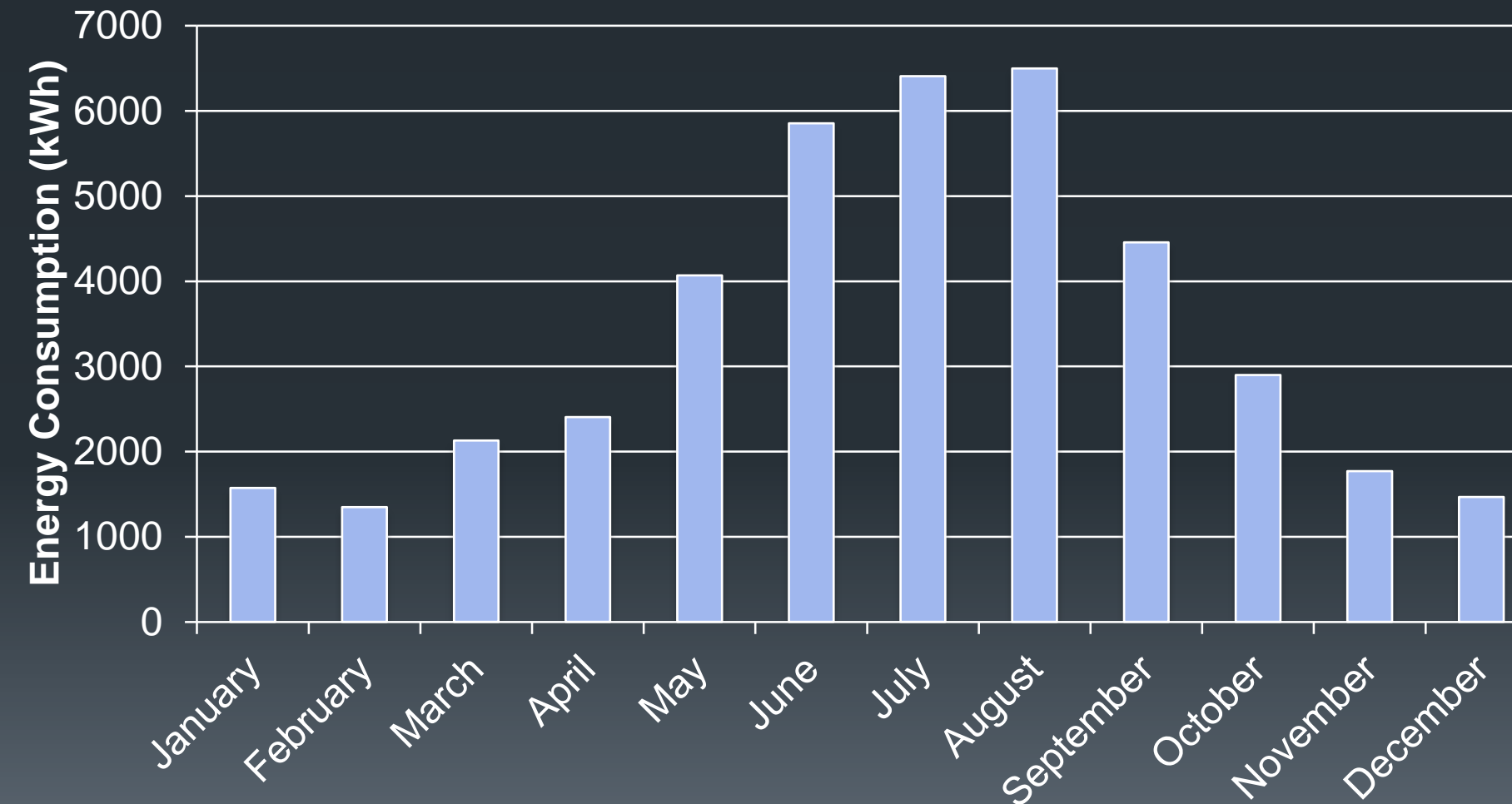
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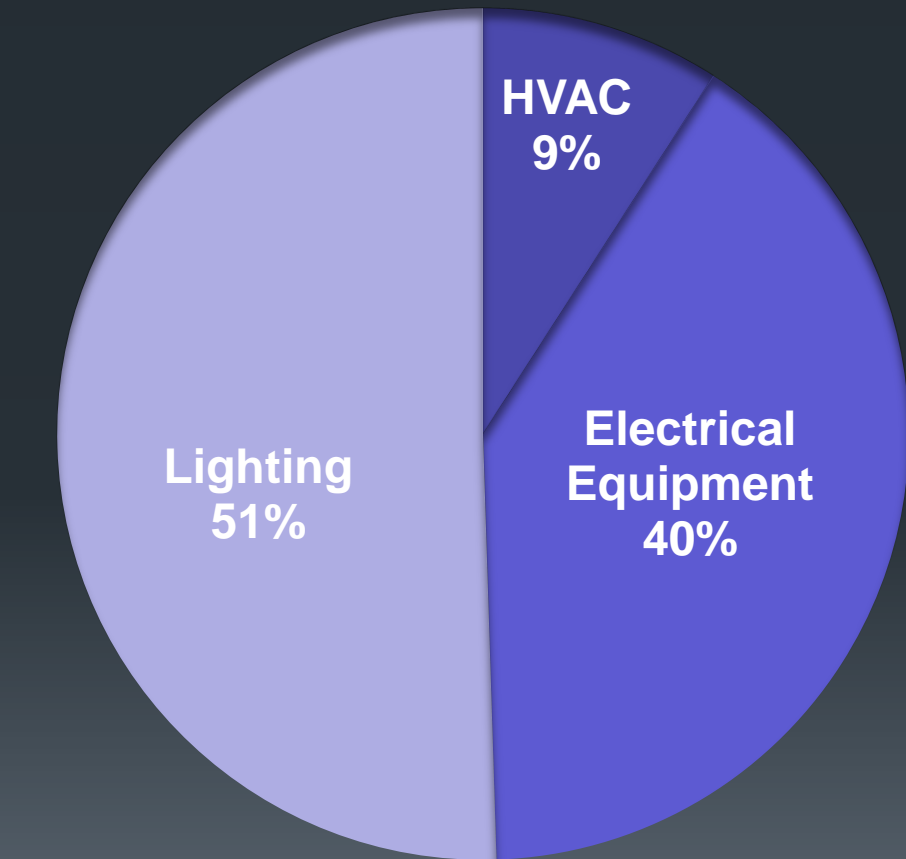
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## Cost Analysis

