WEST WING GEOTHERMAL PRESENTATION

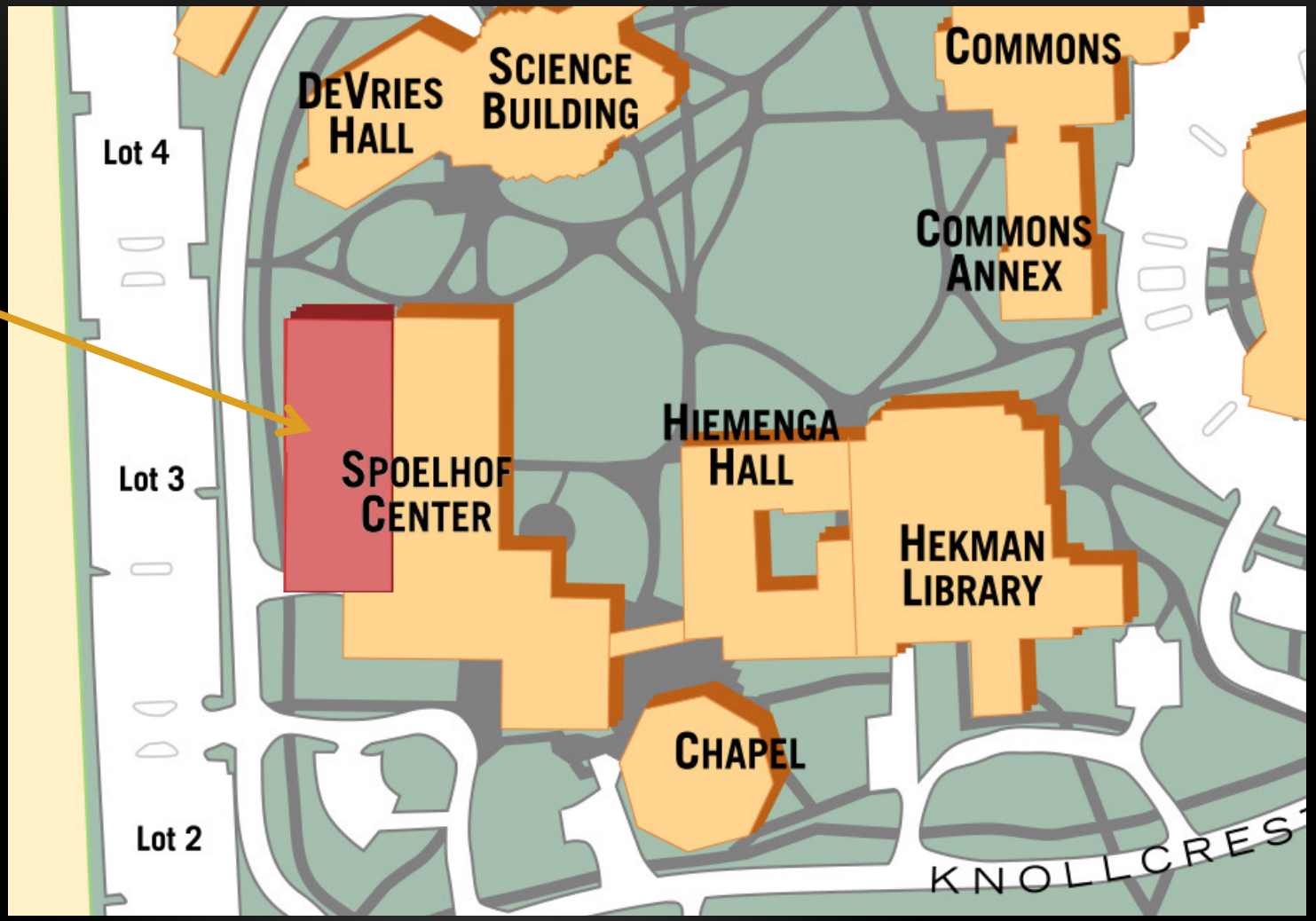
ENGR 333

DECEMBER 4, 2012

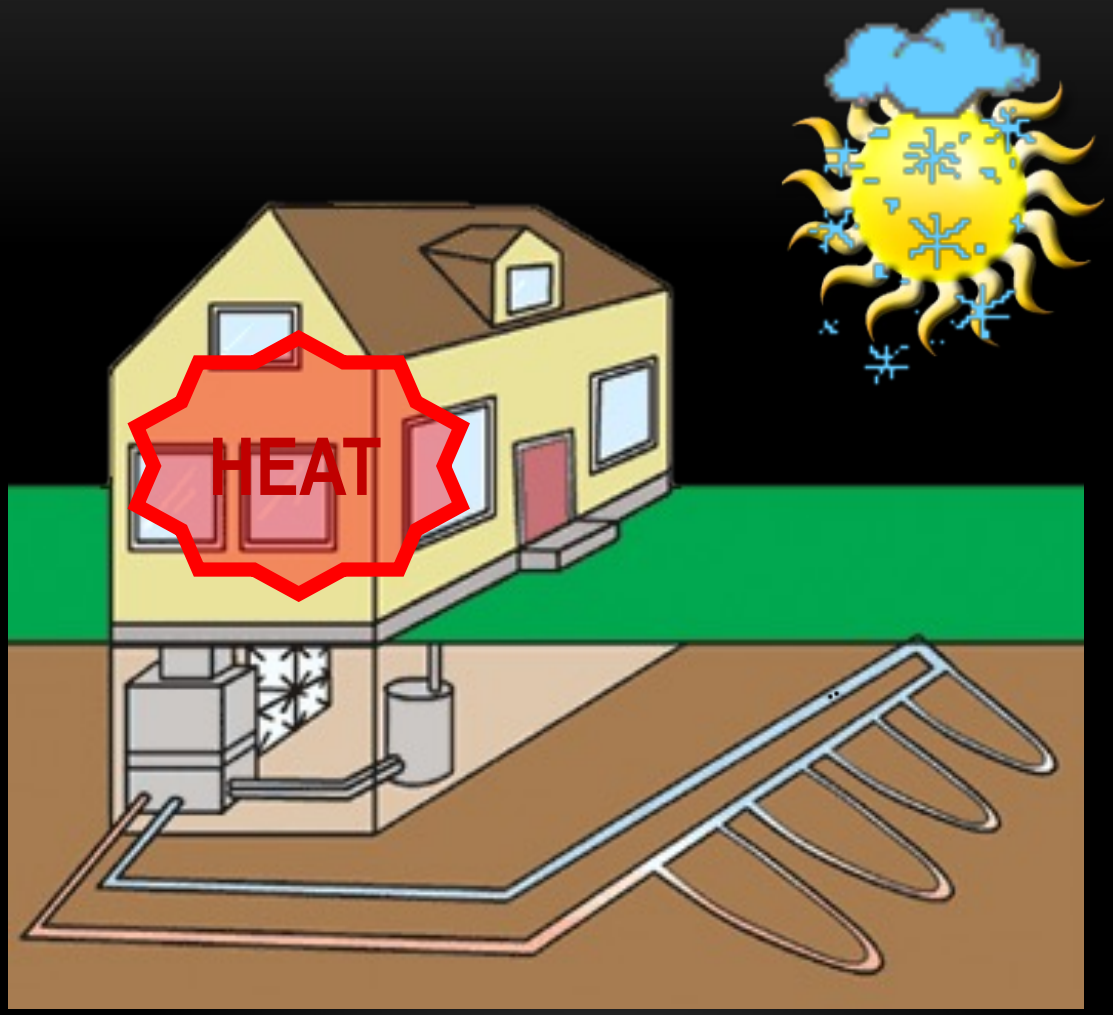
SPOELHOF CENTER WEST WING ADDITION

LOCATION

Proposed West Wing Addition



HOW DOES GEOTHERMAL WORK?



http://www.drenergysaver.com/renewable-energy/geothermal-heat.html

GEOTHERMAL BENEFITS AND COSTS

Benefits

- Reduced energy consumption
- Reduced maintenance

Costs

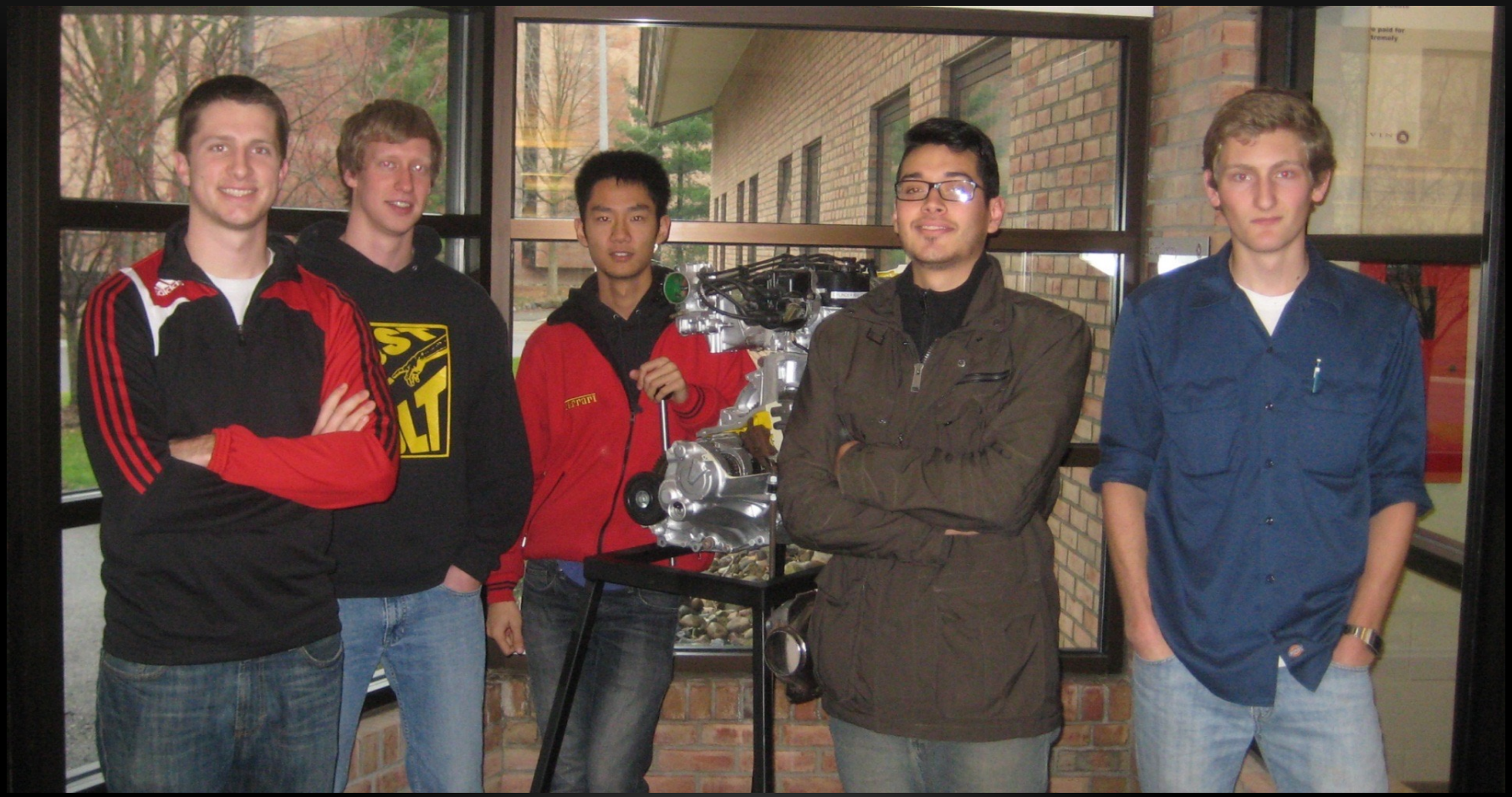
- More complex
- Installation

PROJECT OVERVIEW

- Objective:
  - As a class we are to determine what it would take to use a geothermal Heating, Ventilation, and Air Conditioning (HVAC) system in the West Wing Addition
- 5 groups for analysis
  - LEED & Energy Modeling
  - Infrastructure
  - Below Ground
  - Above Ground
  - Financial

LEED & ENERGY MODELING

TEAM MEMBERS



~~Introduction~~ Infrastructure Above Ground Recommendation

Energy Modeling Below Ground Financial

KEY QUESTIONS

- How will a geothermal system contribute to achieving LEED certification?
- What are the heating & cooling loads for the West Wing addition?

