

# Integrating Large Scale, Innovative Solar Thermal Systems into the Built Environment



June 26, 2013

11:00am – 12:30PM

Track: Renewable & Alternative Energy Sources

Sponsor: 6.7 Solar Energy Utilization

**Hybrid Geothermal / Solar Thermal  
HVAC System: Part1 Design**  
*(OU Human Health Building)*

**Jim Leidel**  
Oakland University  
Denver, June 26, 2013

# Session Learning Objectives

1. What do solar thermal energy systems provide for the built environment?
2. Components of active solar thermal systems?
3. Examples of loads served by solar thermal systems.
4. Three case studies where large solar thermal systems.
5. Thermal energy storage (it's use and sizing) required by solar energy supply vs load. Review for each case.
6. Design challenges & major system design options faced while implementing large solar thermal projects.

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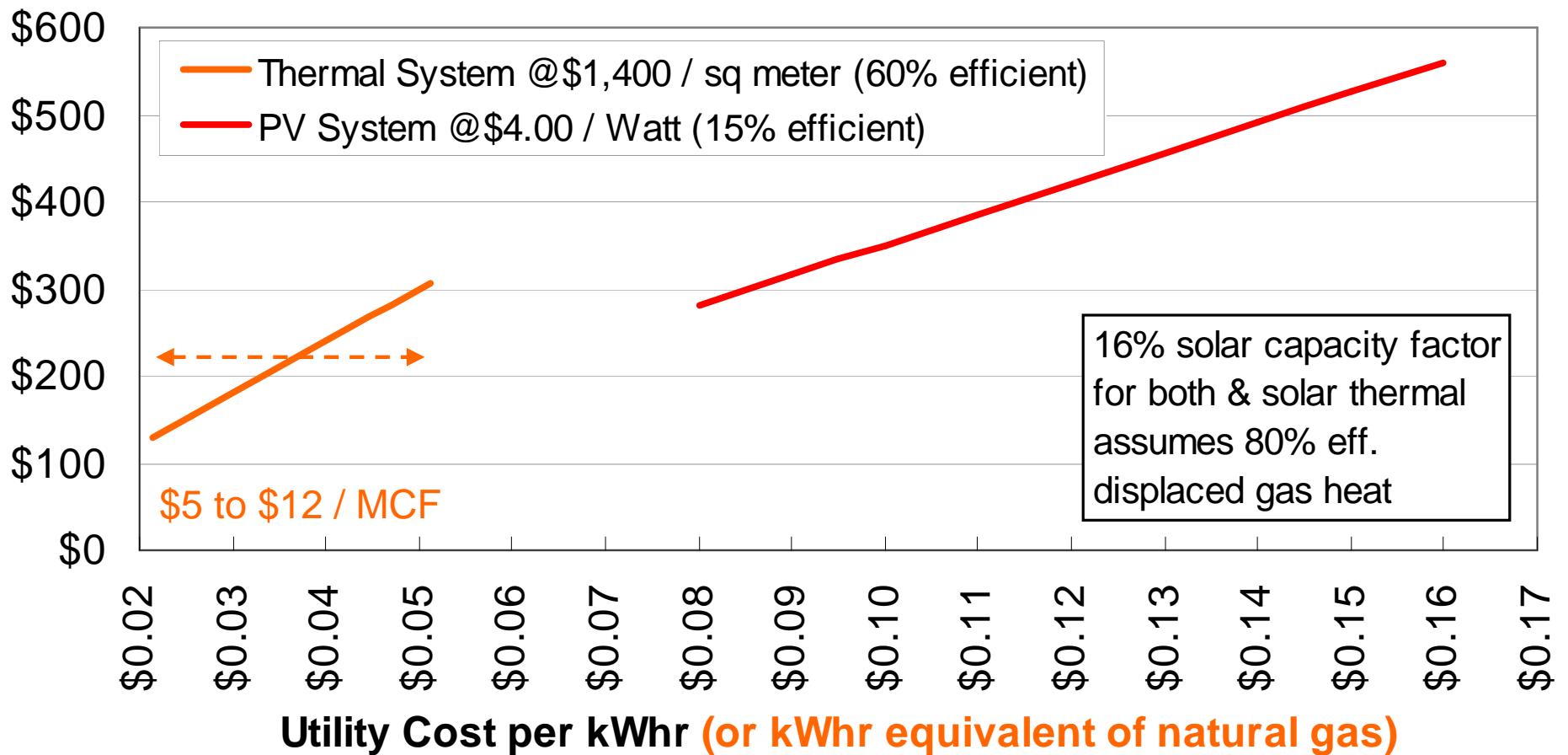
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# AGENDA

- Quick Look at Solar Thermal Economics as Compared to Solar PV
- Case Studies:
  - Oakland University Human Health Building: Hybrid Geothermal / Solar Thermal HVAC System: Pt 1 Design
  - District Energy St. Paul: Solar Thermal & Biomass for Downtown St. Paul, Minnesota
  - Drake Landing Solar Community with Seasonal Energy Storage

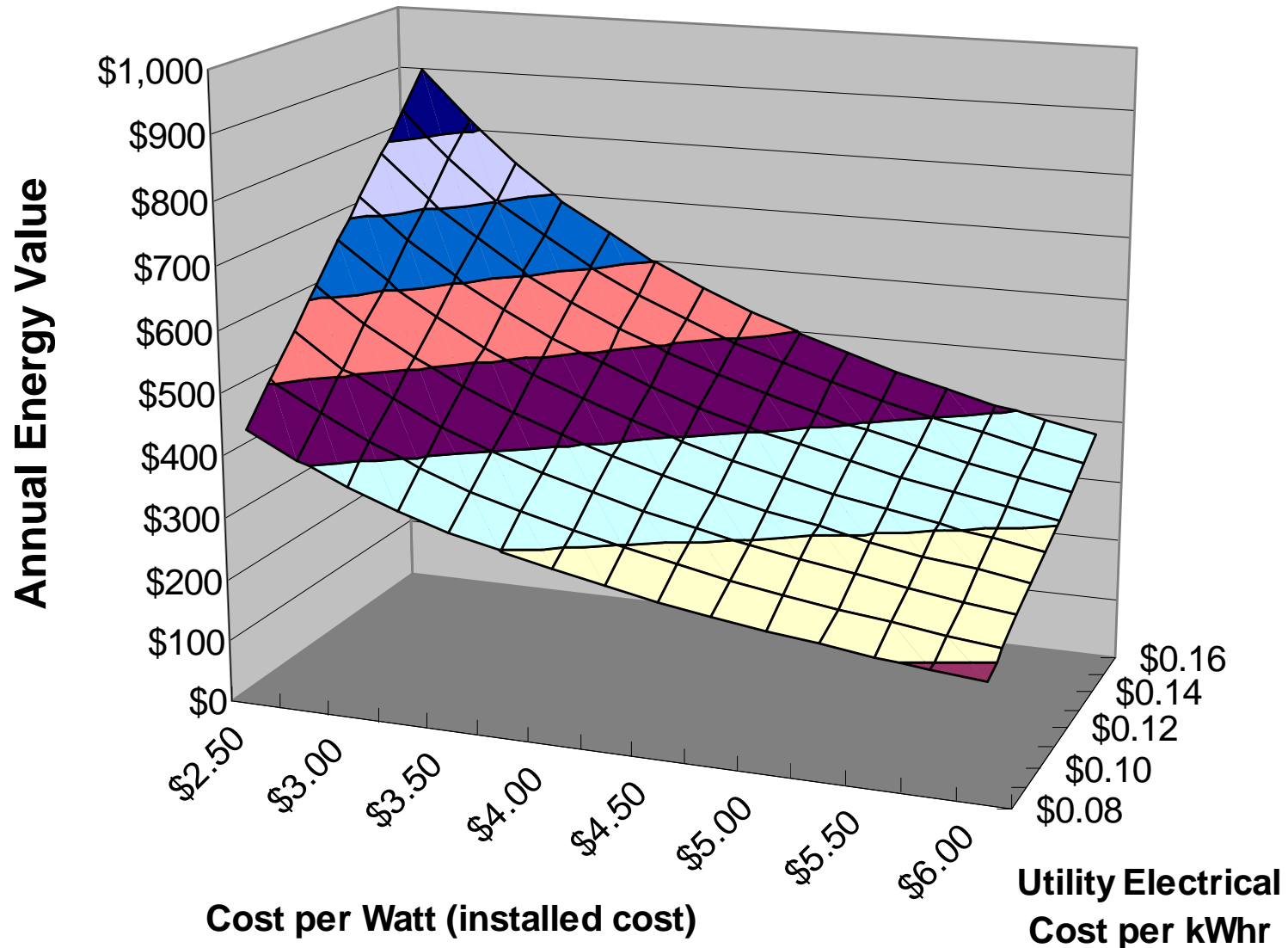
# **Economics of Solar Thermal**

*Solar PV vs. Solar Thermal  
in Today's Marketplace*



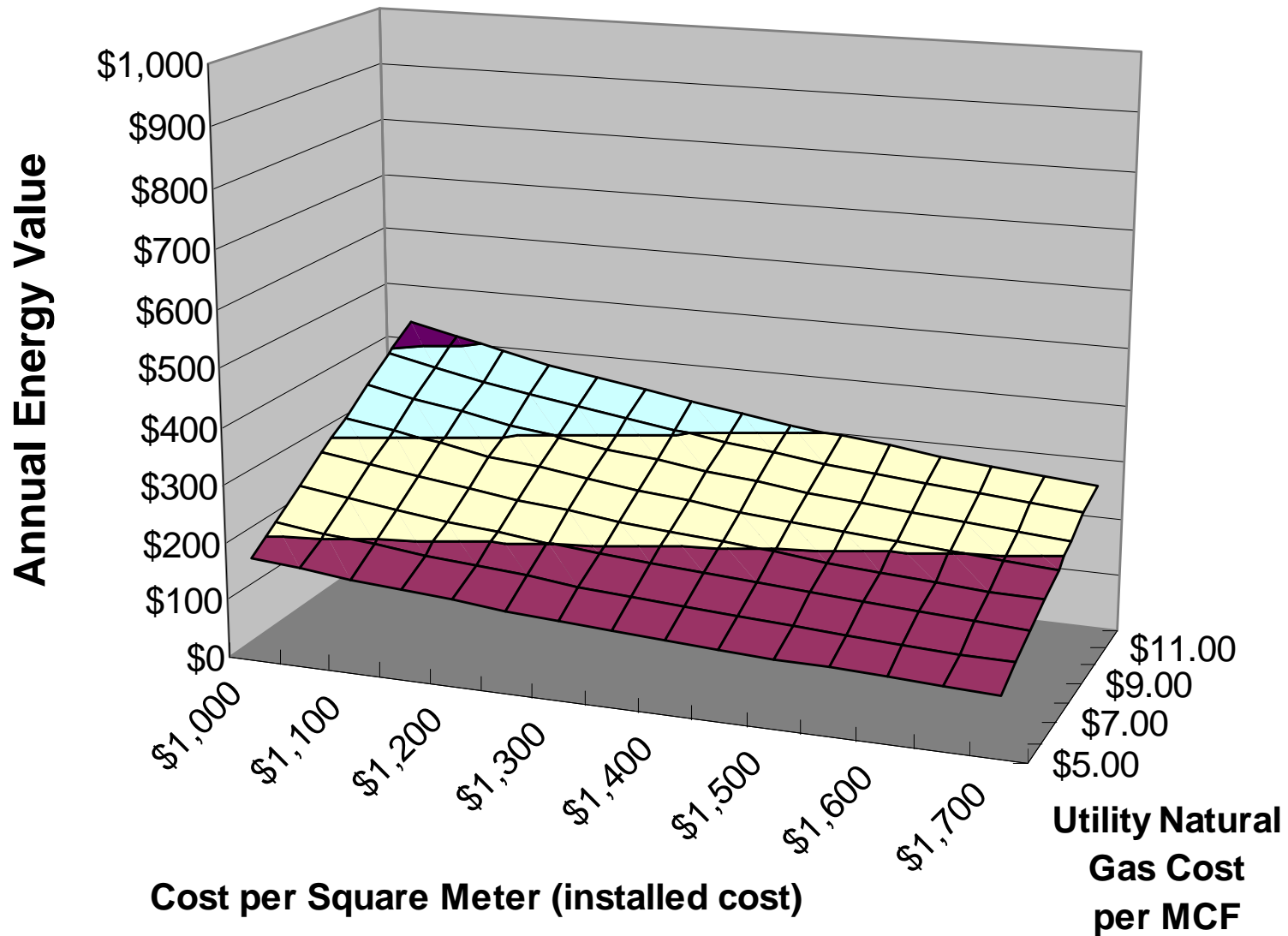
**Comparison of the annual energy value of two separate \$10,000 solar systems: PV and solar thermal at various utility rates.**

# PV Annual Output Value for a \$10,000 Investment



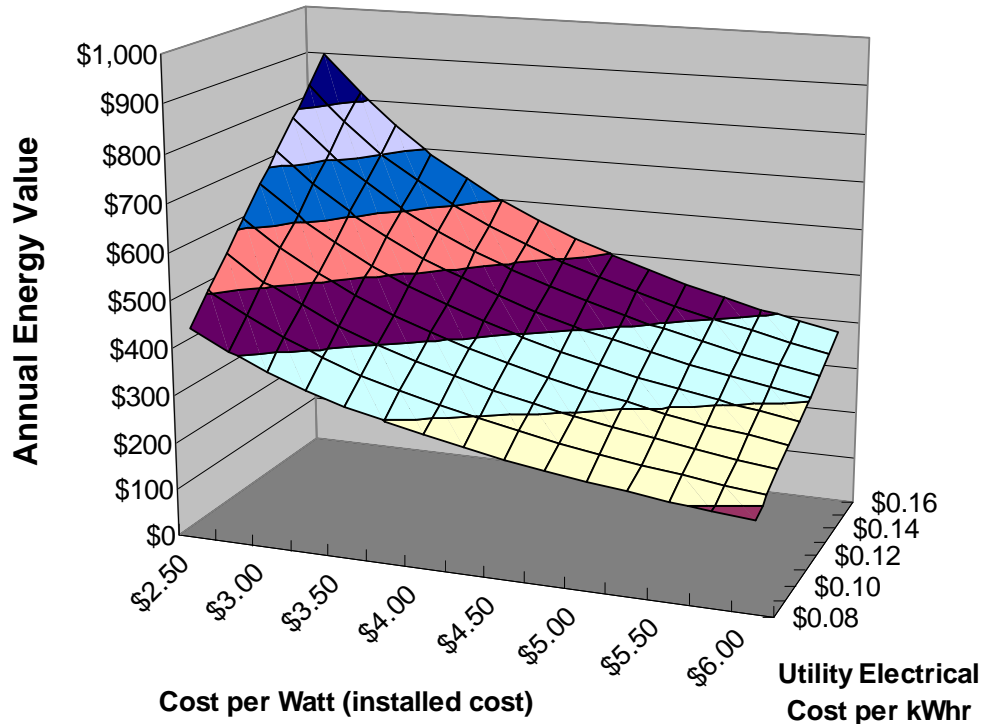
**Sensitivity analysis of \$10,000 PV investment with varying installed cost and natural gas or electric rates**

# Thermal Annual Output Value for a \$10,000 Investment

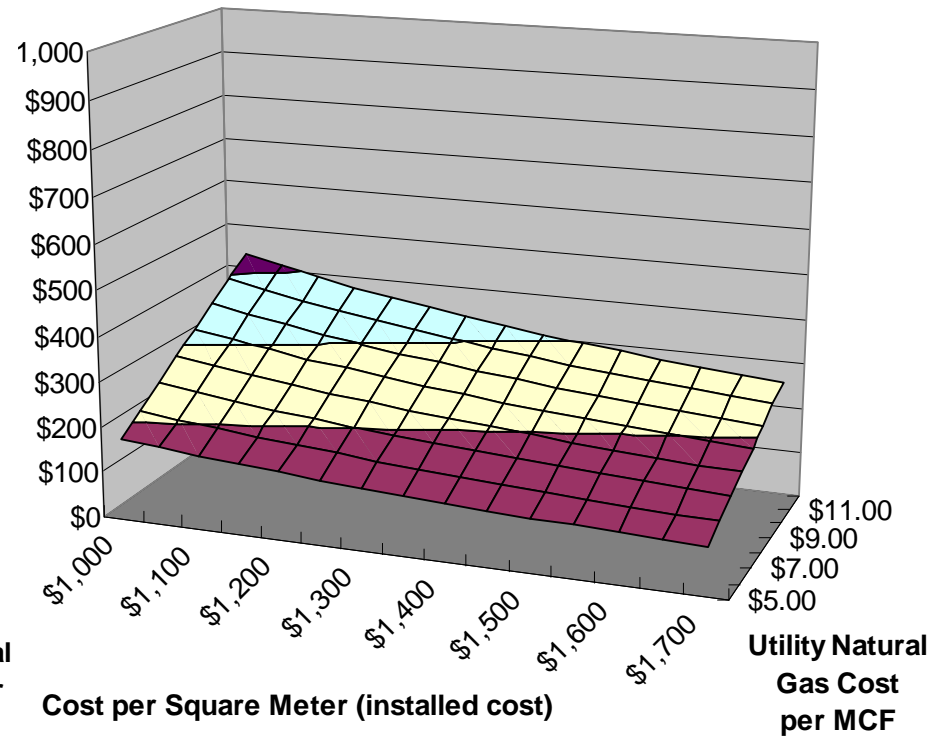


**Sensitivity analysis of \$10,000 solar thermal investment with varying installed cost and natural gas or electric rates**

