Georgetown University

# New Science Center

Washington, DC


## Kevin Edstrom

Mechanical Option


2011 Senior Thesis

April 12th, 2011

PENNSTATE

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- Project Overview
- Existing Mechanical System
  - DOAS
  - Space Heating and Cooling
  - Plumbing
  - Energy Consumption
- Mechanical Depth: Solar Thermal System
  - Overview
  - Key Design Decisions
  - Energy Savings and Payback Period
- Construction Breadth
  - Constructability
  - Trade Coordination and Schedule
- Summary and Conclusion
- Q/A

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PENNSTATE

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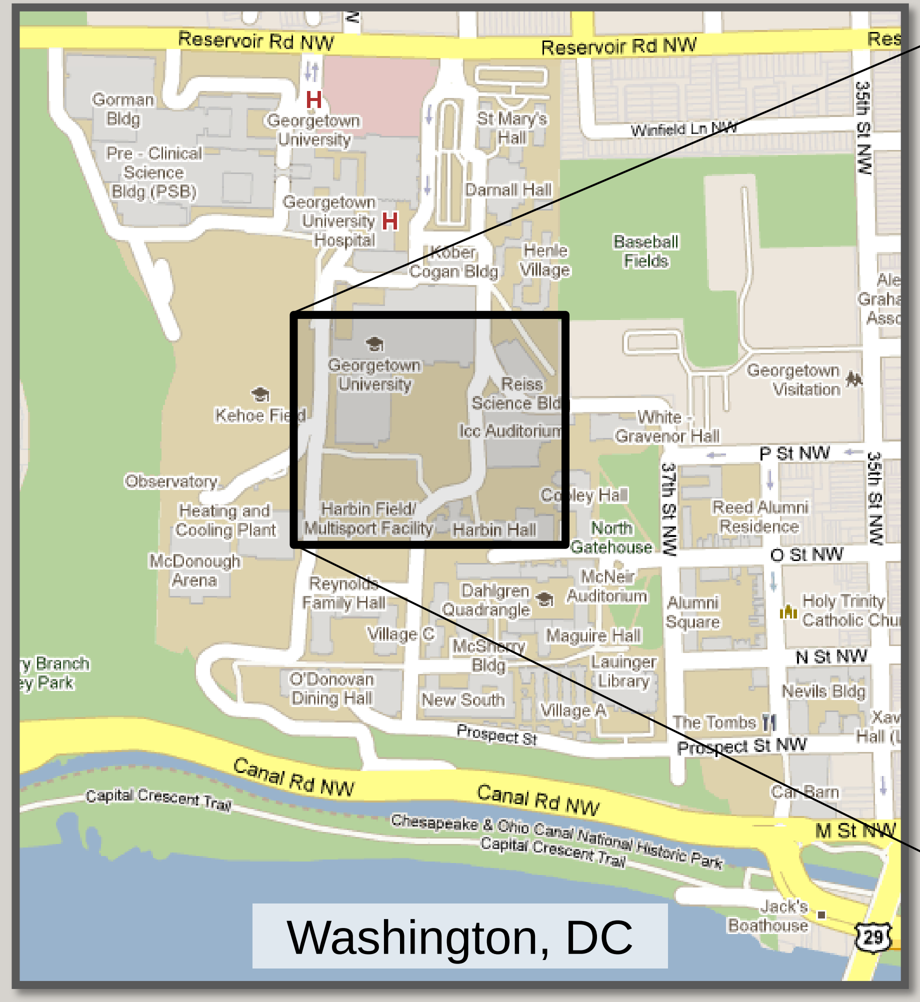
# Project Overview

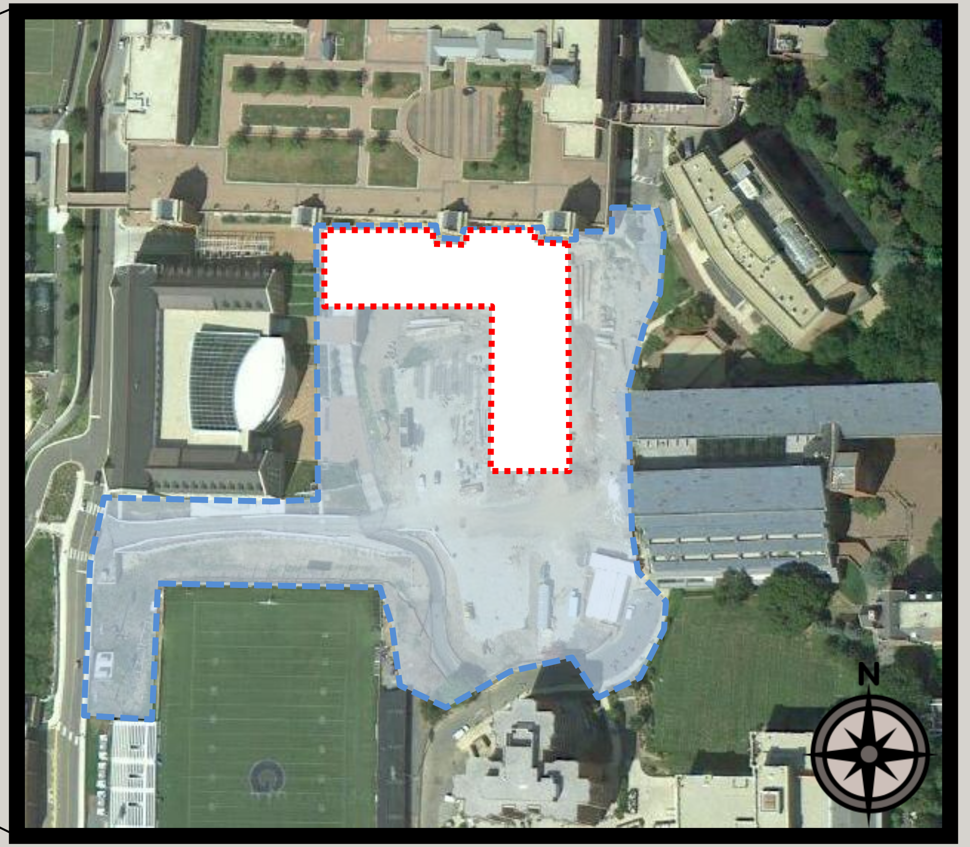


## Georgetown University New Science Center

| | |
|---|---|
| Size: | 154,000 SF |
| Client: | Georgetown University |
| Architect: | Payette Associates |
| MEP Consultants: | R.G. Vanderweil Engineers |
| CM: | Whiting-Turner Contracting |
| Construction Dates: | May 2010 – July 2012 |

## Location



Site in blue
Building footprint in red

# Project Overview

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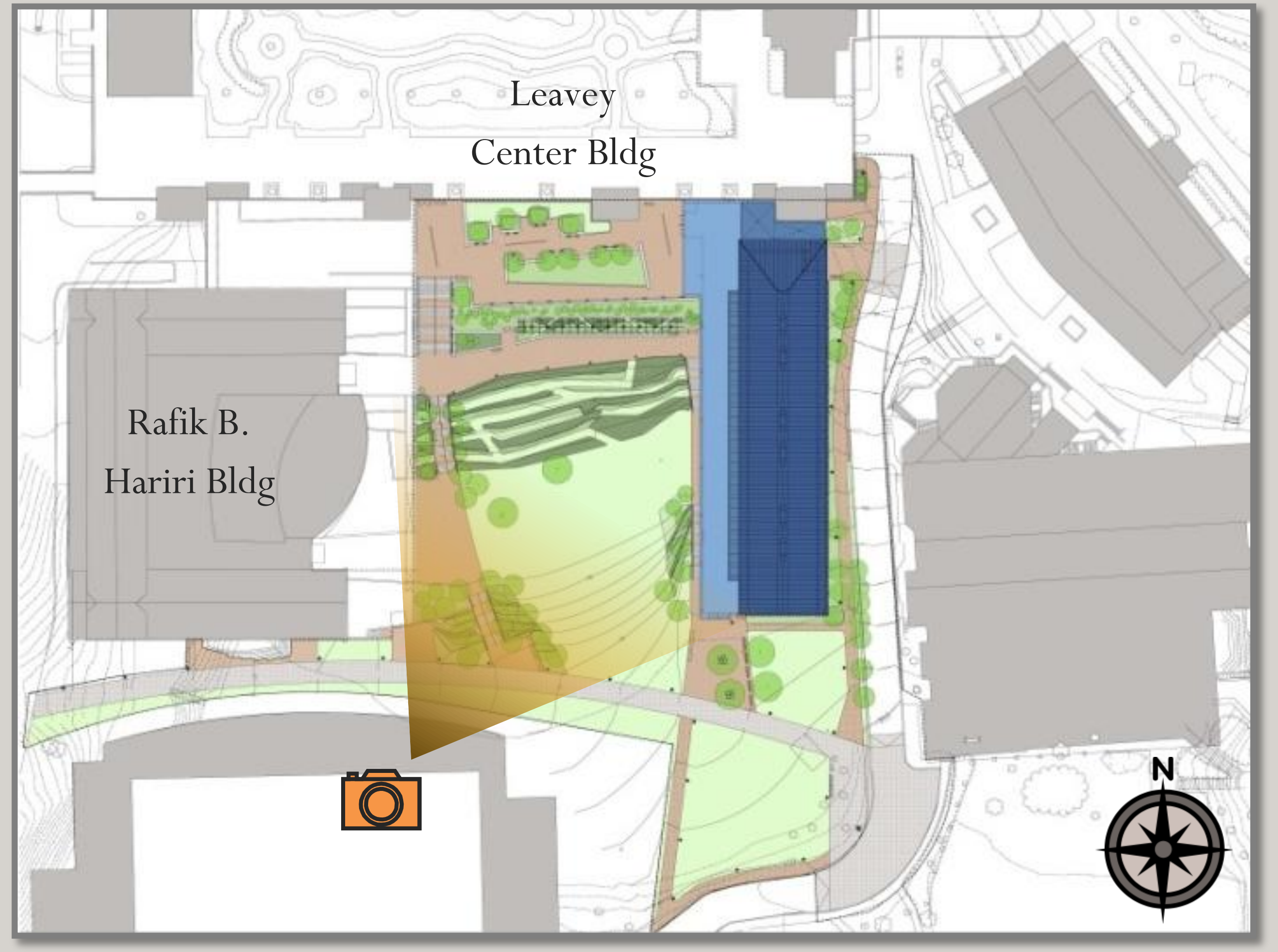


