GeoExchange™: The "Other" Geothermal

Advances in Geothermal Direct Use Workshop

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Major Geothermal
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Direct Use vs. GeoExchange

Direct Use	GeoExchange
Requires active geothermal resource	May be installed nearly anywhere
Direct use for heating to electrical generation, to binary strategies to exploit the resource	Utilizes a heat pump to reject and extract heat from an earth coupled heat exchanger
May use surface resources (hot springs) or more commonly wells	Closed loop heat exchangers include vertical, horizontal and surface water types
Development infrastructure can range from simple to complex	Open loop heat exchangers range from source and reinjection wells, to standing column wells

Direct Use vs. GeoExchange (continued)

Direct Use	GeoExchange
Development infrastructure can range from simple to complex	Open loop heat exchangers range from source and reinjection wells, to standing column wells
Quality and quantity of the resource determines limits of use	May be sized for the smallest residential needs to the largest commercial facilities
Lifespan dependent upon resource variables, maintenance and application	Heat pump typical lifespan 20+ years, closed loop heat exchangers 50+ years
Permitting varies but may include extensive environmental studies and consideration of mineral rights	Permitting minimal for most jurisdictions

Definition of a Heat Pump

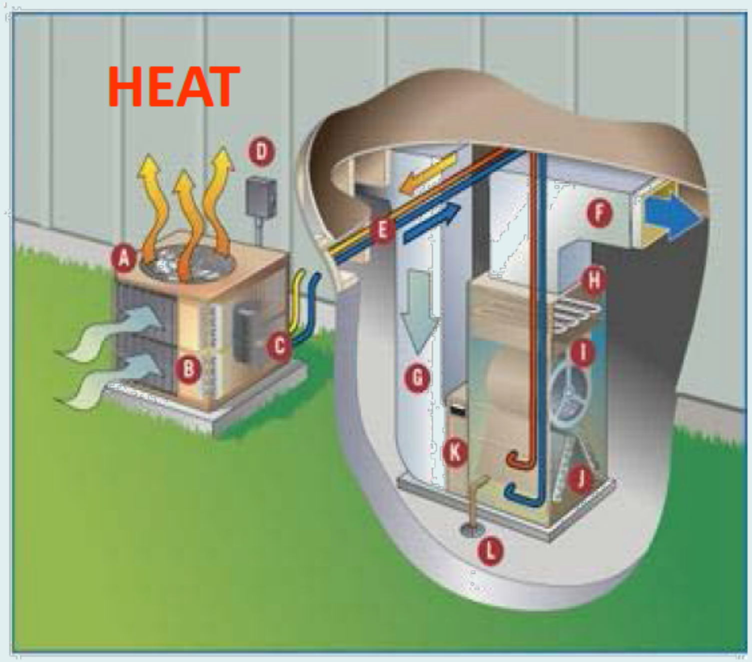
- What is a heat pump?
  - According to the second law of thermodynamics heat cannot spontaneously flow from a colder location to a hotter area
  - Any mechanical device that moves energy from one space to another is considered a ‘heat pump’
  - Modern heat pumps rely on refrigerants that easily change phase from liquid to gas and back to achieve heat transfer
- Examples:
  - Brine plants used to make ice
  - Ice rink plants
  - Refrigerators
  - Air conditioners
  - Reversing air conditioners – air source heat pumps
  - Ground source heat pumps

GeoExchange – Ground Source Heat Pump Technology

Heat Pumps – Common Examples

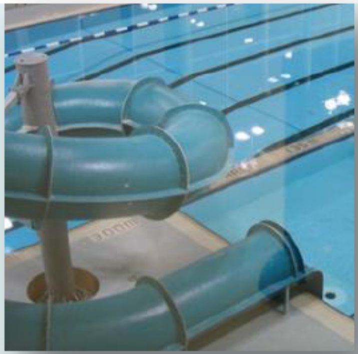
Air conditioners and air-source heat pumps transfer heat from inside houses to the air outside

