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A River of Energy Solutions

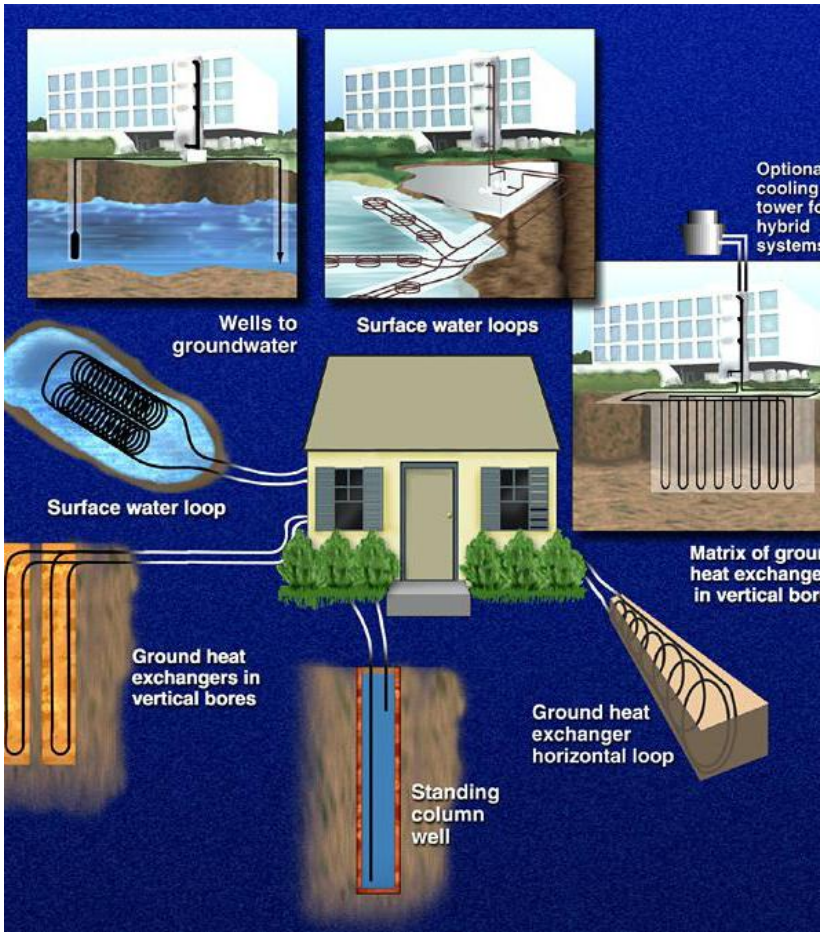
Discover Opportunities with Ground Source Heat Pump (GSHP)

Xiaobing Liu, Oak Ridge National Laboratory

Agenda

- Status of GSHP technology and its applications
- Federal government support of GSHP
- Emerging technologies
- What can be expected from the new generation of GSHP systems?

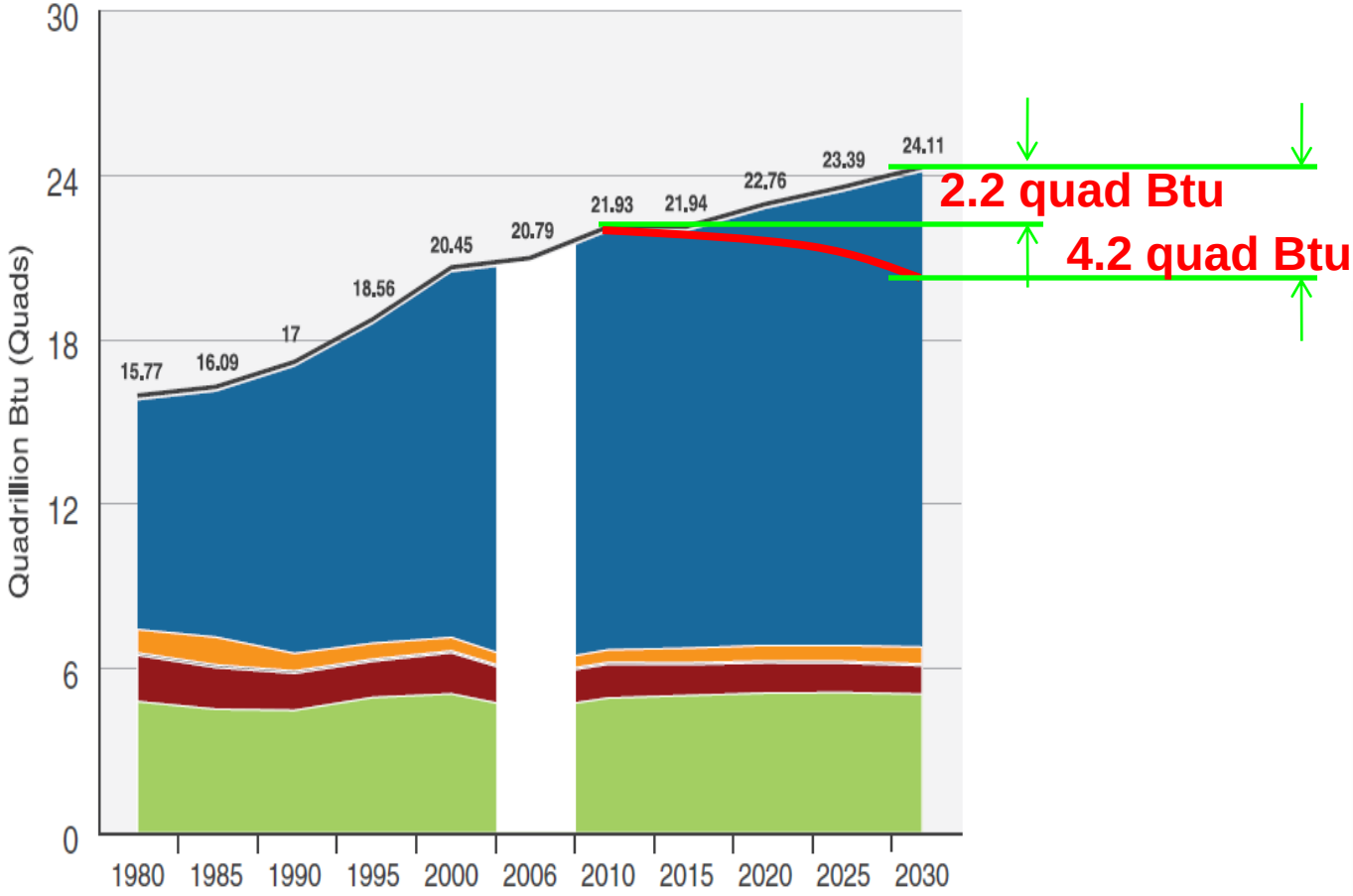
Characteristics of GSHP



- Use renewable low-grade energy
- Widely applicable
  - New and retrofit
  - Commercial and residential
- Can heat and cool buildings and/or domestic water at high efficiency
- Able to reduce peak electrical demand
- Require more labor to install

