Geothermal Heat Pump Systems

Metropolitan Washington Council of Governments

Built Environment and Energy Advisory Committee May 19, 2016






U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Geothermal Technologies Office

Systems Analysis & Low Temperature Program

Arlene Anderson, Technology Manager

Outline

Part I GHP Overview

Part II Energy Loans & Grants

Part III GHP systems Examples

- Energy & Water Savings
- Lifetime Economic Benefits
- Social Benefits

Part I GHP Overview

Geothermal Heat Pump Systems Overview

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- All Inclusive terms: GHP, GSHP, GeoExchange
- Use ground, groundwater, or surface water as heat source and sink
- Exterior Heat Exchange System
  - Ground Coupled Heat Pump Closed-Loop
  - Ground Water Heat Pump – Open Loop with Water Wells
  - Surface Water Heat Pump
    - Closed or Open Loop
    - Connected to lakes, streams and reservoirs

- Single pipe
- Multiple pipe
- Coiled pipe

- Vertical
- Horizontal

GROUND-COUPLED HEAT PUMPS

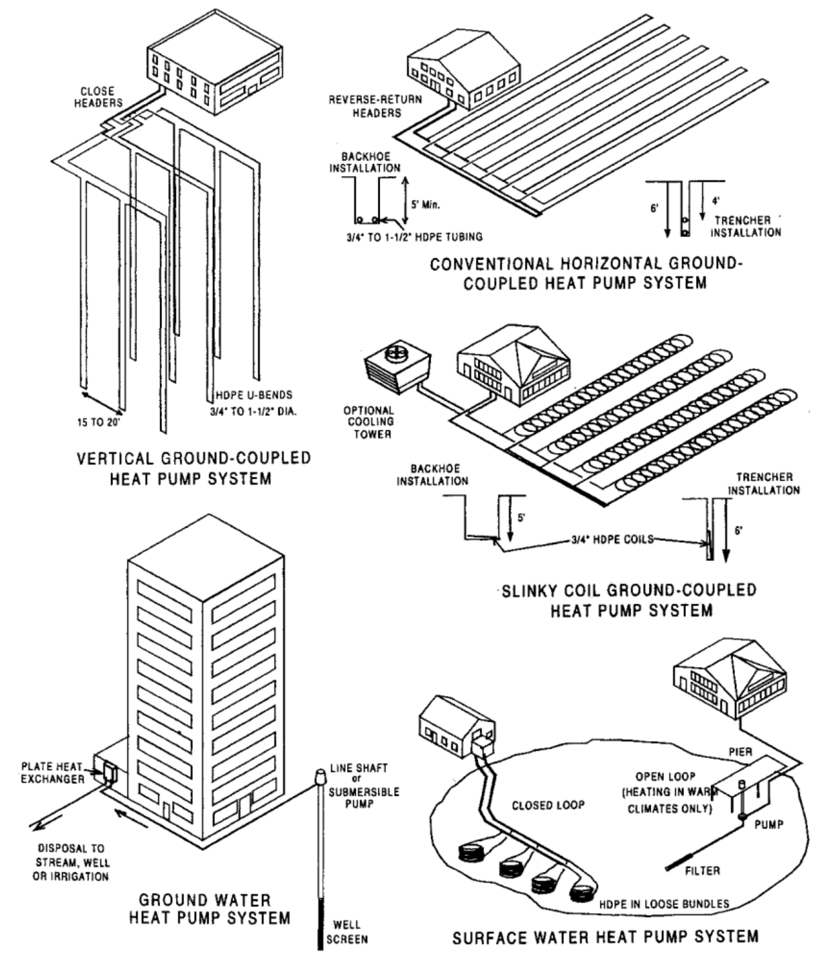

Figure 1.1 Ground-source (or geothermal) heat pump types.

2 *Ground-Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings*

Geothermal is the "Fuel" Source

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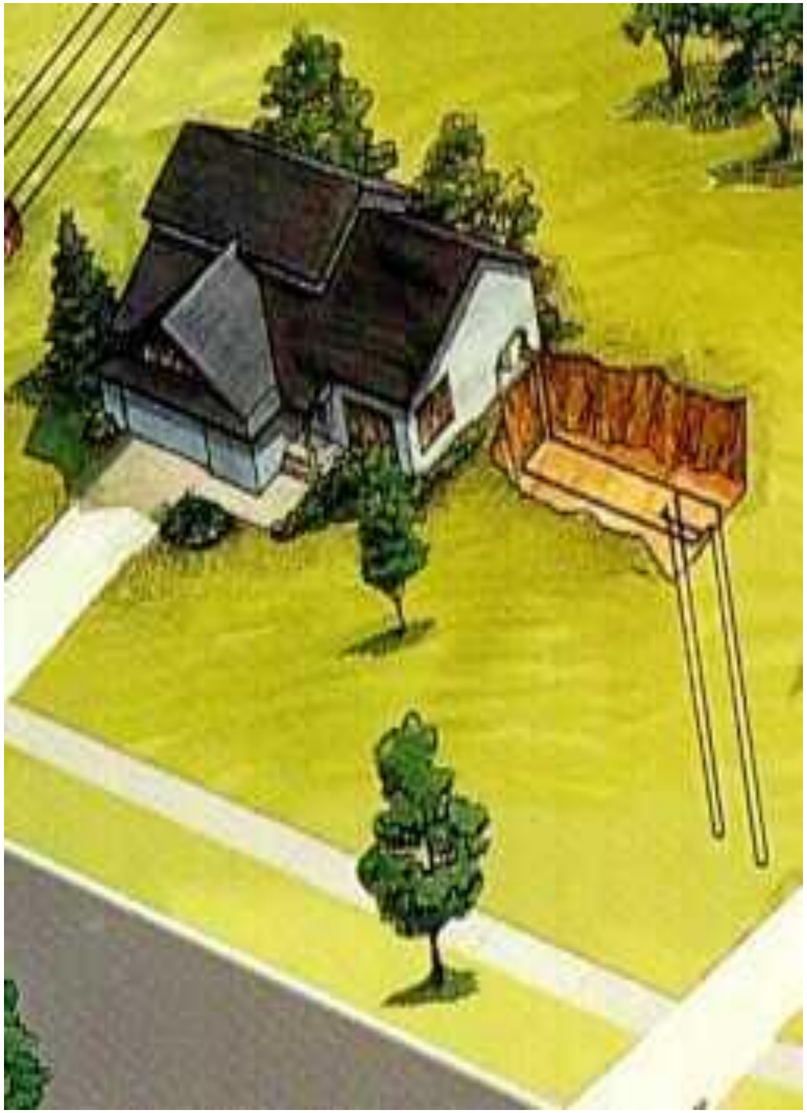
- Direct Geothermal a Renewable Resource aka Renewable Thermal
  - Ground warmer than outdoor air in winter, cooler in summer
- GHPs enable faster heat transfer
  - 3-5x today, 4-8x tech. possible with R&D
- Distributed Systems
  - No transmission investments needed
- Naturally peak load reducing
  - Earth storage effect
  - Available anytime by design
- Widely applicable
  - New Construction
  - Retrofits
  - Commercial, Institutions, Residential
  - Cascaded & Hybrid with Other Energy
  - Small, Medium & Large-Scales
- Available everywhere technology varies
  - Closed loop horizontal
  - Closed loop vertical
  - Open loop (standing column)
  - Open & Closed Lake, Stream, Reservoir