## PV



## Solar Thermal



**Sensitivity analysis of separate \$10,000 PV or solar thermal investments with varying installed cost and natural gas or electric rates**



# Conclusion?

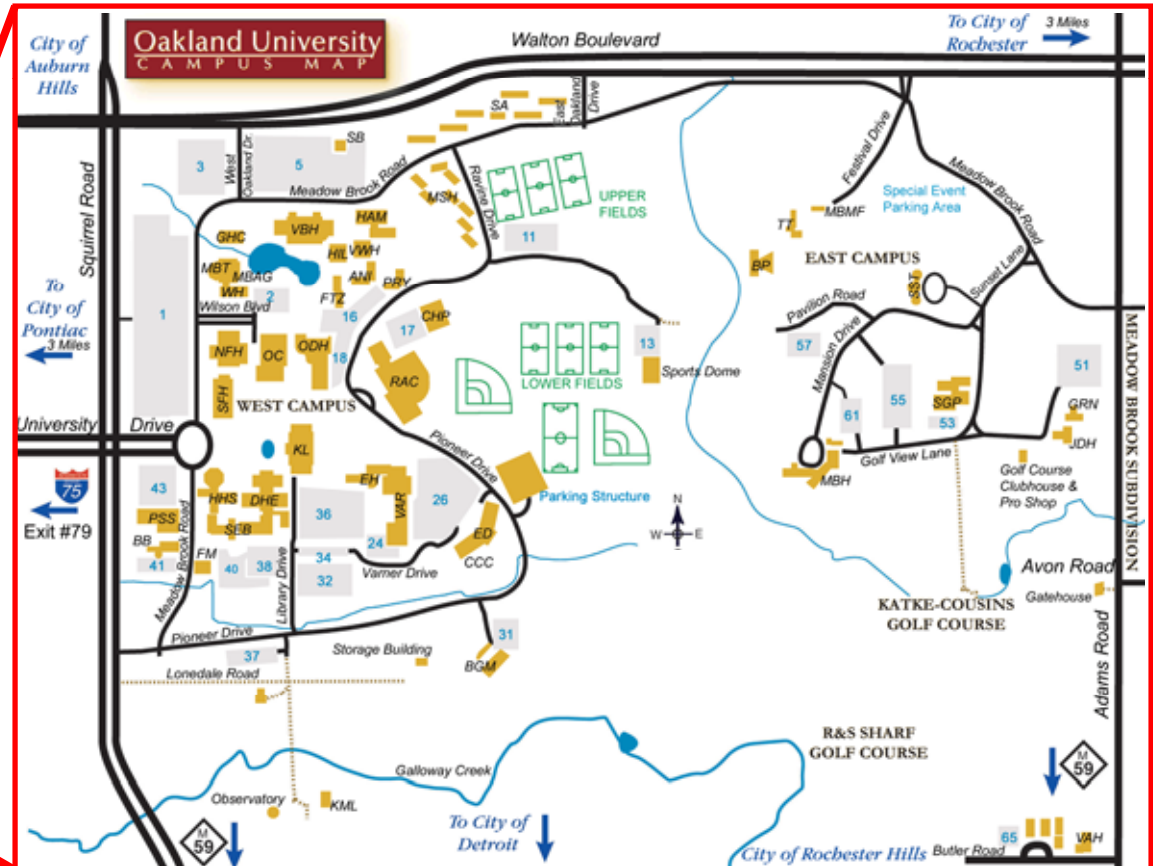
*Need to utilize solar thermal energy for more than just space heating & domestic HW.*



*Look at space cooling  
(displacing electricity usage)*



**Located in Southeast Michigan, just north of Detroit in suburban Oakland County**





***Public University***

***Golden Grizzlies***

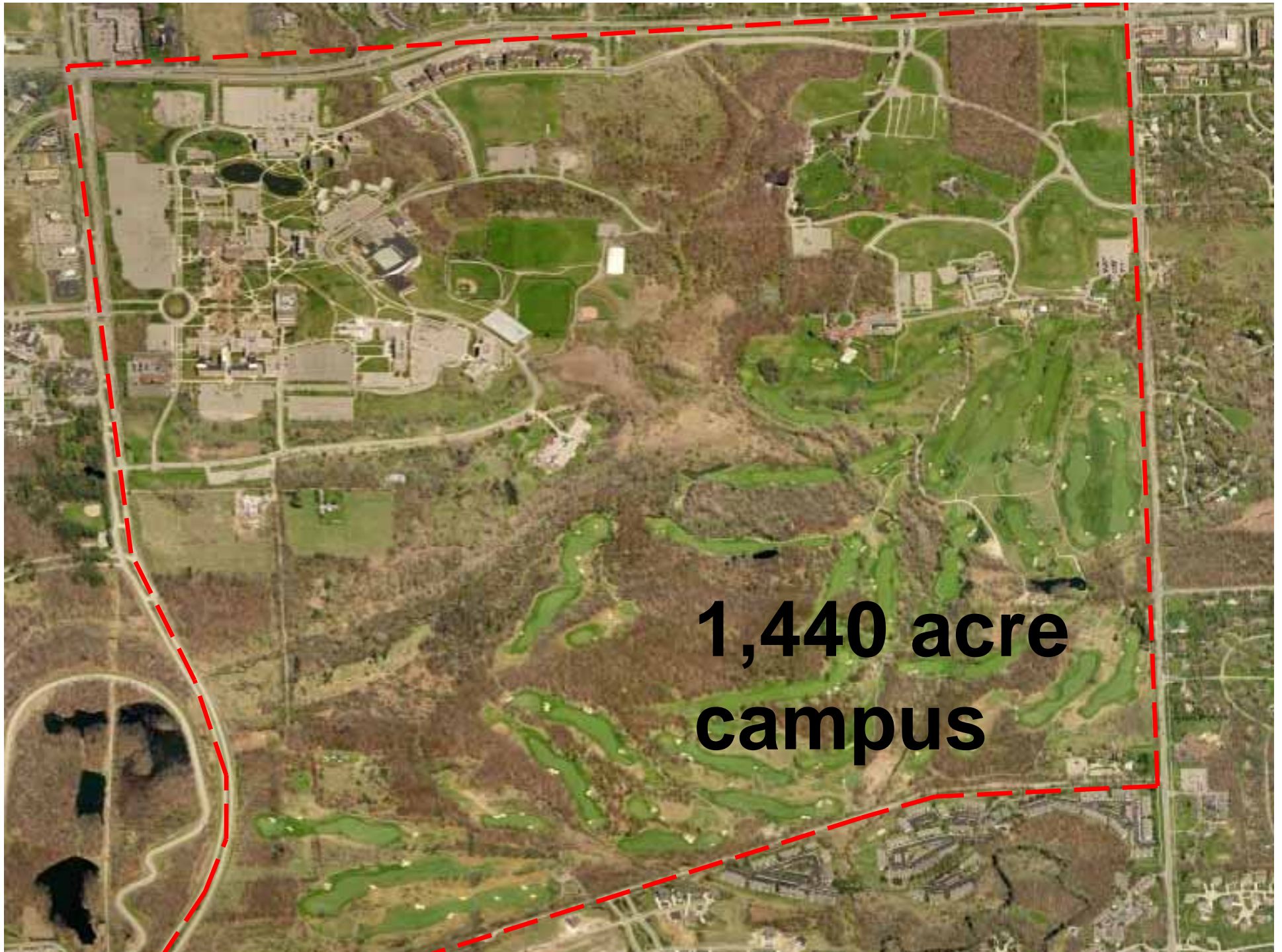
***19,000 students***

***3.0M square feet***

***132 baccalaureate  
degree programs***

***126 graduate  
degree and  
certificate  
programs***





**1,440 acre  
campus**



# Clean Energy Projects at Oakland

**OAKLAND UNIVERSITY.**



Wind Turbine Proposal:  
2.1MW turbine with third party finance is *proposed* & would provide 10% of campus electricity at a cost less than grid power (\$6M outside investment)



Clean Energy Research Center:  
New center is launched showcasing A wood boiler, bldg efficiency, biodiesel, biomass, ethanol & solar energy systems at the OU INC



Engineering Center: \$72M Hybrid building design with chilled beams & micro-turbines with cogeneration

Energy Project: \$8.5M energy savings performance contract (new windows, air conditioning chillers, lighting & controls)



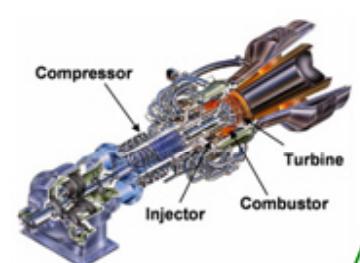
10 kW Solar Roof:  
\$120,000 building integrated solar electric shingle project



Wood Chip Boiler Plant Study & Proposal (abandoned):  
\$30M third party financed, new central heating plant was proposed, but the development was canceled as gas prices fell.



Outdoor LED Lighting \$0.5M project to install 150 parking lot & roadway fixtures



Cogeneration RFQ: \$8-10M On-site natural gas turbine to heat, cool, and power campus. 8yr payback while lowering carbon footprint by 40%



Energy Metering:  
\$0.6M for "smart grid" upgrades, to meter heating and electrical usage

Energy Project: \$11M energy savings (and deferred maintenance) performance contract

Wind Energy Study:  
100 meter tall wind speed sensing tower & study

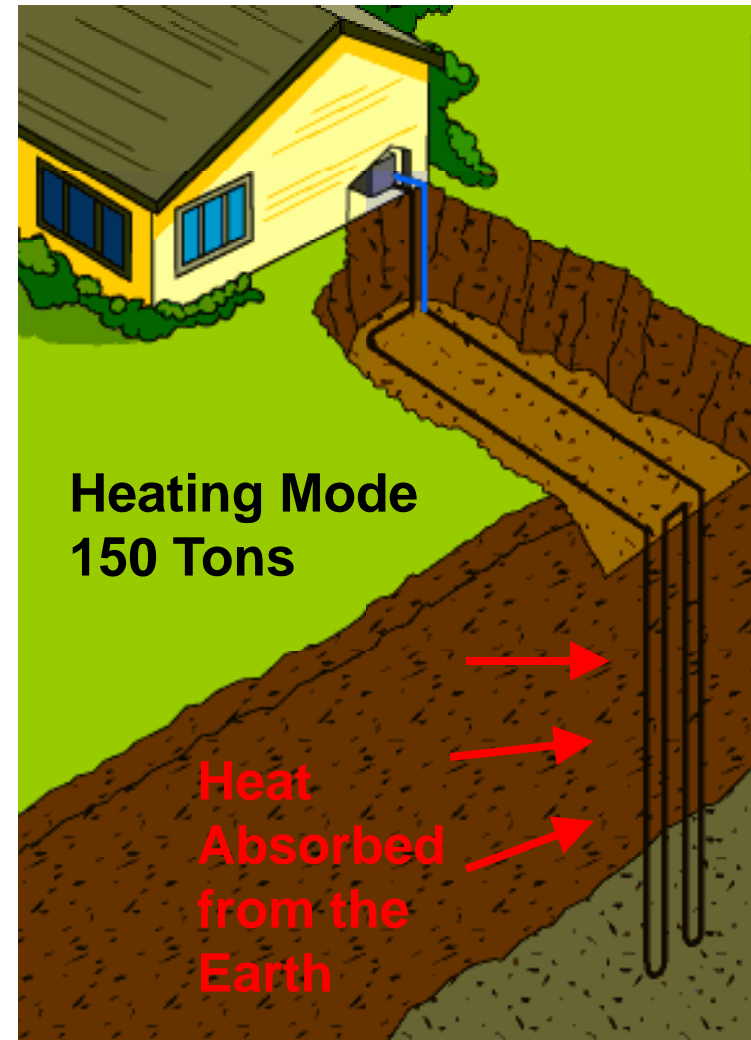
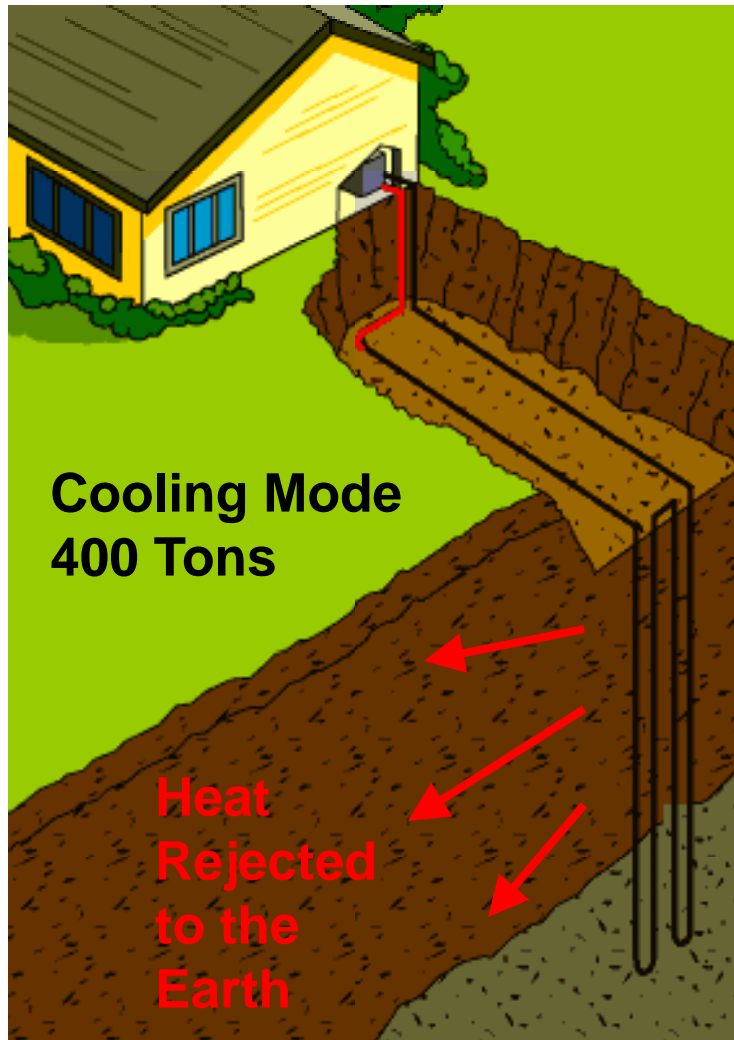


Human Health Building: \$65M Platinum rated green building project geothermal / solar thermal design



**Human Health Building: Geothermal / Solar Thermal Hybrid Project**

# What are Ground Source Heat Pumps?



*also referred to as Geothermal Heat Pumps  
or GeoExchange*

# HHB Project Overview

- **Timeline**

- **Geothermal ground array bid package:** April 2010
- **Geothermal ground array construction:** Summer 2010
- **Main building construction begins:** June 2010
- **Substantial completion:** Summer 2012
- **Performance monitoring & reporting:** 2012 through 2014

- **Budget**

- **Total project:** \$9,778,930
- **DOE share** \$2,738,100
- **Awardee share** \$7,040,830

- **Barriers**

*(No funds received yet)*

- **Lack of experience with: Geothermal projects of this size, VRF heat pumps, large solar thermal systems, & desiccant cooling**

- **Architect / Engineer:** Smithgroup
- **Construction Manager:** Christman Company
- **Geothermal Specialist:** Strategic Energy Solutions

# *Technologies Utilized*

## Geothermal Heat Pump Demonstration

Utilize a ground sourced heat pump HVAC system.

## Variable Refrigerant Flow Technology

Utilize variable refrigerant flow (VRF) heat pumps, allows for less compressors and enhanced internal heat recovery.

