National Law Enforcement
MUSEUM
A MATTER OF HONOR

# National Law Enforcement Officers Memorial Fund

Anya Godigamuwe | AE Senior Thesis | Mechanical | April 2015

# National Law Enforcement Museum

- **Introduction**
- Project Information
  - Mechanical System Redesign
    - Existing VAV System
    - Proposed VRF System
  - Pavilion Façade Redesign
    - Existing Façade
    - Proposed Façade
  - Acoustic Analysis
- Conclusion
- Acknowledgements

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# National Law Enforcement Museum



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**Project Information**

Location
Project Team
Construction & Cost
Schedule
Architecture

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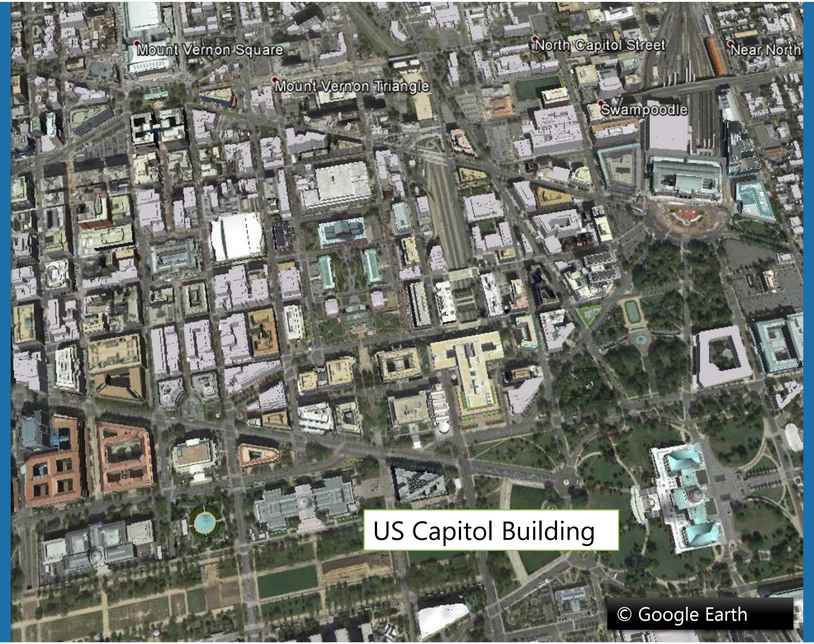


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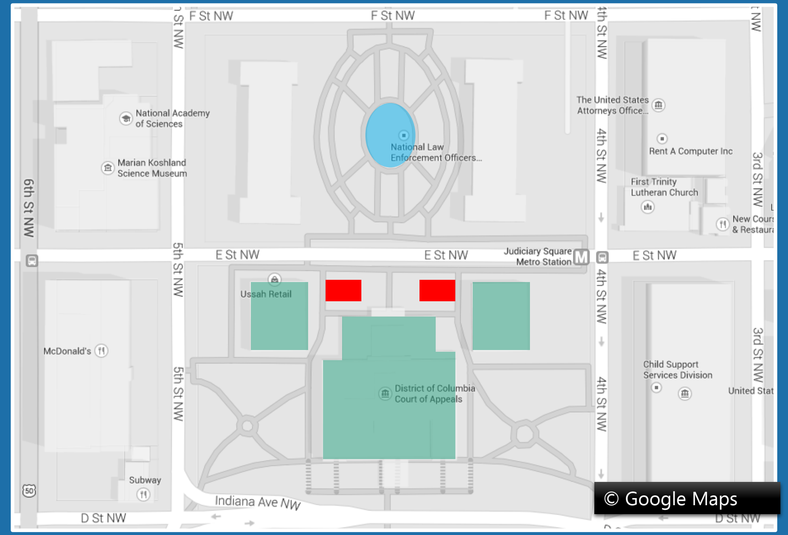


DC Court of Appeals

Museum Location

Nat'l Law Enforcement Officers Memorial

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# National Law Enforcement Museum



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# Project Information

## Project Team

Architect: Davis Buckley Architects & Planners
MEP: Loring Consulting Engineers
Structural: Spiegel, Zamecnik & Shah
Construction Manager: Clark Construction
Acoustic Consultant: Shen Milsom Wake
Lighting Consultant: Claude R. Engel
Landscape: Urban Tree + Soils


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# Project Information

## Construction, Cost & Schedule

Design – Bid – Build
Cost: $50 million
Mechanical Cost: $4.5 million
Schedule: 28 months
Summer 2015

**Project Information**

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Architecture

# National Law Enforcement Museum



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# Project Information


## Architecture

Building: 54000 GSF
Two entry pavilions
Museum Spaces
Underground
- Research Center
- Café
- Gift Shop
- Offices
- Exhibit Spaces
- Theater
- Hall of Remembrance
- Central Plant


**Project Information**
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# National Law Enforcement Museum



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# Project Information


© Davis Buckley Architects & Planners

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# National Law Enforcement Museum



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# Project Information

Courtesy of NLEOMF

## Architecture

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# Depth One: Mechanical System Redesign

# National Law Enforcement Museum



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# Depth: Mechanical System Redesign

