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

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

GSHP installed-base
- China reached 2.44 billion ft² 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.
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)

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

<table>
<thead>
<tr>
<th>Task / Event</th>
<th>FY2012</th>
<th>FY2013</th>
<th>FY2014</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Name: Advancing GSHP (under CERC-BEE)</strong></td>
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<tr>
<td>Q2 Milestone: Report on GSHP applications in US</td>
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<tr>
<td>Q4 Milestone: Complete evaluation of new GHXs</td>
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<tr>
<td><strong>Project Name: GSHP Data Mining</strong></td>
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<tr>
<td>Q1 Milestone: Review available data and select sites for case study</td>
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<td>Q2 Milestone: Determine evaluation procedure and performance metrics</td>
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<tr>
<td><strong>Current work and future research</strong></td>
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<tr>
<td>Q4 Milestone: Complete case study</td>
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<tr>
<th>Legend</th>
<th>Work completed</th>
<th>Active Task</th>
<th>Milestones &amp; Deliverables (Original Plan)</th>
<th>Milestones &amp; Deliverables (Actual)</th>
</tr>
</thead>
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| WBS Number or Agreement Number | | | |
| Project Number | | | |
| Agreement Number | | | |

**Summary**

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

Variance: None so far

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

Additional Funding: None expected

### Budget History

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<tr>
<th></th>
<th>FY2011</th>
<th>FY2012 (U.S.-China CERC BEE 1st phase)</th>
<th>FY2013 (GSHP ARRA Grantee Data Mining)</th>
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<tbody>
<tr>
<td>DOE</td>
<td>Cost-share</td>
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<tr>
<td>NA</td>
<td>NA</td>
<td>150K</td>
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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, Chongqing)

- 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
Technology Transfer, Deployment, Market Impact: Success in 1\textsuperscript{st} phase of CERC-BEE project led to reduced cost of vertical borehole GHX. A separately funded BTO project led to ClimateMaster’s Trilogy\textsuperscript{™} Q-Mode\textsuperscript{™} ground-source integrated heat pump. ARRA data mining is expected to verify superiority of decentralized GSHP systems over central. CERC BEE 2\textsuperscript{nd} 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)
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

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