Refrigerators transfer heat from food into the kitchen



Heat Pumps – Bigger Examples

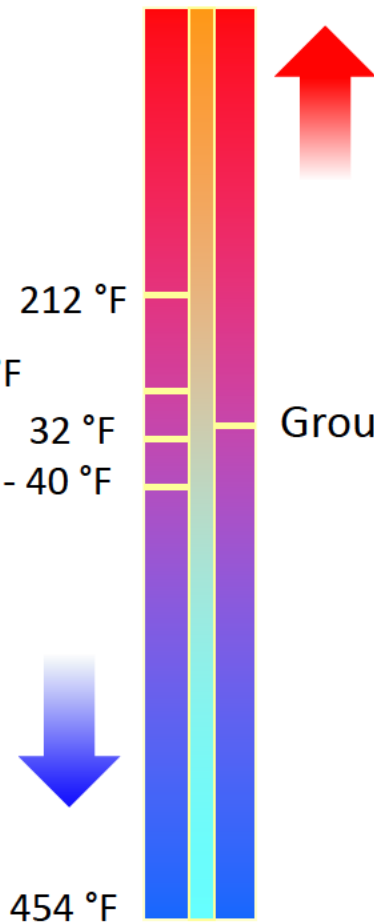
The average sheet of ice for a hockey rink can heat two or more Olympic size swimming pools, with heat to spare, simply by extracting heat from the ice sheet.



Heat Pumps – History

- Heat pumps are not new -
  - 1748: William Cullen demonstrates artificial refrigeration
  - 1834: Jacob Perkins builds a practical refrigerator with diethyl ether
  - 1852: Lord Kelvin describes heat pump theory
  - 1855–1857: Peter Ritter von Rittinger develops and builds the first heat pump
  - Ice-making ammonia brine plants were in use in the latter part of the 19th century

Heat Pumps – The Amount of Energy in Mass Determines Temperature



Greater energy density in mass – gas,fluid, solid – will result in a higher temperature

Less energy density in mass – gas,fluid, solid – will result in a lower temperature

Energy (heat) can potentially be recovered from anything above absolute zero

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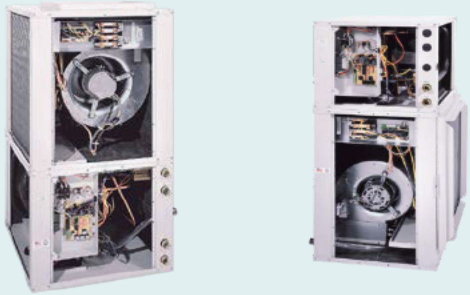
Ground Source Heat Pumps
Sizes and configurations for every application