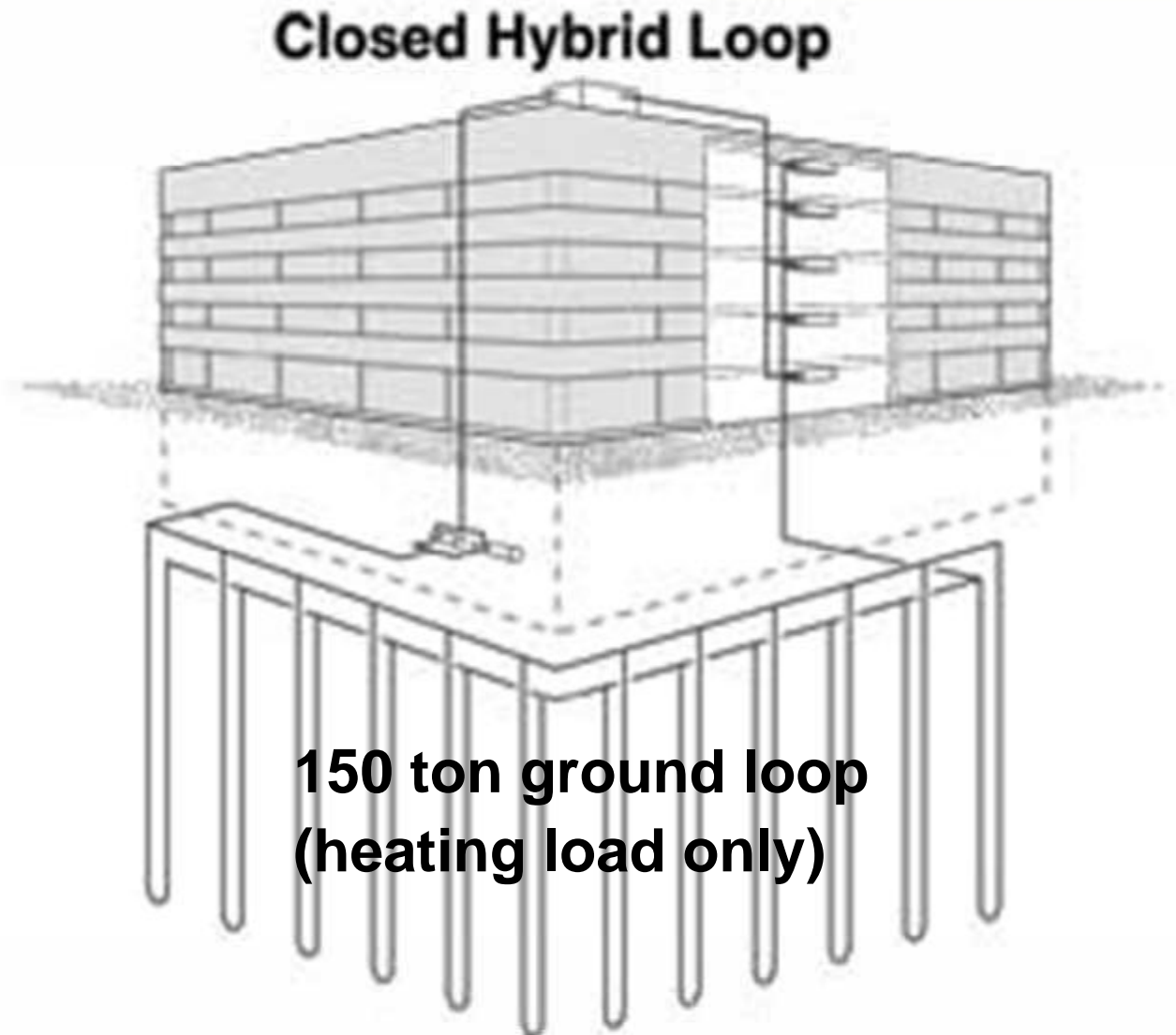
## Solar Thermal Desiccant Dehumidification

Dedicated outdoor air supply units will utilize a thermally regenerated desiccant dehumidification section. A large solar thermal system along with a natural gas backup boiler will provide the thermal regeneration energy.