### VRF System Monthly HVAC Energy Consumption



### VRF Zone Annual Energy Consumption By Use



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## Cost Analysis

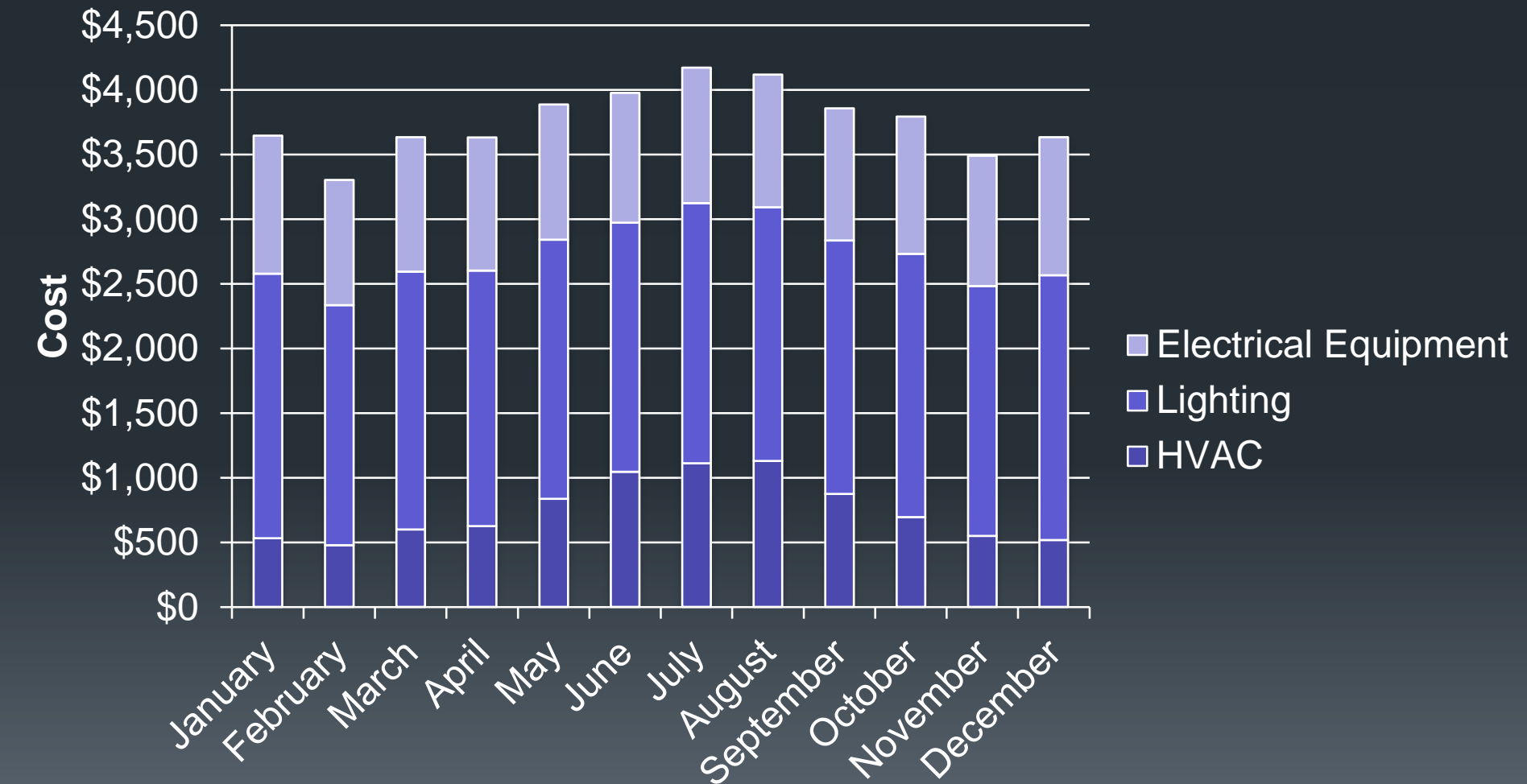
Annual HVAC Cost Per Unit Area:

**\$0.71/ft<sup>2</sup>**

Total Annual HVAC Energy Cost:

**\$9,001**

VRF System Zones Electrical Cost by Use



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## Energy Consumption Comparison

Original Design Annual HVAC Energy Consumption:

**85,148 kWh**

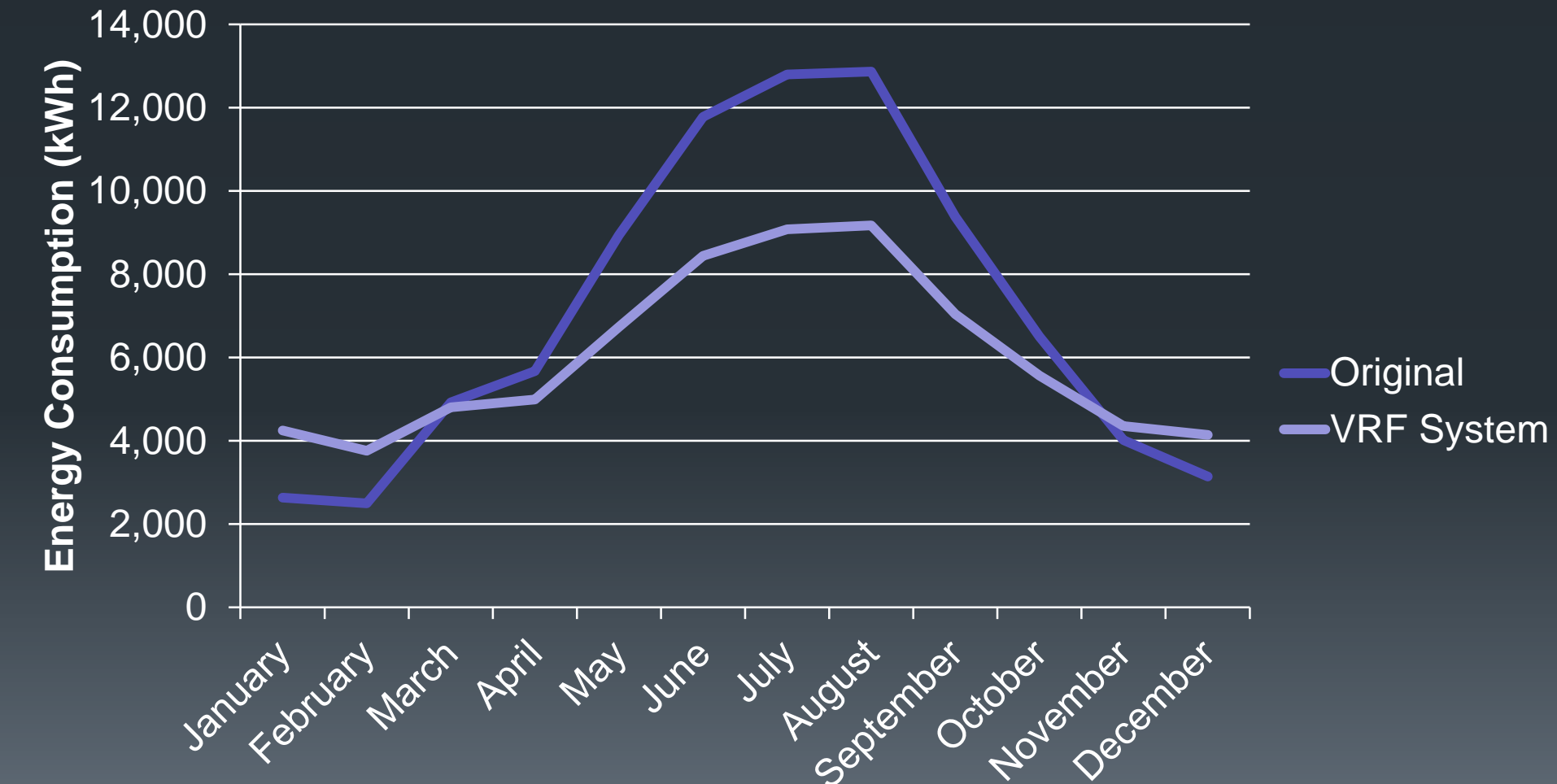
VRF System Annual HVAC Energy Consumption:

**72,316 kWh**

Difference:

**12,832 kWh**

Monthly HVAC Energy Consumption



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## Energy Cost Comparison

Original Design Annual HVAC Energy Cost:

**\$16,416**

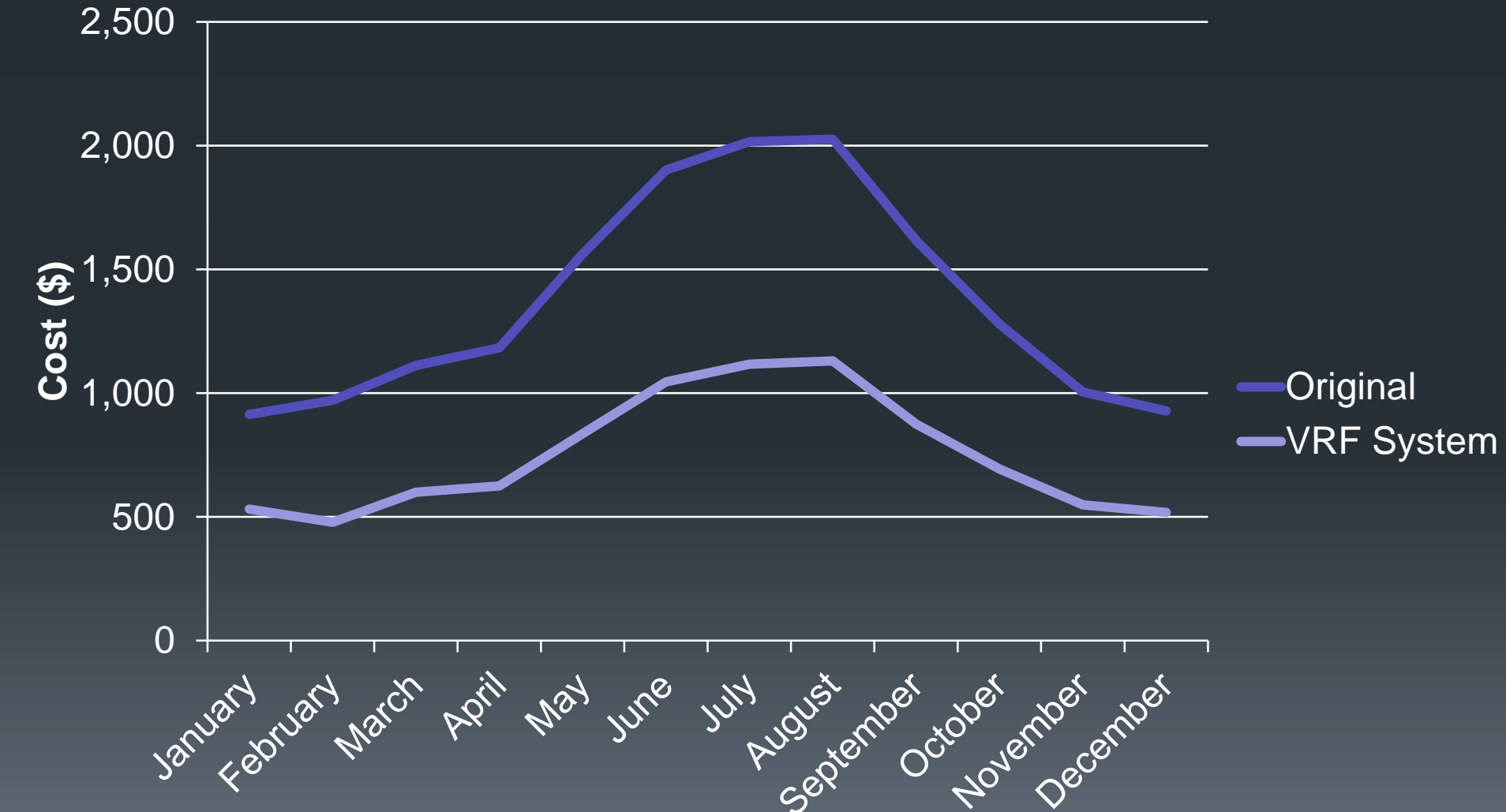
VRF System Annual HVAC Energy Cost:

**\$9,001**

Difference:

**\$7,415**

Monthly HVAC Energy Cost



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# Mechanical First Costs Comparison

## Original HVAC vs. VRF System First Costs

	Materials	Labor	Total
Original HVAC System	\$144,663.88	\$79,733.00	\$222,396.88
VRF System	\$327,702.26	\$20,690.81	\$348,393.07
Difference	-\$178,038.38	\$59,042.19	-\$118,996.19

Materials Difference:

**+118%**

Labor Difference:

**-74%**

Total First Cost Difference:

**+51.8%**

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# Payback Period

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## Variables

FC<sub>O</sub>= First Cost of Original HVAC System

AEC<sub>O</sub>= Annual Energy Cost of Original HVAC System

FC<sub>VRF</sub>= First Cost of Original VRF System

AEC<sub>VRF</sub>= Annual Energy Cost of VRF HVAC System

X= Payback Period in years

## Equation

$$FC_O + (AEC_O * X) = FC_{VRF} + (AEC_{VRF} * X)$$

$$\$229,396 + (\$16,416 * X) = \$348,393.07 + (9001 * X)$$

$$\$118996 = \$7415 * X$$

## Payback Period

**X= 16.04 years**

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## Emissions Comparison

Pollutant	Regional Grid Emission Factors 2007 (lb/kWh)	Calculated Emissions (lb/year)		Emissions Reduction %
		Original	VRF	
C02e	1.55	701,073	611,089	12.84%



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## Acoustical Breadth Investigation

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### Recommended Noise Criterion - NC

	Recommended NC Rating	Equivalent Sound Level dBA
Open-Plan Offices	<b>35-40</b>	<b>45-50</b>
Private Offices	<b>30-35</b>	<b>40-45</b>
Conference Rooms	<b>25-30</b>	<b>35-40</b>



