Residential & Multi-Family Community District Geothermal Systems
Why District Systems

• #1 = Diversity
  – Even in heating dominant or cooling dominant climates, there is some diversity in the thermal load profile due to occupancy living habits.
    • Especially in the potable hot water demand.
  – This allows an inter-connected system to have reduced overall size based on block loads.
Why District Systems

• #2 = All Piping Has Heat Transfer
  – Lateral loop piping connecting the homes to the main heat exchanger also have heat transfer.
  • In small systems that energy is not accounted for as it is minimal, but in large scale systems the lateral piping can be a large amount of heat transfer that should be accounted for as it can reduce the overall heat exchanger size.
Why District Systems

• #3 = 3rd Party Ownership
  – Most 3rd party owner/operator/financing companies have capital investment thresholds that need to be met to be a viable project.
  – District Energy systems already have infrastructure precedents and utility models that have been used and are easier to replicate.
  – One at a time per home loop systems don’t offer the same type of financial agreements that a community system offers. Becomes harder to setup and create community wide systems.
Why District Systems

• #4 = Common Hybrid Point of Use
  – Depending on load profile, and many other factors (space, cost, etc.) a hybrid peak shaving and/or backup system could be employed at a single point of use in the system.
  – Allows for one location of the hybrid plant.
  – The sum of the block load peak load is less than the sum of the individual peak loads due to diversity.
Challenges to District Systems:

• #1 = Cost
  – The lateral piping connecting the homes to the heat exchanger location add cost to the total project vs. individual loops per home.
  – Large pump stations to move the fluid from the heat exchanger location to the homes.
  – More volume of fluid and potentially more antifreeze and chemical treatment.
  – Piping within the network of streets with regulated utility infrastructure can be complex and difficult to work through with city, developer, etc.
  – Parasitic energy use (pumping) needs to be kept to a minimum.
Challenges to District Systems:

• **#2 = Space**
  - If you have only one common heat exchanger does the site have enough green space to place the heat exchanger
  - Right of Way space for infrastructure, lateral piping throughout the streets
  - Yard boxes for shut off/service valves for each home
  - Pump station locations
    - Above ground or Below ground
Challenges to District Systems:

• #3 = Logistics/Operations
  – Working through all the red tape with city, developer, civil, etc. for all infrastructure details.
    • Serviceability of assets if any is needed
    • Removal or abandonment process after life cycle (if there is one)
    • Right of Way access agreements
    • If any streets, etc. need to be repaired due to service how it is handled
Step #1 - Developing Thermal Energy Profiles

• Energy Modeling and Utility Metering
  – Chiller/Boiler plant metering
  – Building level metering
• Thermal Peaks and Energy Consumed
  – Base and simultaneous loads
  – Unbalanced heating and cooling loads
• Diversity of Buildings
  – Aggregate loads
  – Simultaneous loads
• Scheduling/Occupancy
• Equipment Efficiency
• Incorporate/Develop Master Plan
  – Renovations
  – Upgrades
Thermal Profiles:
• Heating or Cooling Dominant
• Any Simultaneous Loads
• How unbalanced are the heating and cooling annual loads
• Aggregate the totals for the district
• Determine if any hybrid or alternate source/sink options are available to balance the loads
Step #2 - Select Geothermal Heat Exchanger

**Vertical:**
- Unlimited Capacity
- Multiple Types
- Small Footprint

**Horizontal:**
- Limited Capacity
- Large Footprint
- One Primary type

**Surface Water:**
- Unlimited Capacity
- Average Footprint
- Multiple Types
Step 3# - Select Distribution Systems

Note: Pumping energy and layout is critical to system efficiency
Two Primary District System Designs
Typical Design Practices