**Design Goals**
Energy Efficiency
Minimum Noise
LEED Silver Status

**Challenges**
Humid Summer
Unobtrusive Design

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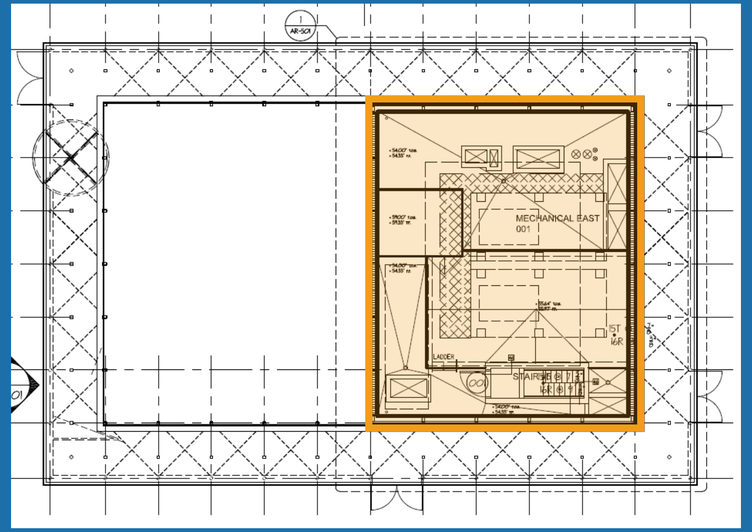
# Depth: Mechanical System Redesign




## Equipment

Mechanical Penthouse East
(1) Air Handling Unit
East Entry
(2) Cooling Towers
Chillers

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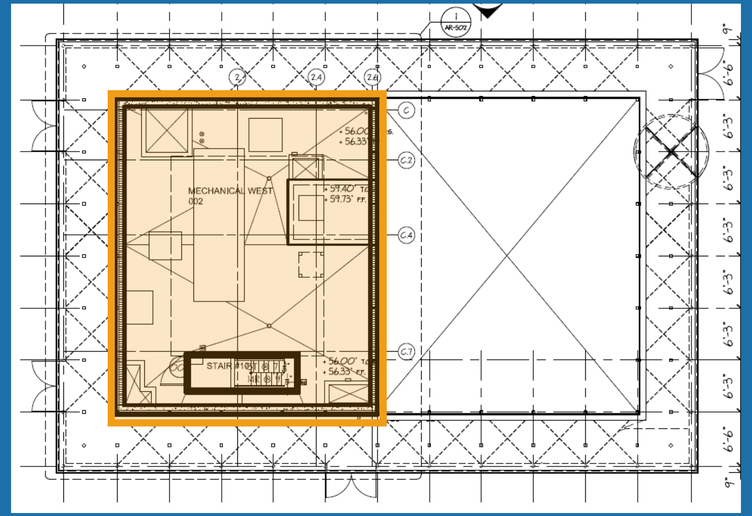
# Depth: Mechanical System Redesign




## Equipment

Mechanical Penthouse West
(1) Air Handling Unit
West Entry

**Existing VAV System**

Design Goals
Challenges
Equipment
Schematic
Heating & Cooling Loads

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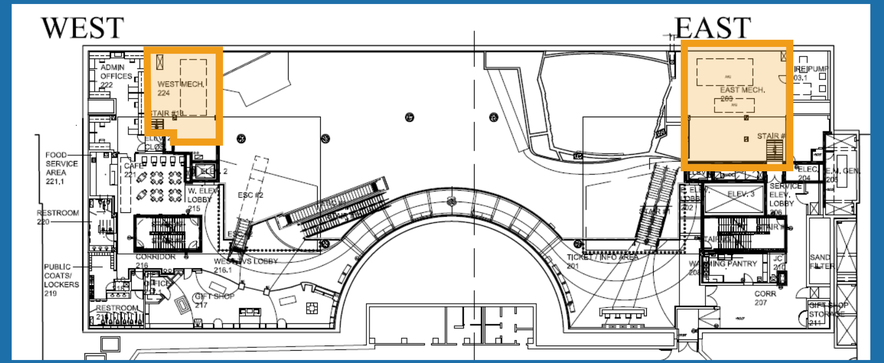
# Depth: Mechanical System Redesign




## Equipment

Mech. Rm. Ticket Level East
(2) Air Handling Units
Exhibits
Theater
Mech. Rm. Ticket Level West
(1) Air Handling Unit
Exhibits
Fan Coil Units

**Existing VAV System**
Design Goals
Challenges
Equipment
Schematic
Heating & Cooling Loads

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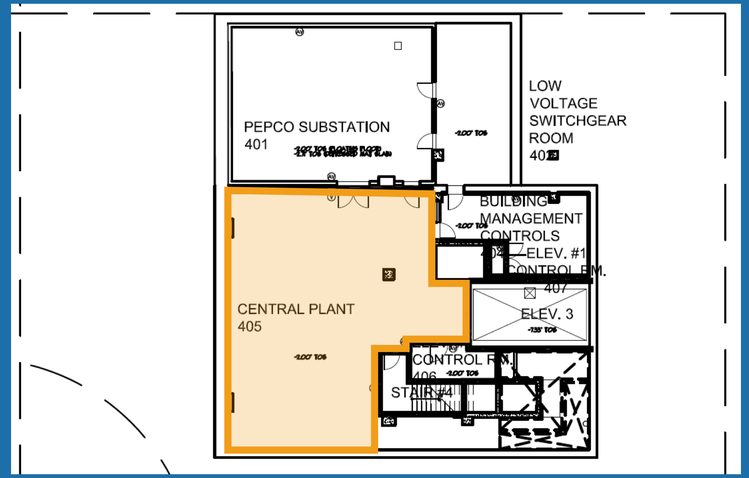
# Depth: Mechanical System Redesign




## Equipment

Central Plant
- (1) Air Handling Unit

Pepco/Switchgear Rm.
- (1) Chiller
- (1) Heat Exchanger
- (4) Pumps
- (1) Expansion Tank
- (1) CHW Buffer Tank