### KEY

-  Private Offices
-  Conference Rooms
-  Open Plan Offices

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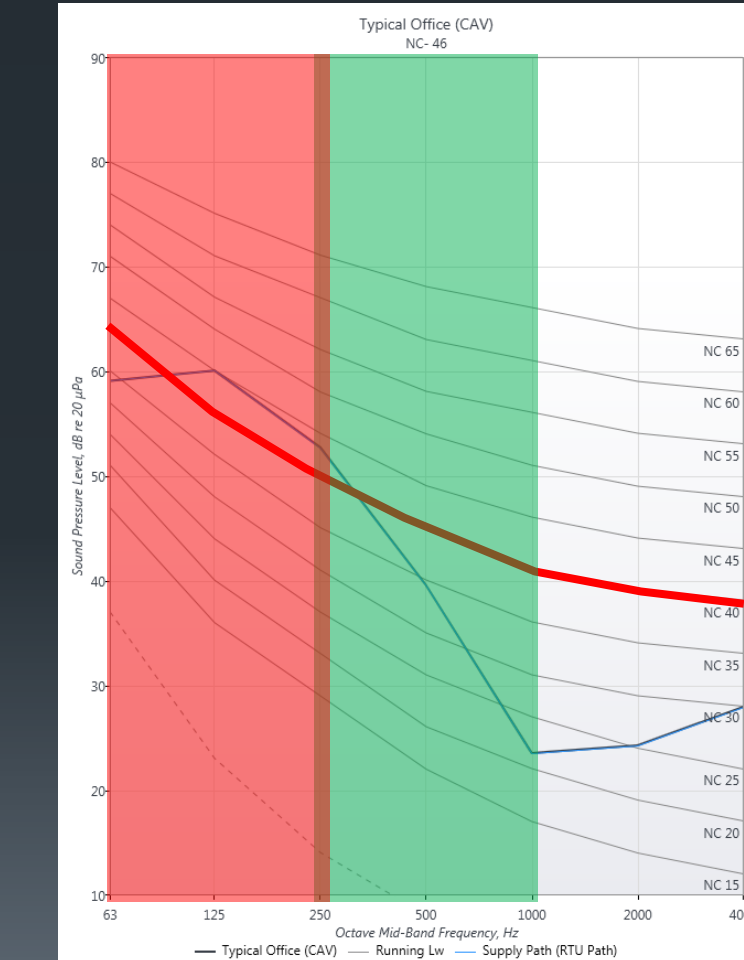
# Acoustical Breadth Investigation

## Existing Mechanical Conditions

- 5 Ton Carrier 50TCD06 Rooftop Unit
- 1" Fiberglass Insulation
- Room Dimensions : 34'x26'x8'
- Measure SPL to nearest diffuser

	Sound Power Level, dB (re 10 <sup>-12</sup> W)						
Octave Band Frequency, HZ	63	125	250	500	1000	2000	4000
Discharge	85.8	84.3	80.5	78.7	76.4	72.7	68.3

## Existing Mechanical NC Rating



NC-46  
~ 48 dBA

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# Acoustical Breadth Investigation

## Recommended Noise Criterion - NC

	Recommended NC Rating	Equivalent Sound Level dBA
Open-Plan Offices	35-40	45-50
Private Offices	30-35	40-45
Conference Rooms	25-30	35-40

## Existing Mechanical NC Rating



NC-46  
~ 48 dBA

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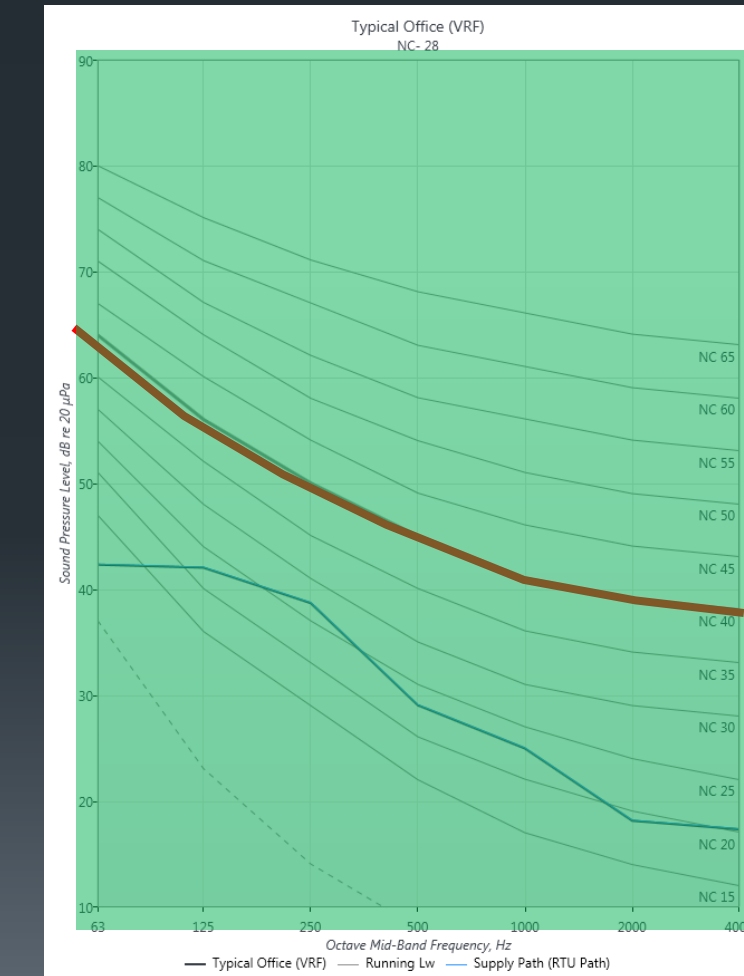
# Acoustical Breadth Investigation