#1 = Central Heat Exchanger with 2-pipe distribution system
- This is very similar to a standard building with a common geothermal heat exchanger and multiple heat pumps within the building.
- Large pump stations to distribute the energy throughout development
- Redundancy and resiliency is more difficult with this design
- Need a location for these large pump stations somewhere between the heat exchanger and the development.
  - May have to have multiple pump stations and smaller district systems.
- Can use a single pipe or a two pipe for the distribution piping to the homes.
  - With a single pipe the flow rate decreases in distribution which requires smaller pipe
  - Single pipe can be difficult to get within a +/-3F DeltaT from the first home to the last home within that network of homes.
  - Two pipe system the flow rate increases as well as the pipe size and the pump power increases.
  - Two pipe system adds more space needed to the right of way area for infrastructure.
Common Geothermal HX System 2-Pipe
Typical Design Practices

#2 = Distributed Heat Exchangers with 1-pipe distribution system

- Smaller heat exchangers strategically placed throughout the development injecting into the main ambient distribution loop connecting all the homes.
- Smaller pump stations to distribute the energy throughout development, possibly even under ground in vaults.
- Ambient loop pumping is easy to design around N+1
- If one small heat exchanger goes off line, the entire system is still running at near full capacity.
- Single lateral pipe takes less room for right of way infrastructure access
- Potentially use multiple styles of heat exchangers for best use of site
  - Water retention ponds, horizontals and verticals
- Vertical loops could be located within the street right of way under the lateral pipe right-of-way, so it reduces space constraints
- Easiest method to provide all the homes within a +/-3F DeltaT from the first home to the last home.
- Lower flow rates and smaller pipe sizes for ambient distribution piping
One-Pipe Ambient Geothermal System
Project Examples
Single Family Community Geo System

- Single Pipe Ambient Loop Serves 312 Homes
- 4 Ambient Pump Vaults
- 11 Vertical Loop Vaults/Pods with 12/14 Bores each.
- Built in 4 Phases
- No More than 5F Delta Between homes.
*Lawn Ornaments*
Distributed Geothermal HX System 1-Pipe
• Modeling Single Pipe Ambient systems to locate energy sources in key points within loop to keep the DeltaT between all homes consistent is a key design component.
• Modeling long term health of systems is another key to proper design
Apartment Complex:
• Common loop serves multiple buildings
• 2-Pipe distribution
• Unitary GSHP’s serving each apartment
• GSHP DHW Central System for each building
• Each GSHP has own circulator back to central Pump Station
• 26 Buildings total, 8 GLHX’s total, all under parking lots.
Townhome Complex:
• Common loop serves multiple buildings
• 2-Pipe distribution
• Unitary GSHP’s serving each townhome.
• Central pumping for both the heat pump loop and decoupled ground loop.
• Had to separate into two separate building loops due to difficulty getting to each townhome without cross-overs.
Mid-Rise Condominium Complex:

- Common loop serves multiple buildings (6 towers) separated with plate heat exchangers.
- 2-Pipe distribution loops
- Unitary GSHP’s serving each condominium.
- Central pumping for both the heat exchanger loop and decoupled ground loop.
Aggregate Load Profiles
Apartment Complex (South):

- Common loop serves multiple buildings (6 apartments + Common Blg)
- 1-Pipe distribution loop with 1 Ambient Pump and each building has injection pump to loop
- Unitary GSHP’s serving each apartment.
- Multiple source energy options to balance loop including Pool Htg, DHW Htg, and Solar PV to operate pumps.
Townhome Complex:

- Common loop serves multiple buildings
- 2-Pipe distribution to buildings
- Unitary GSHP’s serving each townhome.
- Central pumping for decoupled ground loop, each GSHP has circulator.
- Pool HX, Desuperheaters, and Dry Fluid Cooler for heat rejection sources.
Downtown Business District:
- Common loop serves multiple buildings (54 stubbed, 14 in Service)
- 2-Pipe Ambient distribution system
- Unitary GSHP’s serving each building.
- Central pumping at each building and at each loop field.
BELLE FARM PDD CONCEPT PLAN
Middleton, Wisconsin

