Ball State University

“Paradigm Shift: Burning Coal to Geothermal”

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Ball State University

Administration Building 1899

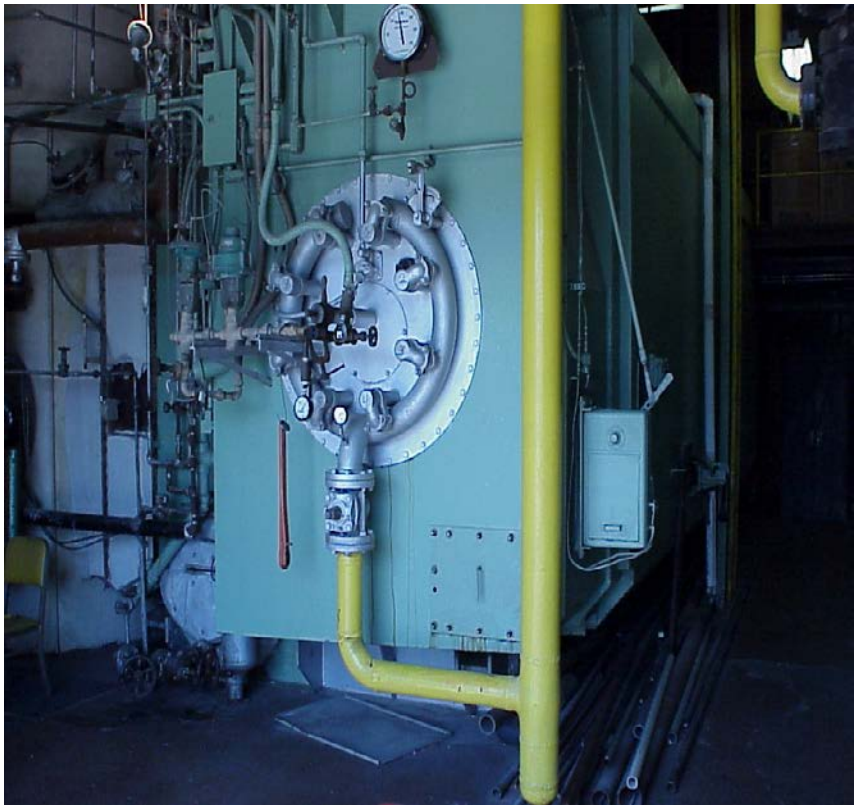
Ball State 1920s

Ball State University

Ball State University

(4) Coal Fired Boilers
Installed 1941/1955

(3) Natural Gas Fired Boilers
Installed in the 1970s



Heat and Chilled Water Plant Operations

Heat Plant:

4 Coal Fired Boilers

3 Natural Gas Fired Boilers

320,000 Lbs/Hr nameplate

240,000 Lbs/Hr current

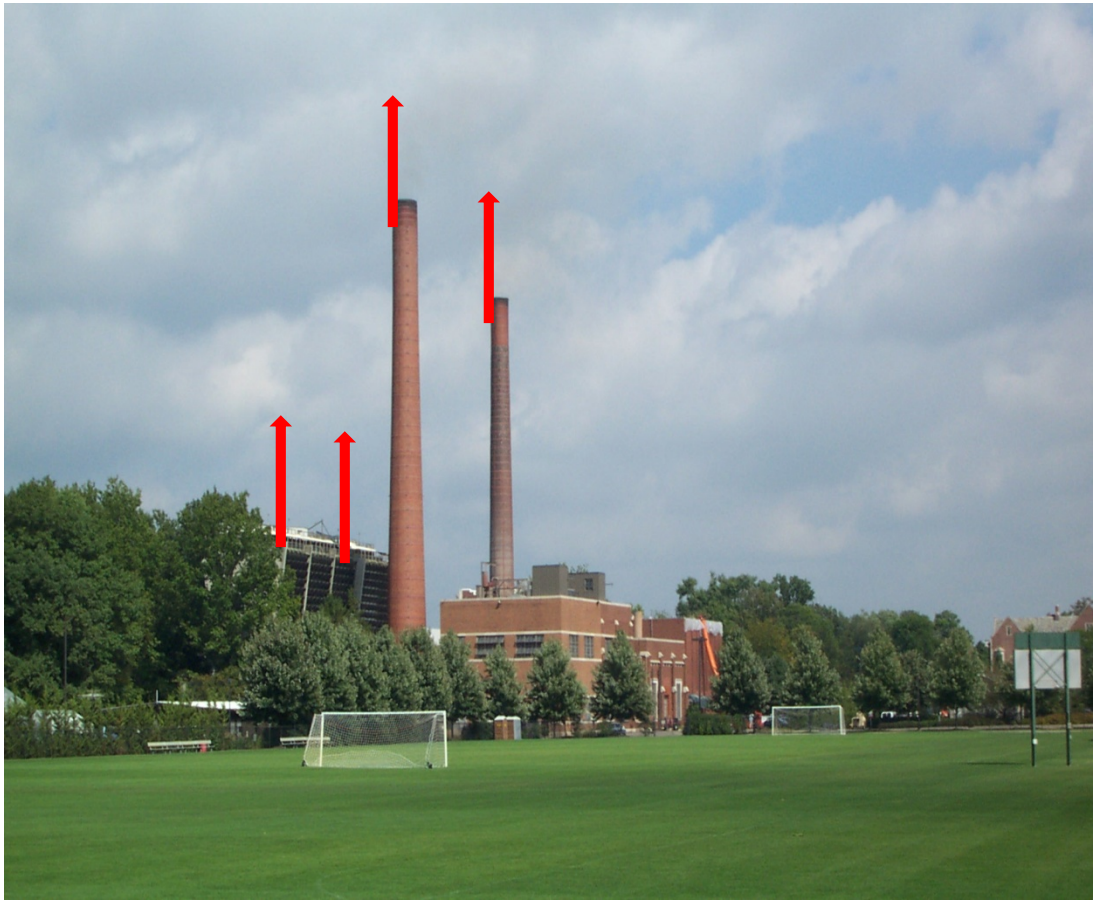
700,000,000 Lbs/Year

Chilled Water Plant:

5 Electrical Centrifugal Chillers

9,300 ton capacity

25,000,000 Ton Hours/Year



Pollutants Produced from Burning 36,000 tons of Coal

- Carbon Dioxide 85,000 tons (Global Warming)
- Sulfur Dioxide 1,400 tons (Acid Rain)
- Nitrogen Oxide 240 tons (Smog)
- Particulate Matter 200 tons (Breathing)
- Carbon Monoxide 80 tons (Headache)
- Multiple Hazardous Air Pollutants now regulated by EPA's Boiler MACT rules

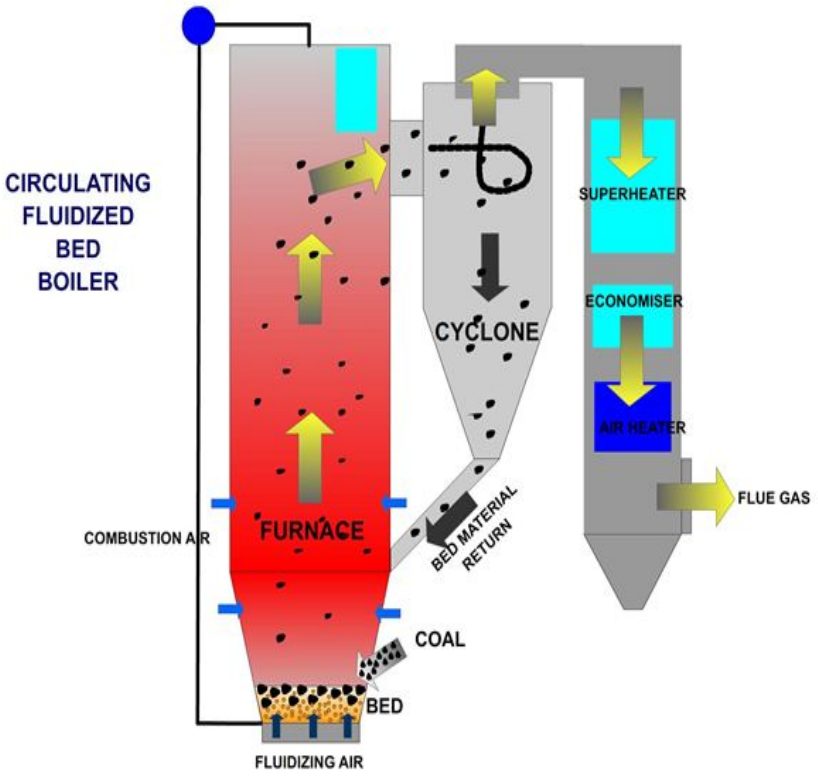
Coal-fired Boiler Replacement

- Condition: Average age over 64 years old
- Capacity: Campus grew in size
  Boiler output degraded
  Title V permit limits
- EPA : Boiler Maximum Achievable Control Technology (BMACT)

State of Indiana appropriated $45 million in 2005 to replace (4) coal fired boilers

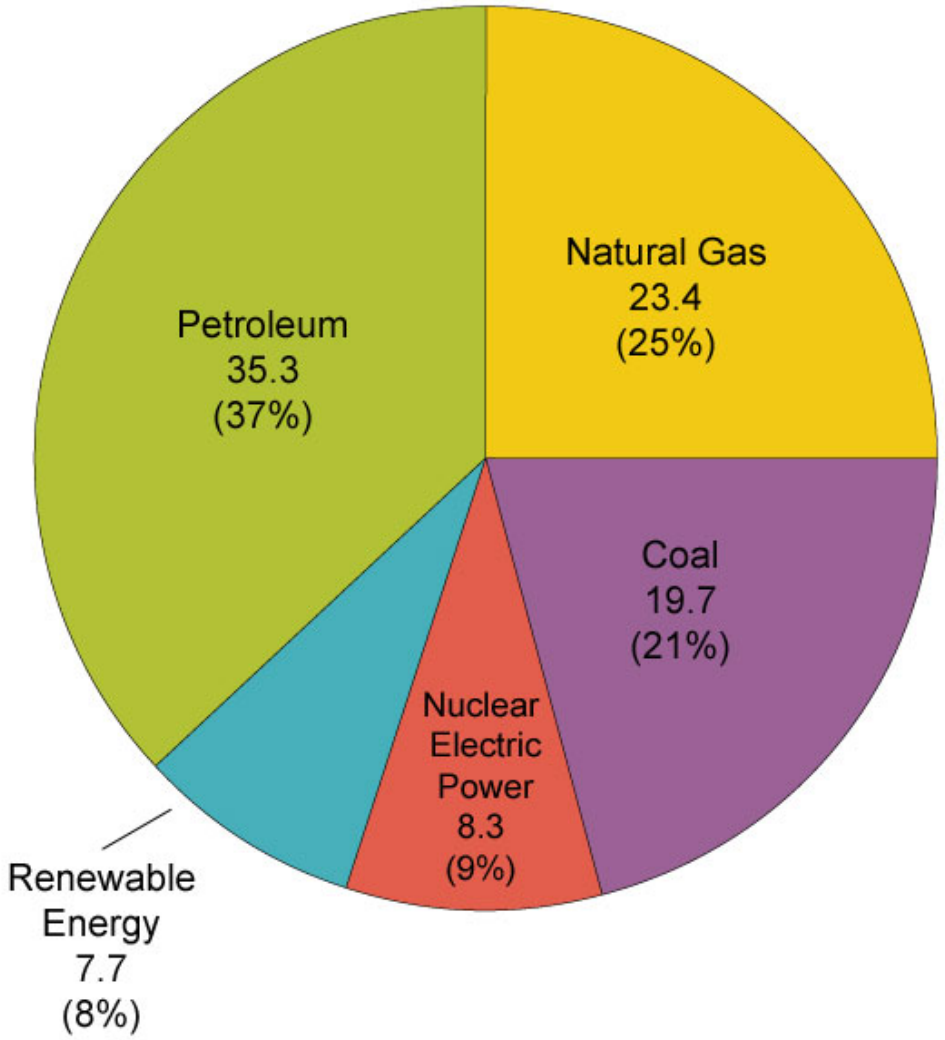
Circulating Fluidized Bed Boiler

- Burn 70% fossil fuel with 30% alternative fuels
- Approximately 15% more efficient
- **Cost escalated to $65 - $70 million by 2008**