Energy Saving Potential of GSHP

U.S. residential primary energy consumption by year and fuel type (DOE 2009)



(Based on Information from ORNL/TM-2010/122)

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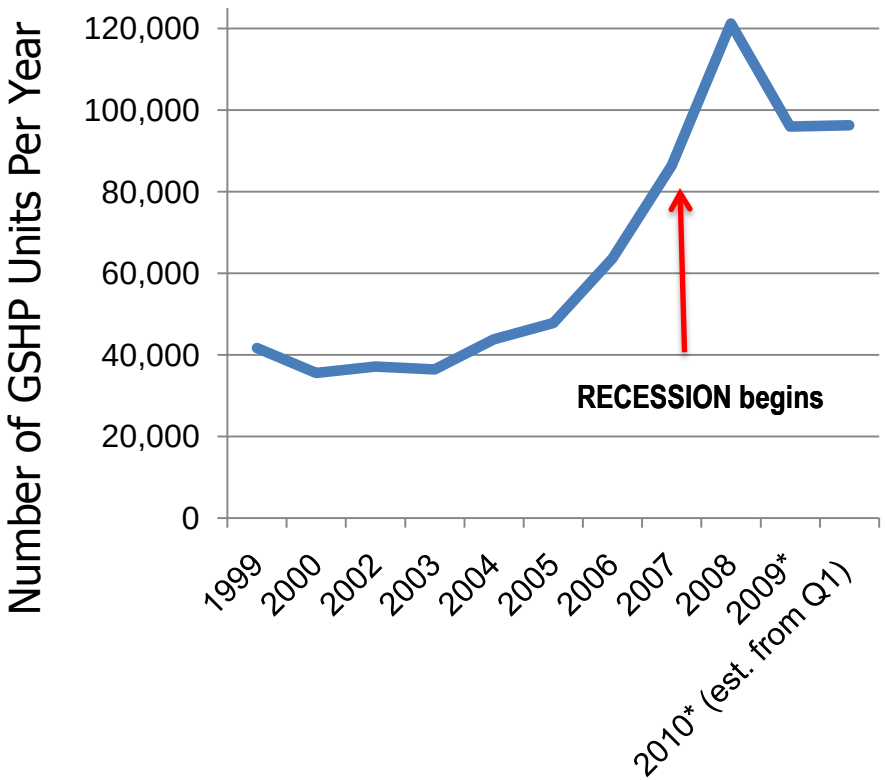
Market Status of GSHP in U.S.

- Approximately 1 million GSHP units have been installed, which is less than **1%** of the total number of US homes
- Today domestic markets absorb ~100,000 units/yr
  - 50-60% residential (new vs. retrofit: 3 to 1)
  - 40-50% commercial



(Source: EIA 2010)

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Market Status of GSHP in Other Countries

- European markets are now 2-3 times the U.S.
- Growth rates and the number of new patents related to GSHP in Europe, parts of Asia (China, S. Korea), and Canada exceed U.S.

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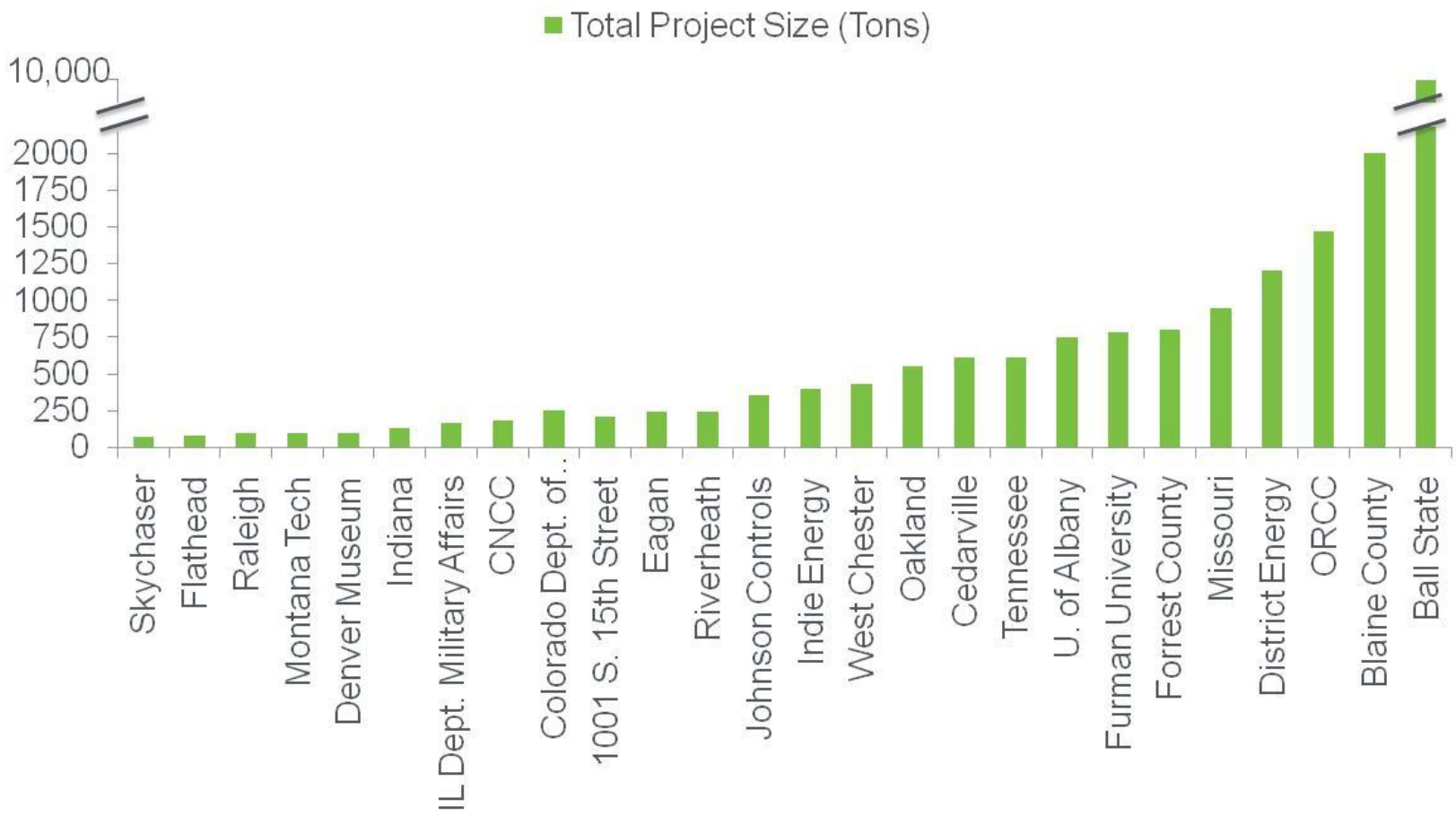
Federal Government Support of GSHP