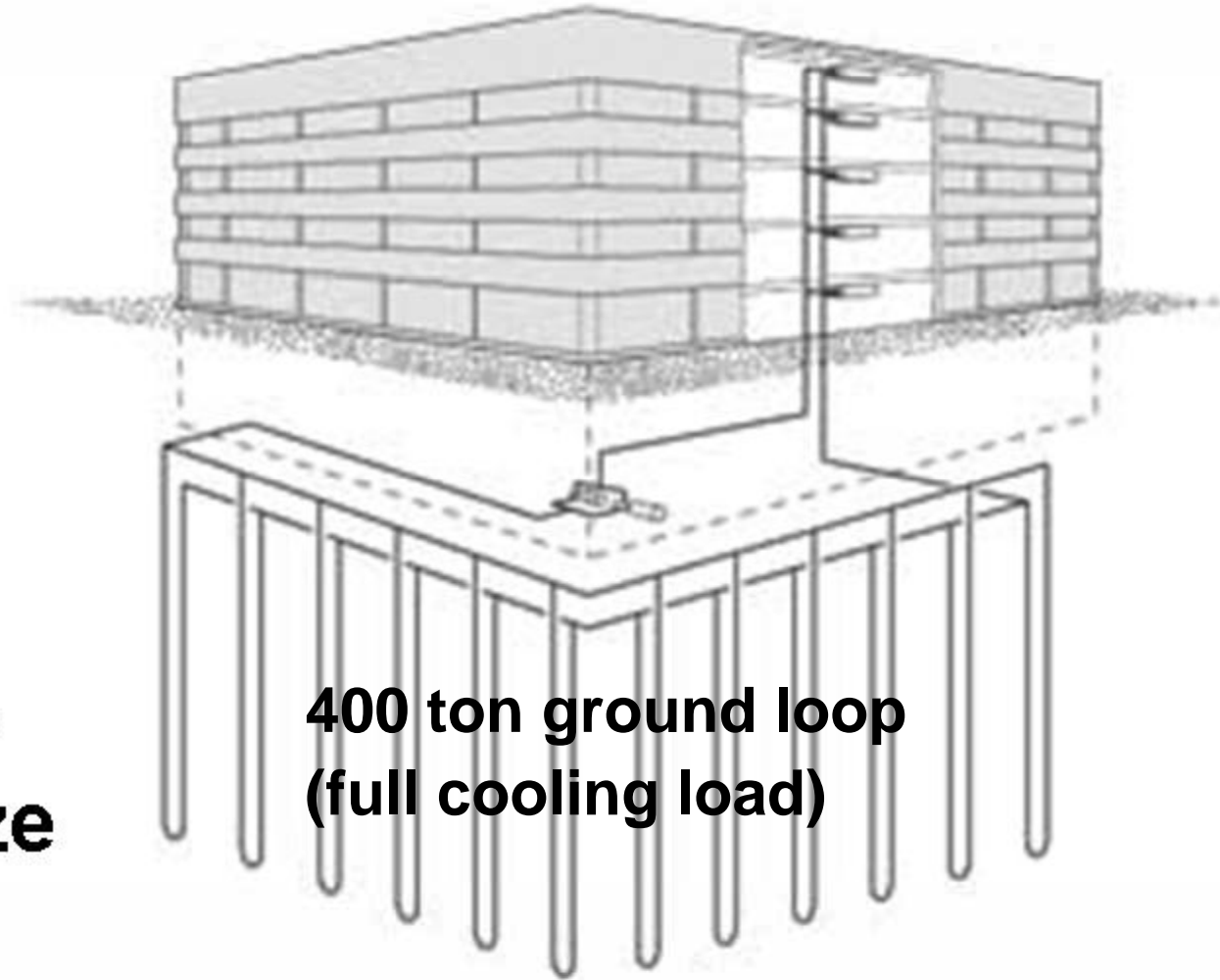
# *Geothermal System*

**Original  
Concept**



# *Geothermal System (grant funded full system)*

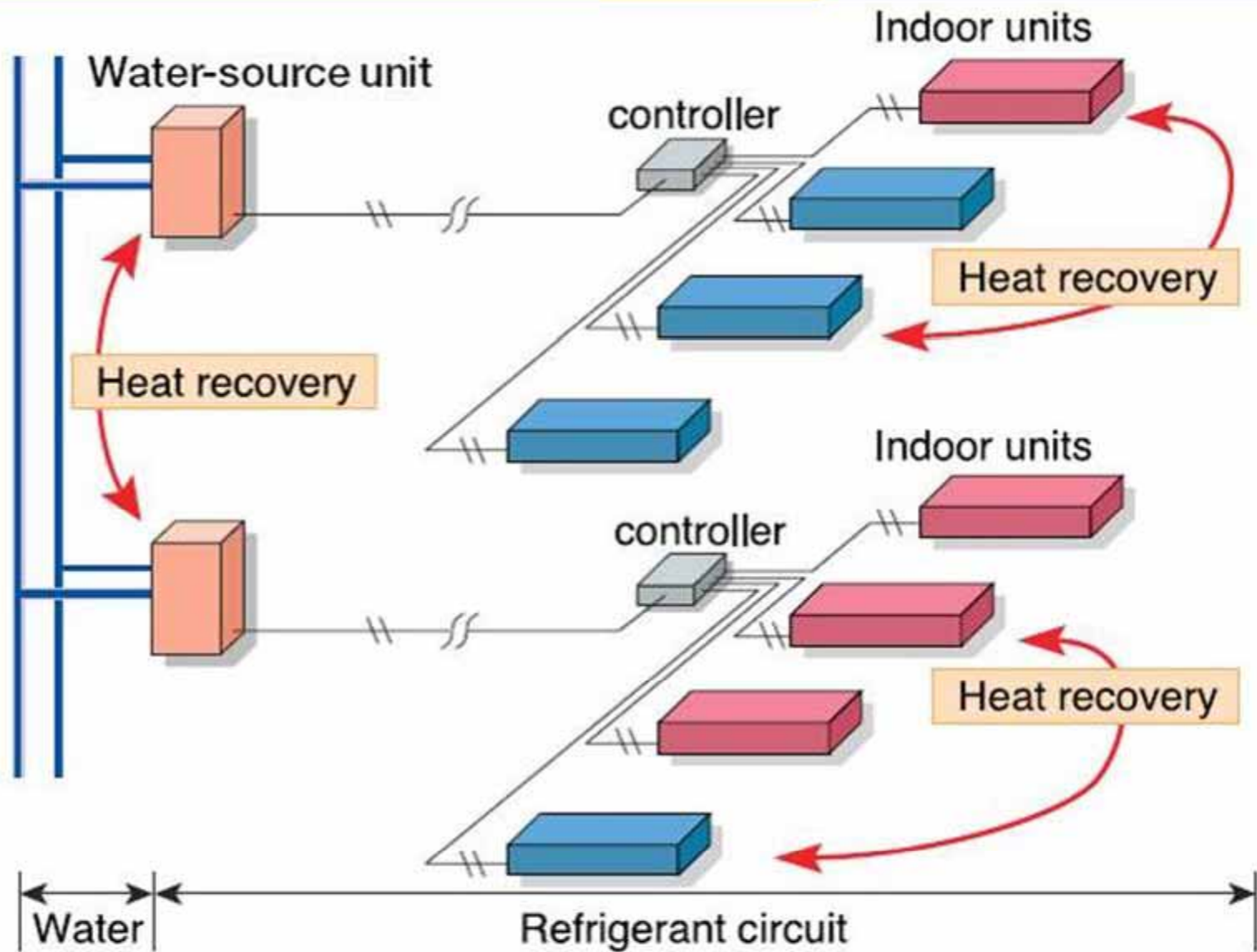
## **Closed Ground Loop**



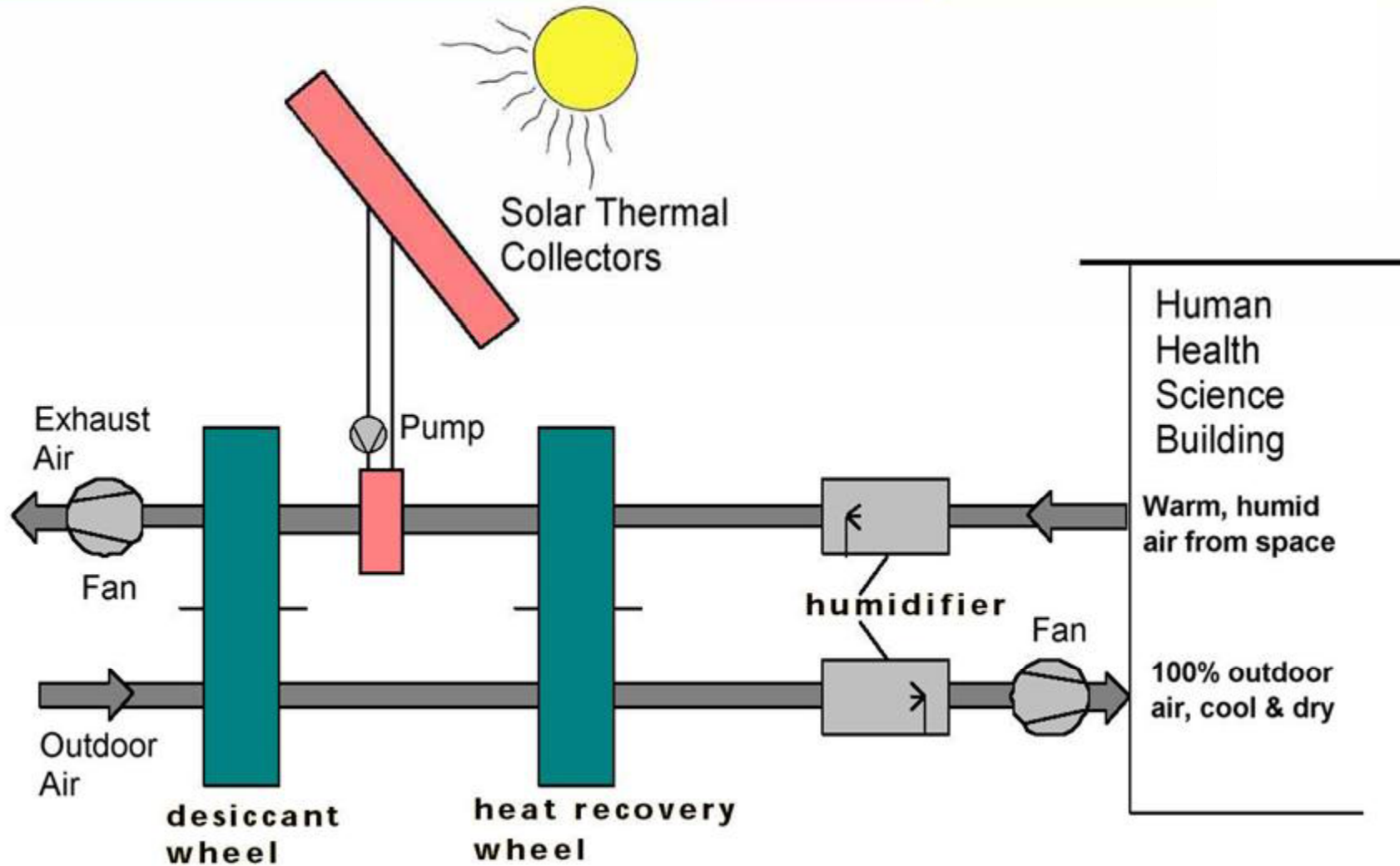
**Water  
Only, No  
Antifreeze**

**400 ton ground loop  
(full cooling load)**

# Variable Refrigerant Flow Heat Pumps

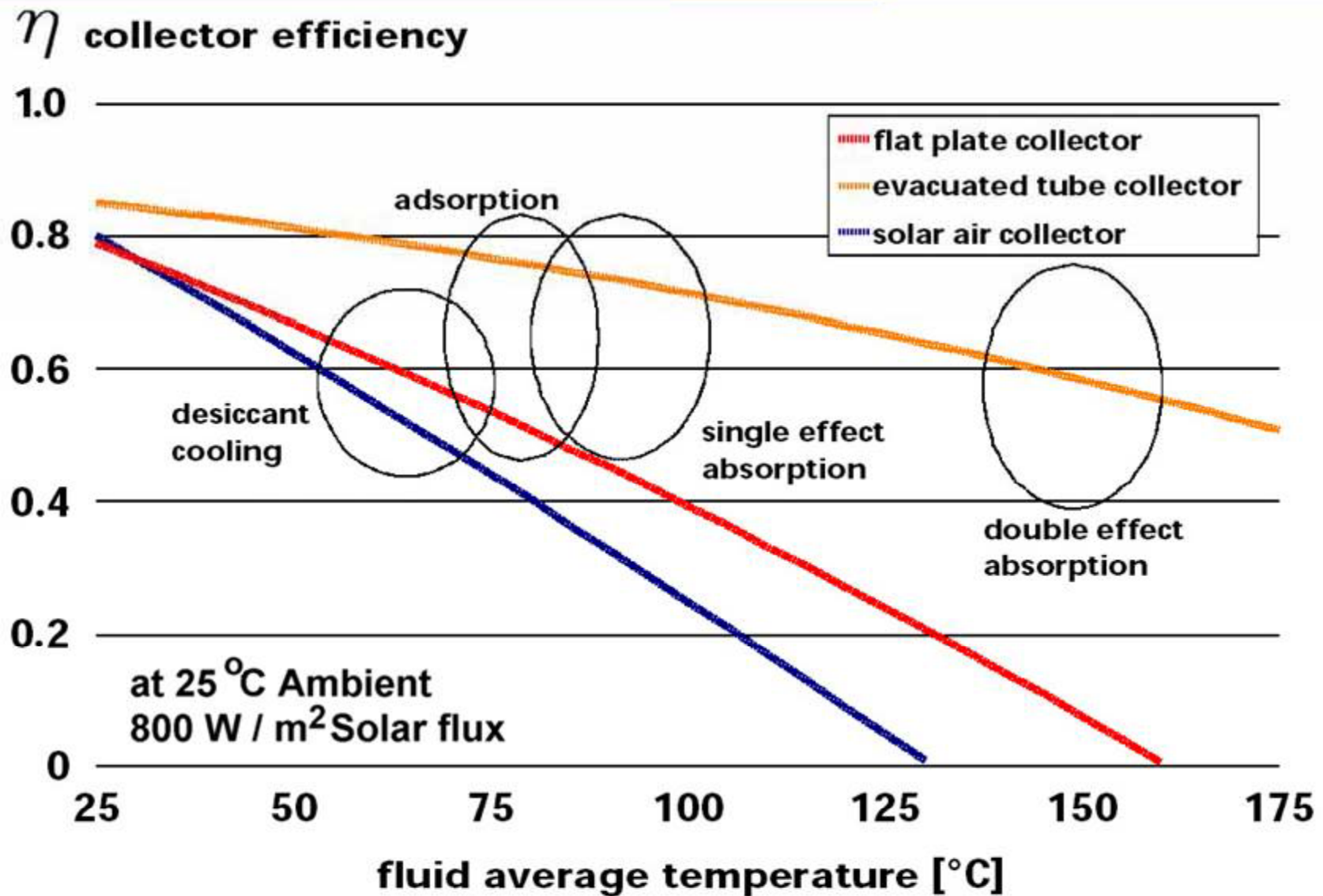


# Solar Thermal Desiccant Dehumidification



***Dedicated Outdoor Air Supply Unit***

# Temperatures Needed for Thermally Activated Cooling Technologies

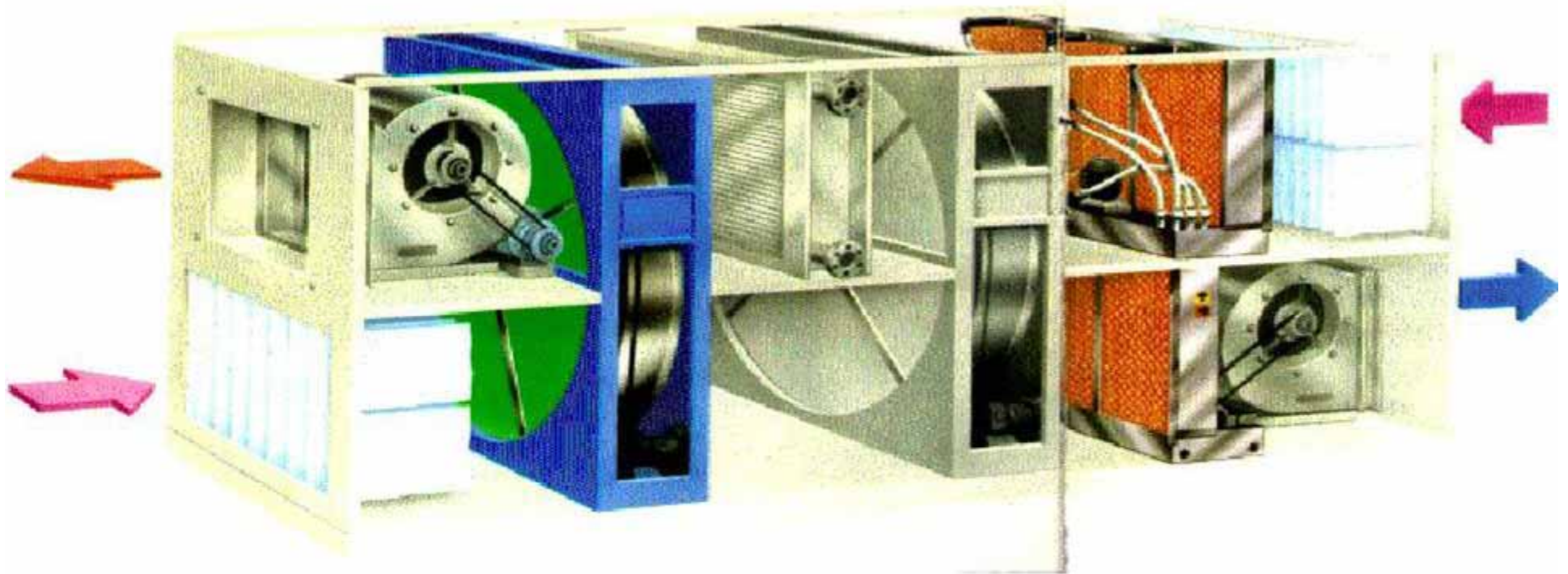




# 100% Outdoor Air Unit (with desiccant)

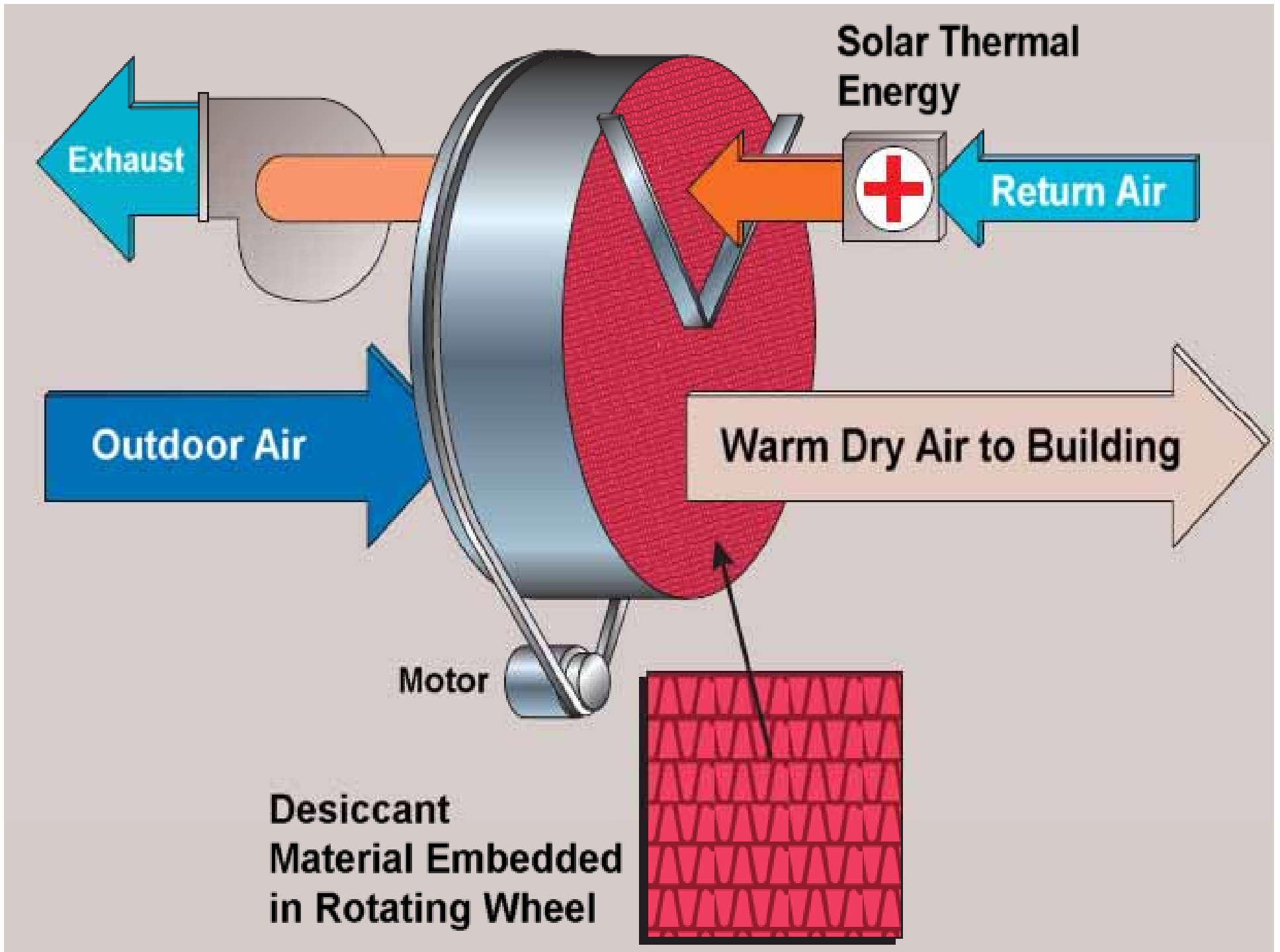
Exhaust Air

Exhaust from Space

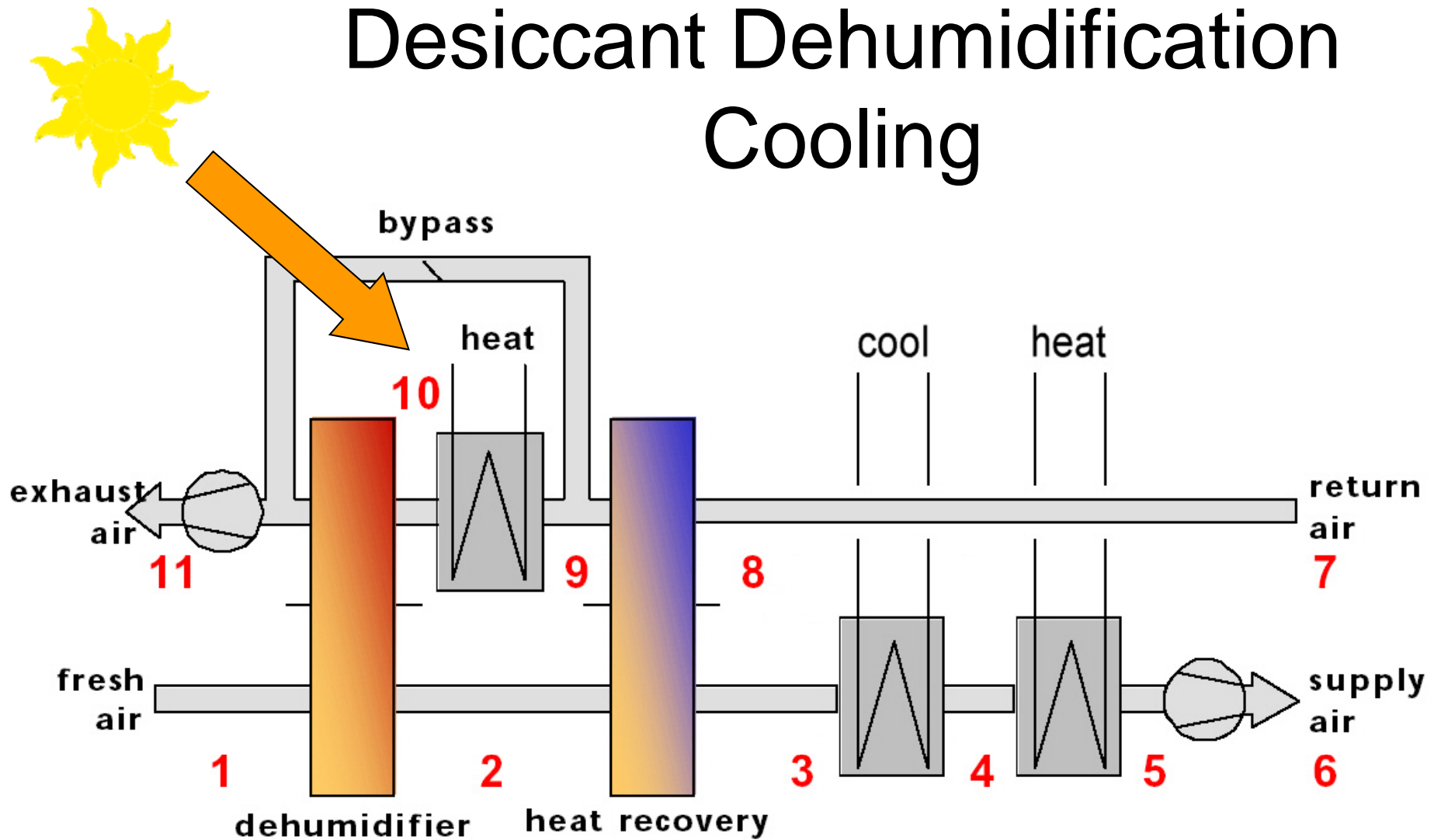


Outdoor Air Intake

Conditioned Air to Space



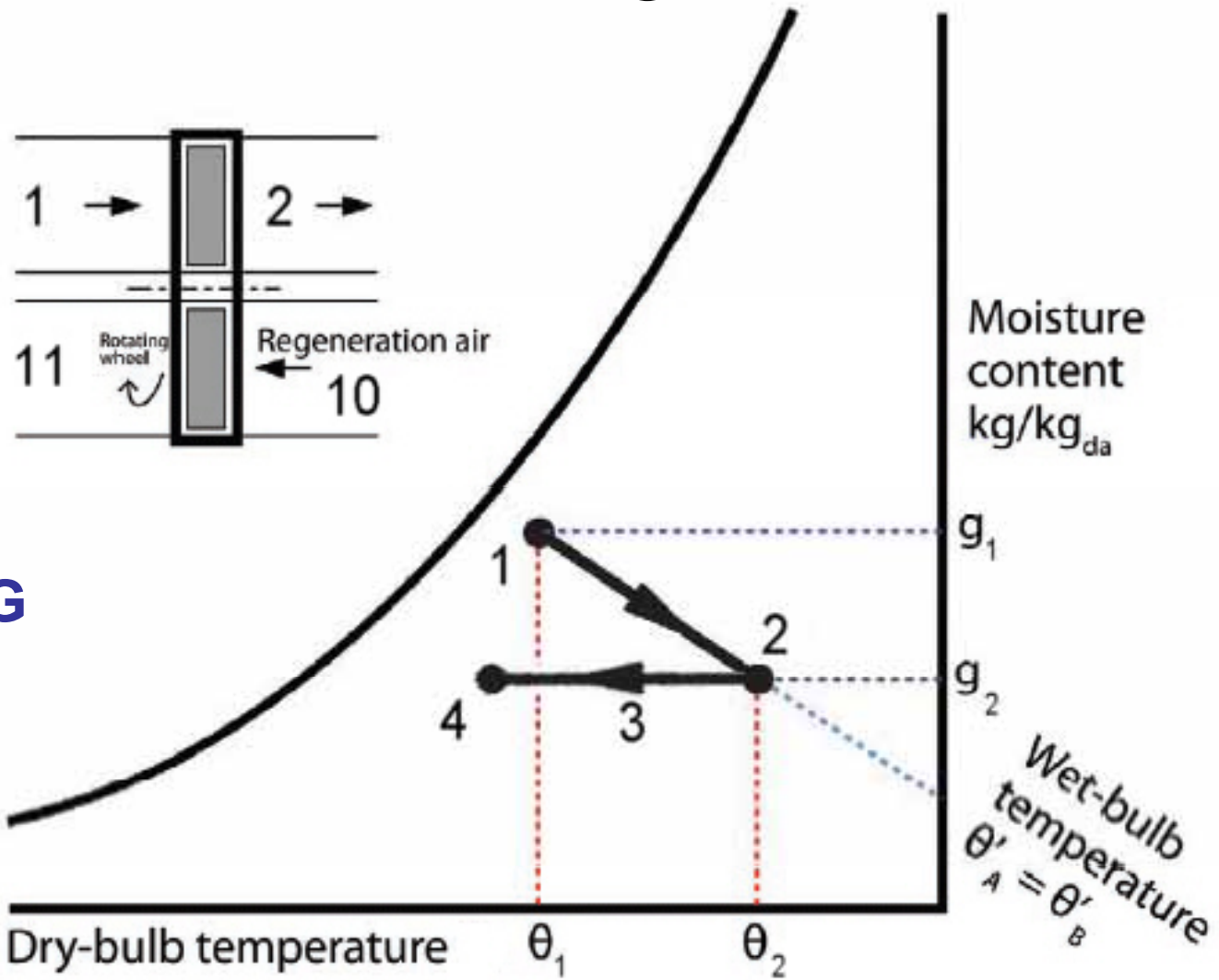
# Desiccant Dehumidification Cooling



**Dedicated Outdoor Air Units (DOAS)**



# Desiccant Dehumidification Cooling



**COOLING  
MODE**

# Ground Loop Spec's

## Geothermal Heat Pump Demonstration

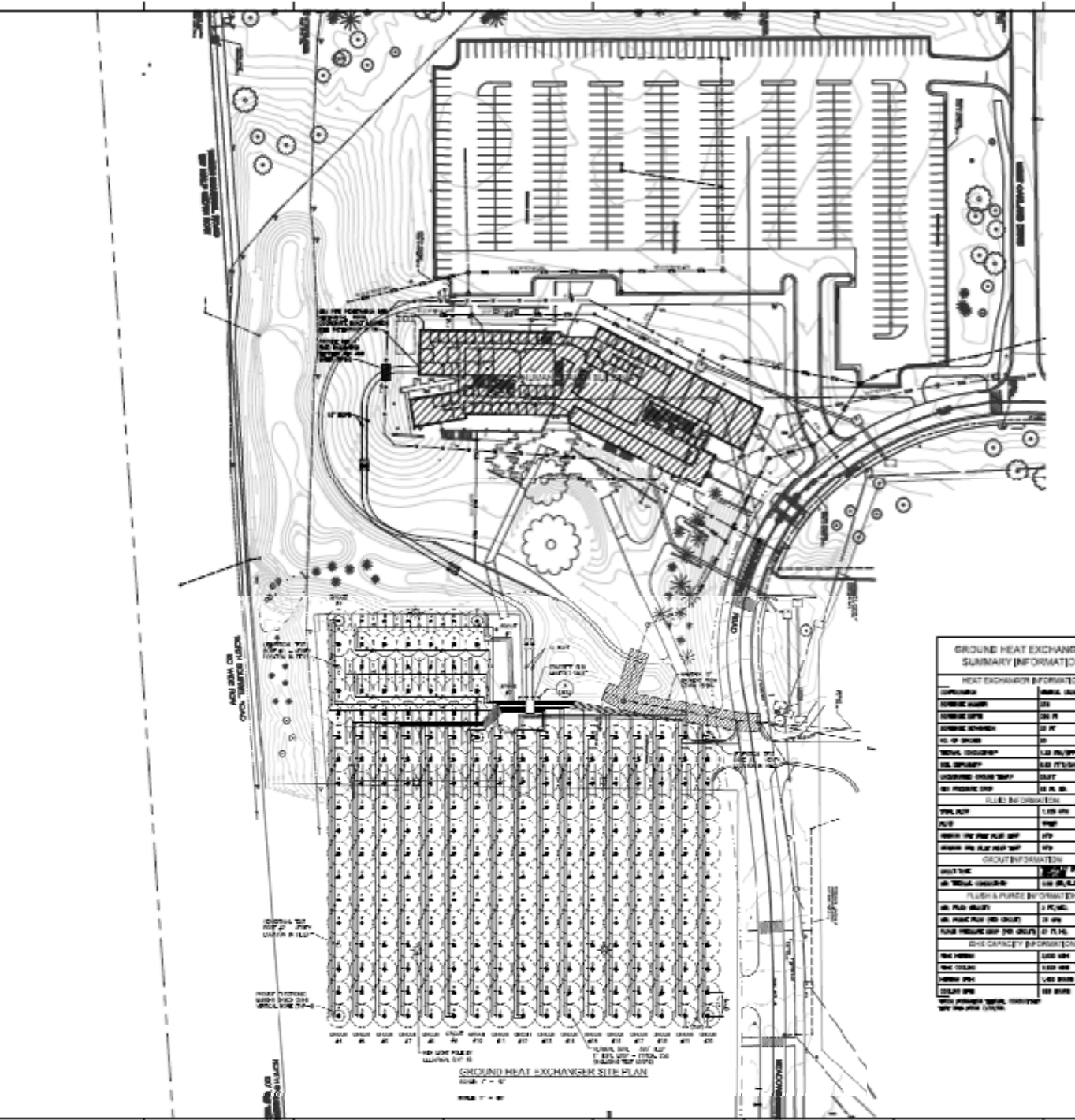
HEAT EXCHANGER INFORMATION	
Configuration	Vertical Closed Loop
Borehole Quantity	256
Borehole Depth	320 feet
Borehole Separation	25 feet
Number of Circuits	20
Thermal Conductivity *	1.23 BTU / (hr-ft-deg F)
Soil Diffusivity	0.83 foot <sup>2</sup> / day
Undisturbed Ground Temperature *	53.0 deg F
GHX Pressure Drop	42 feet of head
FLUID INFORMATION	
Total Flow	1,225 GPM
Fluid	Water only
Minimum HP Unit Inlet Fluid Temp	40 deg F
Maximum HP Unit Inlet Fluid Temp	90 deg F

\* From formation thermal conductivity test data taken July 30, 2009

# Ground Loop Spec's (pg2)

## Geothermal Heat Pump Demonstration

GROUT INFORMATION	
Grout Type	Thermally Enhanced Bentonite
Minimum Thermal Conductivity	0.88 BTU / (hr-ft-deg F)
FLUSH & PURGE INFORMATION	
Minimum Fluid Velocity	2 feet / second
Minimum Purge Flow (per circuit)	75 GPM
Purge Pressure Drop (per circuit)	47 feet of head
GHX CAPACITY INFORMATION	
Peak Heating	2,000,000 BTU / hour (166 tons)
Peak Cooling	4,920,000 BTU / hour (410 tons)
Heating EFLH	1,455 hours
Cooling EFLH	929 hours



- GROUND HEAT EXCHANGER NOTES**