Primary Energy Use by Source, 2009,

Quadrillion Btu and Percent



Source: U.S. Energy Information Administration, *Annual Energy Review 2009.*

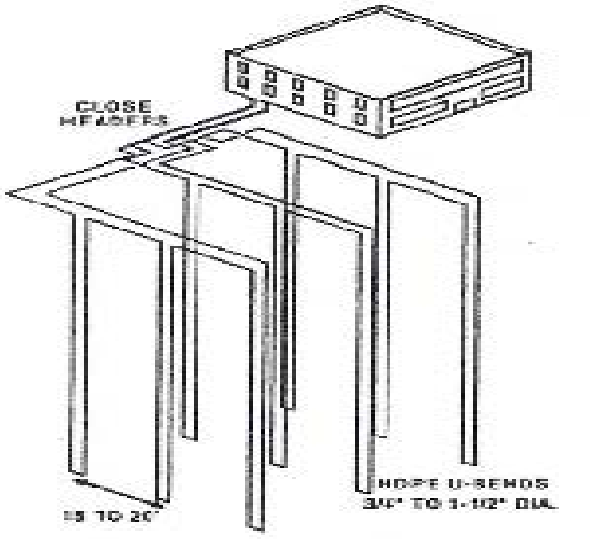
Geothermal Research

- MAPPA Survey of Universities
- International Ground Source Heat Pump Association(IGSHPA)
- National Ground Water Association (NGWA)
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- US Department of Energy
- Galt House --Louisville
- Stockton College (NJ)
- AUL/One American Building in Indianapolis
- Dr. Steve Kavanaugh and Kevin Rafferty

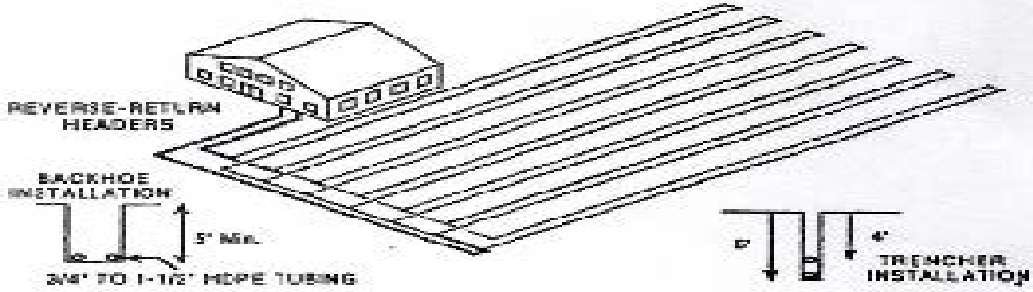
Ball State University

- Proof of Concept: District System Capable
- Provide both Hot Water and Chilled Water
- Project Estimate $75 - $80 Million
- Estimated $2,000,000 Savings by Eliminating Coal Purchases

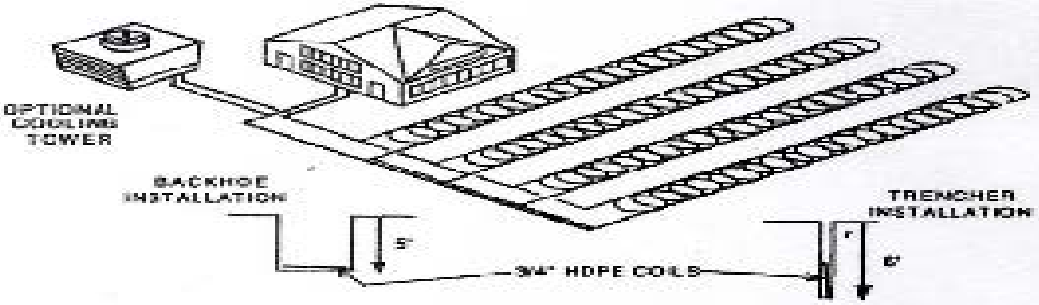
Received a $5 million US Department of Energy grant in 2009 ; total funds available $50 million



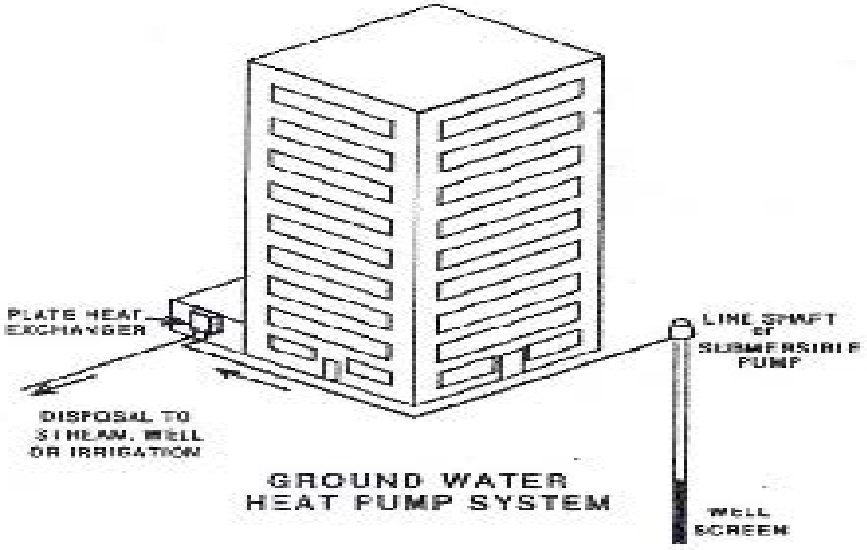
VERTICAL GROUND-COUPLED HEAT PUMP SYSTEM