- Federal tax credits through 2016
  - Homes: 30% of GSHP system cost
  - Businesses: 10% of GSHP system cost, 5 yr depreciation
- Rural electric cooperatives have access to 35-yr loans at low rates from USDA
  - Use the money to install 'GSHP infrastructure'
  - Recover costs through a tariff on utility bill
- $67 million in ARRA grants were awarded by DOE to 36 projects

DOE ARRA Funded GSHP Program

- **Technology Demonstration**: 26 projects to demonstrate innovative business and financial strategies and/or technical approaches, including making use of municipal grey water, water-filled abandoned mines, ice rink, and improved conventional ground coupling technologies
- **Analysis and Data Collection**: 9 projects to improve design and simulation tools of GSHP systems, gather and analyze GSHP system performance data at various climates
- **Personnel Certification**: 1 project to create a national certification standard for all primary personnel involved in GSHP projects

26 GSHP Demonstration Projects



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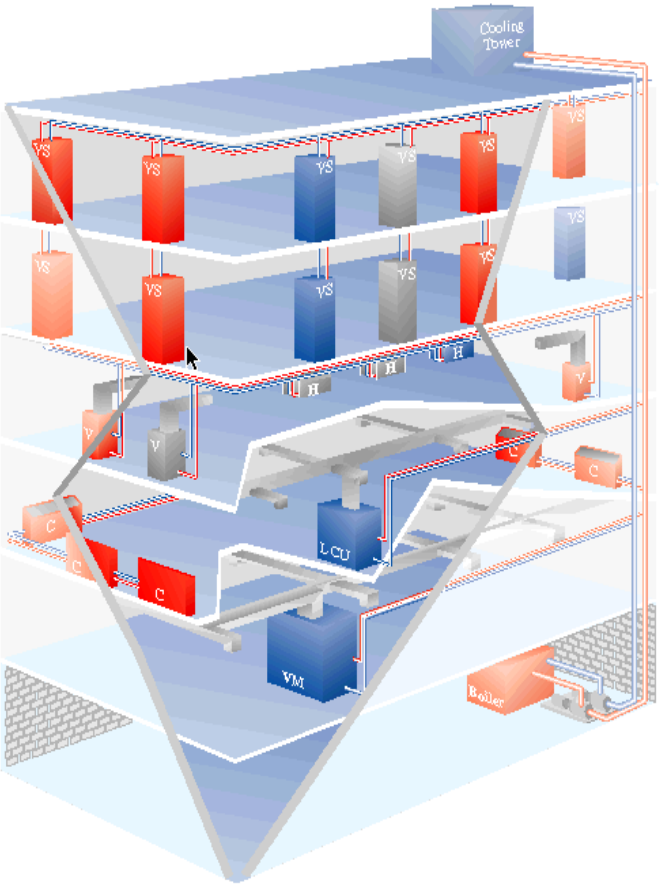
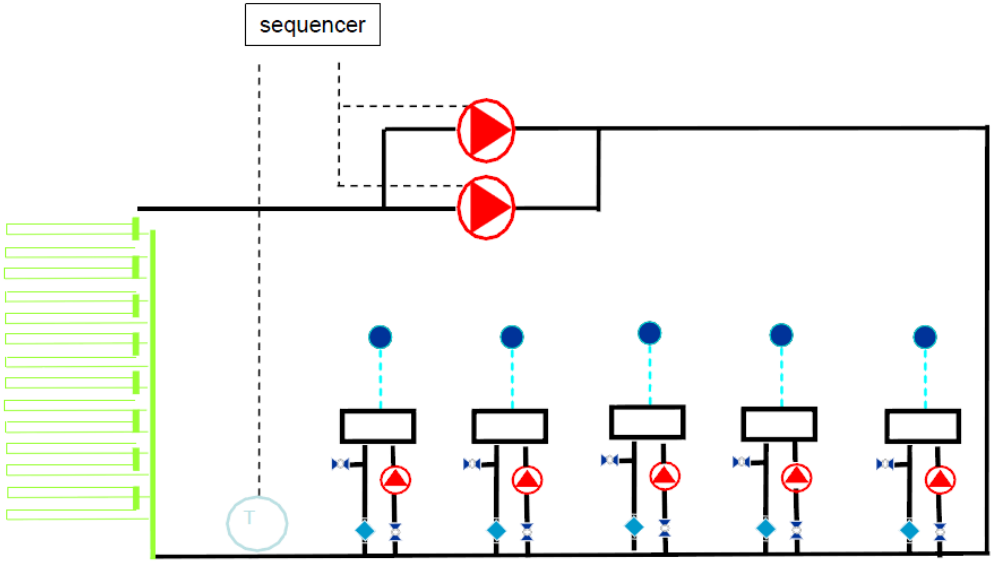
Emerging Technologies

- GSHP system configurations
- Ground coupling technologies
- Design and simulation tools
- Geological Information for GSHP systems design and installation