## Proposed Mechanical Conditions

- Samsung DMV AM024FN4dCH/AA 4 Way Cassette Fan Coil Units
- Room Dimensions : 34'x26'x8'

	Sound Power Level, dB (re 10 <sup>-12</sup> W)						
Octave Band Frequency, HZ	63	125	250	500	1000	2000	4000
Discharge	40.1	37.2	36.4	33.0	29.7	27.3	22.6

## Recommended Noise Criterion - NC



NC-25  
~ 32 dBA

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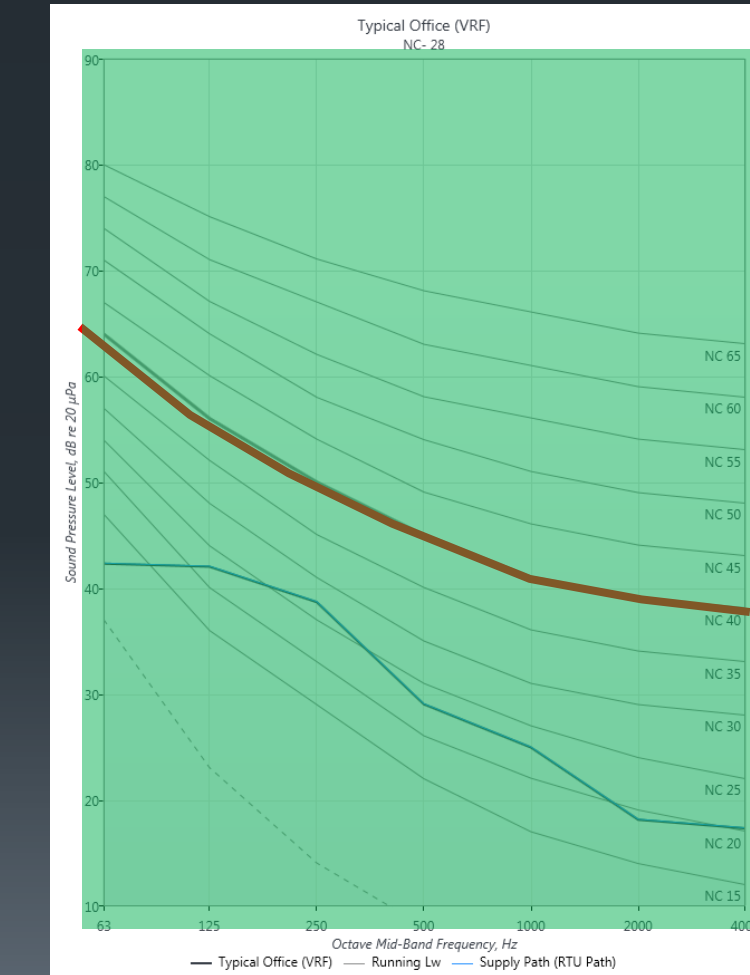
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# Acoustical Breadth Investigation

## Recommended Noise Criterion - NC

	Recommended NC Rating	Equivalent Sound Level dBA
Open-Plan Offices	<b>35-40</b>	<b>45-50</b>
Private Offices	<b>30-35</b>	<b>40-45</b>
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## Recommended Noise Criterion - NC



NC-25  
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## Conclusion

### Variable Refrigerant Flow System

- First Costs – 51% more expensive than original
- Annual Costs – 45% cheaper than original system
- Payback Period – 16 years (uneconomical)
- Emissions – 13% less annually than original
- Improve occupant comfort

### Acoustical Investigation

- Original Design – did not meet recommended NC Ratings for office spaces
- Potential for rumbly HVAC noise
- VRF Design – met all recommended NC Rating and dBA values

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## Acknowledgements

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**Joel Butler**

**Dan Gardner**

**My friends and family**

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Variable Refrigerant Flow System

Cost Analysis

Emissions Analysis

Acoustical Design

Conclusion

Questions?

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Mechanical Option | Spring 2014

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