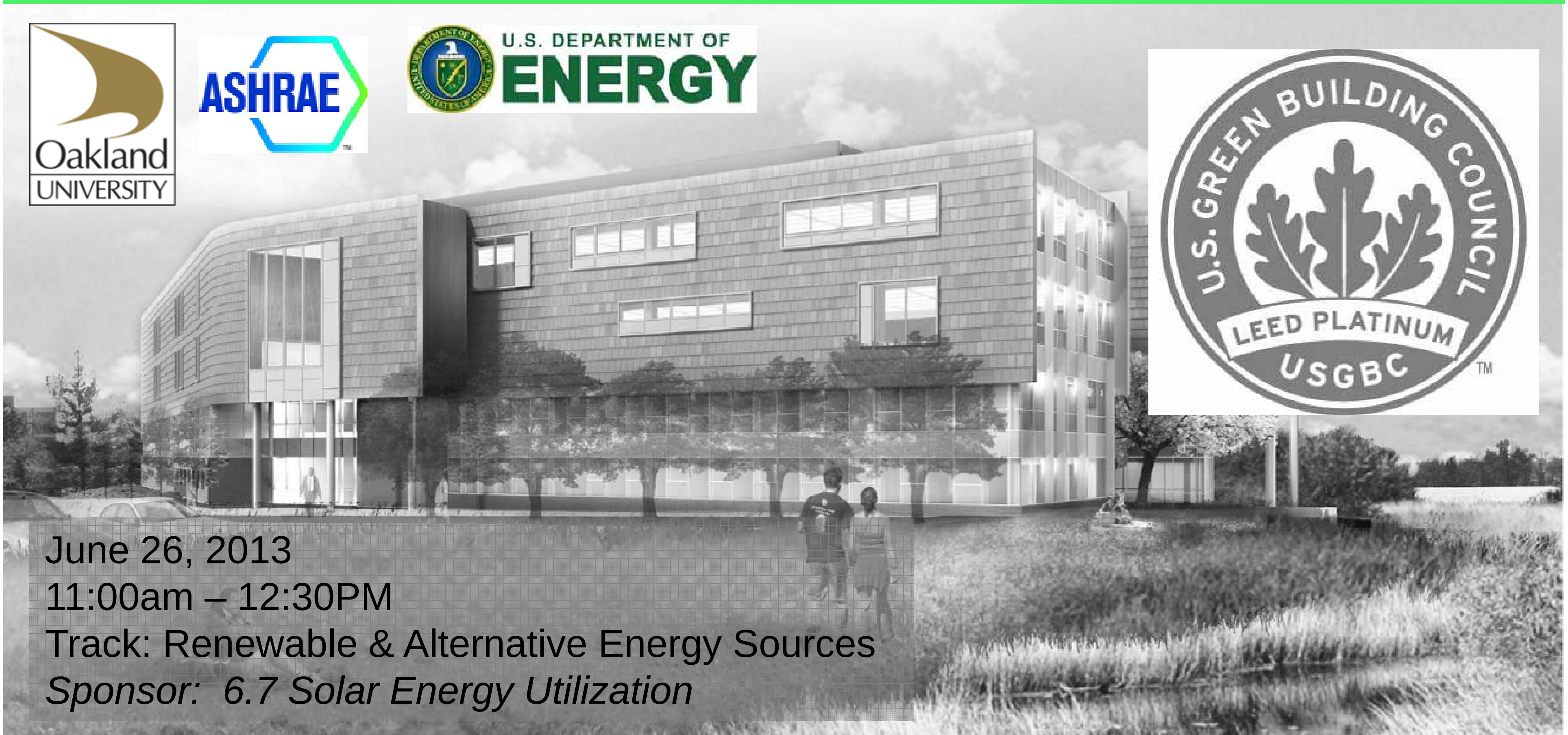
Integrating Large Scale, Innovative Solar Thermal Systems into the Built Environment



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

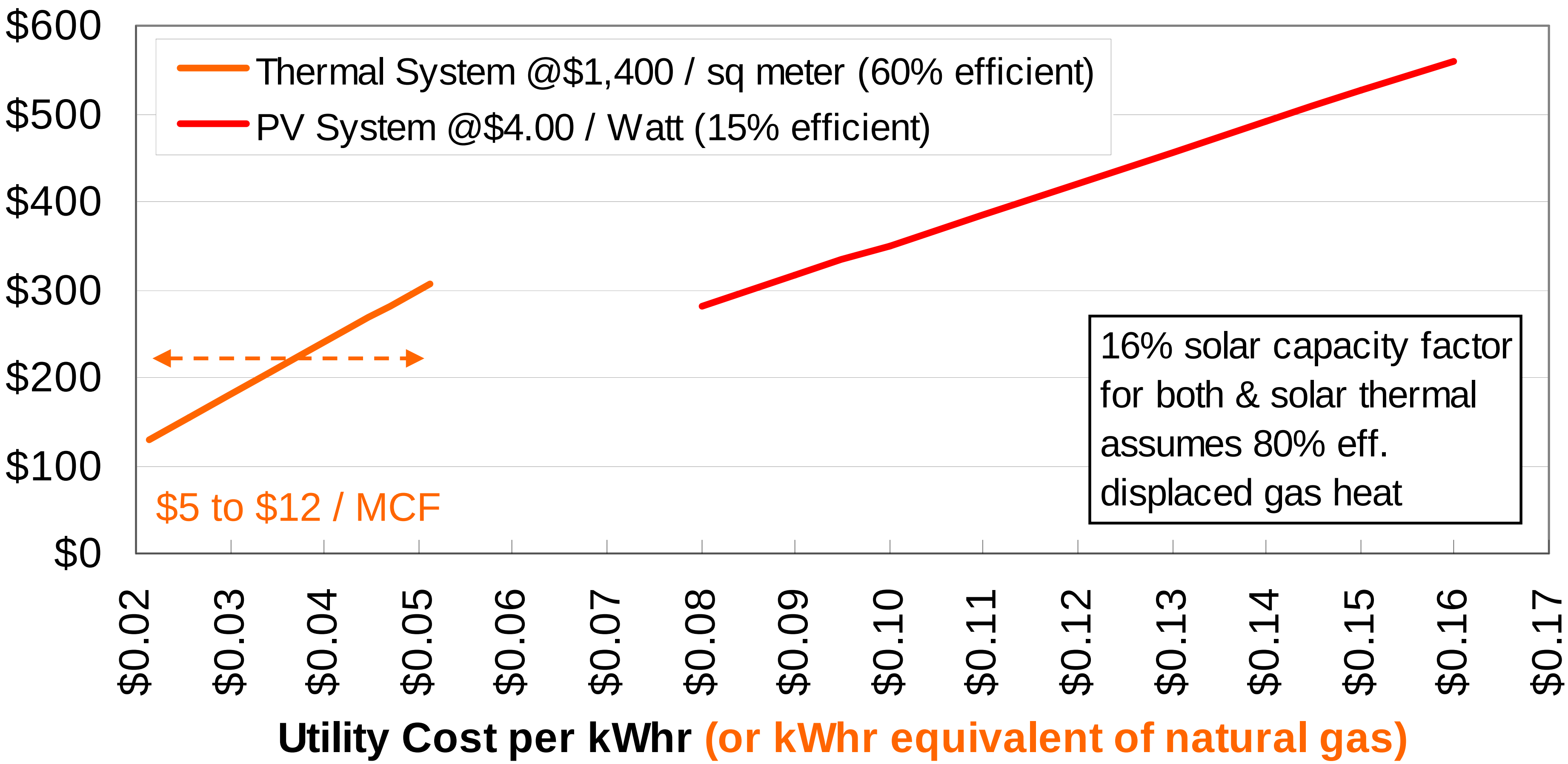
1. What do solar thermal energy systems provide for the built environment?
2. Components of active solar thermal systems?
3. Examples of loads served by solar thermal systems.
4. Three case studies where large solar thermal systems.
5. Thermal energy storage (it's use and sizing) required by solar energy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

AGENDA

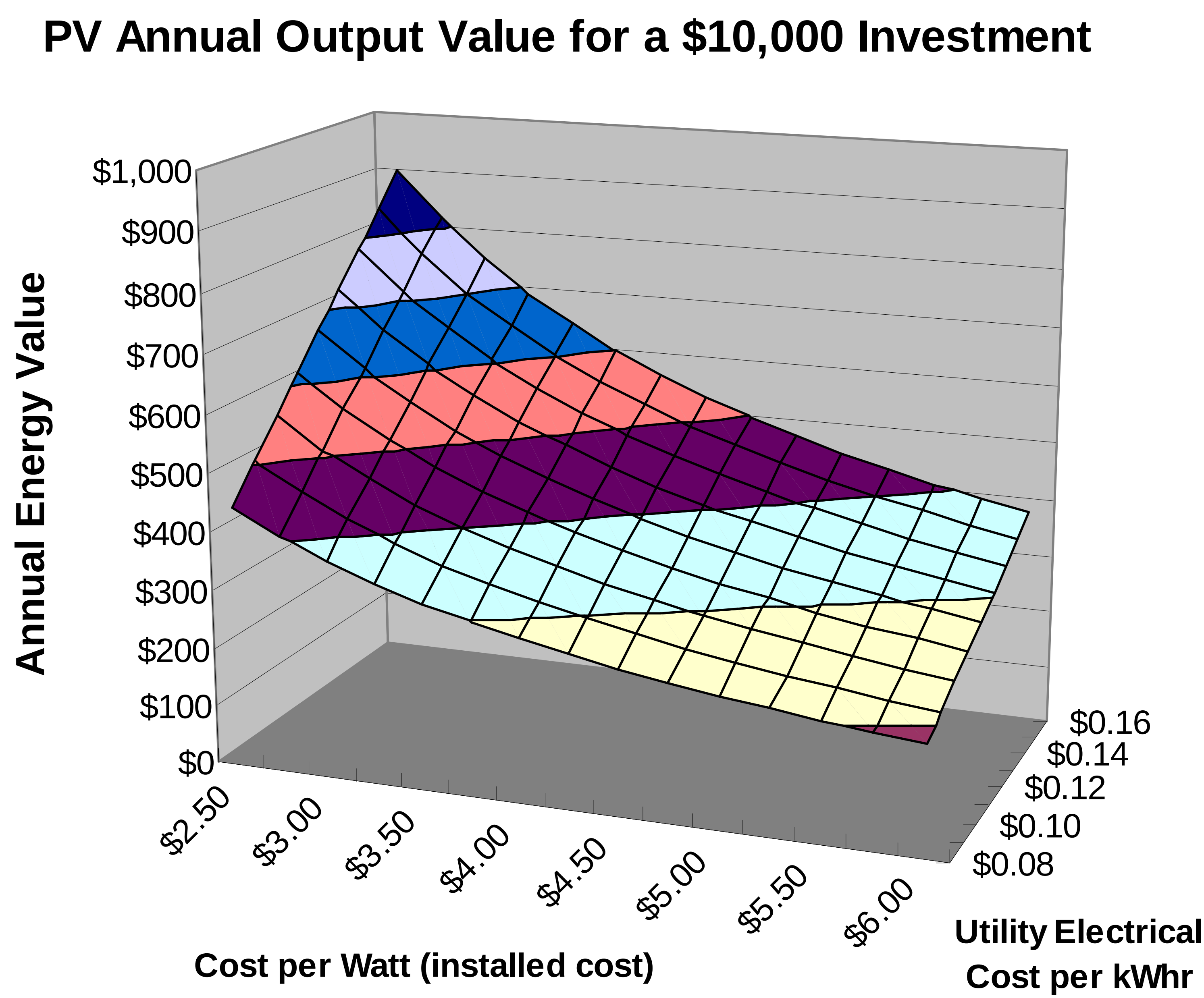
- Quick Look at Solar Thermal Economics as Compared to Solar PV
- Case Studies:
  - Oakland University Human Health Building: Hybrid Geothermal / Solar Thermal HVAC System: Pt 1 Design
  - District Energy St. Paul: Solar Thermal & Biomass for Downtown St. Paul, Minnesota
  - Drake Landing Solar Community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

Economics of Solar Thermal

Solar PV vs. Solar Thermal
in Today's Marketplace

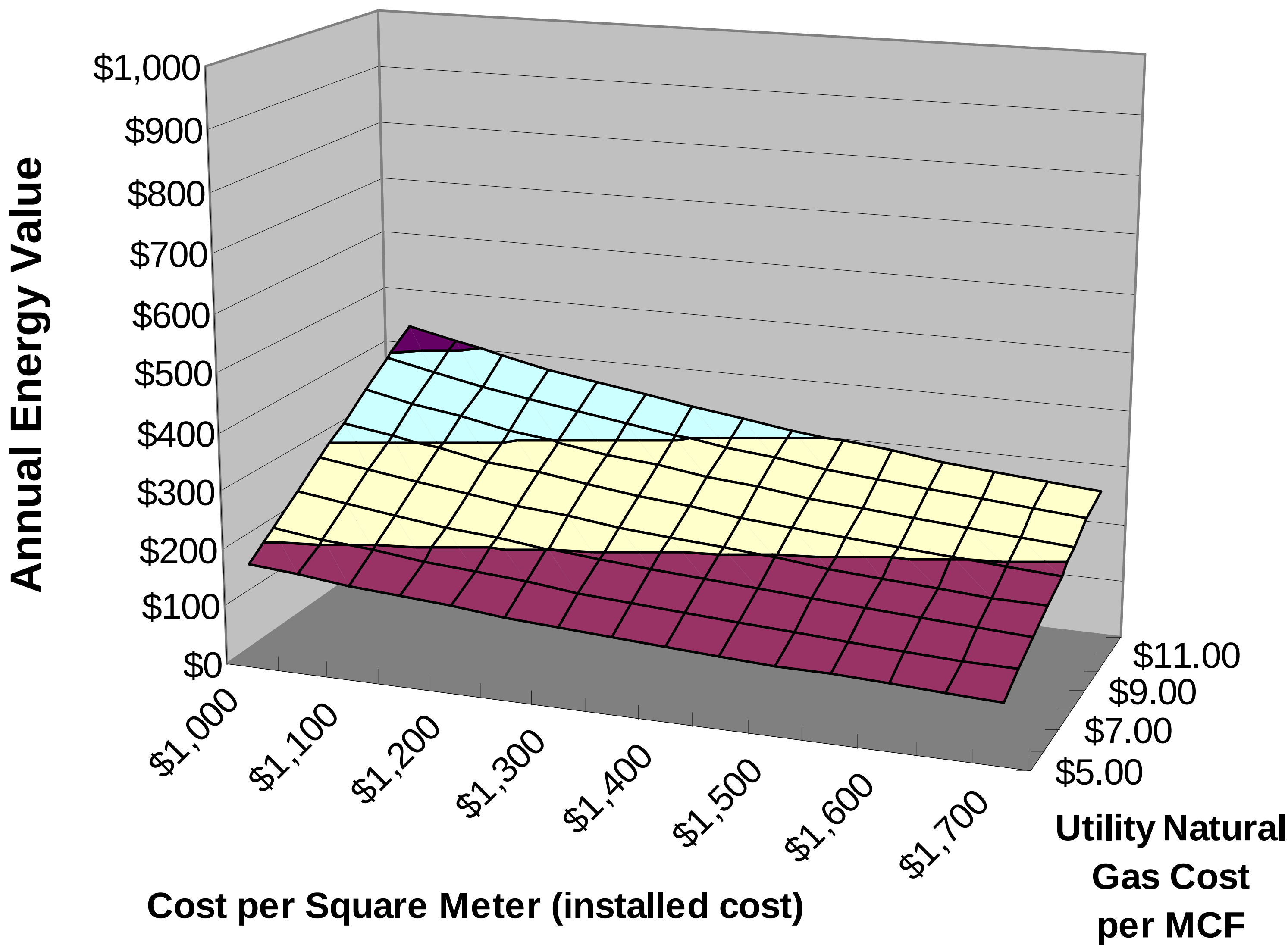


Comparison of the annual energy value of two separate $10,000 solar systems: PV and solar thermal at various utility rates.