1. THE GROUND HEAT EXCHANGER SHALL BE INSTALLED AT A MINIMUM 2 FEET FROM ANY FOUNDATION OR EXISTING UTILITY. ALL BOREHOLES SHALL BE INSTALLED TO THE SAME DEPTH AND SPACING UNLESS OTHERWISE NOTED ON THE STRUCTURAL DRAWINGS.
  2. LOCATIONS FOR THE GROUND HEAT EXCHANGER SHALL BE DETERMINED BY THE ENGINEER TO AVOID EXISTING FOUNDATIONS, UTILITY LOCATIONS, AND OTHER OBSTRUCTIONS. ALL BOREHOLES SHALL BE INSTALLED TO THE SAME DEPTH AND SPACING UNLESS OTHERWISE NOTED ON THE STRUCTURAL DRAWINGS.
  3. THE GROUND HEAT EXCHANGER SHALL BE INSTALLED TO THE SAME DEPTH AND SPACING UNLESS OTHERWISE NOTED ON THE STRUCTURAL DRAWINGS. THE GROUND HEAT EXCHANGER SHALL BE INSTALLED TO THE SAME DEPTH AND SPACING UNLESS OTHERWISE NOTED ON THE STRUCTURAL DRAWINGS.
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**REVISIONS**

NO.	DATE	DESCRIPTION
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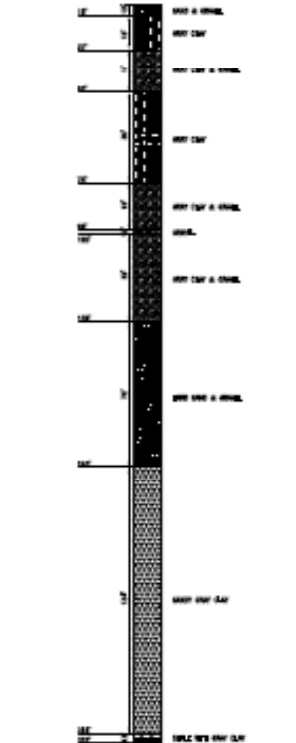
**GROUND HEAT EXCHANGER SUMMARY INFORMATION**

**HEAT EXCHANGER INFORMATION**

SYSTEM TYPE	WATER-LOOPS
EXCHANGER SIZE	12" X 12"
EXCHANGER DEPTH	200 FT
NO. OF BOREHOLES	20
TOTAL CAPACITY	1200 TONS
MAX. CAPACITY	600 TONS
EXCHANGER LENGTH	200 FT
EX. PRESSURE	100 PSI
INSTALLATION	SEE FOUNDATION PLAN
FLUID	WATER
MAX. TEMPERATURE	180°F
MIN. TEMPERATURE	40°F
MAX. FLOW RATE	100 GPM
MIN. FLOW RATE	20 GPM

**GROUND INFORMATION**

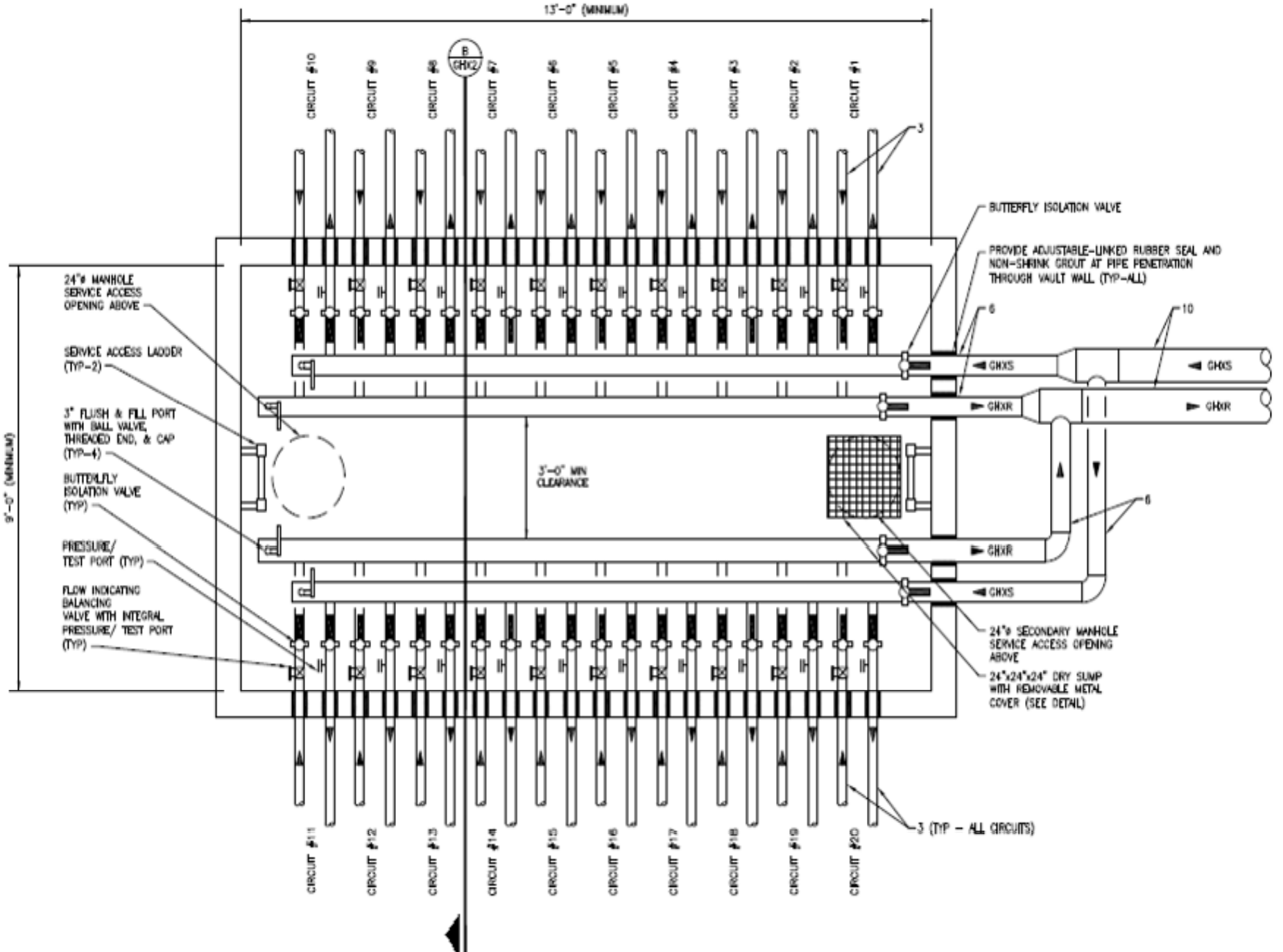
SOIL TYPE	CLAY
SOIL TEMPERATURE	55°F
FLASH & FURZE INFORMATION	SEE FOUNDATION PLAN
MAX. FLOOR AREA	10,000 SQ FT
MAX. FLOOR AREA (GROSS)	12,000 SQ FT
FLOOR HEATING CAP (BTU/H)	100,000 BTU/H
COOLING CAPACITY (BTU/H)	100,000 BTU/H
MAX. FLOOR AREA	10,000 SQ FT
MAX. FLOOR AREA (GROSS)	12,000 SQ FT
FLOOR HEATING CAP (BTU/H)	100,000 BTU/H
COOLING CAPACITY (BTU/H)	100,000 BTU/H
MAX. FLOOR AREA	10,000 SQ FT
MAX. FLOOR AREA (GROSS)	12,000 SQ FT
FLOOR HEATING CAP (BTU/H)	100,000 BTU/H
COOLING CAPACITY (BTU/H)	100,000 BTU/H



**DRILL LOG FROM VERTICAL TEST BORE #1  
FORMATION THERMAL CONDUCTIVITY TEST**

**811** Home starts below.  
Call before you dig.

1" = 10'  
0" 10" 20" 30" 40" 50" 60" 70" 80" 90" 100"



9'-0" (MINIMUM)

15'-0" (MINIMUM)

BUTTERFLY ISOLATION VALVE

PROVIDE ADJUSTABLE-LINKED RUBBER SEAL AND NON-SHINK GROUT AT PIPE PENETRATION THROUGH VAULT WALL (TYP-ALL)

