BTO Peer Review

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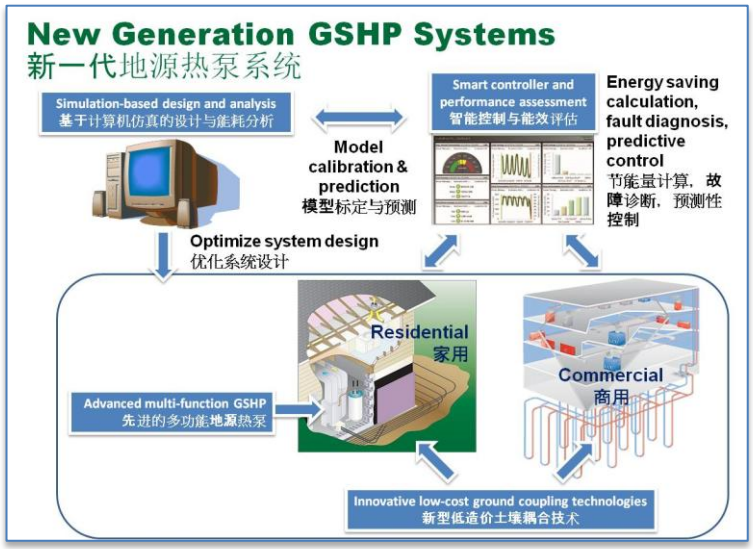

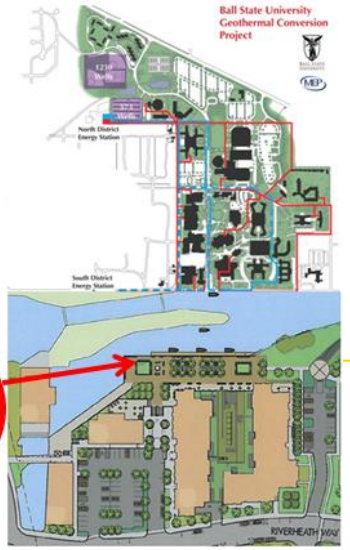

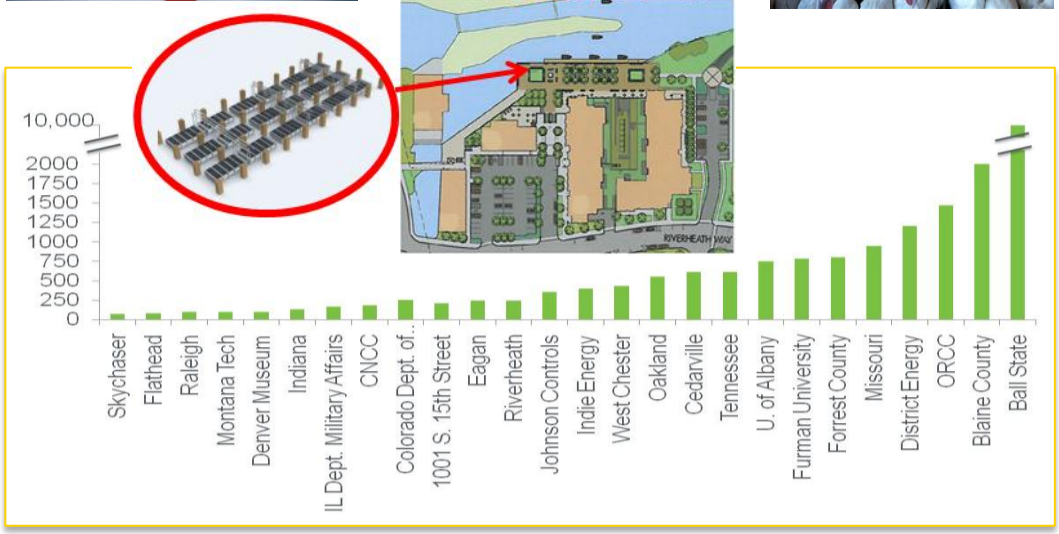

GSHP System Data Analysis

- GSHP Data Analysis in 1st phase of U.S.-China CERC-BEE
- GSHP ARRA Grantee Data Mining