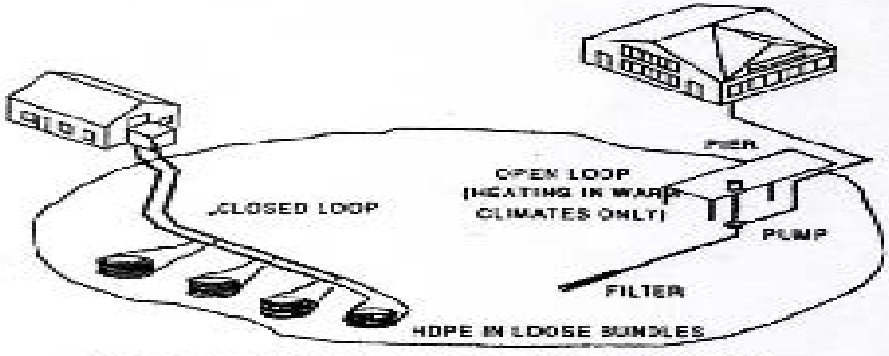
CONVENTIONAL HORIZONTAL GROUND-COUPLED HEAT PUMP SYSTEM



SLINKY COIL GROUND-COUPLED HEAT PUMP SYSTEM



GROUND WATER HEAT PUMP SYSTEM



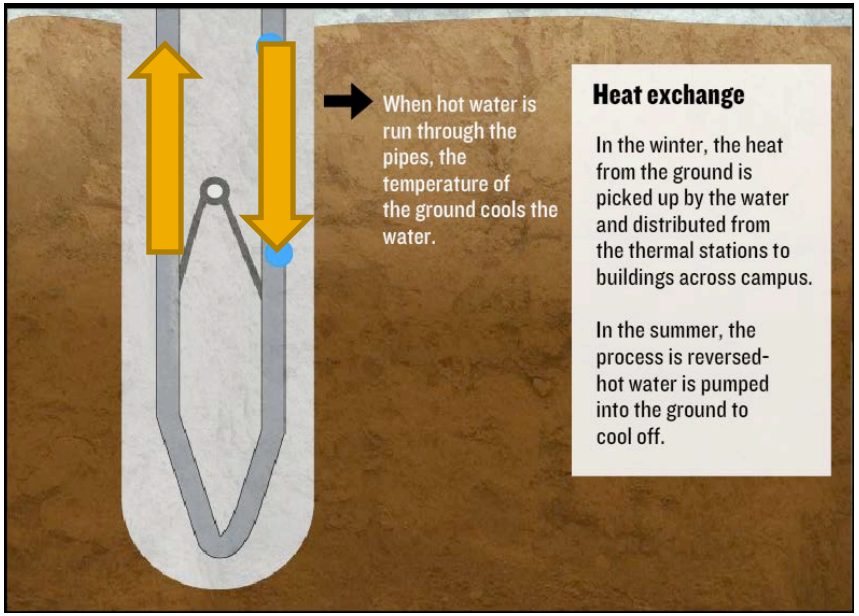
SURFACE WATER HEAT PUMP SYSTEM

Figure 1.1 Ground-source (or geothermal) heat pump types.

Geothermal Process

Borehole Loops

Thermal Energy Flow



Laws of Thermodynamics
"Engineers Holy Grail"

Zeroth law: **"Thermal equilibrium"**
if two thermodynamic systems are each in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.
First law: **"Conservation of energy"**
energy can neither be created nor destroyed. It can only change forms.
Second law: **"Energy flows from higher to lower temperature objects"**
heat can spontaneously flow from a higher temperature region to a lower temperature region, but not the other way
Third law: **"Minimum Kinetic Energy"**
As temperature approaches absolute zero, the molecular kinetic energy of a system approaches a minimum, 0 degrees K, -273.15 degree C or -459.67 degree F.

Senator Richard Lugar
Geothermal Groundbreaking Ceremony, May 9, 2009

Borehole Drilling

Drilling Rigs

Drilling Process

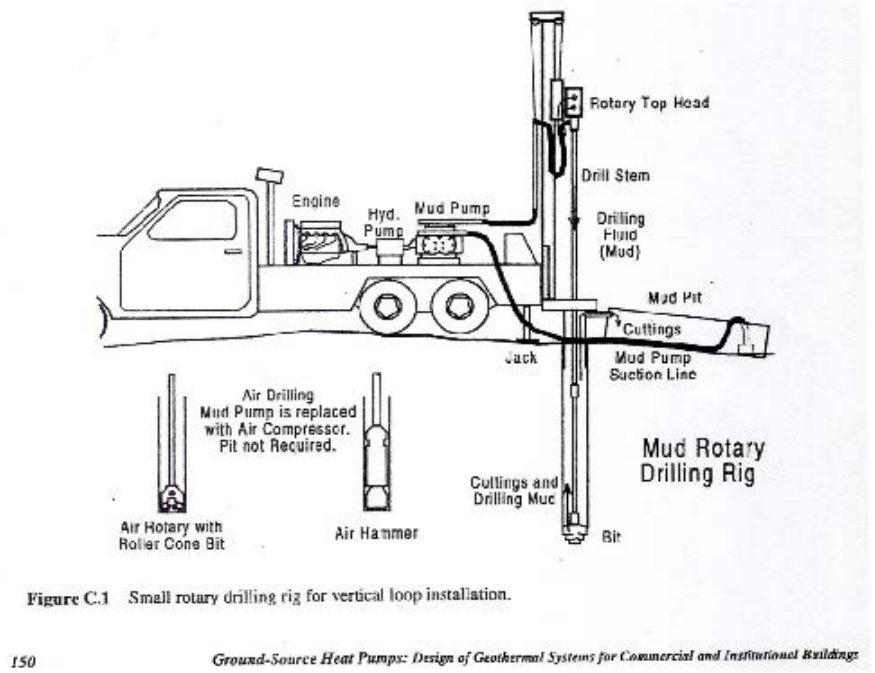


Figure C.1 Small rotary drilling rig for vertical loop installation.