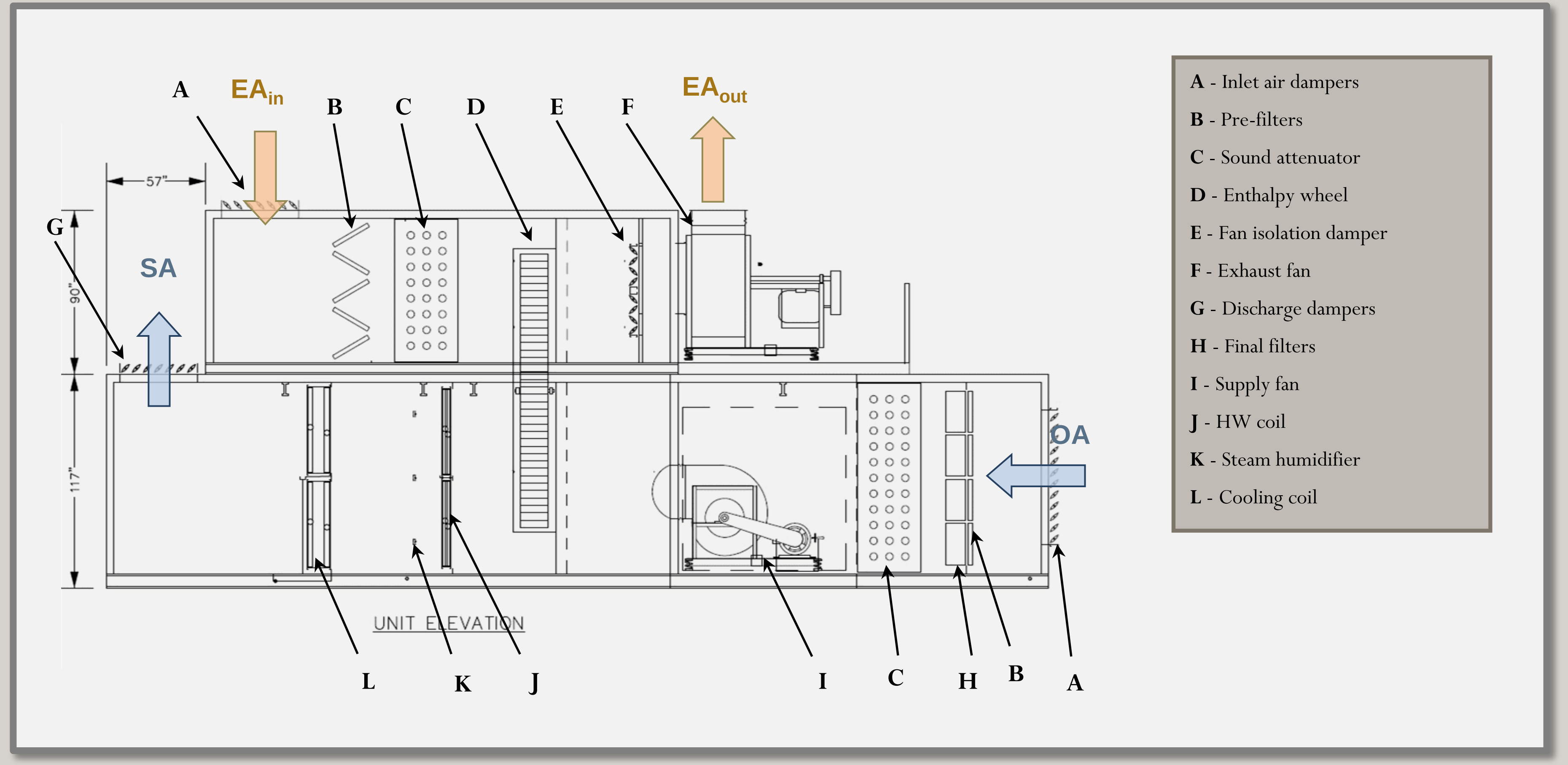

Site Plan

# Existing Mechanical System



## Dedicated Outdoor Air System

- (4) Built-up AHUs
  - 50,000 cfm supply/exhaust each
- VAV supply and exhaust terminal units
- (97) High efficiency fume hoods




Typical Air Handling Unit detail

# Existing Mechanical System



## Space Heating and Cooling System

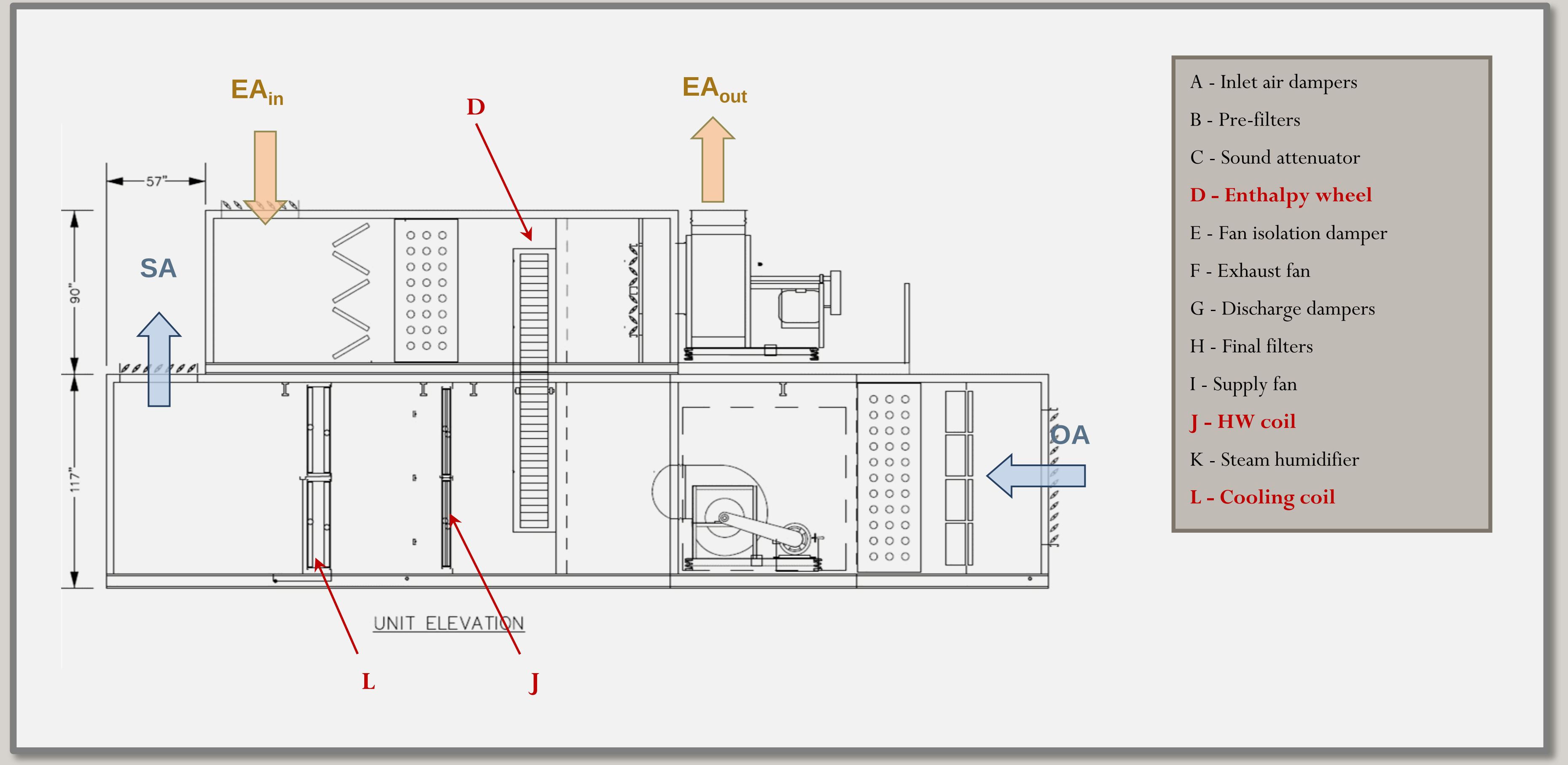
- AHU preconditioning
- Active chilled beams
- Fan coil units
- Unit heaters

