STEMMING THE LOSSES

BPA Webinar 2017 - Hot Water Pilot Study
Ecotope, Inc.
May 17th, 2017
Goals for DHW Systems
Multifamily Hot Water Loads
Temperature Maintenance Systems
Pilot Study
Why Recirculation Flow Measures are Limited.
High Performance Hot Water Systems
MOVING EMERGING TECHNOLOGIES TO MARKET PENETRATION

1. Research Emerging Technologies
2. Feasibility Study
3. Pilot Design
4. M&V Study and Findings
5. Market Penetration
HEAT PUMP HOT WATER HEATING FOR APARTMENTS

Central Hot Water Heat Pump EUI's

Current Average: 10
High Efficiency Central Hot Water: 3

Heat Pump Technologies
Design and Application
Load Reduction
Demand Response (DR)
ECOTOPE’S PORTFOLIO OF HPWH TECHNOLOGIES

Water Source
- Horizontal and Vertical Ground Source
- Wastewater Source
- Ocean Source
- Single and Multi-Pass
- 410a. 134a, CO2

Air Source
- Reverse Cycle Chiller (RCC) in Parking Garage
- Inverter Driven R-410a
- VRF Source Heat Pump Water Heating
- HPWH Integrated
- Single and Multi-Pass
- 410a. 134a, CO2
Based on billing analysis of 10 Multi-family Buildings in Seattle
Median Energy Use Index (EUI): 39 kBTU/sf/yr

DHW EUI ~ 10 kbtu/sf/yr
APARTMENT - ANNUAL HOT WATER HEATING LOAD

Multi-Family Hot Water EUI (kbtu/sf/yr)

- Heating Water: 4
- Hot Water Load: 6
- Temperature Maintenance: 30

Heating Water + Temperature Maintenance/Losses
PARTS OF A CENTRAL HOT WATER SYSTEM

- Central Plant
- Primary Supply
- Risers
- Balancing
- Temperature Maintenance System
TEMPERATURE MAINTENANCE SYSTEMS

Making Hot Water Available in 20-30 Seconds in a Central Hot Water System

Three Different Approaches

1. Traditional Circulation System
2. Pipe in a Pipe Circulation System
3. Electric Heat Trace and No Circulation
TRADITIONAL CIRCULATION LOOP

• Connects a Return line and Hot Water Circulation Pump to the end of the supply line and circulates hot water to keep supply pipe hot.

• Uses 100-200’ of extra piping and insulation.

• Balancing can be tedious

• Pinhole leaks can occur in copper recirculation systems after 20+ years
PIPE IN A PIPE CIRCULATION LOOP

Similar to traditional hot water circulation, except return piping is located inside of supply riser.

Reduced surface area results in less heat loss

Can still get COP on recirculation load.

Reduced insulation costs trades off with copper risers.

Cost Effective
Electric controller set to maintain temp

Results in reduced piping length and elimination of pumping energy *(24/7 typ)*

Advantage is it is simpler and neutral cost increment over traditional

Disadvantage is no COP on reheating

20 year life, need to locate primary lines in common spaces
**Building A**  
Traditional Recirculation Loop  
12 Units ~ 1450 SF each, 2 Bedroom

**Building B**  
Electric Heat Trace  
12 Units ~ 1450 SF each, 2 Bedroom

**Building D**  
Pipe in a Pipe Recirculation Loop  
13 Units ~ 1450 SF each, 2 Bedroom

- Heat Pump plants installed in below grade parking garage

---

**Temperature Maintenance Pilot Study**

Heat Pump plants installed in below grade parking garage
Temperature Maintenance Pilot Study Objectives

Compare Performance of 3 Different Temperature Maintenance Systems in 3 Similar 12 Unit Multi Family Buildings

Use Hydronic Inverter Driven Heat Pump To Heat Water in a Central Plant.