DOE GHP Facebook Post
EERE's Most Liked and Shared Post of 2015

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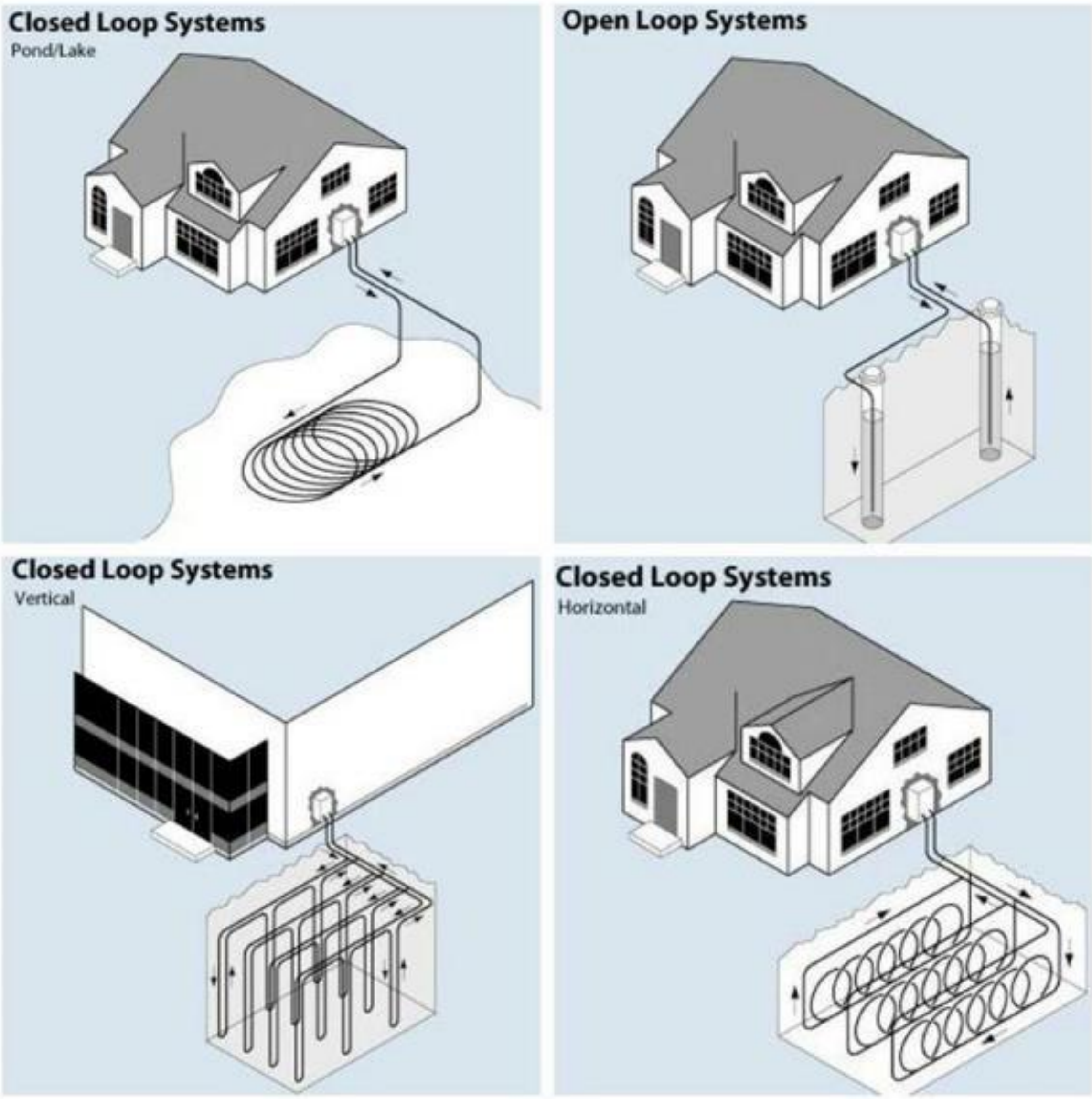