# Existing Mechanical System



## Space Heating and Cooling System

- **AHU preconditioning**
- Active chilled beams
- Fan coil units
- Unit heaters



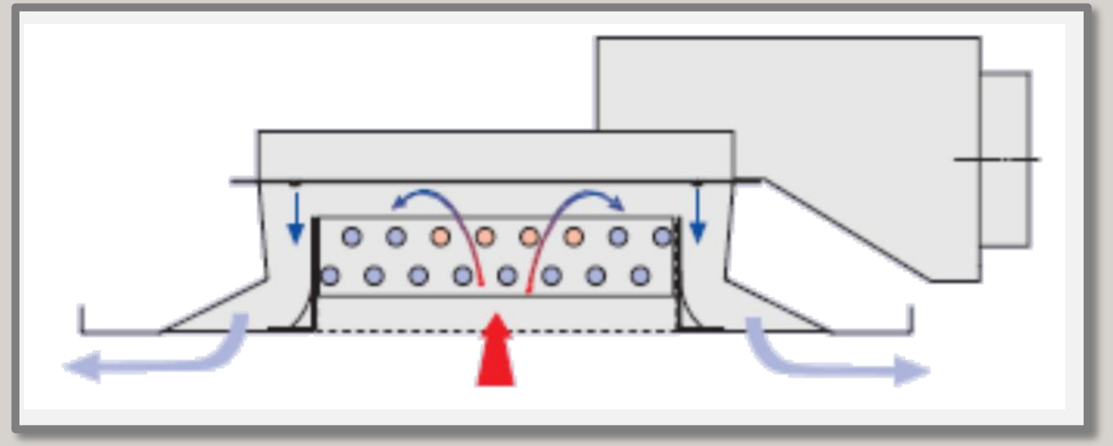

Typical Air Handling Unit detail

# Existing Mechanical System



## Space Heating and Cooling System

- AHU preconditioning
- **Active chilled beams**
- Fan coil units
- Unit heaters



Typical chilled beam detail

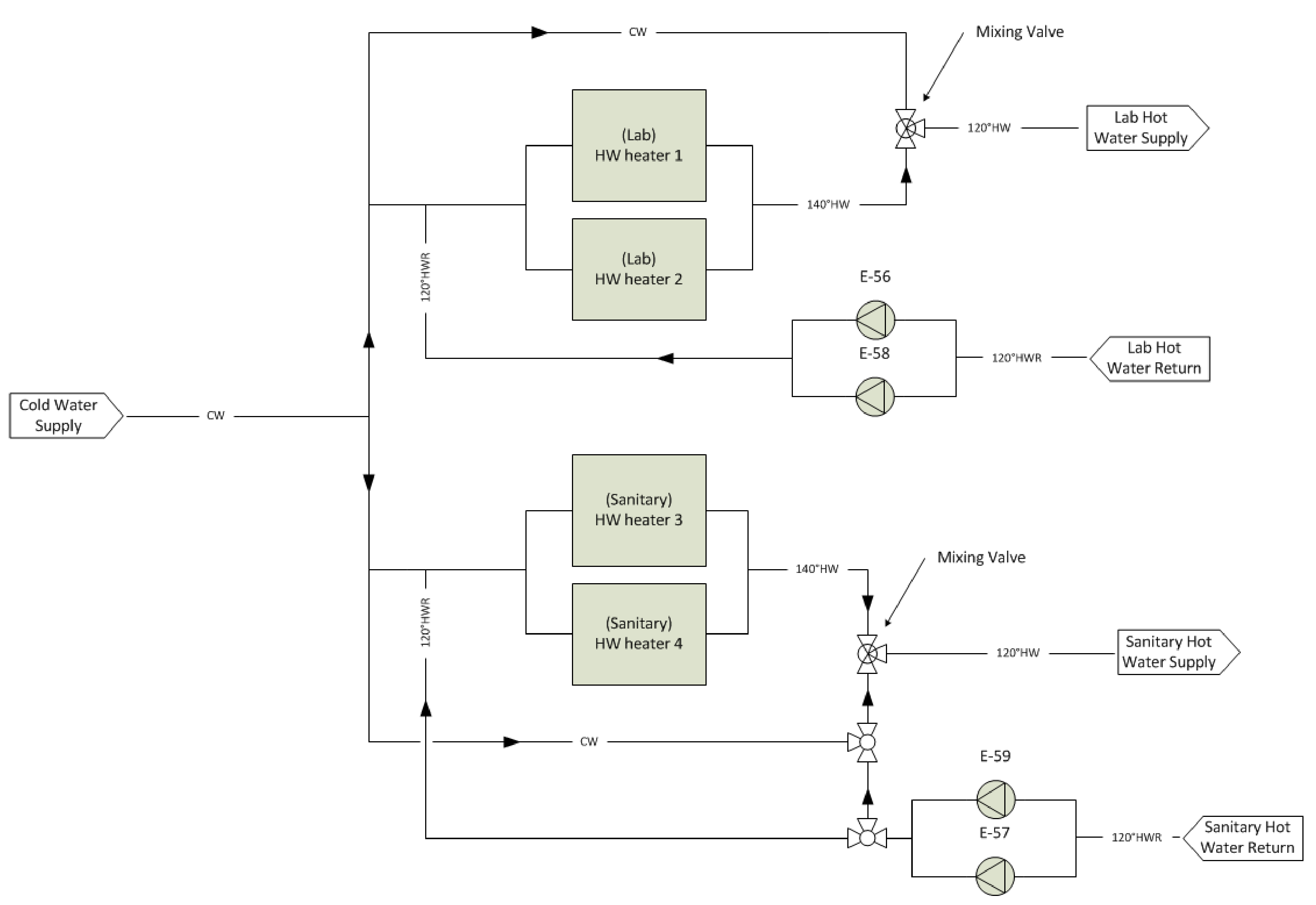
# Existing Mechanical System

## Plumbing System

Domestic Hot Water

- Sanitary and lab loop
- Recirculated system

Existing Domestic Hot Water Distribution



# Existing Mechanical System



## Energy Consumption

**HVAC Cooling Demand:**
848.5 MMBtu/yr

- Primarily summer demand

**HVAC Heating Demand:**
6411 therms/year or 641.1 MMBtu/yr

- Primarily winter demand

**Domestic HW Demand:**
2080 gal/day → 1223 MBtu/day
1223 x 1.25 = 1529 MBtu/day *(recirculated system losses)*

3,975 therms/yr or **397.5 MMBtu/yr**

- Relatively constant demand throughout the year

# Mechanical Depth - Solar Thermal System



## System Objective:

Utilize solar energy to offset district steam demand

↓

Reduced operating costs and carbon footprint

## Design Goals:

- Minimize changes in existing design (structural / mechanical)
- Prevent delays in existing construction schedule

$$/BTU

lbs C02

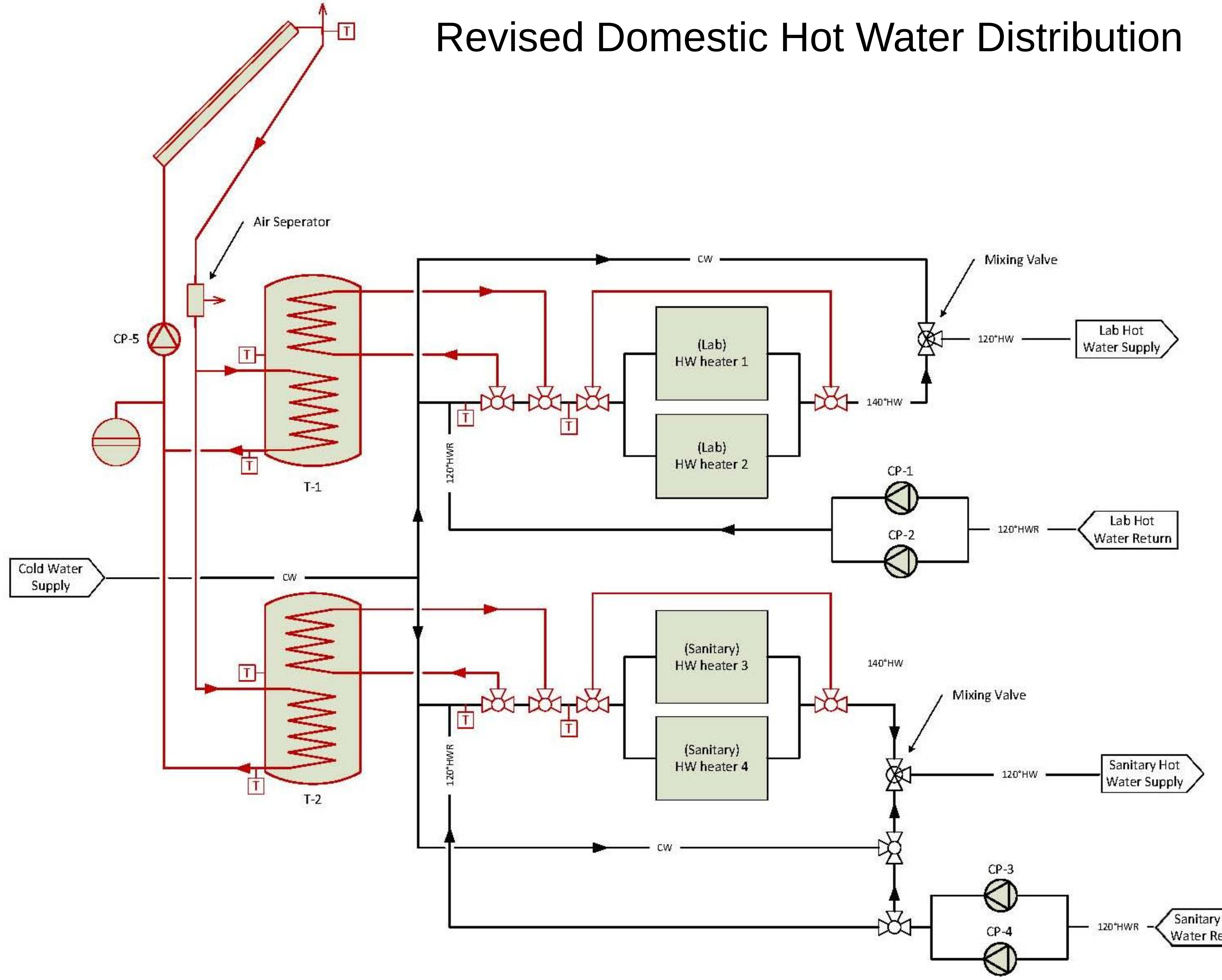
# Mechanical Depth - Solar Thermal System

## Overview

Proposed system will supplement existing domestic hot water heaters

- (77) Evacuated tube solar collectors (1716 sf total absorber area)
- (2) 5000 liter (total 2641 gal) thermal storage tanks
- 17.4 gpm circulator pump
- 1100 gal diaphragm expansion tank
- Air separation equipment

