

Mechanical Option



# Kevin Edstrom

- 2011 Senior Thesis
- April 12<sup>th</sup>, 2011

- 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

# Kevin Edstrom



- Mechanical Option
- 2011 Senior Thesis
- April 12<sup>th</sup>, 2011

## Project Overview

### 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

Georgetown
------------

Size:

Client:

Architect:

**MEP Consultants:** 

CM:

**Construction Date** 

University	New Science Center
	154,000 SF
	Georgetown University
	Payette Associates
5:	R.G. Vanderweil Engineers
	Whiting-Turner Contracting
es:	May 2010 – July 2012



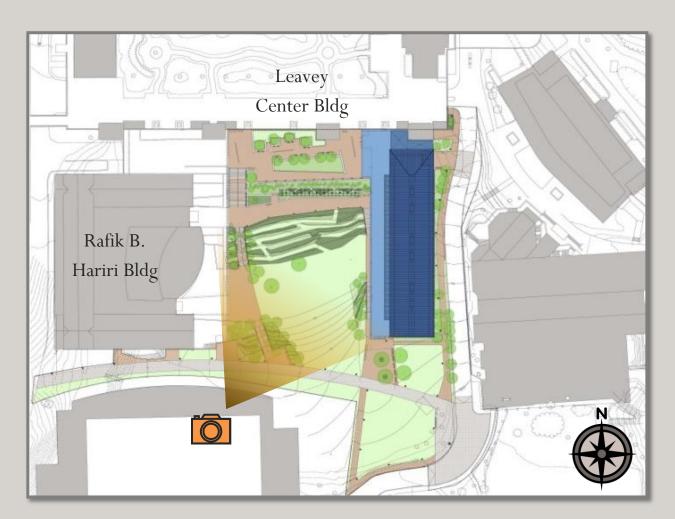
### Location



## Project Overview

### 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



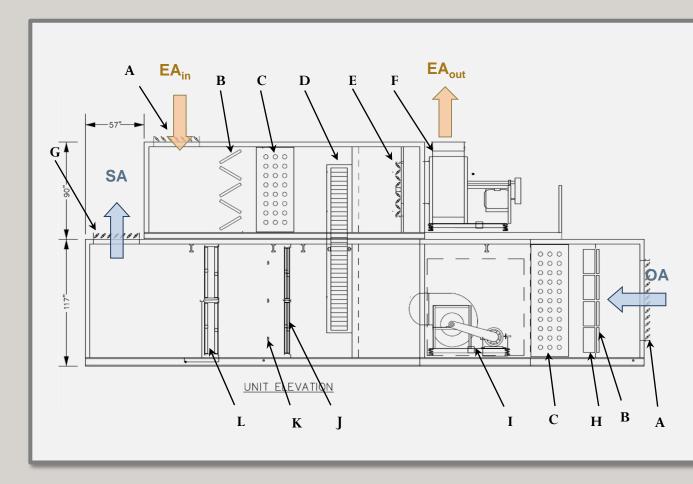
Site Plan



- 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

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

Dedicated Outdoor Air System





A - Inlet air dampers **B** - Pre-filters C - Sound attenuator **D** - Enthalpy wheel **E** - Fan isolation damper **F** - Exhaust fan G - Discharge dampers H - Final filters I - Supply fan J - HW coil **K** - Steam humidifier L - Cooling coil

### Typical Air Handling Unit detail

- 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

- AHU preconditioning

- Active chilled beams
- Fan coil units
- Unit heaters

- Space Heating and Cooling System

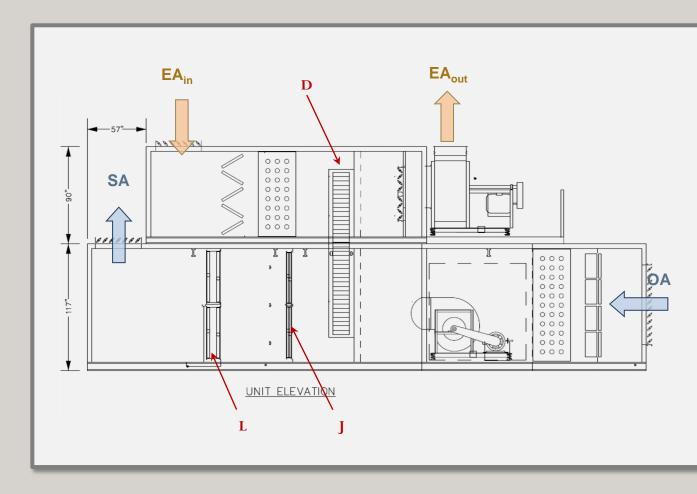
- Project Overview
- Existing Mechanical System
  - DOAS
  - Space Heating and Cooling
  - Plumbing
  - Energy Consumption
- Mechanical Depth: Solar Thermal System
  - Overview
  - Key Design Decisions
  - Energy Savings and Payback Period
- Construction Breadth
  - Constructability
  - Trade Coordination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

