



Energy Trust of Oregon, Inc.

BSUG – April 16, 2008

Building Simulation Users' Group

Reminder

- **Collegial Organization - Volunteer**
- **Attend, Recruit, Participate**



Building Simulation Users' Group

Sponsors

- **The Energy Trust - Funding**
- **NW Natural – Space & AV**
- **ODOE – Technical Input**
- **BPA – Outreach**
- **NEEA - Outreach**
- **ASHRAE - PDHs for P.E.s**

Building Simulation Users' Group

eQuest Intermediate Training Present Configuration

- **Four sessions – April 2, 9, 16 & 23**
- **5:30 – 9:00 p.m.**
- **Hosted by the Energy Trust**
- **First session appeared to go very well**
- **Will have some holes in curriculum**

Building Simulation Users' Group

Networking

- **The meeting room will be open at least by 11:30 a.m. for casual networking**
- **Members will also be allowed to help setup tables, etc.**

Building Simulation Users' Group

Today's Discussion

*Modeling of Ground Source Heat Pumps
in eQuest*

*Xiaobing Liu, PhD.
ClimateMaster, Inc.*

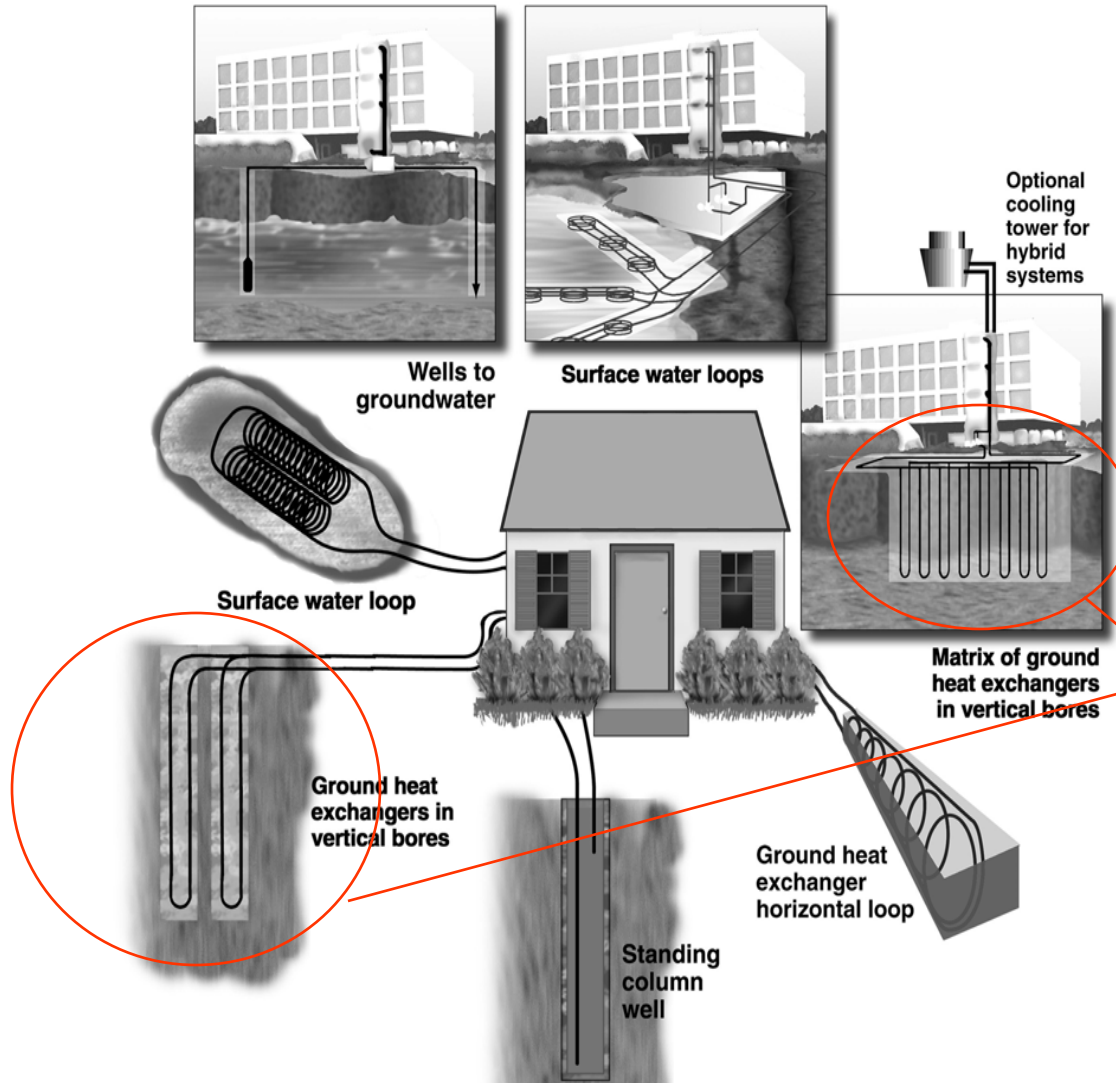
Geothermal Heat Pump System Simulation with Enhanced eQUEST

Xiaobing Liu, Ph. D.
ClimateMaster
xliu@climatemaster.com

Agenda

- Introduction of geothermal heat pump (GHP) systems
- Overview of enhanced GHP simulation algorithms/capabilities of eQUEST
- Simulation-based design and energy analysis of GHP systems using eQUEST
- Current limitations and future enhancements
- Q & A

Geothermal Heat Pump Systems



GHP systems with various ground heat exchangers

Vertical close loop ground loop heat exchangers are most commonly used in the US

Geothermal Heat Pump Systems

“the most energy-efficient, environmentally clean, and cost-effective space-conditioning system”

“produce the lowest carbon dioxide emissions, including all source effects, of all available space-conditioning technologies”

(EPA, 1993)

Equivalent to



More trees



Fewer cars



Greater clean power

Geothermal Heat Pump Systems

- Hurdles in initial cost
- Hurdles in design
 - Cumulative heating and cooling loads required for sizing ground heat exchanger (GHX) is much more complicated to calculate than the peak loads
 - Performance of various type of GHX is affected by many factors and their design heavily relies on computerized calculation
 - Lack of GHX design required geology information
 - Unfamiliar with GHX related construction technologies
- Hurdles in the construction field

GSHP Simulation Algorithms/Capabilities

- Advanced model for vertical close loop ground loop heat exchangers (VGLHE)
- Dedicated wizard interface for specifying VGLHE with on-line help, database, and/or design tips for each input entry
- Access to water-to-air heat pump libraries
- Capability for simulating advanced water-to-air heat pump with staged capacity and airflow

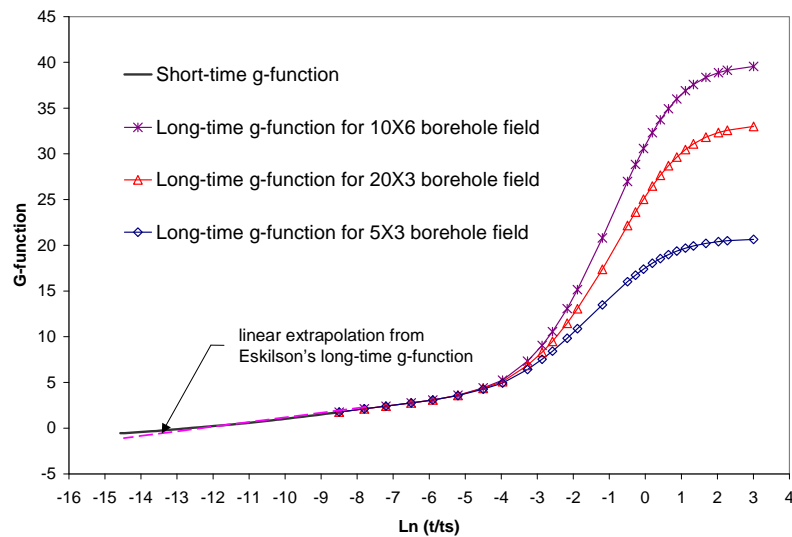
GSHP Simulation Algorithms/Capabilities

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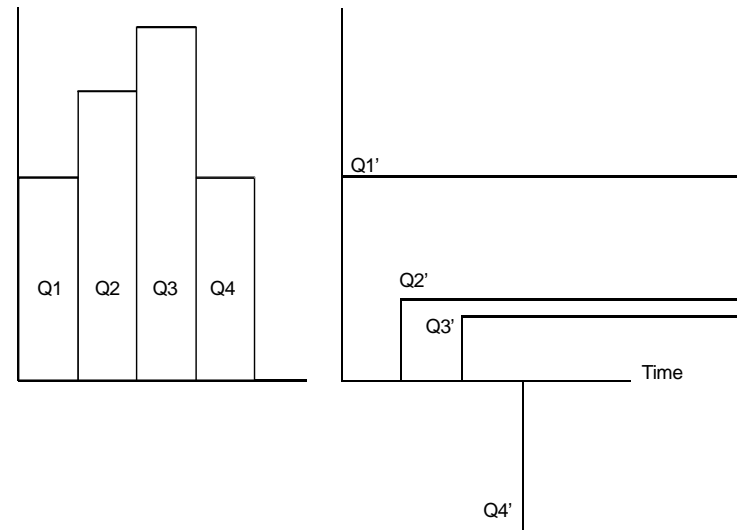
Modeling VGLHE

- Advanced model for VGLHE
 - ✓ Based on widely-accepted g-function algorithm developed by Eskilson et al at Sweden (1987)
 - ✓ Extended short-term g-functions for hourly simulation of VGLHE
 - ✓ Unlimited borehole field configurations *
 - ✓ Sophisticated borehole thermal resistance calculation that accounts for the effects of borehole geometry, grouting material, and anti-freeze solution (Hellstrom 1991)

Example of g-functions

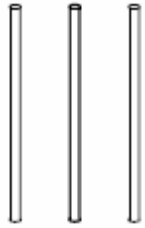


Example of normalized borehole wall temperatures (g-functions) in response to given constant heat rejection flux

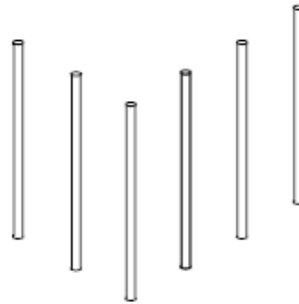


Superposition of piece-wise linear step heat inputs in time. The step heat inputs Q_2' , Q_3' and Q_4' are super-imposed in time on to the basic heat pulse Q_1' .