Compare Recirculated Systems with Non-Circulated Systems. Heat Pump Impact

Comparisons with other heat pump buildings

All Buildings used good insulation 2” thick wall for garage and 2x6 cavity, dense pack for risers (R-11)
PILOT STUDY HEAT PLANTS
### HOT WATER USAGE
**GROW BUILDING A**
**12 UNITS**

<table>
<thead>
<tr>
<th>Building</th>
<th># Occupants</th>
<th>Mean DHW (Gal/Day)</th>
<th>Hot Water pp/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>18</td>
<td>290</td>
<td>16.1</td>
</tr>
</tbody>
</table>

---

#### Grow Building A: Hot Water Demand by Hour of Day

**Weekday**

- 6AM: 0.25 GPM
- 9AM: 0.5 GPM
- 12PM: 1.5 GPM
- 3PM: 1.25 GPM
- 6PM: 0.75 GPM
- 9PM: 0.5 GPM
- 12AM: 0.25 GPM

**Weekend**

- 6AM: 0.25 GPM
- 9AM: 0.5 GPM
- 12PM: 1.5 GPM
- 3PM: 1.25 GPM
- 6PM: 0.75 GPM
- 9PM: 0.5 GPM
- 12AM: 0.25 GPM

---

#### Grow Building A Daily Hot Water Demand

- **Summary Stat**
  - 5%
  - 25%
  - Median
  - 75%
  - 95%

---

**Daily Flow (gallons)**

- August 2016
- September 2016
- October 2016
- November 2016
- December 2016
- January 2017
- February 2017
- March 2017
- April 2017
- May 2017
**HOT WATER USAGE**

**GROW BUILDING B**

12 UNITS

<table>
<thead>
<tr>
<th>Building</th>
<th># Occupants</th>
<th>Mean DHW/ Day</th>
<th>Hot Water/ pp/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>30</td>
<td>525</td>
<td>17.5</td>
</tr>
</tbody>
</table>

---

**Grow Building B: Hot Water Demand by Hour of Day**

**Weekday**

**Weekend**

**Summary Stat**
- 5%
- 25%
- Median
- 75%
- 95%

**Grow Building B Daily Hot Water Demand**

---

[Image of building A102 on the first floor]
# HOT WATER USAGE

## GROW BUILDING D

## 13 UNITS

<table>
<thead>
<tr>
<th>Building</th>
<th># Occupants</th>
<th>Mean DHW/Day</th>
<th>Hot Water/pp/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>7</td>
<td>120</td>
<td>17.1</td>
</tr>
</tbody>
</table>

**Grow Building D: Hot Water Demand by Hour of Day**

**Grow Building D Daily Hot Water Demand**

*Summary Stat:
- 5%
- 25%
- Median
- 75%
- 95%*
TEMPERATURE MAINTENANCE LOSSES

Grow Bainbridge: Temperature Maintenance Losses

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BuildingA: Classic Recirc</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>BuildingB: Heat Trace</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
<tr>
<td>BuildingD: Pipe-in-a-Pipe</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
<td>2.25</td>
</tr>
</tbody>
</table>

Temperature Maintenance Losses (Watts)

- Traditional Circ: 2100 Watts
- Pipe in a Pipe: 1500 Watts
- Heat Trace: 800 Watts
20 degree F seasonal swing in the garage. Building D is closer to the garage entry, hence the lower garage temps.
Resistance Heat Triggered As Daikin HP Errored out due to voltage fluctuation in grid.

Notice that in the summer less energy is needed for heating as the city water is 20-30 degrees warmer.

Building D Still Not Fully Occupied
60 Degree Air Entering Heat Pump Produces COP 2.9

45 degree Air Entering Heat Pump Produces COP 2.2

COP ~ 2.5 for Daikin Altherma with constant Circulation in BG Parking Garage
Lower COP in Building D attributable to:

a) Heat Plant Proximity to Garage Entry
b) Controls Issues within Daikin
c) Warmer Return Water Temps

We aren’t setup to answer this question with the metering setup out there... A lab test is needed to test the sensitivity
TEMPERATURE MAINTENANCE HEAT LOSS COMPARISONS (LOAD ONLY)

Watts/Apt (# Units)