LEED RATING SYSTEM

- LEED = Leadership in Energy and Environmental Design
- Aiming for LEED silver rating, according to Henry DeVries
  - Requires 50-59 points out of possible 110 points

LEED

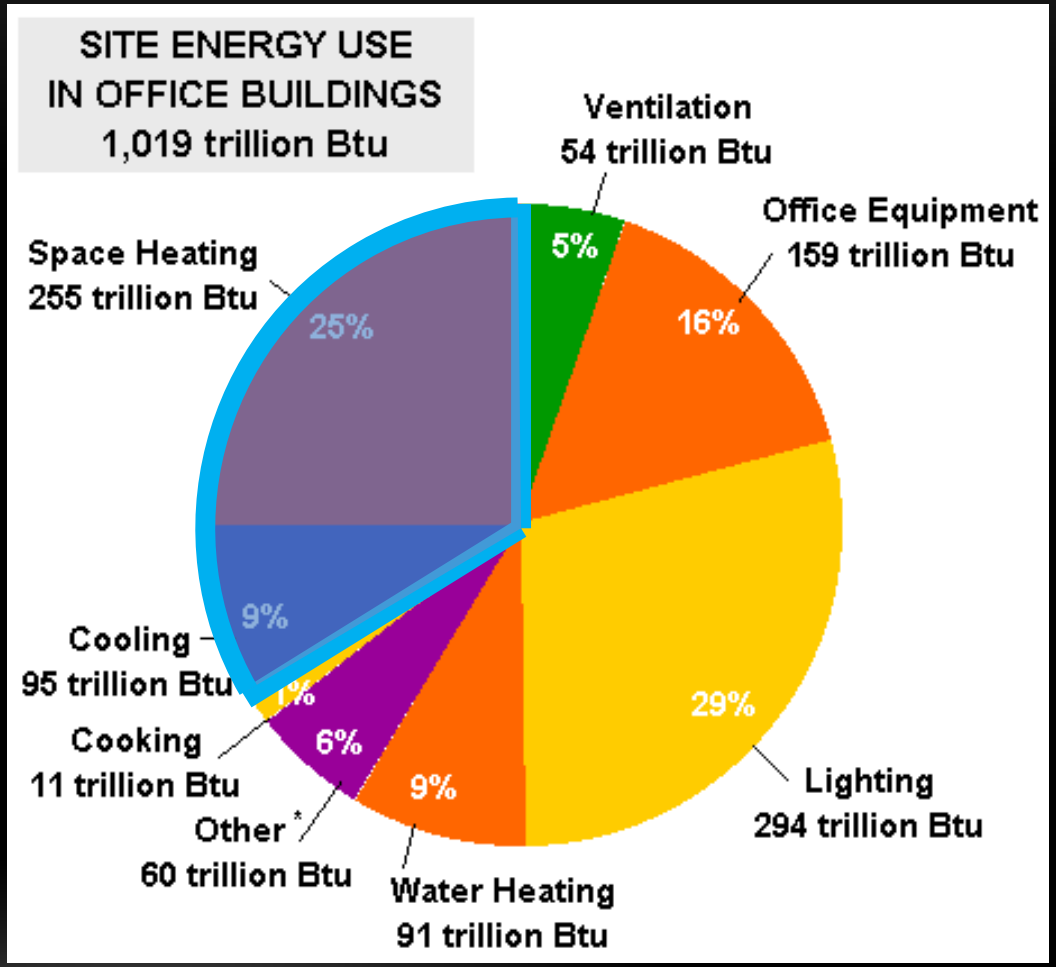
LEED POINT CATEGORIES

- 6 categories
  - Sustainable Sites
  - Water Efficiency
  - Energy and Atmosphere
  - Materials and Resources
  - Indoor Environmental Quality
  - Innovation in Design

LEED Core Concepts and Strategies Online Couse

ENERGY CONSUMPTION BREAKDOWN

Heating and Cooling accounts for approximately 34% of a building's energy usage



US Energy Information Administration

ON-SITE RENEWABLE ENERGY LEED POINTS

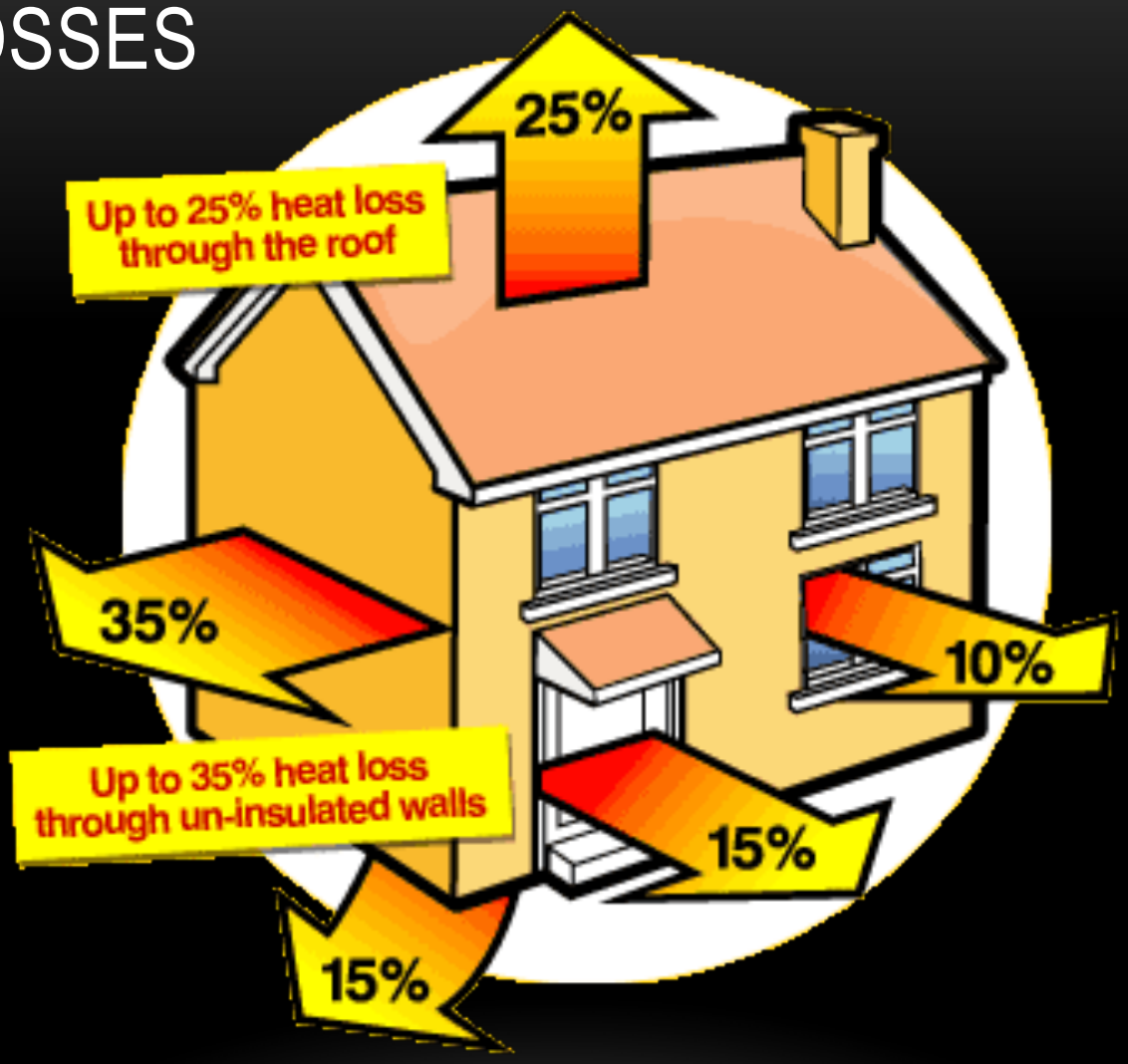
Percentage Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

From LEED 2009 for New Constructions and Major Renovations

IMPORTANCE OF HEATING/COOLING LOADS

- “Load” is the heat that must be removed in the summer and added in the winter.
- Prevent oversized/undersized HVAC system
- Directly affect the progress of other teams.