Topic: GHPs Making a Difference in American Lives

Direct Likes – 1,481

Shares – 888

Total Likes (direct + from shared posts – 2,815

Reaches - 133,763

System Configurations

- Central
- Distributed
- District

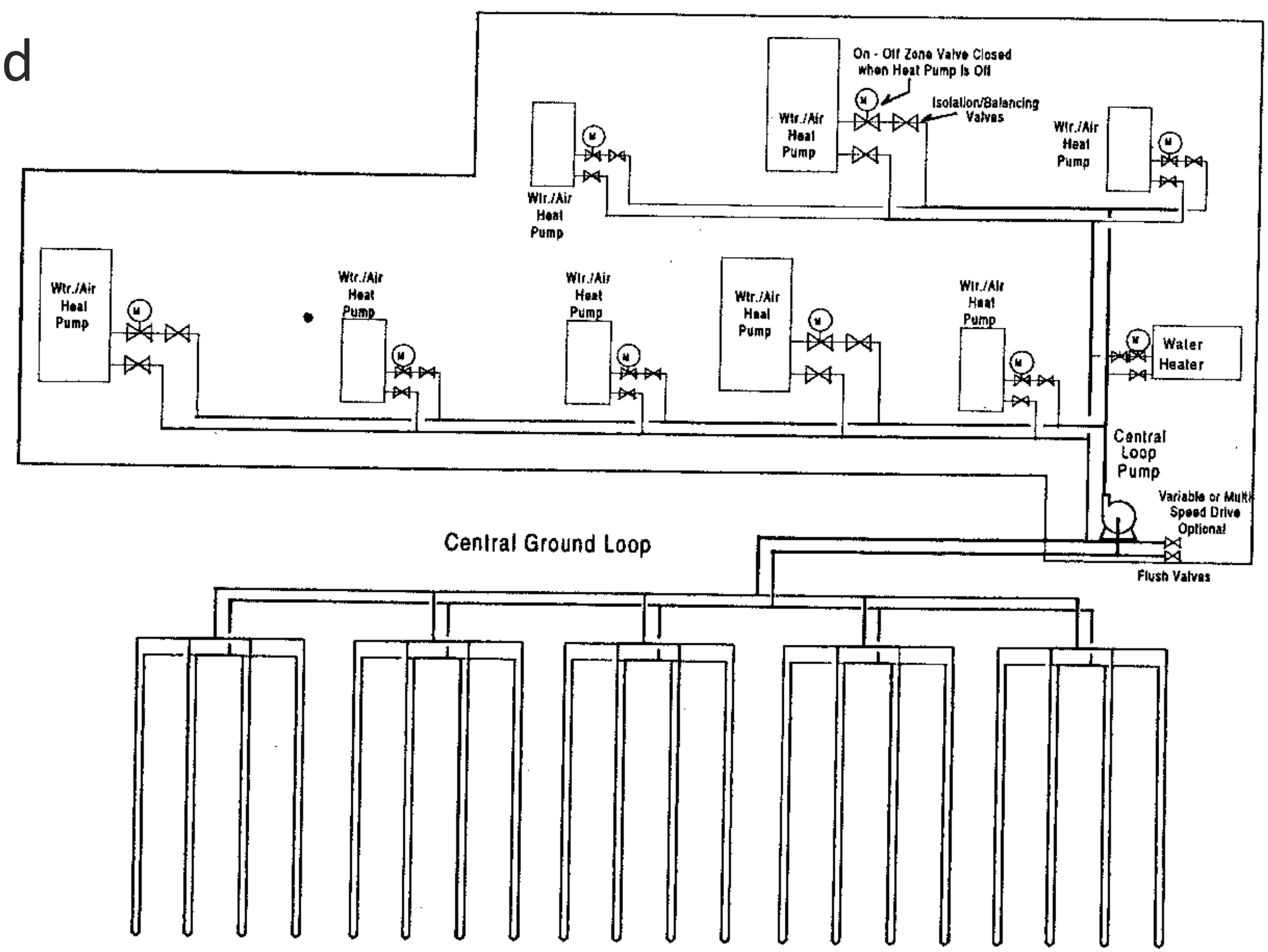

Figure 1.2 Ground-coupled heat pump system with a central loop and pump.

System Configuration: District

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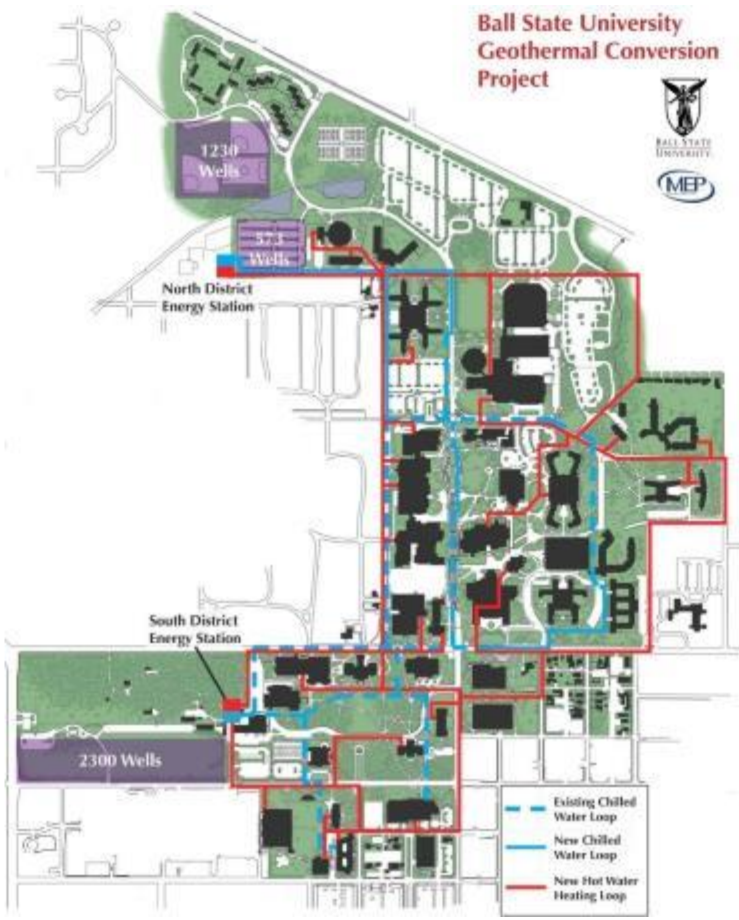

A campus wide district GHP system (Source: Ball State University)

- Single or multiple heat sink/source
- Take advantage of diversified loads in various buildings connected with a common water loop

Overview GHP Advantages / Disadvantage

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Advantages	Disadvantages
High Efficiency and Stable Capacity	Higher First Cost
Comfort and Air Quality	Performance Dependent on Ground Coil and Equipment
Simple Controls and Equipment	Limited Number of Qualified Designers
Low Maintenance Cost	Limited Number of Qualified Contractors
No Need for Auxiliary Heating	HVAC Equipment Vendor Profit is Reduced
Low-Cost Water Heating	
No Outdoor Equipment	
Packaged Refrigeration Equipment	
Environmentally Friendly	
Low Demand Characteristics	
Excellent Life-Cycle Cost	
Outstanding Potential for Advancement	

Estimate Useful Life

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OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
3400 DEFENSE PENTAGON
WASHINGTON, DC 20301-3400

ENERGY, INSTALLATIONS AND ENVIRONMENT

October 14, 2015

MEMORANDUM FOR ASSISTANT SECRETARY OF DEFENSE (HEALTH AFFAIRS)
ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, ENERGY AND THE ENVIRONMENT)
ASSISTANT SECRETARY OF THE NAVY (ENERGY, INSTALLATIONS AND ENVIRONMENT)
ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, ENVIRONMENT AND LOGISTICS)
DIRECTORS OF THE DEFENSE AGENCIES

SUBJECT: Submissions of Projects for the FY 2017 Energy Conservation Investment Program (ECIP) and Plans for the Remainder of the Future Years Defense Program

This memorandum is a data call for Defense Components to submit proposed ECIP projects for FY 2017 and for the remainder of the Future Years Defense Program (FY 2018 to FY 2021). Detailed guidance for the FY 2017 ECIP program is included in Attachment A.

