Josephine Commons Affordable Housing, Phases I & II
Boulder County, Colorado
Optimized GSHP System Design for Maximum ROI

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Josephine Commons – Affordable Housing Project

Overview – Location Perspective
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Josephine Commons - 455 N Burlington Ave, Lafayette, CO 80026
Historic Background

- The property was originally owned by Rocky Mountain Fuel Company which operated various coal mines in the area, including many beneath the project site.
- The site is named after Josephine Aspinwall Roche (1886-1976), who was the controlling owner of the Rocky Mountain Fuel Company (inherited from her father).
- Josephine Aspinwall Roche was involved in advancing mine safety, mine labor relations and various social causes.
- Ms. Roche was on the cabinet of President Franklin Roosevelt as Assistant Secretary of the Treasury.
• Affordable housing development owned by Boulder County Housing Department, Boulder County, Colorado
• Josephine Commons Phase I consists of 78,023 ft² three level 70 apartment facility with various common areas, and four duplex units of 2,850 ft² total utilizing a common GHX (completed 2012)
• Aspinwall (Josephine Commons Phase II) composed of 72 single family homes totaling 71,355 ft² utilizing a single borehole GHX for each structure and a 12,000 ft² multi-use facility (occupancy beginning 2014 as units are completed)
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Why the GSHP option was shortlisted

Architectural rendering of Josephine Commons
Image - HB&A Architects
BCHA engaged a GSHP pilot project with NREL providing building simulations and evaluation services.


GSHP system was compared to a 95% gas furnace/13 SEER AC/gas water heater installation for duplex residential unit.
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Why the GSHP option was shortlisted

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Why the GSHP option was shortlisted

### Why the GSHP option was shortlisted

<table>
<thead>
<tr>
<th></th>
<th>GSHP – Horizontal Loop Field</th>
<th>Furnace &amp; SEER 13 AC</th>
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<td>Heating Efficiency</td>
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<td><strong>Simple Payback</strong></td>
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</tbody>
</table>
Why the GSHP option was shortlisted

Net zero pilot project ~2 miles south of Josephine Commons project.
Drill rig installing single loop GHX
Site underlain with abandoned coal mines

- Supposedly collapsed or backfilled, subsidence was a concern
- Depth of mines typically 300’ or deeper but could vary
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GHX Design Challenge

Josephine Commons Phase I, district GHX, 50 boreholes

- 5 header pairs x 10 boreholes x 30’ spacing
- 400’ depth, 1.25” DR11 HDPE u-bends
• Preliminary simulations generated from 1st pass mechanical evaluation:
  – Load profiles (8760 hourly)
  – Mechanical schedules (flow rates, HP efficiencies)
  – Available area
  – Contractor capabilities
  – Thermal conductivity ranges determined from area geology
• TC test depth of 400’ determined for best fit for variables allowing for most options for expansion or compression of final GHX requirements
  – 1.29 btuh/ft/°F thermal conductivity
  – 63°F undisturbed temperature
  – 0.66 ft²/day diffusivity
Interactive design team work

- Initial loads overwhelmingly cooling dominant due to ultra-tight construction for apartment facility retaining heat
- Initial GHX simulation of 90 boreholes x 400’ to maintain maximum EWT to heat pumps under 90°F
- Engineer (Farnsworth Group) worked various energy simulations to balance loads – including reducing window efficiency, other – *lowered heat gain, increased heat loss*
- Revised load resulted in greater balance, loopfield reduced to 50 boreholes x 400’
  - 1st cost savings for GHX reduced by $227,000
  - Lower grade windows, less cost
  - Commensurately reduced mechanical component cost (pumps, etc.)
Mechanical configuration

- 2-Pipe packaged heat pump system, most with premium 2 stage compressors and ECM blowers
- Dedicated heat pump for every apartment
- Packaged units used for common area space conditioning
- OA managed by efficient ERV units
- SOO optimized for least adverse impact on loads
- Packaged units used in single family units, 4 total between two duplex units
- GHX is decoupled, allowing for maximum load sharing and least pumping cost
Decoupled pumping