Borehole Construction

Installation of Pipe

Installation of Grout

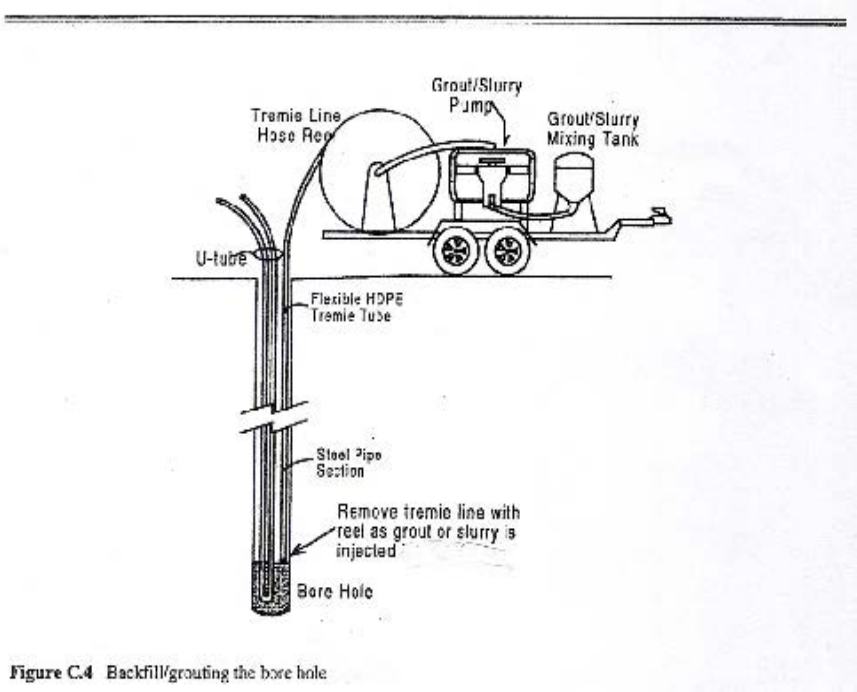
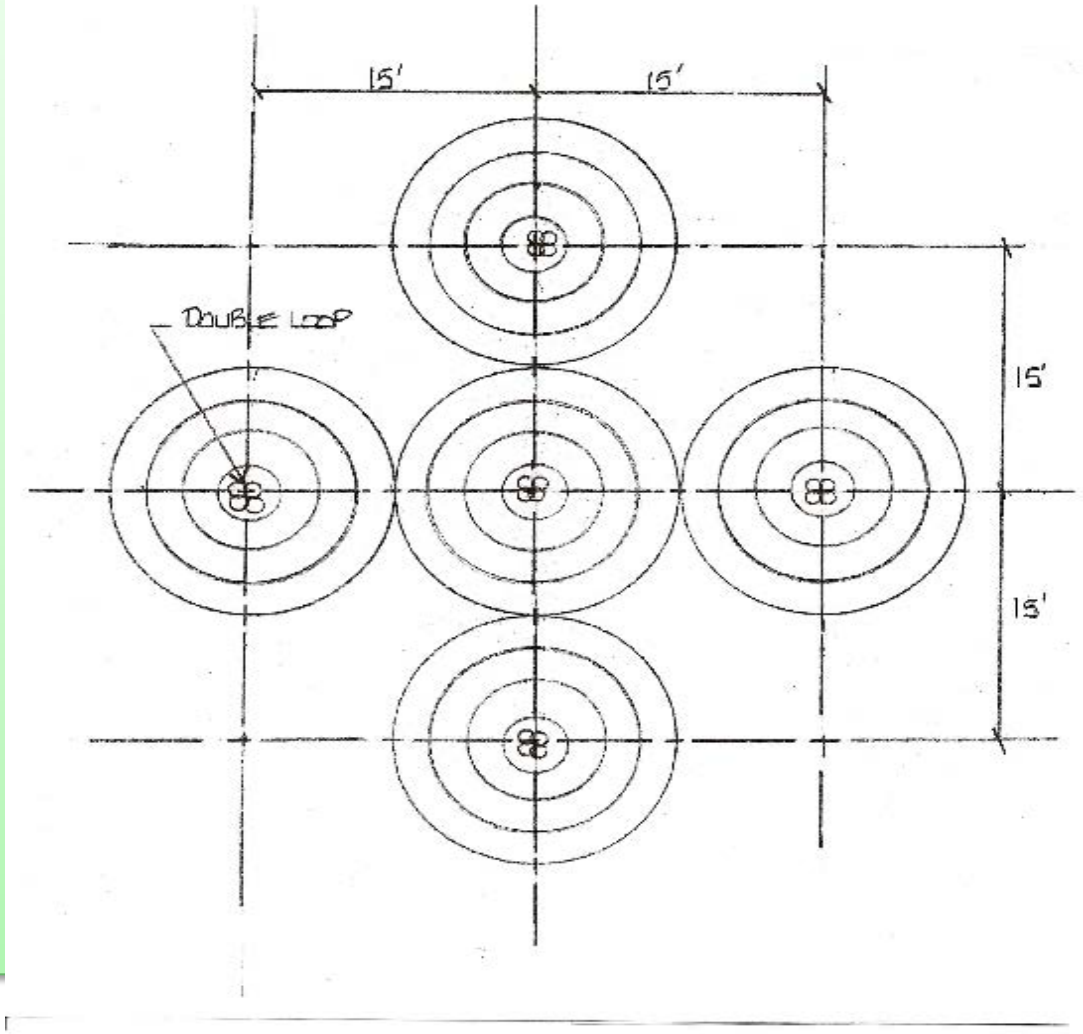