Please provide your proposed FY 2017 projects in the "FY17 ECIP Project Submission Template" (Attachment B) and upload the associated project documentation to the ECIP Portal. In general, your submissions should focus on proposed projects that would not necessarily be candidates for third party financing or Operations and Maintenance (O&M) funds. Please return Attachment B and upload projects by **16 December 2015**.

To support advanced project and program planning, submit proposed projects across the remainder of the five-year planning period (FY 2018 – FY 2021) using the "FY18-21 ECIP Project Submission Template" (Attachment C). In addition to aligning ECIP planning with the rest of your MilCon planning process, this will enable you to communicate funding plans for phased and multi-year ECIP projects. Please return Attachment C by **31 March 2016**.

Please direct all submissions and questions to CDR Wally Ludwig at walter.s.ludwig.mil@mail.mil. Thank you for your continued support of this critical program.

Lisa A. Jung
Deputy Assistant Secretary of Defense
(Installation Energy)

Attachments:
As stated

Estimated Useful Life of Energy Efficiency, Renewable Energy and Water Conservation Technologies

Project Category	Technology	Economic Life	Description
Energy Efficiency (EE)	EMCS or HVAC Controls	15 years	Projects that centrally control energy systems with the ability to adjust temperature, shed electrical loads, control motor speeds or adjust lighting intensities.
EE	Steam and Condensate Systems	20 years	Projects to install condensate lines, cross-connect lines, distribution system loops, repair or install insulation, and repair or install steam flow meters and controls.
EE	Boiler Plant Modifications	20 years	Projects that upgrade or replace central boilers or ancillary equipment to improve overall plant efficiency. This includes fuel switching or dual fuel conversions.
EE	Heating, Ventilation, Air Conditioning	20 years	Projects to install more efficient heating, cooling, ventilation or domestic hot water heating equipment. This includes the HVAC distribution system (ducts, pipes, etc.).
EE	Weatherization	15 years	Projects that improve the thermal envelope of a building. This includes building insulation (wall, roof, foundation, doors), windows, vestibules, earth berms, shading, etc.
EE	Lighting Systems	15 years	Projects to install replacement lighting systems and controls. This would include new fixtures, lamps, ballasts, photocells, motion sensors, light wells, highly-reflective painting, etc.
EE	Energy Recovery Systems	20 years	Projects to install heat exchangers, energy wheels, heat reclaim units or other systems to recapture energy lost to the environment.
EE	Electrical Energy Systems	25 years	Projects that increase the energy efficiency of an electrical device or system or reduce the cost by reducing peak demand.
EE	Daylighting	25 years	Projects that optimize natural light for internal lighting.
Water Conservation (WC)	Potable Water Conservation	20 years	Projects that involve devices or processes to reduce potable water loss, waste or use most of these are in the ground, but liners will be less in ponds but under normal maintenance.
WC	Non-Potable Water Conservation	25 years	Projects that involve the re-use, recycling and eventual reduction of non-potable water such as waste water and irrigation run-off most of these are in the ground, but pumps etc are under normal maintenance.
Renewable Energy (RE)	Geothermal	40years	Projects that generate electrical power or process thermal energy using a high-temperature geothermal source.
* RE	Ground Source Heat Pump	40 years	Projects to install a central heating and/or cooling system to store and retrieve heat from the ground. 40 years for in-ground systesm, 15 years for controls.
RE	Hydroelectric	30 years	Projects to generate electrical power using water as the potential energy source.
RE	Solar Power	25 years	Projects to generate electrical power with a heat engine using solar energy as the source (solar Stirling engines, heliostats, etc.)
RE	Solar Photovoltaic	25 years	Projects to install solar photovoltaic panels to generate electrical power.
RE	Solar Thermal	25 years	Projects to generate thermal energy using solar energy as the source.
RE	Waste to Energy	30 years	Projects to generate electrical power using waste products as the energy source.
RE	Waste to Fuel	30 years	Projects to generate fuel products from waste products.
RE	Wind	25 years	Projects to generate electrical power using wind energy as the source.
RE	OTEC – Ocean	25 years	Projects to generate electrical power using deep ocean thermal gradients as the source.
RE	Biofuels	25 years	Projects to develop liquid fuel sources (biodiesel, ethanol, etc.) from biomass feedstocks.
RE	Biogas	25 years	Projects to develop gas fuel sources from the breakdown of organic matter.
RE	Hydrokinetic	25 years	Projects to generate electrical power using the energy available in waves or water currents.

Table 3

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Part II Energy Loans & Grants

GHP Applicability to DOE Loan Program

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The Loan Programs Office currently has more than $4 billion in remaining loan authority to help finance innovative Renewable Energy and Efficient projects located in the United States. There are four key eligibility criteria for projects:

1) *Projects must be located in the U.S. but can be foreign owned*
2) *Projects must utilize a new or significantly improved technology (according to our final rule, these are technologies that have not been deployed at commercial-scale in the U.S. more than three times within the past five years)*
3) *Projects must demonstrate a greenhouse gas benefit; a lifecycle greenhouse gas analysis is required*
4) *Projects must demonstrated a reasonable prospect of repayment (we run a loan program, not a grant program, so we need to see how the project sponsors intends on paying back the government)*

GHP's are part of DOE Geothermal Vision Study

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Large potential benefits by 2030
  - Save 3.4-3.9 quads/yr primary energy
  - Defer 91-105 GW of power gen (42-48% of net additions by 2030)
  - Consumers save $33-38 B/yr on utilities (plenty to cover loops on a pay from savings basis)
- Technical and Market Potential to 2050 Being Assessed
- #1 barrier is high 1st cost of GHP systems to consumers
- Primary market failure – expecting building owners to pay for the 'GHP Infrastructure' with their own credits

GHP Infrastructure Investment Provides Value to Electric and other Utilities

- Increase margins with incremental electric sales
- Improve load factor w/o load control
- Earn loyalty from members for:
  - Helping lower total energy bill
  - Carbon emission reductions
- Enhanced Compliance with Renewable Portfolio Standards and Clean Power Plans
  - Include "thermal" renewable energy
  - Credit for CO_2 reduction (e.g., EPA 1.11b)

American Recovery and Reinvestment Act - 2009

Of the $400 million in economic stimulus funds received by GTO, $60 million for GHPs were transferred to EERE's Building Technologies Office to manage.