- Electric Tank in Unit (1) - 60
- A - Trad Circ (12) - 175
- D - Pipe in Pipe (13) - 125
- B - Heat Trace (12) - 67
- Midrise (92) - 92
- Midrise (118) - 64
DAILY DHW ENERGY/UNIT WITH COP
(ACTUAL USAGE AND LOSS/UNIT (NOT NORMALIZED))

<table>
<thead>
<tr>
<th></th>
<th>Daily Hot Water Load/Unit (kwh/day)</th>
<th>Temp Maintenance (kwh/day/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank in Unit</td>
<td>3.1</td>
<td>1.4</td>
</tr>
<tr>
<td>A-Traditional</td>
<td>2.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Recirc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D-Pipe in Pipe</td>
<td>1.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Pipe Recirc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-Heat Trace</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Midrise (SE)</td>
<td></td>
<td>1.3</td>
</tr>
<tr>
<td>Midrise (SU)</td>
<td></td>
<td>1.7</td>
</tr>
</tbody>
</table>
**Daily Hot Water Energy (KWH/Unit)**

**Normalized to Equal Water Usage**

<table>
<thead>
<tr>
<th>Tank In Unit:</th>
<th>Assumptions</th>
<th>Electric Resistance (ER) Tank in Unit, Approximate Losses, “Base-Case”</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Traditional Recirc</td>
<td>Grow A, Traditional Recirc, Daikin Primary Water Heat to 120F, Electric Trim Included but hardly needed, 24/7 HWC Pump for TM. Losses are hidden when heat pump COP is applied. Low Hot Water Usage makes TM a larger fraction of the total load</td>
<td></td>
</tr>
<tr>
<td>D-Pipe In a Pipe Recirc</td>
<td>Grow D, Still Not Fully Occupied. Pipe in a Pipe Recirc, Daikin Primary Water Heat to 120F, Electric Trim Included but only used if Daikin has Error, 24/7 HWC Pump for TM. 45% Savings in Pipe in a Pipe for this install includes the garage horizontal runs (60%)</td>
<td></td>
</tr>
<tr>
<td>B-Heat Trace</td>
<td>Grow B. High Hot Water Usage compared to other buildings. Only a supply pipe used and heat trace under insulation.</td>
<td></td>
</tr>
<tr>
<td>Midrise (SE)</td>
<td>92 Unit 6 story apartment in Seattle with a garage located Colmac Heat Pump Water Heating System, Traditional Recirc</td>
<td></td>
</tr>
<tr>
<td>Midrise (SU)</td>
<td>118 Unit 6 story apartment in Seattle with a garage located Colmac Heat Pump Water Heating System, Traditional Recirc</td>
<td></td>
</tr>
</tbody>
</table>

**Graph**

- Daily Hot Water Load/Unit (kwh/day)
- Temp Maintenance (kwh/day/unit)
TEMPERATURE MAINTENANCE CONSIDERATIONS

• Recirculation Systems and Heat Pumps Can be Tricky, don’t underestimate simple.

• Heat Trace is a 25-30 year life and will likely need to be replaced, integrate replacement planning into design.

• Hot water recirculation systems built out of copper do develop pinhole leaks due to constant circulation and abrasive forces of water.

• Single Pass heat pump systems should consider heat trace and extra insulation as single pass systems work best without warm return water.

• Multi-pass heat pump systems should consider pipe in a pipe technology over traditional recirculation, cost effective and qualifies for Utility Incentives
Multi-Family Central DHW Measurement Projects: Odds of No Flow Occurring

Meter Resolution 1gal at Grow, 10gal at Sunset/Stream

HWC PUMP CONTROL MEASURES ARE LIMITED, BEWARE..