LANDUSE PROGRAM for 30-ACRE SITE
OPEN-TO-BUILT SPACE
RESIDENTIAL USES
1. Open space 20%
2. Built space 30%

PHASE 3
Open Space 12 ac
Built Space 9 ac

PHASE 4
Open Space 18 ac
Built Space 12 ac

PHASE 5
Open Space 6 ac
Built Space 3 ac

RESIDENTIAL USES
1. 40 units 300+ sq ft
2. 20 units 300-350 sq ft
3. 10 units 200-250 sq ft

LANDUSE PROD
1. Apartments
2. Condominiums
3. Multi-units
4. Single family

Soccer Field
Basketball Court

Dog Park
Plaza
Park (West)
Pump House
Green Space
Park (East)

Aggregate Thermal Profile

<table>
<thead>
<tr>
<th></th>
<th>Annual kBTU</th>
<th>Peak kBTU/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Hot Water</td>
<td>18,166,593</td>
<td>3,982</td>
</tr>
<tr>
<td>Heating</td>
<td>34,832,103</td>
<td>10,292</td>
</tr>
<tr>
<td>Cooling</td>
<td>10,308,514</td>
<td>16,170 (1,348 tons)</td>
</tr>
</tbody>
</table>

- Heating Dominant Load
Closed Loop Geothermal Concept w/ Single Pipe

Ambient Loop

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**Bungalow**

- Building Pumps
- Desuperheater Connection
- Cold Water Supply

**Townhome**

- Building Pumps
- Desuperheater Connection

**Commercial**

- Building Pumps

---

**Multi-Family Apt**

- Sewage to Wastewater Plant
- Cold Water Supply

**DHW**

- Sewage to Wastewater Plant
- Cold Water Supply

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**Bore Field Pumps**

**Geothermal Vertical Bore Field**

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**Ambient Loop Pumps**

**DHW heaters / Storage Tanks**

---

**Closed Loop Geothermal Concept w/ Single Pipe Ambient Loop**

- **Bungalow**
  - Building Pumps
  - Desuperheater Connection
  - Cold Water Supply

- **Townhome**
  - Building Pumps
  - Desuperheater Connection

- **Commercial**
  - Building Pumps

- **Multi-Family Apt**
  - Sewage to Wastewater Plant
  - Cold Water Supply

- **DHW**
  - Sewage to Wastewater Plant
  - Cold Water Supply

- **Bore Field Pumps**
- **Geothermal Vertical Bore Field**

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**Ambient Loop Pumps**

---

**Desuperheater Connection**
**DHW heaters / Storage Tanks**

---

**Cold Water Supply**

---

**Ambient Loop Pumps**

---

**Bore Field Pumps**

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## Aggregate Thermal Profiles

### Baseline

<table>
<thead>
<tr>
<th></th>
<th><strong>Annual kBtu</strong></th>
<th><strong>Peak kBtu/h</strong></th>
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</thead>
<tbody>
<tr>
<td>Domestic Hot Water</td>
<td>20,455,607</td>
<td>4,365</td>
</tr>
<tr>
<td>Heating</td>
<td>8,772,480</td>
<td>7,818</td>
</tr>
<tr>
<td>Cooling</td>
<td>21,975,988</td>
<td>16,621 (1,385 tons)</td>
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</table>

### Multi-Family Passive

<table>
<thead>
<tr>
<th></th>
<th><strong>Annual kBtu</strong></th>
<th><strong>Peak kBtu/h</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Hot Water</td>
<td>20,455,607</td>
<td>4,365</td>
</tr>
<tr>
<td>Heating</td>
<td>5,640,964</td>
<td>4,939</td>
</tr>
<tr>
<td>Cooling</td>
<td>20,913,824</td>
<td>14,282 (1,190 tons)</td>
</tr>
</tbody>
</table>