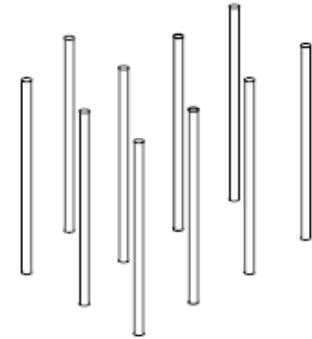
Example of Borehole Field Configurations



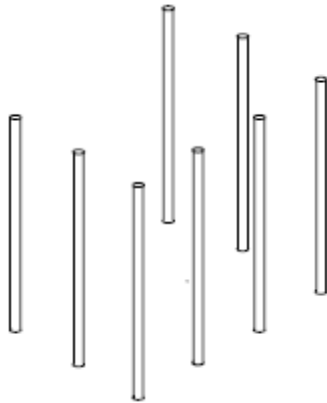
Straight line



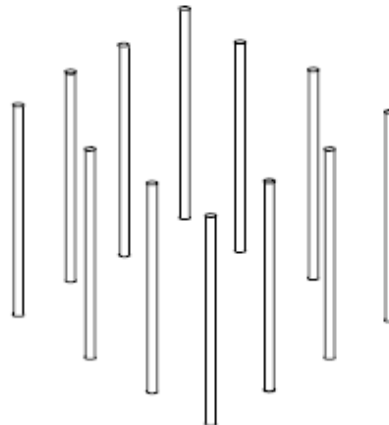
One L- shaped line



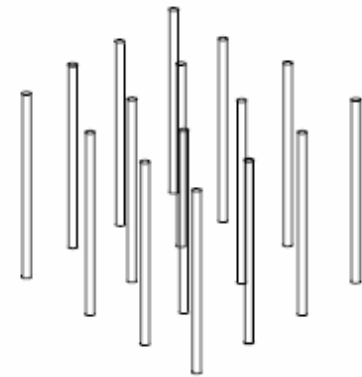
Two parallel L- shaped lines



U-shaped lines

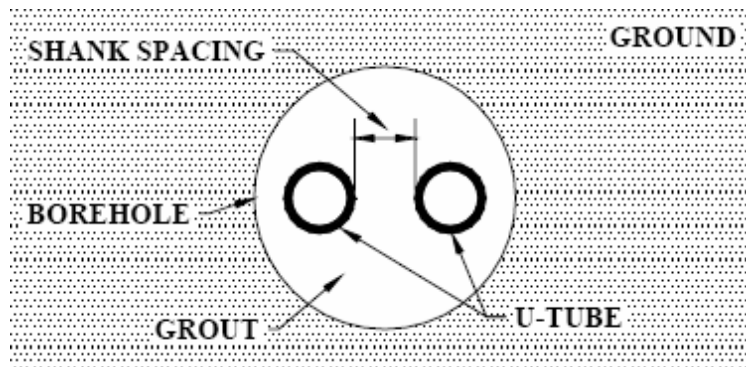


Open rectangle



Rectangle

Borehole Thermal Resistance



- Convective heat transfer resistance of the fluid in the U-tube
- Tube wall thermal resistance
- Conductive thermal resistance of grout

GSHP Simulation Algorithms/Capabilities

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Dedicated Wizard Interface

- Dedicated wizard interface for specifying VGLHE with on-line help, database, and/or design tips for each input entry
 - ✓ Water loop properties
 - ✓ Soil thermal properties & History
 - ✓ Ground heat exchanger properties
 - ✓ Fluid properties

Dedicated Wizard Interface

Dedicated wizard interface for specifying VGLHE

Soil/rock Types

- Amphibolite
- Andesite
- Anhydrite
- Aplite
- Arkose
- Basalt
- Breccia
- Clay, dry
- Clay, moist/wet
- Claystone

Main Ground-Source HP Equipment Screen

eQUEST Schematic Design Wizard

Ground-Source HP Equipment

Water Loop Properties

Pump Config:

Loop Flow:

Operation:

Loop Temp: Min: °F Max: °F

Loop Pump(s) Number:

Head: ft Flow: gpm

Motor Eff:

Soil Thermal Properties & History

Ground Temp: Temp: °F

Years of Previous Operation: yrs

Ground:

Grout:

Cond: Btu/h-ft-°F

GHX Type:

Configuration:

Num of Identical Well Fields: units

Depth: ft Spacing: ft

Borehole Diameter: in

Pipe Material:

Pipe Size: Rating:

U-Tube Leg Separation: in

GHX Pipe Head: ft

Fluid Properties

Fluid:

Anti-freeze Concn: %

Wizard Screen 39 of 50

Help Previous Screen Next Screen

GHX Configurations

- L Config 2x3
- L Config 2x4
- L Config 2x5
- L2 Config 3x3
- L2 Config 3x4
- L2 Config 3x5
- U Config 3x2
- U Config 3x3
- U Config 3x4
- U Config 3x5
- Open Rectangle 3x3
- Open Rectangle 3x4
- Open Rectangle 3x5
- Rectangle 2x2
- Rectangle 2x3
- Rectangle 2x4
- Rectangle 2x5
- Rectangle 2x6
- Rectangle 2x7
- Rectangle 2x8
- Rectangle 2x9
- Rectangle 2x10
- Rectangle 3x3
- Rectangle 3x4
- Rectangle 3x5
- Rectangle 3x6

Grout Types

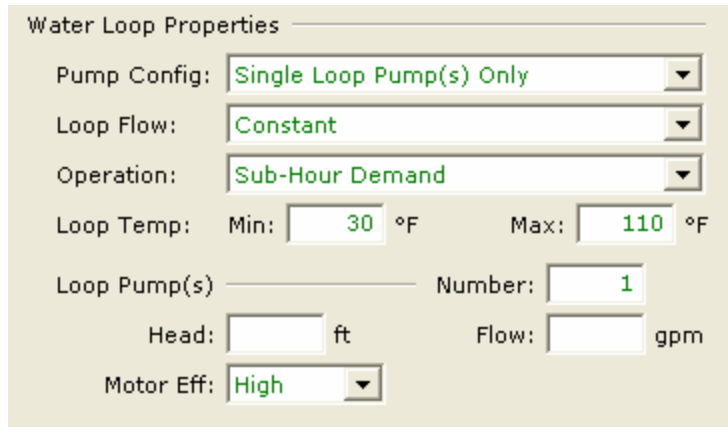
- Sand, moist
- Sand, saturated
- Silt, dry
- Silt, moist/wet
- Till
- 20% Bentonite -40% Quartzite
- 30% Bentonite -30% Quartzite
- 30% Bentonite -30% Iron Ore
- 60% Quartzite -Flowable Fill (Cement)

Fluid Types

- Propylene Glycol
- Water
- Propylene Glycol
- Ethanol
- Ethylene Glycol
- Methanol

Dedicated Wizard Interface

Water Loop Properties



The screenshot shows the 'Water Loop Properties' dialog box with the following settings:

- Pump Config: Single Loop Pump(s) Only
- Loop Flow: Constant
- Operation: Sub-Hour Demand
- Loop Temp: Min: 30 °F, Max: 110 °F
- Loop Pump(s): Number: 1
- Head: [] ft, Flow: [] gpm
- Motor Eff: High

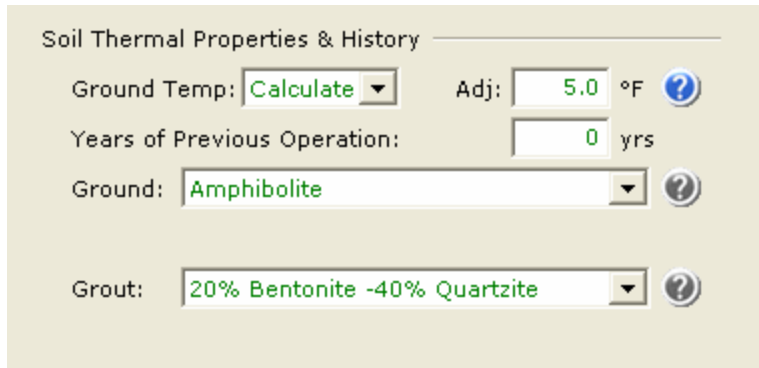
Tips:

1. To properly simulate variable flow, isolation valve option of heat pump should be “Yes”.
2. Loop temperature range will affect both the sizes of GHX and heat pump(s).

- Pump configuration
 - ✓ Single Loop Pump(s) only
- Loop flow
 - ✓ Constant
 - ✓ Variable
- Operation
 - ✓ Standby
 - ✓ Demand
 - ✓ Sub-hour Demand
- Loop temperature range
- Loop Pump(s)

Dedicated Wizard Interface

Soil Thermal Properties & History



The screenshot shows a software interface titled "Soil Thermal Properties & History". It contains four input fields:

- Ground Temp:** A dropdown menu set to "Calculate".
- Adj:** A text input field containing "5.0" followed by "°F" and a help icon.
- Years of Previous Operation:** A text input field containing "0" followed by "yrs".
- Ground:** A dropdown menu set to "Amphibolite" with a help icon.
- Grout:** A dropdown menu set to "20% Bentonite -40% Quartzite" with a help icon.

Tips:

1. For projects with large borehole field, in-situ test of ground thermal properties is highly recommended.
2. Specify "Years of previous operation" to assess the effect of heat/cool built-up on the performance of GHX.

- Ground temperature
 - ✓ Calculated via weather data
 - ✓ User specified
- Years of previous operation
- Ground thermal properties
 - ✓ Picked from built-in database
 - ✓ User specified
- Grout thermal properties
 - ✓ Picked from built-in database
 - ✓ User specified

Dedicated Wizard Interface

Soil Thermal Properties & History

Ground Temp: Calculate Adj: 5.0 °F

Years of Previous Operation: 0 yrs

Ground: Amphibolite

Grout: 20% Bentonite -40% Quartzite

eq_wiz

GSHP Ground Temperature - Undisturbed Ground Temperature

Mean Undisturbed Ground Temperature.