GHXS

GHXR

GHXS

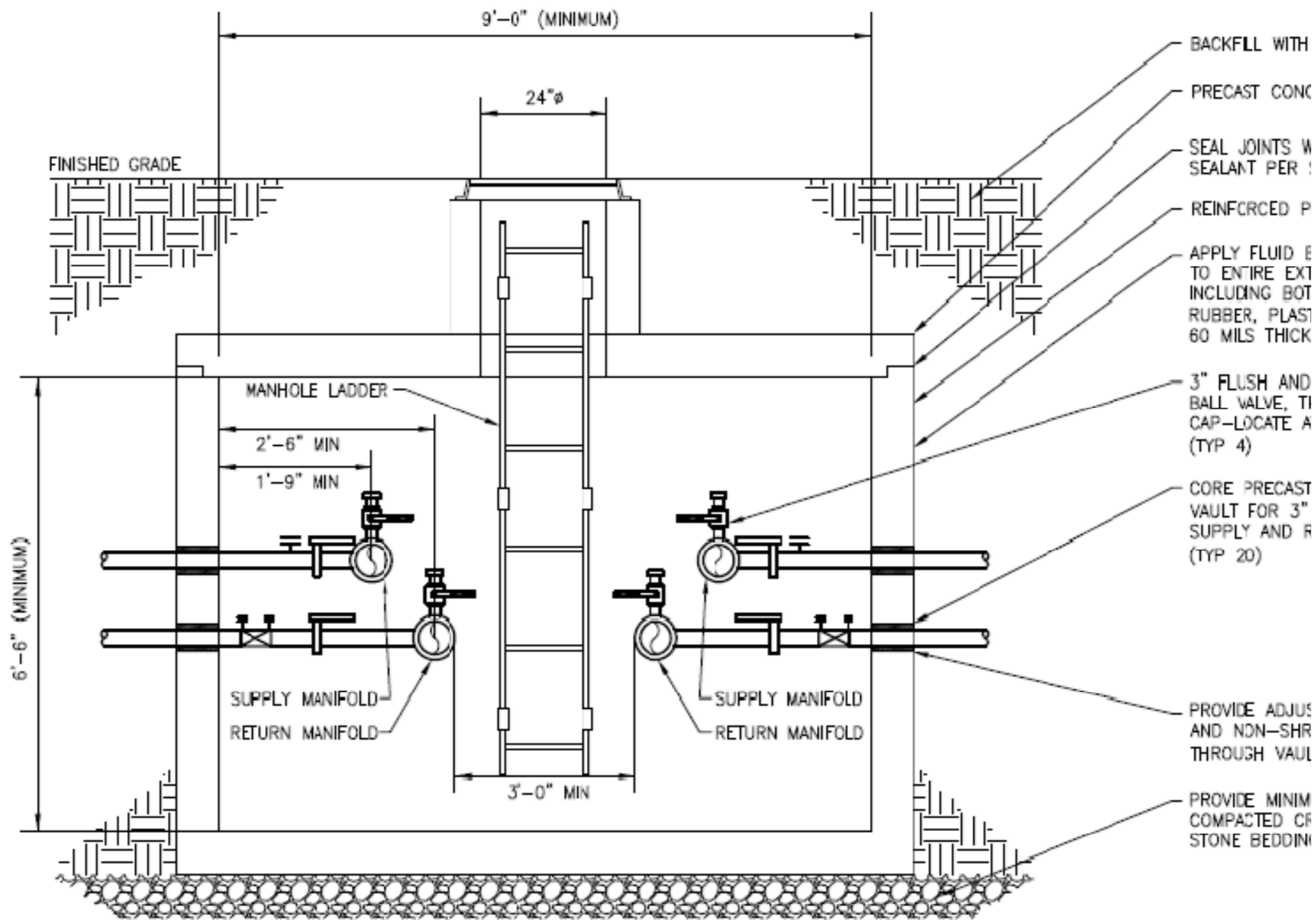
GHXR

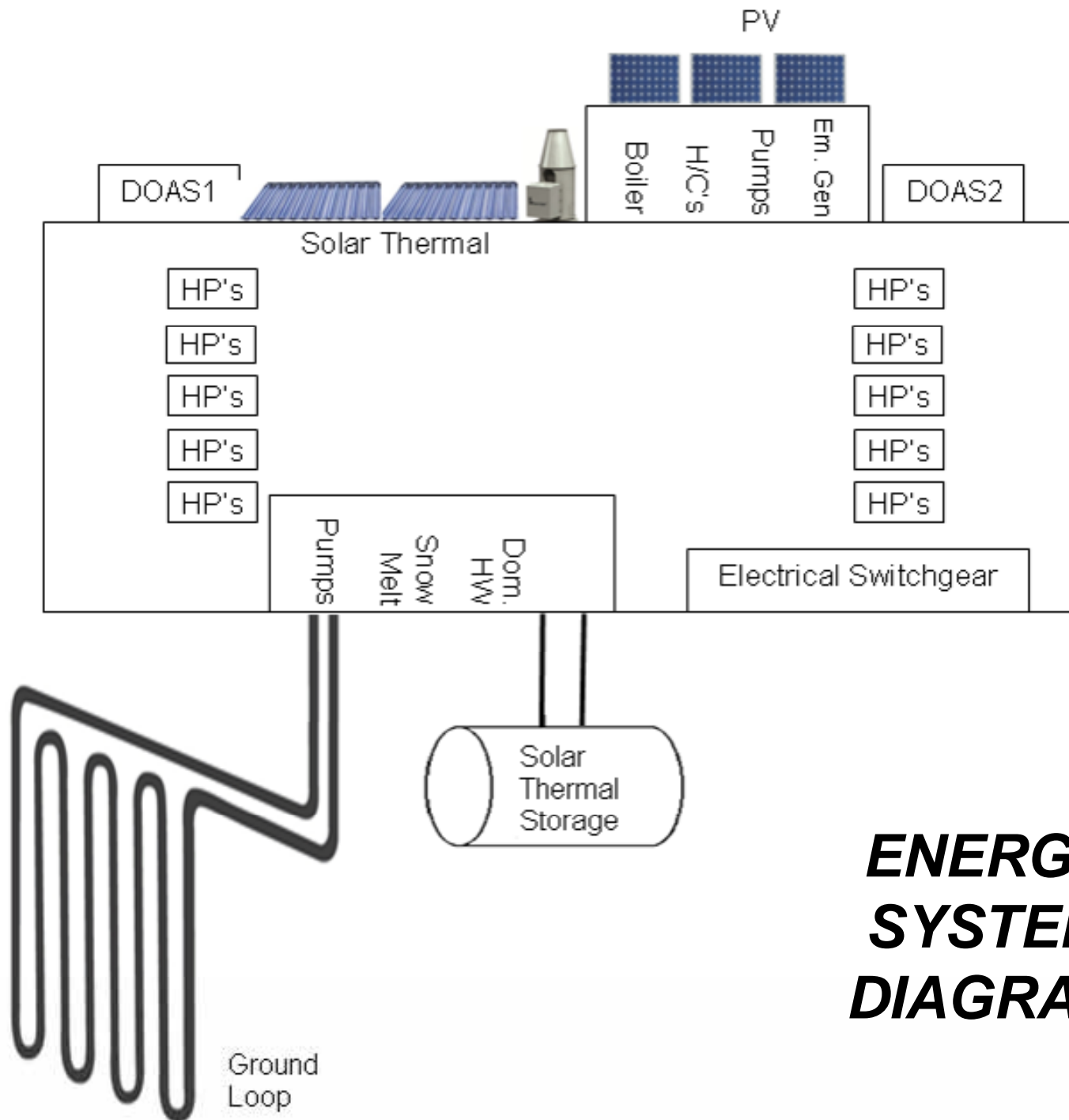
24"x24"x24" DRY SUMP WITH REMOVABLE METAL COVER (SEE DETAIL)

3 (TYP - ALL CIRCUITS)

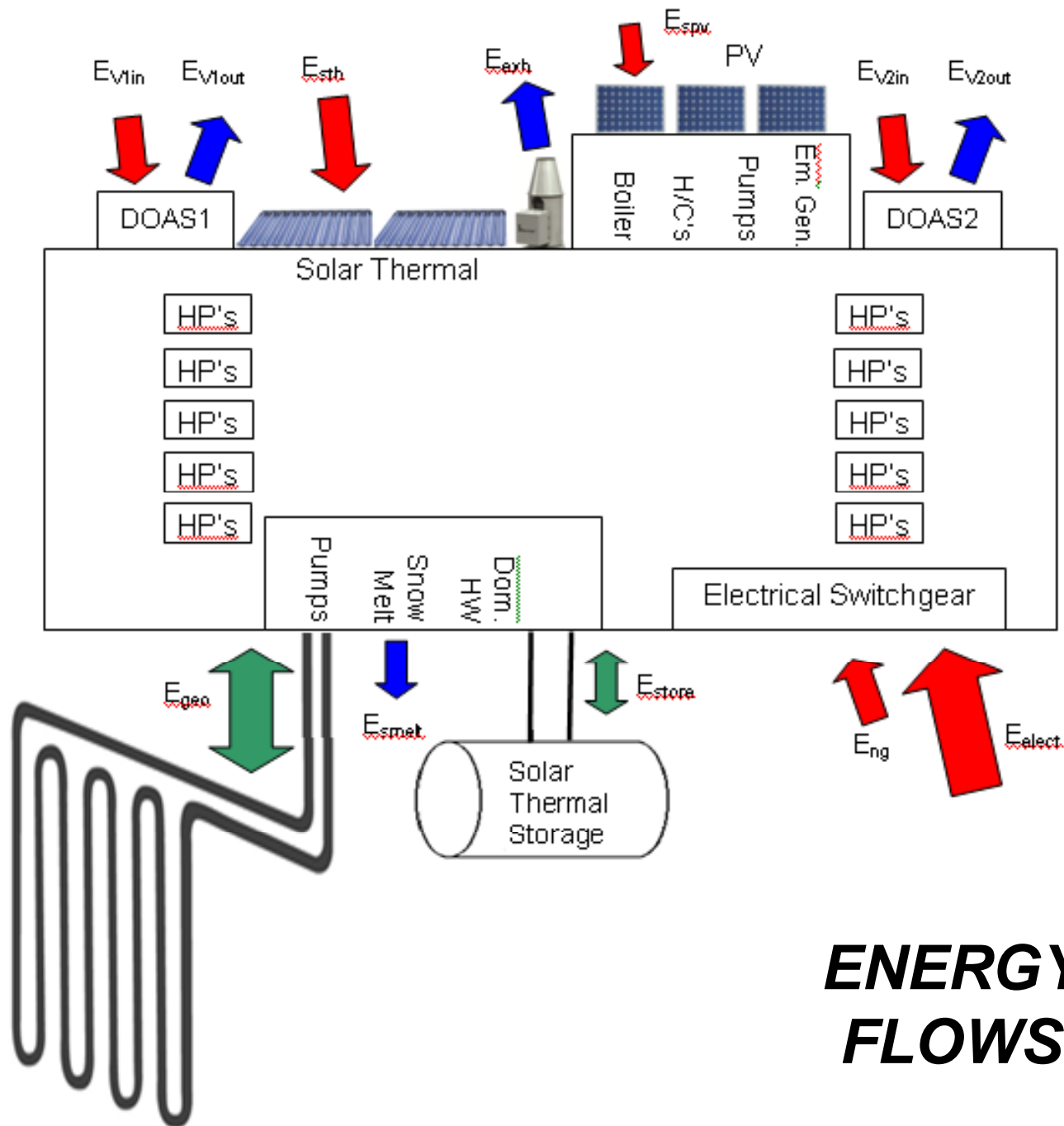
3'-0" MIN CLEARANCE







***ENERGY  
SYSTEM  
DIAGRAM***





# Meter Information

<b>TAG</b>	<b>Description</b>	<b>Unit</b>	<b>Media</b>	<b>Dirctn</b>	<b>Meter</b>
<b>E<sub>elect</sub></b>	<b>Electrical utility</b>	<b>kWhr</b>	<b>Electricity</b>	<b>In</b>	<b>Nexus 1262</b>
<b>E<sub>spv</sub></b>	<b>Solar photovoltaics</b>	<b>kWhr</b>	<b>Electricity</b>	<b>In</b>	<b>Shark 200</b>
<b>E<sub>ng</sub></b>	<b>Natural gas utility</b>	<b>MCF</b>	<b>Natural gas</b>	<b>In</b>	<b>Gas</b>
<b>E<sub>sth</sub></b>	<b>Solar thermal system</b>	<b>BTU</b>	<b>Solar hot water</b>	<b>In</b>	<b>Ultrasonic BTU</b>
<b>E<sub>geo</sub></b>	<b>Ground loop</b>	<b>BTU</b>	<b>Ground loop water</b>	<b>Bi-dir</b>	<b>Ultrasonic BTU</b>
<b>E<sub>store</sub></b>	<b>Solar ground storage</b>	<b>BTU</b>	<b>Solar hot water</b>	<b>Bi-dir</b>	<b>Ultrasonic BTU</b>
<b>E<sub>V1in</sub></b>	<b>DOAS intake air</b>	<b>BTU</b>	<b>Outdoor air</b>	<b>In</b>	<b>Air flow &amp; temp</b>
<b>E<sub>V1out</sub></b>	<b>DOAS intake exhaust</b>	<b>BTU</b>	<b>Exhaust air</b>	<b>Out</b>	<b>Air flow &amp; temp</b>
<b>E<sub>V2in</sub></b>	<b>DOAS intake air</b>	<b>BTU</b>	<b>Outdoor air</b>	<b>In</b>	<b>Air flow &amp; temp</b>
<b>E<sub>V2out</sub></b>	<b>DOAS intake exhaust</b>	<b>BTU</b>	<b>Exhaust air</b>	<b>Out</b>	<b>Air flow &amp; temp</b>
<b>E<sub>exh</sub></b>	<b>Laboratory exhaust</b>	<b>BTU</b>	<b>Exhaust air</b>	<b>Out</b>	<b>None</b>
<b>E<sub>smelt</sub></b>	<b>Snow melt system</b>	<b>BTU</b>	<b>Hot water</b>	<b>Out</b>	<b>Ultrasonic BTU</b>

## **Meter information**

<b>Nexus 1262</b>	Utility switchboard electric meter
<b>Shark 200</b>	Multifunction panel electric meter
<b>Gas</b>	Rotary natural gas meter with pulser
<b>Ultrasonic BTU</b>	Ultrasonic flow and energy meter
<b>Air flow &amp; temp</b>	Dedicated Outdoor Air Unit (DOAS) with packaged air flow station and temperature / humidity sensors used by the building automation system to calculate energy



FEEDER 2A  
METERING



FEEDER 2B  
METERING



FEEDER 2C  
METERING



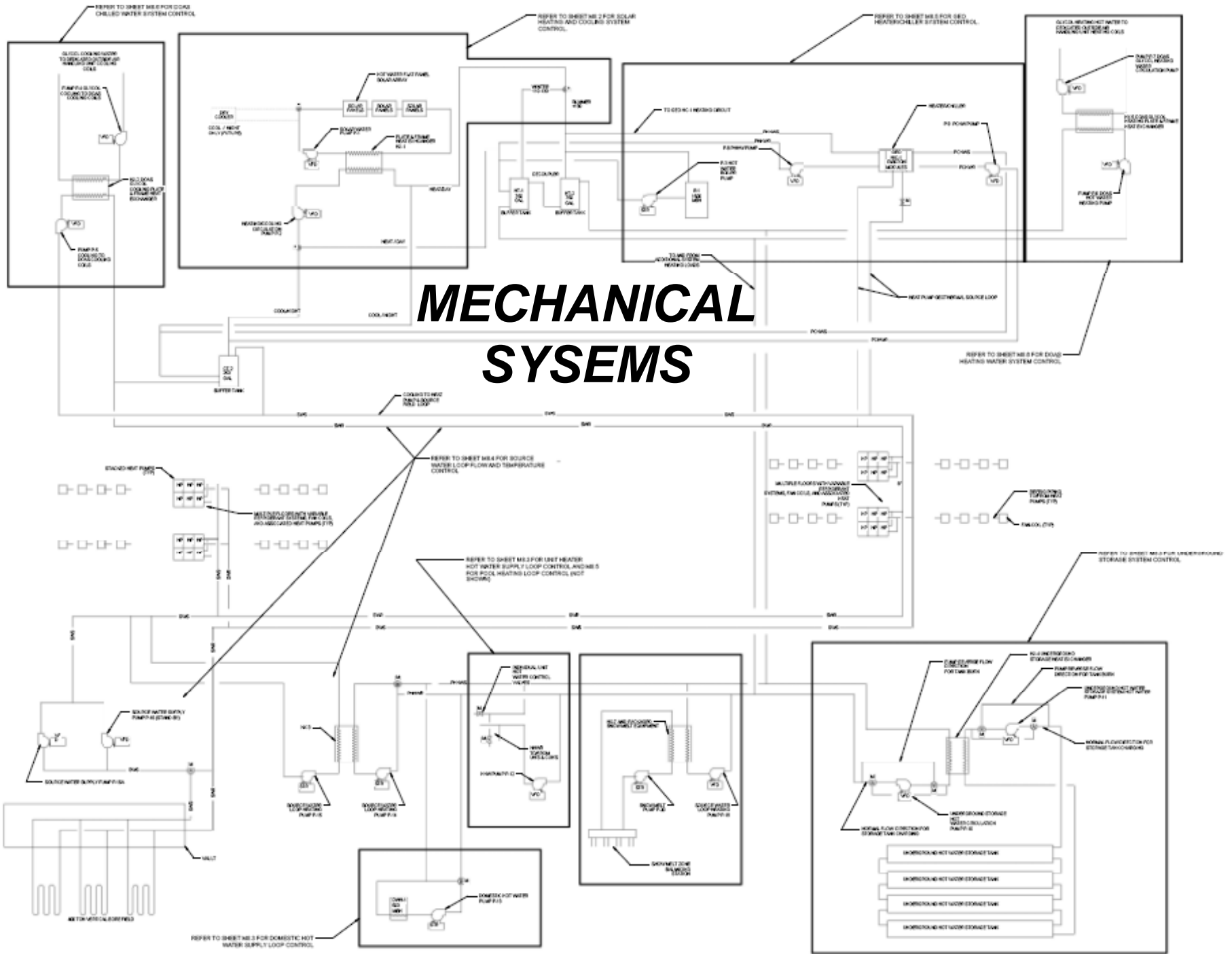
FEEDER 4A  
METERING



FEEDER 4C  
METERING







# MECHANICAL SYSTEMS

REFER TO SHEET M4.1 FOR CHILLED WATER SYSTEM CONTROL.

REFER TO SHEET M4.2 FOR SOLAR HEATING AND COOLING SYSTEM CONTROL.

REFER TO SHEET M4.3 FOR BOILER HEATING SYSTEM CONTROL.

ALCOHOLIC HOT WATER TO COOLING COILS

REFER TO SHEET M4.4 FOR SOURCE WATER LOOP FLOW AND TEMPERATURE CONTROL.

REFER TO SHEET M4.5 FOR HOT WATER SUPPLY LOOP CONTROL AND M4.6 FOR COOL HEATING LOOP CONTROL (NOT SHOWN).

REFER TO SHEET M4.7 FOR UNDERGROUND STORAGE SYSTEM CONTROL.

REFER TO SHEET M4.8 FOR DOMESTIC HOT WATER SUPPLY LOOP CONTROL.