Upflow & Downflow
Packaged

Water-to-Water

Outdoor Split

Indoor Split

Horizontal Packaged

Console

Commercial Roof Top

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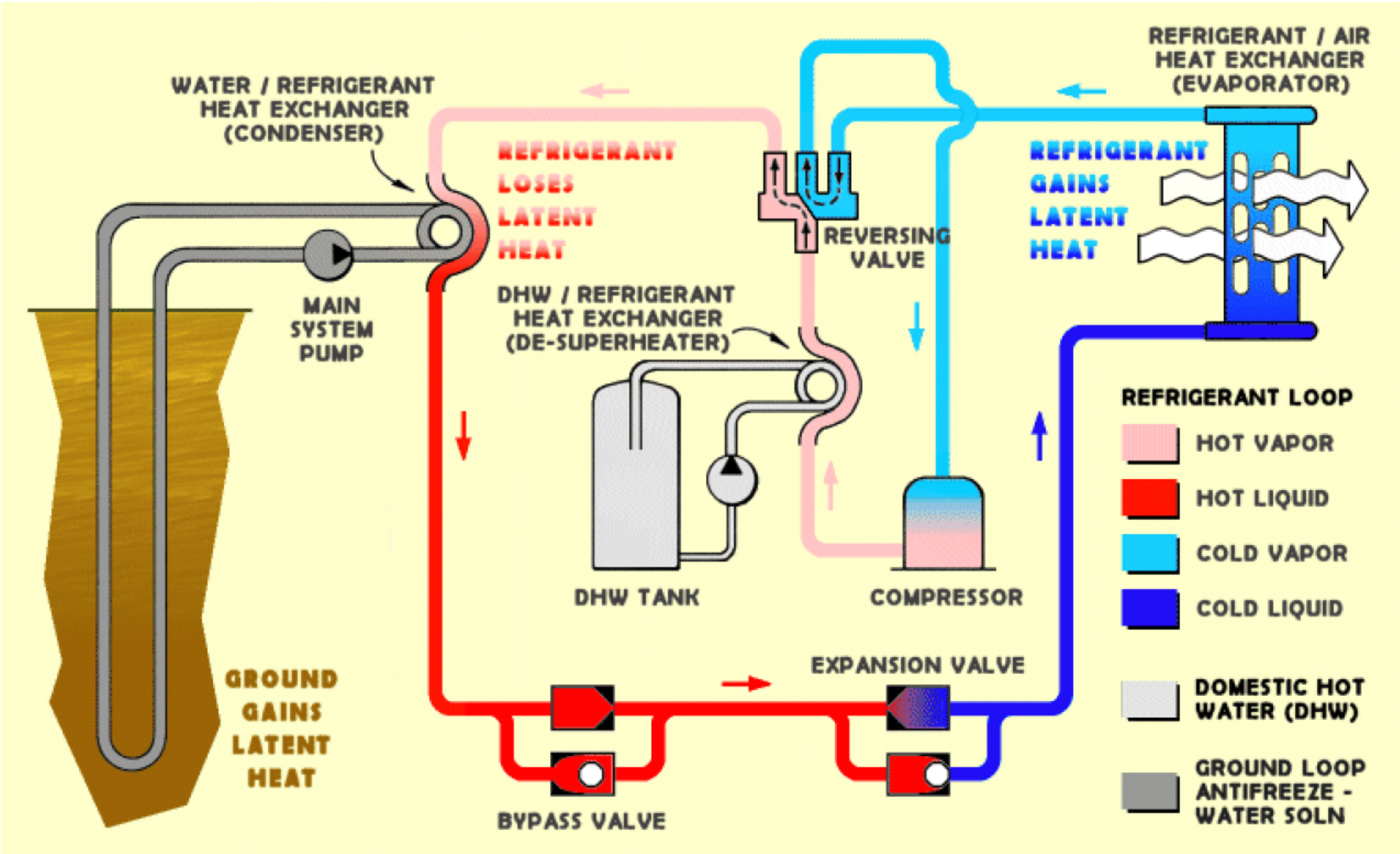
Fundamental Operation – Refrigeration Cycle, Cooling