GSHP System Configuration
Distributed Systems



Two Pipe Water Loop



One Pipe Water Loop

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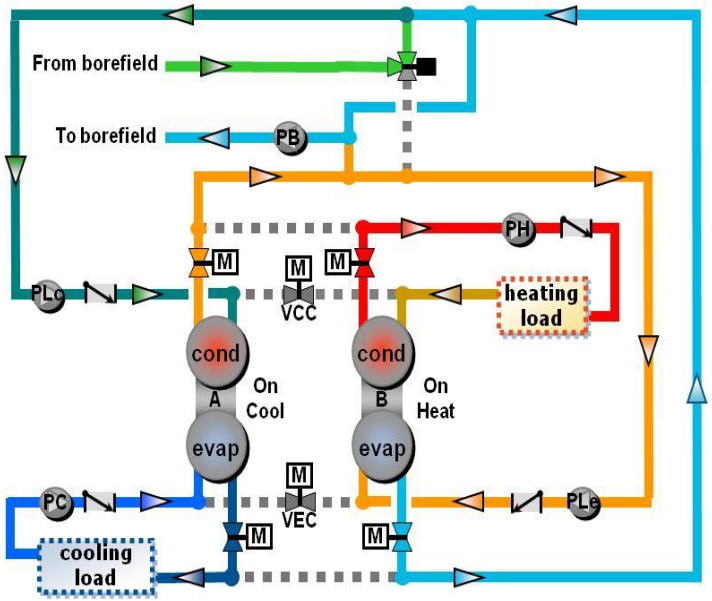
GSHP System Configuration
Distributed Systems (Cont'd)

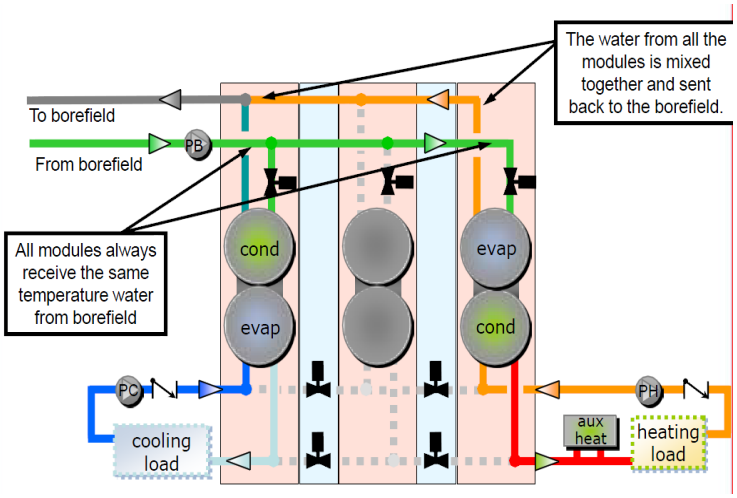
- Advantages
  - Simple design and limited floor space requirement
  - Isolated impact of equipment failure and easy to self-service
  - Superior efficiency at part load conditions and capable of individual metering of energy consumption
- Disadvantages
  - Distributed service and maintenance
  - Possible acoustic concerns and water leakage
  - Requires a separate dedicated outdoor air system (DOAS)

GSHP System Configurations

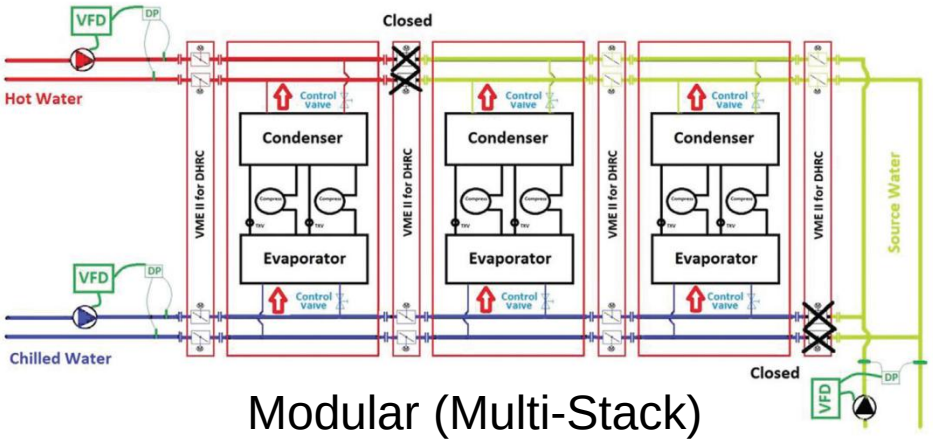
Central Systems



Chiller/Heater Cascade



Central Heat Pumps



Modular (Multi-Stack)

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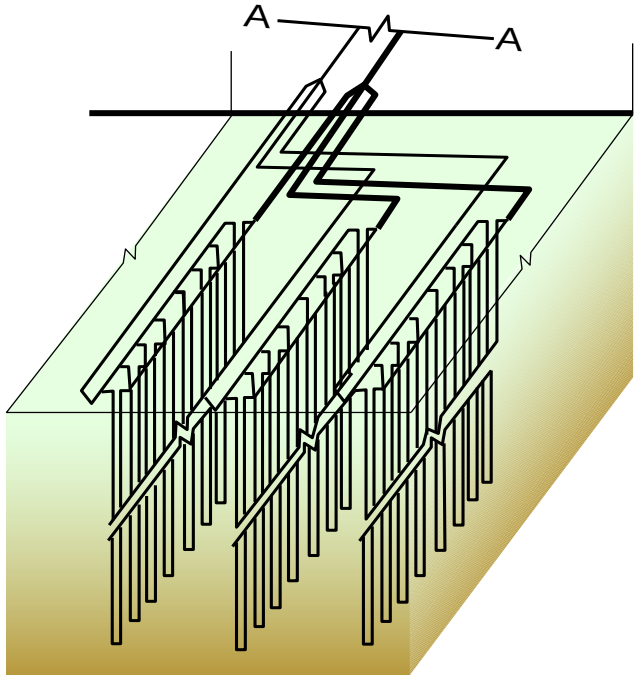
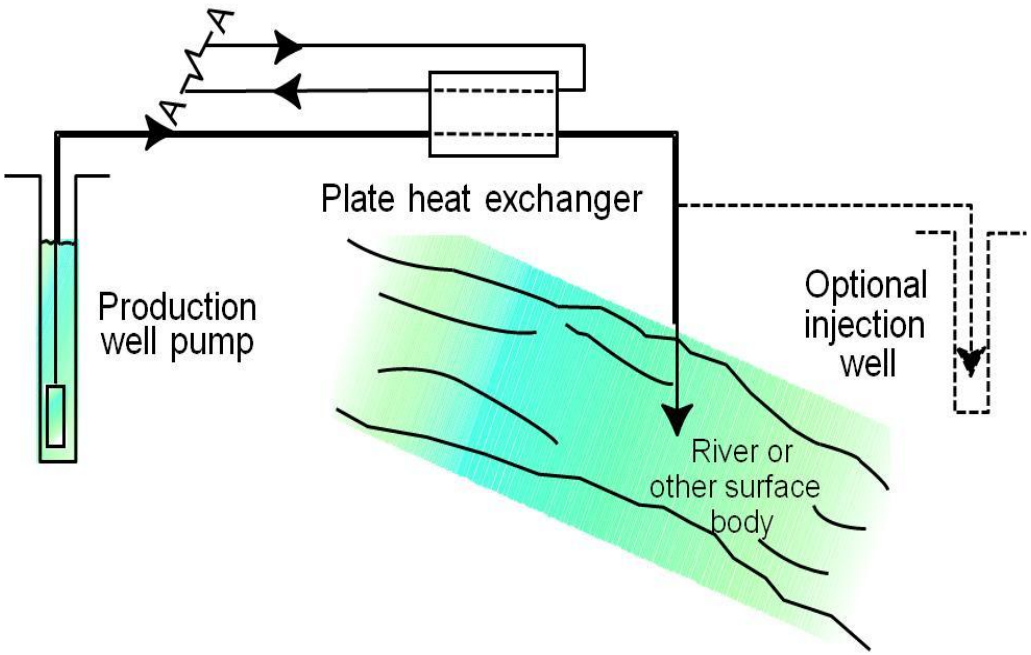
GSHP System Configurations
Central Systems (Cont'd)