**Existing VAV System**

Design Goals
Challenges
Equipment
Schematic
Heating & Cooling Loads

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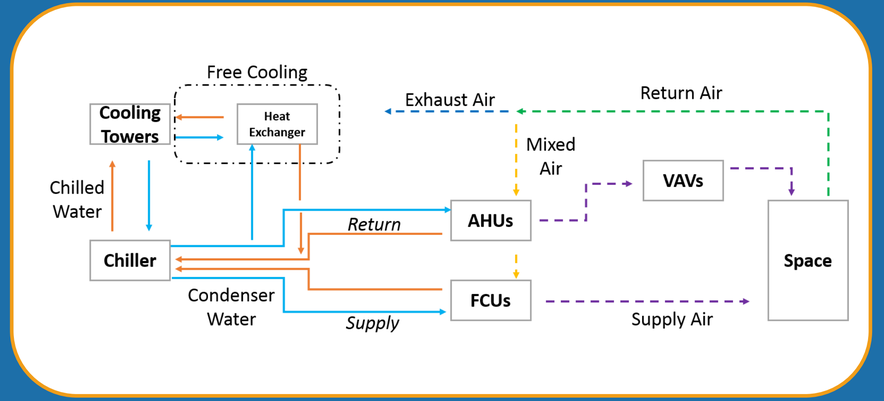
# Depth: Mechanical System Redesign




**Existing VAV System**

Design Goals
Challenges
Equipment
Schematic
Heating & Cooling Loads

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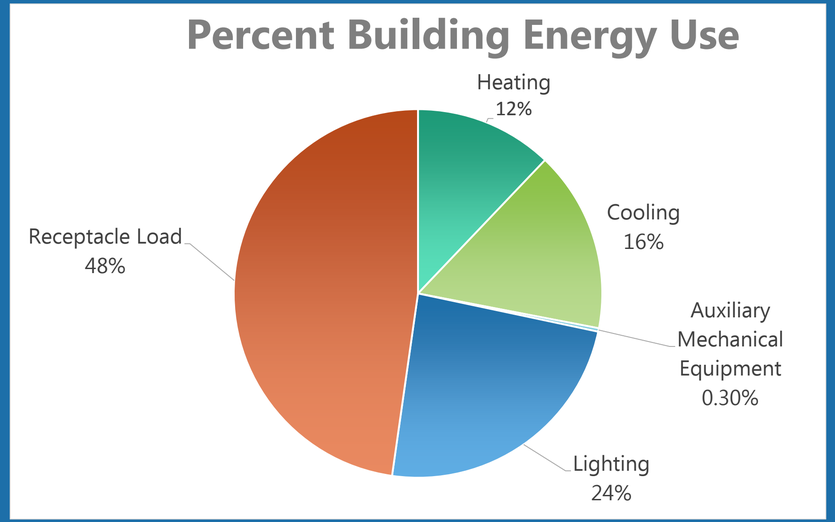
# Depth: Mechanical System Redesign




| Energy Costs | KWH | KBTU/YR |
|---|---|---|
| Heating | 142345 | 485825 |
| Cooling | 186857 | 637742 |
| Auxiliary Mechanical Equipment | 3954 | 13496 |
| Lighting | 280914 | 958760 |
| Receptacle Load | 559656 | 1910107 |

**Existing VAV System**

Design Goals
Challenges
Equipment
Schematic
Heating & Cooling Loads

# Proposed Redesign – VRF System

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# Depth: Mechanical System Redesign

## Reasoning

Less Energy
Lower Noise
Long Term Cost

## Model

Trace 700
Zoning by Use
DOAS

**Proposed VRF System**

Reasoning
Model
Schematic
Heating & Cooling Loads
Annual Energy Use
Cost Analysis
Comparison
Conclusion

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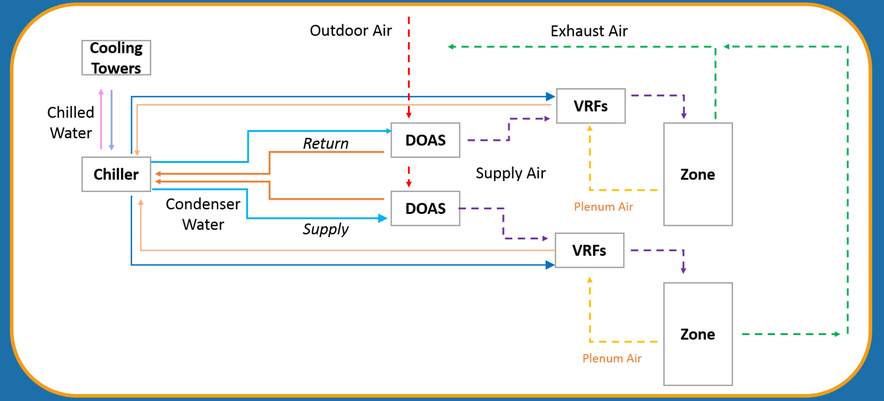
# Depth: Mechanical System Redesign



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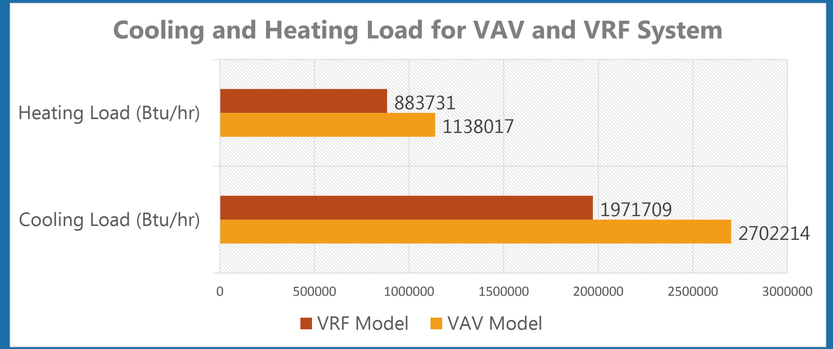
# Depth: Mechanical System Redesign