Figure C.4 Backfill/grouting the bore hole

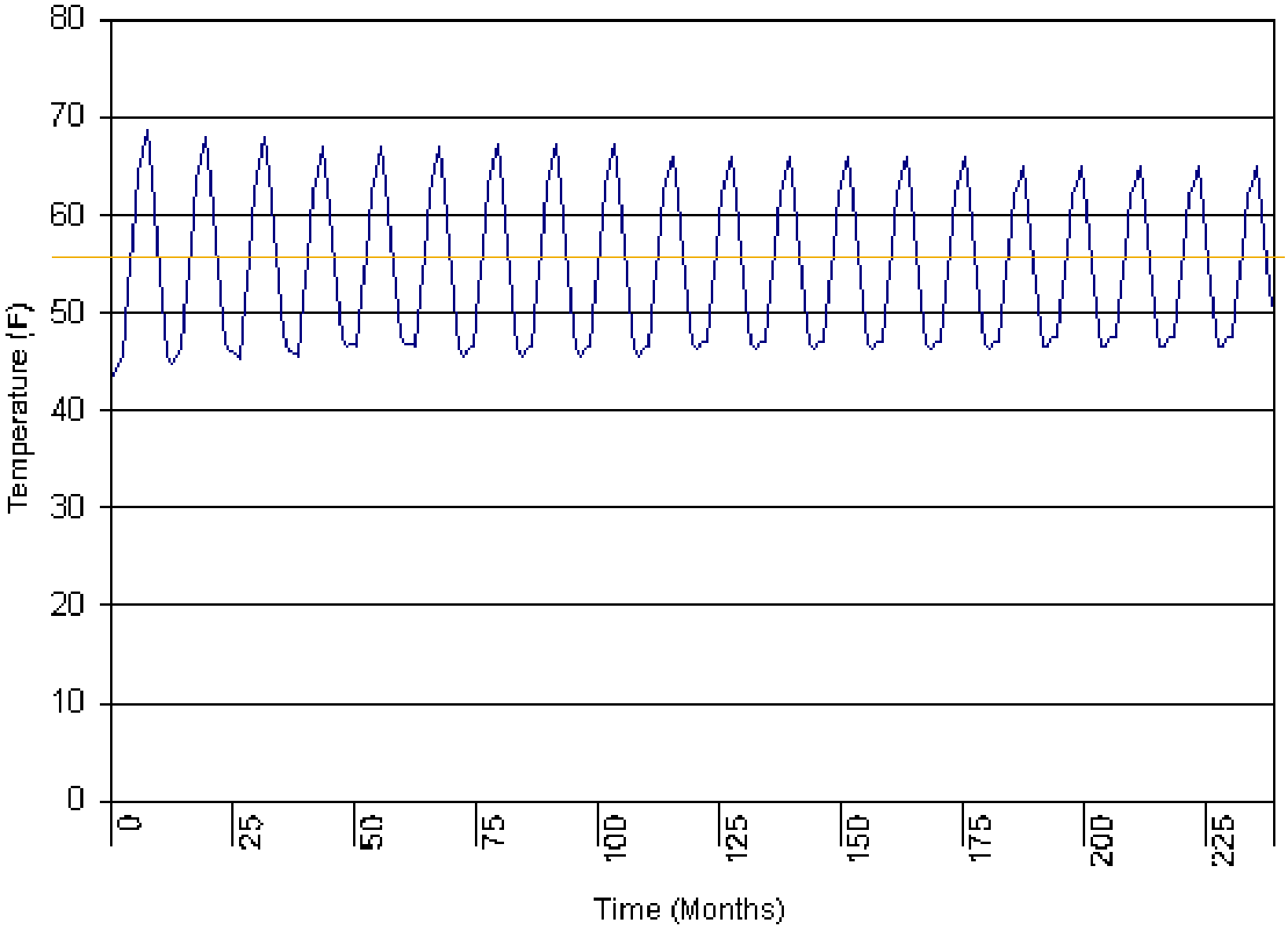
Borehole Design

- 15 feet apart
- 225 SF per borehole
- 400/500 feet deep
- Double and Single Loop
- 1-1/4 inch diameter pipe
- High Density Polyethylene

3,600 boreholes; total of 1,000 miles of pipe



20 Year Ground Temperature Model



District Energy Station North

(4) CYK York Chillers:
R134A Refrigerant

Heating:
150 degree F hot water
38,000,000 BTU/Hour

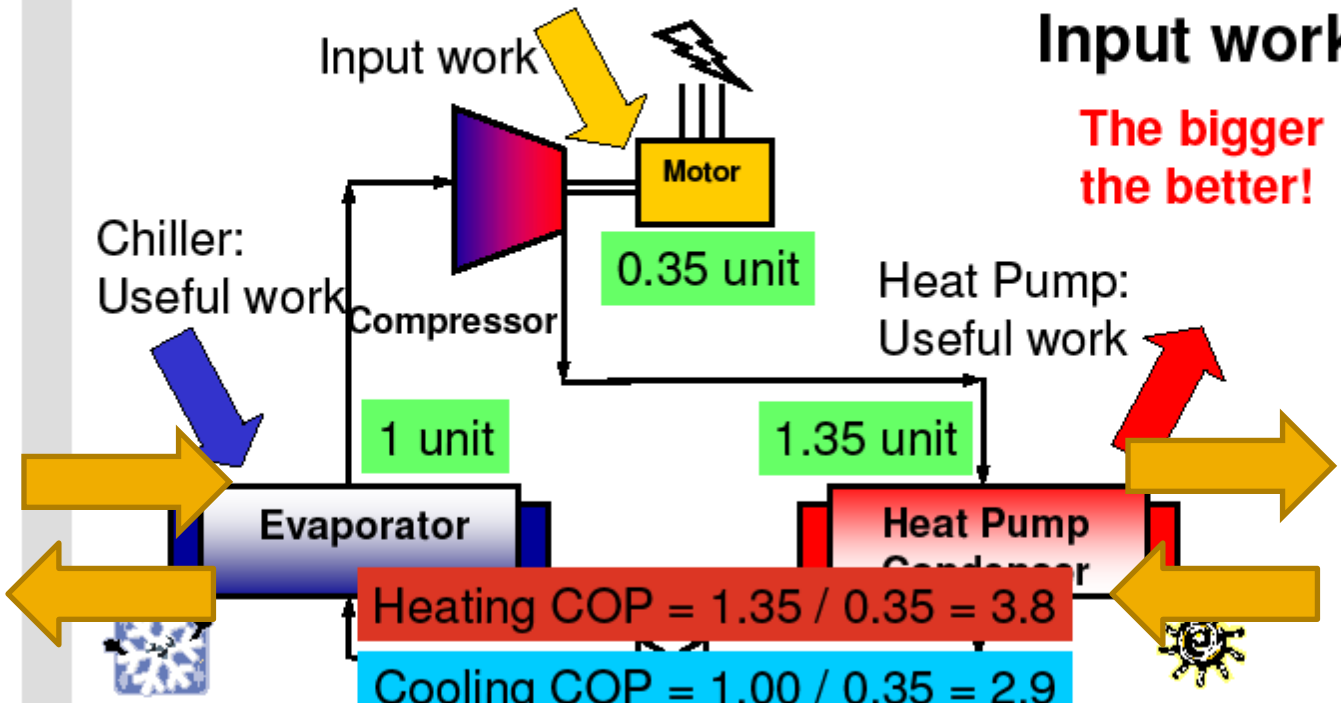
Cooling:
42 degree F chilled water
2,500 tons