## Revised Domestic Hot Water Distribution



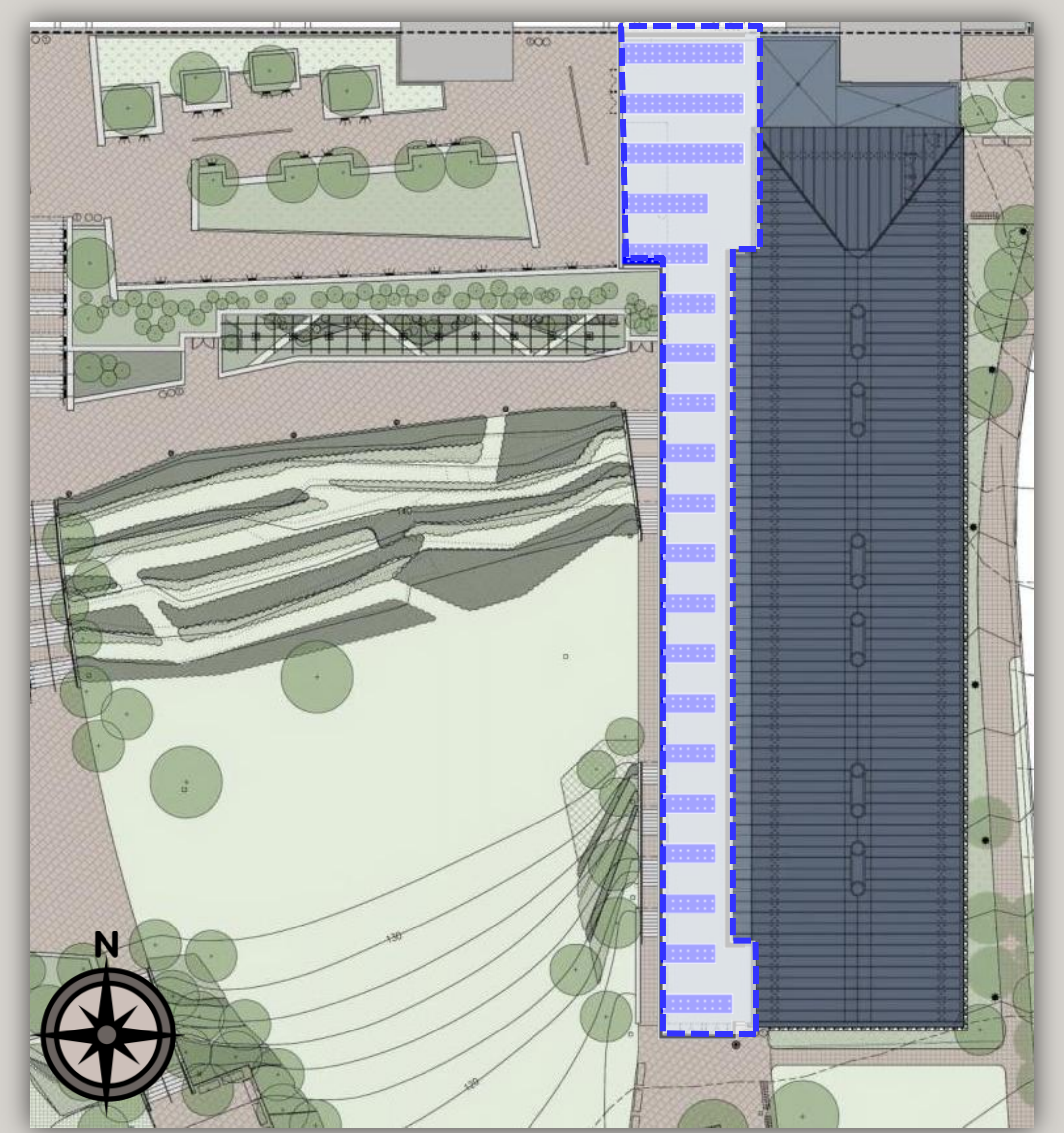
# Mechanical Depth - Solar Thermal System



## Key Design Decisions

**Collector location**: Mechanical penthouse level

- Sufficient space for (77) 2x3m solar collectors at 45° tilt angle
- Total absorber area: 1716 sf



# Mechanical Depth - Solar Thermal System

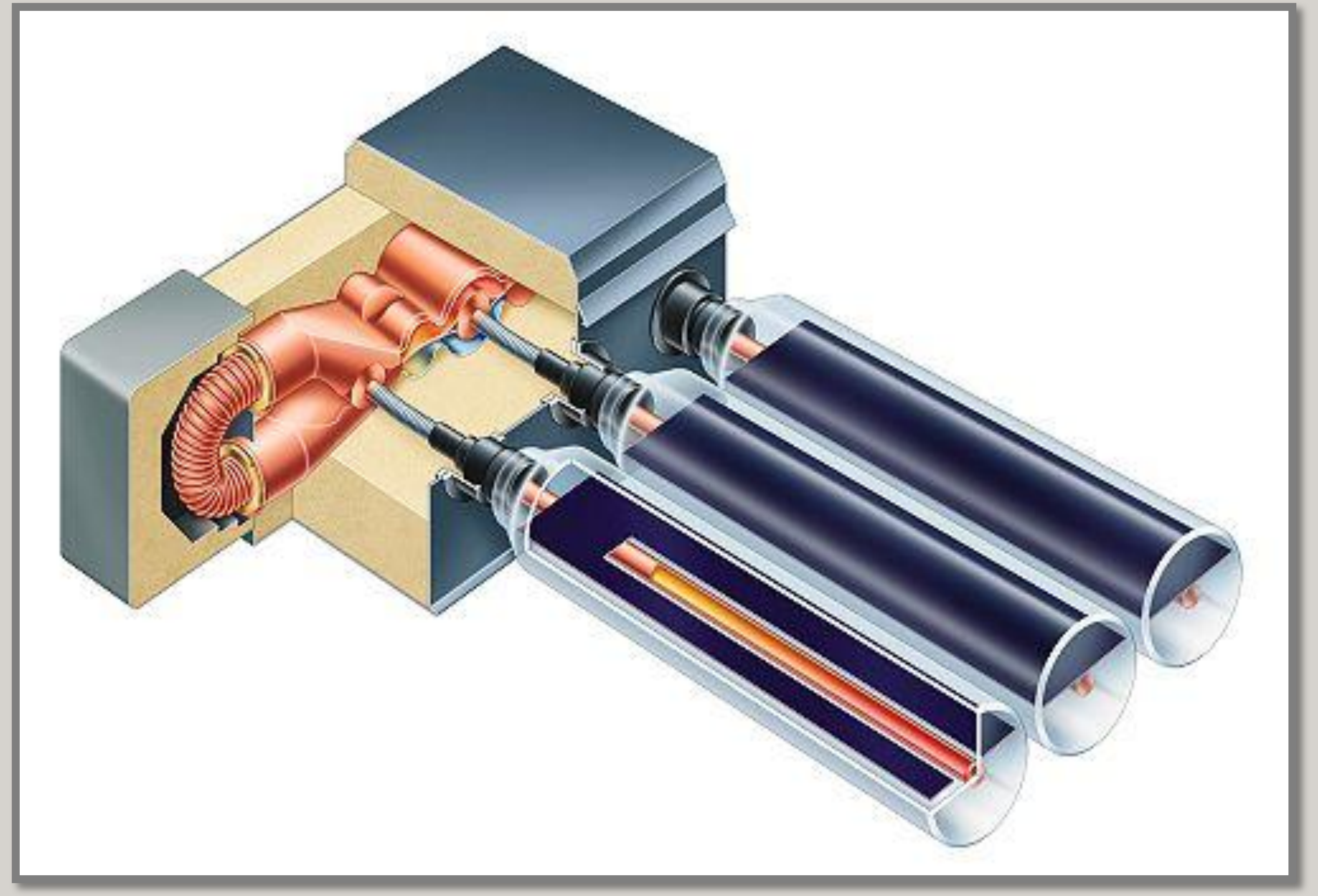


## Key Design Decisions

Collector location: Mechanical penthouse level

**Collector type:** Evacuated tube

- Better insulation reduces heat losses at low ambient temperatures
- Dry connection increases flexibility and serviceability