## Heating & Cooling Loads

VRF – 164 Cooling tons
27% less than VAV
VRF – 884 MBH
22% less than VAV

**Proposed VRF System**
Reasoning
Model
Schematic
Heating & Cooling Loads
Annual Energy Use
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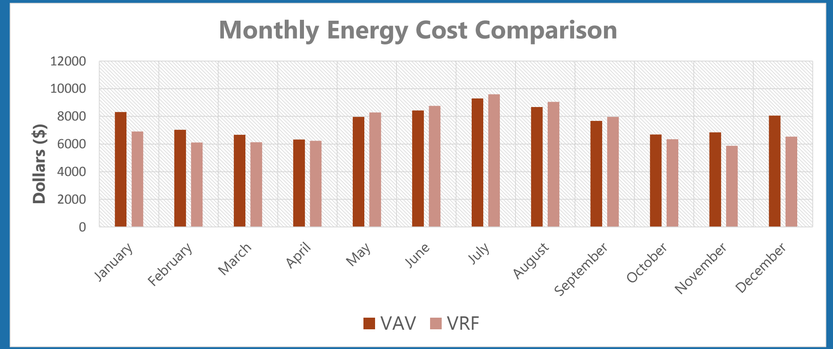
# Depth: Mechanical System Redesign




## Annual Energy Use

VRF uses less energy in winter

Both system's energy use is similar

Cannot choose one over other

**Proposed VRF System**

Reasoning

Model

Schematic

Heating & Cooling Loads

Annual Energy Use

Cost Analysis

Comparison

Conclusion

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# Depth: Mechanical System Redesign

| Life Cycle Cost Estimate | |
|---|---|
| Delta First Cost | $ 40,555.00 |
| Net change in annual operating cost | $ 4,168.00 |
| Simple Payback Period | 9.73 |
| Length of life | 20 years |
| Discount Rate | 3% |
| Savings over life (20yrs @ 3%) | $ 62,009.29 |
| Benefit to Cost Ratio | 1.53 |
| Is BCR Cost effective? | YES |
| Internal Rate of Return | 8.13% |

## Cost Analysis

Length of Life – Mitsubishi
3% expected discount rate
8.13% IRR

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# Depth: Mechanical System Redesign

| Alternative 1 & 2 Comparison | | | |
|---|---|---|---|
| | VAV | VRF | %Difference |
| CFM | 109761 | 106867 | 2.64% |
| KW | 1181926 | 1108271 | 6.23% |
| CO2 (lbm/yr) | 3265014 | 3090651 | 5.34% |
| SO2 (gm/yr) | 11672 | 11049 | 5.34% |
| NOX (gm/yr) | 4982 | 4716 | 5.34% |

## Comparison

Similar operation to VAV
Less cooling energy, 6%
10 year payback period
Potential 5% reduction in CO2 emissions

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# Depth: Mechanical System Redesign

**Conclusion:**
VRF is not a good option
Cost
Energy Use
Emissions

# Depth Two: Pavilion Façade Redesign

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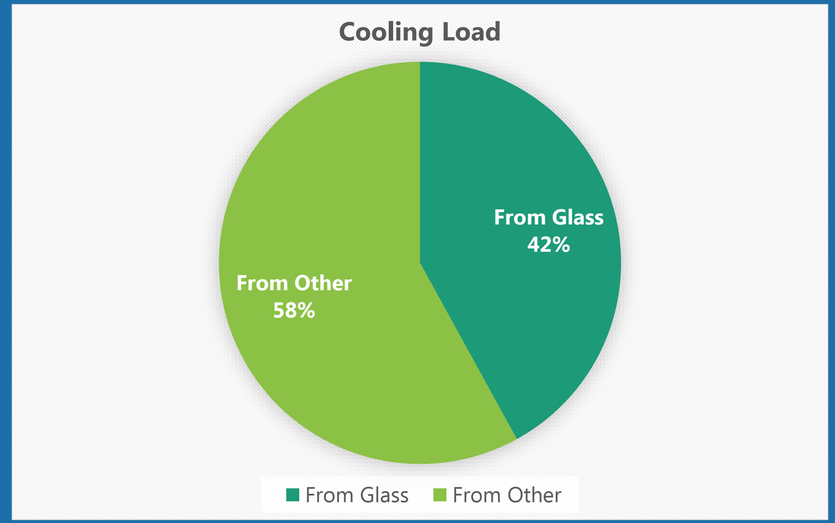
# Depth: Pavilion Façade Redesign




## Design Goals

Minimize Solar Heat Gain
Minimize Cooling Load

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# Depth: Pavilion Façade Redesign

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## Challenges

Maintain Aesthetic

*"minimize intrusion to surrounding square…strong and elegant…respectfully respond to the heavier mass…"*
*- DBA Website*

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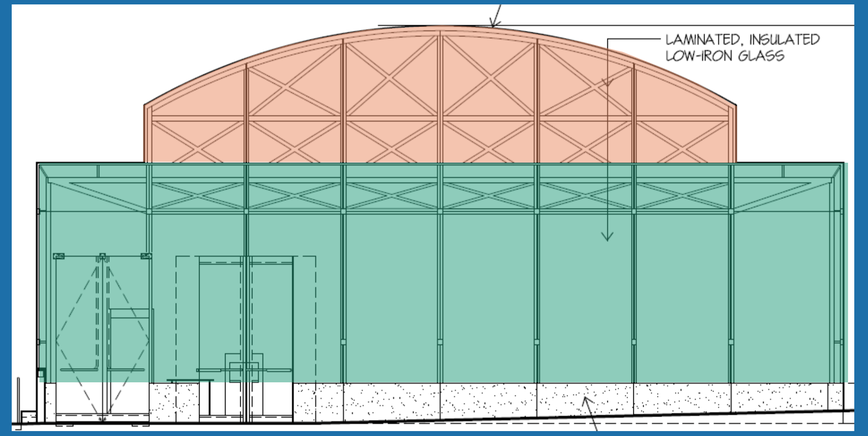
# Depth: Pavilion Façade Redesign