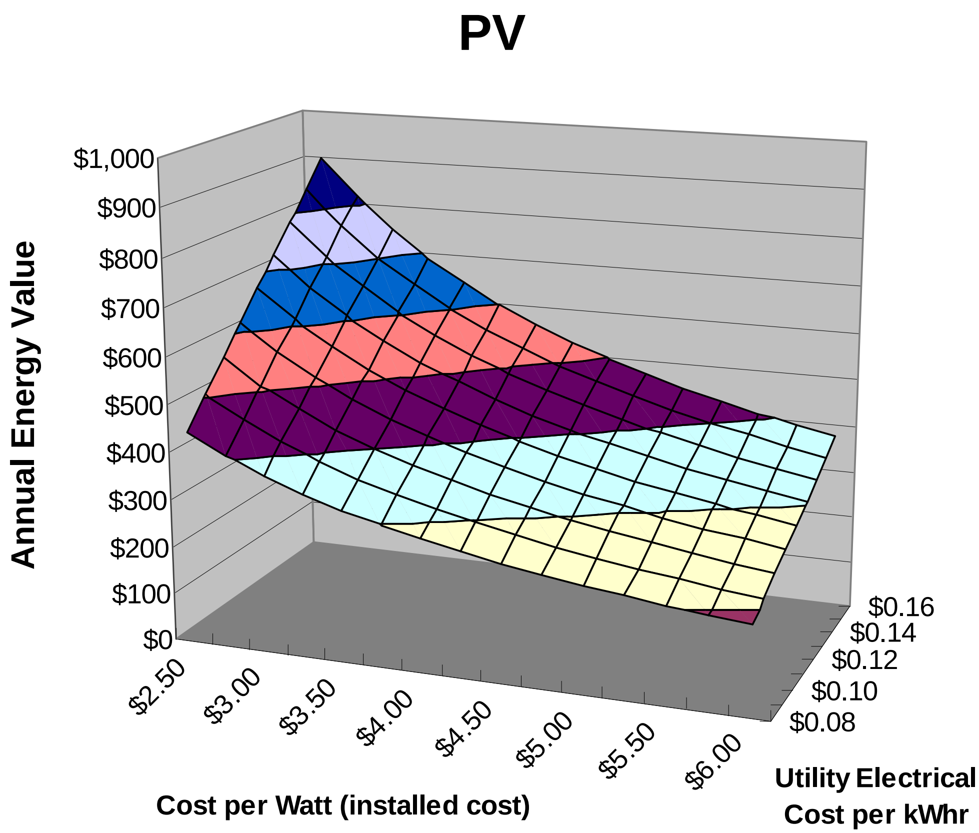


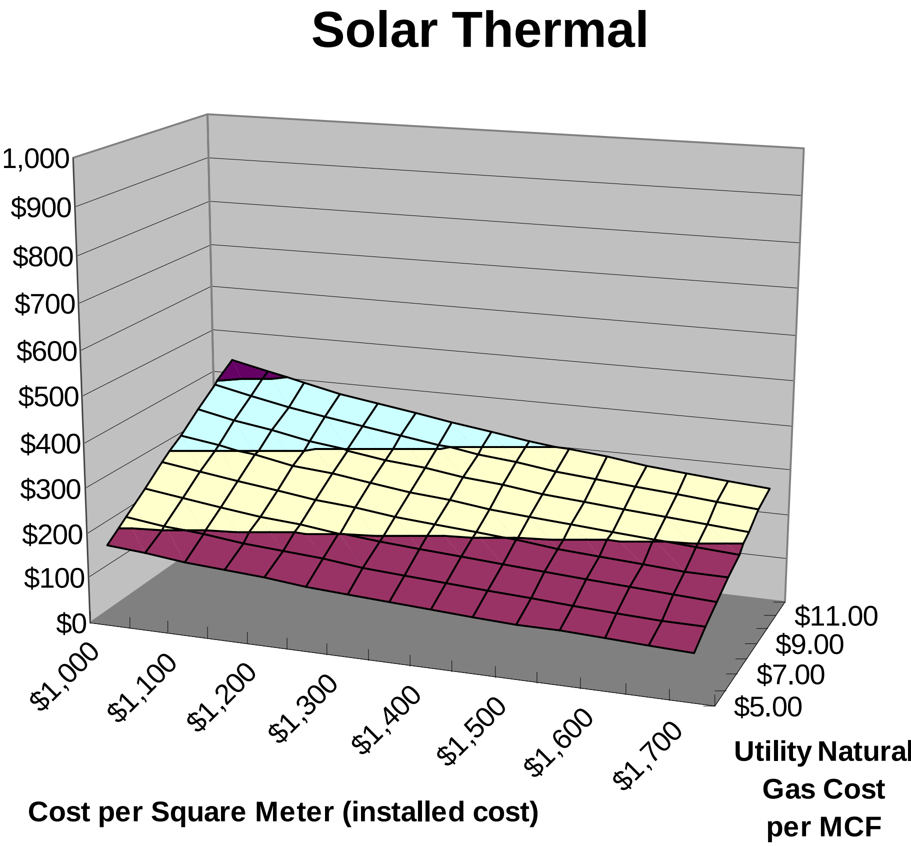
Sensitivity analysis of $10,000 PV investment with varying installed cost and natural gas or electric rates

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





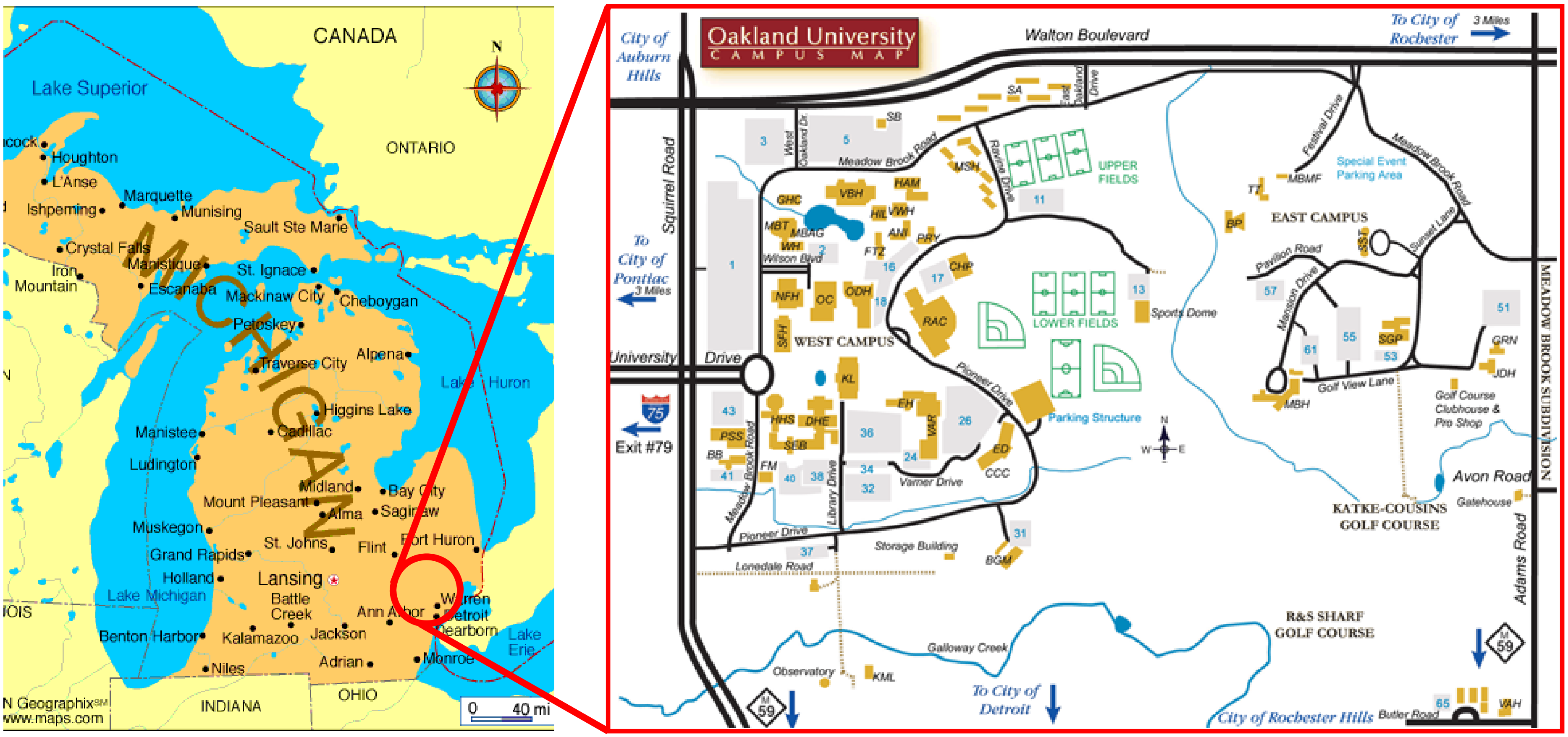
Sensitivity analysis of separate $10,000 PV or solar thermal investments with varying installed cost and natural gas or electric rates