Viessman Vitosol 300-T model

# Mechanical Depth - Solar Thermal System



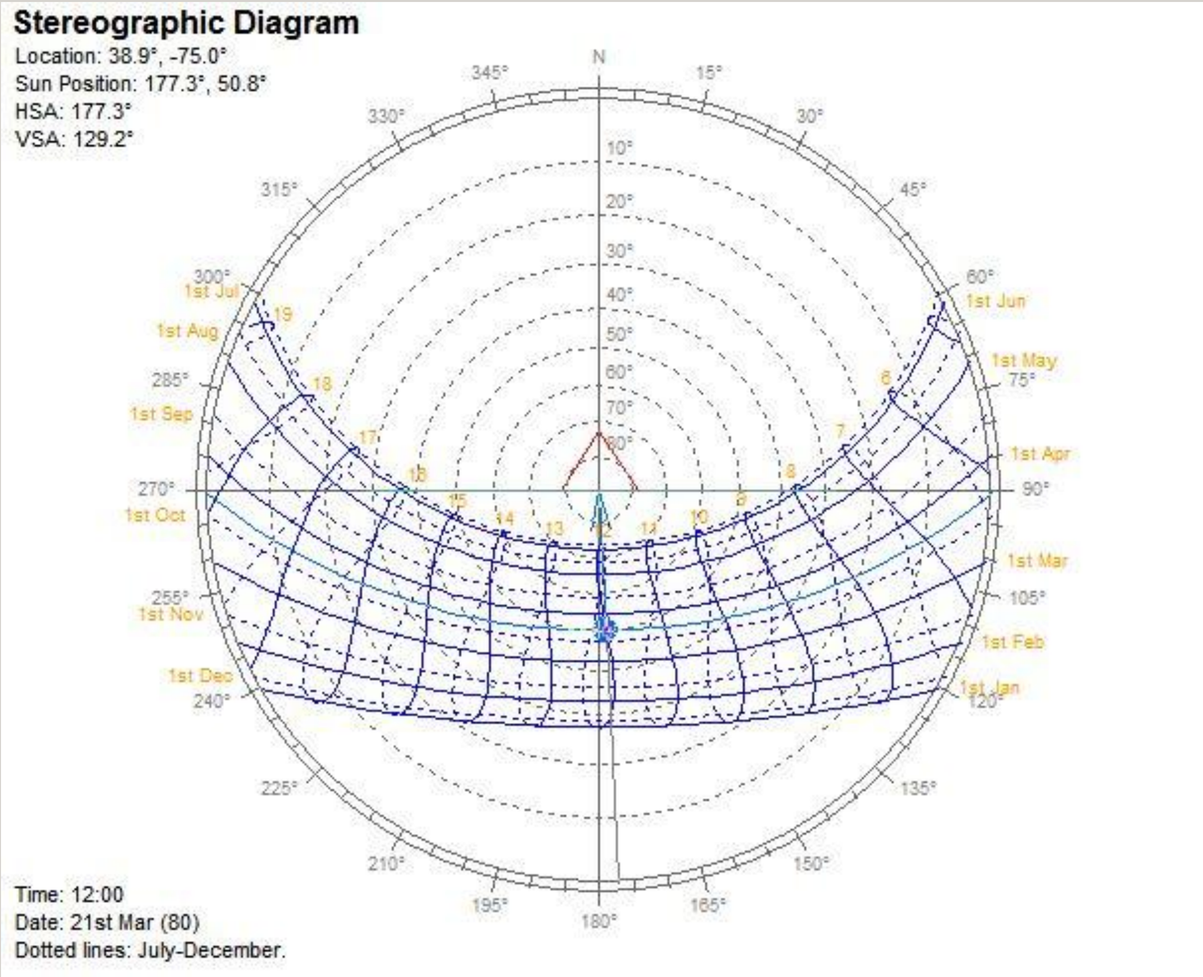
## Key Design Decisions

Collector location: Mechanical penthouse level

Collector type: Evacuated tube

**Collector orientation**:45° tilt angle facing south

- Increased winter exposure accounts for greater heat losses and higher demand in winter




At latitude of 38°54’N, solar altitude ranges from 27.7° to 74.55°.

# Mechanical Depth - Solar Thermal System



## Key Design Decisions

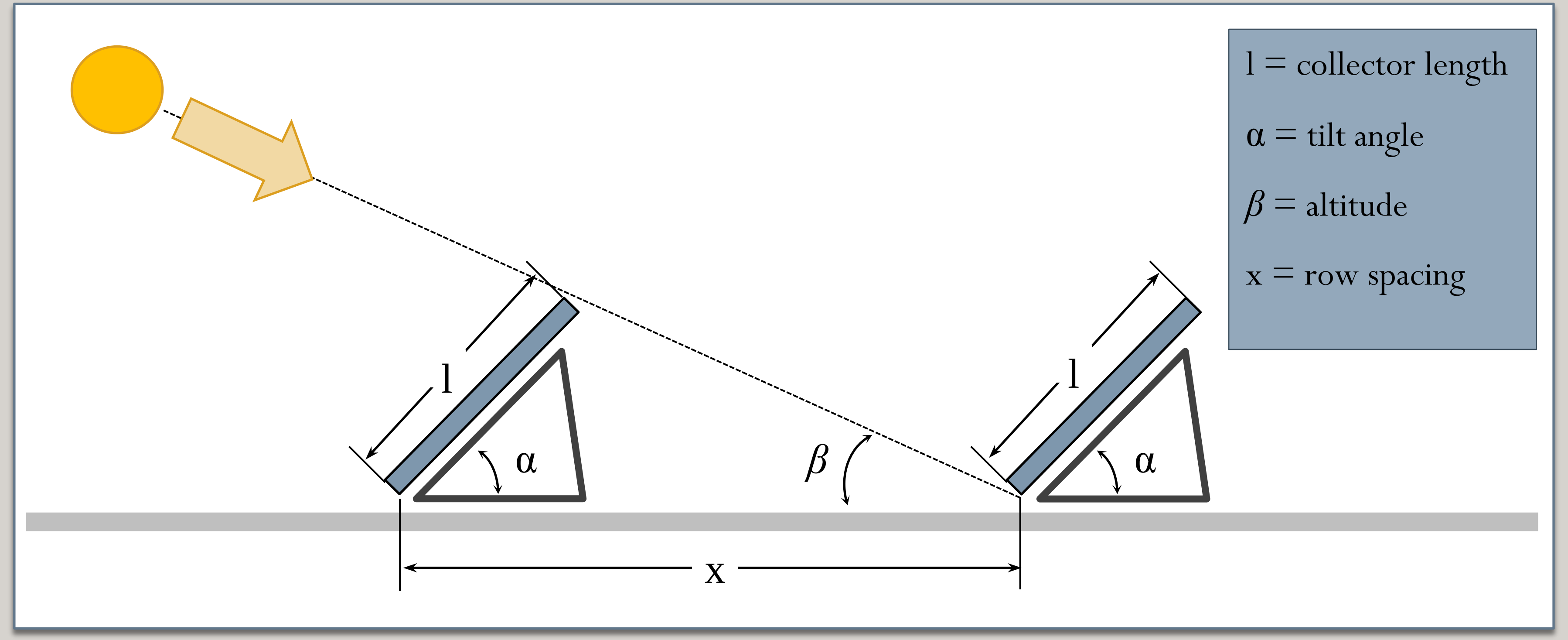
Collector location: Mechanical penthouse level

Collector type: Evacuated tube

Collector orientation: 45° tilt angle facing south

**Collector spacing:** 13.7 ft

- Sufficient collector spacing provides maximum solar exposure throughout the year




Tilt angle (α) = 45°

At winter solstice: solar altitude (*β*) = 27.7°

# Mechanical Depth - Solar Thermal System



## Key Design Decisions

Collector location: Mechanical penthouse level

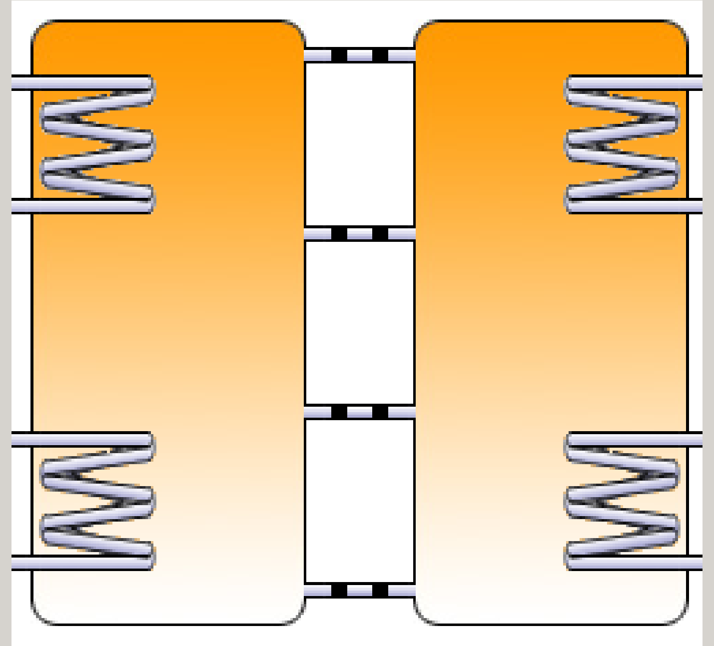
Collector type: Evacuated tube

Collector orientation: 45° tilt angle facing south

Collector spacing: 13.7 ft

**Thermal storage**: (2) 5,000 liter tanks (2,641 gal total)

- Unpressurized storage
- Vertical orientation
- Parallel connection



Plain tube internal heat exchangers required on the solar and load side

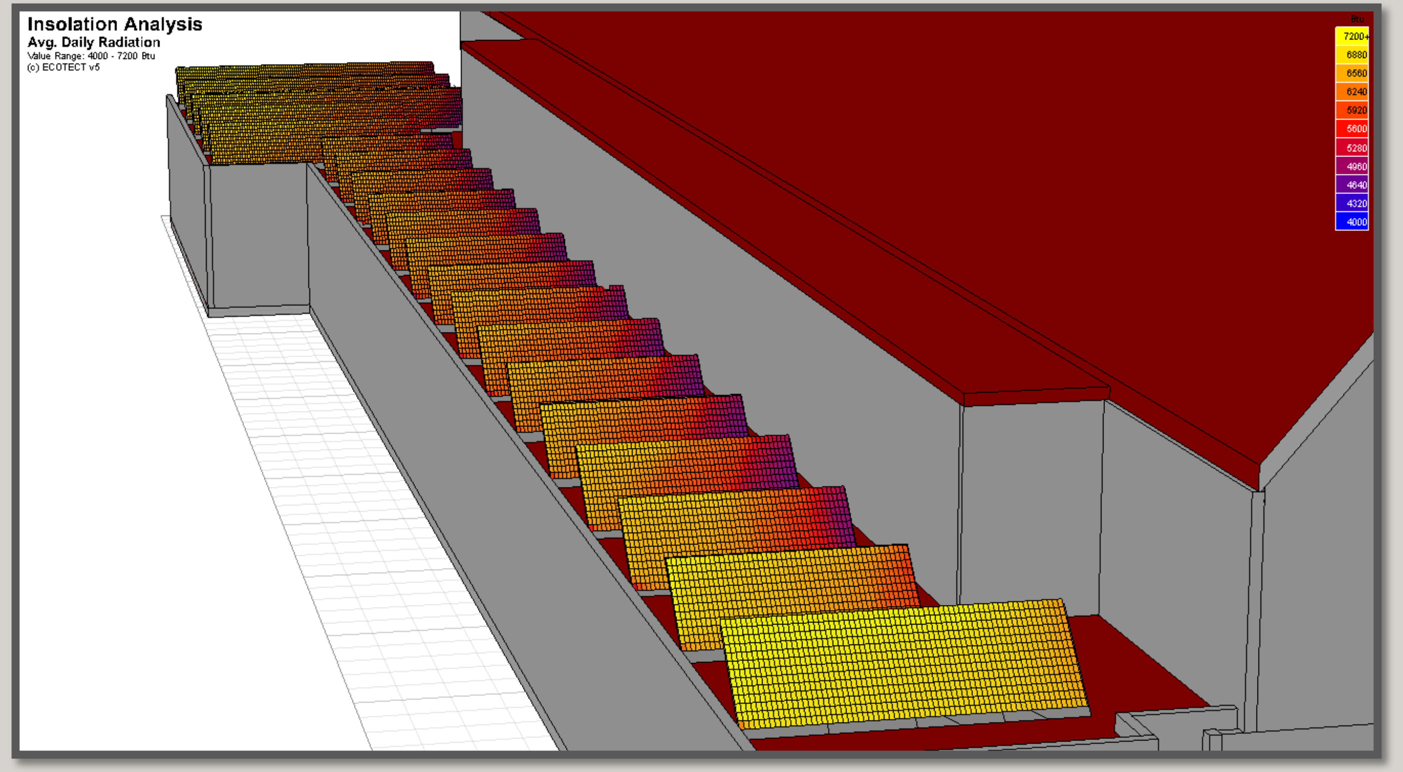
# Mechanical Depth - Solar Thermal System