**Proposal**

Replace roof

Utilize better curtain wall

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# Depth: Pavilion Façade Redesign

| Original Glass | | |
|---|---|---|
| **Material** | *Description* | *Thickness (in.)* |
| **Outboard Lite** | clear (low iron) heat tempered, heat soaked glass with Low Emissivity Coating on Number 2 Surface, and with flat ground and polished edges | 0.31 |
| **Air Space** | Air | 0.5 |
| **Inboard Lite x2** | Clear (low iron) heat soaked glass laminated with 0.060" DuPont SentryGlass Plus structural interlayer with flat ground and polished edges | 0.625 |
| **Thickness** | | 1.50 |
| **Approximate U-Value** | | 0.31 |
| **Shading Coefficient** | | 0.50 |
| **Visible Transmissivity** | | 0.90 |

| Proposed Viracon Glass | | |
|---|---|---|
| **Material** | *Description* | *Thickness (in.)* |
| **Outer Layer** | Insulating tempered glass with 30% silk screen coverage | 0.25 |
| **Air Space** | Air | 0.5 |
| **Inner Layer** | Tempered glass with low-E coating | .25 |
| **Thickness** | | 1.00 |
| **Approximate U-Value** | | 0.26 |
| **Shading Coefficient** | | 0.35 |
| **Visible Transmissivity** | | 0.55 |

## Model

Trace 700 VAV Model
Alternative with new glass type
Compare with VAV design

**Depth: Pavilion Façade Redesign**

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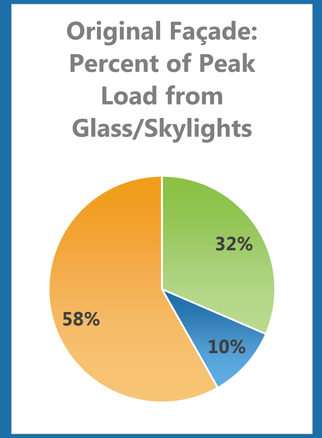
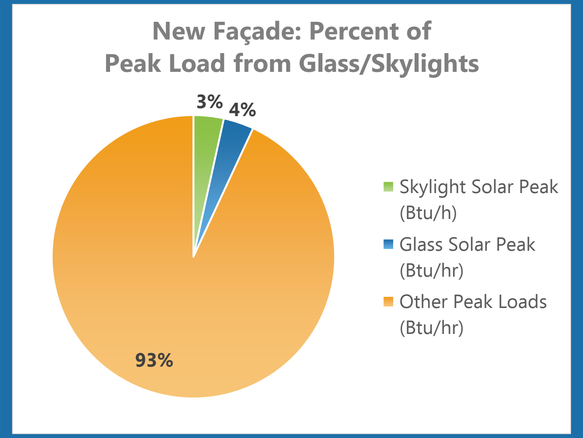
# Depth: Pavilion Façade Redesign




## Solar Heat Gain

Peak Solar Load Comparison

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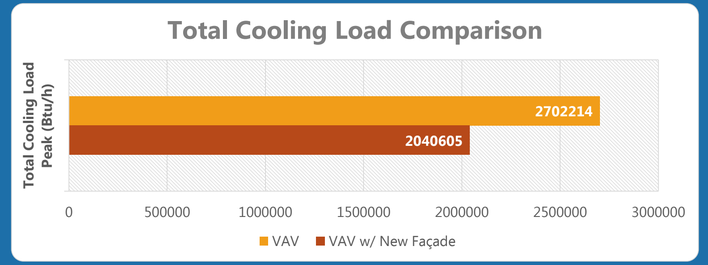
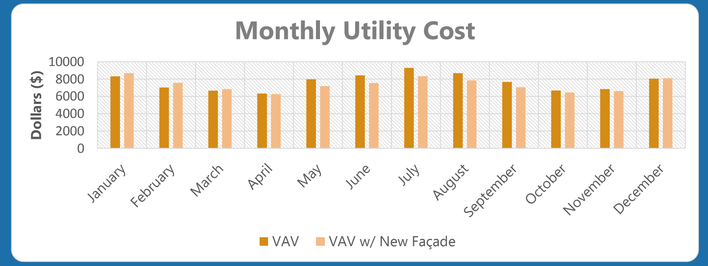
# Depth: Pavilion Façade Redesign




## Cooling Load

Cooling Load Comparison
Monthly Utility Cost

**Depth: Pavilion Façade Redesign**

Design Goals
Challenges
Proposal
Model
Solar Heat Gain
Cooling Load
Conclusion

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# Depth: Pavilion Façade Redesign

## Conclusion

Façade change beneficial
Reduced energy cost
Aesthetic unharmed

# Breadth Topic: Acoustic Analysis

# National Law Enforcement Museum



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# Breadth: Acoustic Analysis

## Space Description

Giving face to loss
Tribute to fallen

**Breadth Topic: Acoustic Analysis**

# National Law Enforcement Museum



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# Breadth: Acoustic Analysis

## Design Goals

Purpose
Low "echo"
Speech intelligibility

**Breadth Topic: Acoustic Analysis**

# National Law Enforcement Museum



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# Breadth: Acoustic Analysis