Performance Measurement

JOHNSON CONTROLS

COP (Coefficient of Performance) = Useful work / Input work

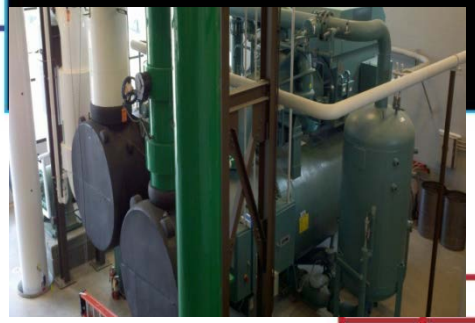
The bigger the better!



YORK

Four Pipe Central Piping

Central Energy



Campus Building

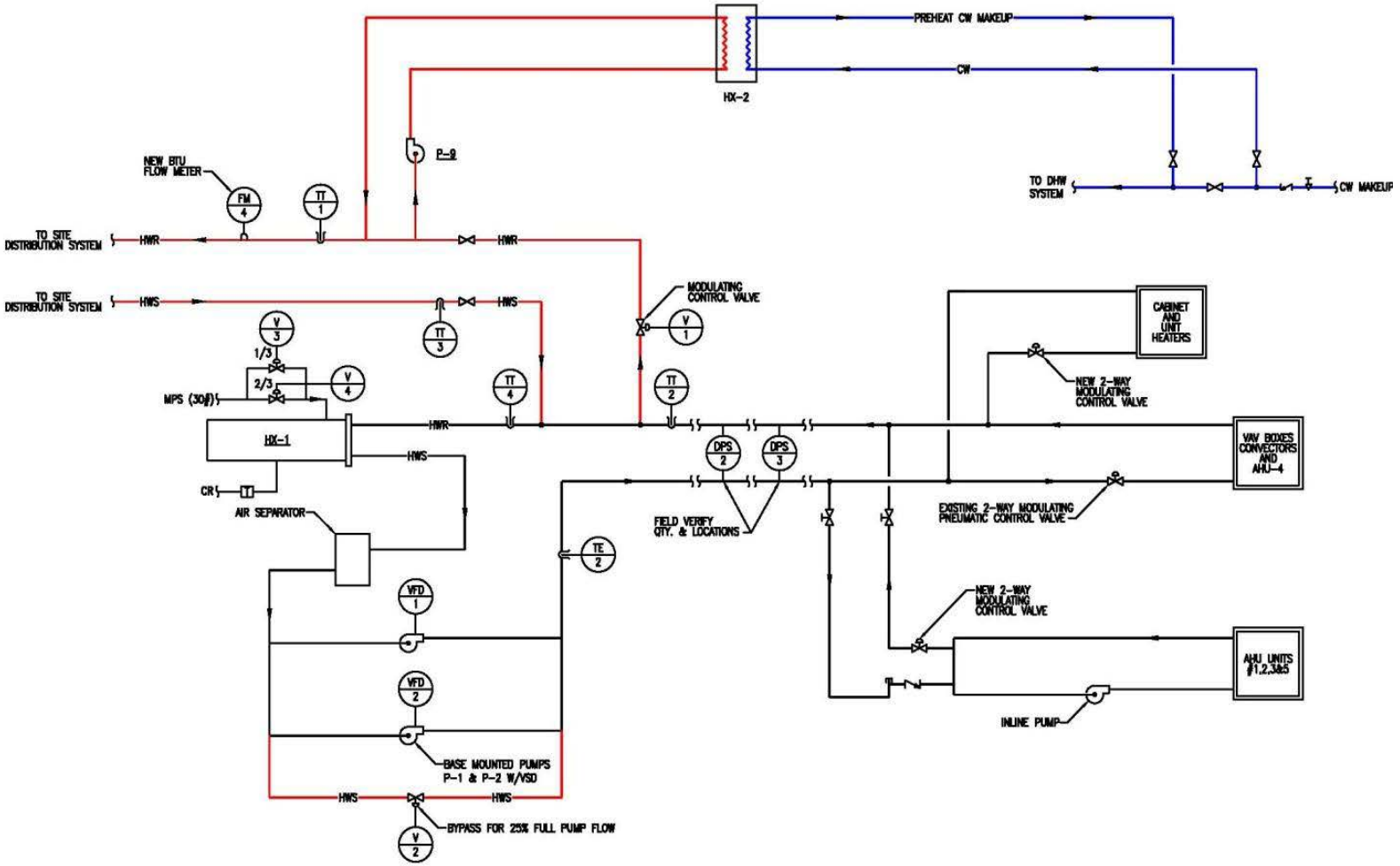
Campus Building

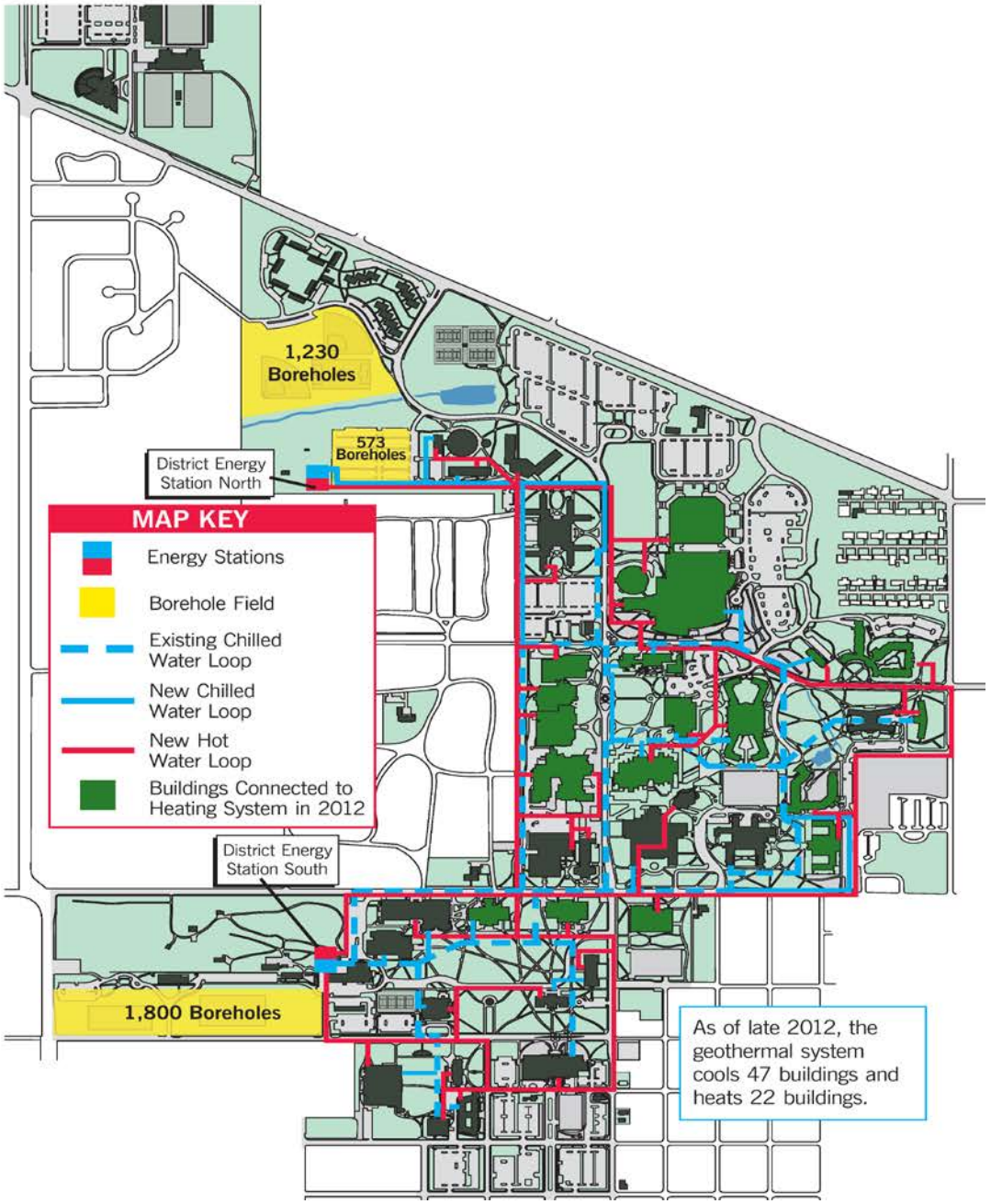
Ball State University

New Hot Water Piping
10 Miles of New Pipe

Typical Air Handling unit
42 F Chilled Water/150 F Hot Water

Typical Hot Water Interface




1,230
Boreholes
573
Boreholes
District Energy
Station North
MAP KEY
Energy Stations
Borehole Field
Existing Chilled
Water Loop
New Chilled
Water Loop
New Hot
Water Loop
Buildings Connected to
Heating System in 2012
District Energy
Station South
1,800 Boreholes
As of late 2012, the
geothermal system
cools 47 buildings and
heats 22 buildings.

Pollutants Eliminated with Geothermal Conversion

- Carbon Dioxide 75,000 tons
- Sulfur Dioxide 1,400 tons
- Nitrogen Oxide 240 tons
- Particulate Matter 200 tons
- Carbon Monoxide 80 tons

"Ball State will be able to comply with Boiler MACT requirements"

Benefits

BTUs per year reduction

500,000,000,000

BTUs/SF/Year

185,000 reduced to 110,000

Water reduction

36,000,000 gallons

Dollars Saved

$2,000,000

Ball State University's Geothermal Project Visits and Inquiries

Colleges & Universities

- Dartmouth College
- Stanford University
- University of Notre Dame
- Ohio State University
- University of Iowa
- Northern Kentucky University
- Colorado College
- Slippery Rock University
- Hampton University
- Pratt Institute
- Oakland University
- Purdue University
- Miami University, Ohio
- Cornell University
- Toledo University
- Bowling Green State
- University of Michigan
- The Evergreen State College