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Purpose & Objectives

Problem Statement: High first cost of ground heat exchangers (GHXs) and lack of knowledge/trust in achievable benefits are major barriers preventing more rapid deployment of GSHP technology

Impact of Project:

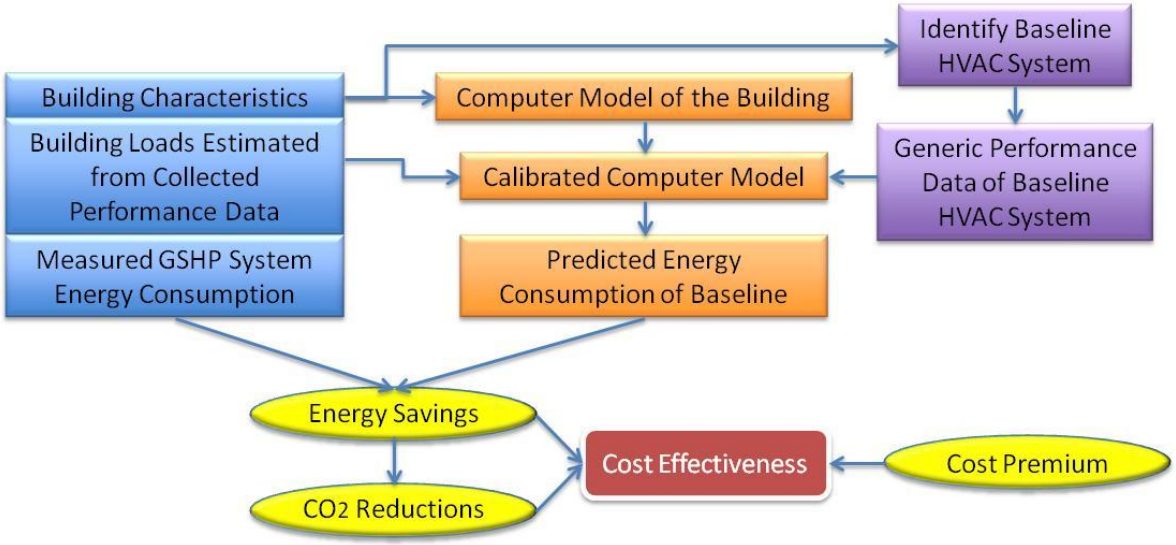
- Cost reduction of performance-neutral vertical borehole GHXs
- Analysis of data from countries with largest installed-bases of GSHPs
- Increased knowledge/trust in GSHP technology

Project Focus:

- BTO's research and development roadmap for GSHP
  - Emerging ground coupling technologies
  - Hard data on performance and cost of GSHP systems vs. alternatives
  - Best practices and innovative technologies for GSHP applications

Approach:

- Extensive literature review and survey
- Field test of alternative vertical bore GHXs, including in-situ borehole resistance measurements, continuous performance monitoring of associated GSHP systems, and analysis aided by calibrated models
- Collection and analysis of available data based on industry standards (i.e., ASHRAE Guideline 14)



Approach

Key Issues:

- Means of determining real performance of emerging alternative GHXs and resulting cost reduction potential
- Methodology for effectively analyzing large data sets collected from GSHP demo projects
- Standardization of procedure and supporting data required for evaluating energy (cost) savings and other benefits of GSHP systems

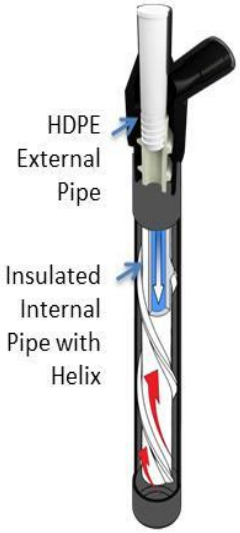
Distinctive Characteristics:

- Utilizes rich data collected from real GSHP systems with various designs, at different locations, and serving a variety of building types
- Leverages decades of experience in advancing GSHP technology, system design, field performance characterization, and modeling
- Conducted in close collaboration with industry and universities

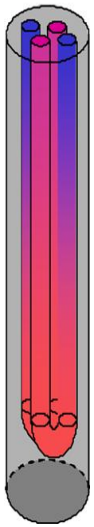
Accomplishments and Progress (1)
Field Test of Alternative GHXs

Tested 8 alterative GHXs and 2 conventional GHXs at 10 nearly identical Habitat for Humanity homes in OKC from October, 2011 though September, 2012.