TO REMOTE HEATING COIL

TO COOL HEATING COIL

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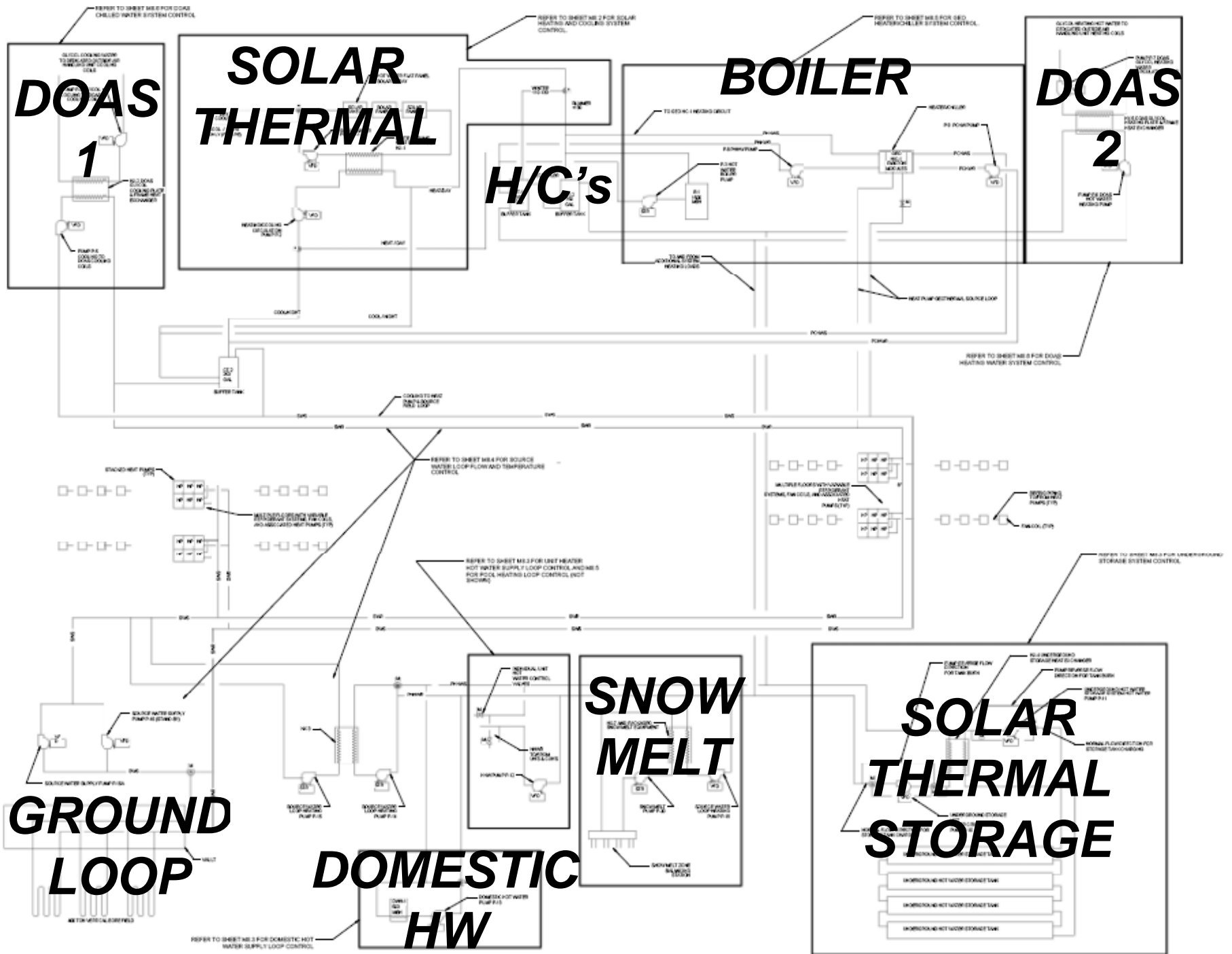
TO COOL HEATING COIL

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**DOAS  
1**

**SOLAR  
THERMAL**

**H/C's**

**BOILER**

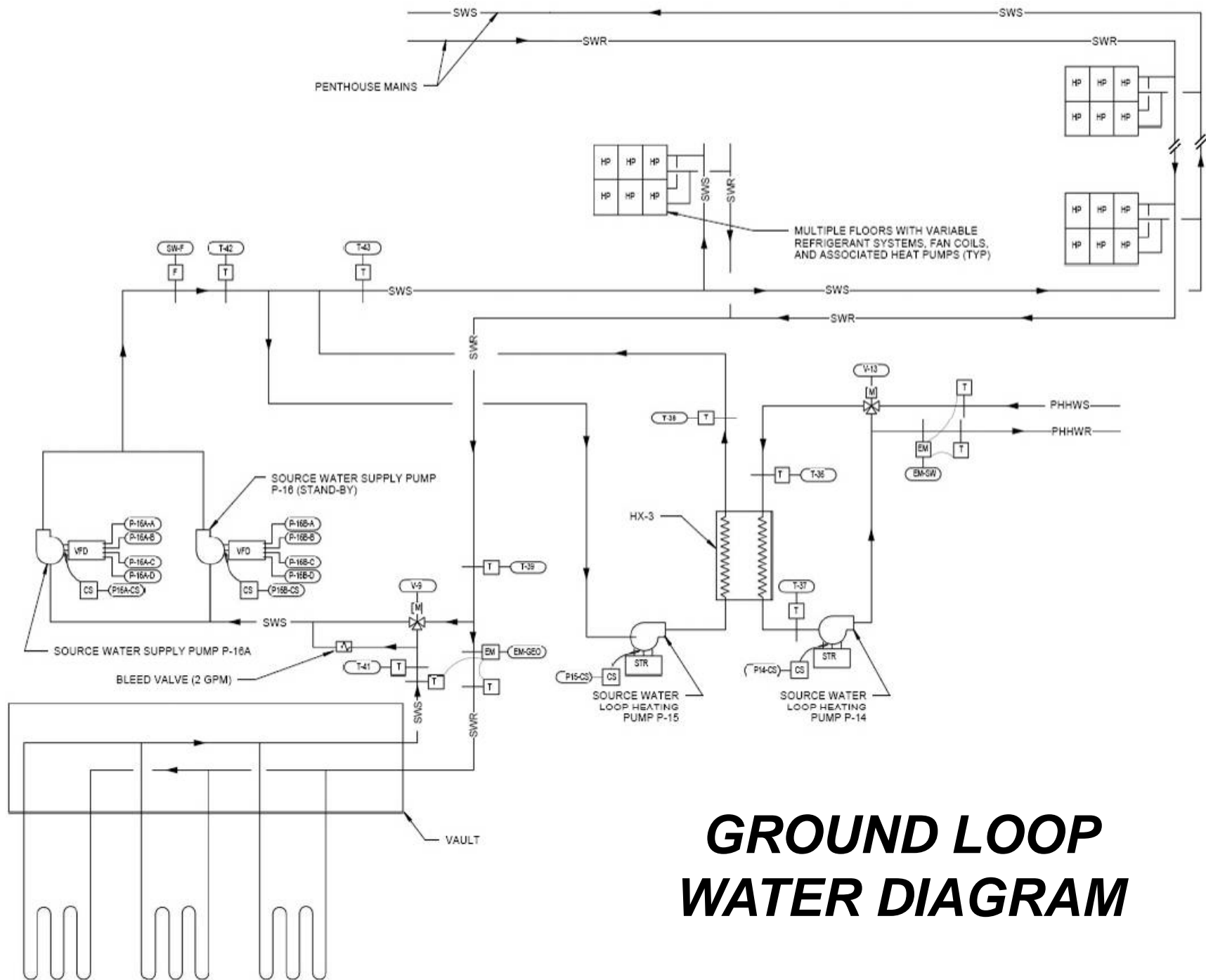
**DOAS  
2**

**GROUND  
LOOP**

**DOMESTIC  
HW**

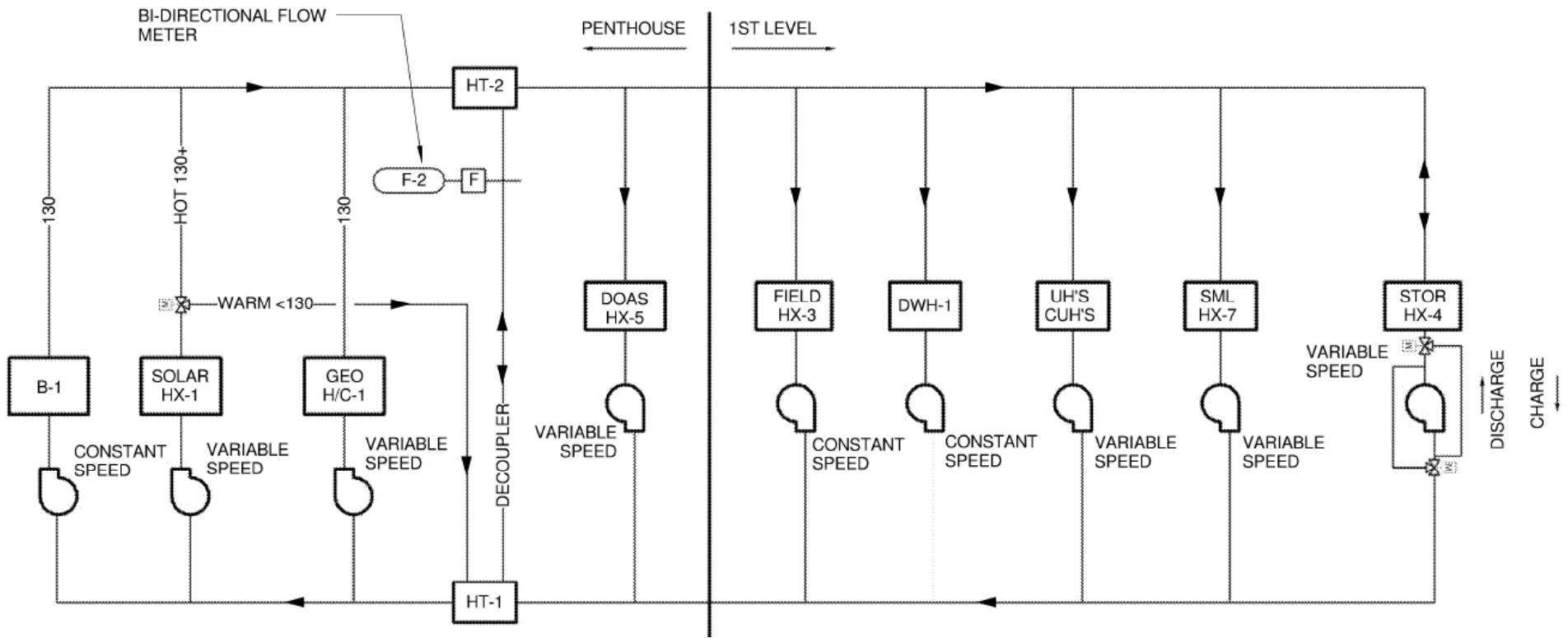
**SNOW  
MELT**

**SOLAR  
THERMAL  
STORAGE**



# ***GROUND LOOP WATER DIAGRAM***

# SIMPLIFIED HEATING DIAGRAM



## PRIORITY:

### SUMMER ON PEAK

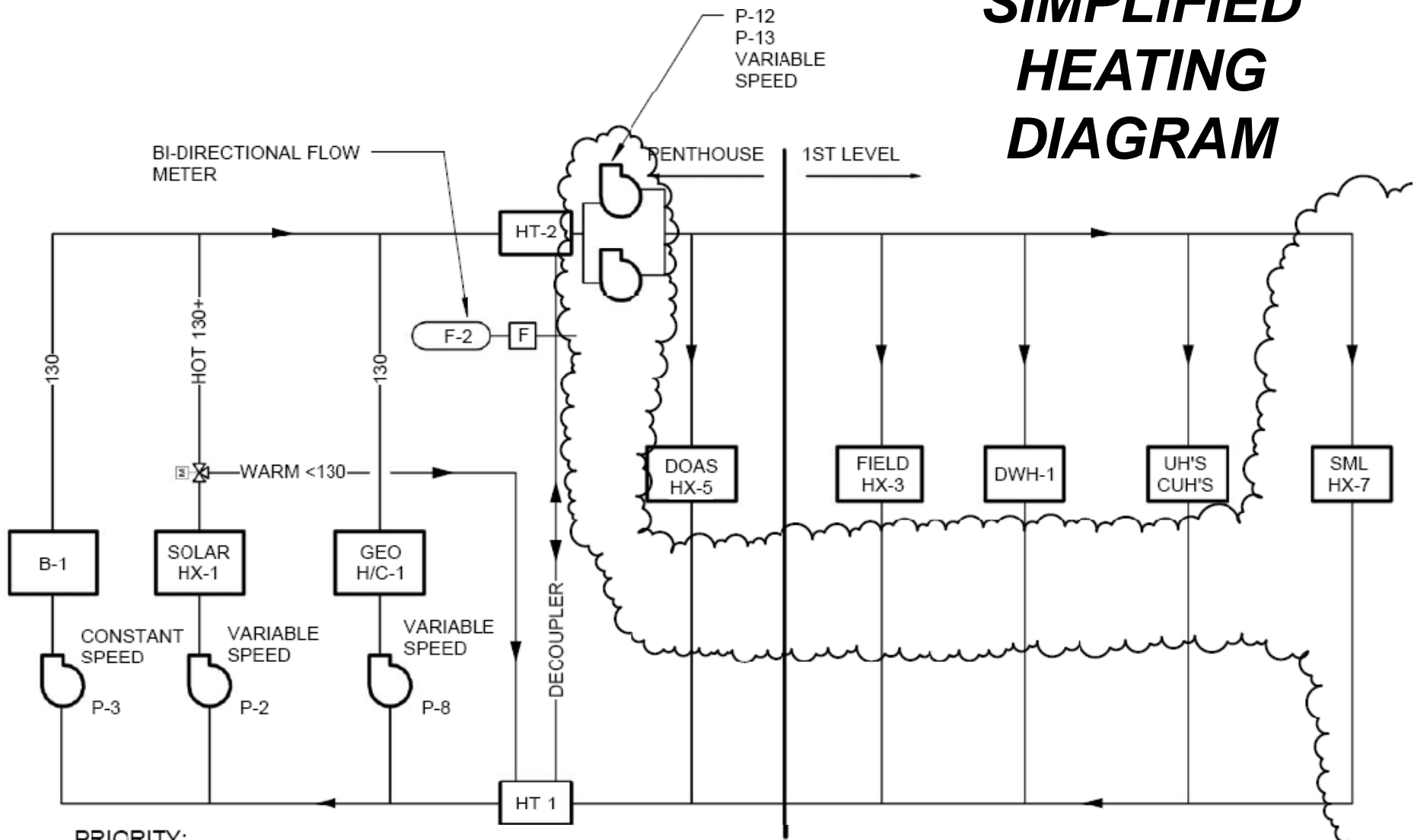
- 1) HX-1
- 2) HX-4
- 3) B-1
- 4) GEO H/C-1

### SUMMER OFF PEAK & WINTER

- 1) HX-1
- 2) HX-4
- 3) GEO H/C-1
- 4) B-1

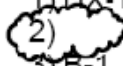


# SIMPLIFIED HEATING DIAGRAM

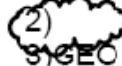


## PRIORITY:

SUMMER ON PEAK

- 1) HX-1
- 2) 
- 3) B-1
- 4) GEO H/C-1

SUMMER OFF PEAK & WINTER

- 1) HX-1
- 2) 
- 3) GEO H/C-1
- 4) B-1

NOTE: IF TEMP @ HT-2 IS > 135° F, DO NOT ADD B-1 OR GEO H/C-1 HEAT.