- Advantages
  - Central service/maintenance and easier for retrofitting conventional central HVAC systems in commercial buildings
  - Able to integrate air economizer if central air distribution is used
- Disadvantages
  - Mechanical room is needed and the system is more complicated
  - System efficiency degrades at part load conditions
  - Requires a chiller technician to service central plant

Conventional Heat Sinks/Sources



HDPE U-tubes in Vertical Bores



Ground Water

(either discharged to other water well or nearby surface water body)

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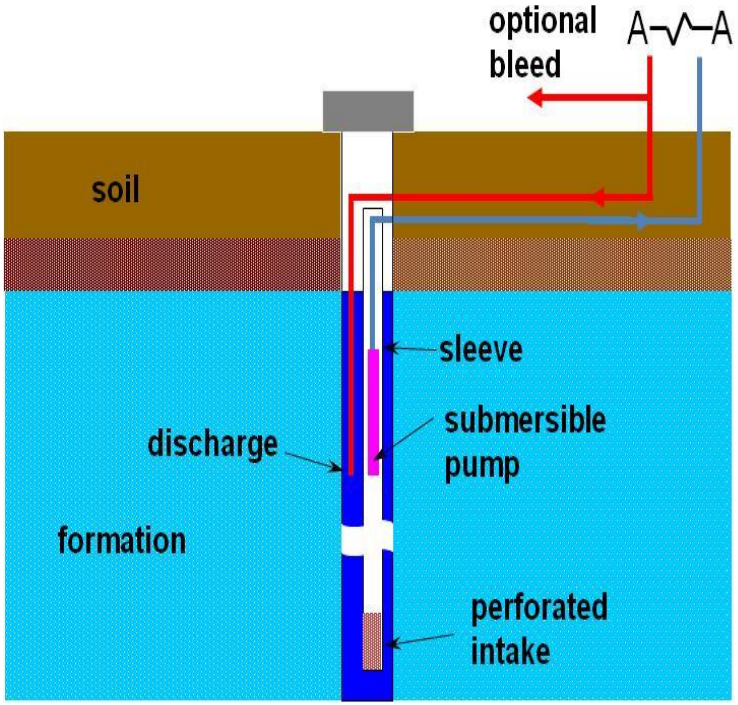
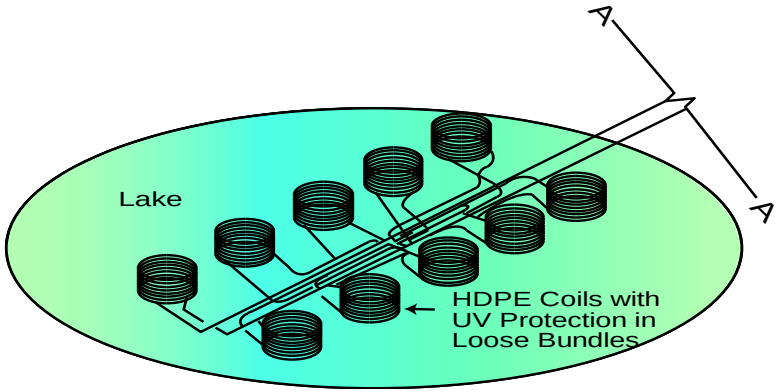
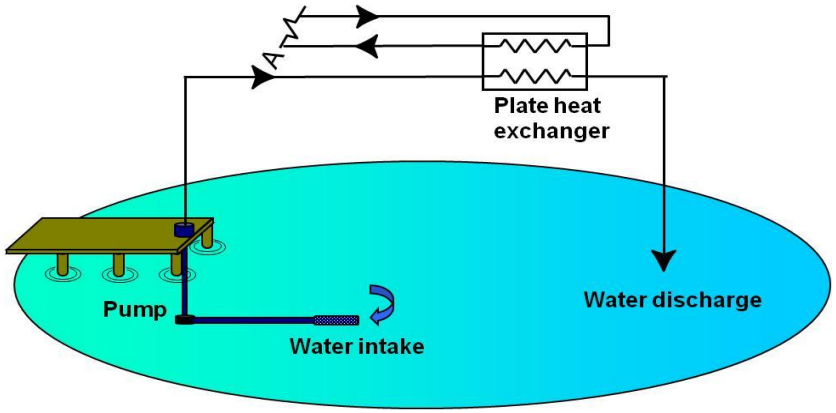
Conventional Heat Sinks/Sources (Cont'd)