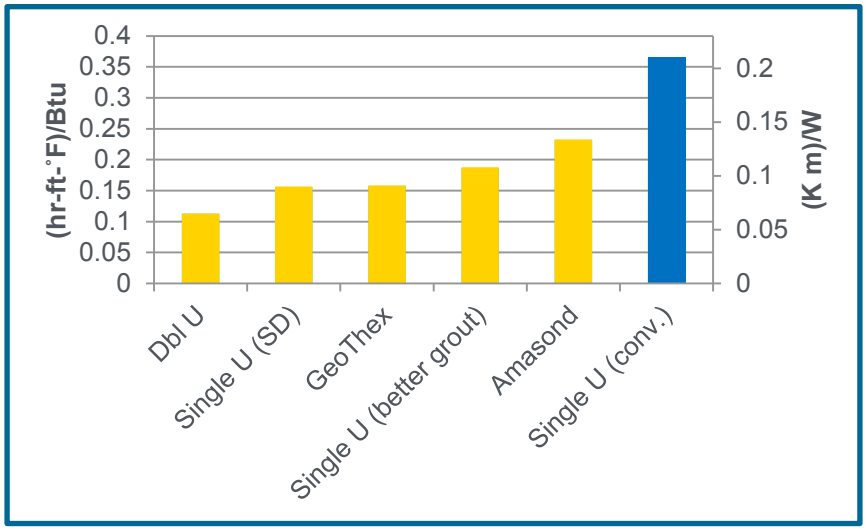
Amasond ®
Co-axial loop



GeoThex®
Co-axial loop



Double-U
loop



Borehole Thermal Resistance of Tested GHXs

Field measurements and calibrated models indicate the **alternative GHXs require 21-36% less borehole depth** compared with conventional single U-tube GHX while retaining same performance

Accomplishments and Progress (2)

Detailed Understanding of GSHP App. in U.S. & China

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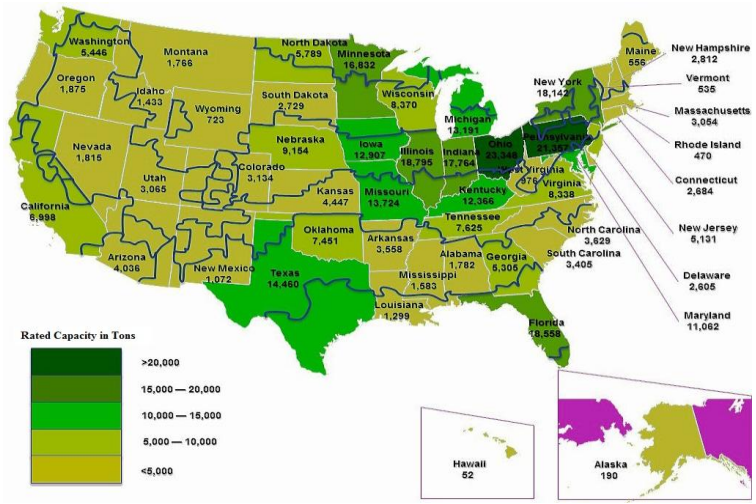
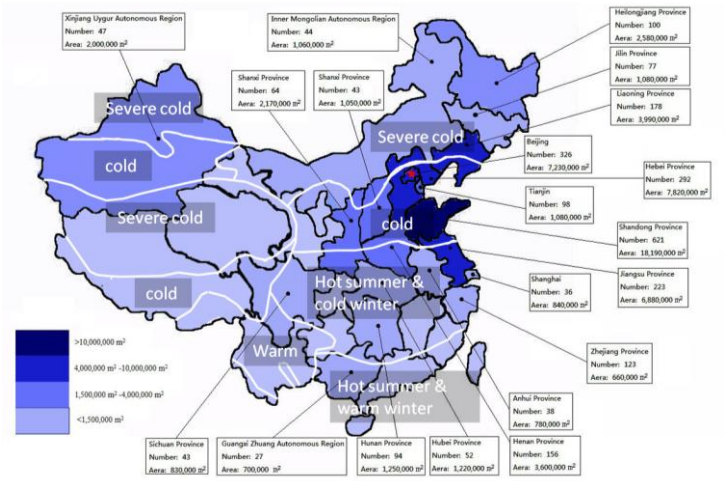