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

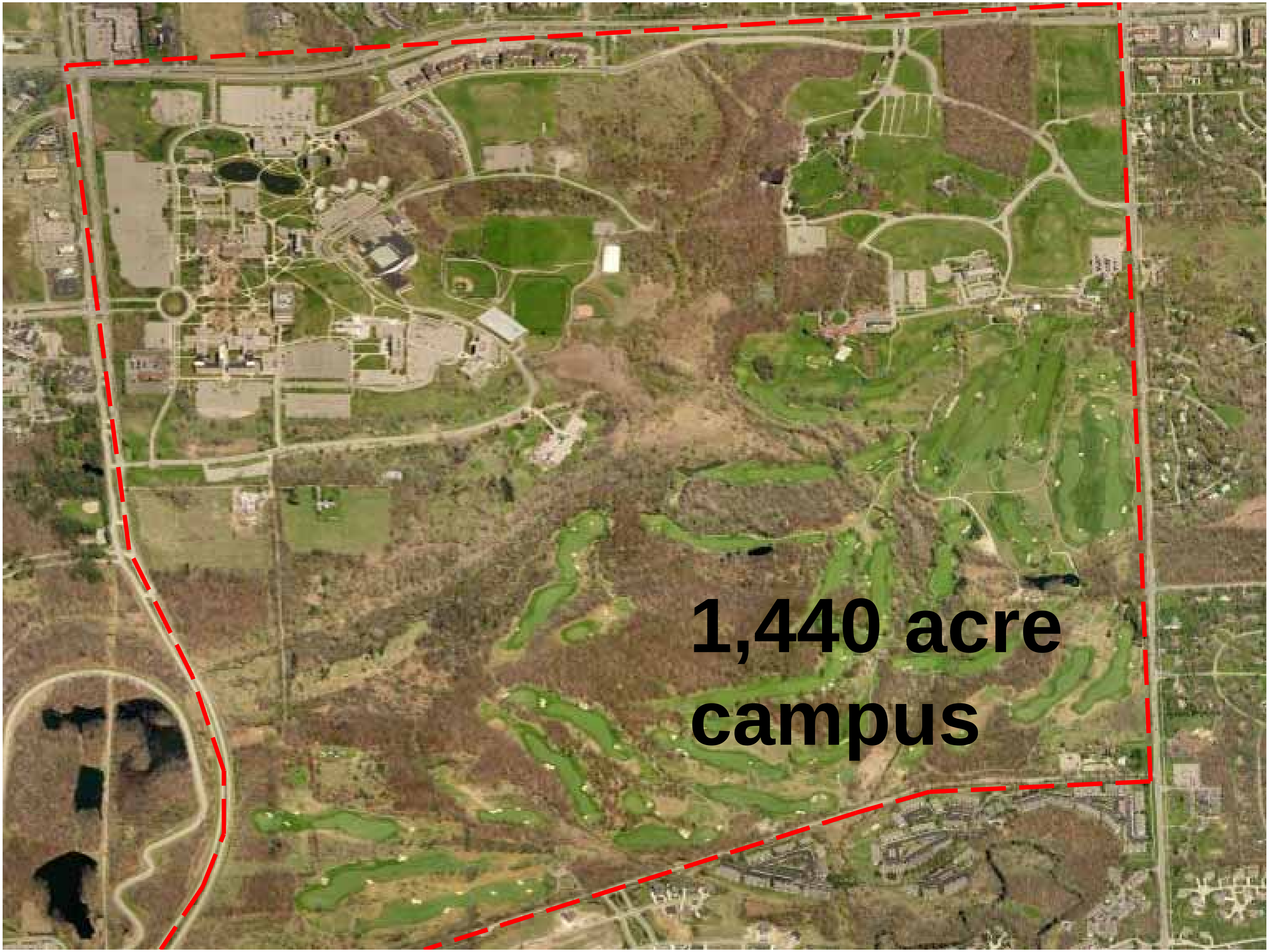
Golden Grizzlies

19,000 students

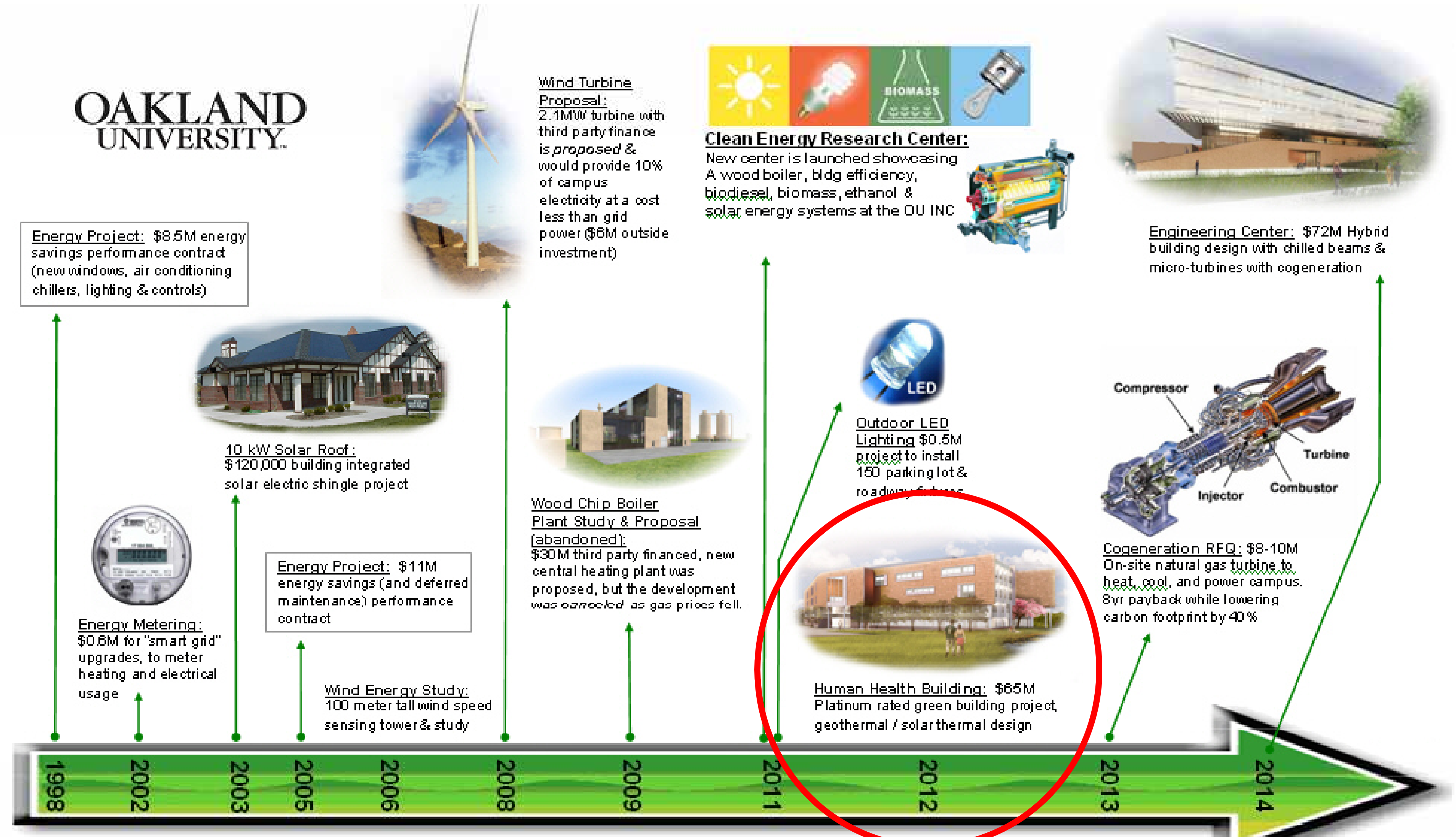
3.0M square feet

132 baccalaureate degree programs

126 graduate degree and certificate programs

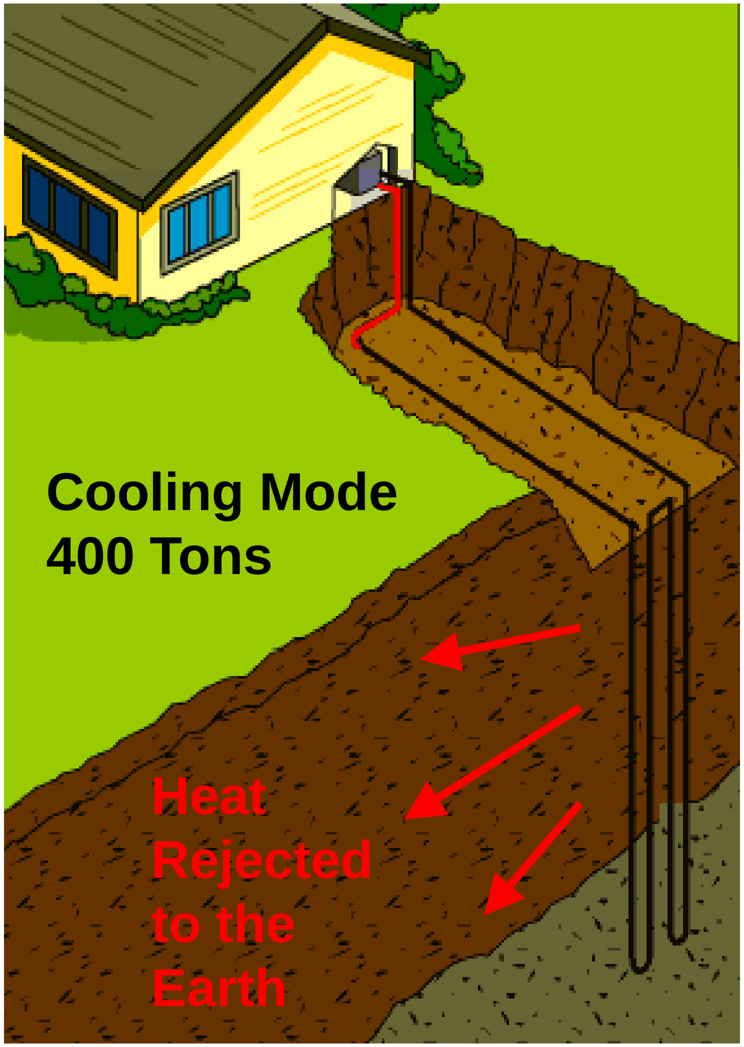

1,440 acre
campus

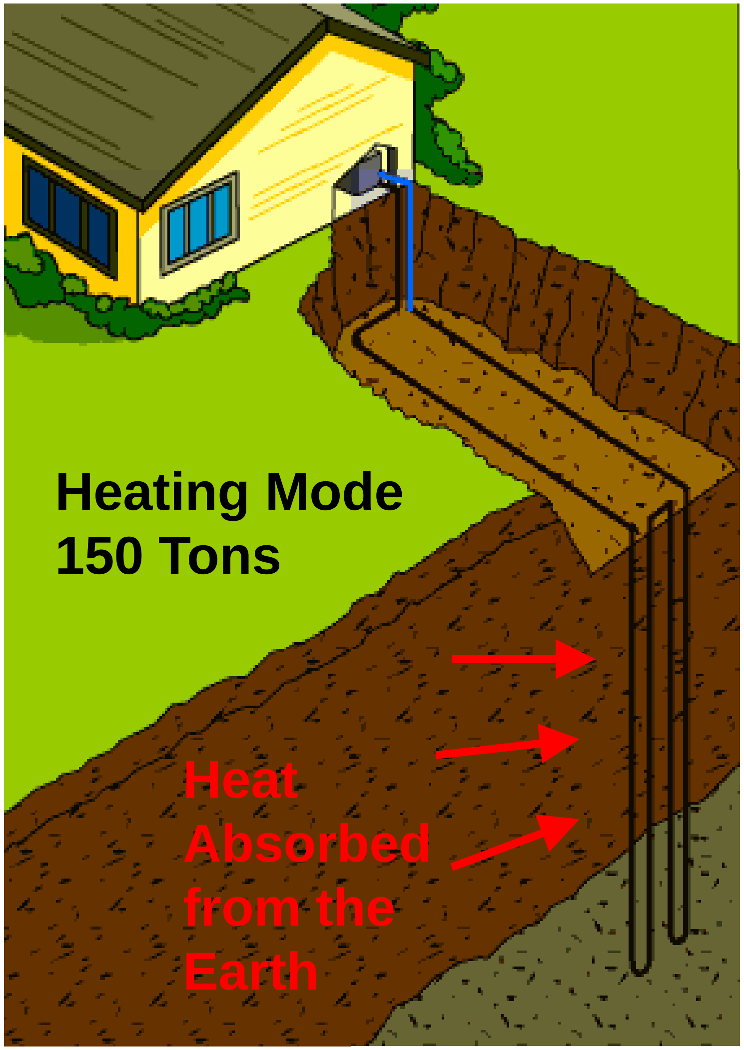
Clean Energy Projects at Oakland



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

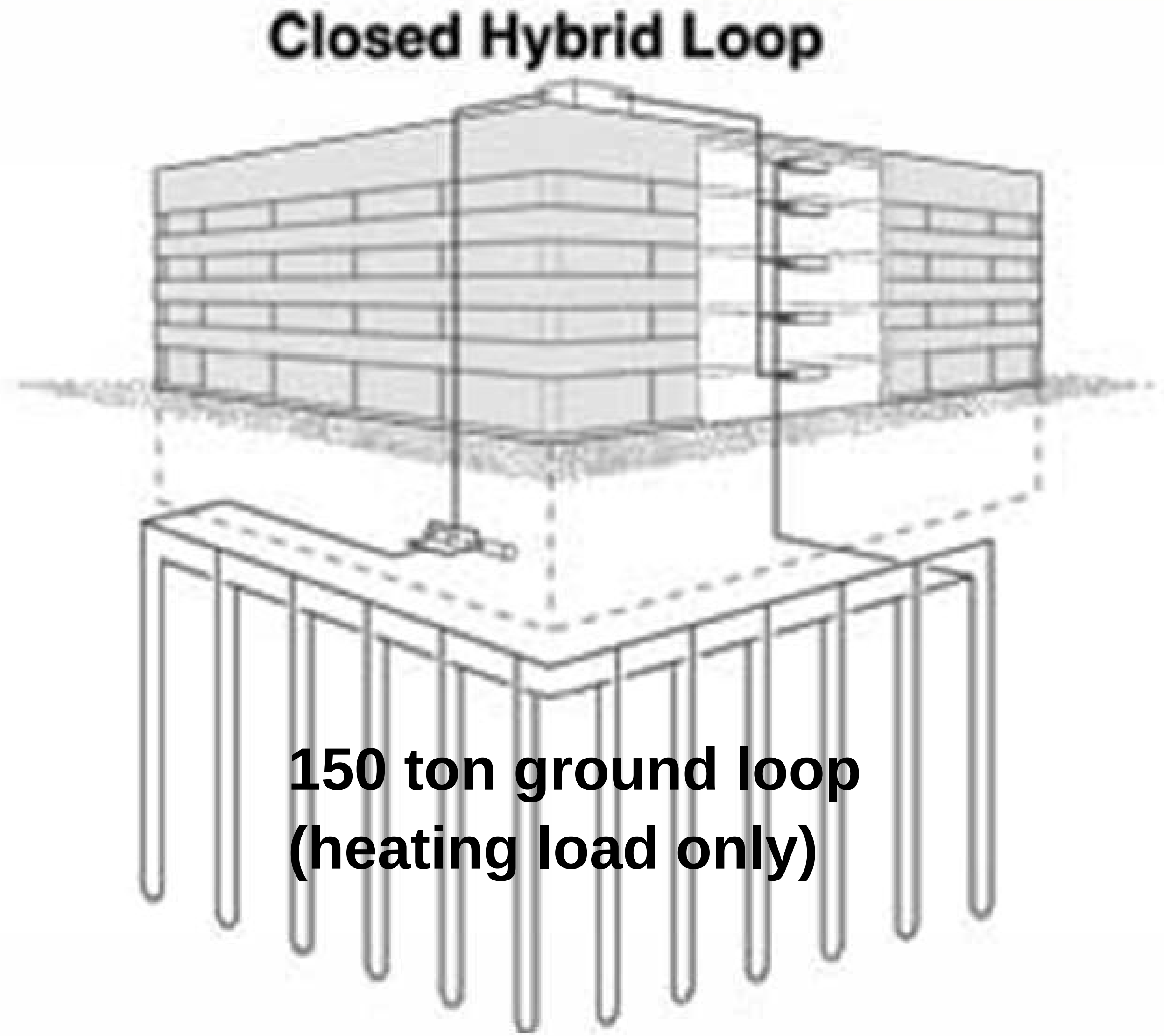
Utilize variable refrigerant flow (VRF) heat pumps, allows for less compressors and enhanced internal heat recovery.

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.

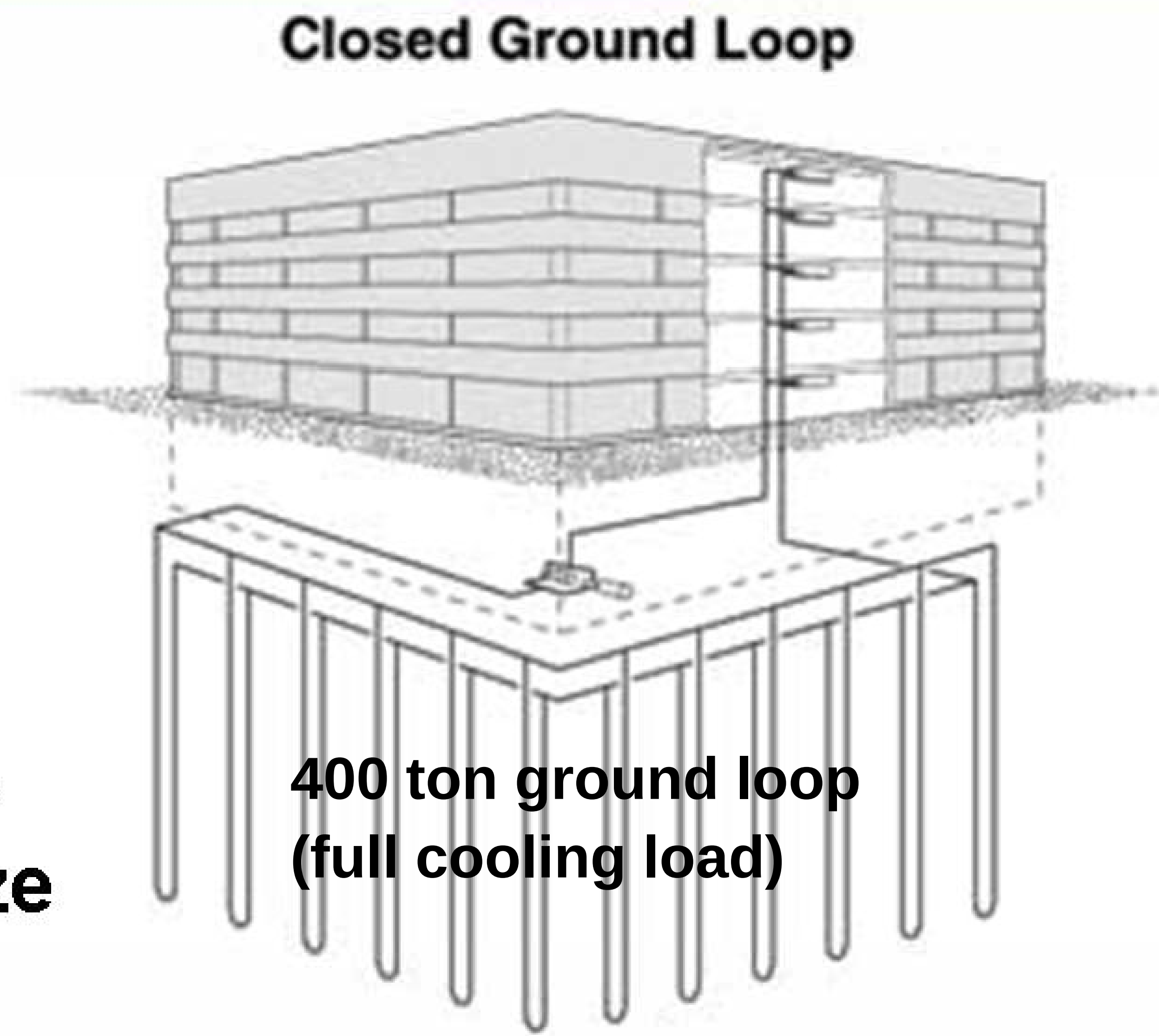
Geothermal System

Original Concept



150 ton ground loop (heating load only)

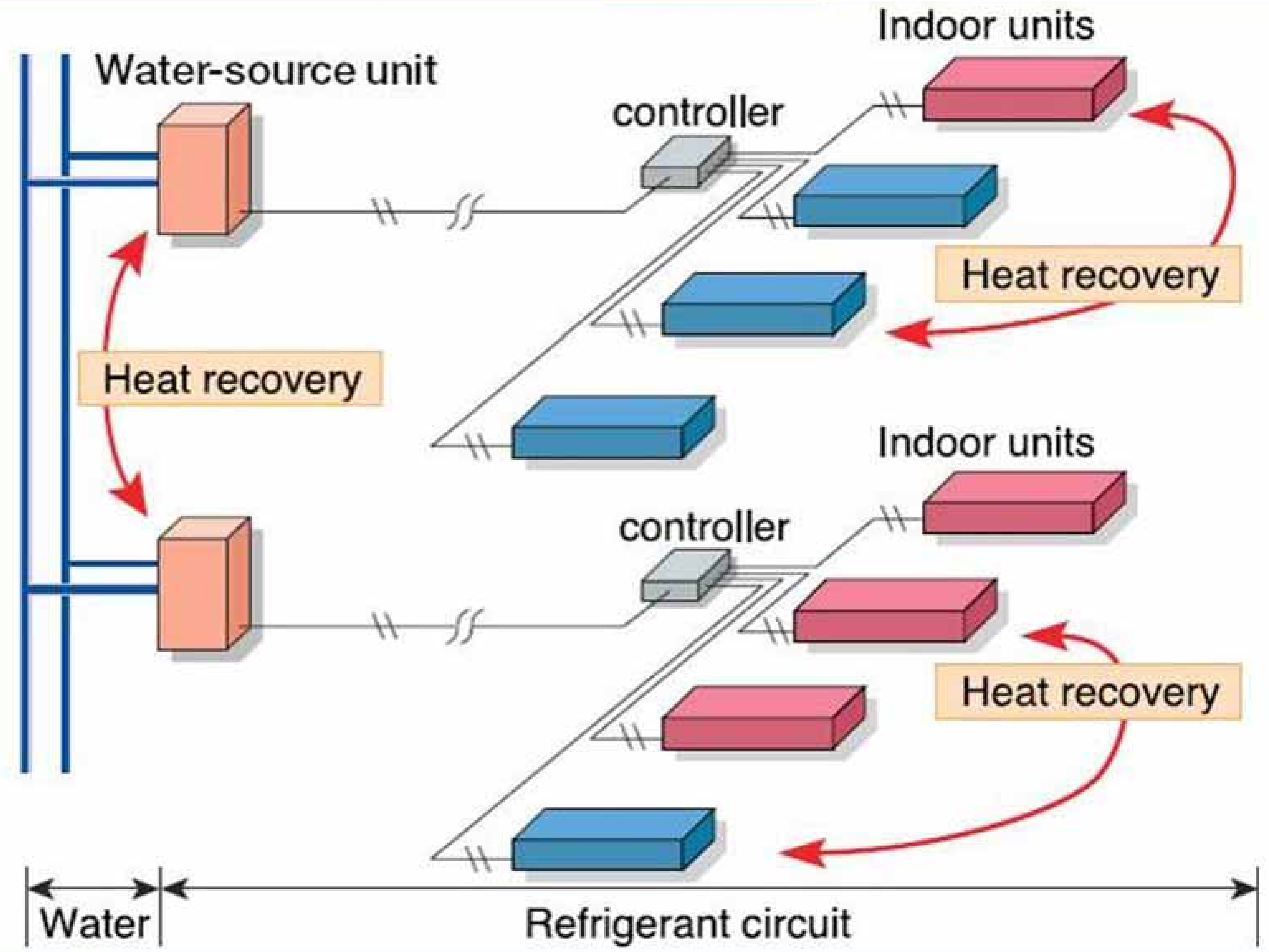
Geothermal System (grant funded full system)



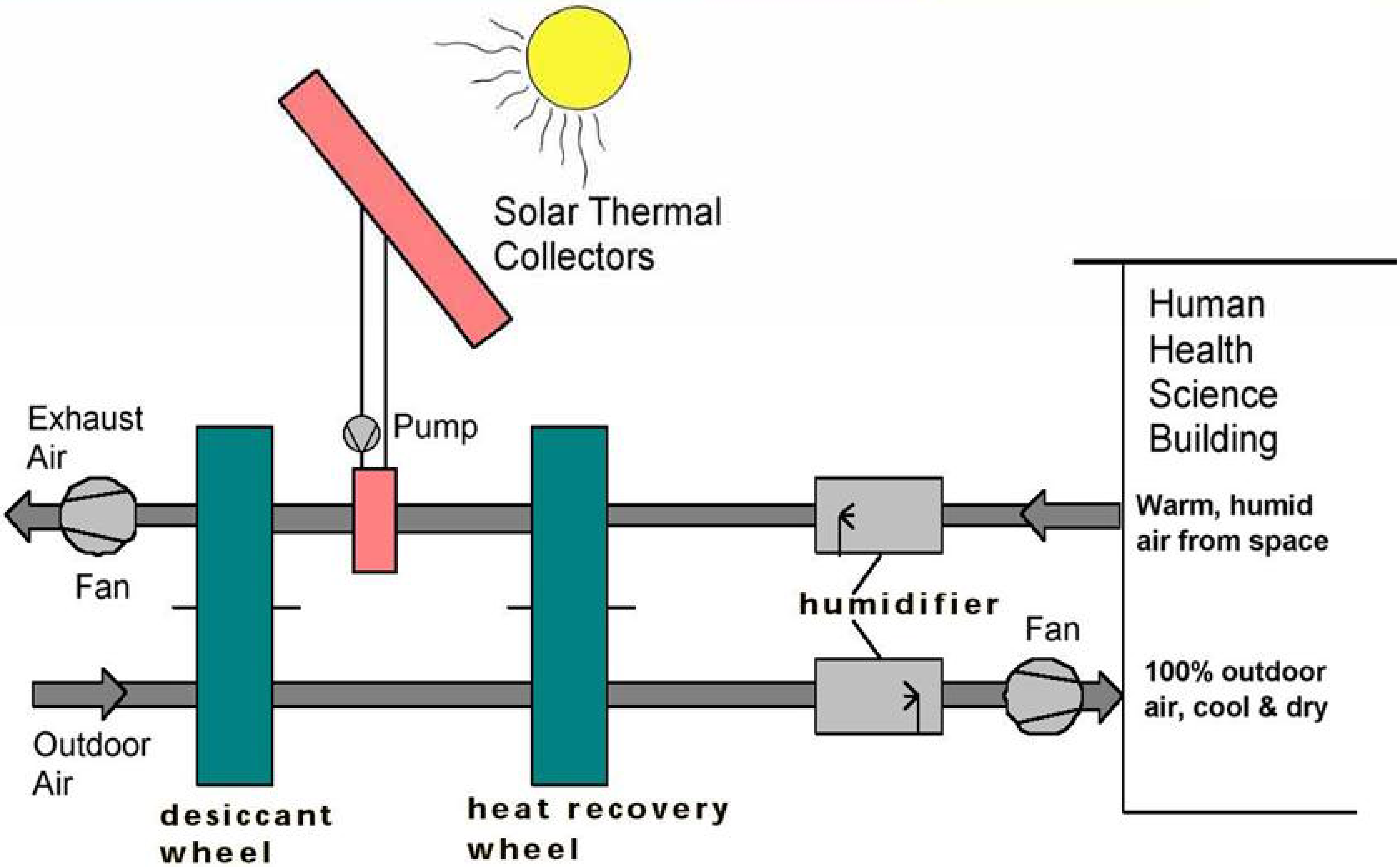
Water Only, No Antifreeze

400 ton ground loop (full cooling load)