- No three-way valving required, or related controls
- Simple, less infrastructure, fewer control points
- Greater efficiency and reliability
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Phase I

Loop installation
Driller encountered substantial drilling fluids loss during first few borehole installations

Wanted change order to redesign to shallower field specifications (single circuit x two 200’ bores in series) claiming bit was drilling into “open” coal mines – GC bought into this initially and advocated for change order

No drill breaks were observed during drilling, where the drill stem would be expected to drop in voids – design team challenged the change order

~100 lbs. of coarse bentonite hole plug resolved issue on first attempt (why did we have to tell the driller how to do his job?)

Another good reason for the designer to visit job sites during construction!
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Phase I

Two rigs used to speed production
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Phase I

Five 3” header pairs, future mechanical room
Construction cost

- 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
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
- 46% of total energy use expected for space conditioning
- 31% in energy savings, 42% in cost savings
- Energy Utilization Intensity (EUI) of 52 kbtu/ft²/yr
- Energy Cost Index (ECI) of $1.02 ft²/yr, or total utility cost per year of $79,583
- Annual expected savings of $59,297 per year, or $0.76 per ft² reduction under baseline of $138,880 annual
Actual energy usage determined from utility invoices for first year of occupancy:

- Simple payback of less than 8 years
- 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
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Phase I – view of Senior Center

Josephine Commons Phase I completed 2012

*Full occupancy!*
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Aspinwall (JC Phase II) – Single family units and community center

Single borehole for each single family unit (72 total)
Six boreholes for community center
• Construction commenced 3rd quarter 2013
• Common loop GHX determined to be used for community center, 12,000 ft²
• Dedicated single loop GHX determined for individual family units, 72 units totaling 71,355 ft²
• Single family unit heat pumps to utilize integrated VFD cartridge pumps to reduce construction costs and optimize efficiency
• Typical single HP installation
• 2 stage compressor operation
• ECM blower
• Integrated VFD cartridge pump eliminates need for field installed pump pack, digitally controlled to feed only the flow rate required for maximum efficiency
• Further reduces labor 1st cost for field installed pump pack and additional electrical connections
• Single borehole, no manifolding of multiple circuits, further reduction in construction costs
• Single family units represented by 9 different floor plans ranging from 650 ft² to 1,592 ft², total 168 nominal tons
• Heat pumps either 2 or 3 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
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Aspinwall (JC Phase II) – Single family units

<table>
<thead>
<tr>
<th>Floorplan</th>
<th>Number of Units</th>
<th>Cond’d Space Ft² (ea)</th>
<th>Nom. HP Tons</th>
<th>Total HP Tons</th>
<th>GHX Depth, Feet (ea)</th>
<th>Est’d EWT Range to Heat Pumps</th>
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<td></td>
<td></td>
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</table>

- All single loops used 1.25” DR11 u-bends – total of 17,250’ of borehole
- Simulations determined TE grout suggested slight performance improvements on some models, no improvement on others
- 0.90 btuh/ft/°F TE grout was specified on all loops for convenience
<table>
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<tr>
<th>Floorplan</th>
<th>Cond'd Space</th>
<th>Nom. HP</th>
<th>Est'd Annual Op. Cost - $0.068/kwh</th>
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- Projected operating costs using GLD Edition 2014, v. 8.0.6, using hourly load profiles
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
- Economy of scale adds value to GSHP option
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Aspinwall (JC Phase II)

View from completed senior center, Ph. I
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Aspinwall (JC Phase II)

Typical single unit construction
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Aspinwall (JC Phase II)

Completed single family unit
People responsible for the success of this project

- Mr. Scott Simkus, Boulder County Housing Authority, Boulder, CO
- Mr. Corey Chinn and MEP team, Farnsworth Group, Colorado Springs, CO
- Mr. Tino Leone and architectural team, HB&A Architects, Colorado Springs, CO
- Mr. Jesse Dean and NREL team, Golden, CO
- The entire Major Geothermal team
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