Q/A

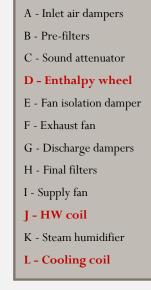
### - AHU preconditioning

- Active chilled beams
- Fan coil units
- Unit heaters

Space Heating and Cooling System







### Typical Air Handling Unit detail

- 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

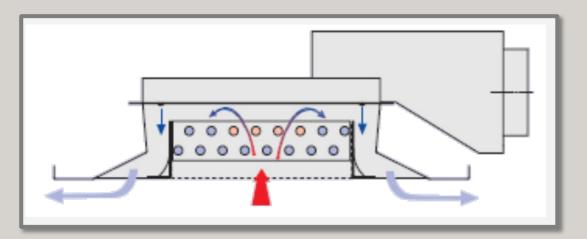
Space Heating and Cooling System

- AHU preconditioning

- Active chilled beams

- Fan coil units

- Unit heaters



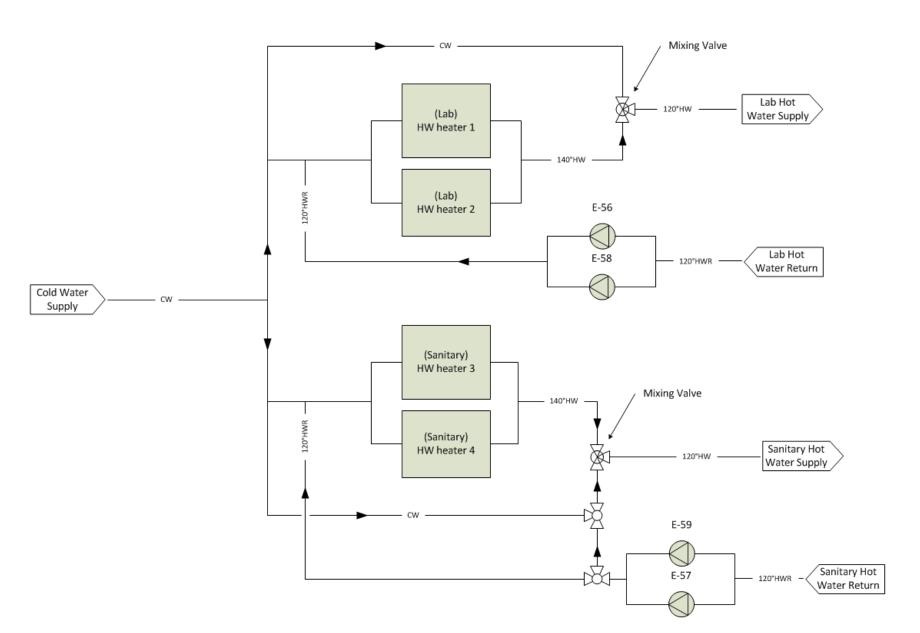
### Typical chilled beam detail

- 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

- Plumbing System
- Domestic Hot Water
  - Sanitary and lab loop
  - Recirculated system

Q/A

### Existing Domestic Hot Water Distribution



- 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

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  $\rightarrow$  1223 MBtu/day 1223 x 1.25 = 1529 MBtu/day

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

- Relatively constant demand throughout the year

# (recirculated system losses)

- 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

System Objective:

Design Goals:

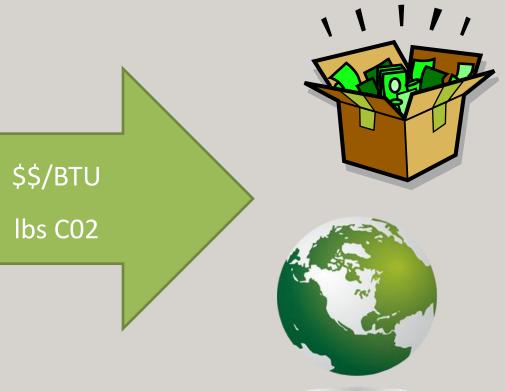
- Minimize changes in existing design (structural / mechanical)
- Prevent delays in existing construction schedule

## Mechanical Depth - Solar Thermal System

Utilize solar energy to offset district steam demand

Reduced operating costs and carbon footprint





- 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

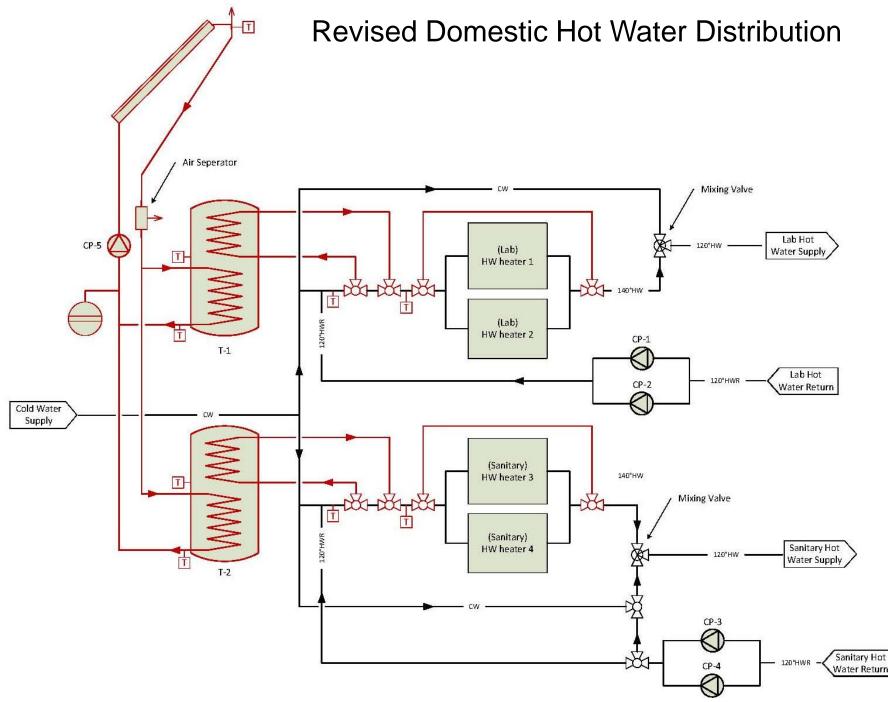
## Mechanical Depth - Solar Thermal System

### Overview

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

Proposed system will supplement existing domestic hot water



- 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

Key Design Decisions

**Collector location**: Mechanical penthouse level

- 45° tilt angle

## Mechanical Depth - Solar Thermal System

- Sufficient space for (77) 2x3m solar collectors at

- Total absorber area: 1716 sf



- 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

# Mechanical Depth - Solar Thermal System

Key Design Decisions

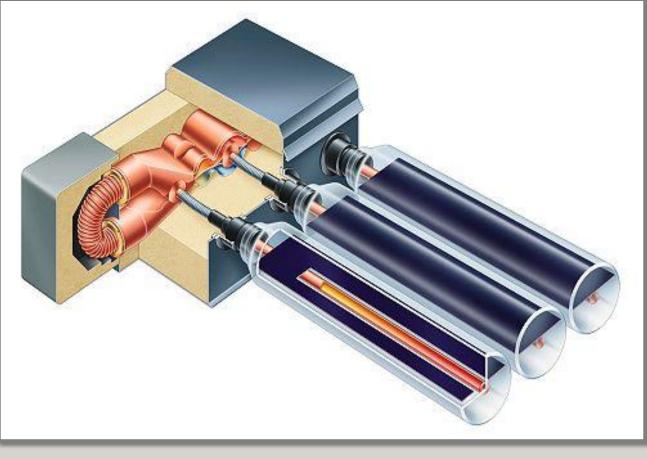
Collector location:

Collector type:

- Better insulation reduces heat losses at low ambient temperatures
- serviceability