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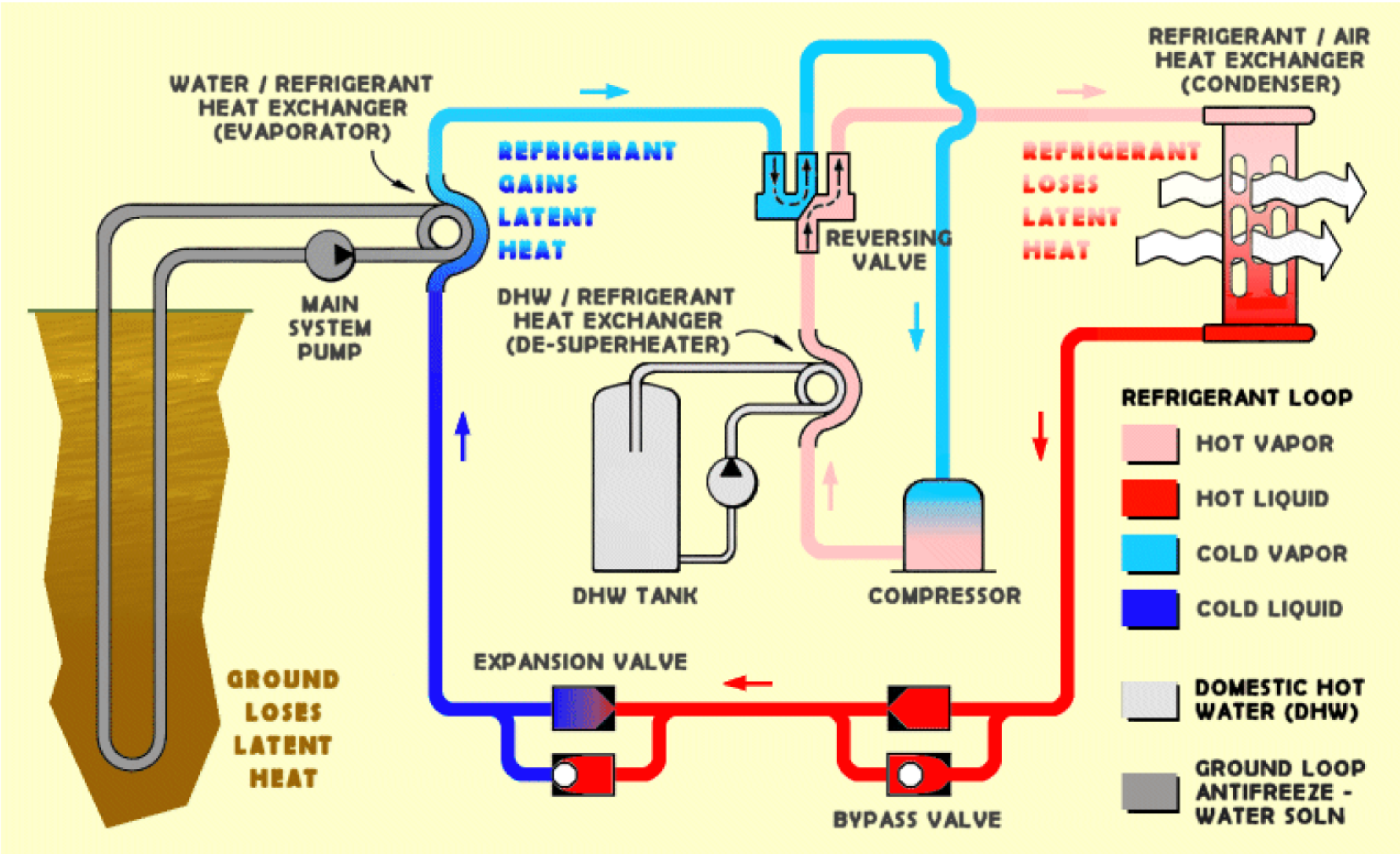
Fundamental Operation – Refrigeration Cycle, Heating