HEAT LOSSES

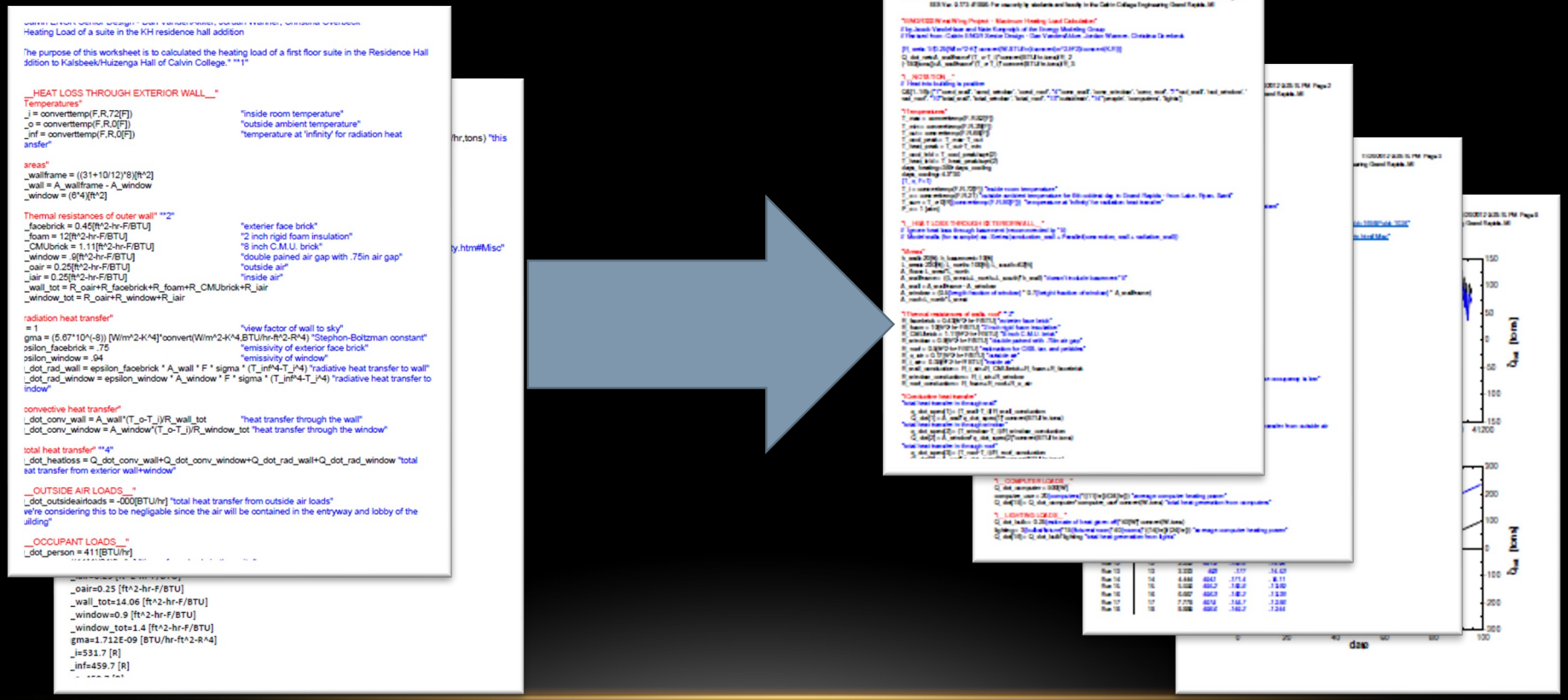


http://www.momgoesgreen.com/keeping-warm%E2%80%A6-while-staying-green/

CALCULATION METHOD

Started with calculations from KHvR geothermal suite

Made additions



Introduction

Infrastructure

Above Ground

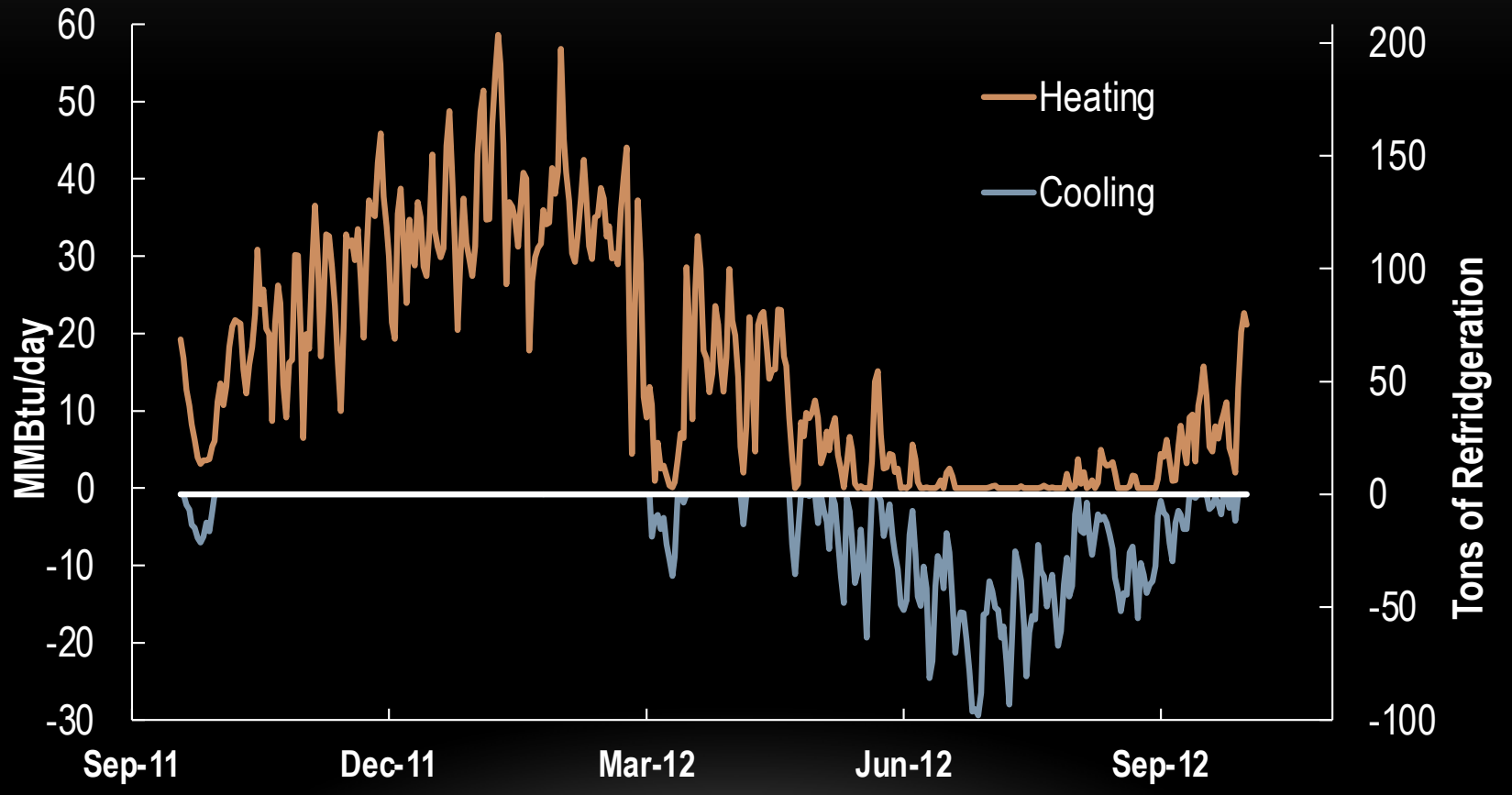
Recommendation

Energy Modeling

Below Ground

Financial

DAILY HEATING & COOLING REQUIREMENTS



HEATING & COOLING LOADS BEST ESTIMATE

- Heating: 174 Tons
- Cooling: 86 Tons
- Tons are a standard unit of heating and cooling: 1 ton = 12,000 Btu/hr

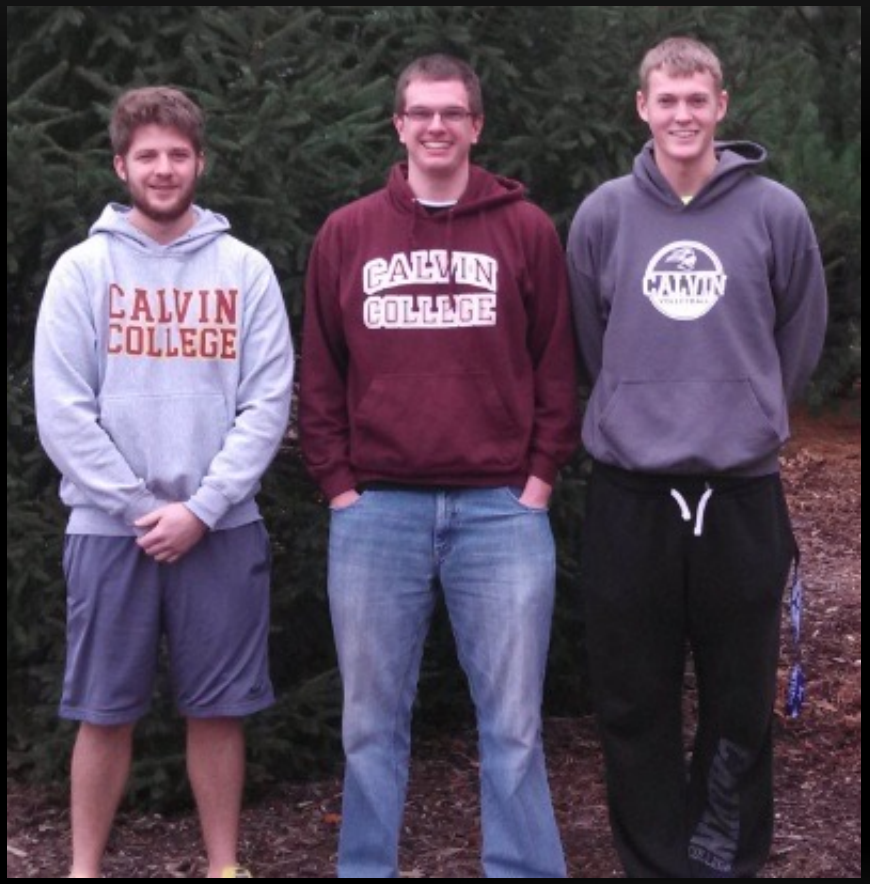
FINAL ANSWERS

- How will a geothermal system contribute to achieving LEED certification?
  - 7 points towards the goal of 50

- What are the heating & cooling loads for the West Wing addition?
  - Heating: 174 Tons
  - Cooling: 86 Tons

INFRASTRUCTURE

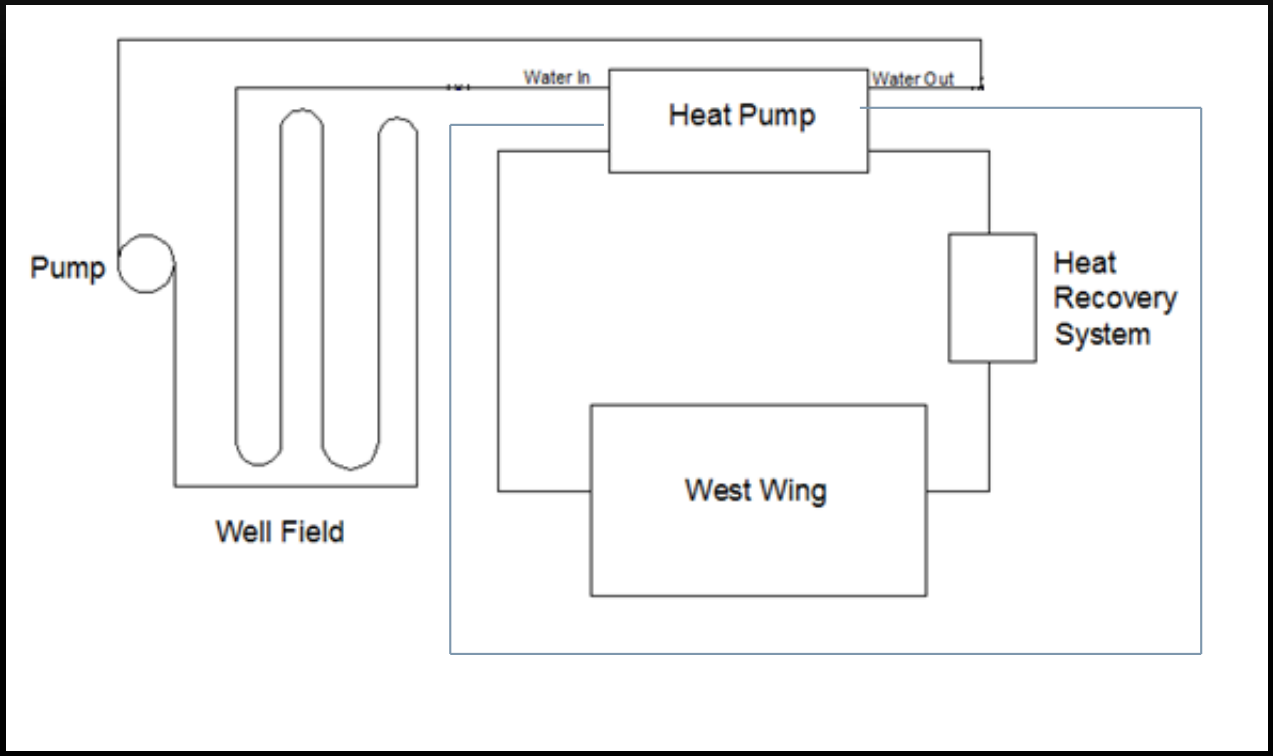
TEAM MEMBERS



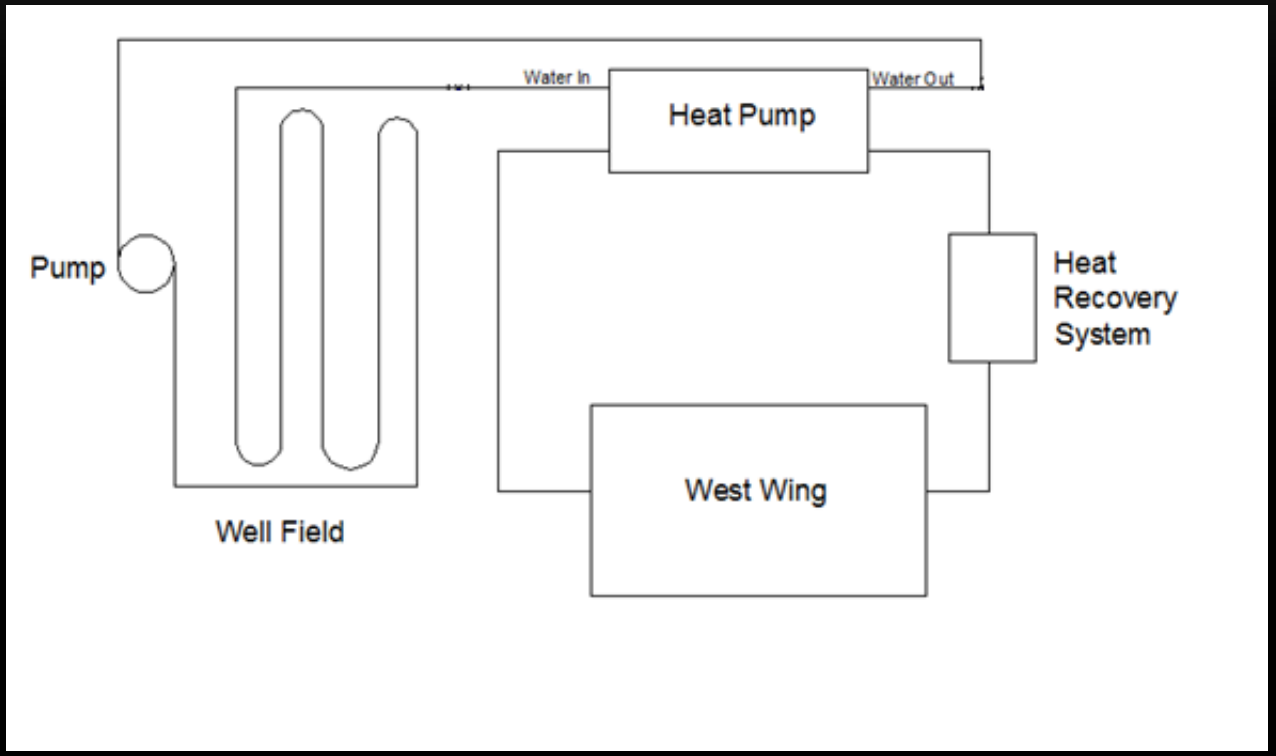
KEY QUESTIONS

- How will the geothermal system fit in at Calvin College?
- What type of loop configuration will be used?
- Where will the geothermal ground loop be located?