The **Mean Undisturbed (far-field) Ground Temperature** (\bar{T}_{ground}) input is available only if the user has chooses "Specify" for the [Ground Temperature Specification Type](#) and is used for simulating vertical wells. It is the mean undisturbed ground temperature along the depth of a ground loop heat exchanger. By default, it is estimated as shown in the following using the mean annual air temperature (\bar{T}_{air}), geothermal heat flux (Q_{ground}), ground thermal conductivity (K_{ground}) and the depth of the ground loop heat exchanger (L_{GLHX}).

$$\bar{T}_{ground} = \bar{T}_{air} + \frac{Q_{ground} \cdot L_{GLHX}}{2 \cdot K_{ground}}$$

Ground Thermal Properties Table

Description	Thermal Conductivity (Recommended)	Thermal Conductivity (Minimum)	Thermal Conductivity (Maximum)	Diffusivity (Recommended)	Diffusivity (Minimum)	Diffusivity (Maximum)
	Btu/hr-ft-F	Btu/hr-ft-F	Btu/hr-ft-F	FF2/day	FF2/day	FF2/day
Amphibolite	1.7	1.1	2.7	1.0		
Andesite	1.3	0.8	2.8	0.9	1.1	1.7
Anhydrite	2.4	0.9	4.5	1.9		
Apfite	1.8	1.5	2.3	1.2		
Arizona	1.7	1.5	2.2	1.3		
Bronze	1.0	0.8	1.4	0.7	0.5	0.9
Bronze	1.8	1.3	2.4	1.2		
Clay, dry	0.2	0.2	0.5	0.2	0.2	0.5
Clay, moist - wet	0.9	0.5	1.3	0.8	0.5	0.8
Claystone	1.3	0.8	1.7	0.9	0.5	1.2
Coal	0.2	0.2	0.4	0.2		
Concrete	0.9	0.5	1.2	0.8		
Conglomerate	1.8	0.8	2.1	1.2		
Diorite	1.5	1.1	1.9	0.8	0.7	1.0
Dolomite	1.9	0.9	3.8	1.2	0.8	2.3
Dunite	2.4	2.3	2.7	1.3		
Eclupite	1.7	1.3	2.4	0.9		
Gabbro	1.1	0.9	1.8	0.7	0.7	1.2
Gneiss	1.7	1.0	3.3	1.3	0.9	2.3
Granite	2.0	1.1	3.0	1.3	0.9	1.8

Grout Thermal Properties Table

Description	Thermal Conductivity Btu/hr-ft-F
Grouts without Additives	
Bentonite 10%, frozen	0.8
Bentonite 10%, in water	0.4
Bentonite 20%, in water	0.3
Bentonite 40%, frozen	0.5
Bentonite 40%, in water	0.3
Bentonite, dry	0.1
Clay, dry	0.2
Clay, moist - wet	0.9
Concrete	0.9
Gravel, dry	0.2
Gravel, saturated	1.0
Sand, dry	0.2
Sand, dry, compacted	0.7

Dedicated Wizard Interface

Ground heat exchanger (GHX) properties

GHX Type:

Configuration:

Num of Identical Well Fields: units

Depth: ft Spacing: ft

Borehole Diameter: in

Pipe Material:

Pipe Size: Rating:

U-Tube Leg Separation: in

GHX Pipe Head: ft

Tips:

1. For access to other borehole field configurations, contact ClimateMaster.
2. Default GHX pipe head is 30 ft. Change when necessary.

- GHX Type
 - ✓ Vertical well field
- Configuration
 - ✓ 42 built-in borehole config
 - ✓ Maximum 32 boreholes
- Num of identical well fields
- Borehole depth
- Borehole spacing
- Borehole Diameter
- Pipe material, size, pressure rating
- U-tube leg separation
- GHX Pipe head

Dedicated Wizard Interface

Fluid Properties

Fluid Properties

Fluid: Propylene Glycol ?

Anti-freeze Concn: 20.0 %

Tips:

1. Select weight concentration of anti-freeze compound based on: design min. loop temperature less max. temperature difference between supply and return.

Freezing point [F]

Anti-freeze Compound	Anti-freeze concentration (% of weight)				
	0	10	20	30	40
Ethylene Glycol	32	26.2	17.9	6.7	-8.1
Propylene Glycol	32	26.1	19.2	9.2	-6
Methanol	32	20	0	-15	-40
Ethanol	32	25	12	-4	-21

- Fluid type
 - ✓ Water
 - ✓ Anti-freeze solution
 - Propylene Glycol
 - Ethylene Glycol
 - Methanol
 - Ethanol
- Anti-freeze weight concentration
(if aqueous anti-freeze solution is selected)

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Water-to-Air Heat Pump Library

eQUEST Schematic Design Wizard

Packaged HVAC Equipment

HVAC System 1: Ground-Source Heat Pump

Select from GSHP Library

Cooling

Overall Size: Auto-size

Typical Unit Size: > 135 kBtuh or 11.25 tons

Efficiency: EER 12.000

Allow Crankcase Heating

Heating

Size: Auto-size

Efficiency: COP 4.200

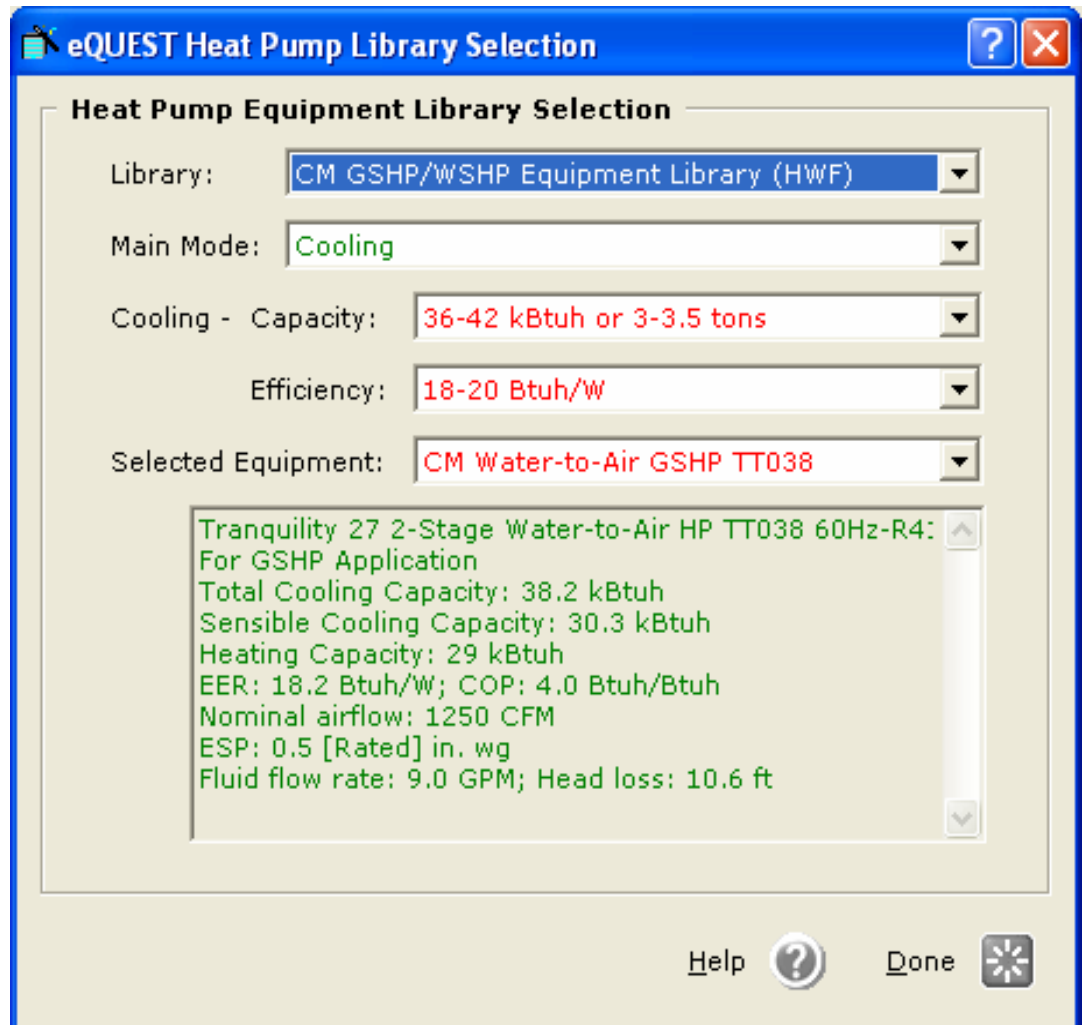
Wizard Screen 21 of 41

Help Previous Screen Next Screen Finish

The access to heat pump library is only available after proper installation of the add-on feature from ClimateMaster

Water-to-Air Heat Pump Library

- Four-steps heat pump selection procedure
- Information include heating and cooling capacities, EER, COP, airflow, water flow, pressure drop, ESP, and etc at ARI/ASHRAE/ISO rating conditions
- Performance curves at off-rating conditions



eQUEST Heat Pump Library Selection

Heat Pump Equipment Library Selection

Library: **CM GSHP/WSHP Equipment Library (HWF)**

Main Mode: **Cooling**

Cooling - Capacity: **36-42 kBtuh or 3-3.5 tons**

Efficiency: **18-20 Btuh/W**

Selected Equipment: **CM Water-to-Air GSHP TT038**

Tranquility 27 2-Stage Water-to-Air HP TT038 60Hz-R4:
For GSHP Application
Total Cooling Capacity: 38.2 kBtuh
Sensible Cooling Capacity: 30.3 kBtuh
Heating Capacity: 29 kBtuh
EER: 18.2 Btuh/W; COP: 4.0 Btuh/Btuh
Nominal airflow: 1250 CFM
ESP: 0.5 [Rated] in. wg
Fluid flow rate: 9.0 GPM; Head loss: 10.6 ft

Help ? Done

Water-to-Air Heat Pump Library

Performance curves required by DOE-2.2 for W-A heat pump simulation

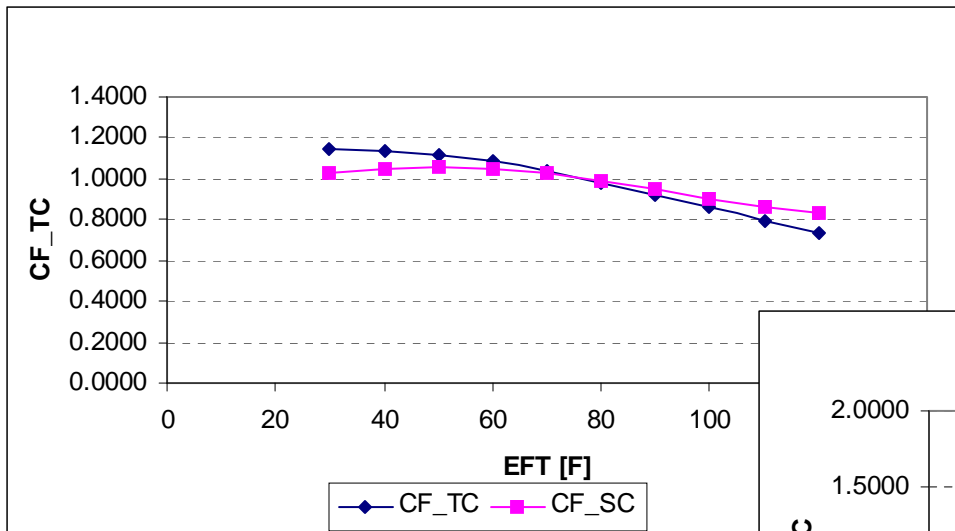
Curve Name	Description	Note
$TC = f(EWB, EFT)$	Correction factor for Total Cooling (TC) capacity as a function of the Entering Wet Bulb temperature (EWB) and the Entering Fluid Temperature (EFT).	For cooling
$SC = f(EWB, EFT)$	Correction factor for Sensible Cooling (SC) capacity as a function of the Entering Wet Bulb temperature (EWB) and the Entering Fluid Temperature (EFT).	For cooling
$EIR_C = f(EWB, EFT)$	Correction factor for Electric Input Ratio (EIR) as a function of the Entering Wet Bulb temperature (EWB) and the Entering Fluid Temperature (EFT).	For cooling
$BPF = f(EWB, EFT)$	Correction factor for Bypass Factor (BPF) as a function of the Entering Wet Bulb temperature (EWB) and the Entering Fluid Temperature (EFT).	For cooling
$HC = f(EDB, EFT)$	Correction factor for Heating Capacity (HC) as a function of the Entering Dry Bulb temperature (EDB) and the Entering Fluid Temperature (EFT).	For heating
$EIR_H = f(EDB, EFT)$	Correction factor for Electric Input Ratio (EIR) as a function of the Entering Dry Bulb temperature (EDB) and the Entering Fluid Temperature (EFT).	For heating
$EIR_C = f(PLR)$	Correction factor for Electric Input Ratio (EIR) as a function of Part Load Ratio (PLR).	For cooling
$EIR_H = f(PLR)$	Correction factor for Electric Input Ratio (EIR) as a function of Part Load Ratio (PLR).	For heating