Types of Earth Coupled Heat Exchangers

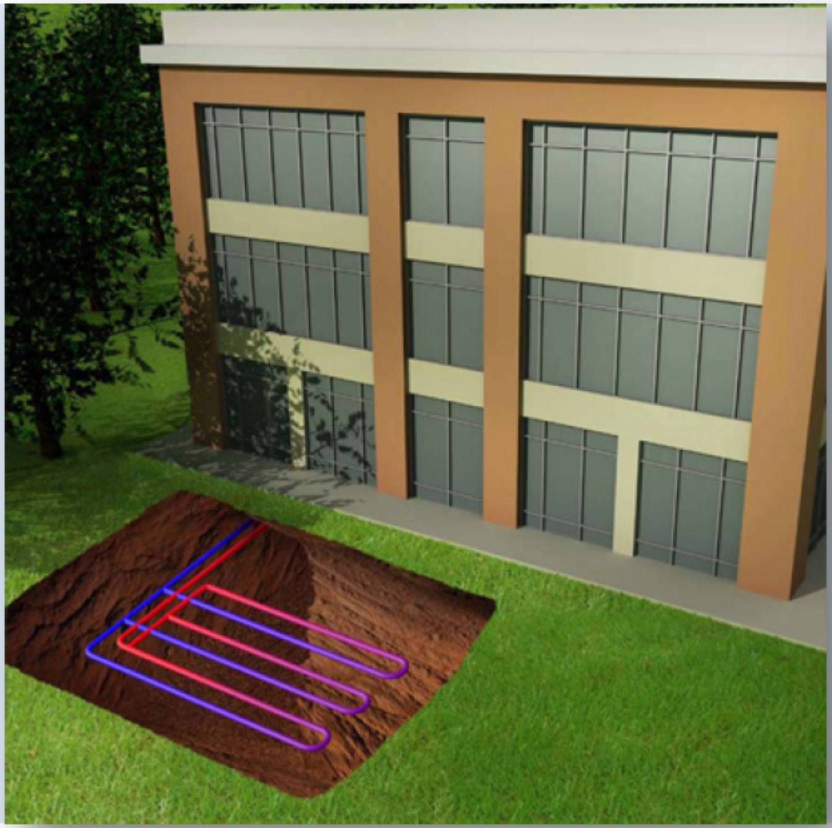
Vertical ground heat exchanger

Types of Earth Coupled Heat Exchangers

Typical vertical GHX installation, most common for applications with limited space

IKEA store, Merriam, KS 2013-2014

Types of Earth Coupled Heat Exchangers



Horizontal ground heat exchanger

Types of Earth Coupled Heat Exchangers

An often overlooked ground loop option for closed loop systems are horizontal heat exchangers where space and conditions permit.

Delaware Air National Guard, Newcastle, DE - 2009

Types of Earth Coupled Heat Exchangers

Surface water heat exchanger

Types of Earth Coupled Heat Exchangers

Lake plate surface water heat exchanger,
prior to filling pond with water

Paepcke Events Center, Aspen Institute - 2010

Types of Earth Coupled Heat Exchangers

Open loop heat exchanger

Types of Earth Coupled Heat Exchangers

Open loop example, source and re-injection water wells

Law enforcement facility, Nueces County, TX - 2014

Why some GSHP installs are problematic or fail:

The dreaded "Rule of Thumb" procedure

Used by inexperienced engineers, contractors, architects and cost estimating firms. GeoExchange, while simple in fundamentals, design, and installation, does not tolerate assumptions well.

GSHP Systems –Design Process Summary

- New construction or retrofit
- Load calculations – *any mechanical design **always** starts with a qualified load calculation!*
  - Peak cooling and heating loads only required for most residential (climate determines loads)
  - Hourly cooling and heating loads for commercial (internal loads dominate)
- Selection of heat pump(s)
- Delivery system to be matched to HP performance
- Ground heat exchanger design
  - Combines load values, HP type(s) and efficiency and geologic considerations (thermal conductivity values)

GSHP Systems –Design Process Summary, Residential

Peak Load Calculation

↓

Select Heat Pump(s) - Must meet heating and cooling loads, air flow requirements for forced air, or hydronic requirements for radiant floor, baseboard, fan coils, other

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Determine appropriate type of earth coupled heat exchanger – consider available area, if a pond or lake may be used or if a water well system is appropriate