Distribution of 2009 GSHP Shipments in US
(color coded per rated capacity based on EIA 2009 Data)



Distribution of GSHP Applications in China
(color coded per building floor area based on 2009 data)

GSHP installed-base

- China reached 2.44 billion ft^2 within **one** decade
- About the same has been developed over **four** decades in U.S.

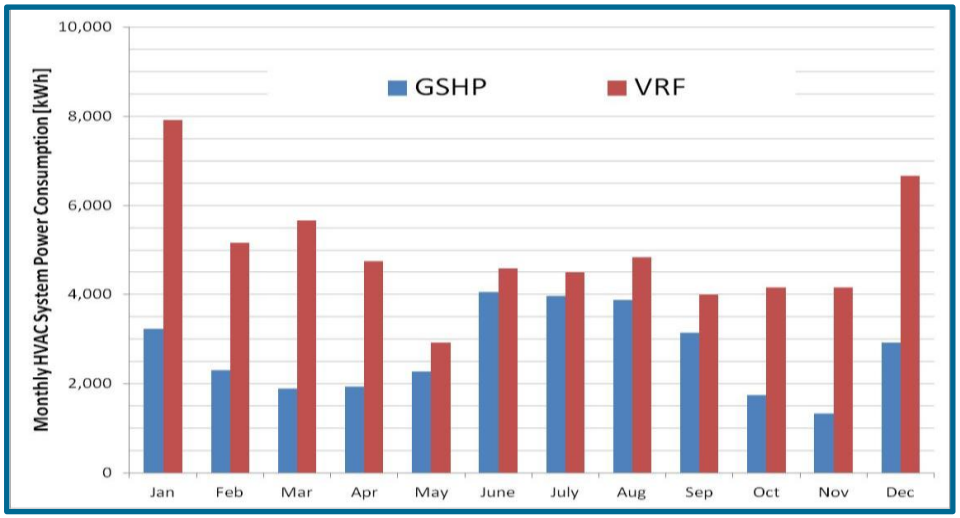
GSHP heat sinks and sources

- China
  - Groundwater (42%)
  - Closed-loop GHX (32%)
  - Surface water and wastewater (26%)
- U.S.
  - Closed-loop GHX (84%)
  - Other (16%)

GSHP system configuration

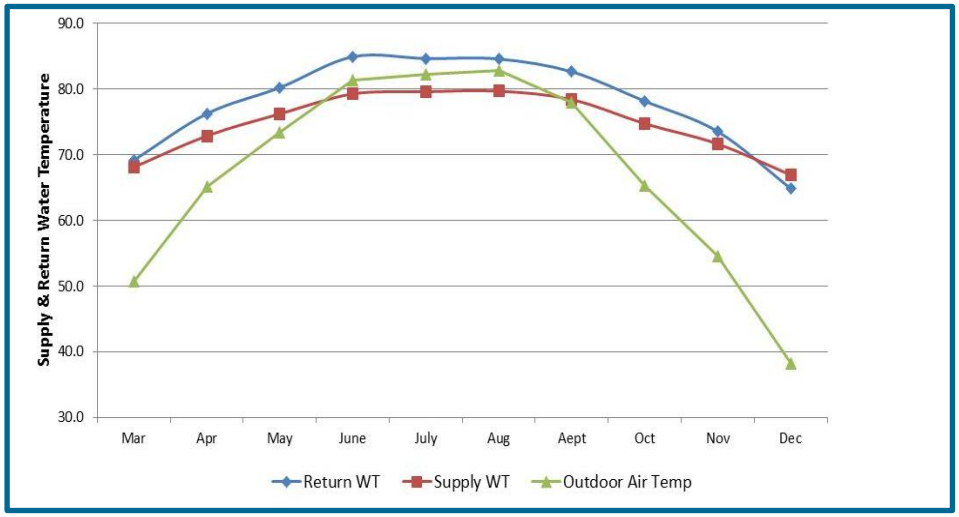
- **Central heat pumps** are predominantly used in China
- **Decentralized heat pumps** (multiple small units) are predominantly used in the U.S.