Thirty-Six GHP projects received ARRA funds, mostly demonstrations of large scale commercial, residential and institutional installments. Other funded projects pertained to modeling and analysis.

http://energy.gov/eere/buildings/recovery-act-funded-geothermal-heat-pump-projects

Energy Center Wisconsin – District Energy Corporation

- Central utility plant with GSHP system for adult detention facility.
- Cooling and heating loads are 858 tons and 6,000 MBh, with 667 boreholes of 300 feet each.
- Work was successfully completed with system tested and balanced.
- Award: $ 5,000,000 Cost Share: $ 11,691,313

District Wide Geothermal Heating Conversion – Blaine County Schools

- Geothermal installation over large portion of school district.
- Added 173 new jobs
- 2000 total installed tons of capacity
- Project completed successfully with over $150,000 annual energy savings.
- Award: $ 5,000,000 Cost Share: $ 10,082,977

Geothermal Heat Pump District Heating and Cooling System – Ball State University

BALL STATE UNIVERSITY

- Biggest GSHP project in the U.S.A.
- 146,733 MWh annual energy savings with $2 million in annual cost savings, and 85 ton annual CO2 reduction.
- Created 278 jobs
- Installed 1,800 boreholes, plus additional 825 closed loop vertical boreholes.
- Refit two district energy station buildings
- Award: $ 5,000,000 Cost Share: $ 5,665,288

Capitol Building Geothermal Program – Colorado Dept. of Personnel & Admin.

- Colorado State Capitol building upgraded to use geothermal energy
- Created 71 new jobs, reduced operating costs by $100,000 per year and reduced CO_2 output by 1,700 tons per year.
- Award: $ 4,600,000 Cost Share: $ 2,159,601

GHP for 500-Bed Student Housing Project – University of Albany

- Closed loop, vertical GSHP system services a 500-bed, 200,000 sf student housing project.
- 22 new jobs created with new facility management staff. These costs were offset by annual utility cost savings of about $135,000.
- Project successfully completed on 343-ton system
- Award: $ 2,786,250 Cost Share: $ 2,698,422

Human Health Science Building Geothermal Heat Pump – Oakland University

- 400-ton GSHP system for 160,260 sf university building
- Innovative solar-thermal driven desiccant dehumidification system
- First higher education building in Michigan to achieve LEED Platinum certification.
- GSHP part of larger University-wide efficiency project
- Award: $ 2,738,100 Cost Share: $ 7,040,830

Geothermal Retrofit of National Guard's HQ Building – Illinois Dept. Military Affairs

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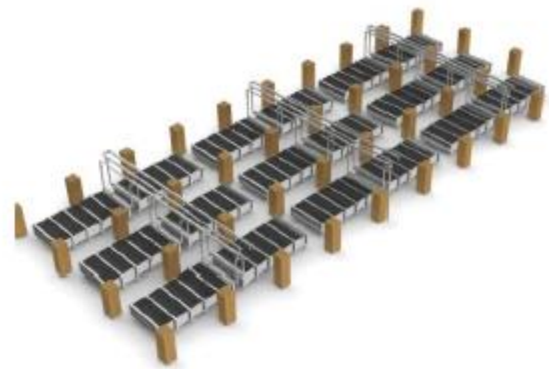
- Retrofit of 74,000 sf National Guard HQ building
- Innovative use of small ductless heat pumps, ceiling mounted within each room.
- Work completed successfully with about $40,000 annual energy cost savings
- Award: $ 1,200,000 Cost Share: $ 400,000