Non-PLR

PLR

Water-to-Air Heat Pump Library

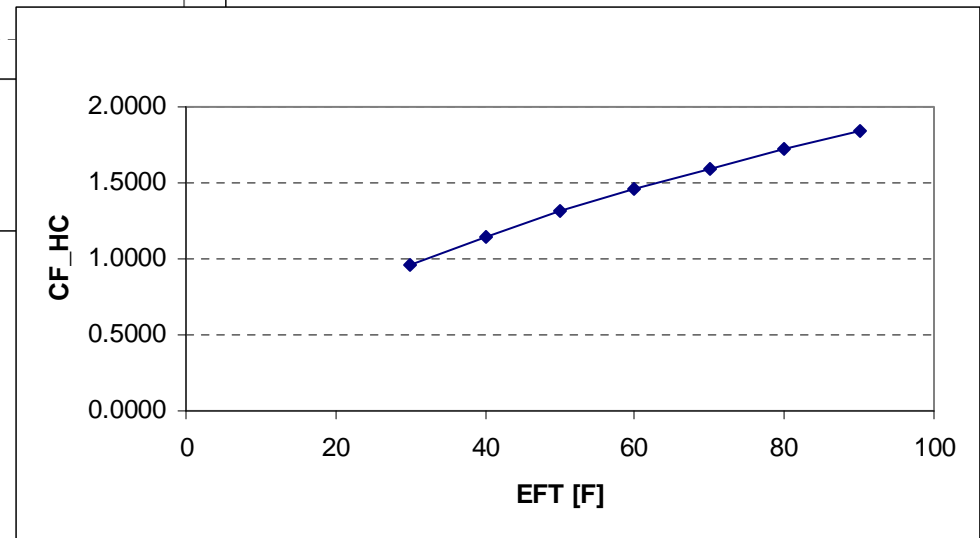
Example of performance curves



Non-dimensional **total and sensible cooling** capacity as a function of entering fluid temperature



Non-dimensional **heating** capacity as a function of entering fluid temperature

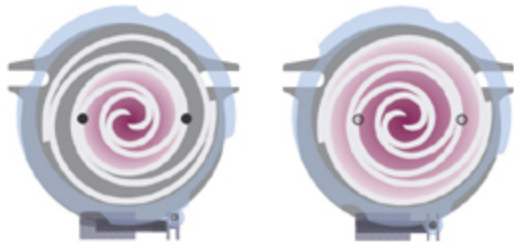


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Staged Capacity and Airflow

Two-stage scroll compressor



67%
Capacity

100%
Capacity

ECM variable speed fan motor



Advantage of heat pump with staged capacity and airflow

- High efficiency cooling and heating at part load conditions
 - ✓ Oversized heat exchangers
 - ✓ Reduced airflow
- Improved humidity control due to longer run time
- More precise temperature control

Staged Capacity and Airflow

**Air-side HVAC:
PVVT**

The screenshot displays the 'Air-Side HVAC System' configuration in eQUEST. The main diagram shows a flow from 'Evap. or Desic' through 'Pre Heat' to two 'Heat Pump' units, which then feed into a 'Supply Fan'. The return path includes a 'Return Fan', 'Humid. stat.', and 'System Baseboards'. A 'Zone Locations' window shows two room layouts. The 'Zone Assignments' list on the right includes:

- South Perim Zn (G.S1)
- South Perim Pl Zn (G.S6)
- East Perim Zn (G.E2)
- East Perim Pl Zn (G.E7)
- North Perim Zn (G.N3)
- North Perim Pl Zn (G.N8)
- West Perim Zn (G.W4)
- West Perim Pl Zn (G.W9)
- Core Zn (G.C5)
- Core Pl Zn (G.C10)
- South Perim Zn (T.S11)
- South Perim Pl Zn (T.S11)
- East Perim Zn (T.E12)
- East Perim Pl Zn (T.E17)
- North Perim Zn (T.N13)
- North Perim Pl Zn (T.N16)

The 'Zone Features' panel shows icons for 'Zone Terminal', 'Exhst', 'Thermostat', and 'Meters', along with a 'Zone Baseboards' area.

Staged Capacity and Airflow

Air-Side HVAC System Parameters ? X

Currently Active System: System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration

Coil Cap / Control | Unitary Power | Preht / Basebrd | Supp Heat/Defrost | Cap Curves/Waste Ht | **Stages**

Heating & Cooling Staging Control:

	Cooling Stages		Heating Stages	
	Capacity Fraction	Delta T °F	Capacity Fraction	Delta T °F
Stage 1:	<input type="text" value="0.6700"/>	<input type="text" value="0.0000"/>	<input type="text" value="0.7300"/>	<input type="text" value="-"/>
Stage 2:	<input type="text" value="1.0000"/>	<input type="text" value="0.0000"/>	<input type="text" value="1.0000"/>	<input type="text" value="0.0000"/>
Stage 3:	<input type="text" value="n/a"/>	<input type="text" value="n/a"/>	<input type="text" value="n/a"/>	<input type="text" value="n/a"/>
Stage 4:	<input type="text" value="n/a"/>	<input type="text" value="n/a"/>	<input type="text" value="n/a"/>	<input type="text" value="n/a"/>

Done

Staged Capacity and Airflow

Air-Side HVAC System Parameters ? X

Currently Active System: **Sys1 (PVVT) (G.S1)** System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration

Fan Power and Control | **Flow Parameters** | Night Cycle Control

Flow Parameters for single-duct systems

	Design cfm	Min Flow cfm/ft2	Min Flow Ratio	Min Fan Ratio	Max Fan Ratio
Supply Flow:			0.83	0.30	1.00
Heating Mode:			0.85		
Return Flow:	n/a				