INTEGRATED SYSTEM



STAND ALONE SYSTEM



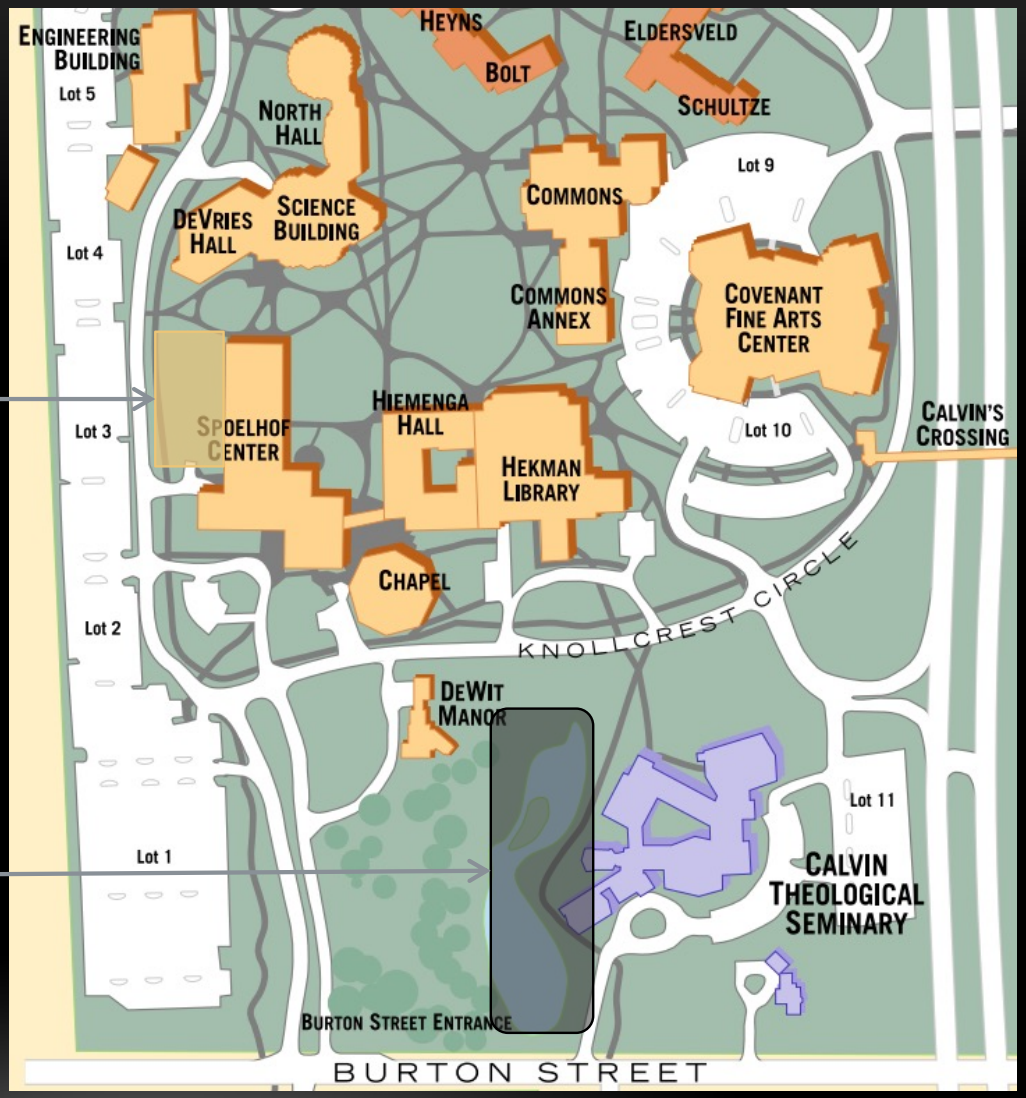
POND LOOP

http://www.fhp-mfg.com/files/images/common/coupCx03.jpg

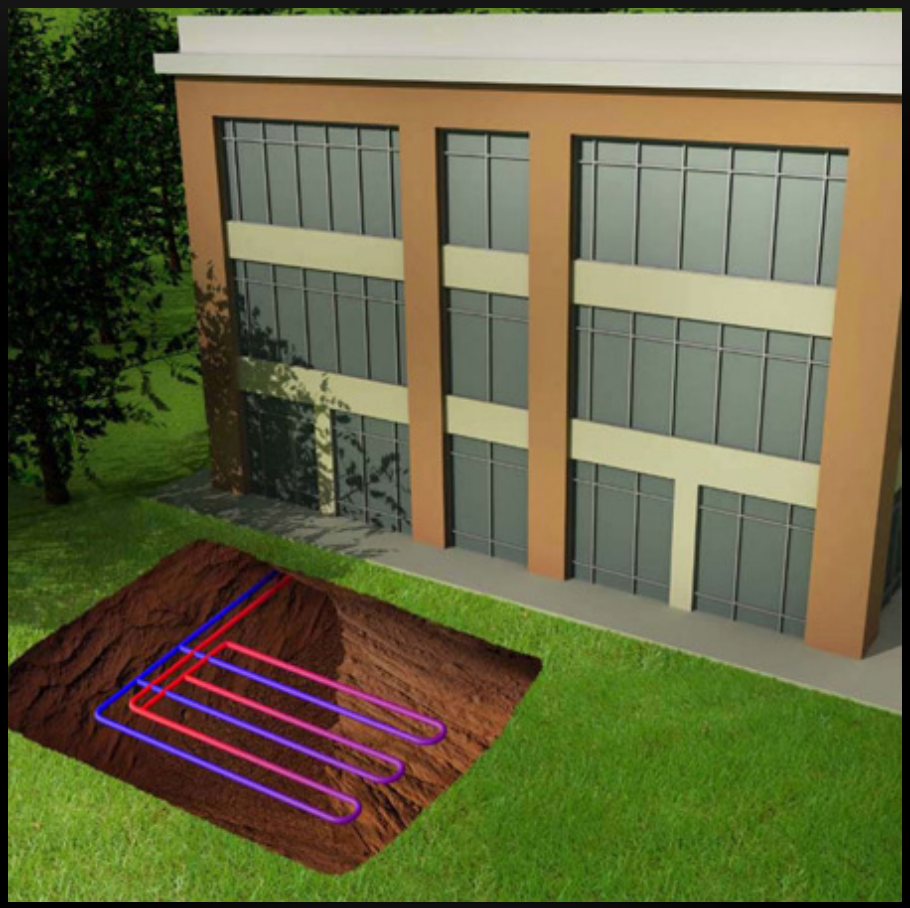
CAMPUS MAP

Building Addition

Pond Loop



HORIZONTAL LOOP



http://www.fhp-mfg.com/files/images/common/coupCx02.jpg

CAMPUS MAP

Horizontal Loop

Building Addition

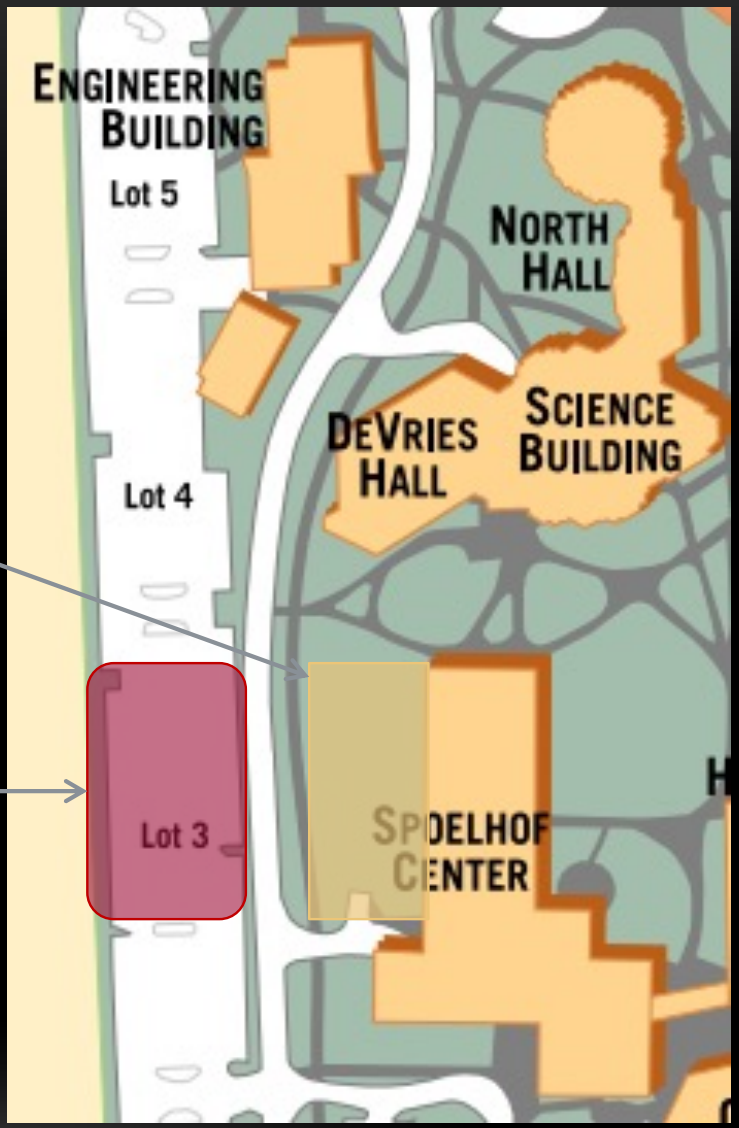
VERTICAL LOOP

http://www.fhp-mfg.com/files/images/common/coupCx01.jpg

CAMPUS MAP

Building Addition

Vertical Loop



ANSWERS

- How will the geothermal system fit in at Calvin College?
  - Mechanical Separation
- What type of loop configuration will be used?
  - Vertical
- Where will the geothermal ground loop be located?
  - West Parking Lot

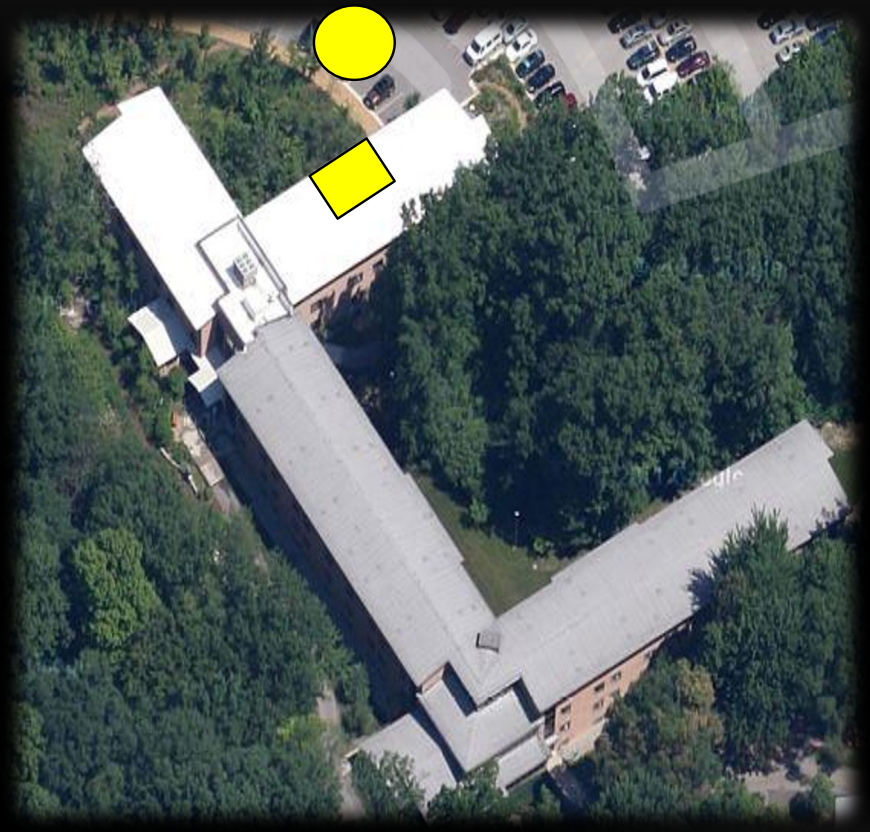
BELOW GROUND

TEAM MEMBERS

KEY QUESTIONS

- What is the Design of the Borefield?
  - How many bores?
  - How deep?
  - How far apart?
  - Will local geology affect the design?
  - How much will it cost?
  - How long will it last?