River-Based Neighborhood Loop Geothermal Exchange – Riverheath, LLC

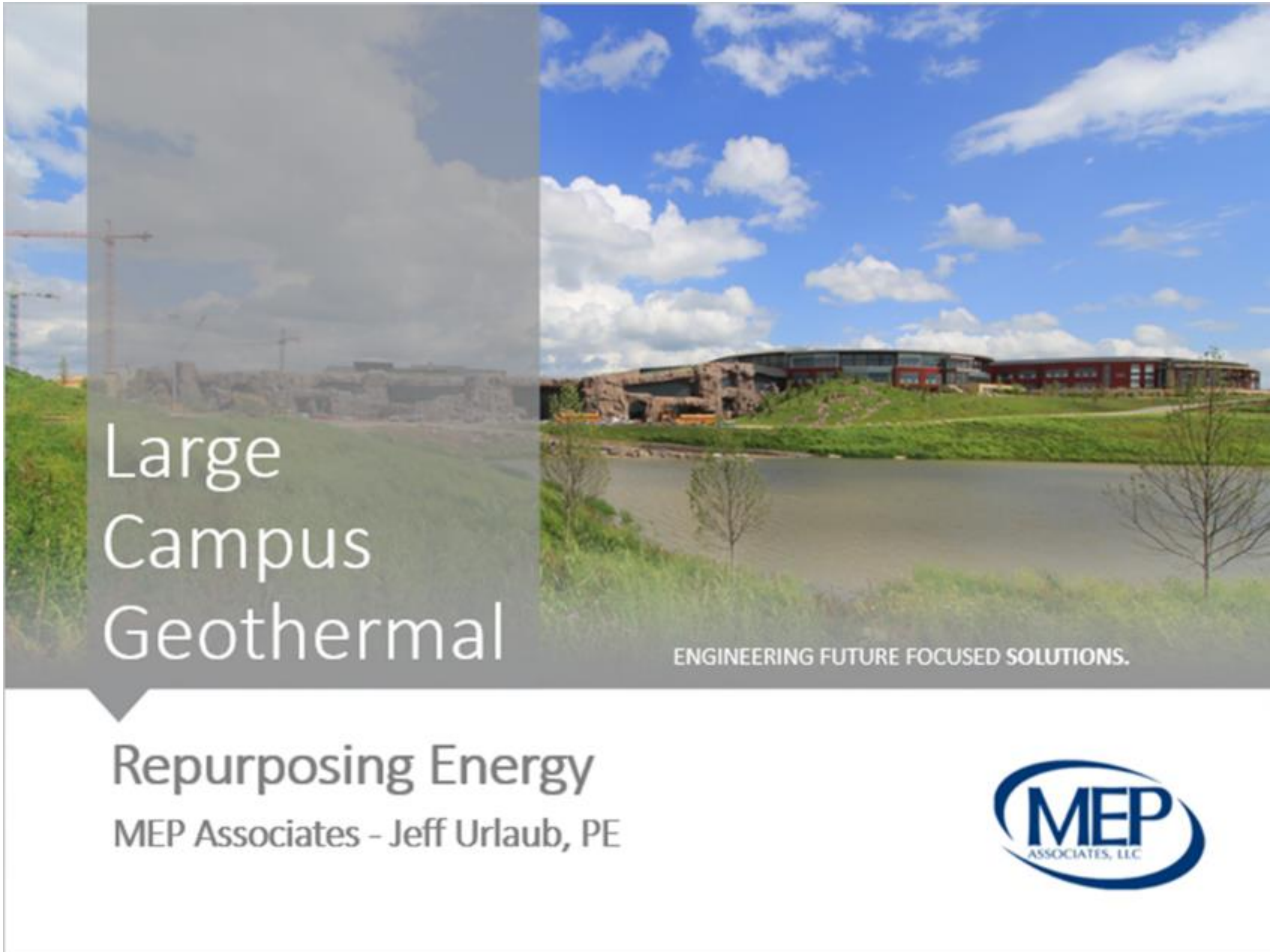


- 600 ton system uses heat exchange plates suspended from boardwalk into river, with system downstream of a hydrothermal plant.
- Heat and cooling provided for residential apartment buildings
- Initial work successfully completed with plans to expand system for additional buildings.
- Award: $ 978,168   Cost Share: $ 978,168

Part III GHP Systems Examples

- –Energy & Water Savings
- –Lifetime Economic Benefits
- –Social Benefits

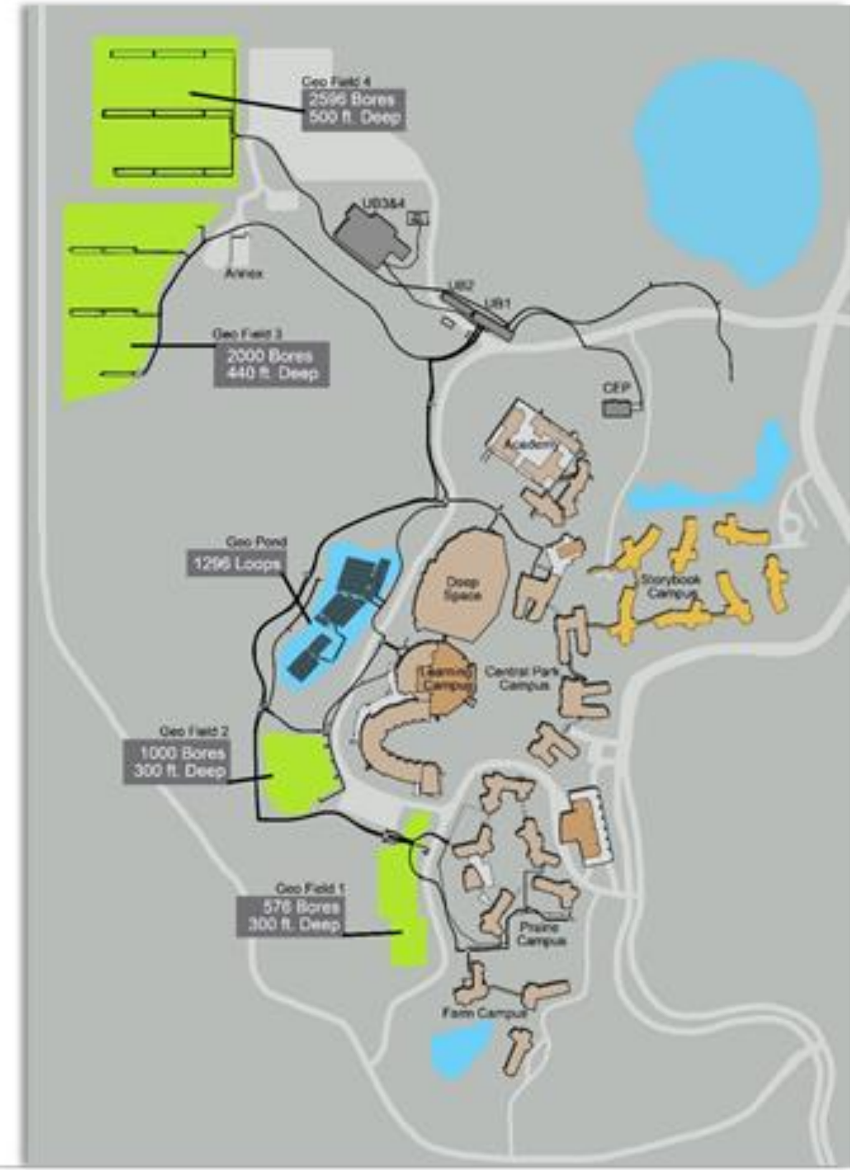
Large Campus Geothermal



Campus Overview

Statistics

- Approximately 1051 Acres
- Over 7.0 Million SF occupied space
- Over 9,000 employees to keep happy and productive
- 27 Existing Buildings
- 12 Buildings under construction
- 7,338 Underground parking stalls (4 multi-level garages)
- 1.5 MW Solar PV
- 10 MW Wind Generation



Campus Overview

Various Systems

- Water-to-air source heat pumps with dedicated outside air system equipped with total energy recovery
- VAV air-distribution systems with dedicated total energy recovery units
- Distributed Central Energy Plants (CEP)
- Water-to-water heat pumps chiller/heaters
- VAV air-distribution systems with integral total energy recovery wheels
- Central pumping station
- Geothermal bore fields
- Geothermal pond
- Variable primary-secondary pumping
- Variable primary-secondary-tertiary pumping
- Variable-primary pumping
- Domestic water heating system that utilizes geothermal water
- Snow/ice melt systems
- Exhaust fan arrays for parking structures
- Commercial kitchen exhaust systems
- Onsite photovoltaic solar panels
- Off-site wind farm

Geothermal System (15,000 ton Cap.)