Dual Speed Fan/Compressor Ratios —

n/a	n/a	n/a	n/a
-----	-----	-----	-----

Min Flow Source: n/a

Indoor Fan Mode: **Continuous**

Induction Ratio: n/a

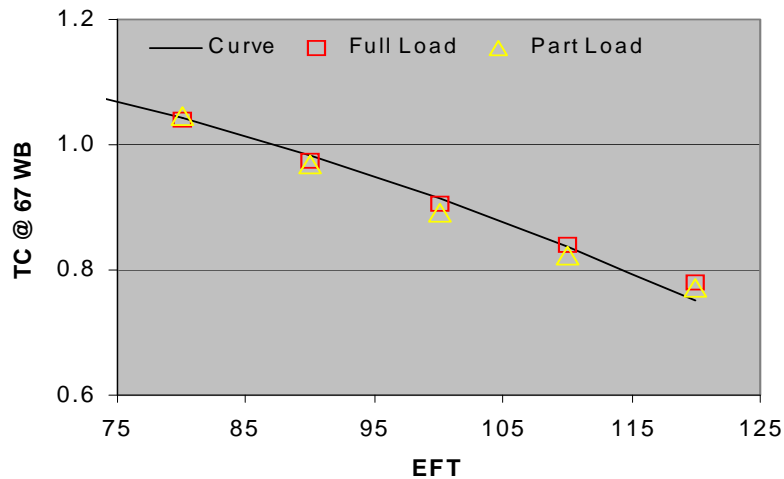
Return Cap Ratio: n/a ratio

Done

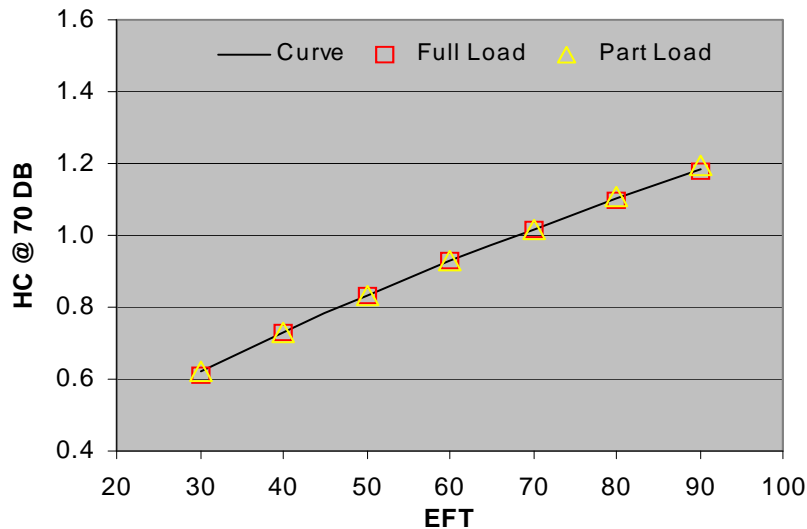
Example of Two-stage Performance Curves

TC and HC as a function of EFT

Normalized Total Cooling (TC) Capacity



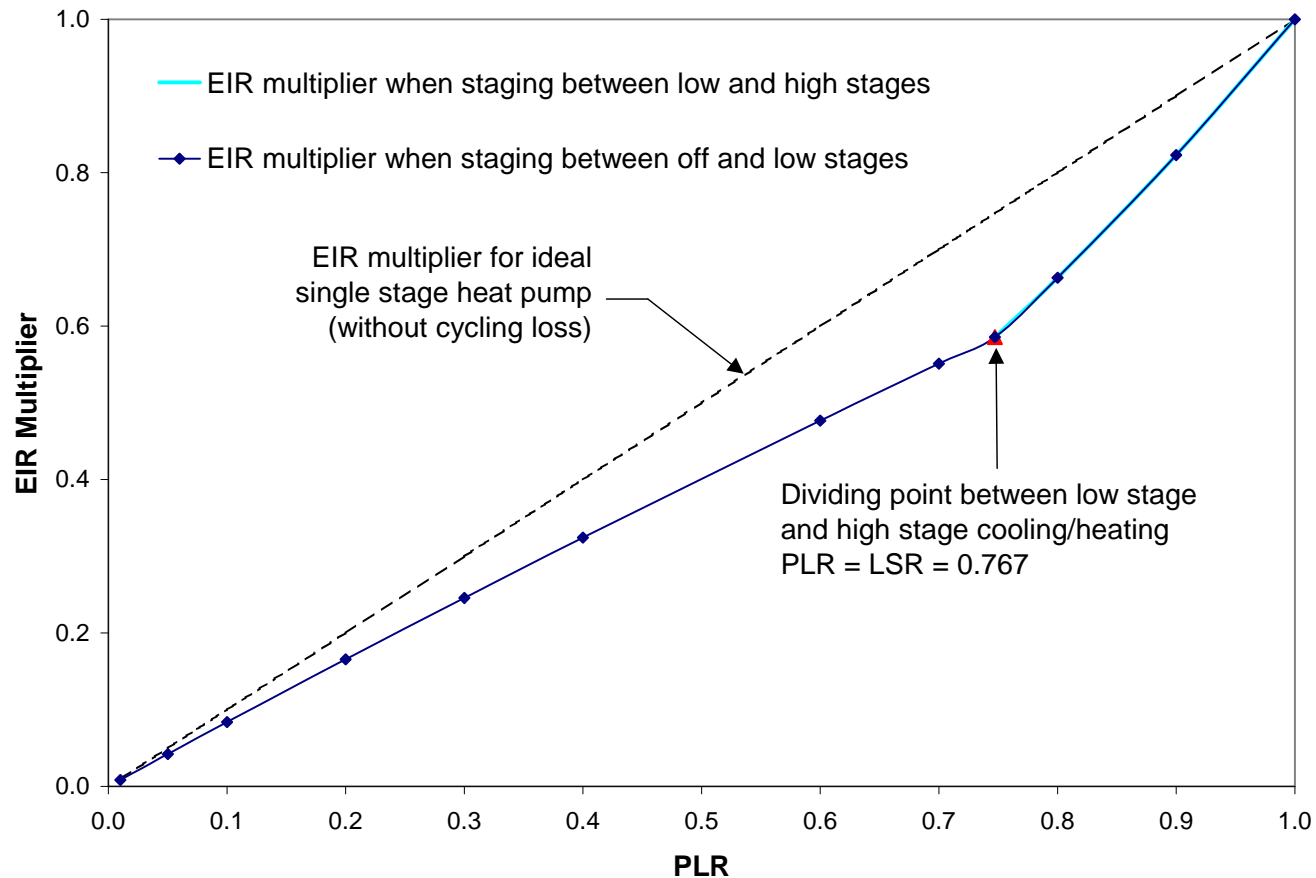
Normalized Total Heating Capacity



Due to the similarity, the average of the non-PLR curves at two stages is used to represent the characteristics of the heat pump and DOE-2 does not distinguish whether the compressor runs at low or high stage.

Example of Two-stage Performance Curves

EIR as a function of PLR



Verification and Validation

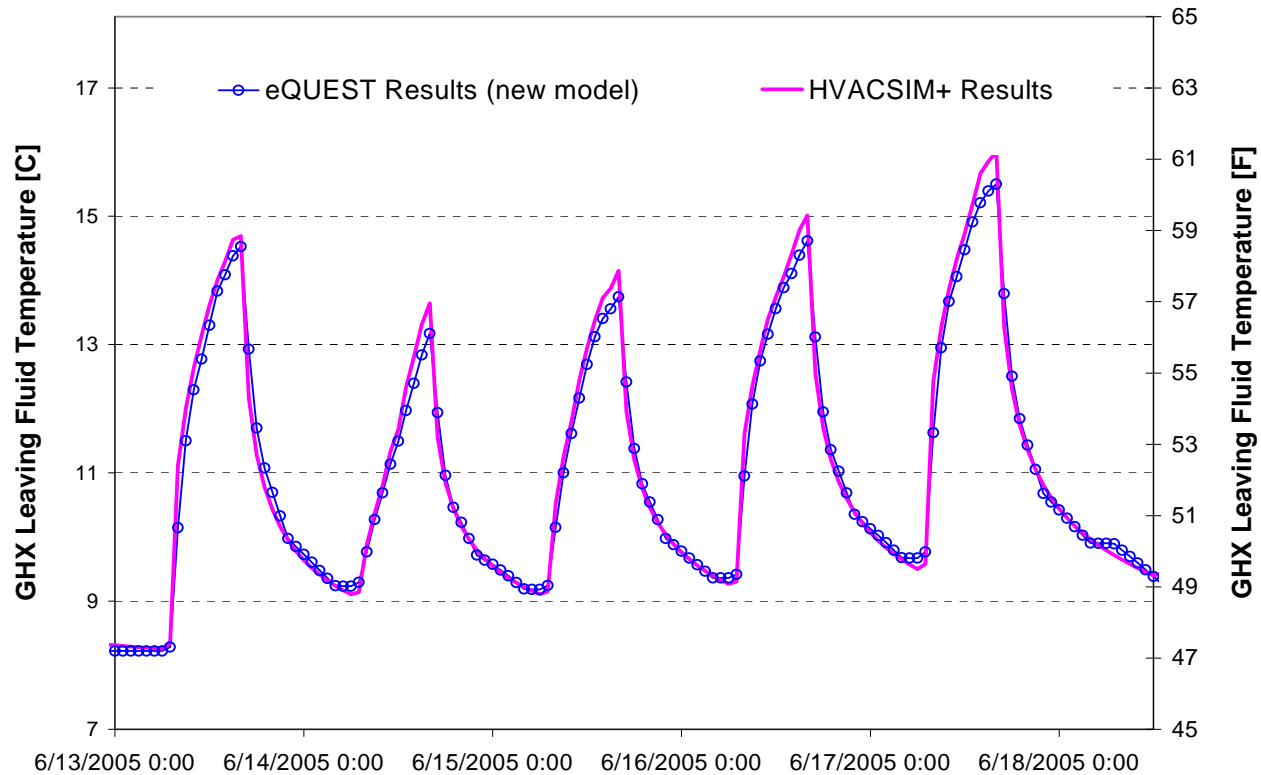
- Verification of newly implemented g-function based VGLHE model
- Sensitivity study through parametric runs
- Validate predicted whole building and GHP system energy consumption with monitored meter level data
- Validate predicted whole building and GHP system performance (including energy consumption, loop/room temperature, and etc) with detailed component level data *

* *Ongoing process using monitored data from a fully instrumented Zero Energy Home.*

Verification and Validation

VGLHE Model Verification

Enhanced eQUEST vs. HVACSIM+ (experimentally validated model)

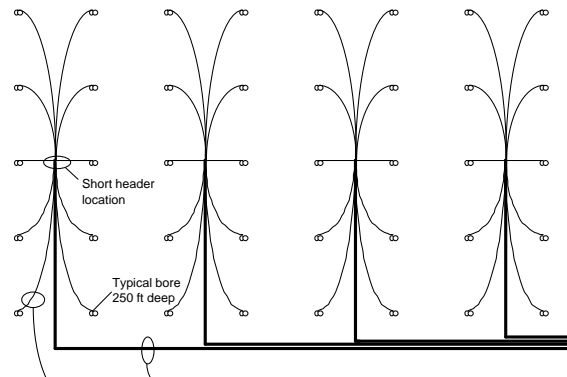


Verification and Validation

Validation with Meter Level Data (1)

Garrett Geothermal Buildings

20,000 sf office conditioned by 50 ton GSHP

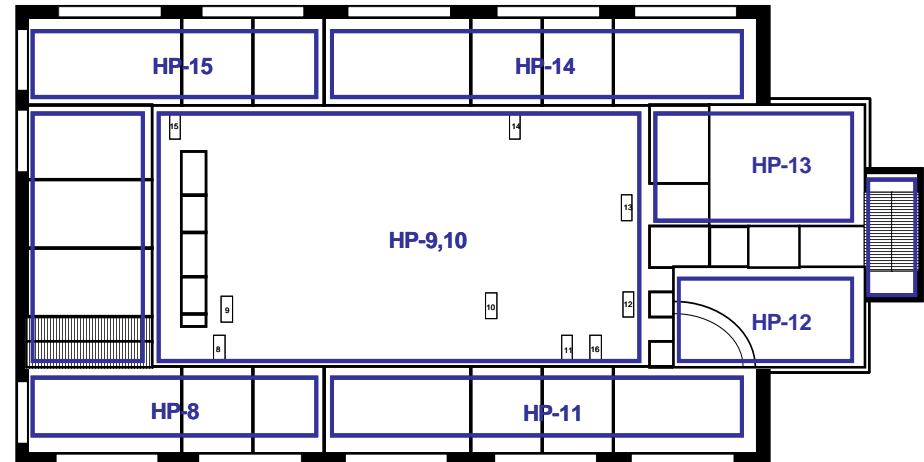


VGLHE

- 40 boreholes
- 5 by 8 grid
- 250' deep
- 20' spacing
- 4.5" bore diameter
- 3/4" PE U-tube
- Standard grout

Zoning

- Two floors
- 7 perimeter zones each floor
- 1 core zone each floor
- Each zone conditioned with individual water-air heat pump

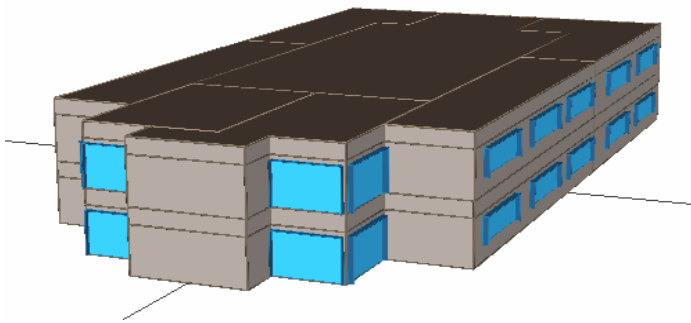


Verification and Validation

Validation with Meter Level Data (2)