## Criteria

Reverberation Time
Quality of sound
Speech intelligibility

**Breadth Topic: Acoustic Analysis**

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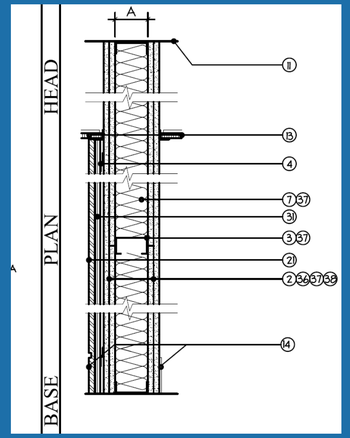
# Breadth: Acoustic Analysis




| Wall Type 37 |
|---|
| *Materials* |
| Metal Panel system |
| 5/8" medium density fiberboard |
| "Z" clips |
| 2 layers 5/8" GWB |
| 3-5/" insulation with metal studs at 16" OC |
| 2 layers 5/8" GWB |

| Octave Band | Absorption Coefficient, α |
|---|---|
| 125 | 0.1 |
| 250 | 0.07 |
| 500 | 0.05 |
| 1000 | 0.05 |
| 2000 | 0.04 |
| 4000 | 0.04 |

## Modeling Process

Absorption Values
Wall Area
RT value per octave band

**Breadth Topic: Acoustic Analysis**

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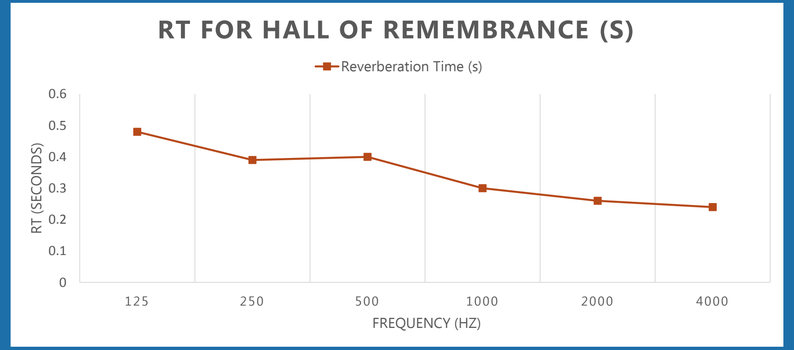
# Breadth: Acoustic Analysis

| Frequency | 125 | 250 | **500** | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|
| Reverberation Time (s) | 0.48 | 0.39 | **0.4** | 0.3 | 0.26 | 0.24 |




## Results

Room RT = 0.4 s.
Highest RT at 125 Hz
*Architectural Acoustics: Principles & Design*

**Breadth Topic: Acoustic Analysis**

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# Breadth: Acoustic Analysis

| Frequency | 125 | 250 | **500** | 1000 | 2000 | 4000 |
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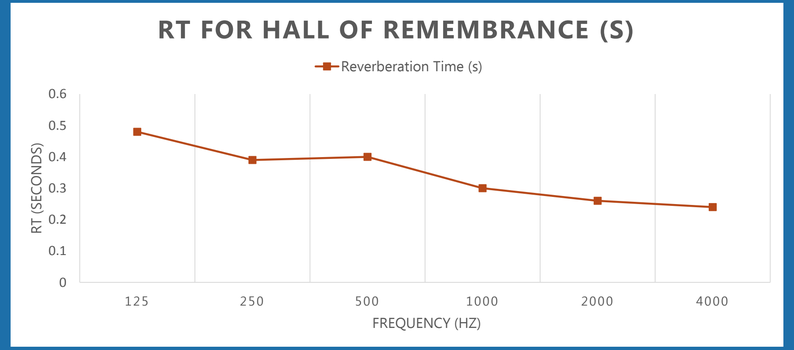


## Conclusion

This RT is good for space
Low frequency concern

**Breadth Topic: Acoustic Analysis**

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# Conclusion

## VRF System
Less energy use
Rate of return, 8.3%
Payback period, 10 years
Cost, $40,000 extra

## Pavilion Facade
Less energy use
Lower cooling load

## Acoustic Analysis
Meets criteria
RT of 0.4 s. ideal

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## Thank you


**My sincere thanks to:**

Mr. J. Michael Galway - Loring Consulting Engineers
Mr. Davis Buckley & Mr. Thomas Striegel -
Davis Buckley Architects & Planners
Ms. Jeni Ashton - National Law Enforcement Museum
Mr. Lincoln Lawrence - Clark Construction Group
Dr. Stephen Treado & Prof. Stephen Parfitt
PSU Architectural Engineering Dept.

**My loving family & friends**

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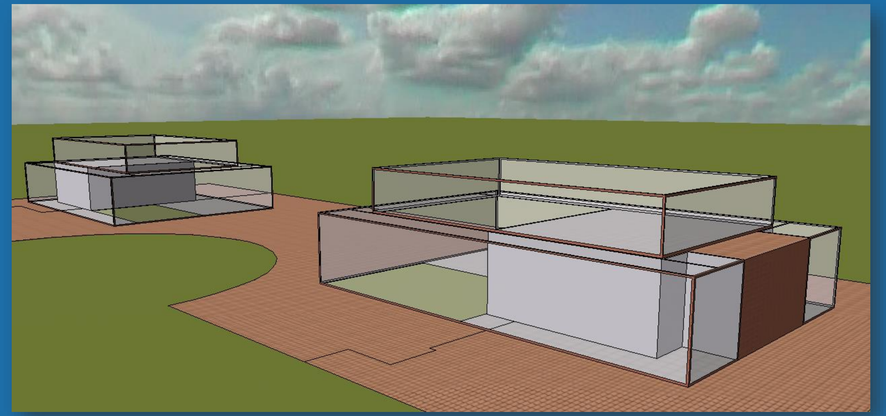
# Appendix A - Daylighting

- Appendices
  - **A – Daylighting**
  - B – VAV System
  - C – VAV/VRF Comparison
  - D – Façade Comparison