Variable Refrigerant Flow Heat Pumps

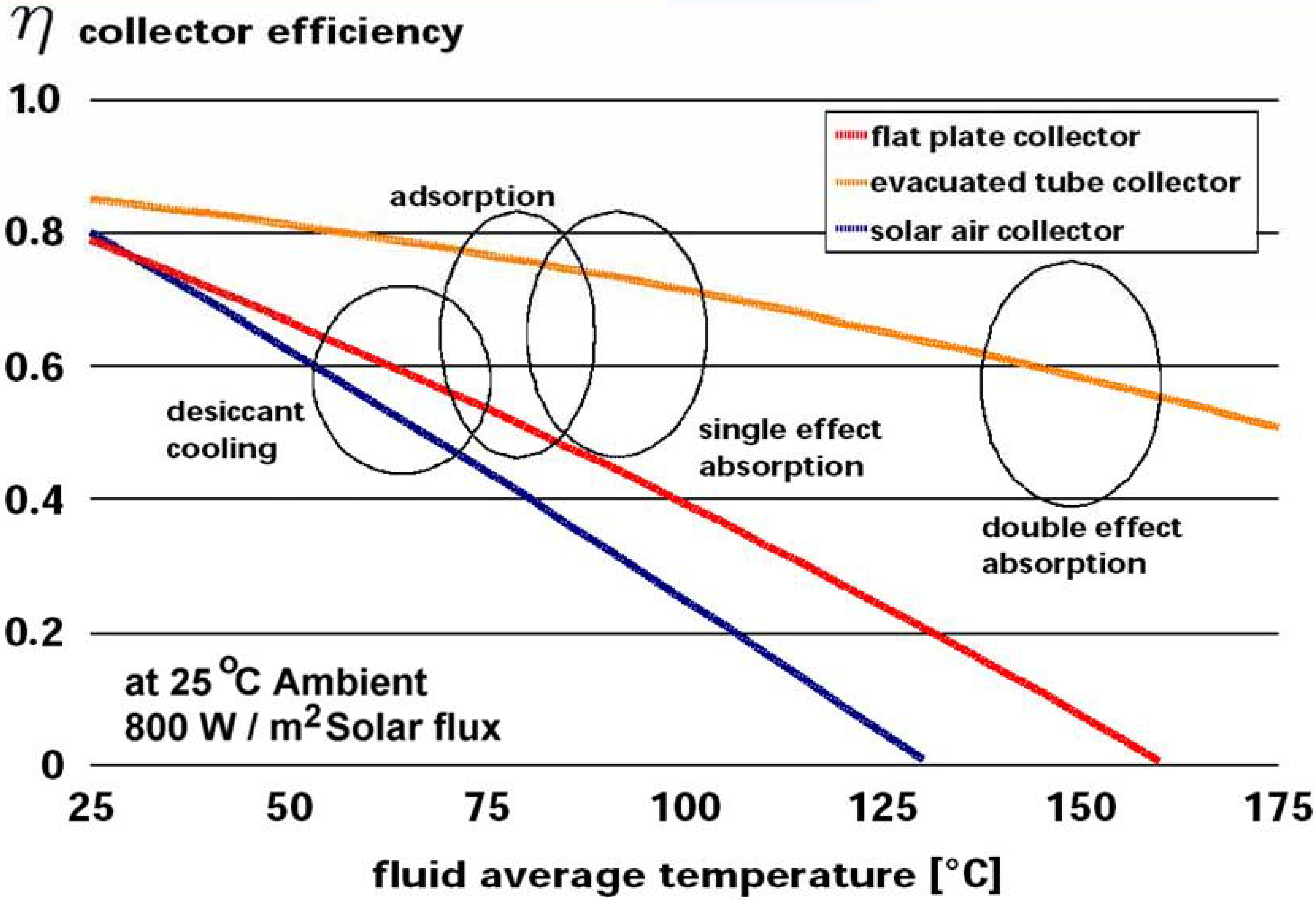


Solar Thermal Desiccant Dehumidification

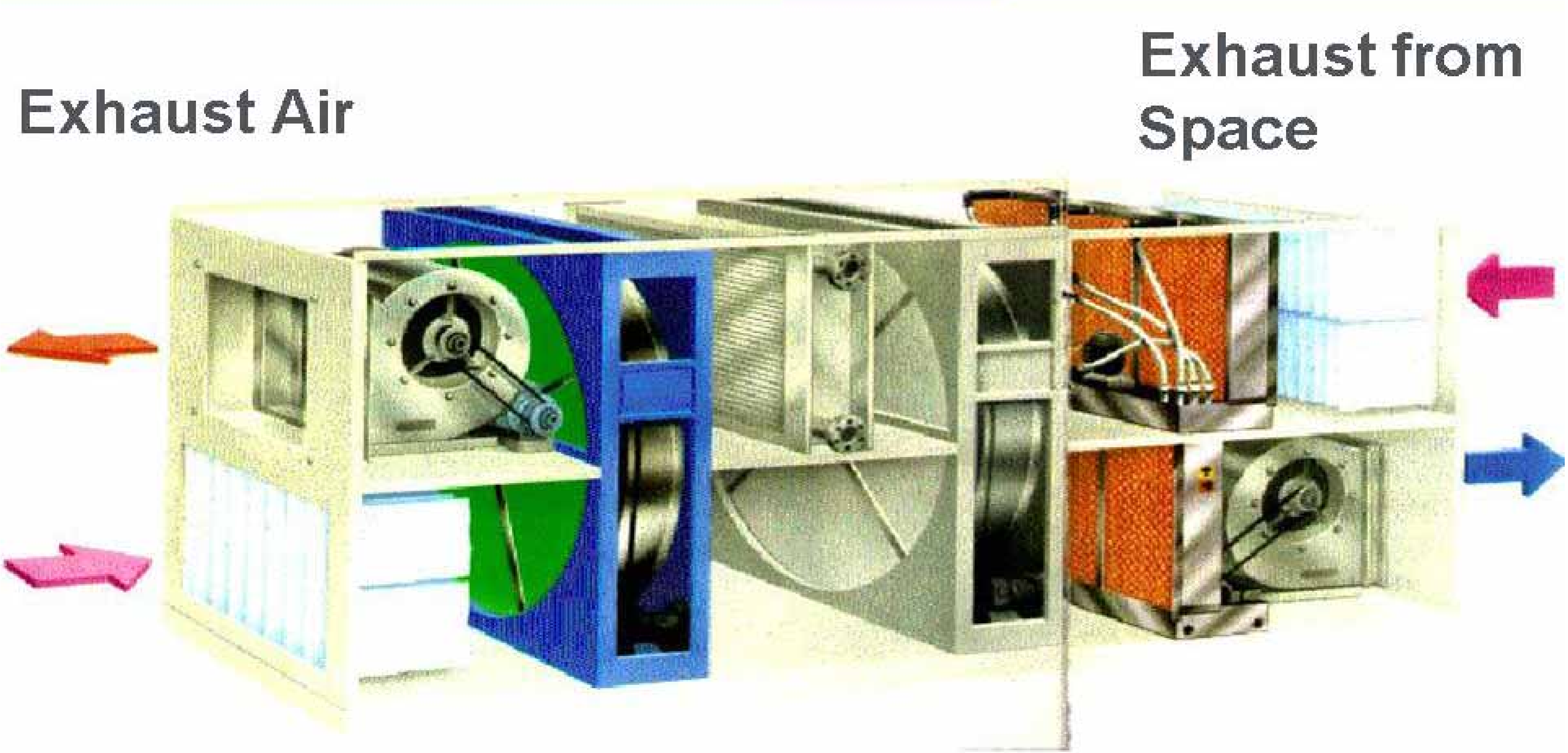


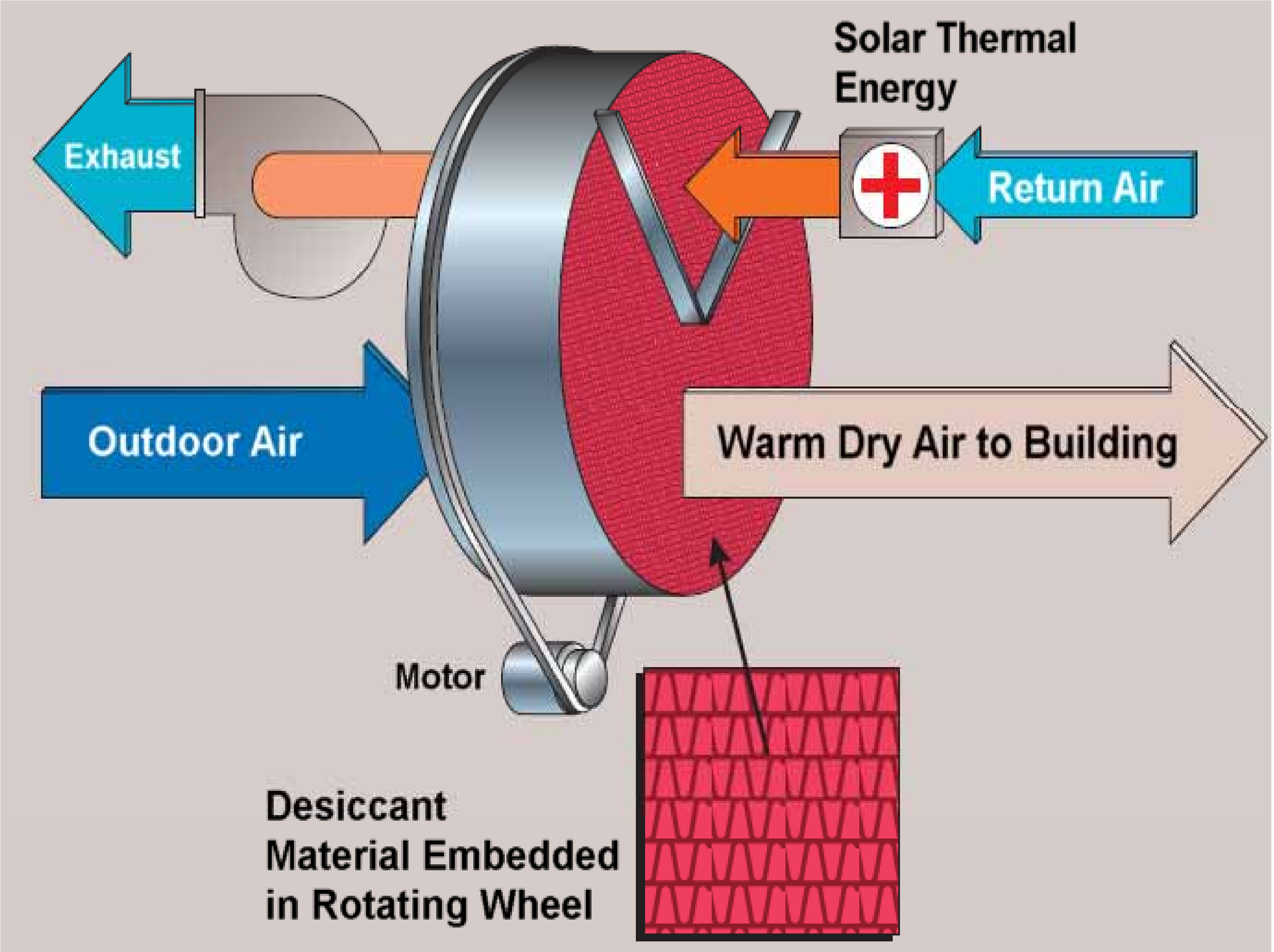
Dedicated Outdoor Air Suppy Unit

Temperatures Needed for Thermally Activated Cooling Technologies



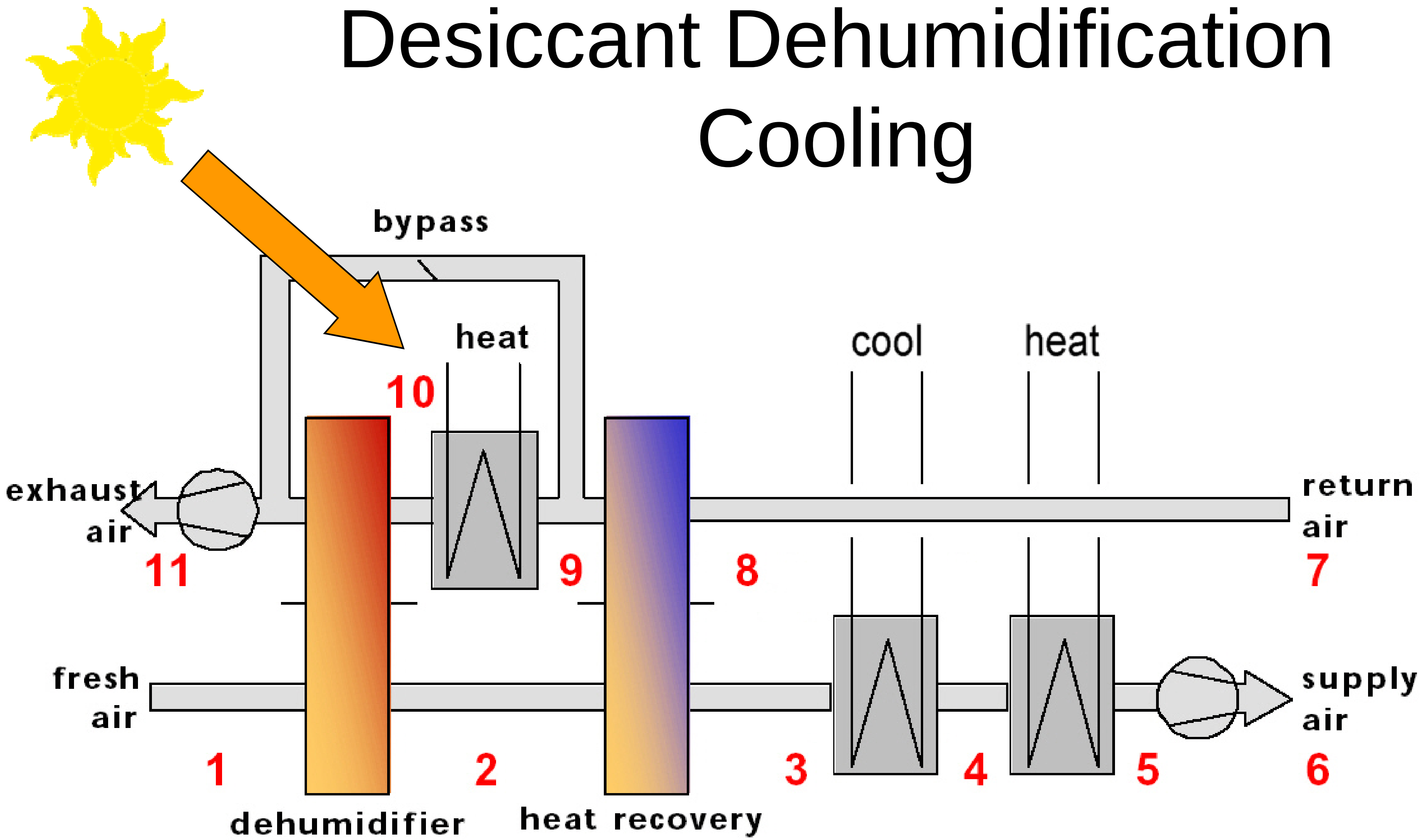
100% Outdoor Air Unit (with desiccant)





Solar Thermal Energy
Exhaust
Return Air
Outdoor Air
Warm Dry Air to Building
Motor
Desiccant Material Embedded in Rotating Wheel