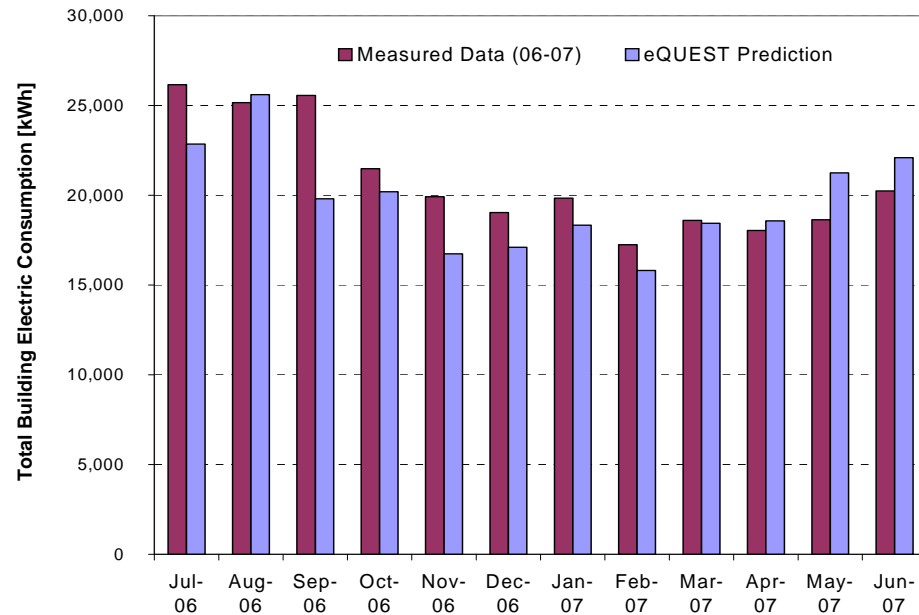


Garrett Geothermal Building



Thermal Model 3-D view in eQUEST

Monthly Electric Use (kWh)



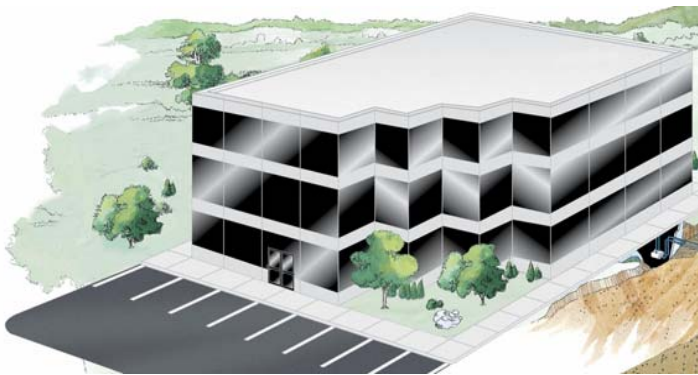
Annual Total Electric Use (kWh)

Metered	Predicted	Error
249,920	236,790	5%

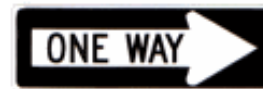
Integrated Simulation-Based Design

- No hassles any more in transferring data among individual programs

Estimate **building loads** using various tools/software



Size **ground heat exchanger** using OTHER tools/software



- Assess GHP system design by examining the system performance in virtual reality

Integrated Simulation-Based Design

- Document energy savings for LEED certification, energy efficiency incentives, and etc.
- Optimize design of high performance building toward the goal of Zero Energy



Zero Energy Home

GSHP

ERV

PV panel

Better insulation

Double low-e windows

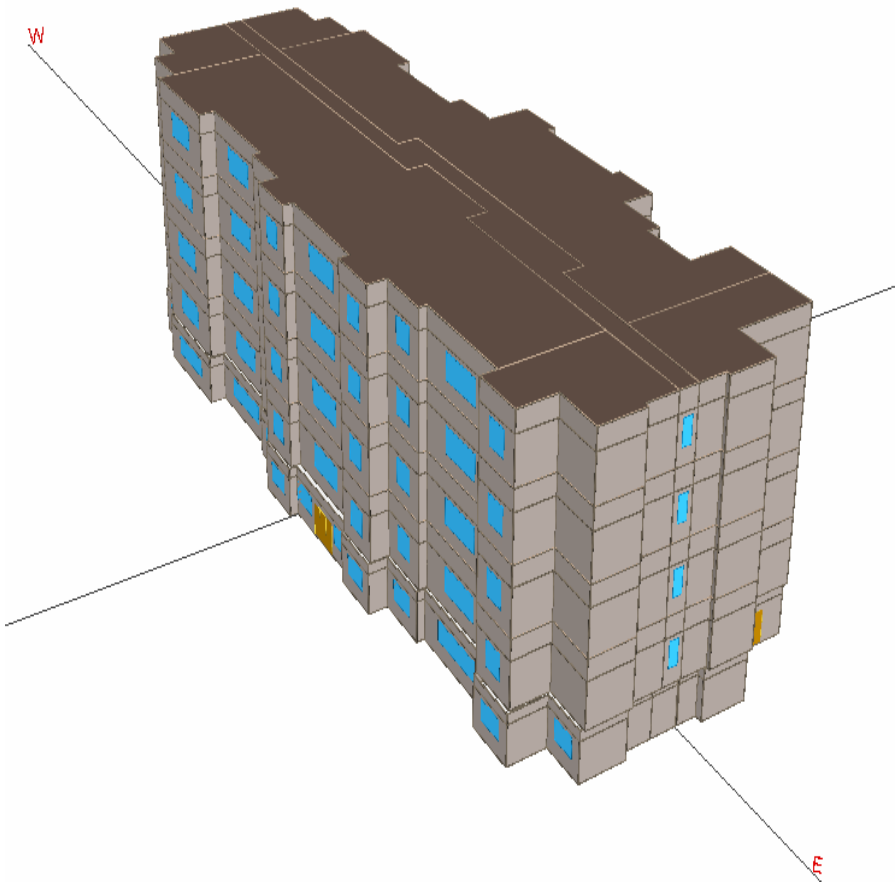
Compact Fluorescent Lights

Energy efficient appliances

The above illustration is from <http://www.ideal-homes.com/>

Applications

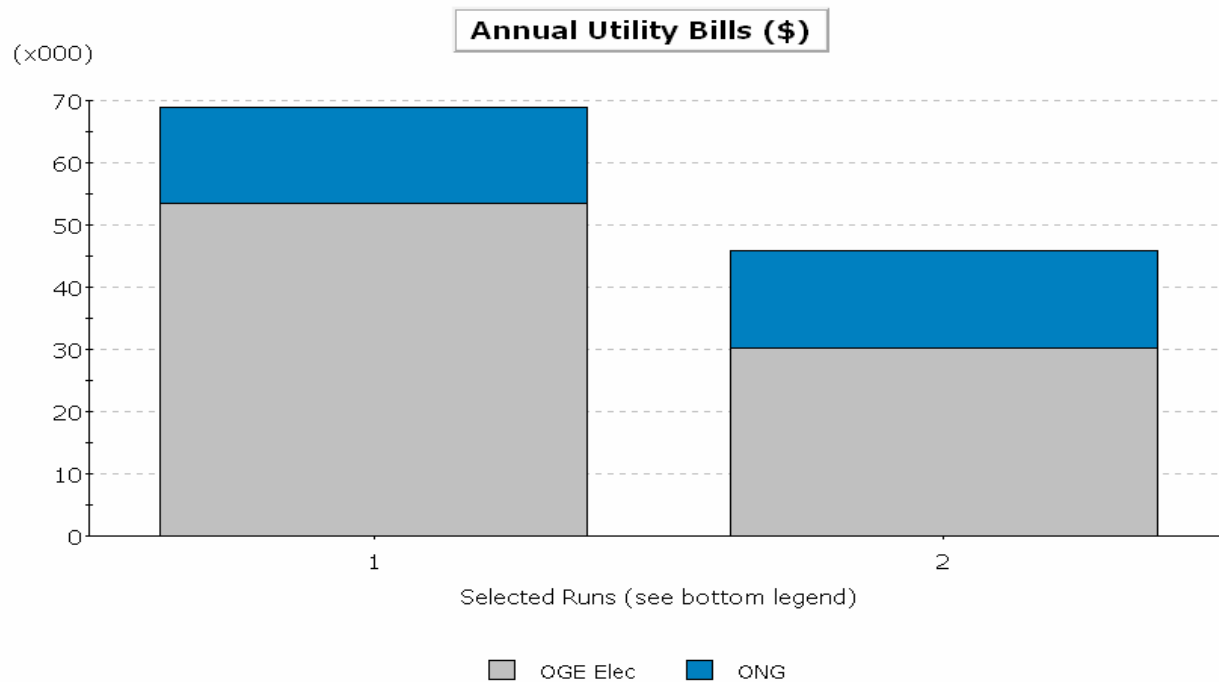
Example of HVAC Systems Comparison (1)



- Building Type: Hotel
- Area: 66,000 sf
- Candidate HVAC systems
 - ✓ PTAC with electric heater
 - ✓ GHP with VGLHE
- Equipment efficiency
 - ✓ PTAC: EER 8.8
 - ✓ GSHP: EER 18.5; COP 4.0
- Utility rates: OG&E PL-1 SL-5

Applications

Example of HVAC Systems Comparison (2)