## Criteria
IES Lighting Handbook

## Model
IES Virtual Environment
RadienceIES

**Breadth Topic:**
**Daylighting Analysis**

Model
Criteria
IES Results

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# Appendix A - Daylighting

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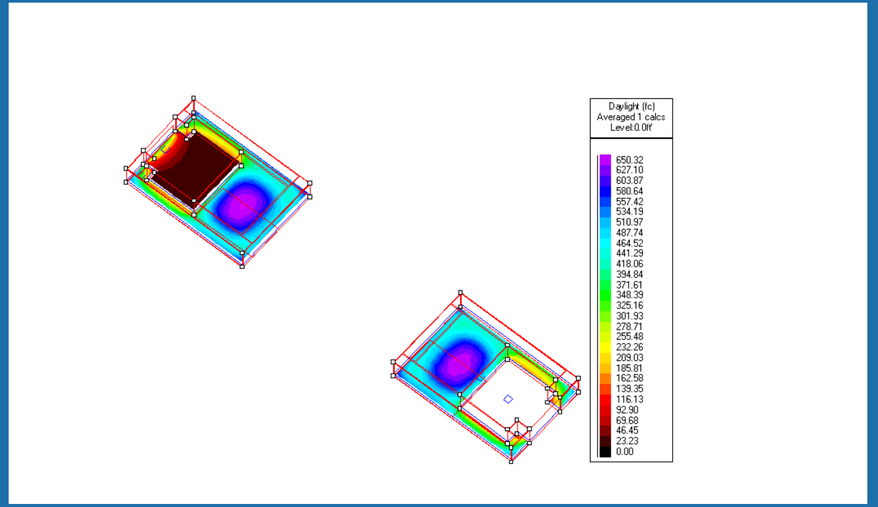


## IES Results

Meet criteria of 100 lux

**Breadth Topic:**
**Daylighting Analysis**

Model
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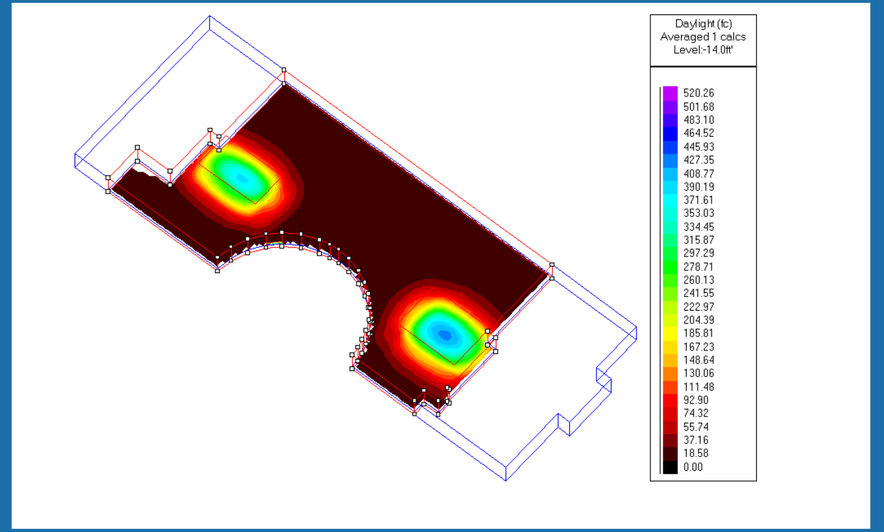
# Appendix A - Daylighting




## IES Results

Meet criteria of 100 lux

**Breadth Topic:**
**Daylighting Analysis**

Model
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IES Results

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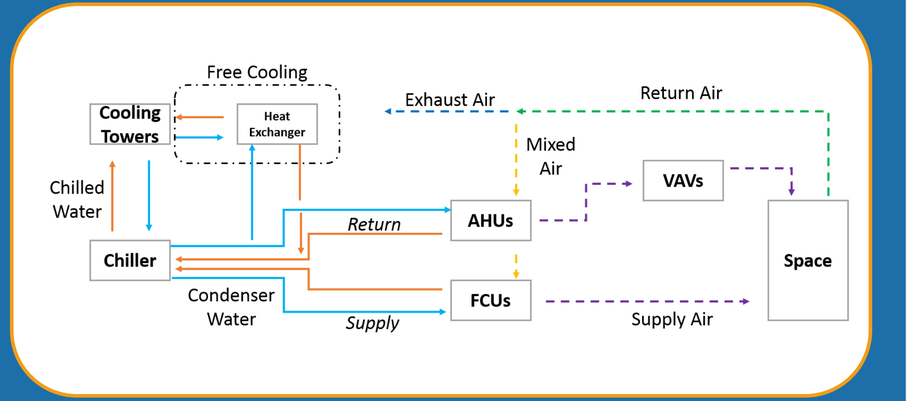
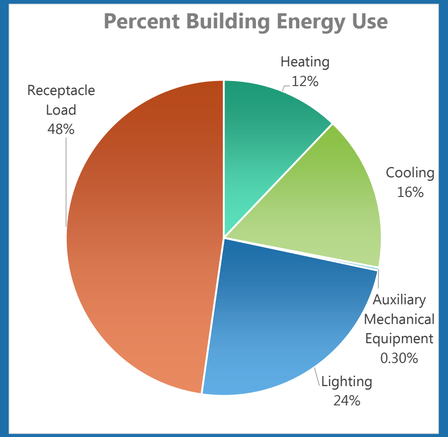
# Appendix B – VAV System




| Energy Costs | KWH | KBTU/YR |
|---|---|---|
| Heating | 142345 | 485825 |
| Cooling | 186857 | 637742 |
| Auxiliary Mechanical Equipment | 3954 | 13496 |
| Lighting | 280914 | 958760 |
| Receptacle Load | 559656 | 1910107 |