Total Hours with No Measured Flow:
- Grow A 14.6%
- Grow B 12.3%
- Stream Uptown 3.7%
- Sunset Electric 3.4%

Building
- Grow A: 12 Units
- Grow B: 12 Units
- Stream Uptown: 118 Units
- Sunset Electric: 92 Units
DESIGN APPROACH TO HIGH PERFORMANCE HOT WATER SYSTEMS
DESIGN CONSIDERATIONS
PROGRAMMING AND DESIGN

• Back to back bathrooms sharing a single stack reduces UA by factor of 2

• Locate hot water storage and primary distribution in heated space to capture losses for ½ the year

• Plan for super-insulated hot water piping runs, Risers- 2x8 studbays, provide for adequate room for insulated pipe clamps

• Consider Distributed Plants versus Single Central Plant. (closer to use, smaller piping, less heat loss)

• Use heat pumps when heating with utility provided power, lowest carbon
DESIGN CONSIDERATIONS
CONTINUOUS INSULATION – 2-3” THICK WALL, W/VB
DESIGN CONSIDERATIONS
FULL PIPING INSULATION MOUNTS

A. PIPE INSULATION SYSTEM
SPECIFICATION:

- Service Pipe
  1. Cold Water Supply
  2. Hot Water Supply
  3. Chilled Water System

B. FULL PIPING INSULATION MOUNTS

- Service Pipe
  1. High Density Insert
  2. Fix Tape

C. Pipe Insulation System

- High Density Insert
  Half of the Insulation Size Equal to the Insulation

D. TYPE A Protection Shield

- As per Table 2.31 in Section 2.3 of the Code

E. PIPE INSULATION SYSTEM

- Cold Water/Chilled As Per Para 2.3.1
- Hot Water As Per Para 2.3.2

- Also As Per Table 1 MINIMAL PRE-INSULATION UNITS SPECIFIED FOR ALL HOT SERVICES
DESIGN CONSIDERATIONS
INSULATION JACKETS ON TANKS AND VALVES
Delta T of 50-70 degrees year round

We insulate houses to R-20 and 30 for 1 week of 47F delta T, HW piping gets R-4.

Every MF Building with a traditional hot water system is wasting 10% of its energy annually

Pipe Insulation is Cost Effective, Need More Market Forces for R-18 to 25
Super-Insulated Hot Water Storage and Distribution System that reduces losses from 75 Watts to 15 watts per unit. Increase U value of entire hot water plant by a factor of 5

**PassivLoop Spec:**

- R-25 Insulation on central hot water piping
- R-25 jackets around storage tanks
- Eliminate Thermal Bridging on Pipe Mounts and Penetrations
- Hot Water Storage Tanks located inside heated space
- Insulated Valves and Pumps.
- 1 hot water stack per 2 back to back apartment stacks (1/2 UA)
- Smaller Distributed Single Pass Heat Pump DHW Plants
- No Recirculation Systems (Use Heat Trace)

- Targeted losses are less than 15 Watts/apartment.
ADDITIONAL PILOT STUDIES
- 70 Units
- Living Building Petal Certification
- Net Zero Energy Apartment Building
- Smaller decentralized hot water plants
- CO2 Based Heat Pumps
- Ductless Heat Pumps
- Inverter Driven PTHP’s
- Energy Recovery Ventilation Systems
- High Efficiency Lighting Design
- Design for Off
- 263 Units
- Ocean Source water to water heat pumps for Central DHW
- CO2 Transcritical heat pump
- Heat Trace Temperature Maintenance Systems
- Increased Hot Water Piping Insulation
- Demand Response (DR) Capable DHW Plant
- 384 Units
- Wastewater Heat Pump Source for Central Hot Water
- Ductless Heat Pumps
- Energy Recovery Ventilation Systems
- Dedicated Air Source Heat Pumps for Temperature Maintenance
- Low Flow Plumbing Fixtures
- Large Greywater Recycling and Reuse System for Irrigation.
Looking at newest RCC 3.0 installation which incorporates lessons learned to date.

194 Unit New Construction in Seattle

Understand impact of lessons learned on performance

Revisit previous RCC projects and understand other costs

Produce a robust RCC design guide
FUTURE RESEARCH OPPORTUNITIES AND PILOTS

- Optimization of Inverter Driven 410a Heat Pumps
- Demand Response integration into central Heat Pump Design
- Air-Source CO2 Heat Pumps for larger apartment projects
- PassivLoup Central Hot Water Piping System (Target 15W/Apt)
- Design and Programming, Smaller Distributed Plants, back to back risers
- Solar Greenhouse Heat Pump Mechanical Rooms
- Geothermal Heat Pump Water Heating
- HPWH’s in apartment units