KHvR GEOTHERMAL INSTALLATION



https://maps.google.com/maps?q=calvin+college&aq=f&sugexp=chrome,mod%3D0&um=1&ie=UTF-8&hl=en&sa=N&tab=wl

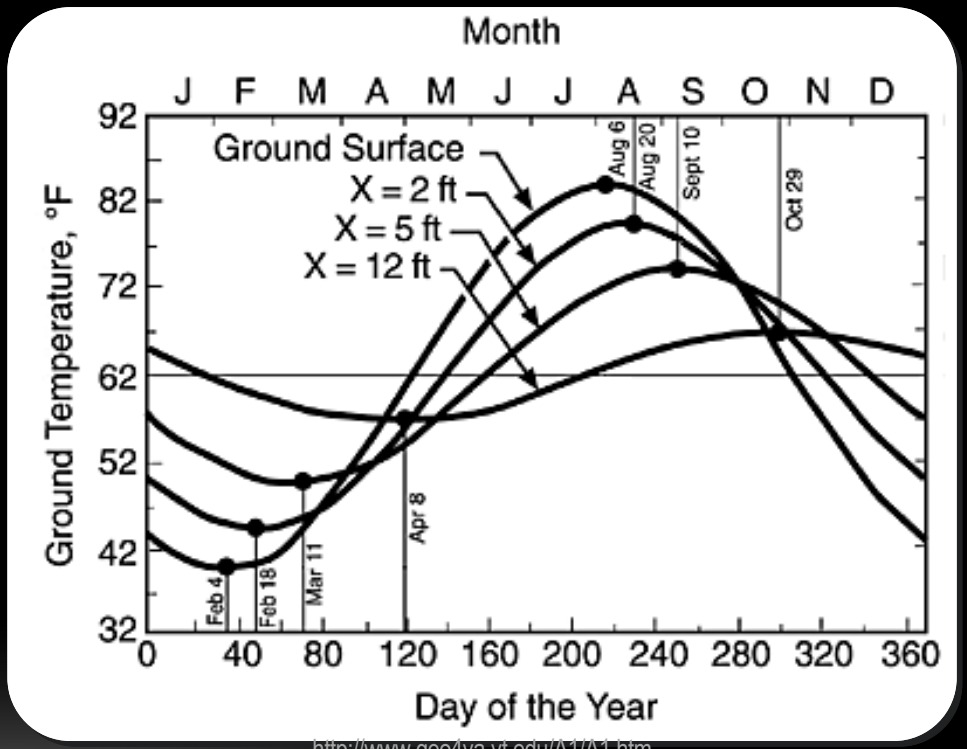
Cleanly Cooling Calvin (Senior Design 2008)

~~Introduction~~ ~~Infrastructure~~ Above Ground Recommendation

~~Energy Modeling~~ Below Ground Financial

THERMAL MODELING - INITIAL

- Factors to account for:
  - Temperature Gradient vs. Constant Ground Temperature
  - Soil Composition/Location



http://www.geo4va.vt.edu/A1/A1.htm

THERMAL MODELING - INITIAL SUMMARY

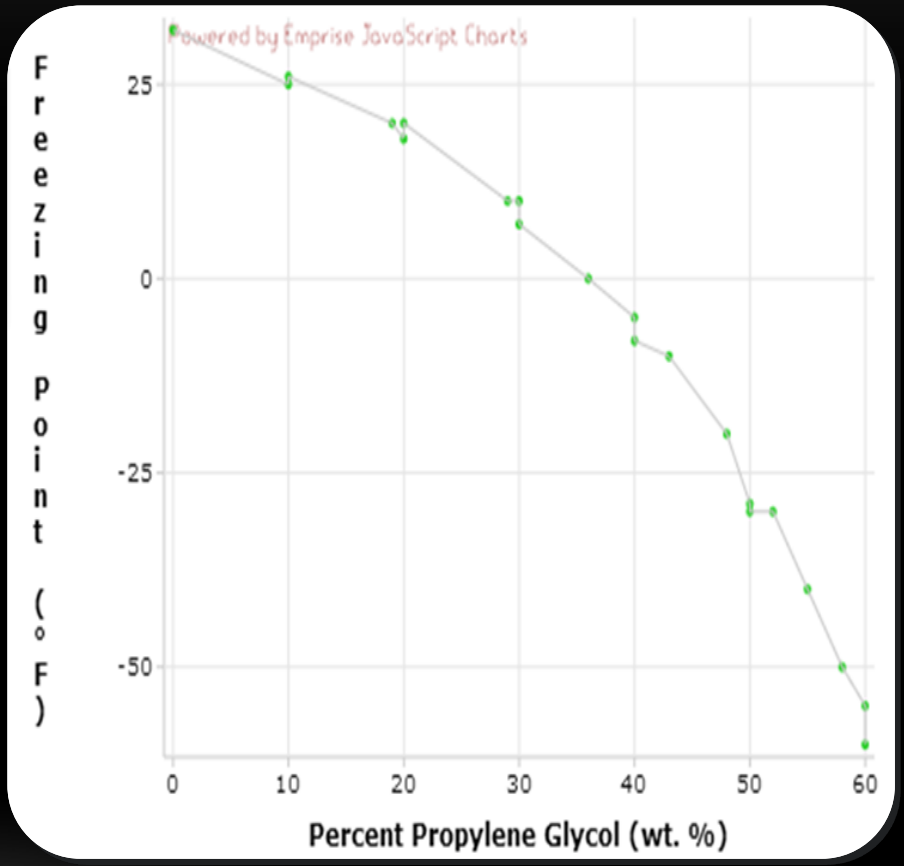
- Heating Load: 140 ton
- Borehole Depth: 300 – 420 feet
- Number of Boreholes: 175 – 200

REFINED BOREFIELD DESIGN

http://mwgeothermal.com/

REFINED BOREFIELD DESIGN

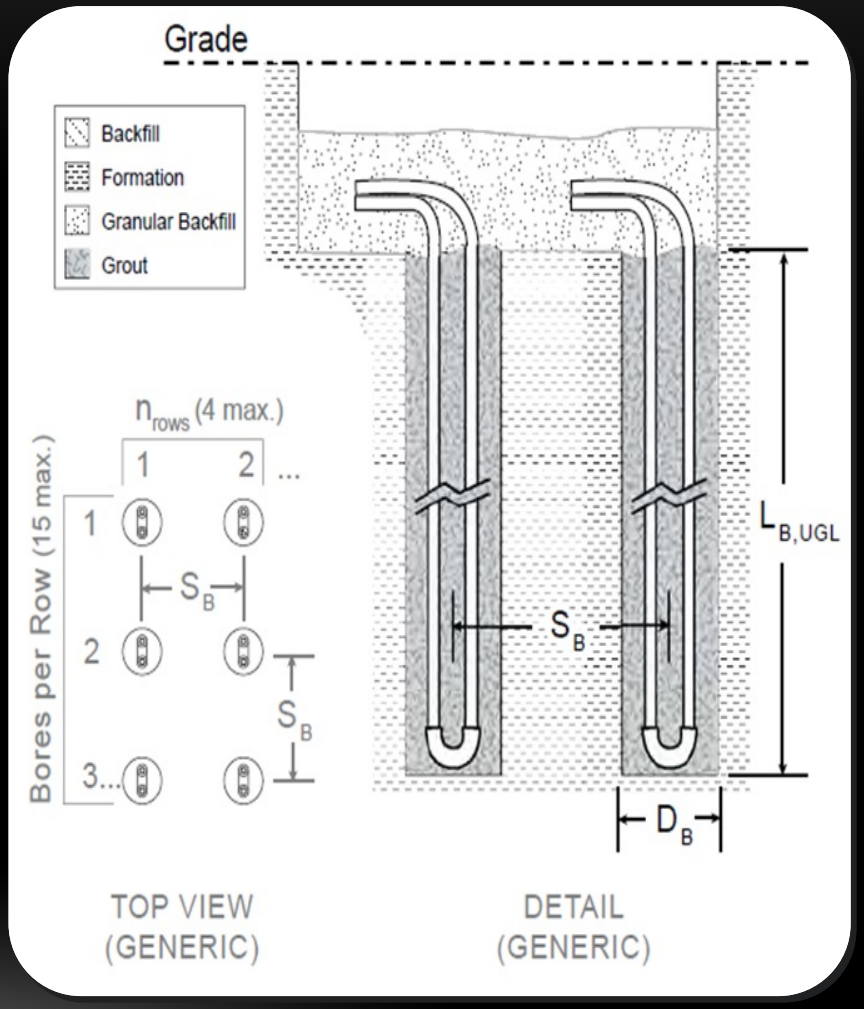
- Thermal Conductivity: 1.35 Btu/hr-ft-°F
- Operating Fluid: Water/Glycol Mix
- Bore Feet needed to accommodate loads
  - 28,447 feet
- Effective Bore Feet
  - 33,180 feet



http://www.xydatasource.com/xy-showdatasetpage.php?datasetcode=234654&dsid=67

PROPOSAL

- What is the Design of the Borefield?
  - How many bores?
    - **88 bore holes**
  - How deep?
    - **400 feet deep (L_B)**
  - How far apart?
    - **20 feet center-to-center (S_B)**
- Additional Details:
  - 5 inch bores (D_B)
  - 1.25 inch HDPE pipe



REFINED BOREFIELD DESIGN

- How must will it cost?
  - Total Installation Costs = **$478,720**
    - $13.60/bore feet
    - Pipe Costs
    - Site Costs
- How long will it last?
  - Economic Life
    - **50 years**

ABOVE GROUND

TEAM MEMBERS

KEY QUESTIONS

- What system should be selected to meet the HVAC demands of the new addition?
  - Water to Air vs Water to Water?
  - Centralized vs Distributed System?
  - Energy Recovery Ventilation?