- Mechanical penthouse level
- Evacuated tube

- Dry connection increases flexibility and



Viessman Vitosol 300-T model

- 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

# Mechanical Depth - Solar Thermal System

Key Design Decisions

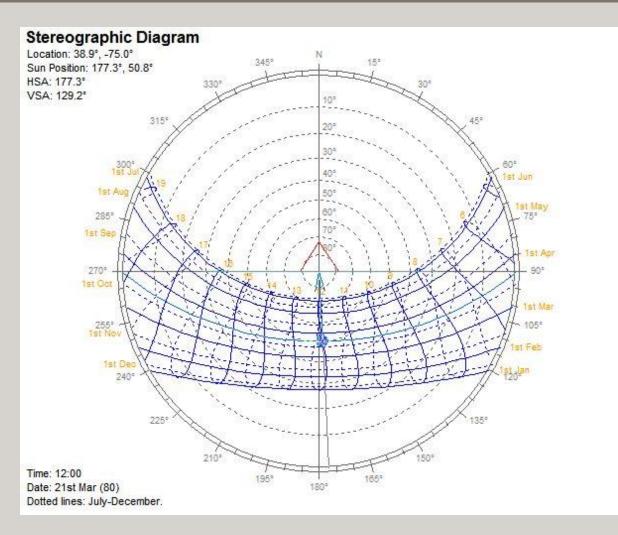
Collector location:

Collector type:

Increased winter exposure accounts for greater

- Mechanical penthouse level Evacuated tube
- **Collector orientation**:45° tilt angle facing south

heat losses and higher demand in winter



27.7° to 74.55°.

### At latitude of 38°54'N, solar altitude ranges from

- 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

## Mechanical Depth - Solar Thermal System

### Key Design Decisions

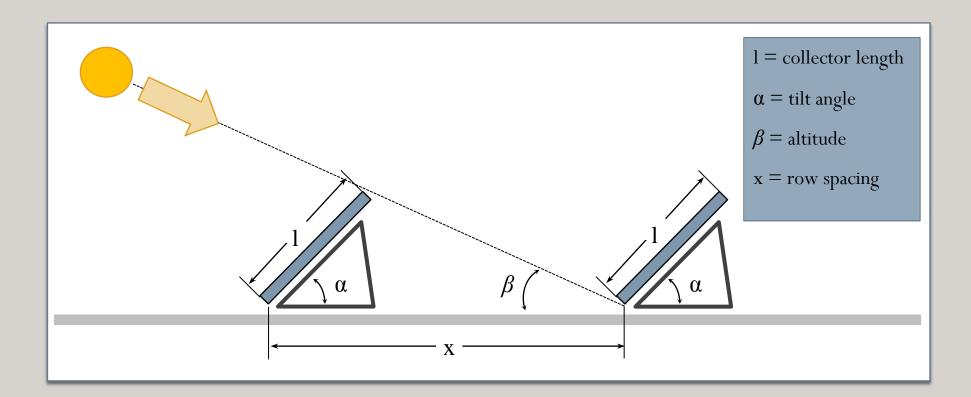
Collector location:

Collector type:

**Collector spacing:** 13.7 ft

Sufficient collector spacing provides maximum solar exposure throughout the year

- Mechanical penthouse level Evacuated tube
- Collector orientation: 45° tilt angle facing south



Tilt angle ( $\alpha$ ) = 45°

At winter solstice: solar altitude ( $\beta$ ) = 27.7°

- 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

# Mechanical Depth - Solar Thermal System

## **Key Design Decisions**

Collector location:

Collector type:

Collector spacing:

Thermal storage:

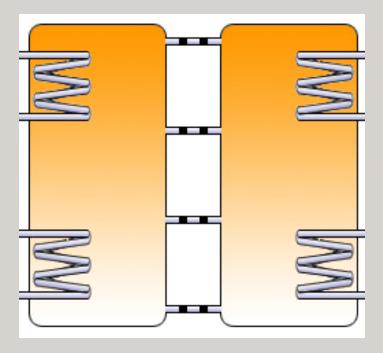
Mechanical penthouse level

Evacuated tube

- Collector orientation: 45° tilt angle facing south
  - 13.7 ft
  - (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