• Bore Fields (vertical bore shafts)

- Bore Field 1: 576 bores @ 300 feet
- Bore Field 2: 1,000 bores @ 300 feet
- Bore Field 3: 2,000 bores @ 420-480 feet
- Bore Field 4: 2,596 Bores @ 500 feet

• Storm Water / Geo Pond

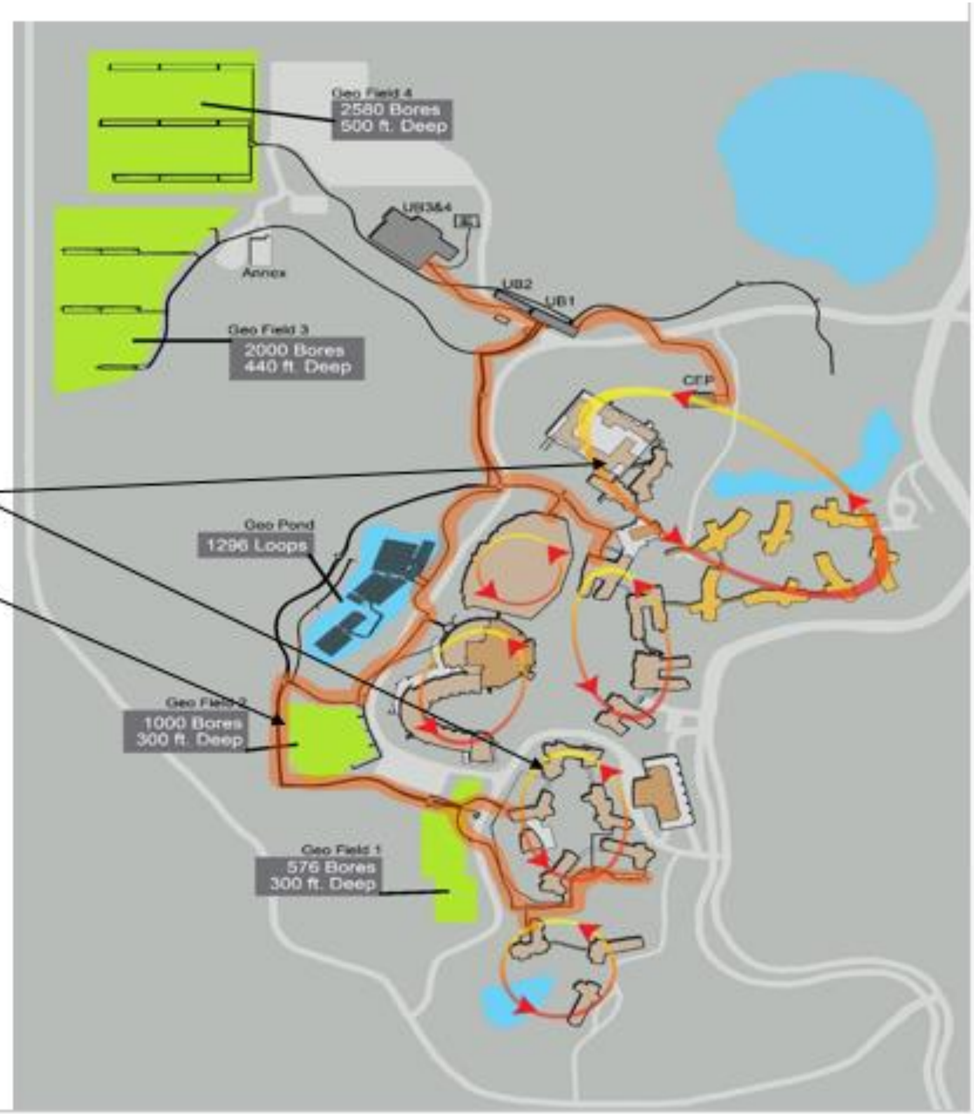
- 1,296 slinky loops @ 600 feet each
- Pond Depth: 10-15 feet

Repurpose

Repurposing Energy throughout your campus

Energy Usage Loops

Energy Exchange Loop



Geothermal Statistics

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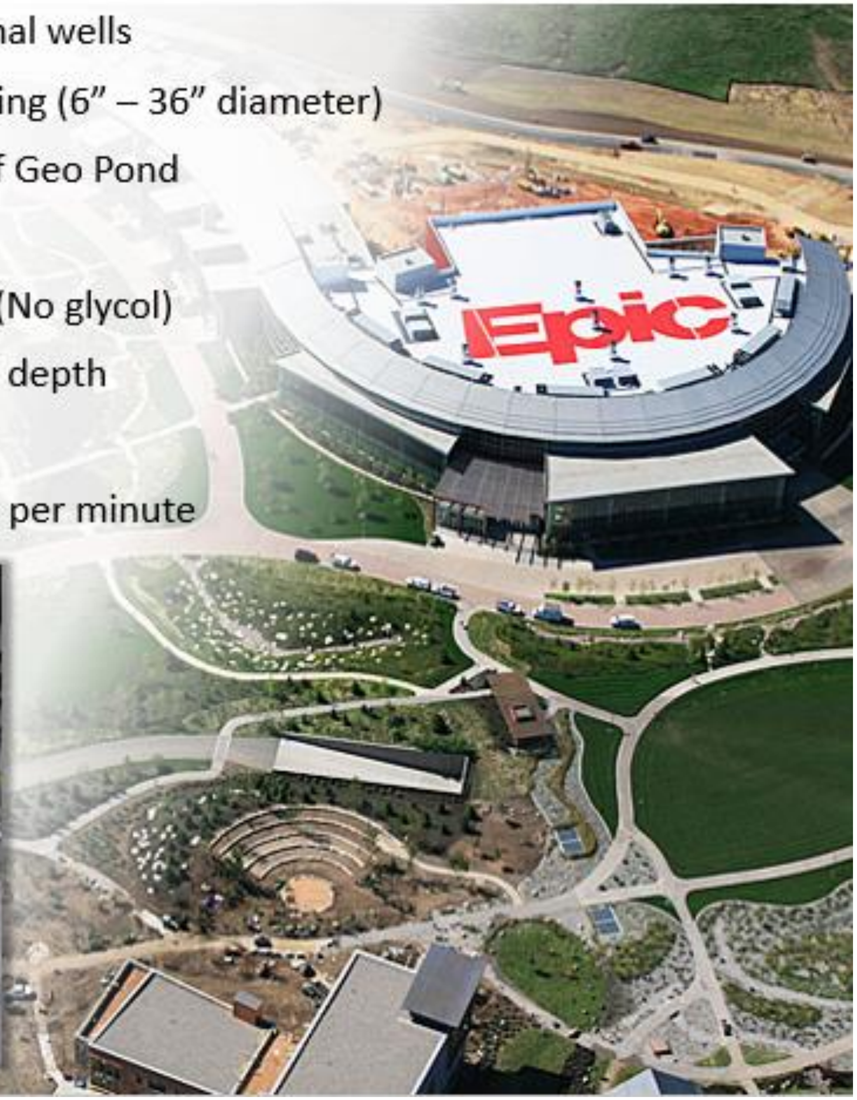
- 502 miles of vertical piping in geothermal wells
- 16 miles of horizontal underground piping (6" – 36" diameter)
- 300 miles of piping resting at bottom of Geo Pond
- 1100 miles total pipe length
- 4 million gallons of water to fill system (No glycol)
- 6,172 Vertical Bores 300 ft. to 500 ft. in depth
- 15,000 tons cooling capacity
- Maximum design flow is 80,000 gallons per minute