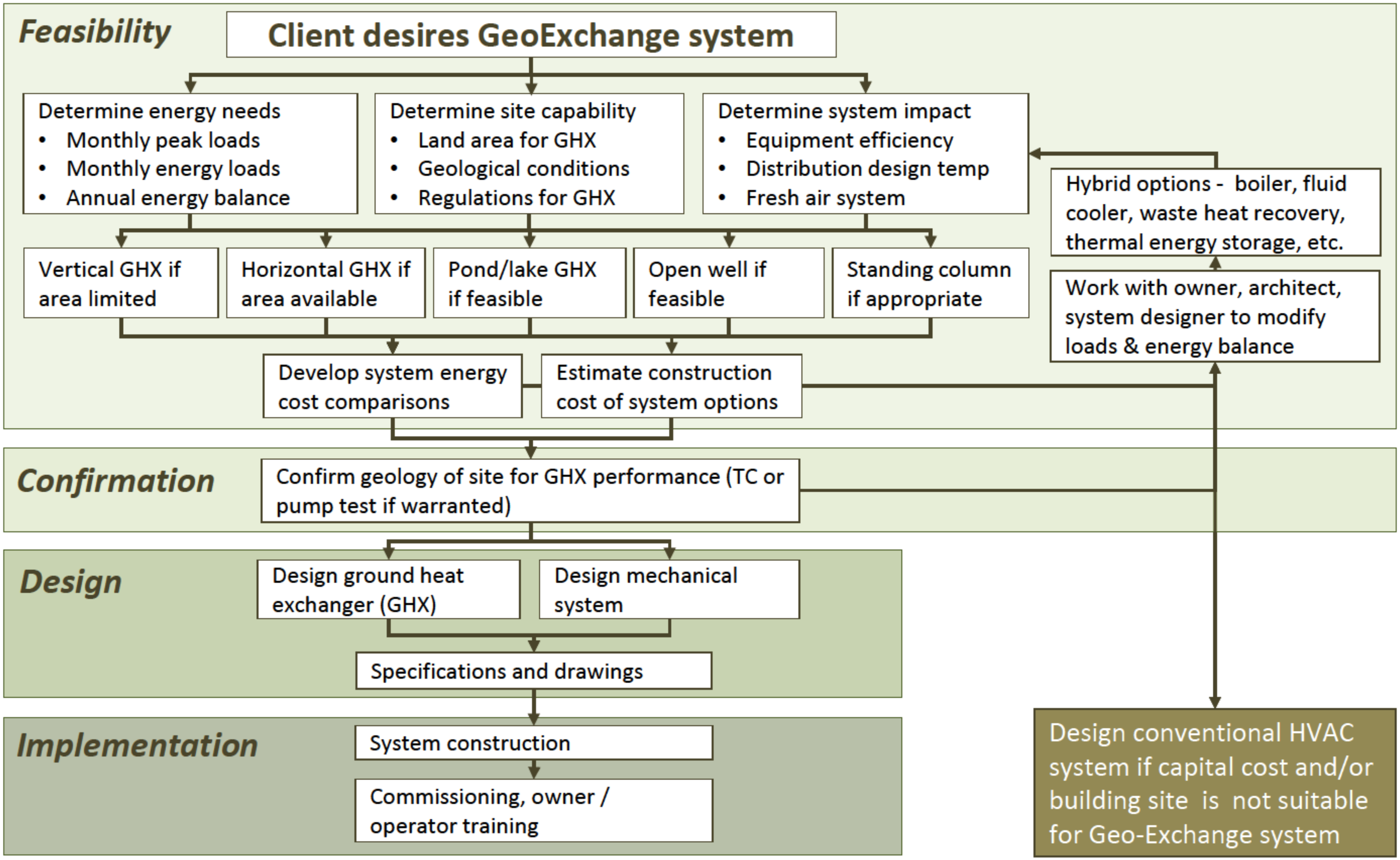
↓

Closed loop GHX – integrate loads, heat pump parameters and geologic variables for final design

Open loop GHX – integrate loads, heat pump parameters to determine water well requirements – *final well design by qualified hydrologist!*

GeoExchange – Ground Source Heat Pump Technology

GSHP Systems – Evaluation and Design Process, Commercial



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Example Applications - Overview

- New construction and retrofit
- Small single family residential with a dedicated ground loop to service a single heat pump
- Large commercial, institutional and municipal with large common ground loops servicing many heat pumps
- District ground loop applications – common ground loop tied to multiple buildings with many heat pumps in each facility