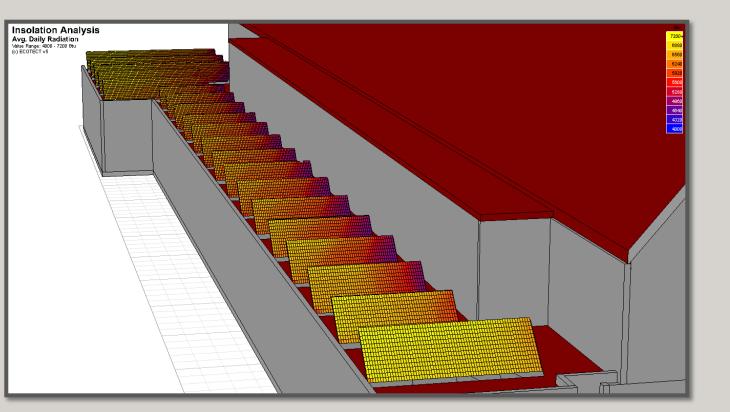
- Project Overview
- Existing Mechanical System
  - DOAS
  - Space Heating and Cooling
  - Plumbing
  - Energy Consumption
- Mechanical Depth: Solar Thermal System
  - Overview
  - Key Design Decisions
  - Energy Savings and Payback Period
- Construction Breadth
  - Constructability
  - Trade Coordination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

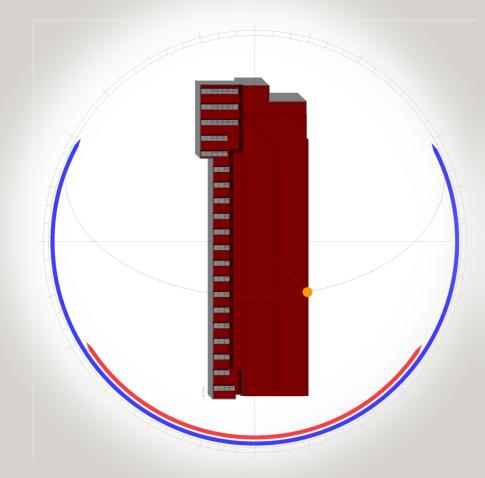
## Mechanical Depth - Solar Thermal System

### Solar Availability

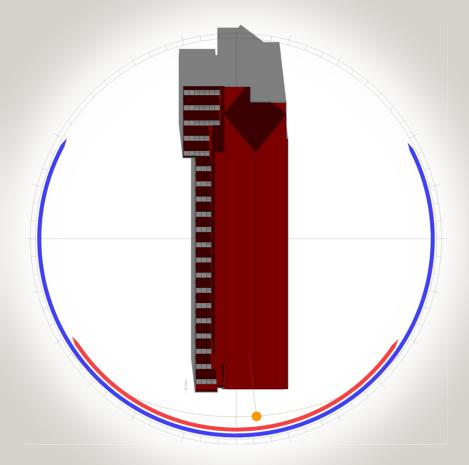
# Ecotect Analysis results:

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





11:05 AM Summer Solstice Full Direct Solar



11:40 AM Winter Solstice Full Direct Solar

- 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

## Energy Savings

Polysun simulation results:

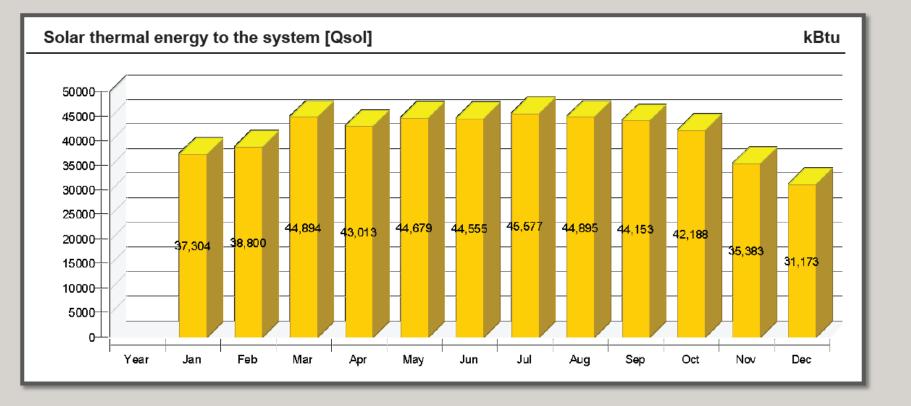
Additional losses will include:

- Variations in energy load profiles

## Mechanical Depth - Solar Thermal System

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

- Heat losses and inefficiencies of tanks and heat exchangers



- 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

## Mechanical Depth - Solar Thermal System

### 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)

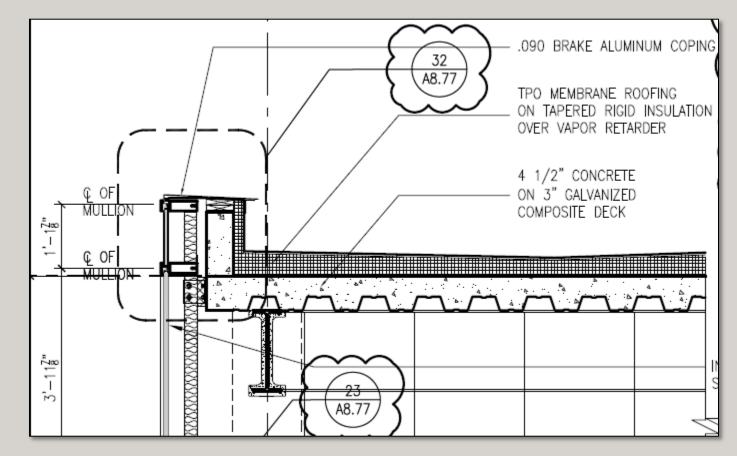
Ann energy offset				4966 therms		Base discount rate: 1				1.9%			
Base fuel rate Steam (nat gas)			is)	\$14.95 /therm		(based on 7yr OMB estimate as of Apr 20				Apr 2010)			
nn fuel co	st savings (2	010)		\$74,258									
100	Analysis						se steam			PV r	evenue per	P	√ revenue
Date	year	_	Capital	PV maint	Nat gas esc.	:	savings	PV s	team savings		year		total
2010		\$	(210,000)							\$	(210,000)	\$	(210,00
2011								į.					
2012	1			\$ (1,000)	1.14	\$	84,655	\$	80,006.93	\$	79,007	\$	(130,99
2013	2			\$ (1,000)	1.14	\$	84,655	\$	78,515.14	\$	77,515	\$	(53,47
2014	3			\$ (1,000)	1.14	\$	84,655	\$	77,051.17	\$	76,051	\$	22,57
2015	4			\$ (1,000)	1.16	\$	86,140	\$	76,941.06	\$	75,941	\$	98,51
2016	5			\$ (1,000)	1.17	\$	86,882	\$	76,157.36	\$	75,157	\$	173,67
2017	6			\$ (1,000)	1.17	\$	86,882	\$	74,737.35	\$	73,737	\$	247,40
2018	7			\$ (1,000)	1.18	\$	87,625	\$	73,970.68	\$	72,971	\$	320,38
2019	8	Ъ		\$ (1,000)	1.18	\$	87,625	\$	72,591.45	\$	71,591	\$	391,97
2020	9			\$ (1,000)	1.2	\$	89,110	\$	72,445.35	\$	71,445	\$	463,41
2021	10			\$ (1,000)	1.21	\$	89,853	\$	71,687.01	\$	70,687	\$	534,10

- 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

**Construction Breadth** 

### Constructability Analysis: Existing Roof Integration

- A solar collector mounting system needs to be integrated into the existing flat roof.
- $7\frac{1}{2}$ " total depth concrete slab-on-deck
- Up to 8" rigid insulation
- Waterproof membrane



