Electrification
Large commercial electrification
Generating hot air

- Electric resistance
- Air to Air Heat Pump
- VRF
- Geothermal with WSHP
Generating HWS

- Electric resistance
- Air Source Heat Pump
- Heat recovery chiller
- Geothermal WTW HP

Electrification options – Hydronic
Healthcare - typical

ROOFTOP

AIR COOLED CHILLER

AIR COOLED CHILLER

BOILER

BOILER

CUSTOM VAV AHU

CUSTOM VAV AHU

DOAS FOR CHILLED BEAM

VRF

24/7 IT + ELEC

ROOFTOP

RADIANT FLOOR

VAV AND DISPLACEMENT VENTILATION

CHILLED BEAM

SOUTH WAITING

HIGH ACH SPACES + SOUTH WAITING AREA

LOW ACH AND COMMON AREAS
Healthcare – all electric
Healthcare – all electric (cold climate)
Rooftop layout
DENVER WATER
OPERATION COMPLEX

Denver, Colorado

Objective:
With construction of a new office building, the owner wanted to pursue net zero, all-electric energy for the campus.

Problem:
The campus is located in a cold climate with a diverse set of campus buildings. Solution would require combination of water main as cooling/heating sink, air source heat pumps, radiant slabs and heating water storage tanks to allow electrification of the heating system.

Outcome:
The all-electric design and solar PV added to other areas of the campus provided a fully decarbonized, zero carbon campus.
Generating HWS

<table>
<thead>
<tr>
<th>Minimum OA operating temp.</th>
<th>Electric resistance</th>
<th>Air Source Heat Pump</th>
<th>Heat recovery chiller</th>
<th>Geothermal WTW HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>NA</td>
<td>0 - 15 F</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Heating COP</td>
<td>1.0</td>
<td>2.0 - 3.5</td>
<td>3.5 - 7.0</td>
<td>4.0 – 5.5</td>
</tr>
<tr>
<td>Key Benefit</td>
<td>Lowest first cost</td>
<td>Energy cost on par with gas when OA &gt;30F</td>
<td>High COP at any OA temp</td>
<td>Ground heat exchange, not air</td>
</tr>
<tr>
<td>Key Limitation</td>
<td>High energy cost 3x+</td>
<td>Minimum OA temp</td>
<td>Only handles simultaneous load</td>
<td>Well field size and cost</td>
</tr>
<tr>
<td>Max HWS temp</td>
<td>Same as gas</td>
<td>Low HWS temp</td>
<td>Maintenance and min. load</td>
<td>125 - 130 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capacity falls off as OA drops</td>
<td>130 – 140 F</td>
<td>130 – 140 F</td>
</tr>
</tbody>
</table>

Electrification equipment considerations
• Low temperature operation/cut-out
• Electrical load and BOH space
• Utility power needs
• Backup generation capacity
• Utility cost impacts
• Demand cost impacts
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