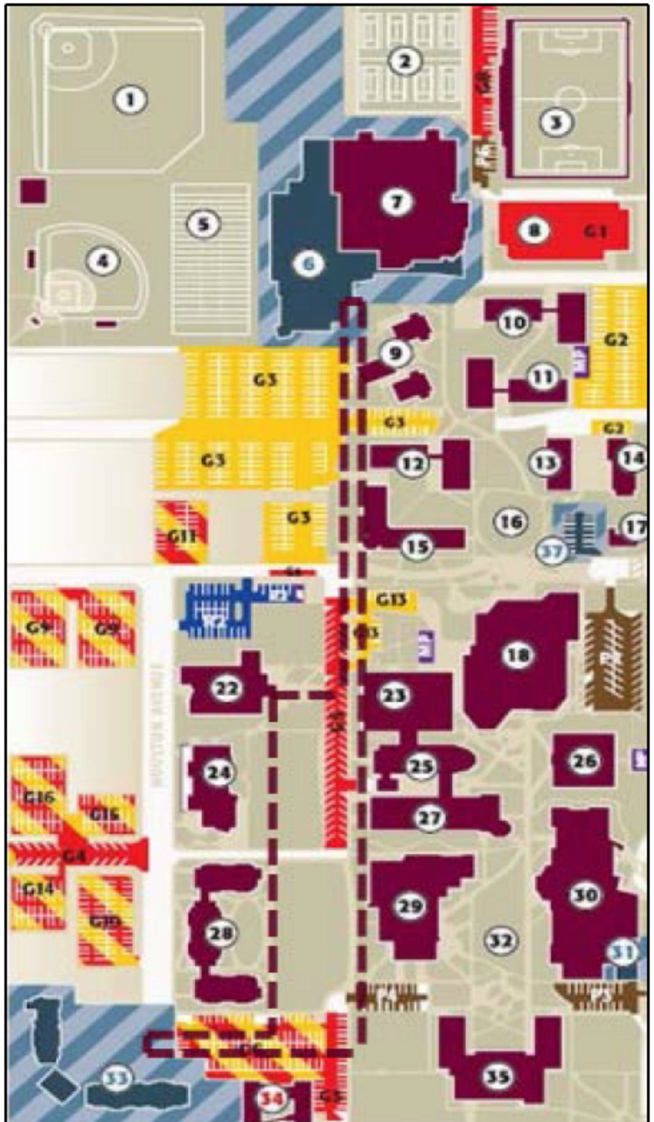
Example Applications - Overview

Single family unit, Boulder County, CO – 1,200 ft^2, horizontally trenched GHX, 3 ton nom. heat pump

Example Applications - Overview

IKEA, Merriam, KS – 360,000 ft^2, 180 boreholes 600' depth, 69 heat pumps total, 761 nom. tons HP capacity

Example Applications - Overview



- District System - Mesa State University, Grand Junction, CO
- 117,000' of vertical borehole
- 2400 nominal tons of HP capacity
- Hybrid supplement (cooling towers)
- Currently 500k ft^2 between 14 buildings (and more to come)

Courtesy of Sound Geothermal

Economics

- GSHP systems can be cost effective regardless of location, scope and size – if properly designed and installed
- Incentives may be available but the technology can stand on its own – proven by the extensive, mature infrastructure supporting the industry
- The following examples will serve to illustrate the efficiency and cost effectiveness of this technology

Economics Example – Josephine Commons Phase I

Josephine Commons Phase I, Boulder County, CO
Completed 2012
Senior Assisted Living Facility

Economics Example – Josephine Commons Phase I

Construction cost, ~78,000 ft² facility

- Total construction cost $12,951,818 - $166 per ft² including site work
  - Mechanical $1,404,414 - $18 per ft²
  - GHX $284,000 – 3.64 per ft² ($14.20 per borehole ft)
- Total GSHP system cost $1,688,414
  - $21.64 per ft² or 13% of total construction cost
- Mechanical costs are comparable to conventional systems *including GHX*
- Economy of scale adds value to GSHP option

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Economics Example – Josephine Commons Phase I

Preliminary projected performance, accounting for all energy reduction measures for lighting, hot water, space conditioning, other:

- ASHRAE 90.1 baseline
- Simple payback of 13.2 years – ***without incentives***
- 46% of total energy use expected for space conditioning
- 31% in energy savings, 42% in cost savings
- Energy Utilization Intensity (EUI) of 52 kbtu/ft^2/yr
- Energy Cost Index (ECI) of $1.02 ft^2/yr, or total utility cost per year of $79,583
- Annual expected savings of $59,297 per year, or $0.76 per ft^2 reduction under baseline of $138,880 annual

Economics Example – Josephine Commons Phase I

Actual energy usage determined from utility invoices for first year of occupancy:

- ***Simple payback of less than 8 years - actual***
- Energy Utilization Intensity (EUI) of 24.3 kbtu/ft²/yr
- Energy Cost Index (ECI) of $0.58 ft²/yr, or total utility cost per year of $45,253
- Operating 68% under ASHRAE 90.1 baseline

Comment from project mechanical engineer - *"I've just finished reviewing the energy bills from the Senior Building on site and it's operating at 24.3 kbtu/sf/yr making it the most efficient facility I know of over 20,000 sf, that's incredible and **it's due in large part to the GSHP system**." – Corey Chinn, P.E., C.E.M., CxA, LEED AP, Farnsworth Group*

Economics Example – Josephine Commons Phase II (Aspinwall)

Completed single family unit

Economics Example – Josephine Commons Phase II (Aspinwall)

- Single family units represented by 9 different floor plans ranging from 650 ft^2 to 1,592 ft^2, total 168 nominal tons
- Heat pumps either 2 or 3 nominal ton units
- Preliminary simulations determined total of 28,800 linear borehole feet for all 72 units using single 400' borehole
- Additional TC testing was completed for anticipated shallower bore depths for single loop HP installations, resulting in total linear borehole reduction to 17,250'
- 40% reduction or ~$130,000 savings *excluding* elimination of headering of multiple circuits
- Detailed simulations determined 200', 250' and 300' single loop depths for specific floorplans

Economics Example – Josephine Commons Phase II (Aspinwall)

Floorplan	Cond'd Space Ft^2 (ea)	Nom. HP Tons	Est'd Annual Op. Cost - $0.068/kwh			
			Cooling	Heating	Total	Cost/SF/Yr
A	885	2.0	$68.20	$36.26	$104.46	$0.12
B	1,186	3.0	$48.01	$85.72	$133.73	$0.11
C	1,455	3.0	$54.58	$122.31	$176.89	$0.12
C-2	1,500	3.0	$55.94	$125.33	$181.27	$0.12
D	838	2.0	$34.04	$94.35	$128.39	$0.15
E	650	2.0	$38.03	$64.83	$102.86	$0.16
F	1,592	3.0	$58.30	$144.44	$202.74	$0.13
G	801	2.0	$37.81	$85.30	$123.11	$0.15
H	759	2.0	$37.15	$97.25	$134.40	$0.18

Operating cost projections for each floorplan

Economics Example – Josephine Commons Phase II (Aspinwall)

Construction cost (estimated, not final)

- Total construction cost $8,919,375 - $125 per ft² including site work
  - Mechanical $1,159,518 – including GHX, 13% of construction total
  - $16.25 per ft² or 13% of total construction cost
- Mechanical costs are comparable to premium residential conventional systems *including GHX*
- ***Simple payback est'd at 4 to 8 years***
- Economy of scale adds value to GSHP option

On the Horizon

- Improved compressor technology (VRF) with integrated controls – heat pumps will only use enough power to satisfy load at any given time - no more, no less
- Thermal rejection and recovery from waste water – potential for substantial reduction in conventional GHX requirements and cost, while ratcheting up efficiency to another level
- Streamlined controls will allow for fewer control points to take advantage of the inherent simplicity of HP operation
- Load sharing technologies to control the interaction between the GHX and building HP system will become ‘smarter’ and ‘learn’ to maximize pumping efficiency
- Better software for residential and commercial system design
- New methods, strategies and hardware for lower cost, higher efficiency GHX installations
- Increase of qualified mechanical engineers, loop designers, looping and mechanical contractors

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