- Northwestern University
- University of Illinois
- Ohio University
- Lake Land College
- Indiana University-Purdue University Indianapolis
- DePauw University
- University of Washington
- Montana State University-Bozeman
- Penn State University
- University of Kentucky
- Indiana State University
- Northampton Community College

Ball State University's Geothermal Project Visits and Inquiries

- U.S. Department of Energy
- Indiana Department of Natural Resources
- Indiana Office of Energy Development
- Representatives of Isparta, Turkey
- National Wildlife Federation
- Union of Concerned Scientists
- Building Indiana Magazine
- WFYI Indiana Expeditions
- The Chronicle for Higher Education
- Delta Sky Magazine
- Second Nature
  (2010 Climate Leadership Award)
- Geo Outlook Magazine
- Allison Transmission
- Waterwell Journal
- International District Energy Association
- Biz World
- The Christian Science Monitor
- National Public Radio
- Argonne National Laboratory
- National Ground Water Association
- Hoosier Environmental Council
  (2010 Technology Innovator of the Year Award)
- Waste Management
- General Service Administration
- Korea: Engineering Firm

Lessons Learned: Ouch!

- Purging: velocity pressure is critical
- Ductile iron pipe: asphalt coating
- Borehole design: double versus single loop
- Borehole quality checks: grout conductivity
- Pressure reliefs: building interfaces
- Heat pump chillers: vary the size

Learning Opportunities

- Classroom Collaboration: Natural Resources, Geology, Architecture, Construction Management
- Research: Geology Department
- Conferences: Geothermal Nexus
- Tours: Universities
- Special Projects: Graduate Students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