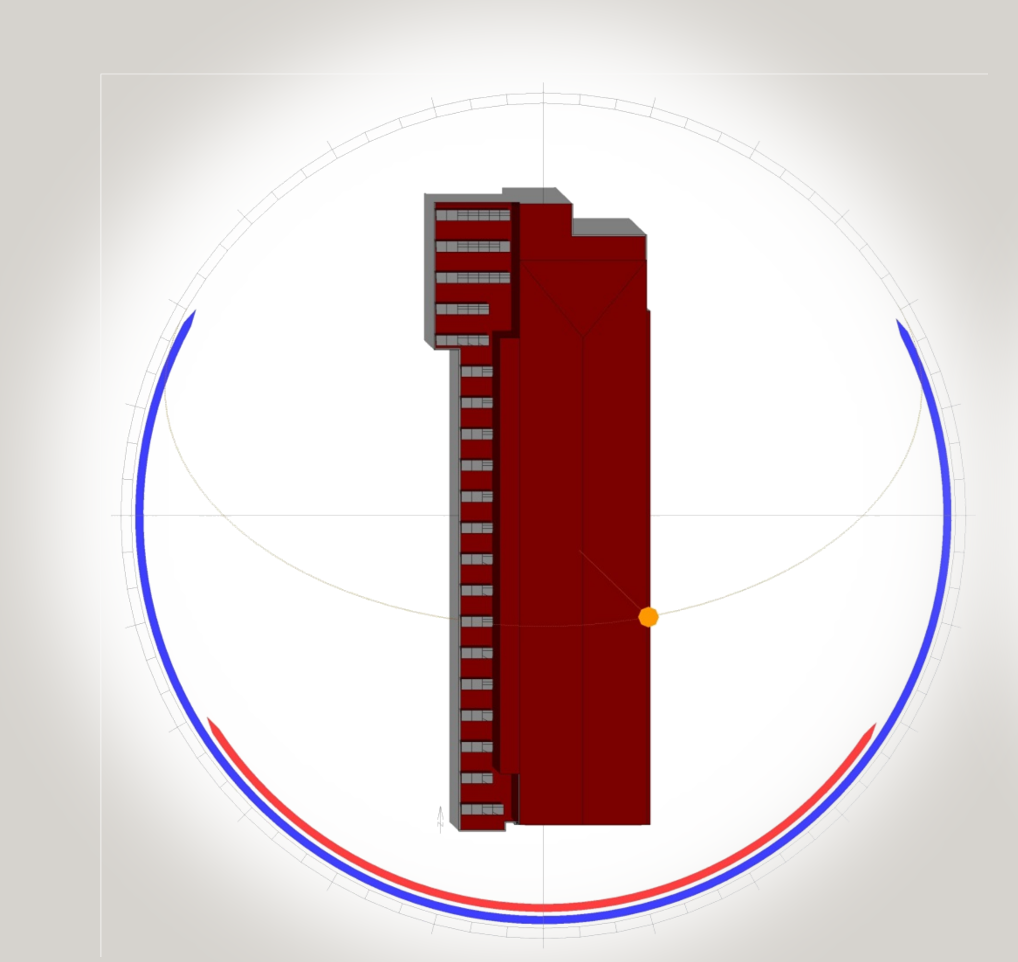


## Solar Availability

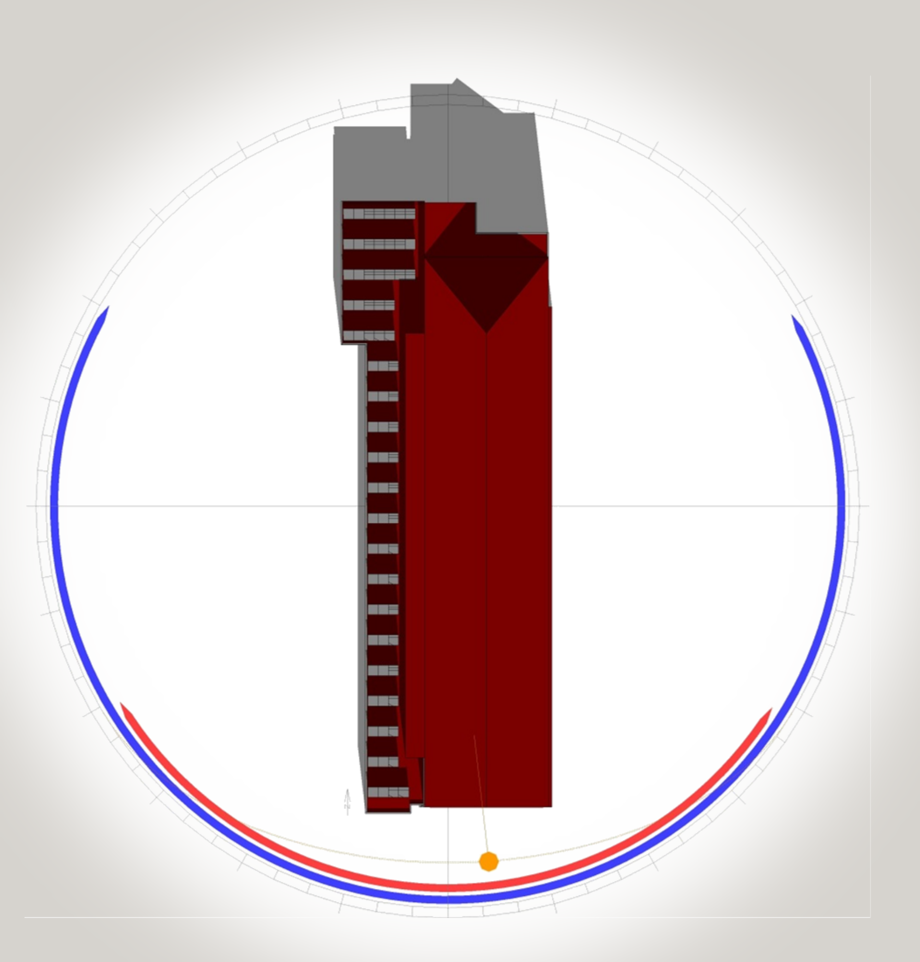
Ecotect Analysis results:

Full direct exposure after 11:05-11:40AM



11:05 AM Summer Solstice
Full Direct Solar



11:40 AM Winter Solstice
Full Direct Solar

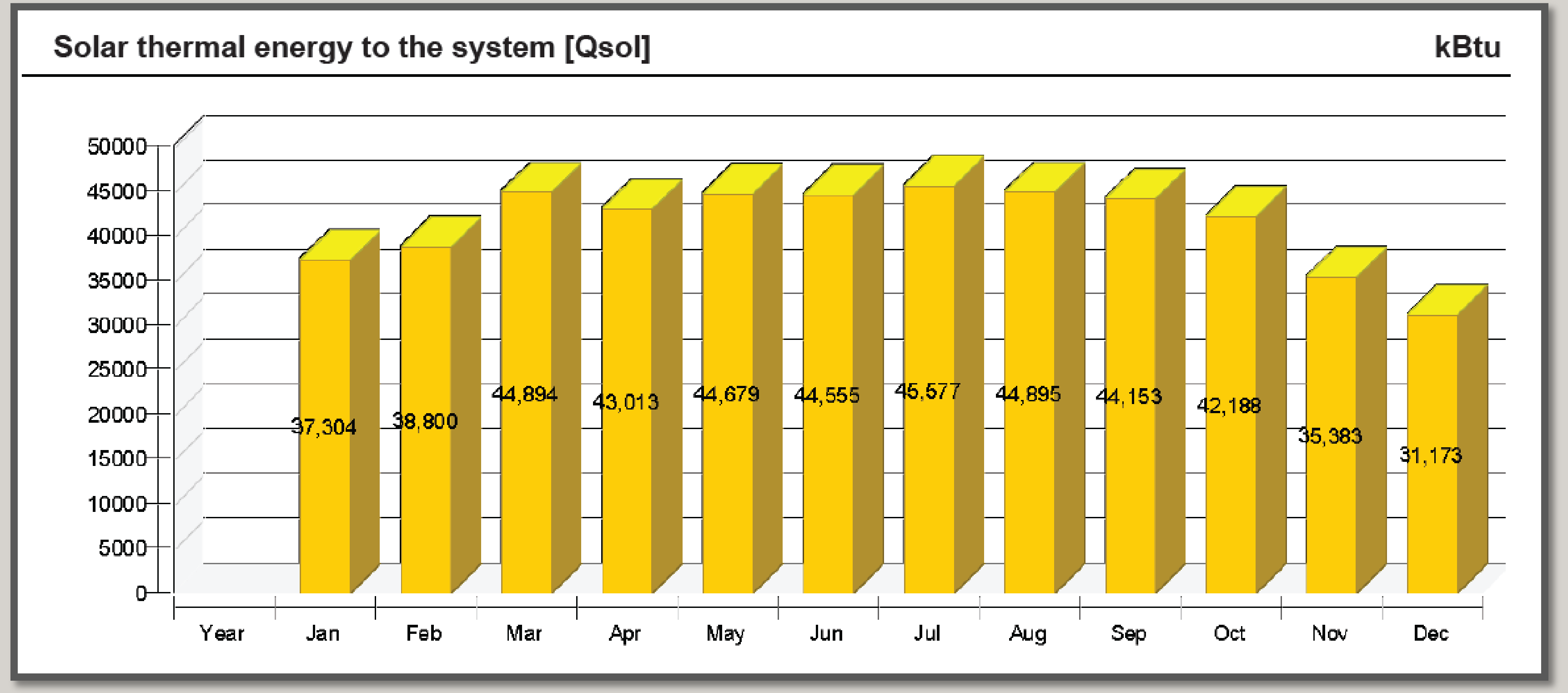
## Energy Savings

Polysun simulation results:

Useful solar gain = 496.6MMBtu/yr or 4966 therms/yr

Additional losses will include:

- Heat losses and inefficiencies of tanks and heat exchangers
- Variations in energy load profiles



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## Payback Period

Life cycle cost analysis results:

10 year revenue (present value) = **$534,103**

Payback period = **3 years of operation**

(assumed 100% useful solar energy gain into system)

**10 Year Life Cycle Cost Analysis**

Ann energy offset 4966 therms — Base discount rate: 1.9%

Base fuel rate Steam (nat gas) $14.95 /therm — (based on 7yr OMB estimate as of Apr 2010)

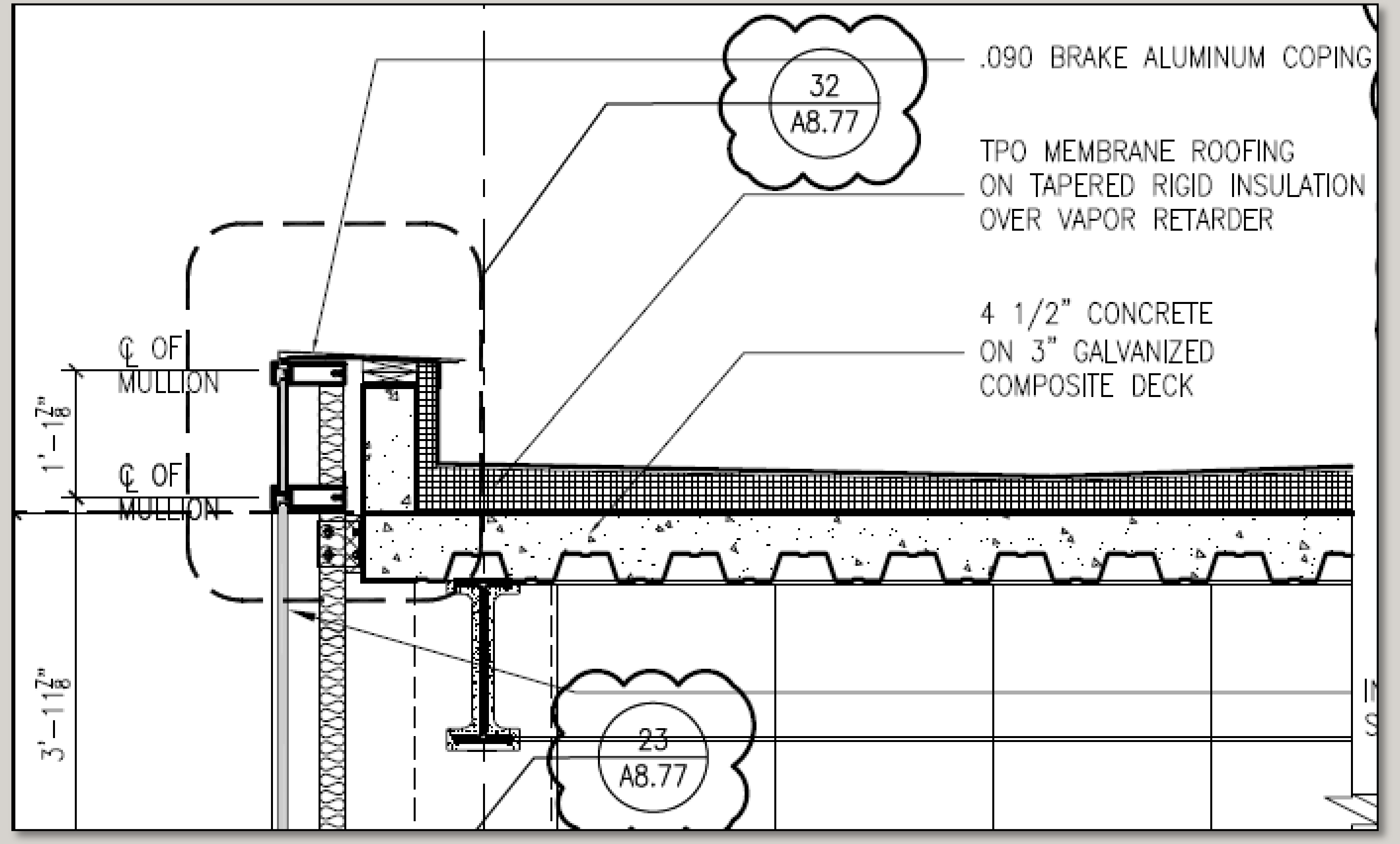
Ann fuel cost savings (2010) $74,258

| Date | Analysis year | Capital | PV maint | Nat gas esc. | Base steam savings | PV steam savings | | PV revenue per year | PV revenue total |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | | $ (210,000) | | | | | | $ (210,000) | $ (210,000) |
| 2011 | | | | | | | | | |
| 2012 | 1 | | $ (1,000) | 1.14 | $ 84,655 | $ 80,006.93 | | $ 79,007 | $ (130,993) |
| 2013 | 2 | | $ (1,000) | 1.14 | $ 84,655 | $ 78,515.14 | | $ 77,515 | $ (53,478) |
| 2014 | 3 | | $ (1,000) | 1.14 | $ 84,655 | $ 77,051.17 | | $ 76,051 | $ 22,573 |
| 2015 | 4 | | $ (1,000) | 1.16 | $ 86,140 | $ 76,941.06 | | $ 75,941 | $ 98,514 |
| 2016 | 5 | | $ (1,000) | 1.17 | $ 86,882 | $ 76,157.36 | | $ 75,157 | $ 173,672 |
| 2017 | 6 | | $ (1,000) | 1.17 | $ 86,882 | $ 74,737.35 | | $ 73,737 | $ 247,409 |
| 2018 | 7 | | $ (1,000) | 1.18 | $ 87,625 | $ 73,970.68 | | $ 72,971 | $ 320,380 |
| 2019 | 8 | | $ (1,000) | 1.18 | $ 87,625 | $ 72,591.45 | | $ 71,591 | $ 391,971 |
| 2020 | 9 | | $ (1,000) | 1.2 | $ 89,110 | $ 72,445.35 | | $ 71,445 | $ 463,416 |
| 2021 | 10 | | $ (1,000) | 1.21 | $ 89,853 | $ 71,687.01 | | $ 70,687 | $ 534,103 |
| Column total | | $ (210,000) | $ (10,000) | | | $ 754,103 | | **$ 534,103** | |

## Constructability Analysis: Existing Roof Integration

A solar collector mounting system needs to be integrated into the existing flat roof.

- 7 ½” total depth concrete slab-on-deck
- Up to 8” rigid insulation
- Waterproof membrane