Accomplishments and Progress (3)
Decentralized GSHP vs. VRF



Over 1,600 data points available to characterize performance of the GSHP system (2nd floor 15,290 sf) and VRF system (1st floor 18,510 sf)

Detailed analysis is ongoing to understand how these systems perform in the real world



Accomplishments and Progress (4)
GSHP ARRA Grantee Data Mining

Data Collection & Analysis Status of ARRA Funded GSHP Demo Projects
(as of the end of March, 2013)

- Data has been collected and initially analyzed (6)
- Data collection plan has been developed (6)
- Waiting for GSHP system design information (13)

An ARRA contractor (CDH Energy) endeavors to collect utility and interval data for one year. For example:

- Ground loop flow and in/out temperatures
- Pump power/speed
- Heat pump power or status
- Utility billing data (pre- and post- if the project is a retrofit)

Accomplishments and Progress (5)
GSHP ARRA Grantee Data Mining

Challenges:

- Data are collected by ARRA demo grantees (not contractors) and the data quality is suspect in some cases (e.g., poor energy balances, only partial implementation of data collection plans)
- Limited time, budget, and leverage on grantees

Solutions:

- Focus on a few sites that enable useful case studies to address issues of most interest to GSHP industry (i.e., decentralized GSHP vs. central GSHP)
- Visit these sites to ensure case study analysis is supported by data of sufficient quality (e.g., fix the DAS, verify instrumentation, take one-time measurements)

Project Plan & Schedule

Project Plan:

- CERC-BEE 1st phase (Data Analysis): Oct. 2011 – Sep. 2012
- GSHP Data Mining: Oct. 2012 – Sep. 2013

Summary	
WBS Number or Agreement Number	
Project Number	
Agreement Number	

Legend
Work completed
Active Task
Milestones & Deliverables (Original Plan)
Milestones & Deliverables (Actual)

Task / Event	FY2012 Q1 (Oct-Dec)	FY2012 Q2 (Jan-Mar)	FY2012 Q3 (Apr-Jun)	FY2012 Q4 (Jul-Sep)	FY2013 Q1 (Oct-Dec)	FY2013 Q2 (Jan-Mar)	FY2013 Q3 (Apr-Jun)	FY2013 Q4 (Jul-Sep)	FY2014 Q1 (Oct-Dec)	FY2014 Q2 (Jan-Mar)	FY2014 Q3 (Apr-Jun)	FY2014 Q4 (Jul-Sep)
Project Name: Advancing GSHP (under CERC-BEE)												
Q2 Milestone: Report on GSHP applications in US			◆									
Q4 Milestone: Complete evaluation of new GHXs				◆								
Project Name: GSHP Data Mining												
Q1 Milestone: Review available data and select sites for case study						◆	◆					
Q2 Milestone: Determine evaluation procedure and performance metrics							◆					
Current work and future research												
Q4 Milestone: Complete case study								◆				

Project Budget

Project Budget:

- CERC-BEE 1st phase (FY12): $150K
- GSHP Data Mining (FY13): $200K

Variances: None so far

Cost to Date:

- CERC-BEE 1st phase (FY12): $150K
- GSHP Data Mining (FY13): $30K

Additional Funding: None expected

Budget History					
FY2011		FY2012 (U.S.-China CERC BEE 1st phase)		FY2013 (GSHP ARRA Grantee Data Mining)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
NA	NA	150K	150K	200K	NA

