Integrating Solar Thermal and Biogas into an Innovative District Energy System Replacement

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District Energy System

Abs. Chiller
Over 30 yrs old

Boilers
23 yrs old

Cooling Tower
Poor condition

"New" Chiller and Tower
Repurposed from campus

Steam Piping
Needs renewal
within 10 yrs

0 tons
320 tons

40,000 lb/hr
2,000 lb/hr

150 tons

475 tons

30 tons
Problems with District Energy System

• District energy infrastructure is aged
• Insufficient redundancy
• Energy supply is not aligned with UC initiatives
• High operating costs
Current Energy Supply and Use

Primate District Annual Energy Use Breakdown (Thousands of MMBtu)

- **Natural Gas**: 40
- **Steam**: 34
- **Loss**: 6

Additional breakdown:

- **Space Heating**: 15
- **Abs. Chiller**: 13
- **IHW, DHW**: 3
- **Loss**: 3

- Cage washing
- Autoclaves
- Lab, bathroom sinks
Opportunities

• Donated solar thermal panels
• Extension of Cal Solar Initiative (rebate)
• Plenty of open land area
• Nearby UC-owned biogas production
• Elimination of 24/7 boiler watch
• Main campus steam-HW conversion knowledge
Solution

• Cost analysis indicated best solution (IDEA 2019 presentation)
• Steam to hot water conversion
  • Space heating and most IHW/DW load
• Solar thermal hot water production
  • Heat pumps and TES
• Biogas capable hot water boilers
• Small, local steam generation for process loads
System Configuration – Central Heating & Cooling

New CHCP Building:
- Electric chillers
- HHW Boilers – NG, Biogas, Propane
- Water source solar thermal heat pumps

25,000 MBtu HW Thermal Energy Storage Tank

Solar Thermal Collector Field:
- 300 total collectors at 40 Deg. incline
- Faces due south for maximum annual production
System Configuration – Building Conversions

- **Quarantine Building:**
  - Steam to HW conversion
  - Electric Process Steam Boilers

- **Main Lab/Animal Building:**
  - Demo existing steam plant
  - Steam to HW conversion
  - Convert 2 cage washers to hot water operation
  - New indirect heater for IHW

- **CCM Lab Building:**
  - Electric process steam boilers
  - Remove existing heating HW boiler

- **Quarantine Building:**
  - Steam to HW conversion
  - Electric Process Steam Boilers
System Configuration – Distribution and IHW

**Primate Shop Building Plant:**
- Electric process steam boilers
- 135 °F Industrial HW
- 195 °F Industrial HW
- Convert 1 cage washer to Hot Water operation

**HHW Distribution Piping:**
- Direct buried PEX construction
- Primarily a manifold & “home run” configuration limiting field joints and valve boxes
New Central Heating and Cooling Plant (CHCP)

- New 3,250 Sq. Ft. Building Housing:
  - Two 585 Ton Electric Chillers (blue)
  - Three 3,980 MBH Flexible Watertube Boilers (yellow)
  - Four 680 MBH Water Source Heat Pumps for solar thermal system (green)
- Estimated 47% of annual heating load satisfied by solar thermal + heat pump output.
- Modular expandable system with potential geothermal and/or HR chiller integration.
- Need for 24/7 boiler attendance eliminated.
Solar Thermal Collectors

• Solar Thermal Collector Conversion Efficiency Depends on Several Factors:
  • ISO Efficiency = 0.736 - 0.68438(P/G) - 0.00132(P²/G)
    • P=Entering Water Temp (Deg. F.) – Ambient Temp (Deg. F)
    • G = Global Radiation
  • By passing through heat pump, collector entering water temperature can be controlled relative to ambient (P)
Solar Thermal Heat Pump System

- Heat Pumps function to amplify the temperature of the solar thermal collector output using electric compressor work.
- Output limited to about 140 Deg. F. Therefore the high end of hot water reset curve is satisfied by hot water boilers as required.
Solar Thermal: Stagnation

Solar Radiation

Loss of Power

Solar Collectors

Heat Pump

HW Pump

TES HX

TES Tank

Loads
Underground HW Distribution System

- PEX Flexible Piping System
  - Magnitude of CNPRC heating loads allows relatively small pipe sizes of 6” and smaller.
  - PEX piping available pre-insulated (up to 4”) and field insulated in larger sizes.
  - Flexibility to route around existing utilities rather than relocate.
  - Manifold & home-run design eliminates most field joints, tees, and valve boxes.
  - Valve boxes only for future system expansion.
## Energy Use Comparison

### Comparison of Existing and Selected Option Energy Use

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Existing</th>
<th>Selected Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>MMBtu/yr</td>
<td>40,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>MMBtu/yr</td>
<td>2,500</td>
<td>15,000</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>MMBtu/yr</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>MMBtu/yr</strong></td>
<td><strong>42,500</strong></td>
<td><strong>34,000</strong></td>
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</tbody>
</table>
Summary

• CNPRC district energy system needed substantial improvements:
  • Redundancy, reliability, sustainability, efficiency
• Multi-faceted solution to satisfy diverse district needs
  • Integrated solar, heat pump, and HW TES
  • Biogas-ready
  • Electrical steam and high-temp HW production
• Load sizes and site layout suitable for PEX
• Alignment with UC initiatives
  • Significant carbon reduction
  • Designed to fully electrify in the future
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