Standing Column Well



Surface Water Body with Closed Loop Heat Exchangers



Surface Water Body with a Open Loop Configuration

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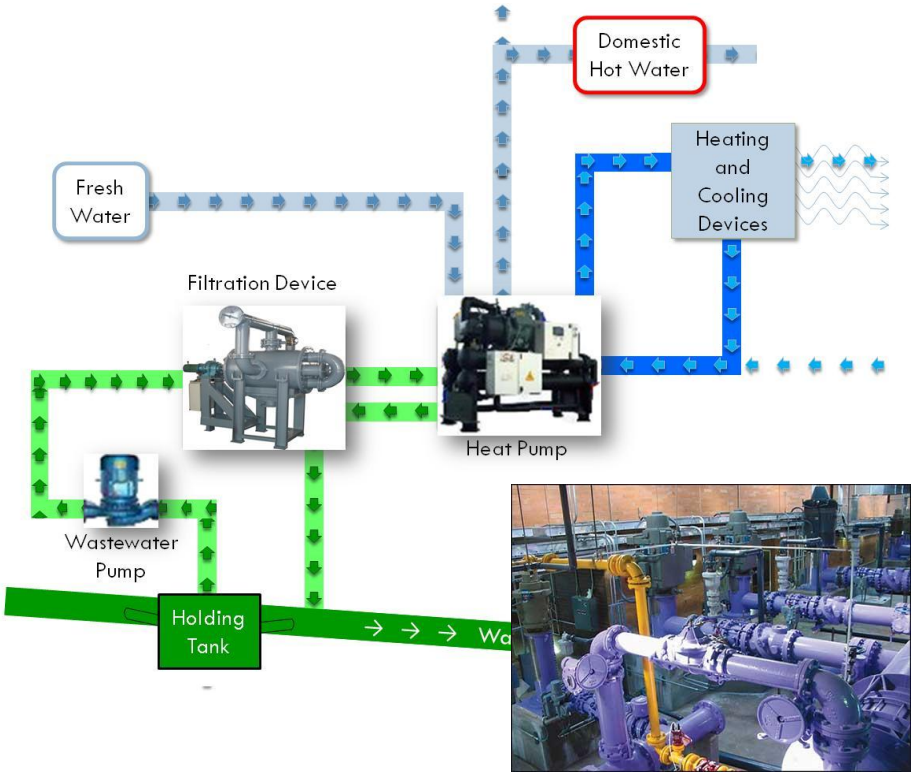
Other Heat Sinks/Sources

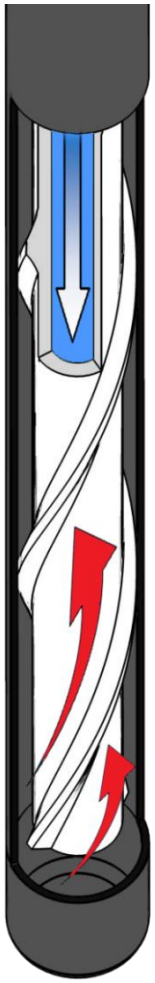


A heat pump system using municipal wastewater infrastructure as heat sink and source (Source: Haider 2011)

Flooded Mine Water

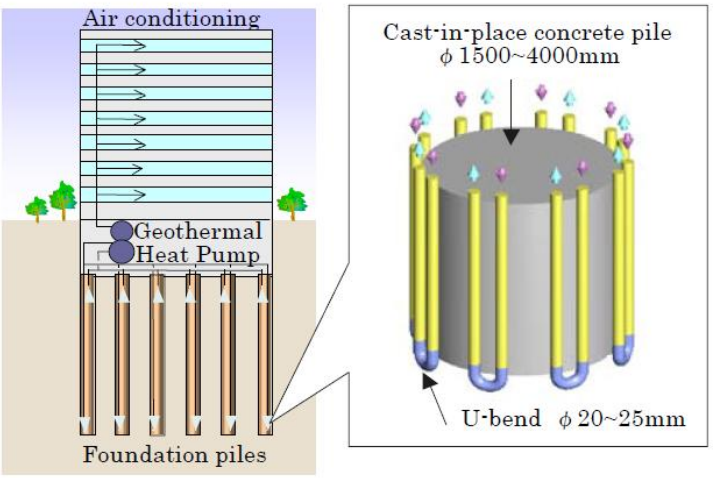
Ice Rink

Emerging Ground Heat Exchangers



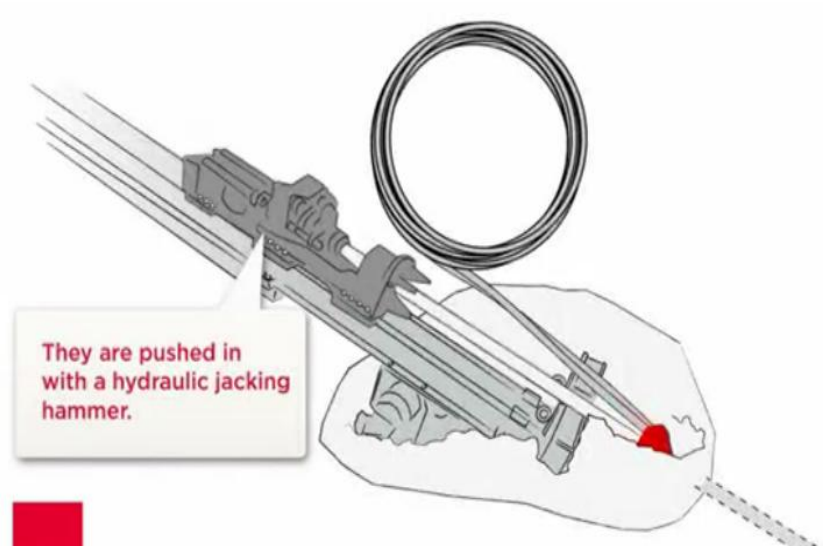
Enhanced coaxial vertical GHX

Horizontal GHX installed in existing building foundation trench/overcut

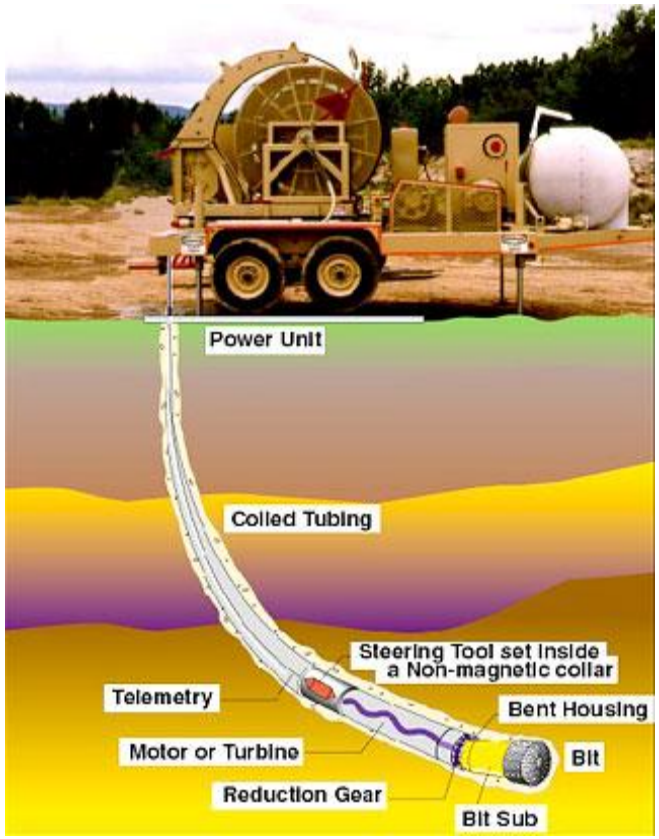


Foundation pile heat exchanger
(Sekine et al. 2006)