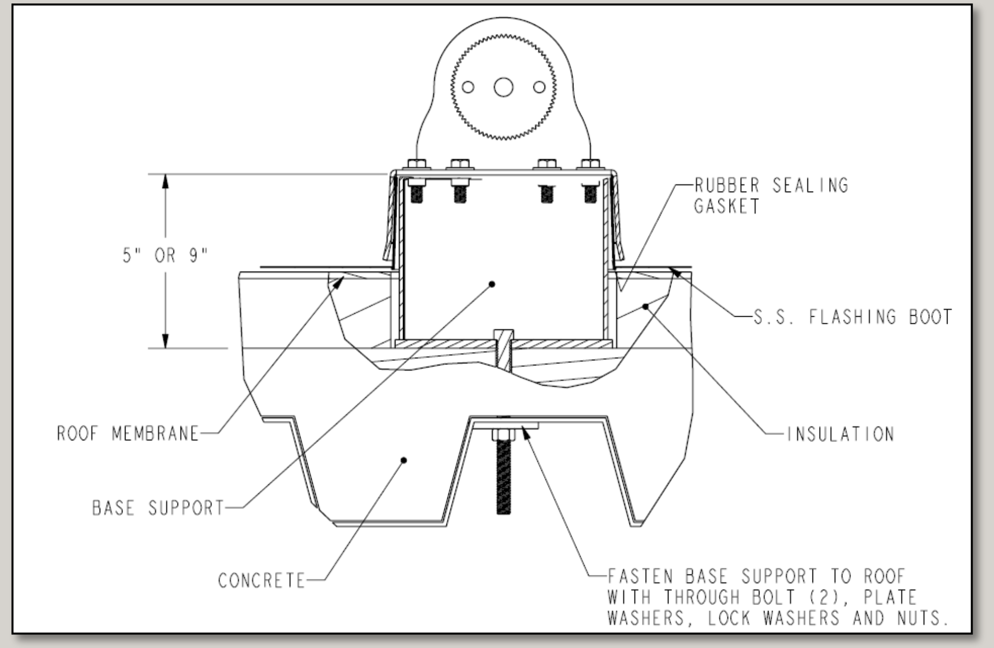

Penthouse level roof section

# Construction Breadth

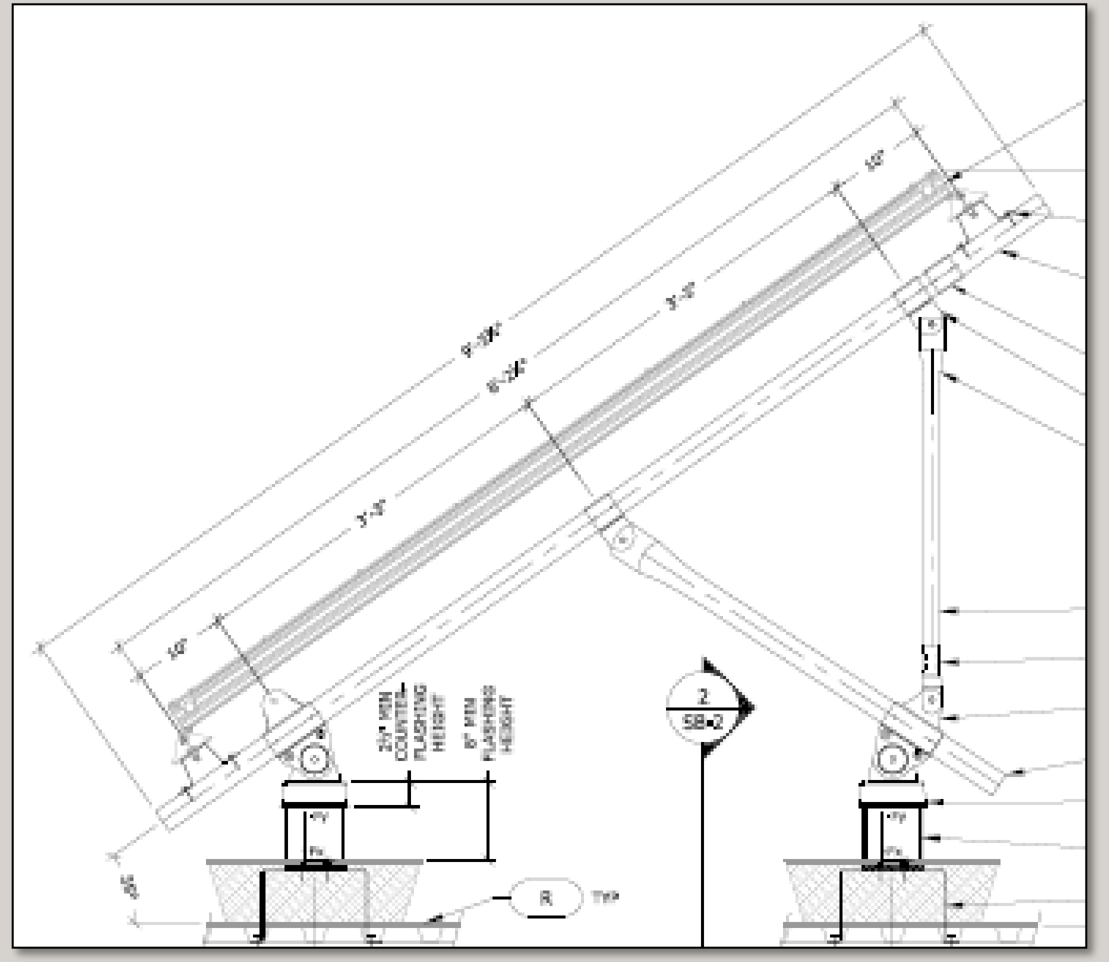


## Constructability Analysis: Existing Roof Integration

Silverback Solar frame and mounting system will be used to provide a secure mounting solution with minimal effects to existing roofing system.




Typical base support mounting detail

Typical Silverback Solar frame detail

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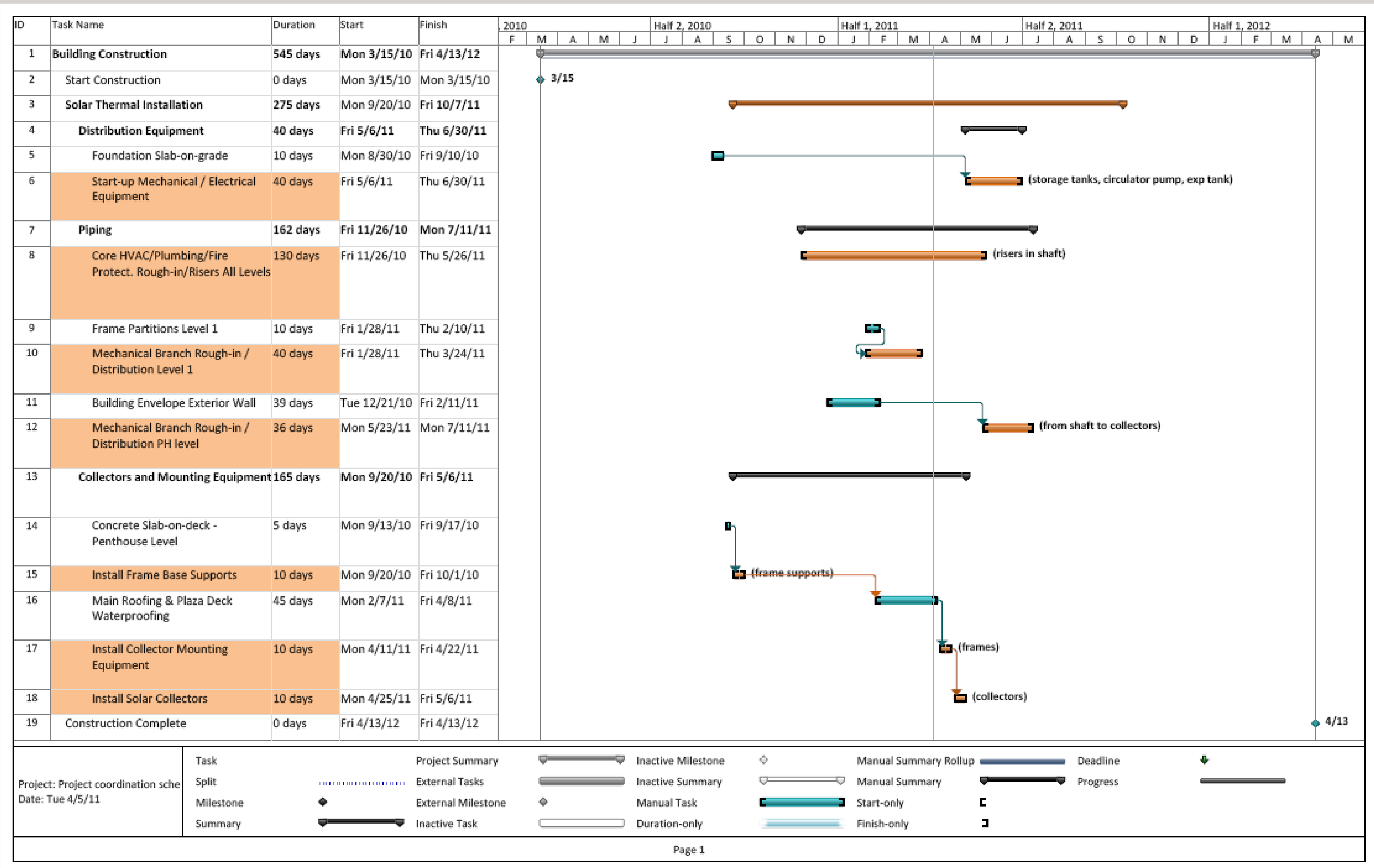
## Trade Coordination and Schedule Impacts

Additional solar subcontractor will allow an efficient installation without any delays in construction

A. Equipment in ground floor mechanical room

B. Piping – risers and distribution

C. Collectors and mounting equipment



# Summary and Conclusion



## Summary

Short payback period

- 3 years

Reduced carbon footprint

- sustainable image and additional LEED points

Minimal structural and construction impacts

- no additional structural resizing (see final report)
- no construction delays with additional solar subcontractor

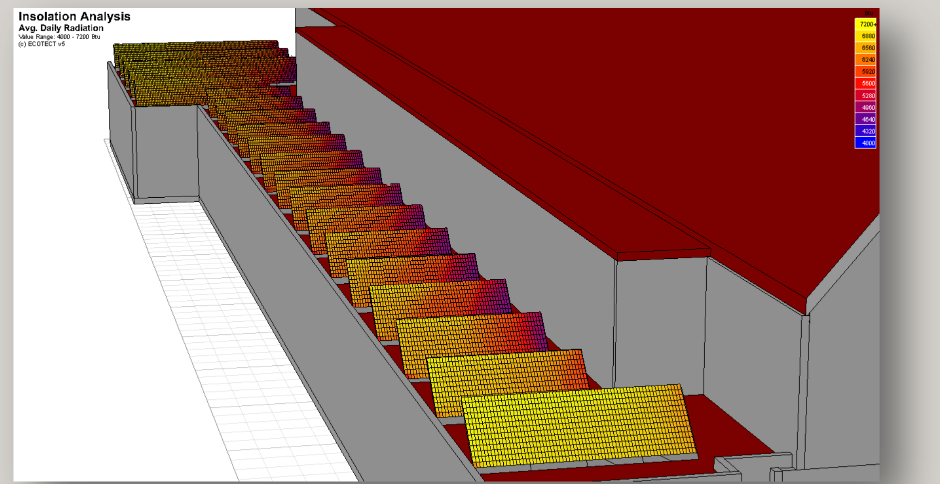
**Highly recommend considering solar thermal implementation for this building**

…even after completed construction

# Q/A



## Questions?




## Acknowledgments

Penn State University AE Department

Project Team

Owner: Georgetown University

CM: Whiting-Turner

Architect: Payette Associates

MEP Consultant: Vanderweil Engineers

Industry Specialists

SOLARHOT

Silverback Solar

Penn State Center for Sustainability