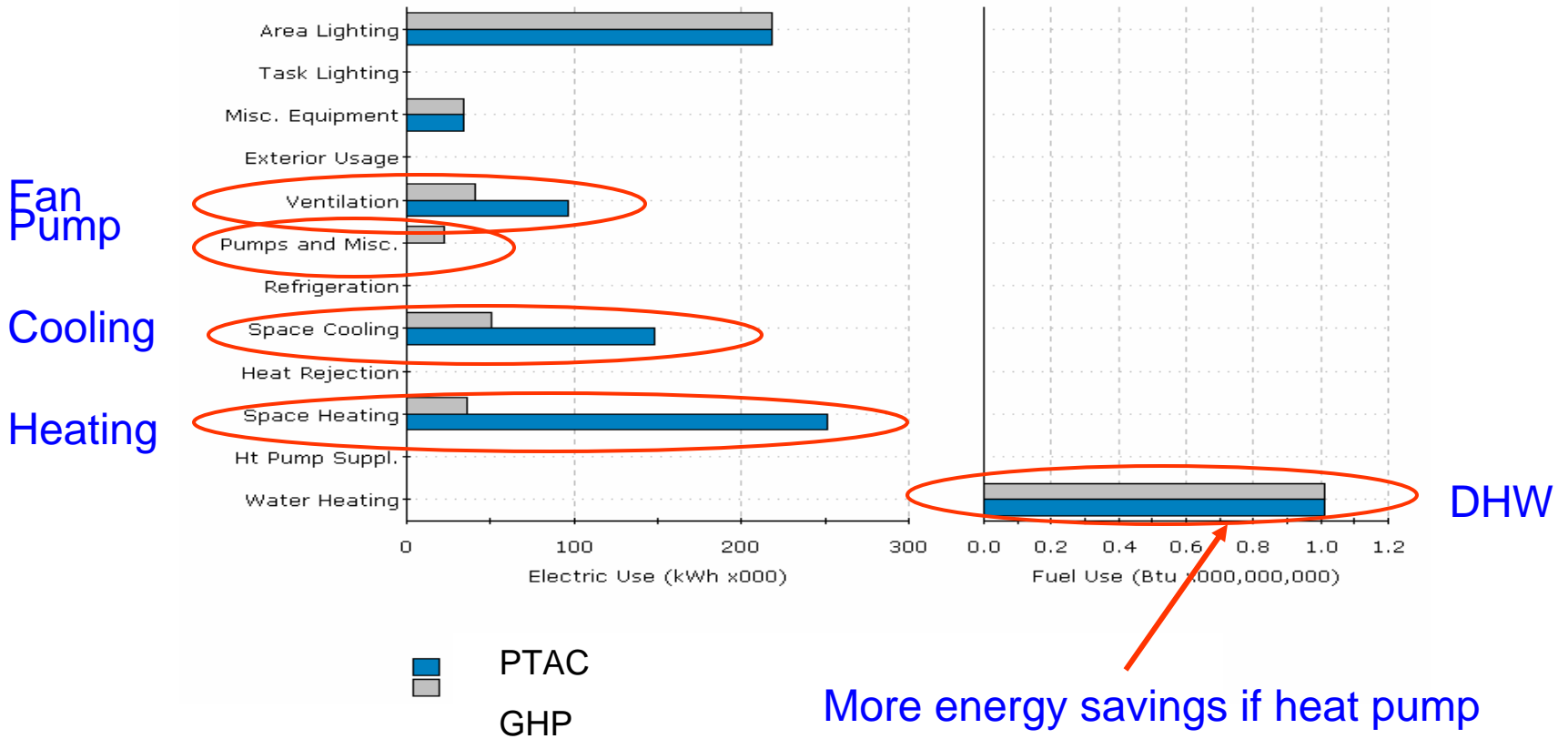
1: PTAC (\$ 69,012)

2: GHP (\$ 45,834)

Applications

Example of HVAC Systems Comparison (3)

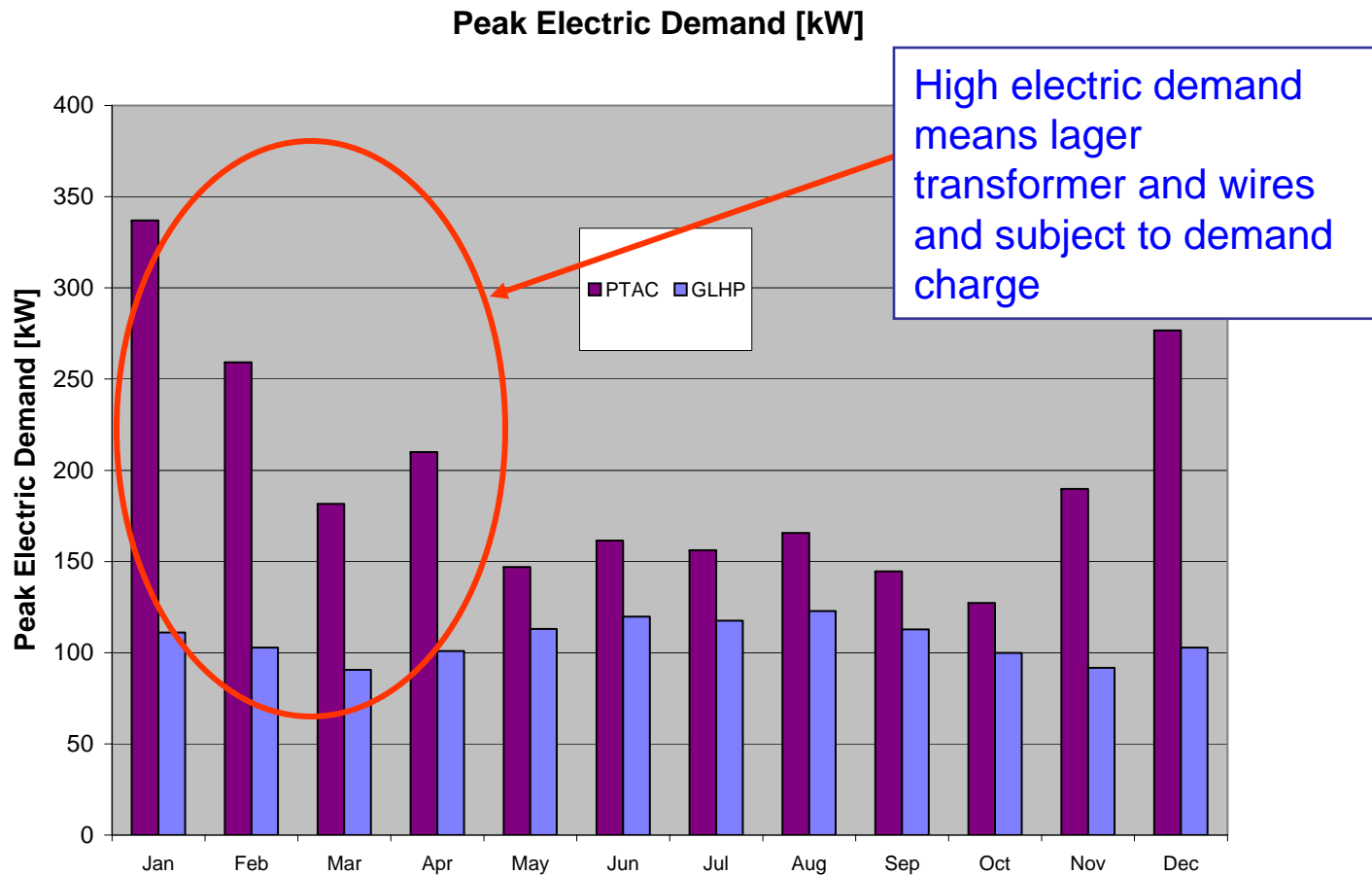
Annual Energy Consumption by Enduse



More energy savings if heat pump condensing heat is used for DHW

Applications

Example of HVAC Systems Comparison (4)



This graph is made with Excel using the hourly results predicted by eQUEST

Applications

Sizing GHX with eQUEST

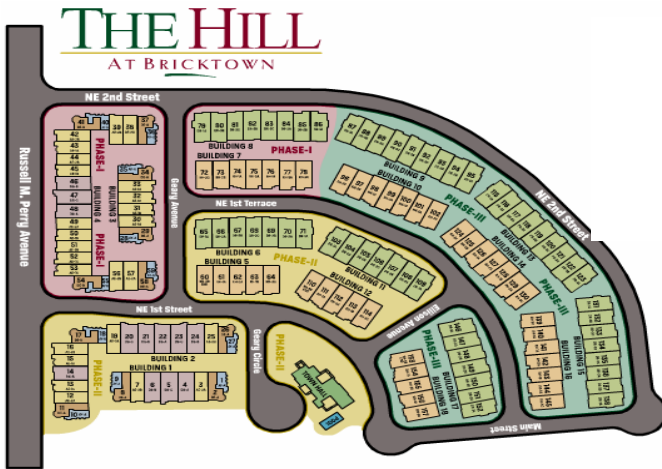
- GHX can not be automatically sized by eQUEST
- The default GHX parameters of eQUEST may be only valid for small commercial buildings
- “Rule of Thumb” of GHX design (i.e. 200 ft bore per ton) may be used as a starting point of the simulation-based design of the GHX
- Iterative process

“Rule of Thumb” → Initial run → Examine hourly report of GHX leaving fluid temperature (LFT) → Adjust GHX parameters → Run simulation

Repeat until LFT within the specified loop temperature range

Applications

Example of GHP System Design (1)



157 town homes grouped in 18 buildings

Varying in height from 2 to 4 stories

Ranging in size from 1600 sf to 3517 sf

Over twenty-six floor plans

Challenges in design

- Boreholes are limited in garage only
- Attached homes but with individual loop for each home
- Very short time for design

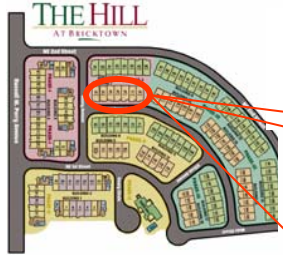
Solution

- Integrated simulation with customized g-function for VGLHE modeling

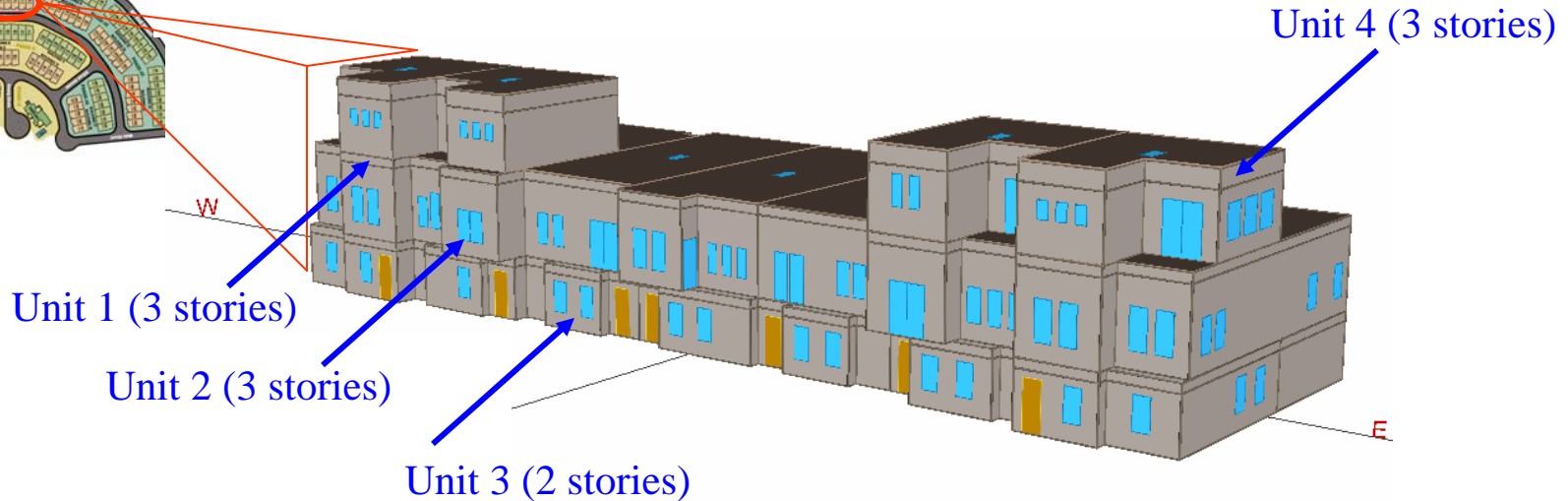
Result

- VGLHE size varies from 200 – 280 ft/ton depending on location, orientation, window/wall ratio of each town home