Emerging Drilling Technologies



Direct-push Method
(Snapshot form http://www.youtube.com/watch?v=_Edfx6O8aVQ)



Coiled Tubing Drilling
(Source: http://www.kingroyalty.com/content.asp?ID=33)

Emerging Design and Simulation Tools

- Based on integrated simulation of building & GSHP system
  - Perform all the related calculations within one program
  - Evaluate, verify, and optimize GSHP system design based on performance predicted by simulations
  - Keep records for all the design parameters
  - Determine energy savings and other benefits for LEED certification, application for energy efficiency incentives, etc.

eQUEST ®
Quick Energy Simulation Tool

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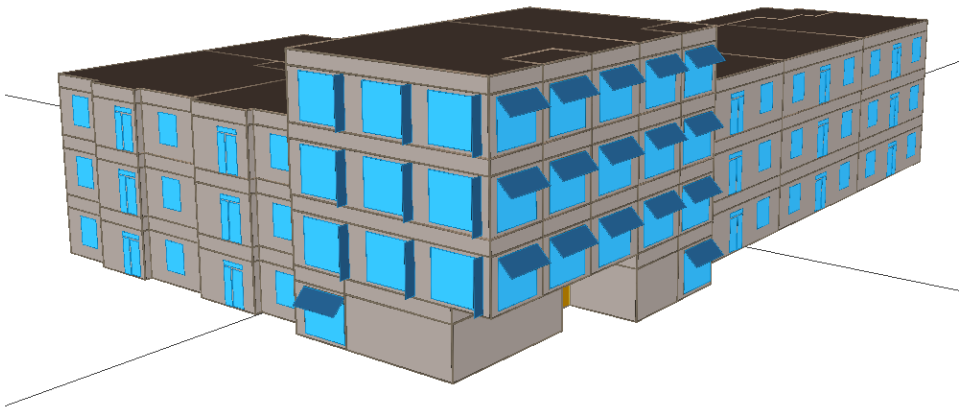
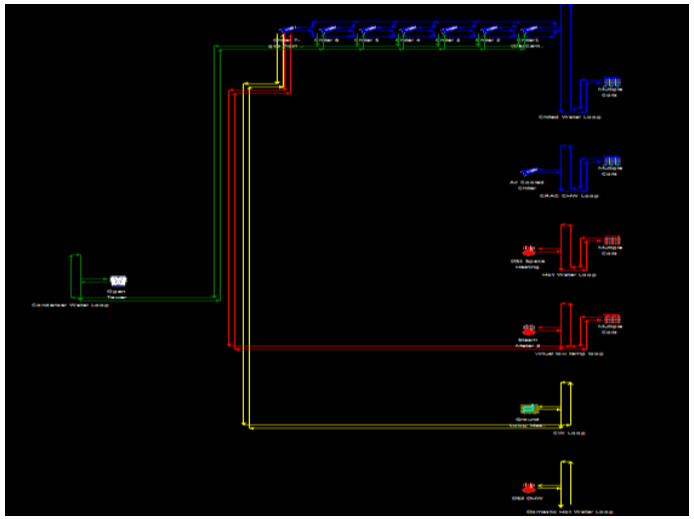
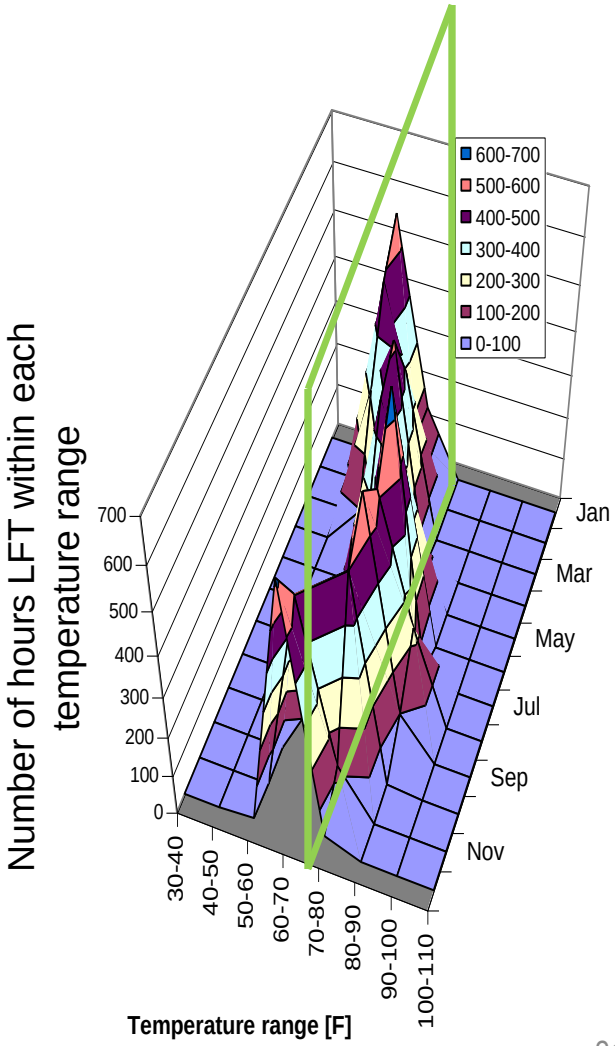
Emerging Design and Simulation Tools (Cont'd)