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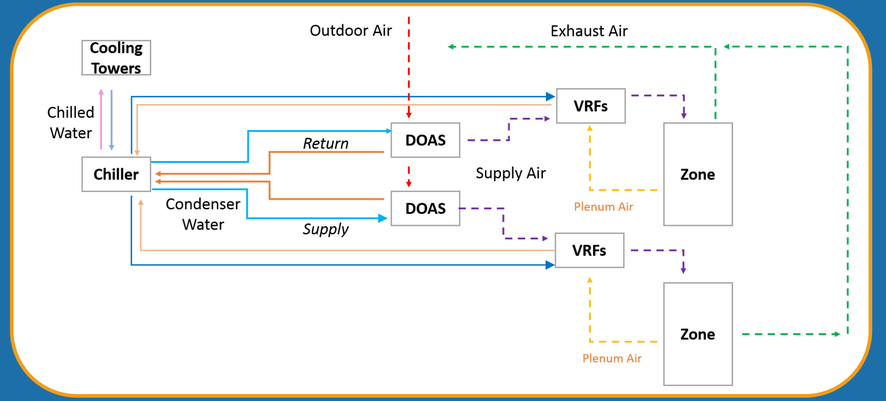
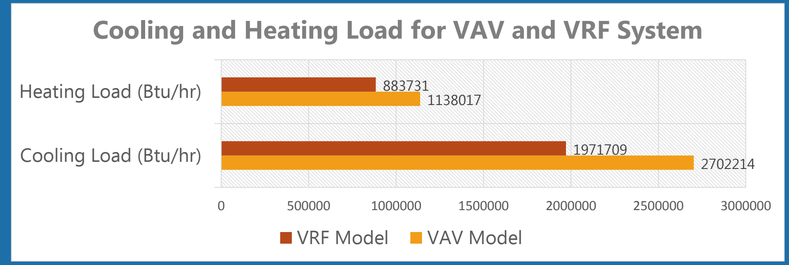
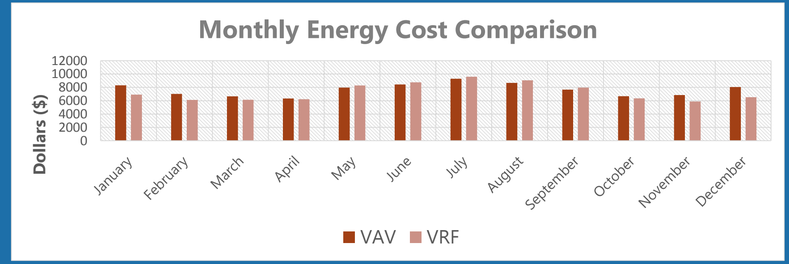
# Appendix C – VAV/ VRF Comparison

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# National Law Enforcement Museum

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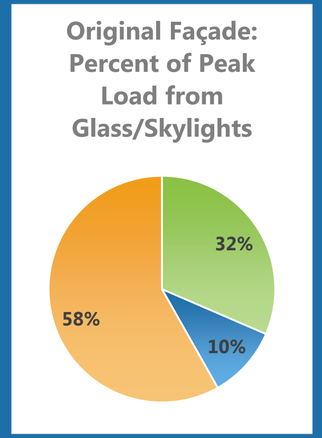
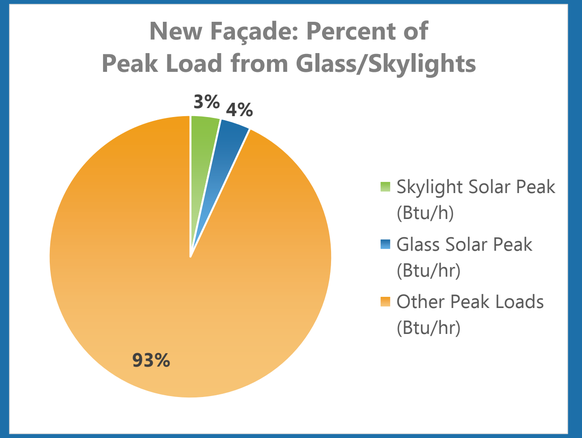
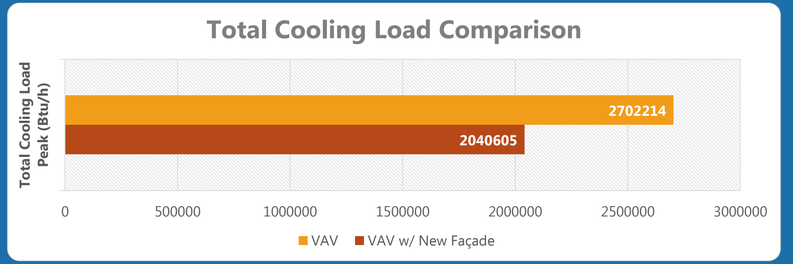
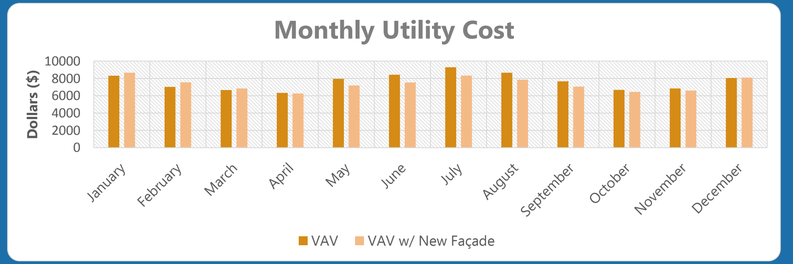
# Appendix D – Façade Comparison

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