SYSTEM REQUIREMENTS

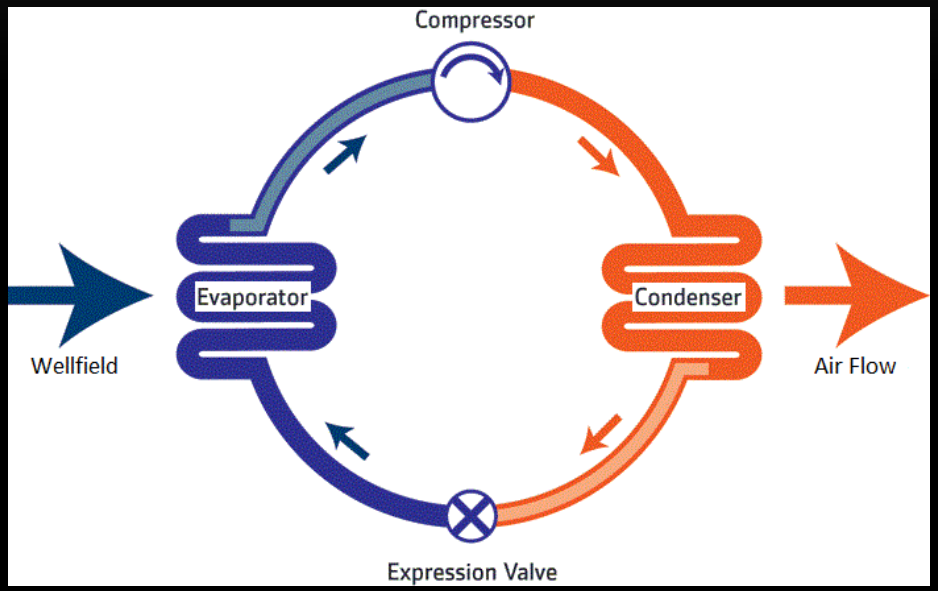
- Heating/Cooling Loads
  - Heating Load: 174 Tons
  - Cooling Load: 86 Tons
- Ventilation Requirements
  - Estimated Air Flow Required: 48,000 cfm
    - Michigan Mechanical Codes/ASHRAE Standards

Figure 6: Excerpt from Table 2 of ASHRAE Standard 62-2001

Application	Estimated Maximum Occupancy (people/1000 ft^2)	Outdoor Air Requirements	
		cfm/person	cfm/ft^2
Offices			
Office space	7	20	
Reception areas	60	15	
Telecommunication centers and data entry areas	60	20	
Conference rooms	20	20	

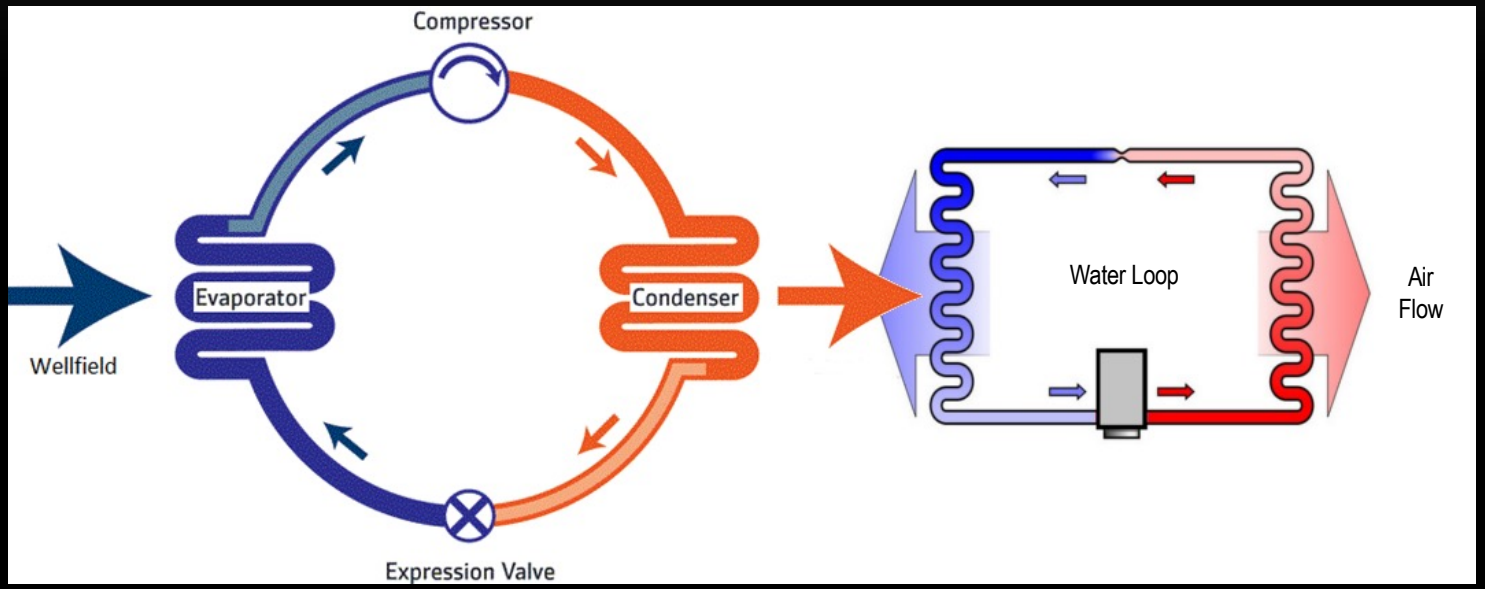
trane.com/commercial/uploads/pdf/520/ISS-APG001-EN.pdf

WATER TO AIR vs WATER TO WATER SYSTEMS



- Ventilation System
- Lower Cost

WATER TO AIR vs WATER TO WATER SYSTEMS



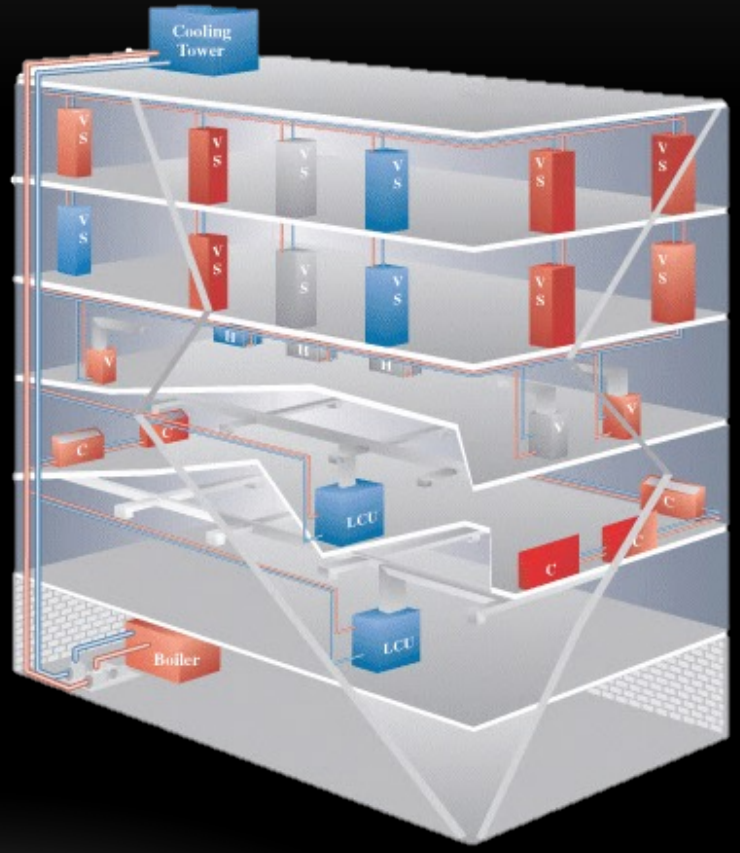
- Ventilation System
- Lower Cost

- Air Handlers and Radiators
- Higher Cost

CENTRALIZED vs DISTRIBUTED SYSTEMS

http://csmdetroit.com/yahoo_site_admin/assets/images/3200_8.345123502_large.jpg

http://4mechanical.com/wp-content/uploads/2011/09/Ductwork1.jpg



http://www.geo4va.vt.edu/A3/A3.htm

HEAT PUMP SELECTION

http://ww.carrier.com/

$1,200,000

http://www.mammoth-inc.com/

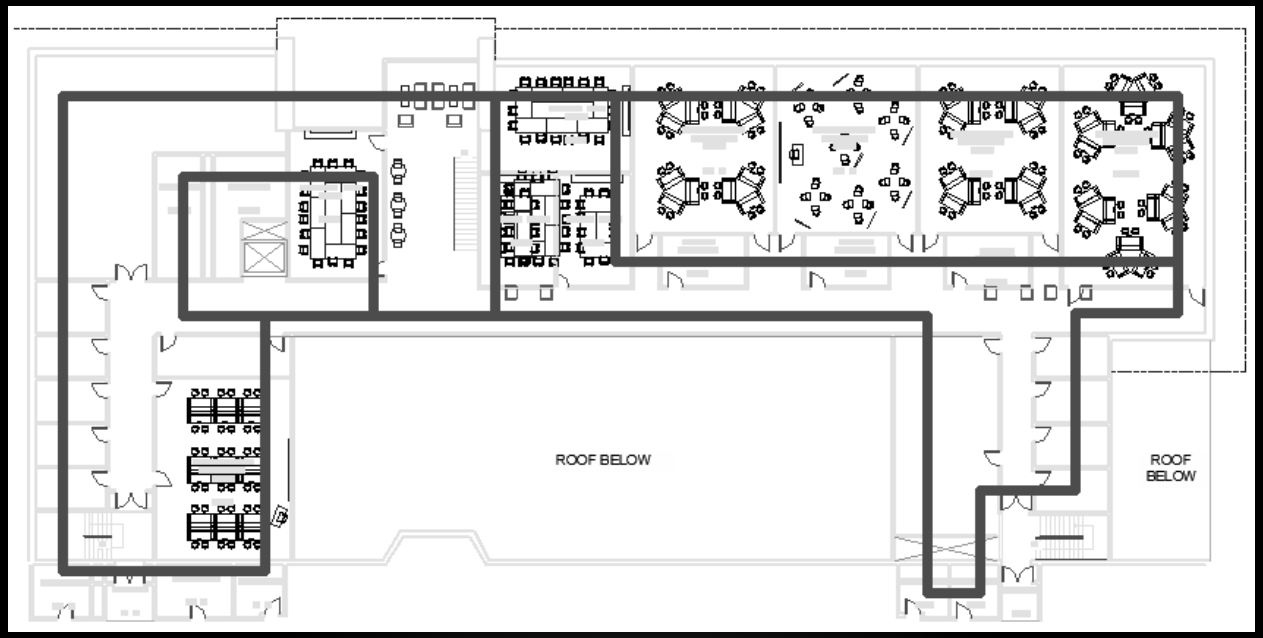
http://www.trane.com/ $840,000

~~Introduction~~ ~~Infrastructure~~ Above Ground Recommendation

~~Energy Modeling~~ ~~Below Ground~~ Financial

DUCTWORK

- Estimated Length of Ducts Required: 5800ft
  - Cost of Installation and Purchase: $54,000



Ductwork diagram (third floor)

ENERGY RECOVERY VENTILATION (ERV)

- Ventilation unit that preheats or precools incoming air using exiting air streams
  - Increases efficiency of the system by roughly 20%
  - Additional cost: $400,000

http://www.renewaire.com/index.php/products/commercial-products/he8xrt

RECOMMENDATION

- Centralized, Water to Air System
- 175 Ton rooftop heat pump (Trane)
- Energy Recovery Ventilation System
- Total Cost: $1,300,000

FINANCIAL GROUP

TEAM MEMBERS

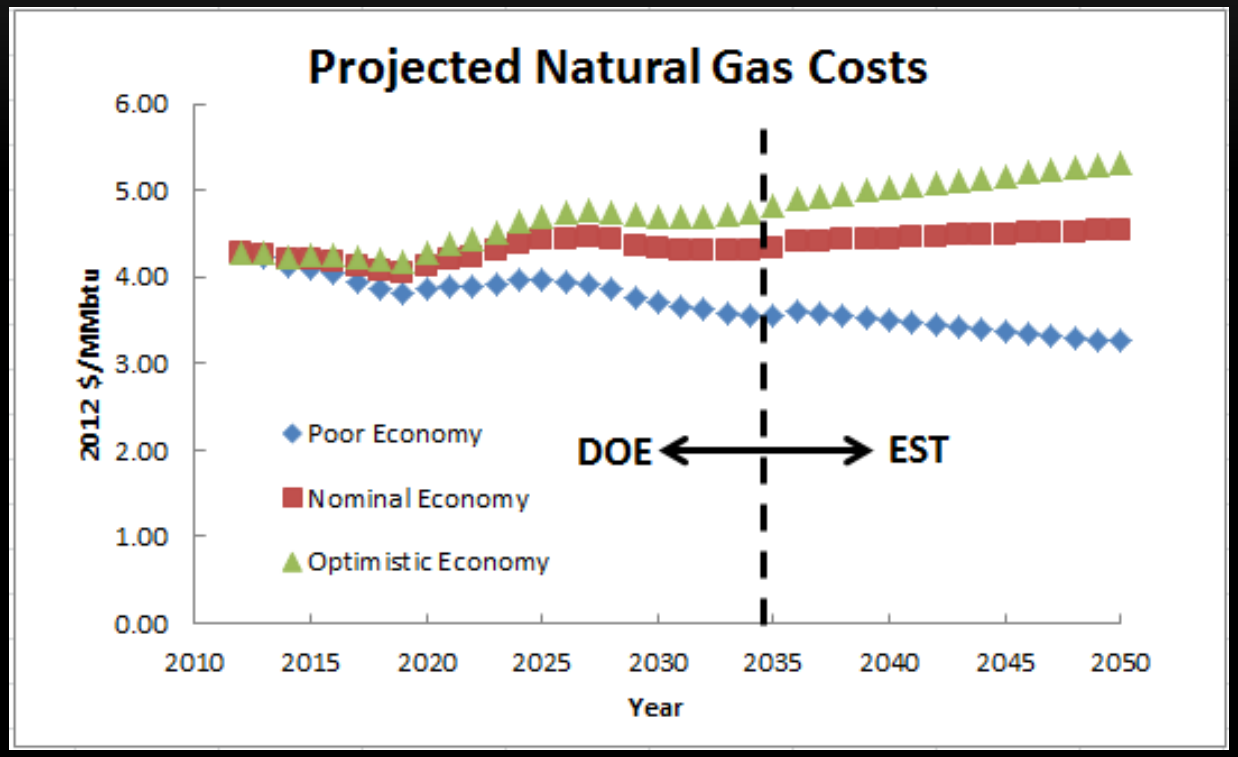
~~Introduction~~ ~~Infrastructure~~ ~~Above Ground~~ Recommendation

~~Energy Modeling~~ ~~Below Ground~~ Financial

KEY QUESTION

Is a geothermal system a financially viable option for the West Wing addition?