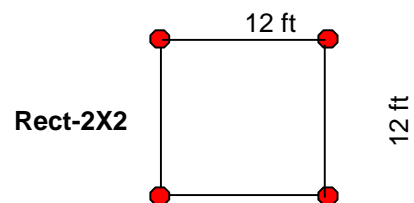
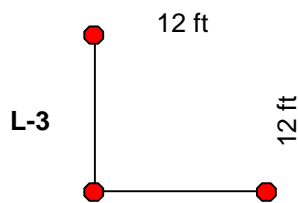
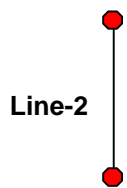
Applications



Example of GHP System Design (2)



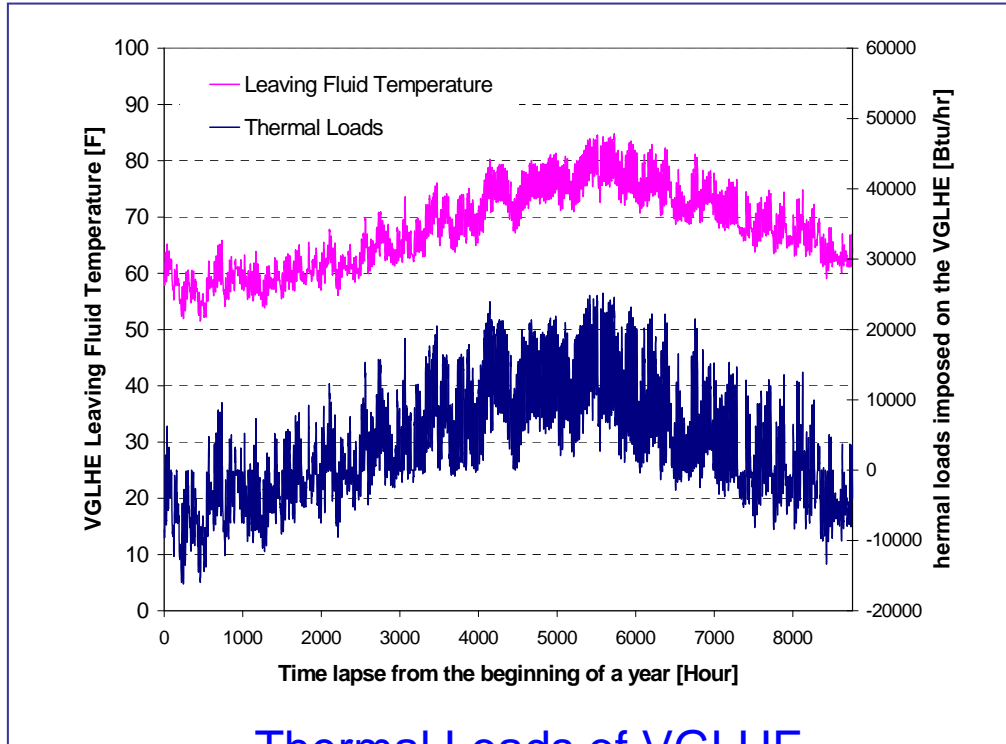
Dwelling Unit		Heat Pump		VGLHE						
Index	Area ft ²	Clg Tons	SF/Ton	Config	Num. of bore	Bore depth	Total bore length	bore length / ton	Min LFT	Max LFT
1	2,698	5.5	491	Rect-2X2	4	360	1440	262	51.9	96.5
2	2,630	4.5	584	L-3	3	300	900	200	50.5	96.0
3	2,045	3.0	682	Line-2	2	320	640	213	51.5	96.5
4	2,698	5.0	540	Rect-2X2	4	320	1280	256	51.1	95.7



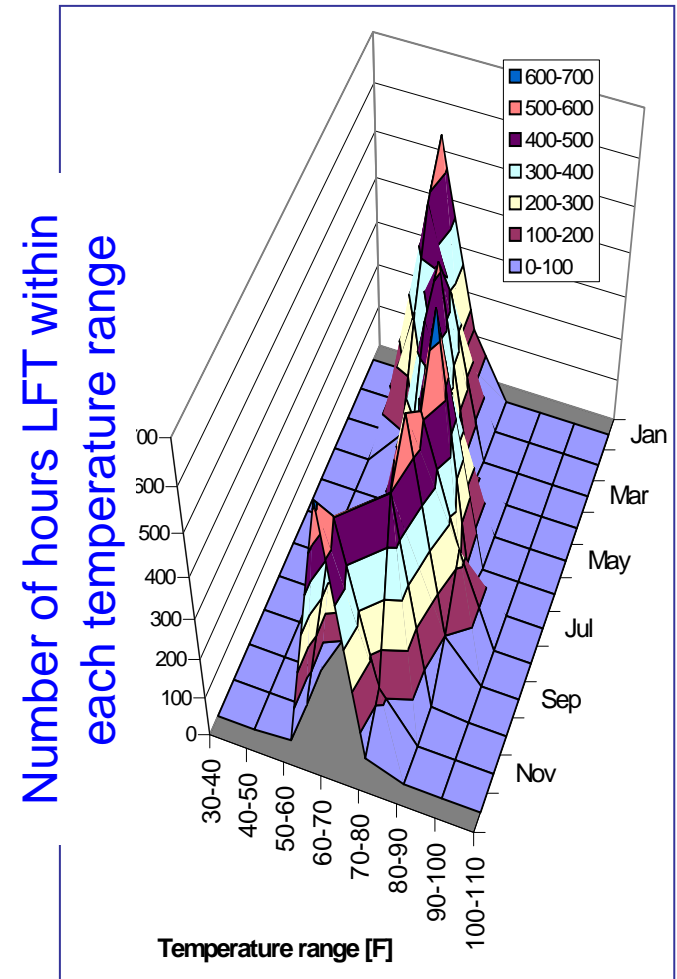
Applications

Example of GHP System Design (3)

The graphs are made with Excel using the hourly results predicted by eQUEST



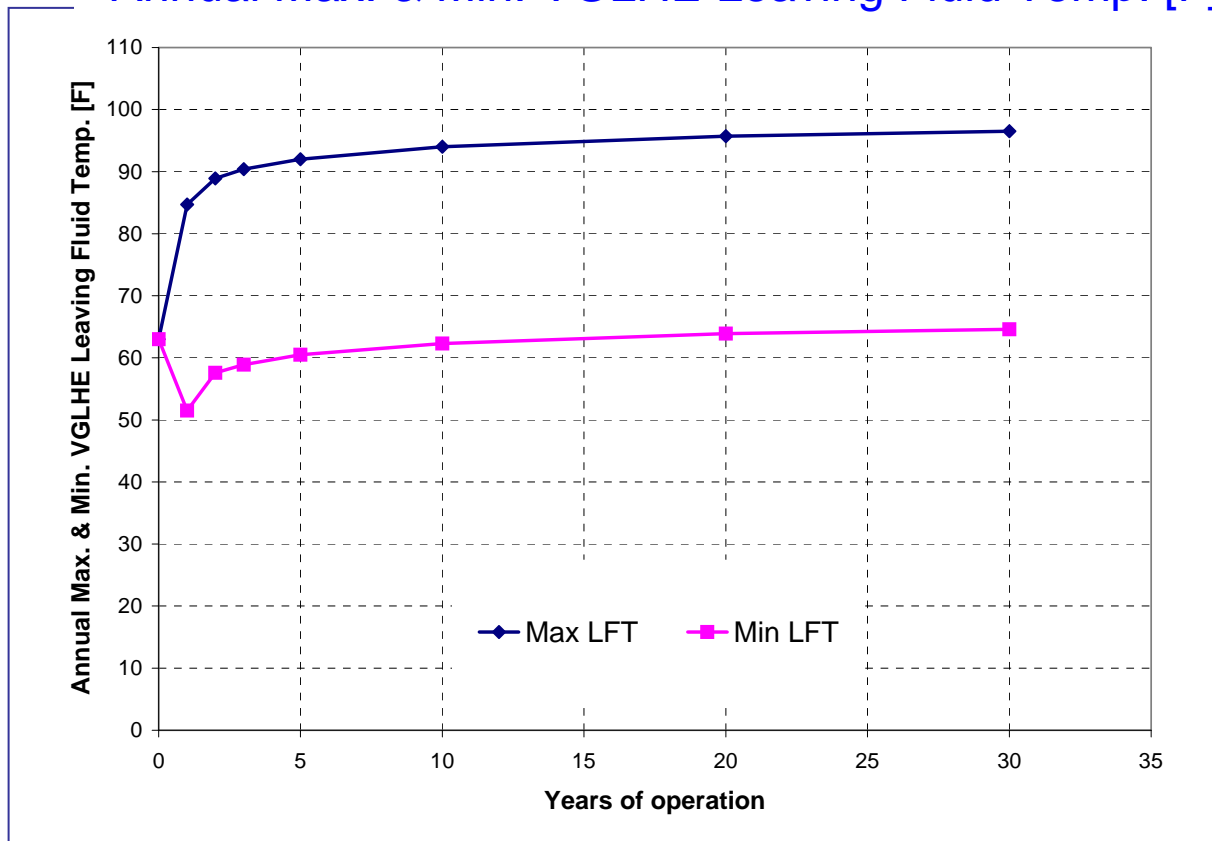
Thermal Loads of VGLHE
and Leaving Fluid
Temperature



Applications

Example of GHP System Design (4)

Annual Max. & Min. VGLHE Leaving Fluid Temp. [F]



This graph is made with Excel using the hourly results predicted by eQUEST

Summary

- To overcome hurdles in GHP system design, eQUEST has been enhanced to facilitate the integrated simulation-based design process
- Extensive efforts have been conducted to validate the enhanced eQUEST and more intensive validation is ongoing
- The enhanced eQUEST is making revolutionary change in GHP system design

Limitations and Future Enhancements

- Prediction of GHP system long-term performance
- Hybrid GHP systems: combination of a variety of heat sink and/or source
- Geothermal water-water heat pump with integrated domestic hot water heater
- Other types of GHX, including horizontal loop, pond/lake, standing column well, and other emerging technologies



Geothermal Heat Pump System
A smart solution for energy efficiency

Thank You!

Questions?