### All Residential Passive House

<table>
<thead>
<tr>
<th></th>
<th><strong>Annual kBtu</strong></th>
<th><strong>Peak kBtu/h</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Hot Water</td>
<td>20,455,607</td>
<td>4,365</td>
</tr>
<tr>
<td>Heating</td>
<td>3,706,275</td>
<td>3,857</td>
</tr>
<tr>
<td>Cooling</td>
<td>20,172,766</td>
<td>13,274 (1,106 tons)</td>
</tr>
</tbody>
</table>
Geothermal Source Heating, Cooling, and DHW

Building cooling peak demands and annual load profile are driving the quantity of bores as peak cooling is much higher than building peak heating or the combination of building peak heating and DHW heating. So, adding DHW heating load to the bore field does not increase the bore quantity/depth. Because the overall annual amount of heat rejected to the field due to cooling load is also much higher than heat extracted from the bore field for heating, extracting additional heat for DHW heating does not increase the bore quantity/depth, and helps reduce the bore quantity that would otherwise be necessary to prevent temperature increase in the bore field due to an unbalanced load.

<table>
<thead>
<tr>
<th>Load</th>
<th>Annual (kBtu)</th>
<th>Peak (kBtu/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW</td>
<td>20,455,607</td>
<td>4,365</td>
</tr>
<tr>
<td>Heating</td>
<td>5,640,964</td>
<td>4,939</td>
</tr>
<tr>
<td>Cooling</td>
<td>20,913,824</td>
<td>14,282</td>
</tr>
</tbody>
</table>
Energy Consumption

<table>
<thead>
<tr>
<th>Energy (kWh)</th>
<th>Baseline</th>
<th>All Elect</th>
<th>Proposed</th>
<th>Proposed wSHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW*</td>
<td>7,493,687</td>
<td>5,994,950</td>
<td>2,210,237</td>
<td>1,736,028</td>
</tr>
<tr>
<td>Heating*</td>
<td>3,213,702</td>
<td>803,425</td>
<td>382,305</td>
<td>338,268</td>
</tr>
<tr>
<td>Cooling</td>
<td>1,690,461</td>
<td>1,997,817</td>
<td>1,024,450</td>
<td>664,942</td>
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<tr>
<td>Fans</td>
<td>833,304</td>
<td>833,304</td>
<td>888,934</td>
<td>888,934</td>
</tr>
<tr>
<td>Pumps</td>
<td>37,760</td>
<td>7,598</td>
<td>616,133</td>
<td>434,412</td>
</tr>
<tr>
<td>Lights</td>
<td>2,947,364</td>
<td>2,947,364</td>
<td>2,947,364</td>
<td>2,947,364</td>
</tr>
<tr>
<td>Plug</td>
<td>4,491,528</td>
<td>4,491,528</td>
<td>4,491,528</td>
<td>4,491,528</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20,707,806</td>
<td>17,075,986</td>
<td>12,560,951</td>
<td>11,501,477</td>
</tr>
<tr>
<td>HVAC Savings*</td>
<td>-</td>
<td>27%</td>
<td>61%</td>
<td>69%</td>
</tr>
<tr>
<td>Total Savings</td>
<td>-</td>
<td>3,631,820</td>
<td>8,146,854</td>
<td>9,206,329</td>
</tr>
<tr>
<td>Total Savings</td>
<td>-</td>
<td>18%</td>
<td>39%</td>
<td>44%</td>
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</table>

* Baseline DHW and Townhome/Bungalow heating are natural gas, but were converted to kWh for comparison purposes

**HVAC savings include heating, cooling, and DHW energy usage
Carbon Emissions

Carbon Emissions (MTCO₂)