Utilizing a Geothermal System

Benefits

- Reduced Maintenance
  - 0.3 FTE
  - Snowmelt System reduces cost of snow removal / salt use
  - Closed loop System – Water Only (no glycol)
  - No Boilers or Cooling Towers to Maintain
  - Oil-Free Centrifugal Chillers
- Energy Footprint Reduction
- Carbon Reduction

High Performance Heat Exchange Technology

geoKOAX, German firm seeking to deploy geothermal technology in the U.S.

- large-scale GHP technology demonstration and advancement
- large volume coaxial probes to achieve high annual performance
- heat exchanger technology uses passive turbulence where continuous change from laminar flows to turbulent flows **increases the heat transfer coefficient by 20%**
- claim 6.5 times as much carrier fluid volume as conventional probe systems

The coaxial tube is filled with a heat carrier liquid with low viscosity and thus stores heat permitting a precise release of the required energy at a constant temperature and also longer down times of the heat pump. The concentric orientation of geoKOAX coaxial tube ensures that the space between the coaxial probe and the soil is even, leading to lower borehole resistance and improved energy absorption.

Tulsa's Guthrie Green Showcases New Geothermal Technology

Additional Information: GeoOutlook 2015 Q4" a publication of the International Ground Source Heat Pump Association

- Tulsa based George Kaiser Family Foundation $8M in Tulsa downtown district – brownfield to nationally recognized green space
- DOE $2.5 million (ARRA) in geothermal field development
- Oklahoma Department of Environmental Quality $200K Energy Demand Reduction and Brownfield Development grant.
- GHP well field circulates water to the neighboring Tulsa Paper Company building and the Hardesty Visual Arts Center reducing their heating and cooling costs by approximately 60%

Guthrie Green - Land made for you and me
https://www.guthriegreen.com/

High Performance Heat Exchange Technology

- Downtown space restrictions - RYGAN High Performance Geo Exchange (HPGX) system
- GHP well field = 120, five hundred foot wells grouped in 15 circuits
- More than 80,000 square feet of low emission heating and cooling
- A traditional polyethylene pipe (HDPE) u-bend system would have required more than double the drilling and land space and energy for comparable thermal performance
- State-of-the-art geothermal technology uses high strength, low weight, and low thermal resistance composite material.
- 600-ton GHP supplemented with a 200-ton cooling tower during peak summer load, Majority of building load serviced without cooling towers

guthrie green

Energy/Water, Social, Techno-Economic Advantages

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Pinellas County, Florida Emergency Operations Center

- 218,000 SF with 1,500 tons
- Cooling tower elimination

✓ Estimated Annual Electricity Savings: $1M

✓ Estimated Annual Water Savings: $70K (77M gallons)

✓ Estimated Payback: 4 years

Energy-Water Nexus Advantages

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Nashville International Airport 3,600 (HR) Tons Capacity – Under Development

- Largest geothermal lake cooling system in North America
- 1.6 mile closed loop system beneath runway circulates lake water
- Compact design utilizes vertically installed lake plates
- **Cooling tower elimination**

✓ **Estimated annual potable water savings: 30 million gallons**

✓ **Estimated annual electricity savings: 1.3 million Kwh (**$430,000)

✓ **+ 2.6 million gallons of water from electricity savings**

- MNAA Rob Wiggins praised the project as **a sustainable business model in reducing water and electricity consumption**

Colorado Mesa University Distributed Energy Loop
Large Integrated Ground Loop System

- 450,000 sf, 1,500 tons within 1.2 million sq. ft. in design
- Existing boilers if needed can back-up central loop system
- 8,200 tons of borehole thermal energy storage.
- Potential for hybrid geothermal storage systems loop field used as storage system

✓ Estimated Annual Electricity Savings to University: $500,000

✓ Estimated Annual Carbon Reduction: 16,000 tons

✓ Estimated annual waste water (evaporative) saved: 10 million gallons

✓ **Reduction of PM 2.5 from reduced cooling tower use**

Photo Courtesy of Colorado Mesa University

Kensington High School for the Creative Performing Arts, Philadelphia, PA

Design & Innovation (LEED™ Platinum Project)

- Geothermal Water Source Heat Pump:
  - High Performance System (EER >30.0)
  - Low Maintenance
  - No outdoor components on roof, grade.
  - Vandal Resistant
  - "Green" Technology, No pollution. No Boiler.
  - Modular Operation, run only rooms that are occupied.
  - Provides Temperature and Humidity control.
- Ventilation:
  - CO_2 Demand-Based Air-to-Air Heat Recovery System
  - Recovers 70% of heat/cool from exhaust
- Energy Management System:
  - Monitors room temp, occupancy, equipment status
  - Web based system, easy to view and control
  - Real Time energy consumption data
- Energy Efficient Lighting w/Daylight Harvesting;
- Rainwater Collection w/Grey Water System;
- Green Roofs.

Economic Advantages

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Kensington High School for the Creative Performing Arts, Philadelphia, PA

HVAC 20-Year Life Cycle Cost Analysis

	Baseline HVAC System	Geothermal HVAC System	Difference
Construction Cost	$2,700,000	$3,700,000	37.0%
Operating Cost/yr	$237,286	$55,478	-76.6%
Maintenance Cost/yr	$28,800	$9,000	-68.8%
20 Yr. Life Cycle Cost*	$9,101,720	$6,469,560	-28.9%

* - 7% Interest for 20 years; No Incentives or Tax Credits.

Simple Payback (Years)	7.60

Thanks for Inquiring About Geothermal

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Frick Park Environmental Center, Pittsburgh PA – 2015
Plans to become one of eight "Living Building Challenge" certified worldwide