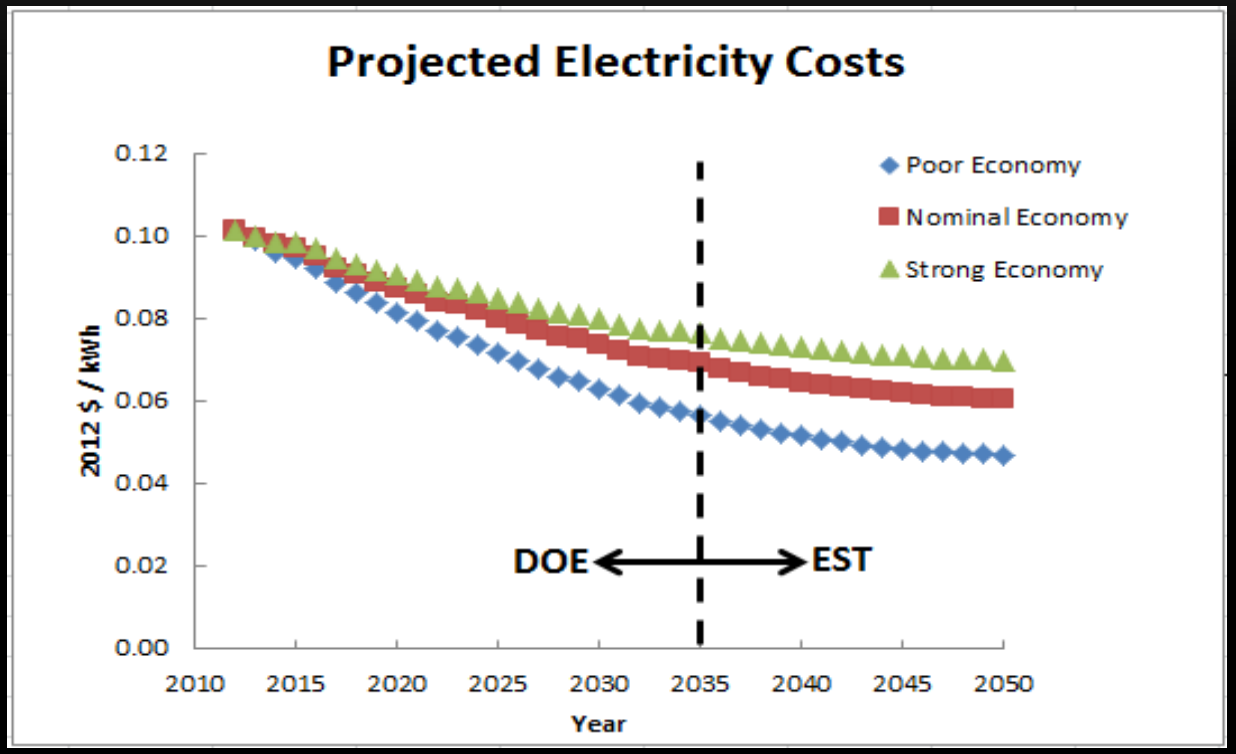
NATURAL GAS PRICES



http://www.eia.gov/forecasts/archive/aeo11/source_natural_gas.cfm

- 2012-2035: Data from Department of Energy
- 2035- : Data projected based on best-fit trends

ELECTRICITY PRICES



http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2012&subject=0-AEO2012&table=8-AEO2012&region=0-0&cases=ref2012-d020112c

- 2012-2035: Data from Department of Energy
- 2035- : Data projected based on best-fit trends

INITIAL COSTS

Geothermal System	
Initial Costs	
Borefield Cost	$ 478,720
Piping/Pumps Cost	$ 10,000
Heat Pump Cost	$ 1,240,000
Total Cost	$ 1,728,720

Conventional HVAC System	
Initial Costs	
Ductwork Cost	$ 53,806
Air Handler Cost	$ 150,000
Total Cost	$ 203,806

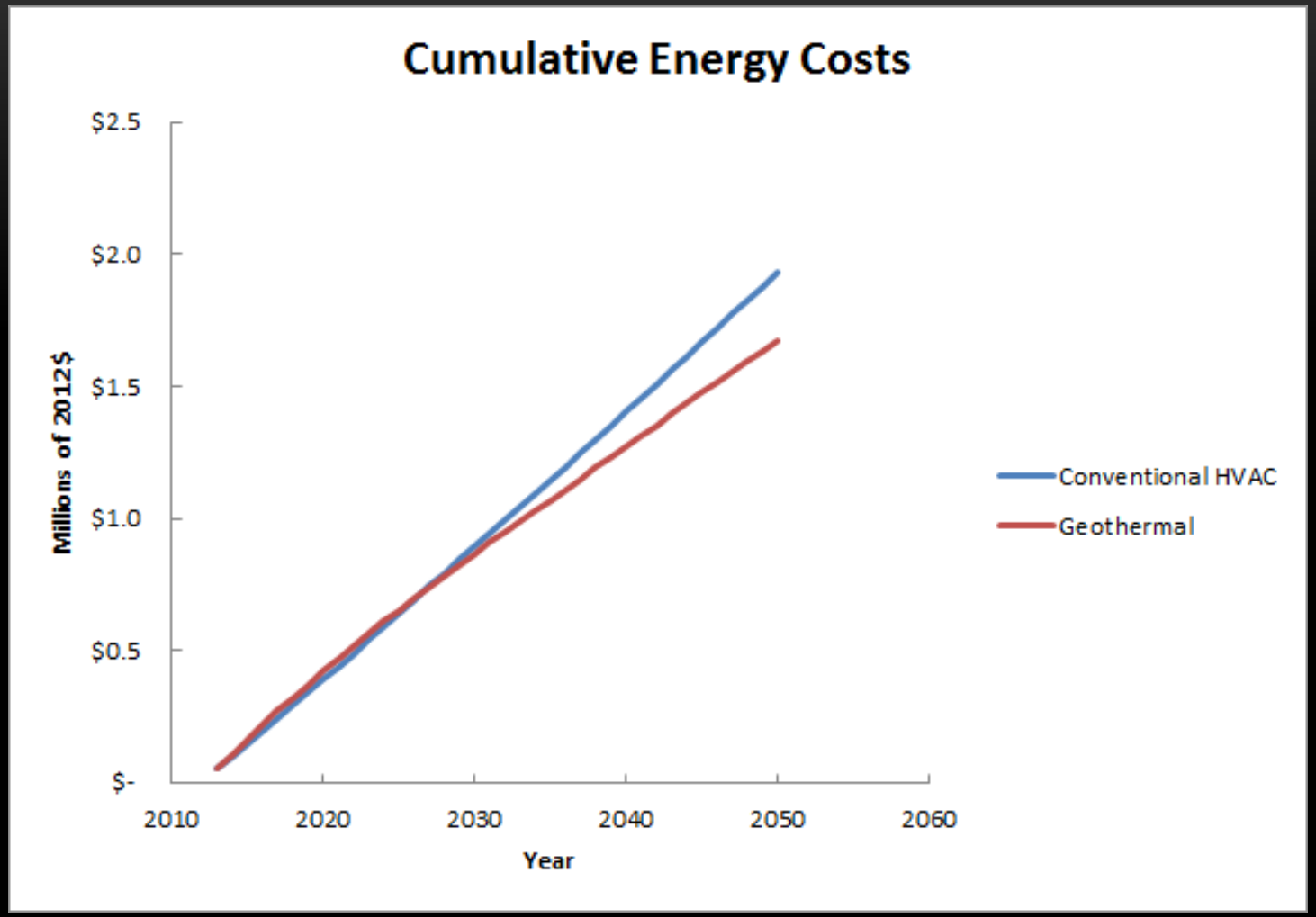
ENERGY COSTS

- GEOTHERMAL
  - Based on Heating/Cooling Loads and pump usage
  - Total Energy Required: **562,040 (kWh/yr)**
- CONVENTIONAL HVAC
  - Heating Load: 7,316 (MMBtu/yr)
  - Cooling Load: 143,808 (kWh/yr)
  - Total Energy Required: **2,288,350 (kWh/yr)**

Geothermal Heating COP	3.68
Geothermal Cooling EER	21.39

Conventional HVAC Heating Eff.	80%
Conventional HVAC Cooling EER	10

http://www.duke-energy.com/pdfs/110371-HVAC-Whitepaper.pdf



(optimistic economic conditions)