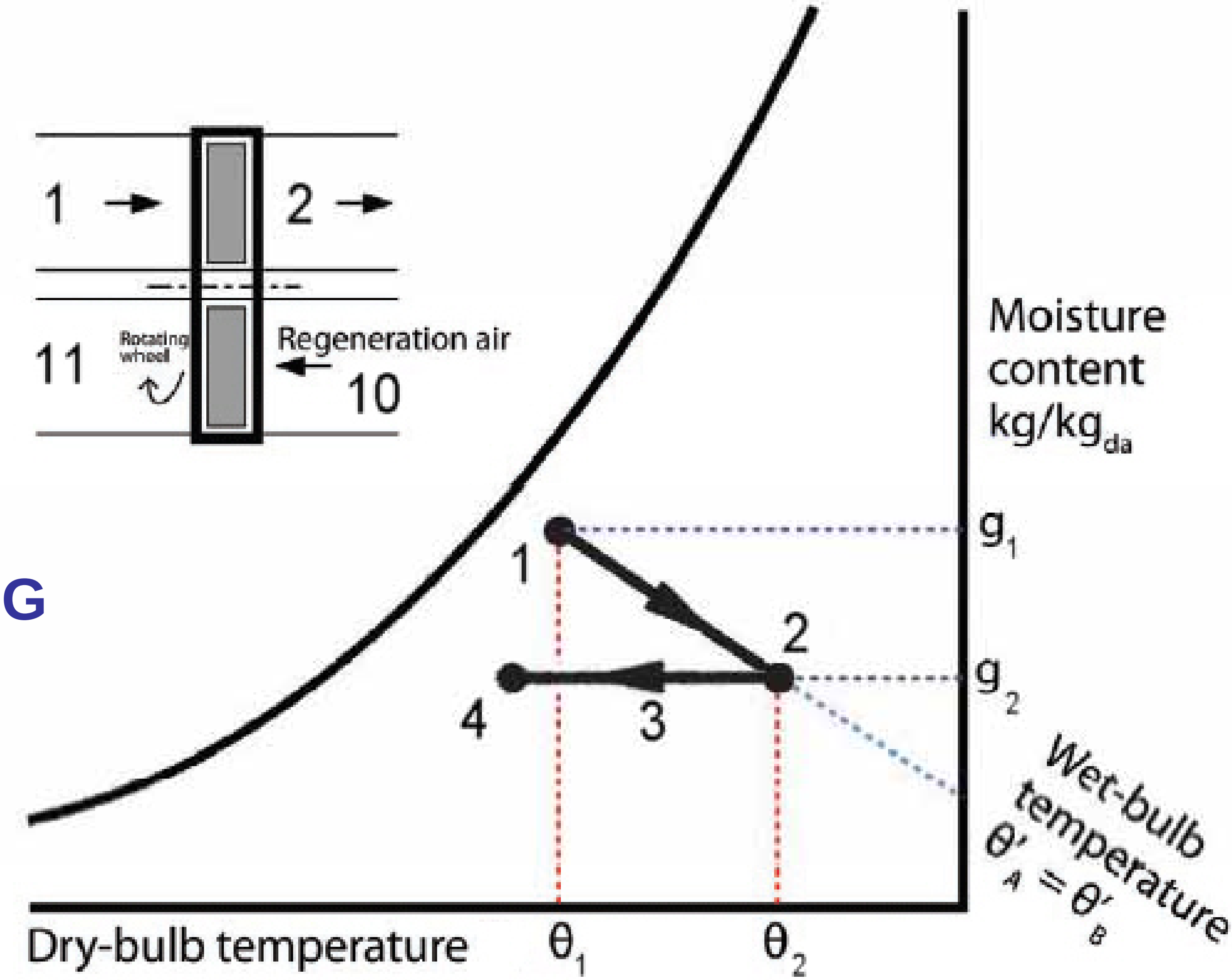
Desiccant Dehumidification Cooling



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 $foot^2$ / 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

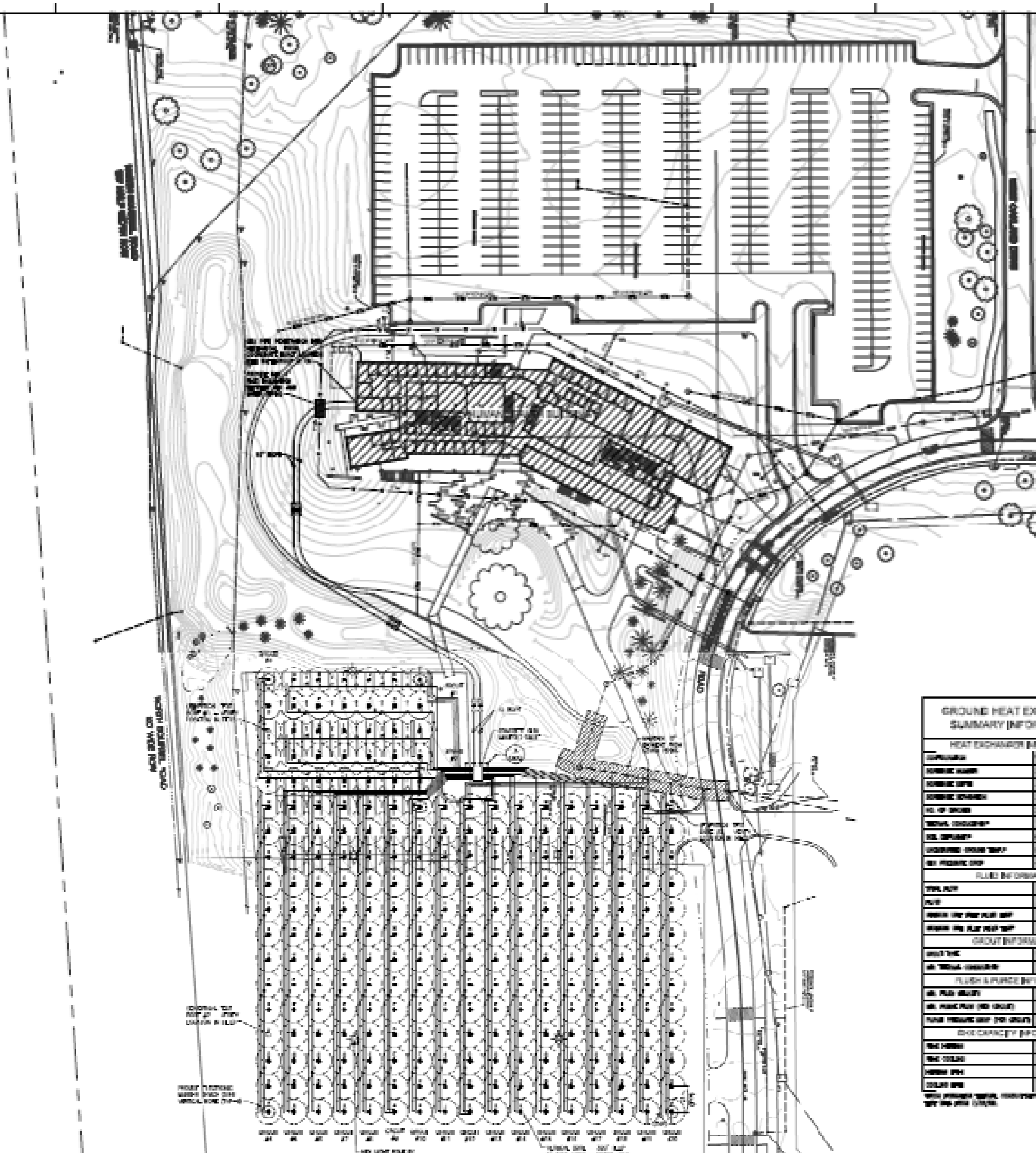
Ground Loop Spec's (pg2)

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

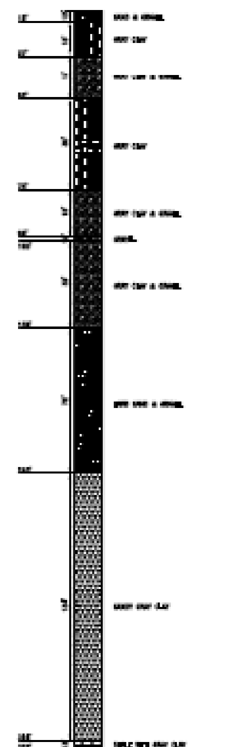
GROUND HEAT EXCHANGER NOTES

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. [illegible]
9. [illegible]



GROUND HEAT EXCHANGER SITE PLAN

GROUND HEAT EXCHANGER SUMMARY INFORMATION	
HEAT EXCHANGER INFORMATION	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
FLUID INFORMATION	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
GROUT INFORMATION	
[illegible]	[illegible]
[illegible]	[illegible]
FLUSH & PURGE INFORMATION	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
GHX CAPACITY INFORMATION	
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

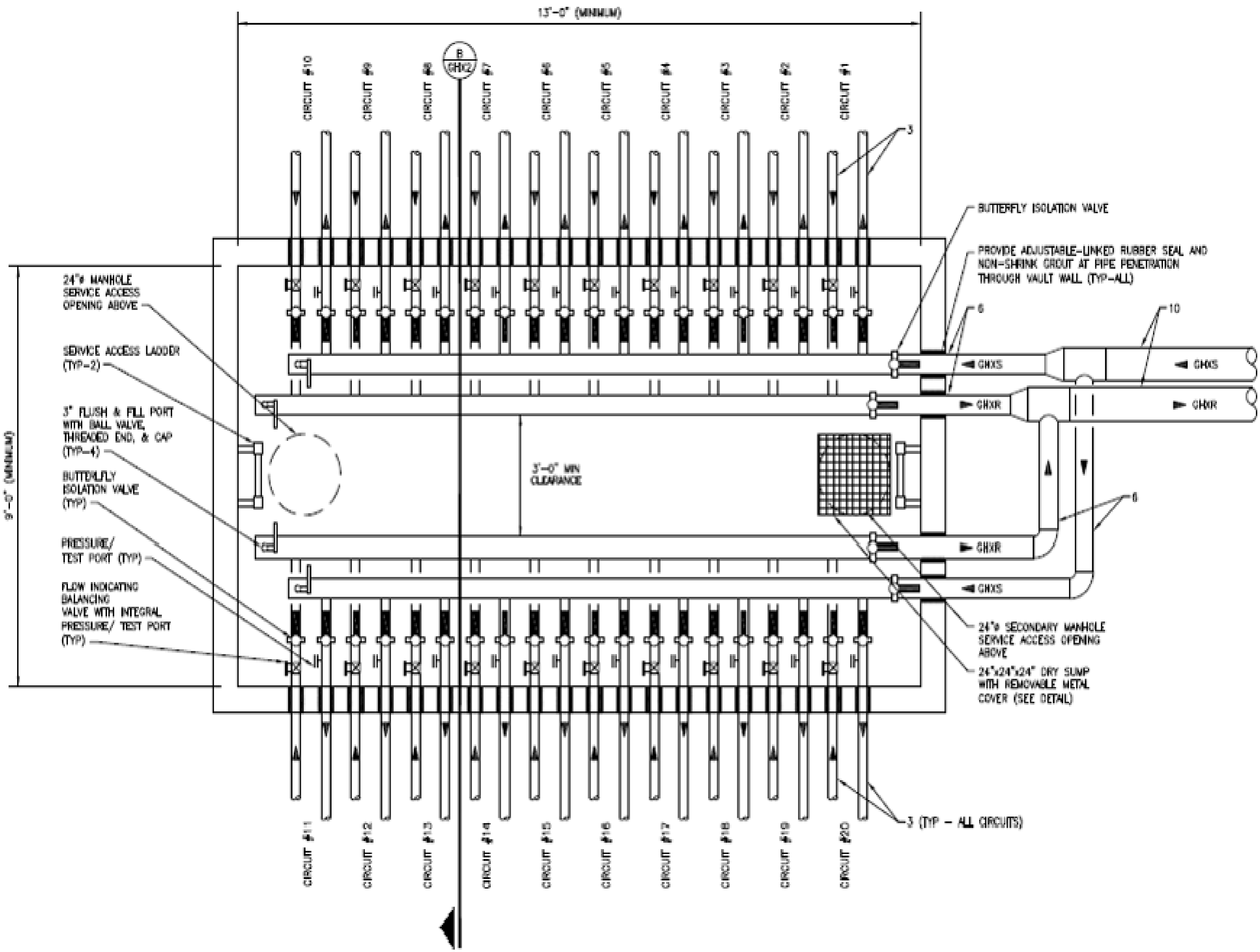


DRILL LOG FROM VERTICAL TEST BORE #1
FORMATION THERMAL CONDUCTIVITY TEST

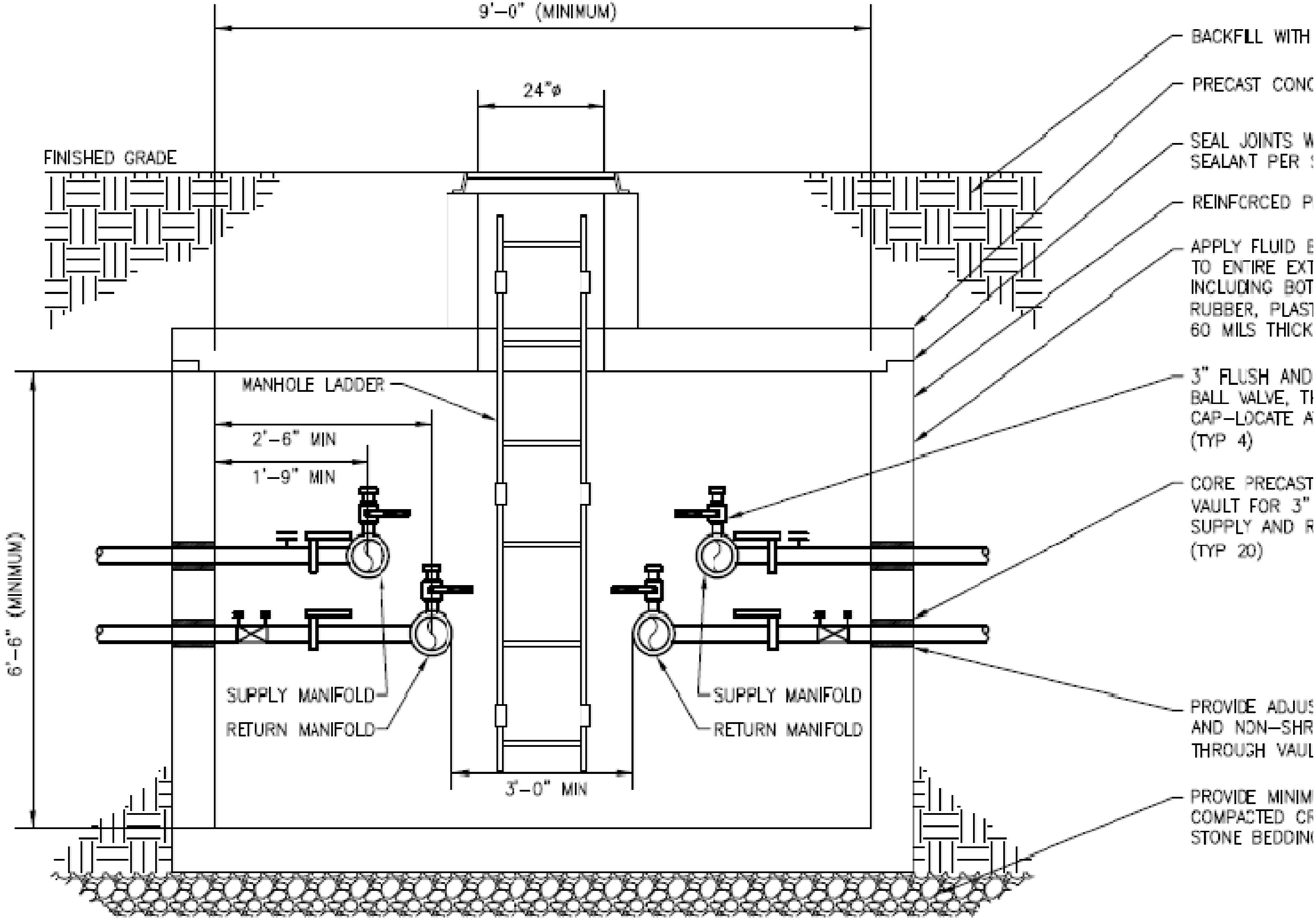
Know what's below. Call before you dig.