<table>
<thead>
<tr>
<th>Category</th>
<th>Baseline</th>
<th>All Elec</th>
<th>Proposed</th>
<th>Proposed wSHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW</td>
<td>1,360</td>
<td>1,027</td>
<td>378</td>
<td>297</td>
</tr>
<tr>
<td>Heating</td>
<td>583</td>
<td>138</td>
<td>65</td>
<td>58</td>
</tr>
<tr>
<td>Cooling</td>
<td>289</td>
<td>342</td>
<td>175</td>
<td>114</td>
</tr>
<tr>
<td>Fans</td>
<td>143</td>
<td>143</td>
<td>152</td>
<td>152</td>
</tr>
<tr>
<td>Pumps</td>
<td>6</td>
<td>1</td>
<td>106</td>
<td>74</td>
</tr>
<tr>
<td>Lights</td>
<td>505</td>
<td>505</td>
<td>505</td>
<td>505</td>
</tr>
<tr>
<td>Plug</td>
<td>769</td>
<td>769</td>
<td>769</td>
<td>769</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,655</strong></td>
<td><strong>2,924</strong></td>
<td><strong>2,151</strong></td>
<td><strong>1,970</strong></td>
</tr>
<tr>
<td><strong>Total Savings</strong></td>
<td>-</td>
<td>731</td>
<td>1,504</td>
<td>1,686</td>
</tr>
<tr>
<td>GHG/SF</td>
<td>0.00185</td>
<td>0.00148</td>
<td>0.00109</td>
<td>0.00100</td>
</tr>
</tbody>
</table>

LL97 Emission Limits

<table>
<thead>
<tr>
<th>Year</th>
<th>MTCO₂/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024-2029</td>
<td>0.00675</td>
</tr>
<tr>
<td>2030-2034</td>
<td>0.00407</td>
</tr>
<tr>
<td>2050</td>
<td>0.0014</td>
</tr>
</tbody>
</table>
Solar PV Energy Savings

- Energy use intensity (EUI) measured in kBtu/ft²-year
- Energy Savings = 23 kBtu/ft²-year

<table>
<thead>
<tr>
<th>Proposed Geothermal EUI (kBtu/SF-year)</th>
<th>Proposed Geothermal + Solar EUI (kBtu/SF-year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 EUI (kBtu/SF-year)</td>
<td>EUI (kBtu/SF-year)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Star Median EUI (kBtu/ft²)</th>
<th>Multifamily Housing</th>
<th>Restaurant</th>
<th>Grocery Store</th>
<th>Office</th>
<th>Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>118.1</td>
<td>573.7</td>
<td>444.0</td>
<td>116.4</td>
<td>120.0</td>
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<tr>
<td>Site</td>
<td>59.6</td>
<td>325.6</td>
<td>196.0</td>
<td>52.9</td>
<td>51.4</td>
</tr>
</tbody>
</table>

Source: MEP
Carbon w/ Solar

LL97 Emission Limits

<table>
<thead>
<tr>
<th>Year</th>
<th>MTCO2/SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024-2029</td>
<td>0.00675</td>
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<tr>
<td>2030-2034</td>
<td>0.00407</td>
</tr>
<tr>
<td>2050</td>
<td>0.0014</td>
</tr>
</tbody>
</table>

Carbon Emissions (MTCO₂)

<table>
<thead>
<tr>
<th></th>
<th>Proposed</th>
<th>Proposed + Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHW</td>
<td>378</td>
<td>378</td>
</tr>
<tr>
<td>Heating</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Cooling</td>
<td>175</td>
<td>175</td>
</tr>
<tr>
<td>Fans</td>
<td>152</td>
<td>152</td>
</tr>
<tr>
<td>Pumps</td>
<td>106</td>
<td>106</td>
</tr>
<tr>
<td>Lights</td>
<td>505</td>
<td>505</td>
</tr>
<tr>
<td>Plug</td>
<td>769</td>
<td>769</td>
</tr>
<tr>
<td>Total</td>
<td>2,151</td>
<td>2,151</td>
</tr>
<tr>
<td>Proposed Solar</td>
<td>-</td>
<td>2,178</td>
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<td>Total Carbon</td>
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<td>-27</td>
</tr>
<tr>
<td>GHG/ft²</td>
<td>0.00109</td>
<td>0</td>
</tr>
</tbody>
</table>
Thank you!

Questions?