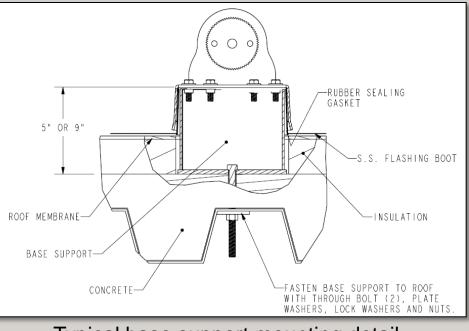
Penthouse level roof section

- 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

# Construction Breadth

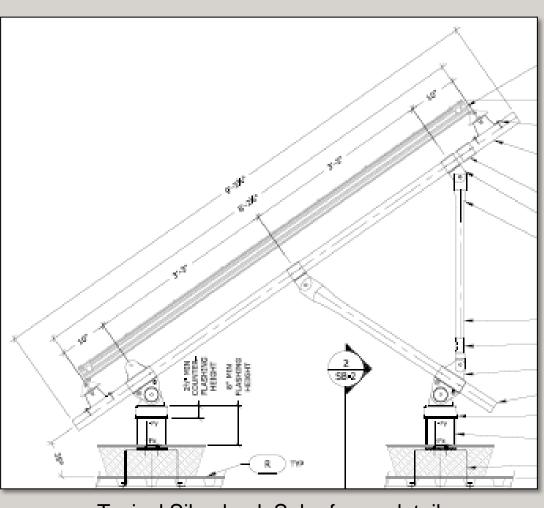
## Constructability Analysis: Existing Roof Integration

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

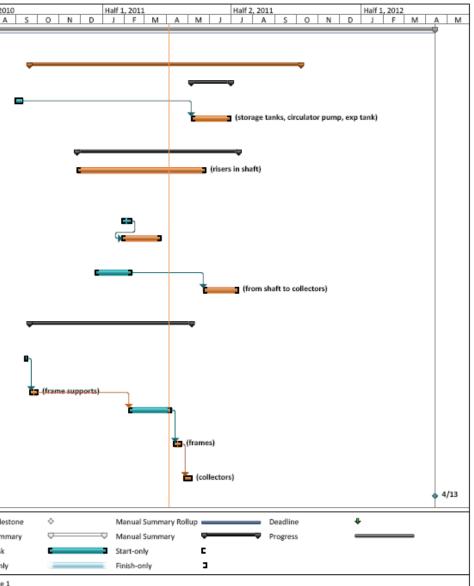
- Project Overview
- Existing Mechanical System
  - DOAS
  - Space Heating and Cooling
  - Plumbing
  - Energy Consumption
- Mechanical Depth: Solar Thermal System
  - Overview
  - Key Design Decisions
  - Energy Savings and Payback Period
- Construction Breadth
  - Constructability
  - Trade Coordination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

# Construction Breadth

## 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

ID	Task Name		Duration	Start	Finish	2010 F M A M	Half 2, 20
1	Building Construction		545 days	Mon 3/15/10	Fri 4/13/12		
2	Start Construction		0 days	Mon 3/15/10	Mon 3/15/10	3/15	
3	Solar Thermal Installa	275 days	Mon 9/20/10	Fri 10/7/11			
4	Distribution Equipm	ent	40 days	Fri 5/6/11	Thu 6/30/11		
5	Foundation Slab-	10 days	Mon 8/30/10	Fri 9/10/10			
6	Start-up Mechani Equipment	cal / Electrical	40 days	Fri 5/6/11	Thu 6/30/11		
7	Piping	162 days	Fri 11/26/10	Mon 7/11/11			
8	Core HVAC/Pluml Protect. Rough-in		130 days	Fri 11/26/10	Thu 5/26/11		
9	Frame Partitions	10 days	Fri 1/28/11	Thu 2/10/11			
10	Mechanical Brand Distribution Level	40 days	Fri 1/28/11	Thu 3/24/11			
11	Building Envelope	39 days	Tue 12/21/10	Fri 2/11/11			
12	Mechanical Brand Distribution PH le	36 days	Mon 5/23/11	Mon 7/11/11			
13	Collectors and Mounting Equipment		165 days	Mon 9/20/10	Fri 5/6/11		
14	Concrete Slab-on-deck - Penthouse Level		5 days	Mon 9/13/10	Fri 9/17/10		
15	Install Frame Base Supports		10 days	Mon 9/20/10	Fri 10/1/10		
16	Main Roofing & Plaza Deck Waterproofing		45 days	Mon 2/7/11	Fri 4/8/11		
17	Install Collector Mounting Equipment		10 days	Mon 4/11/11	Fri 4/22/11		
18	Install Solar Colle	10 days	Mon 4/25/11	Fri 5/6/11			
19	Construction Complete	0 days	Fri 4/13/12	Fri 4/13/12			
		Task			Project Summary		Inactive Mile
	t: Project coordination sche	Split			External Tasks		Inactive Sum
Date:	Tue 4/5/11	Milestone	*		External Mileston	ie 🔶	Manual Task
		Summary			Inactive Task		Duration-on



- 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

## 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

- 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

## 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