OAKLAND UNIVERSITY

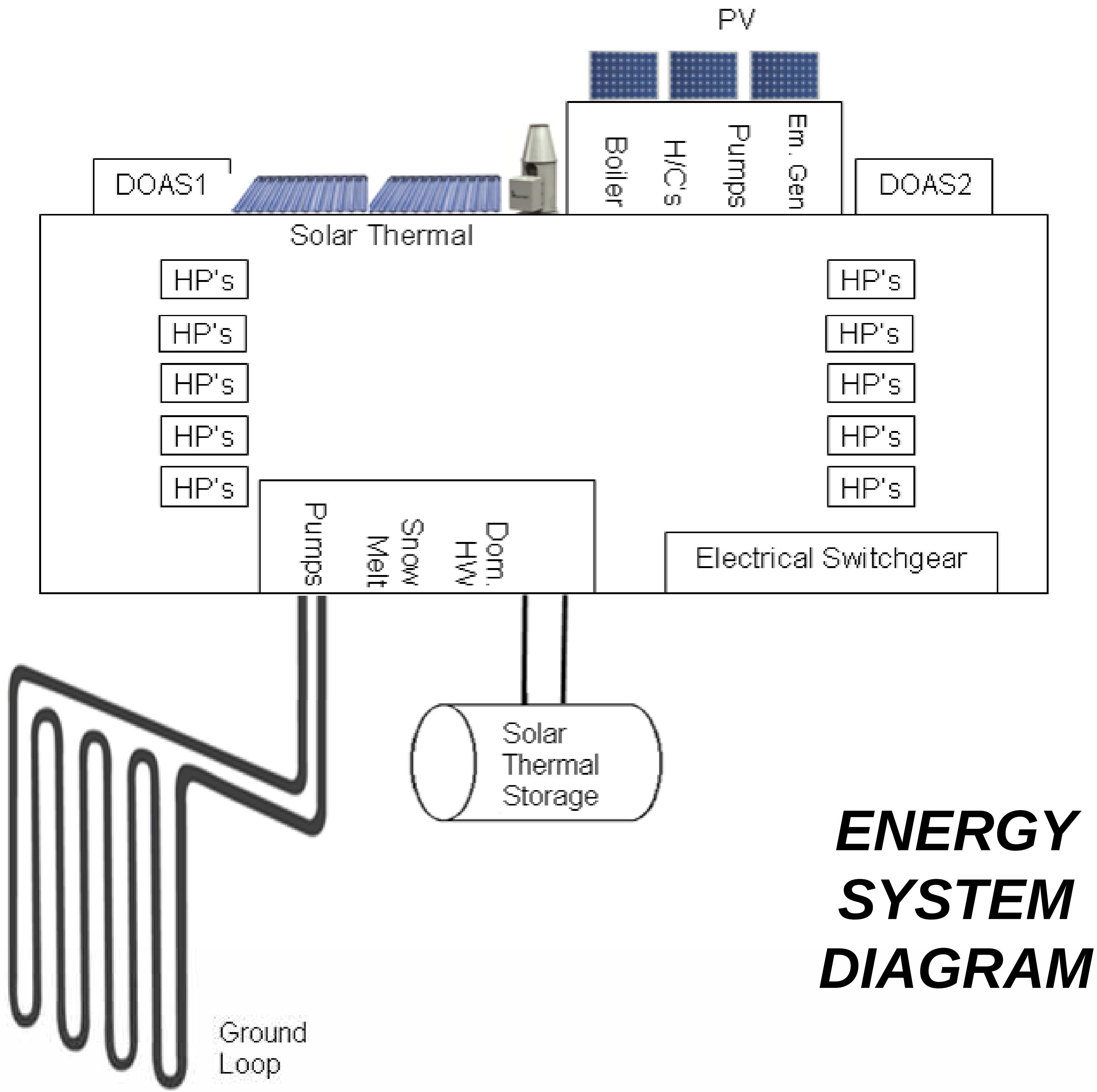
HUMAN HEALTH BUILDING
GROUND HEAT EXCHANGER
SITE PLAN



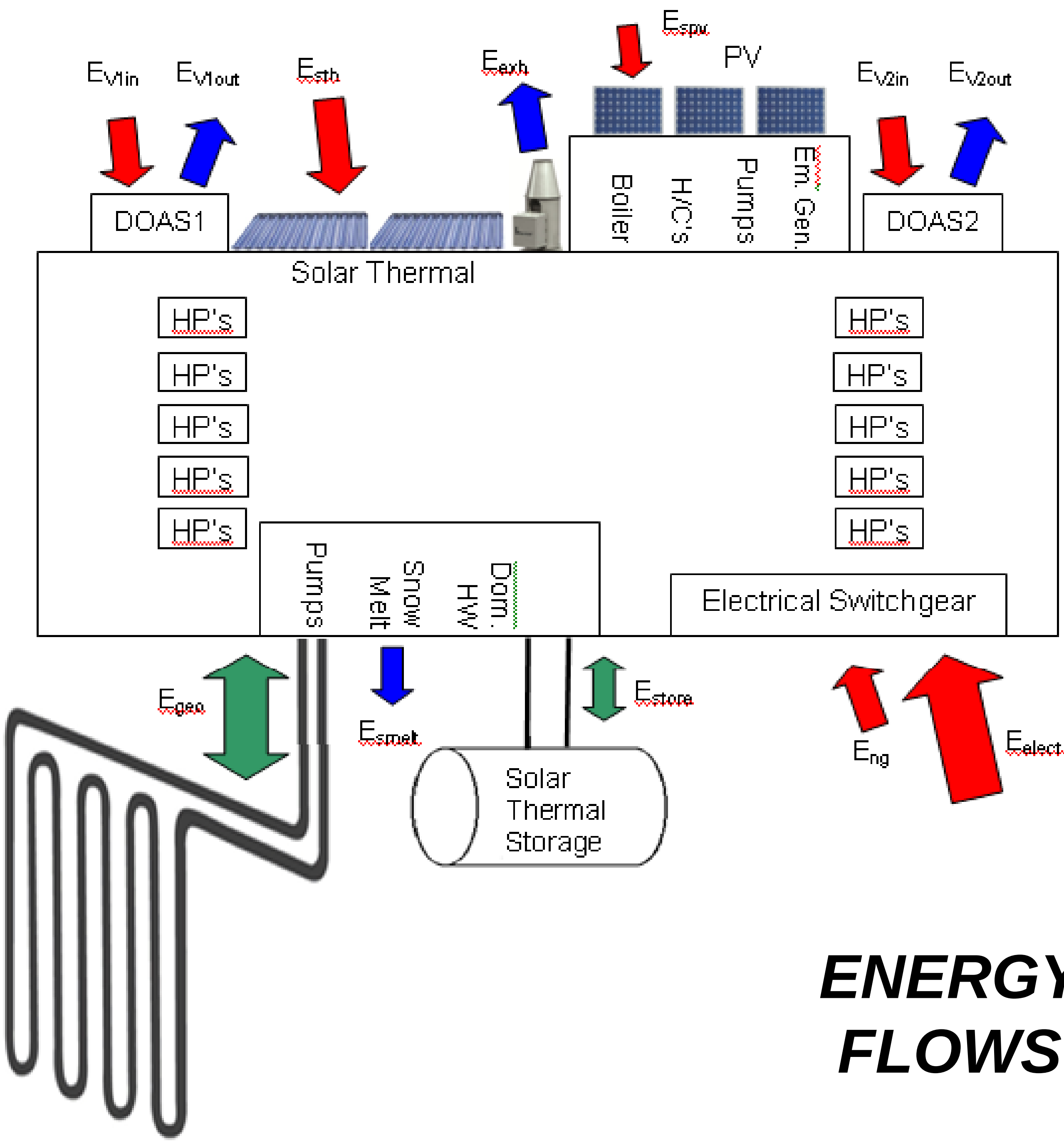
13'-0" (MINIMUM)
9'-0" (MINIMUM)
B
GHX2
CIRCUIT #10
CIRCUIT #9
CIRCUIT #8
CIRCUIT #7
CIRCUIT #6
CIRCUIT #5
CIRCUIT #4
CIRCUIT #3
CIRCUIT #2
CIRCUIT #1
3
BUTTERFLY ISOLATION VALVE
PROVIDE ADJUSTABLE-LINKED RUBBER SEAL AND NON-SHRINK GROUT AT PIPE PENETRATION THROUGH VAULT WALL (TYP-ALL)
6
10
GHXS
GHXR
24"ø MANHOLE SERVICE ACCESS OPENING ABOVE
SERVICE ACCESS LADDER (TYP-2)
3" FLUSH & FILL PORT WITH BALL VALVE, THREADED END, & CAP (TYP-4)
BUTTERLFLY ISOLATION VALVE (TYP)
PRESSURE/ TEST PORT (TYP)
FLOW INDICATING BALANCING VALVE WITH INTEGRAL PRESSURE/ TEST PORT (TYP)
3'-0" MIN CLEARANCE
24"ø SECONDARY MANHOLE SERVICE ACCESS OPENING ABOVE
24"x24"x24" DRY SUMP WITH REMOVABLE METAL COVER (SEE DETAIL)
3 (TYP - ALL CIRCUITS)
CIRCUIT #11
CIRCUIT #12
CIRCUIT #13
CIRCUIT #14
CIRCUIT #15
CIRCUIT #16
CIRCUIT #17
CIRCUIT #18
CIRCUIT #19
CIRCUIT #20



9'-0" (MINIMUM)
24"ø
FINISHED GRADE
MANHOLE LADDER
2'-6" MIN
1'-9" MIN
6'-6" (MINIMUM)
SUPPLY MANIFOLD
RETURN MANIFOLD
SUPPLY MANIFOLD
RETURN MANIFOLD
3'-0" MIN
BACKFILL WITH
PRECAST CONC
SEAL JOINTS W
SEALANT PER
REINFORCED P
APPLY FLUID B
TO ENTIRE EXT
INCLUDING BOT
RUBBER, PLAST
60 MILS THICK
3" FLUSH AND
BALL VALVE, TI
CAP-LOCATE A
(TYP 4)
CORE PRECAST
VAULT FOR 3"
SUPPLY AND R
(TYP 20)
PROVIDE ADJUS
AND NON-SHR
THROUGH VAUL
PROVIDE MINIM
COMPACTED CR
STONE BEDDING



ENERGY SYSTEM DIAGRAM



ENERGY FLOWS

Meter Information

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

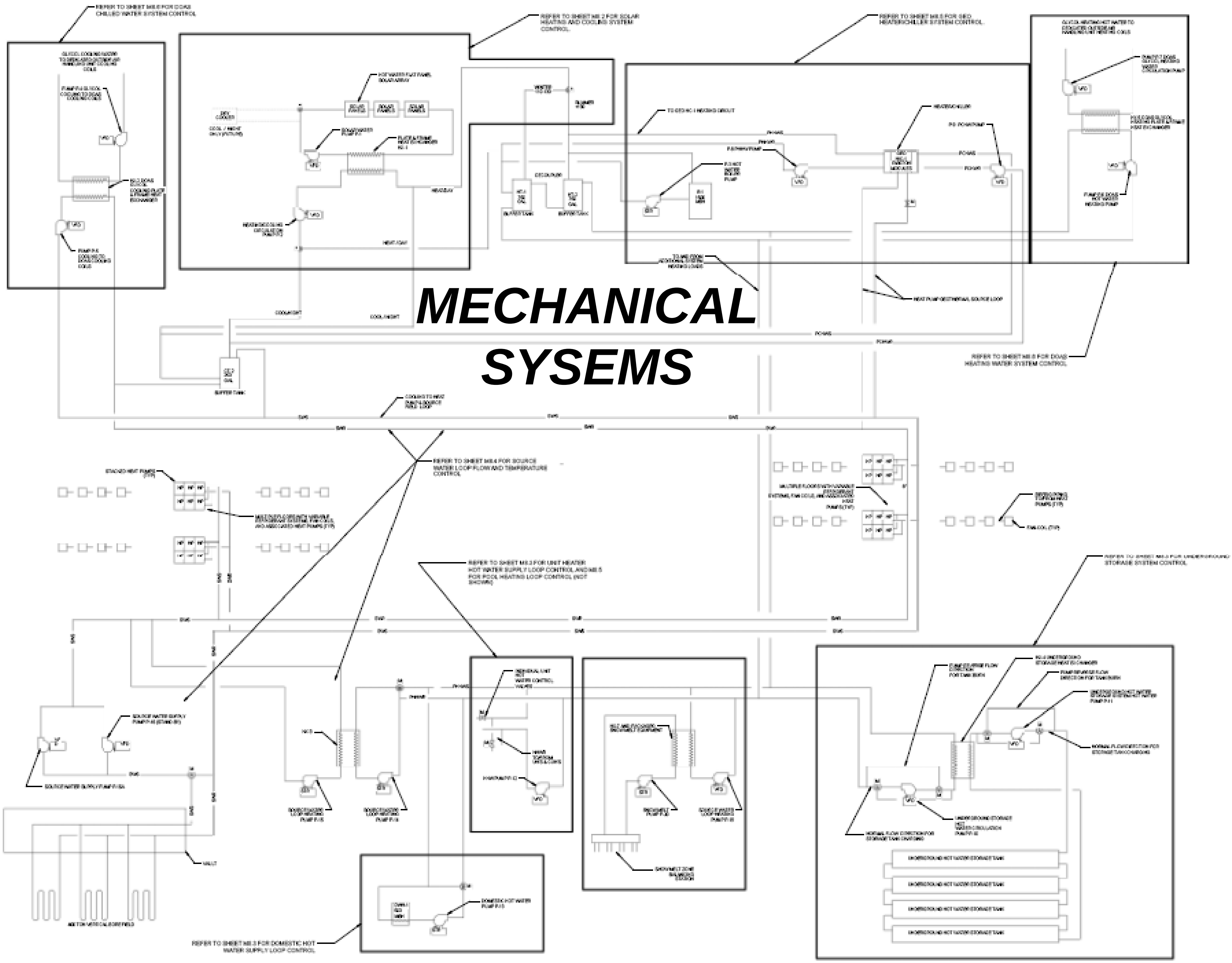
Meter information

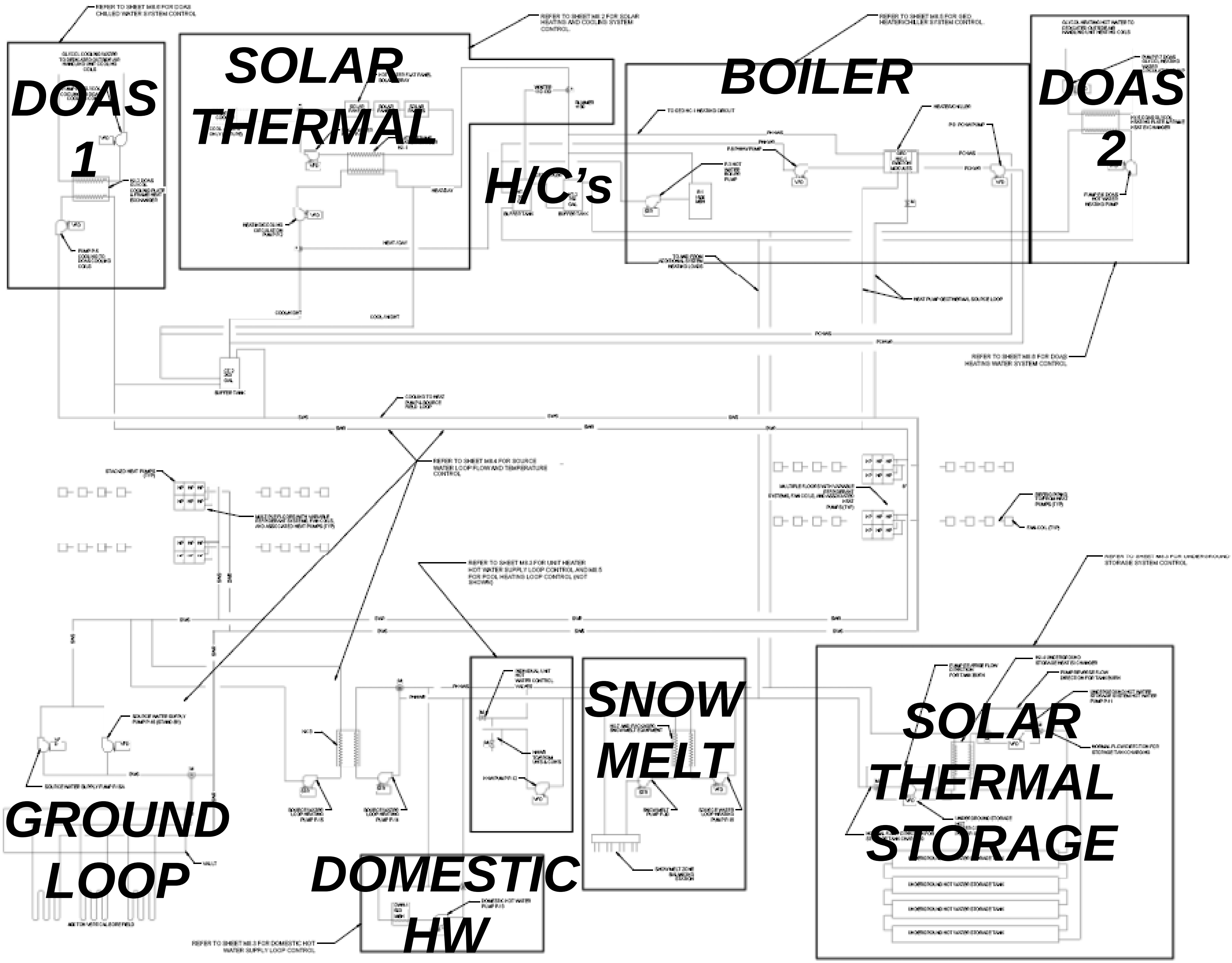
Nexus 1262	Utility switchboard electric meter
Shark 200	Multifunction panel electric meter
Gas	Rotary natural gas meter with pulser
Ultrasonic BTU	Ultrasonic flow and energy meter
Air flow & temp	Dedicated Outdoor Air Unit (DOAS) with packaged air flow station and temperature / humidity sensors used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

