Hybrid geothermal systems: less is more
Lessons learned, impacts and tools

IGSHPA Conference 2014

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www.ecw.org/hybrid
Today’s discussion

- The basics of the hybrid approach
- Buildings we studied, and how we studied them
- Design and operational lessons learned
- Economic / environmental impacts of the hybrid approach
- Resources for you
Ground source heat pump system
Ground source heat pump system

Heating load

Core Heat Pumps

Perimeter Heat Pumps

Building

Pump

Ground HX

Heat absorbed

Temperature (°F)

Time (yr)
Ground source heat pump system

- Cooling load
- Core Heat Pumps
- Perimeter Heat Pumps
- Pump
- Ground HX
- Heat rejected
- Cooling Tower
The buildings (cooling dominant)

Cashman Equipment
300k ft² equipment dealer in Henderson, NV

- Distributed heat pumps
- Dedicated outdoor air
- GHX: 144,000 ft
- Towers: 500 tons (var. spd. fluid coolers)
The buildings (cooling dominant)

East Career and Technical Academy
250k ft² vocational high school in Las Vegas, NV

- Distributed heat pumps
- GHX 168,000 ft
- Towers: 333 tons
  (two spd. fluid coolers)

Courtesy: SH Architecture
The buildings (heating dominant)

**Tobacco Lofts**

74k ft\(^2\) multifamily building in Madison, WI

- Distributed heat pumps
- Dedicated outdoor air
- GHX: 11,300 ft
- Boiler: 199 MBH (condensing)
Cashman and East CTA: Tobacco Lofts: Monitoring
Validation

**GHX Model**
- Within measurement uncertainty

**System Model**
- Within typical design goals (2°F)
The bottom line

...for East CTA

- Conventional HVAC
- GSHP System
- Hybrid GSHP System

Cooling Tower Cost
GHX Cost
Other Costs

Annual Costs ($/ft²)

First Costs

GSHP
Hybrid
Conventional

$8,000,000
$9,000,000
$10,000,000
$11,000,000
$12,000,000
Effective hybrid design/operation
Lessons learned—Cashman/East CTA

To Separate Borefields

Flow Meas.
Temp. Meas.

Towers ramped together
Tower downstream
No antifreeze, low ΔP
Simple, circuited loops, decoupled
Parallel approach (not monitored)

- Simple on-off or VS tower based on downstream temp
- See Xu (2007) for more on control
- Need this approach if: ground loop $\ll$ building load
### Extra care needed in sizing

- Primarily the GHX is oversized
- Systems oversized in general

<table>
<thead>
<tr>
<th>Ground Heat Exchanger</th>
<th>Supplemental Device</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>actual</strong></td>
<td><strong>optimized</strong></td>
</tr>
<tr>
<td>Cashman</td>
<td>144,000 ft</td>
</tr>
<tr>
<td>East CTA</td>
<td>168,000 ft</td>
</tr>
<tr>
<td>Tobacco Lofts</td>
<td>10,900 ft</td>
</tr>
</tbody>
</table>
Focus on part-load pumping

- Size for it
- Control for it
- Consider multiple pumps

Part Load Ratio

Hours

• Tobacco Lofts
• Cashman
• East CTA
Control the tower

- Choose variable speed equipment
- Ramp equipment down quickly
- Tweak setpoints after occupancy
- Don’t pull energy out of the ground!
To precool or not to precool?

Precooling

- Operate tower at night
- Not all night

In ideal case, can save 10%+ of energy cost for pumps/towers

Careful: can also cause energy penalty.
Other control learnings

Boiler

- ‘On’ setpoint should be ~5–10°F below the GHX
- 40°F optimum at Tobacco Lofts
- Facility staff should maintain this setting
Should we avoid heating hybrids?

- Heating dominated: Multifamily in Wisconsin
- Some complexity with boiler hybrid; could consider direct heat…

Diagram labels:
- Preheat
- Baseboard
- Vestibules
- Basement UHs
More bottom line
The bottom line

Energy

- Heat Pumps
- Pumping
- Supplemental

- Tobacco Lofts
- Cashman
- East CTA

<table>
<thead>
<tr>
<th>Energy Use</th>
<th>Tobacco Lofts</th>
<th>Cashman</th>
<th>East CTA</th>
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<tbody>
<tr>
<td>Heat Pumps</td>
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<tr>
<td>Pumping</td>
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<tr>
<td>Supplemental</td>
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</table>
Cost of Energy/Water

- Conventional HVAC
- GSHP System
- Hybrid GSHP System

The bottom line
The bottom line

Life Cycle Savings, over conventional

<table>
<thead>
<tr>
<th></th>
<th>Cashman</th>
<th>East CTA</th>
<th>Tobacco Lofts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid instead of Conventional</td>
<td>10%</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>GSHP instead of hybrid</td>
<td>5%</td>
<td>4%</td>
<td>1%</td>
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</table>

The bottom line
The bottom line: loads dependent

A high-level study with one building: office building
The other bottom line

Carbon Savings (lbs/ft²/yr)

<table>
<thead>
<tr>
<th>Building</th>
<th>GSHP System</th>
<th>Hybrid GSHP System</th>
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<tbody>
<tr>
<td>East CTA</td>
<td>46%</td>
<td>47%</td>
</tr>
<tr>
<td>Cashman</td>
<td>19%</td>
<td>20%</td>
</tr>
<tr>
<td>Tobacco Lofts</td>
<td>11%</td>
<td>14%</td>
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</table>

Courtesy: NREL
Resources
HyGCHP

Ground Heat Exchanger

maximum drilling depth

Ground temperature (at mid-bore depth)
Drilling depth
Bore spacing
Header depth
Center-to-center half distance
Borehole radius
Ground thermal diffusivity
Ground thermal conductivity
U-tube size
Grout thermal conductivity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Ground temperature (°F)</td>
<td>57.0</td>
</tr>
<tr>
<td>Drilling depth (ft)</td>
<td>300.2</td>
</tr>
<tr>
<td>Bore spacing (ft)</td>
<td>20.01</td>
</tr>
<tr>
<td>Header depth (ft)</td>
<td>5.9</td>
</tr>
<tr>
<td>Center-to-center half distance</td>
<td>1.496</td>
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<tr>
<td>Borehole radius (in)</td>
<td>2.244</td>
</tr>
<tr>
<td>Ground thermal diffusivity (ft²/day)</td>
<td>1.076</td>
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<tr>
<td>Ground thermal conductivity (btu/h-ft-°F)</td>
<td>1.400</td>
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<tr>
<td>U-tube size (20mm)</td>
<td>0.75</td>
</tr>
<tr>
<td>Grout thermal conductivity (btu/h-ft-°F)</td>
<td>0.803</td>
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Models

- HyGCHP
- Simulation: Energy Plus, TRNSYS, eQUEST
- Sizing tools: GHLEPro, GLD2010
  - Limited guidance on supplemental device
References

- Kavanaugh – design basics
- OSU – controls information
  - Spitler
  - Xu
  - Others
- More info on this study: www.ecw.org/hybrid
  - Full report
  - Fact sheet
www.ecw.org/hybrid

Contact us to:

- Obtain a copy of the software.
- Obtain a copy of the full report.
- Ask a question.

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