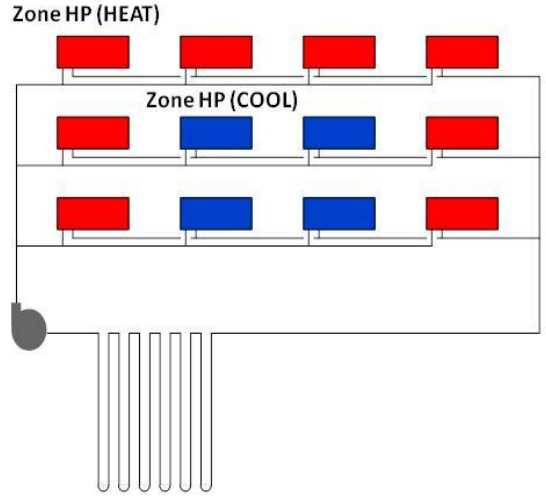
Project Integration, Collaboration & Market Impact

Partners, Subcontractors, and Collaborators:

- Collaborators for field performance characterization of alternative GHXs
  - Oklahoma Gas & Electric
  - International Ground Source Heat Pump Association
  - ClimateMaster
  - Various vendors of new GHXs from several countries
  - Ewbank and Associates
  - Baroid Industrial Drilling Products
- Collaborators in the study of GSHP applications in U.S. and China
  - Three Chinese universities (Tongji, Tianjin, Chongqin)
- Collaborator in the ASHRAE HQ field performance characterization
  - Oklahoma State University
- 25 GSHP ARRA demo project grantees
- CDH Energy, an ARRA contractor specializing in field data acquisition

Project Integration, Collaboration & Market Impact (1)

Technology Transfer, Deployment, Market Impact: Success in 1st phase of CERC-BEE project led to reduced cost of vertical borehole GHX. A separately funded BTO project led to ClimateMaster's Trilogy™ Q-Mode™ ground-source integrated heat pump. ARRA data mining is expected to verify superiority of decentralized GSHP systems over central. CERC BEE 2nd phase is expected to lead to a Trilogy-based decentralized GSHP system demo in high-rise housing in China (by Broad Homes) and potentially another in U.S. (possibly involving Gate Precast and Trump Properties)



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Project Integration, Collaboration & Market Impact (2)

Communications:

- Completed a technical report on cost reduction of performance-neutral vertical borehole GHXs (ORNL/TM-2013/39)
- Submitted a paper to Journal of Building Research Institute on comparison of GSHP applications in China and US, and three more papers are in preparation
- Presented at IGSHPA annual conference and BTO Building America team meeting
- Hosted a delegation of Chinese GSHP industry reps at IGSHPA and ClimateMaster
- Hosted a visit at ORNL by reps from Broad Homes Industrial, ClimateMaster, Dow Chemical, Gate Precast, and the Congress for the New Urbanism

Next Steps and Future Plans

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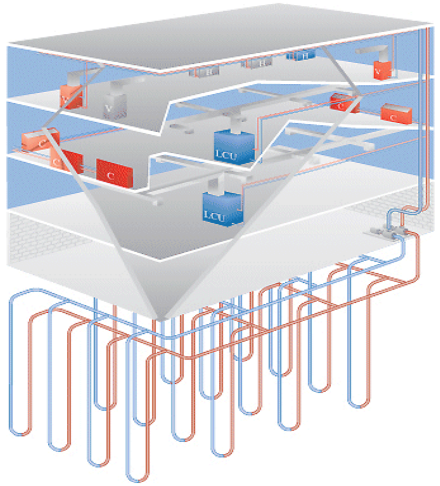
Next Steps:

- Complete case studies for 2-3 projects in FY13

Future Plans:

- Implement BTO GSHP roadmap as funding becomes available
- In the meantime, focus on 2nd phase of CERC-BEE to further advance decentralized GSHP technologies and establish U.S. leadership in global markets



- **Install a decentralized GSHP system with integrated zone HPs in ORNL's 2-story FRP test building**
- **Optimize controls at zone and system levels**
- **Fault detection and diagnostics**