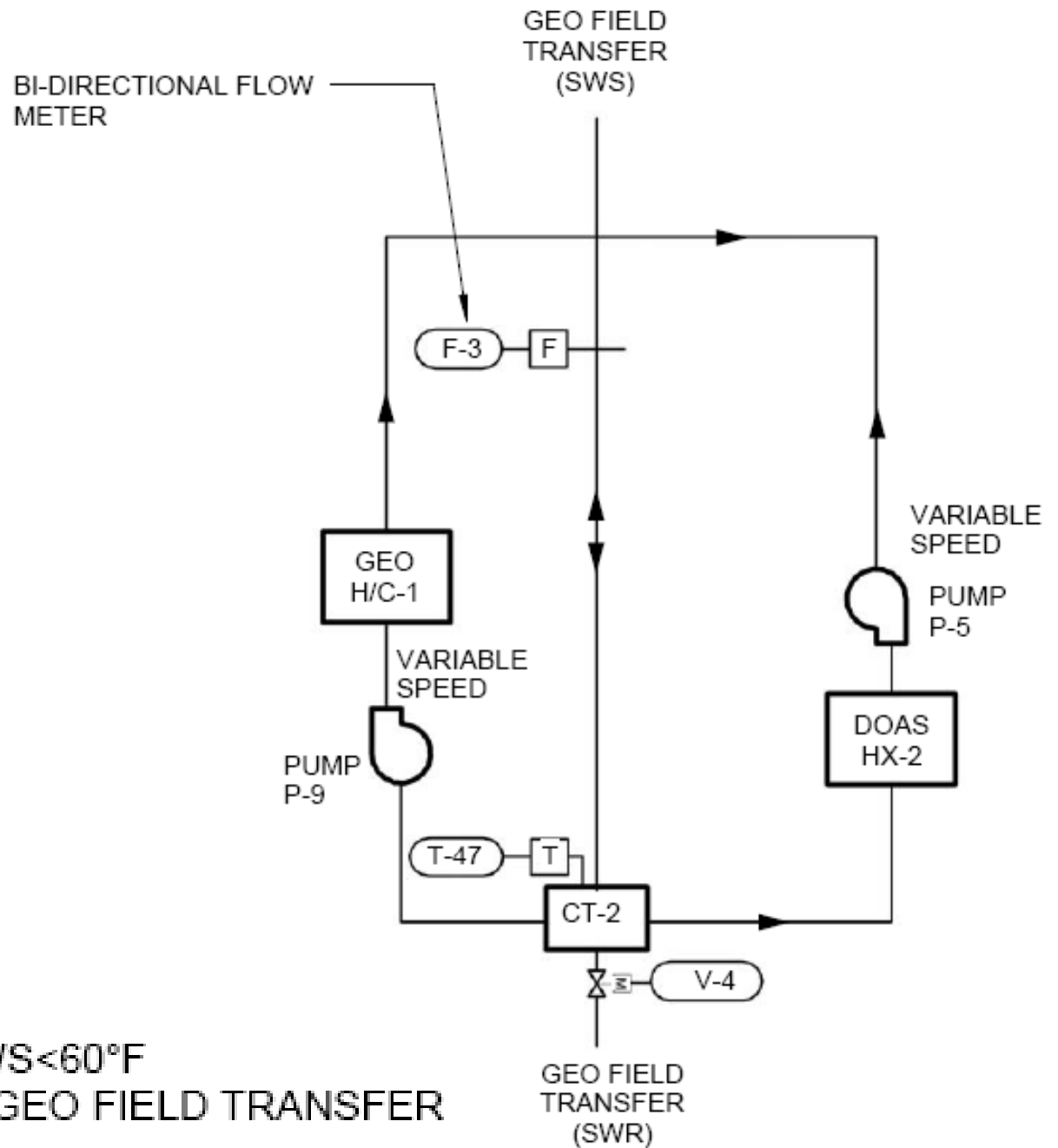
# ***SIMPLIFIED COOLING DIAGRAM***

***SWS = SOURCE  
WATER SUPPLY***

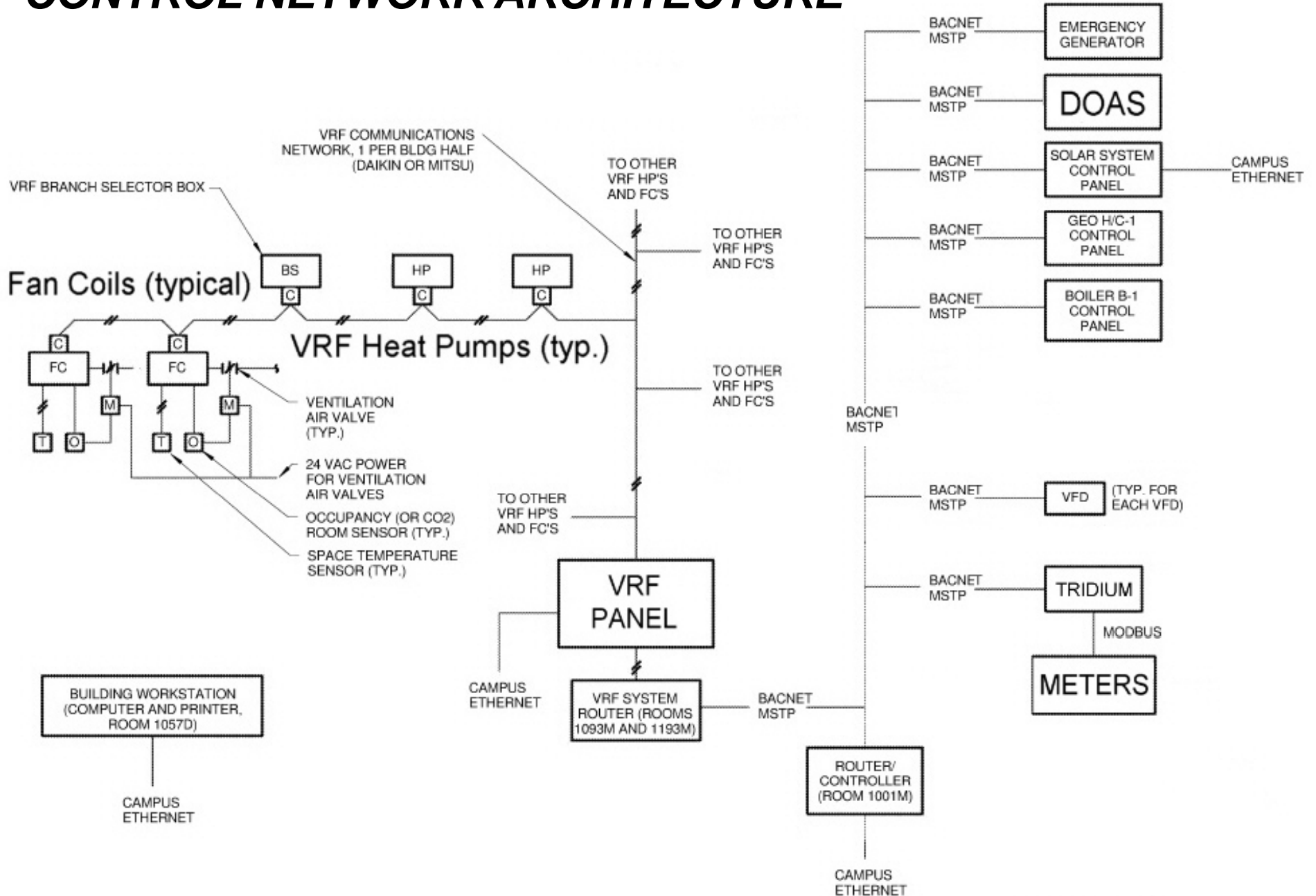
**PRIORITY:**

**SWS > 60°F**  
1) GEO H/C-1

**SWS < 60°F**  
1) GEO FIELD TRANSFER



# CONTROL NETWORK ARCHITECTURE







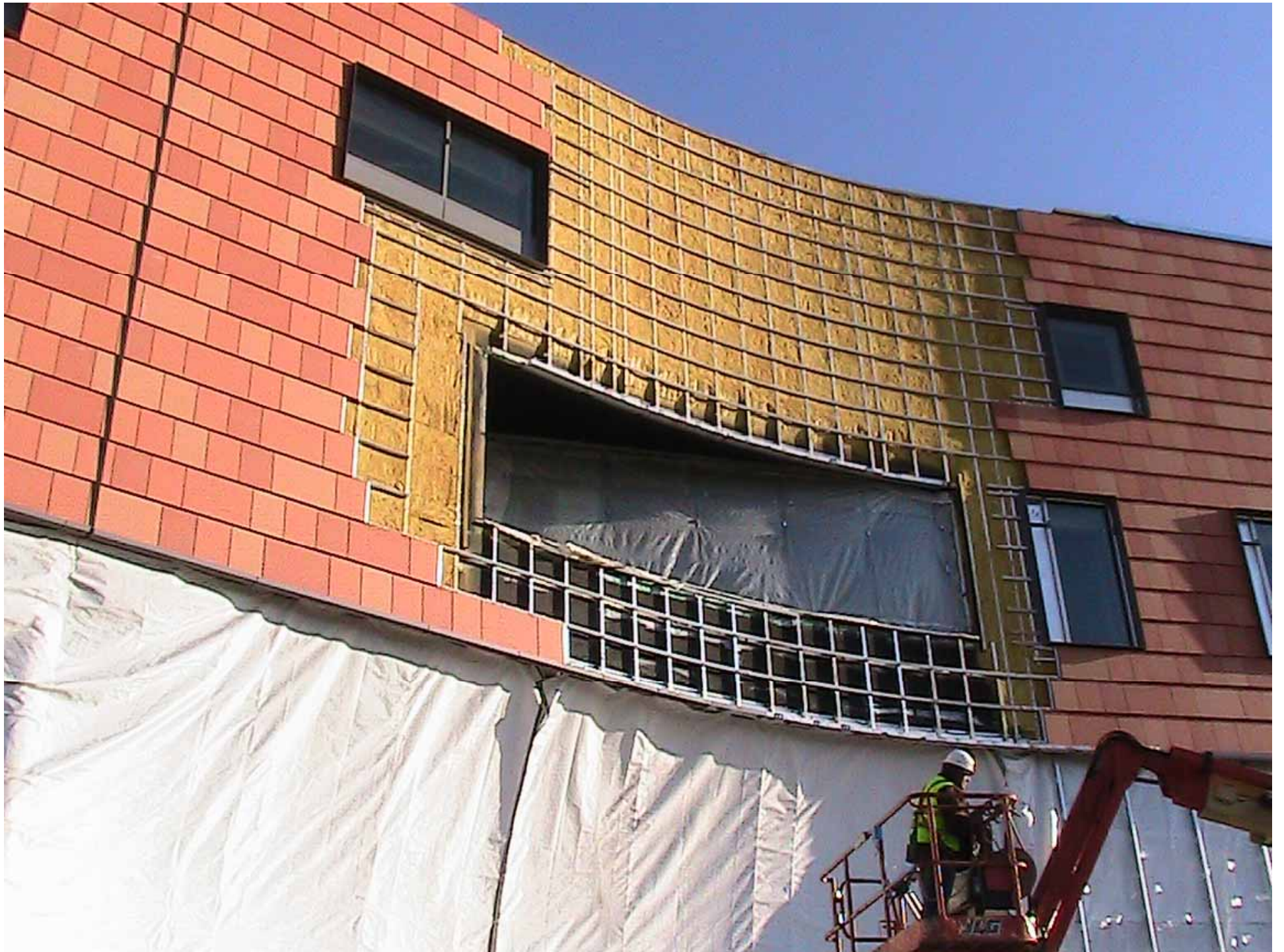














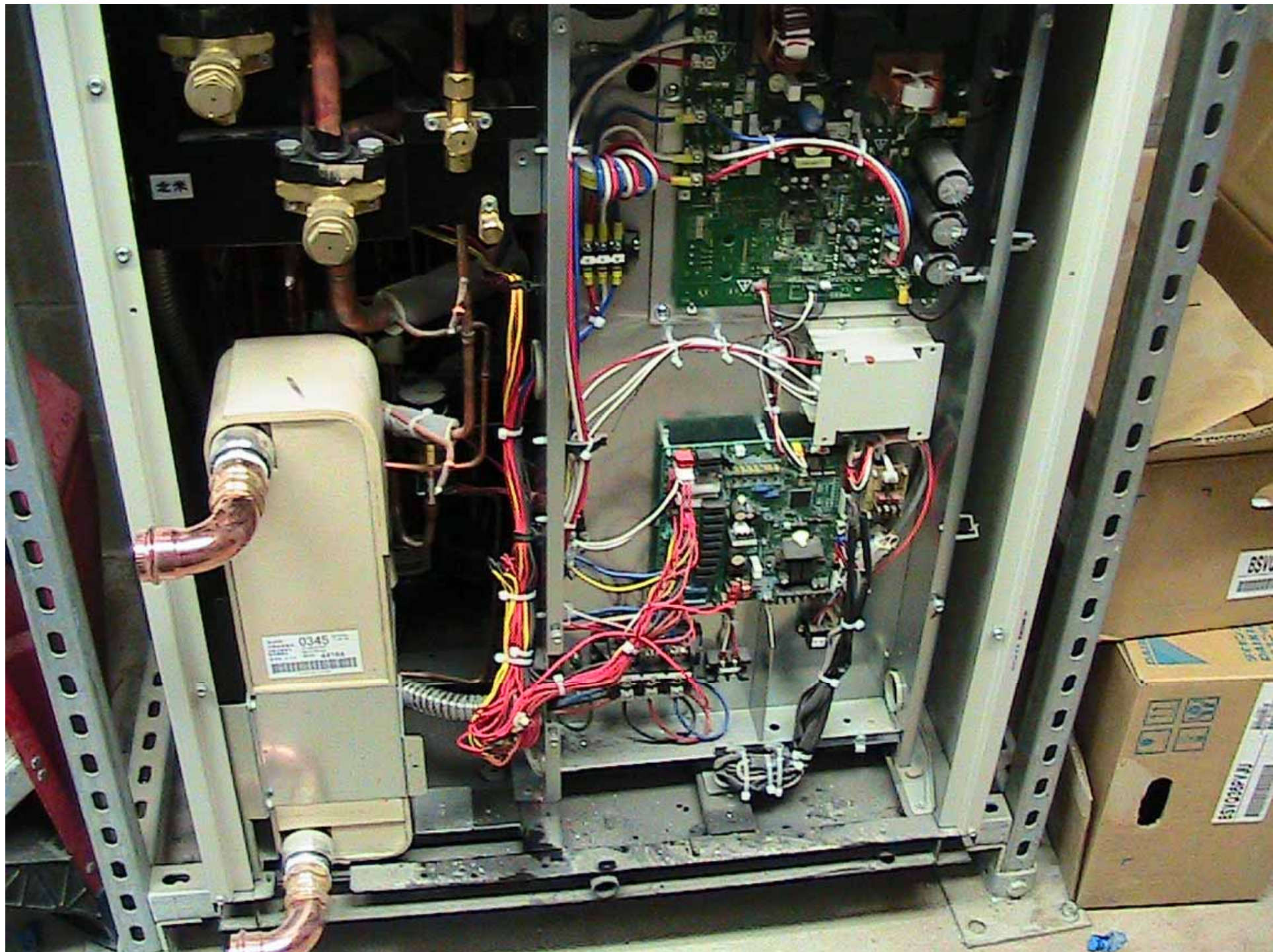






# VRF Heat Pumps









# Variable Refrigerant Flow Compressors with VFD's

















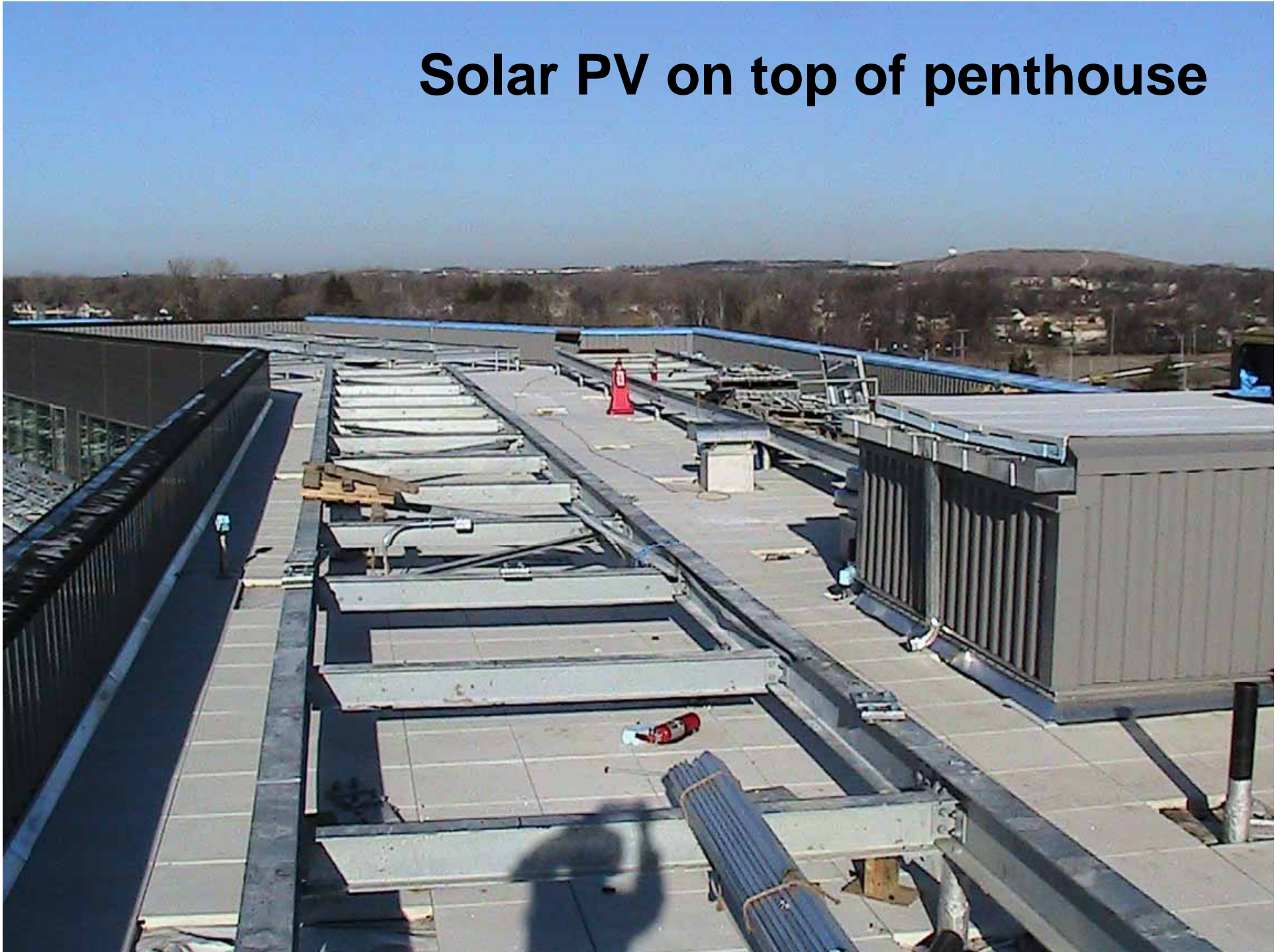








# Solar PV on top of penthouse











# End of Part 1: System Design

Part 2: Construction, Commissioning & Lessons Learned

Part 3: Energy Monitoring & Performance



## *Questions ?*



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