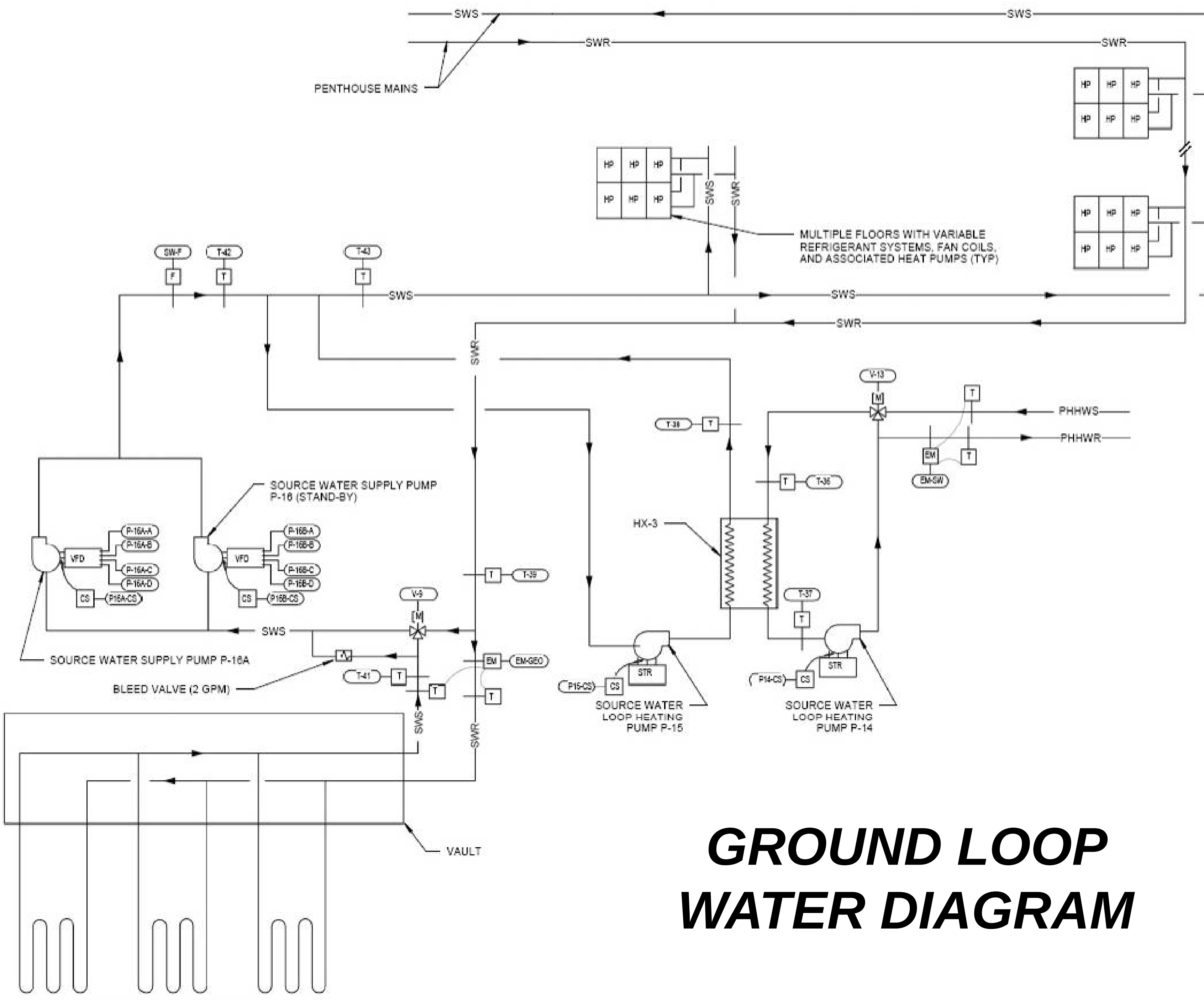

FEEDER 2A
METERING
FEEDER 2B
METERING
FEEDER 2C
METERING
FEEDER 4A
METERING
FEEDER 4C
METERING


EM-SW
EM-HHW
CHW-DECOUPLER
HW-DECOUPLER

MECHANICAL SYSEMS

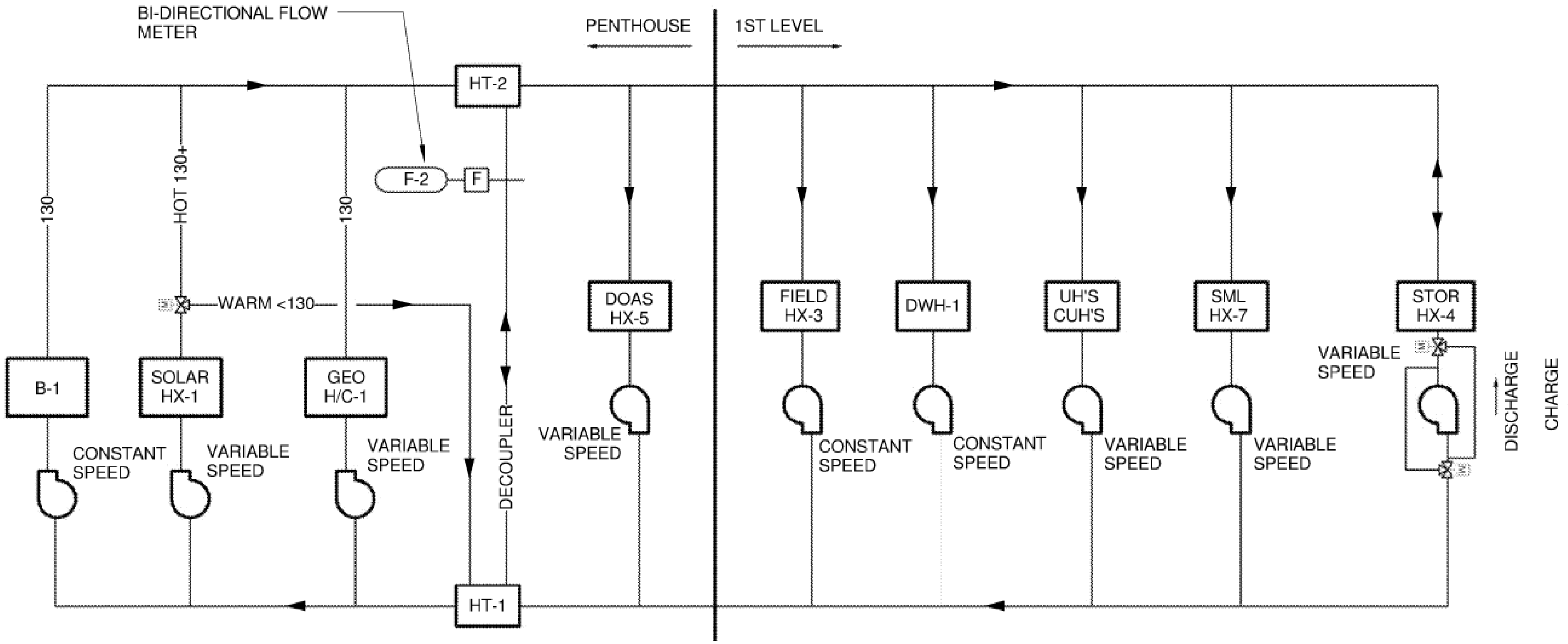



DOAS 1
SOLAR THERMAL
H/C's
BOILER
DOAS 2
SNOW MELT
SOLAR THERMAL STORAGE
GROUND LOOP
DOMESTIC HW



GROUND LOOP WATER DIAGRAM

SIMPLIFIED HEATING DIAGRAM

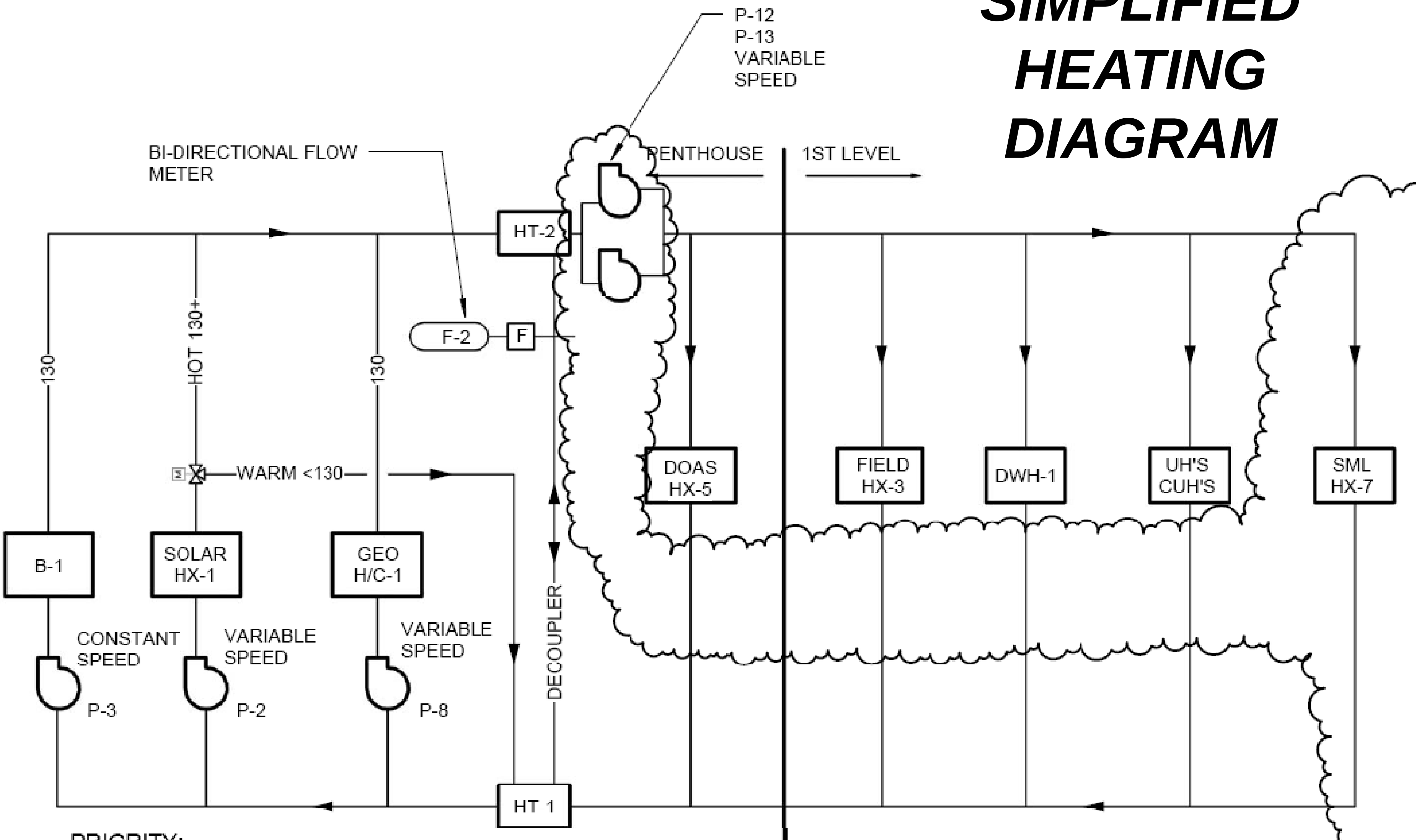


PRIORITY:

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



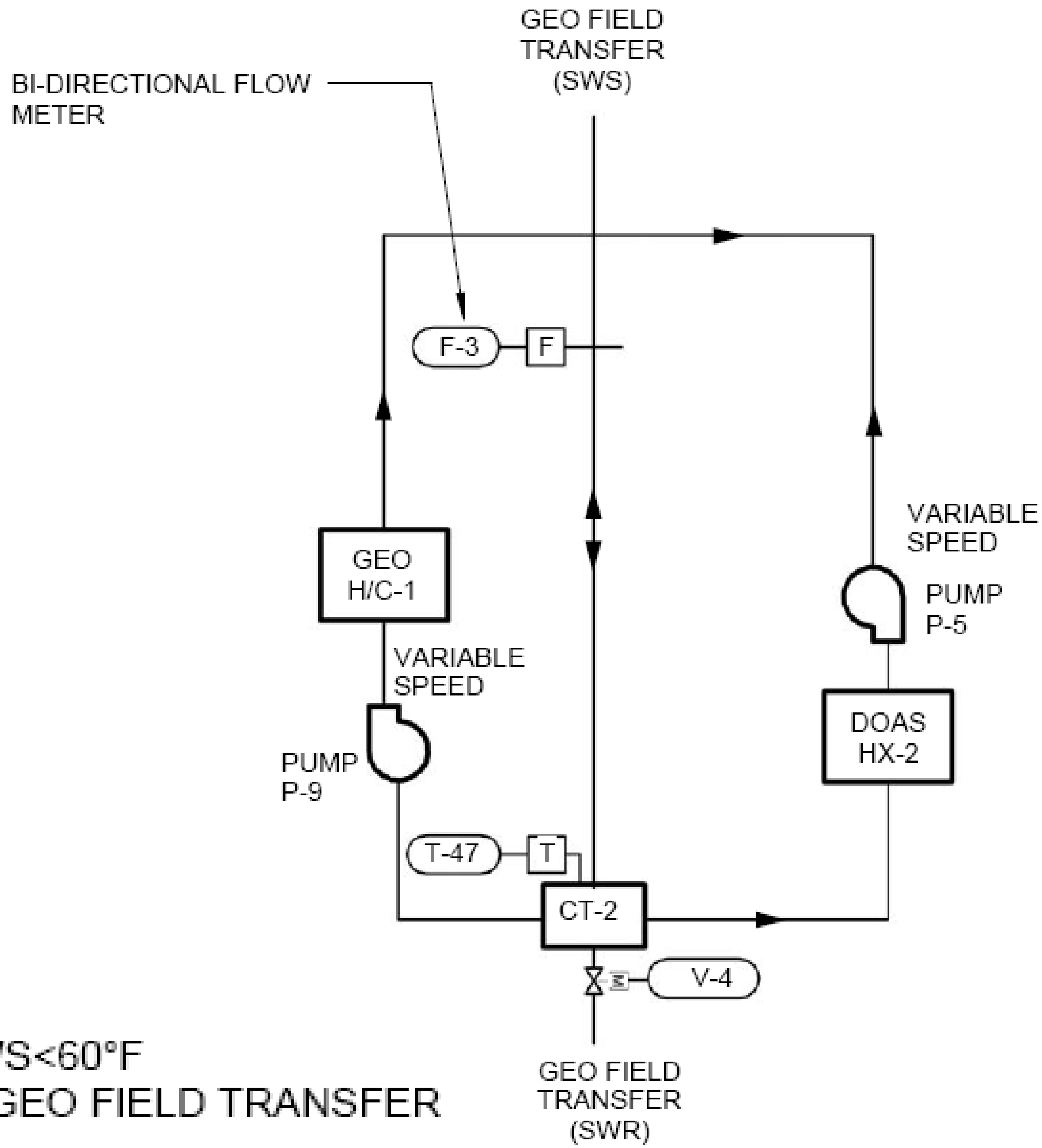
PRIORITY:

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



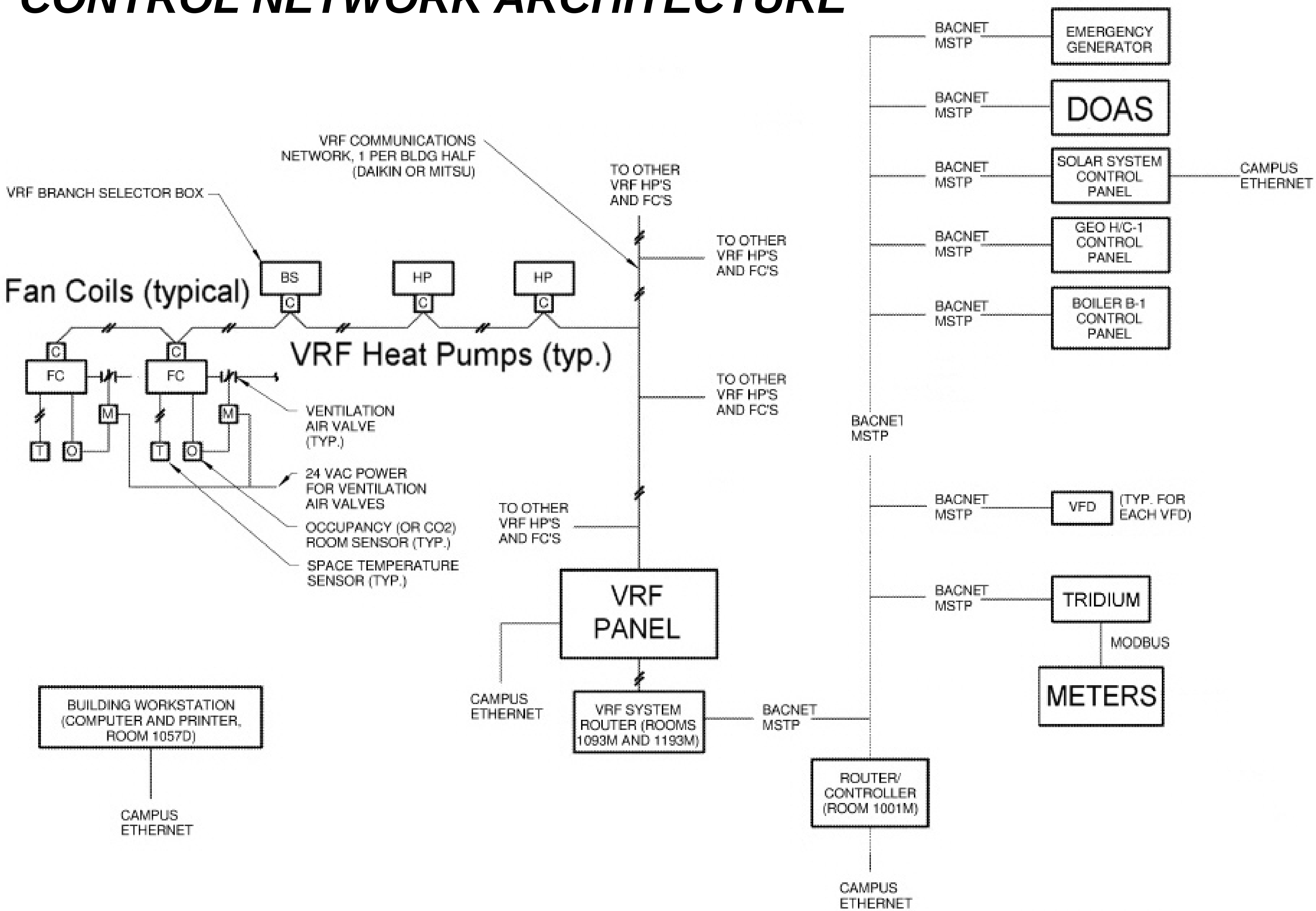
SWS = SOURCE WATER SUPPLY

PRIORITY:

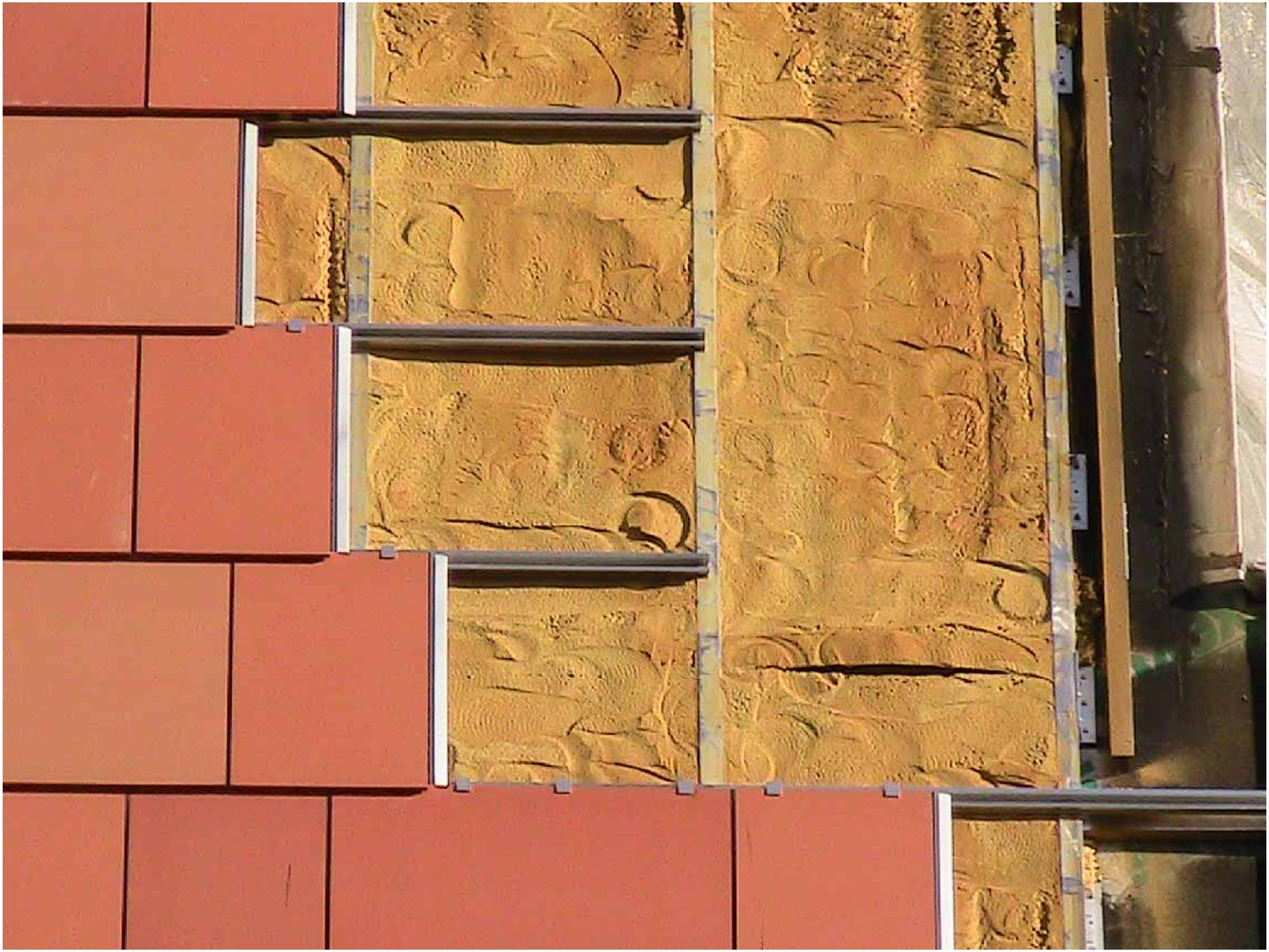
SWS>60°F
1) GEO H/C-1

SWS<60°F
1) GEO FIELD TRANSFER

CONTROL NETWORK ARCHITECTURE



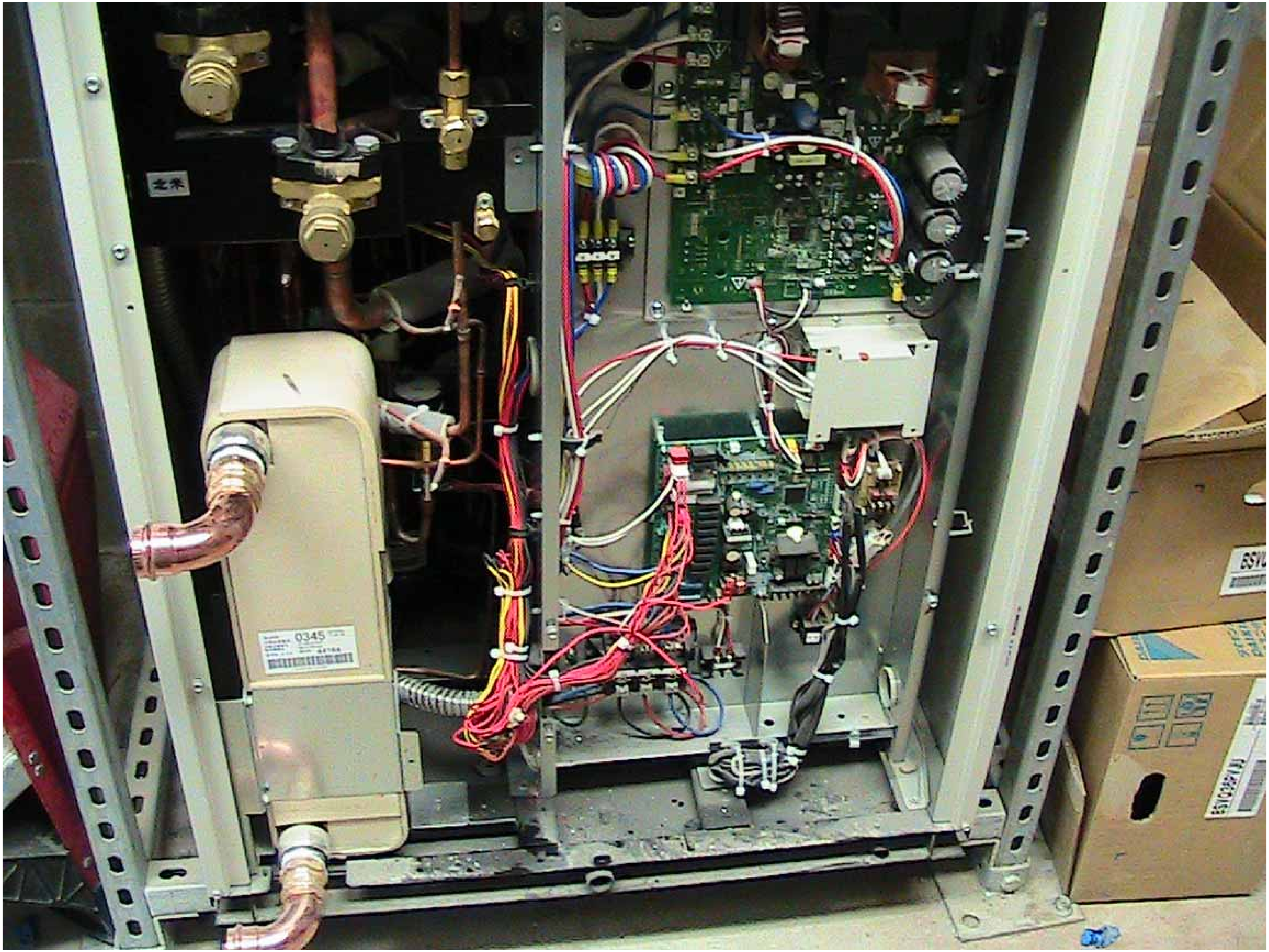

HUMAN HEALTH BUILDING



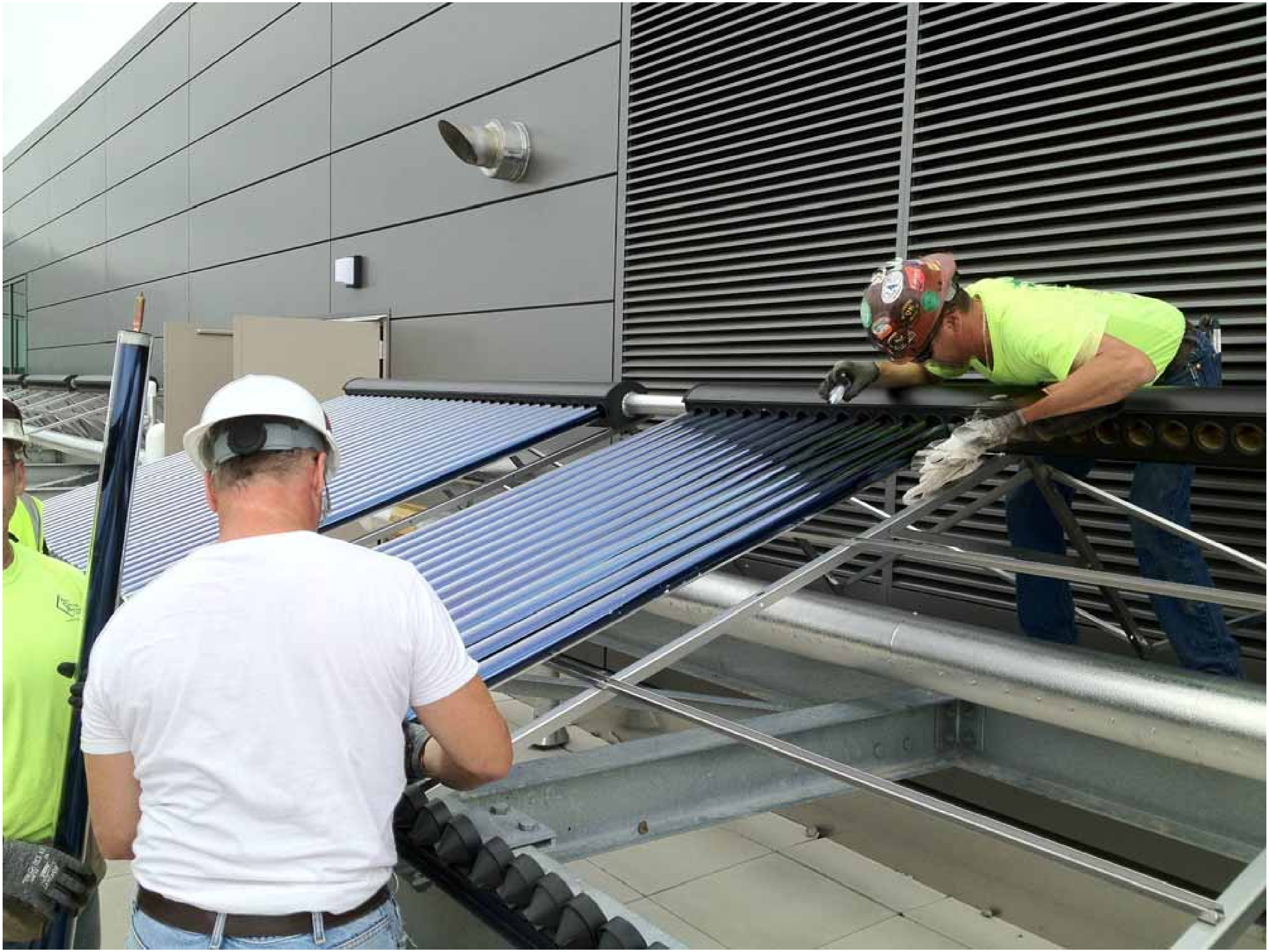
VRF

Heat

Pumps

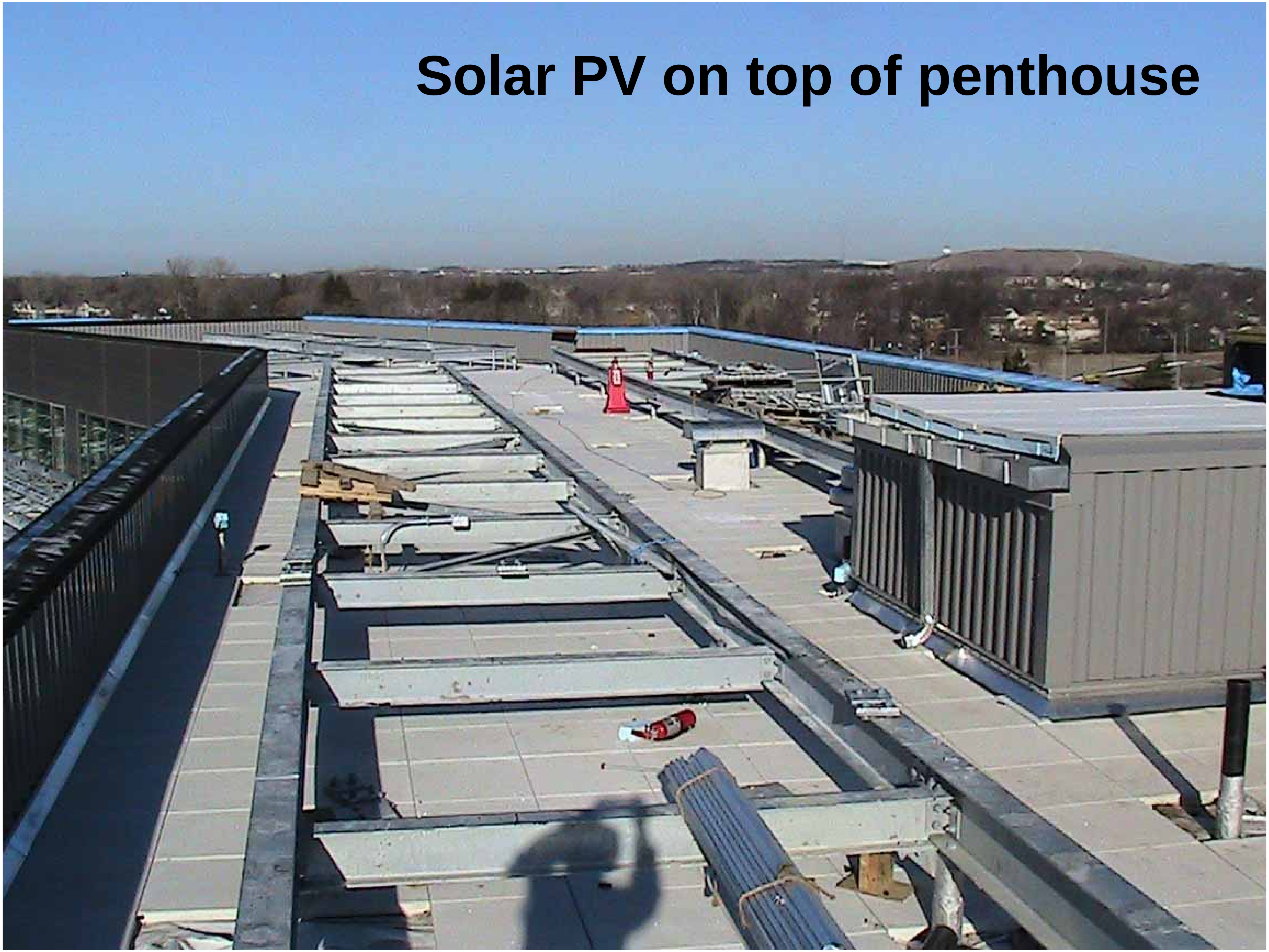

0345

Variable Refrigerant Flow Compressors with VFD’s




T-FP600A
NIBCO

Solar PV on top of penthouse



End of Part 1: System Design

Part 2: Construction, Commissioning & Lessons Learned

Part 3: Energy Monitoring & Performance

OU INC Clean Energy Research Center

Questions ?

ASHRAE

Oakland UNIVERSITY

Jim Leidel

Director of Clean Energy Systems

leidel@oakland.edu

www.oakland.edu/CERC and www.oakland.edu/ENERGY