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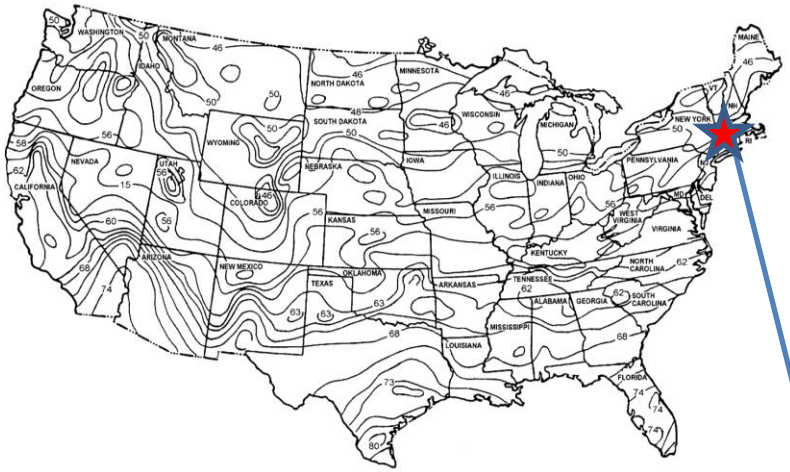
Geological Information for GSHP System Design and Installation

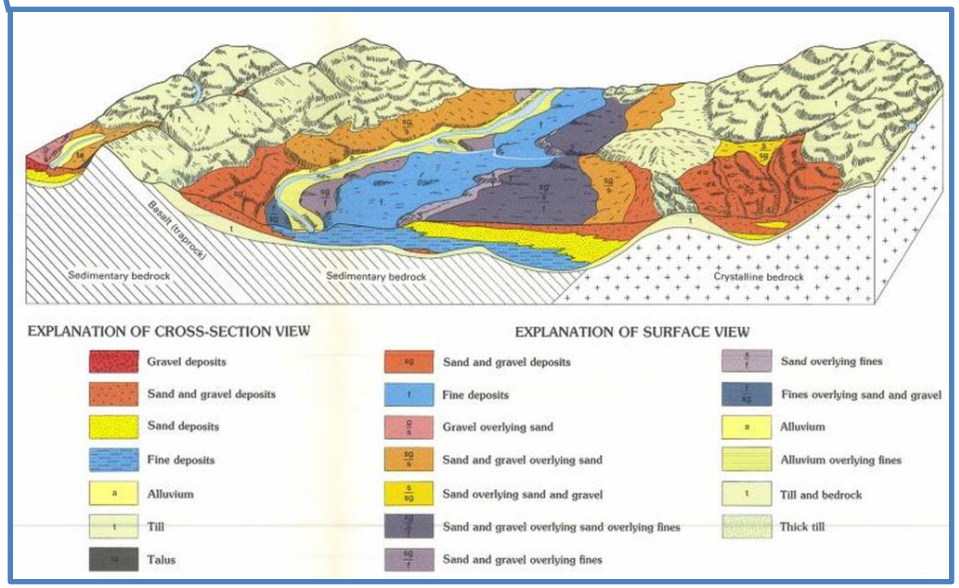


Ground Temperature Map of the U.S.

National data of ground formation and the associated thermal properties 0-600 ft below grade is NOT available.

In-situ test is thus usually required. A national map and database is highly desirable.

In-situ test of ground thermal conductivity



Surficial Materials Map of Connecticut (Source: USGS)

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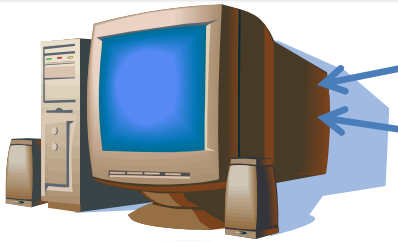
New Generation GSHP Systems

Simulation-based design and analysis

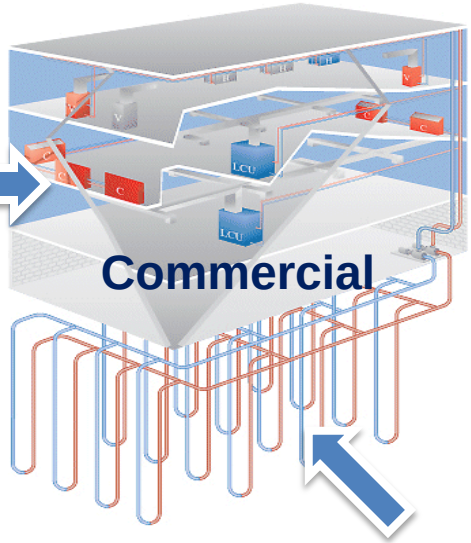


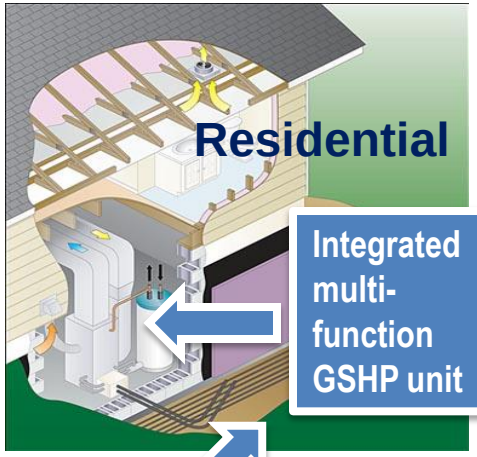
Geological information for GSHP system design and installation

Building information, weather data, utility rates, equipment and installation costs

Optimized system design

Advanced commercial GSHP equipment





Integrated multi-function GSHP unit

Innovative low-cost ground coupling technologies

What can be expected from the new generation of GSHP systems?

- Energy (cost) savings you can depend on
  - Energy (cost) savings is the difference between the measured energy consumption of a GSHP system and the otherwise consumed energy should other HVAC system be used
  - Energy (cost) savings of GSHP comes from properly designed, installed, and operated systems
  - Advanced technologies and optimal system integration can increase energy savings

What can be expected from the new generation of GSHP systems? (Cont'd)

- With competitive initial cost to consumers
  - Technical aspects
    - Optimized system integration
    - Cost-effective equipment and ground coupling technologies
  - Business and financial aspects
    - Direct funding or energy performance contract
    - Third-party (i.e. utility) owned ground loops may emerge in some areas

Conclusions

- GSHPs have tremendous potential to reduce energy consumption and CO_2 emissions
- They can be applied in commercial and residential buildings (new construction or retrofit)
- Emerging technologies are reducing the cost and/or improving the performance of GSHP systems
- A new generation of GSHP systems is coming, and the value continues to improve

For more information, please contact:

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