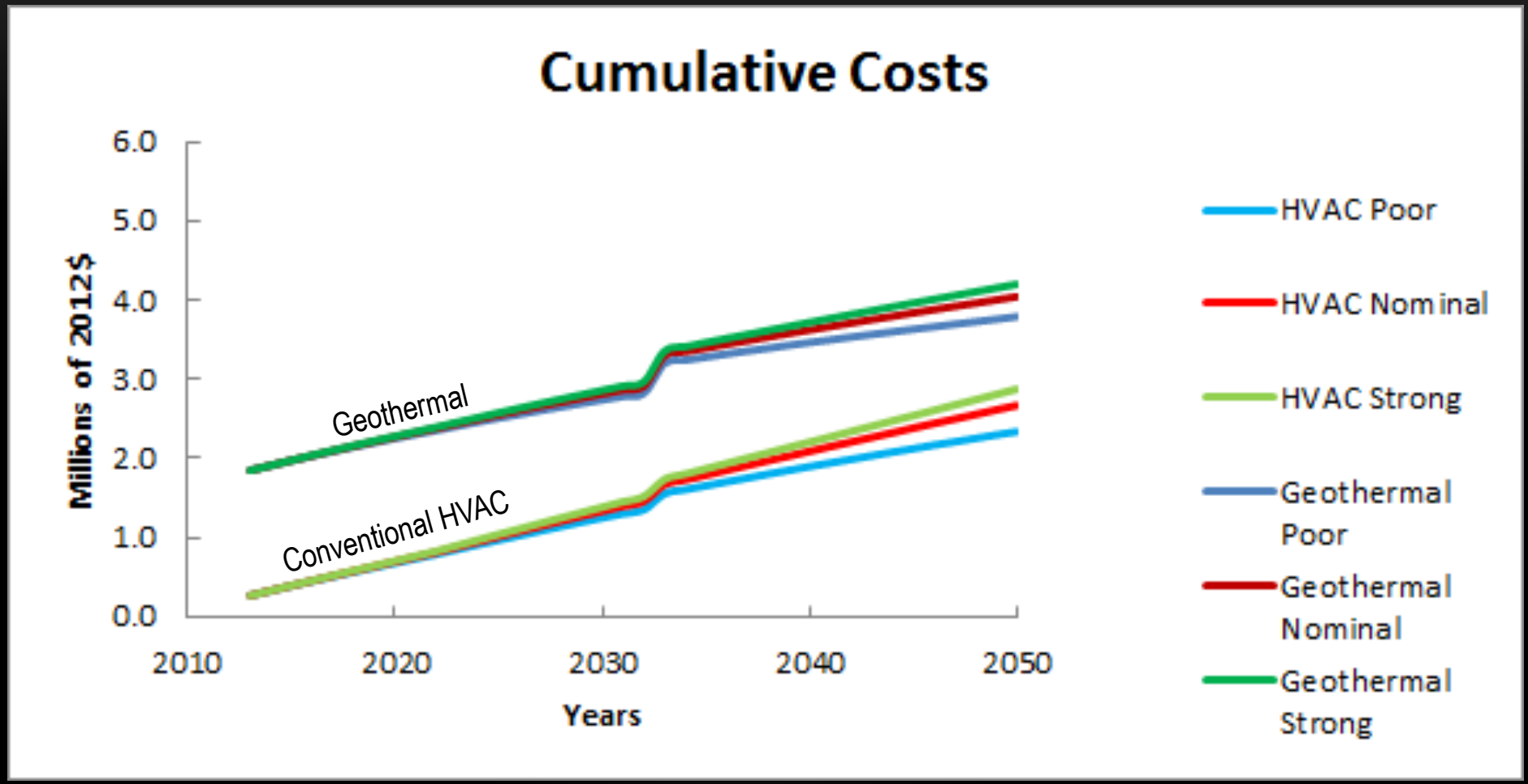
MAINTENANCE COSTS

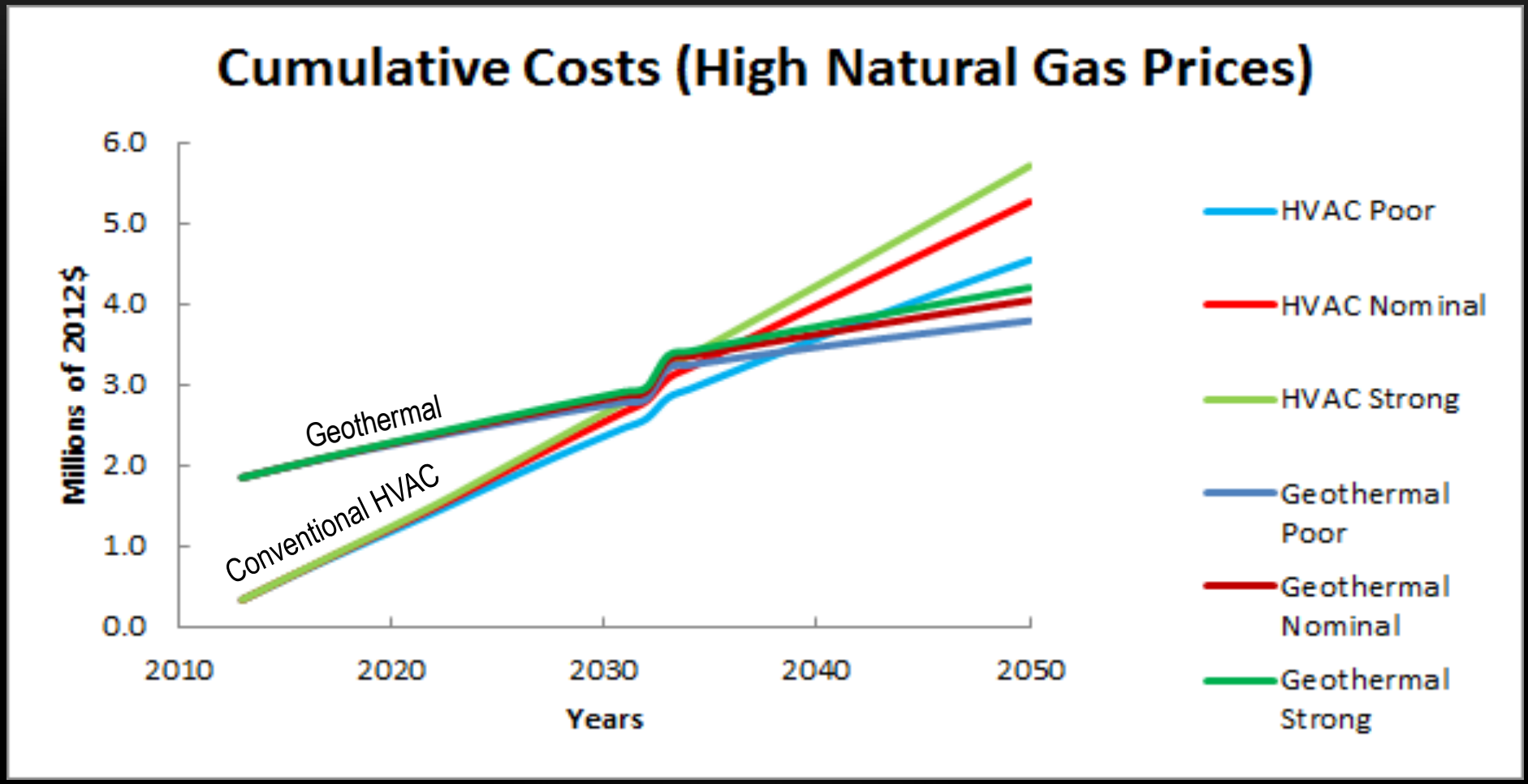
- GEOTHERMAL
  - **$9,000 per year** (ASHRAE)
  - Heat Pump replacement after 20 yrs.
- CONVENTIONAL HVAC
  - **$15,000 per year**
  - Air Handler replacement after 20 yrs.

Annual Maintenance ($/yr)	9000
Later Maintenance ($/yr)	13500
Heat Pump Replacement Cost ($)	336000

Annual Maintenance ($/yr)	15000
Later Maintenance ($/yr)	22500
Air Handler Replacement Cost ($)	150000

Later Maintenance: costs increase by 50% after 10 yrs.


Cumulative Costs
Millions of 2012$
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2010
2020
2030
2040
2050
Years
Geothermal
Conventional HVAC
HVAC Poor
HVAC Nominal
HVAC Strong
Geothermal Poor
Geothermal Nominal
Geothermal Strong


Cumulative Costs (High Natural Gas Prices)
Millions of 2012$
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2010
2020
2030
2040
2050
Years
Geothermal
Conventional HVAC
HVAC Poor
HVAC Nominal
HVAC Strong
Geothermal Poor
Geothermal Nominal
Geothermal Strong

FINANCIAL PROPOSAL

- As Christians, we have a calling to be stewards of Creation and Money

  (Luke 14:28-30, 1 Corinthians 4:7)
- There is no foreseeable financial payback
- From a solely financial standpoint, the financial group recommends a geothermal system not be constructed until such time as:
  - Natural gas prices rise dramatically
  - Entire campus considered

FINAL RECOMMENDATION – ENGR. 333 CLASS

Geothermal Advantages

- Reduce energy costs
- Lower maintenance costs
- Promotes stewardship of creation
- Contributes to LEED certification
- Small scale example of possible campus wide geothermal
- Enhancement of college image

Geothermal Disadvantages

- High initial cost
- Additional construction site – well field
  - Coordinate with parking lot construction

Proposal: Utilize existing HVAC system

ACKNOWLEDGEMENTS

Class Advisors

- Trent DeBoer
- Henry DeVries
- Professor Heun
- Paul Pennock

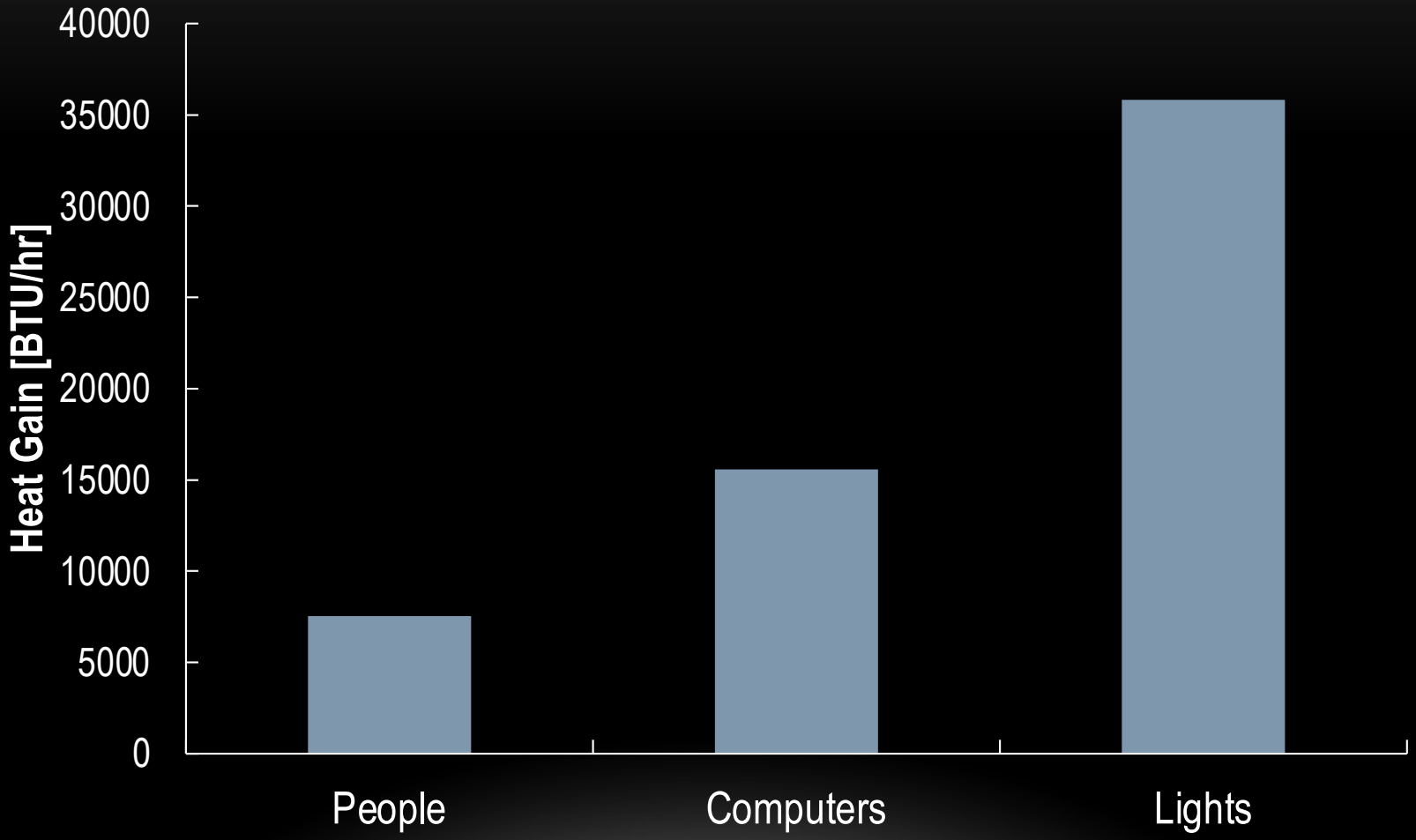
Additional Help

- Phil Beezhold
- Scott Skoog & Kortney Lull, Midwest Geothermal
- Dan Pabst
- Dean Anderson
- Dan Slager

QUESTIONS

HEAT GAINS

- Several factors also provide heat gain to a building
  - Occupants (1 person produces around 400 BTU/day)
  - Equipment in rooms (computers, projectors, etc)
  - Lighting


Heat Gains
Heat Gain [BTU/hr]
40000
35000
30000
25000
20000
15000
10000
5000
0
People
Computers
Lights

EXTERNAL FUNDING

- Direct external funding (tax refunds/incentives) are unavailable as Calvin College is a tax-exempt entity
- However, according to Scott Skoog of Midwest Geothermal, indirect incentives are a possibility.
- In this case, an architect/engineering firm can apply for a tax deduction for designing or building an energy saving building for a non-profit or government agency.
- In this way, the firm saves money on designing/building Calvin's geothermal, and partially passes these savings on to Calvin.

CALVIN ENERGY RECOVERY FUND (CERF) UTILIZATION

- CERF is a revolving fund used to improve energy efficiency and decrease carbon emissions.
- CERF is currently growing by investing in smaller scale projects (lighting, computer shutdown)
- The scale of this project vs. CERF's budget (~$65,000) seems to be a bad fit.
- Recommendation: Don't utilize CERF in this project