MF Opportunities, Challenges

- Flat roofs
- Storage location
- Piping runs!

Brooklyn System
- 24 40-ft², flat-plate collectors
- 1,500-gallon storage tank
- Initial Cost: ~$105,000 ($109/ft²)
Solar O&M

• Smooth, reliable operation of SDHW is the exception (in my experience).

• **Drainback** systems may alleviate reliability concerns, but high pumping energy ($50-$100/y for SF system)

• O&M needs/costs hard to estimate (poor documentation – just anecdotes).
Reliable Solar Systems

Recommendations:

• Good **design** and **installation**
• **Monitor** SDHW performance
• Clear **O&M** manual/instructions
• Perhaps explore service contracts, PPAs.
Solar DHW

Advantages
• Direct use of renewable energy
• No fuel costs
• $ more attractive on MF scale

Disadvantages
• High first cost*
• Reliability and O&M requirements vary

• Aesthetics
• Aesthetics
Heat Pump Water Heaters

1. Heat pump pulls hot surrounding air in
2. Heat pump transfers heat from air to water
3. Heat pump pushes cold/dry air out

- Filter
- Heat Pump
- Condenser coil heats water in tank
- Backup electric heating elements
- Water tank
How do they Work?

- Moves heat from surrounding air into water.

- Cools & dehumidifies the surrounding air.
HPWH Monitoring

• Monitored 14 HPWHs at sites in MA and RI for over 1 year (2010-11)

• Seasonal COPs ranged from 1.0* to 2.6

<table>
<thead>
<tr>
<th>HPWH model</th>
<th>No. Monitored</th>
<th>Capacity (gal)</th>
<th>Energy Factor</th>
<th>Avg. COP</th>
<th>% Electric Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>10</td>
<td>50</td>
<td>2.35</td>
<td>1.82*/ 1.64</td>
<td>33%*/ 41%</td>
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<tr>
<td>AO Smith</td>
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<td>2.33</td>
<td>2.13</td>
<td>5%</td>
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<tr>
<td>Stiebel Eltron</td>
<td>2</td>
<td>80</td>
<td>2.51</td>
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<td>6%</td>
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</table>
Where can HPWHs Work Well?

• Basements of NE homes
• Down south
Where may HPWHs NOT work well?

• Closets

• Finished or occupied basements (noise, cold)

• Apartments (space, noise, comfort)
HPWH Costs (MA, RI Study)

• Average savings: ~$300-350/yr compared to electric resistance ($0.17/kWh)

• $1,400-$2,700 incremental installed cost (over std. elec. tank)

• Some costs have come down over past few years, some incentives available.
HPWH Performance Factors

For a given HPWH, COP varies with:
- Surrounding air temp
- Total water consumption
- Water draw profile
Air Temperature Dependence
Site 5: Low Ambient Temps

Site 5: COP = 0.77; Average Ambient Temperature = 48°F
Site 3: Concentrated Draws

Dec 6: 70 gallons, no Elec. Resistance
Site 3: Concentrated Draws

Nov. 11: 71 gallons, 81% Elec. Resistance

HW Used (Gallons)

Energy Used (Wh)

Time
To Minimize Resistance Heat:

BIGGER IS BETTER
HOTTER IS BETTER
## Monitoring Summary

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Mixing Valves and Temperature

- Unlike most water heaters, increasing the setpoint of HPWHs can increase efficiency.

- Temperering (anti-scald) valves are good practice.
Managing Condensate

- Install condensate pump, if needed
- Place on blocks
- Install drain pan

HPWH Sitting in Water

Proper Installation
Maintenance

- Some filters in HPWHs should be regularly cleaned.

- Educated homeowners.
HPWHs in Multifamily

Proper HPWH Application?
Space Conditioning Impacts

Latest Study

- 3 HPWHs
- in 3 CT basements

Switched between **Hybrid** (HP) mode and **Resistance** (ER) mode to see if any more heating fuel was used.
Monitoring Heating Fuel

Cycle between:
• HP (hybrid) mode
• Resistance mode
Furnace Gas in Heat Pump Mode

- Hybrid mode

- Daily Gas Used [ft³] vs. Average Daily OAT [°F]

Data points show a downward trend as OAT increases.
Furnace Gas in **Resistance** Mode

![Graph showing daily gas use vs. average daily OAT](image)

- **Daily Gas Used [ft³]**
- **Average Daily OAT [°F]**

- **Hybrid mode**
- **ER Mode**
HPWHs

Advantages

• With COP ~2, uses half the electricity of resistance

Limitations:

• Needs volume (~1,000 ft³)
• Cools surrounding space
• Surroundings >45°F
• Condensate draining
• Noise
Solar Option: PV + HPWH?

PV needed to power HPWH in efficient home:

1-1.5 kW_{STC}

Cost @ $4/Watt:

$4,000 - $6,000

*All HPWH caveats still apply.
HPWH Resources


Systems Discussed

1. Resistance Tanks
2. Tankless Resistance
3. Solar Thermal
4. Heat Pump Water Heaters
SF Cost Summary

<table>
<thead>
<tr>
<th></th>
<th>Resist. Tank</th>
<th>Resist. Tankless</th>
<th>Solar Therm.</th>
<th>HPWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx. Cost</td>
<td>$1,000</td>
<td>$1,000</td>
<td>$10,000*</td>
<td>$2,400*</td>
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<tr>
<td>Ann. DHW Cost</td>
<td>$530</td>
<td>$500</td>
<td>$160</td>
<td>$250</td>
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</tbody>
</table>

Assumptions
- 40 gal/day
- 70°F temp rise
- $0.20/kWh
- 70% solar fraction
## MF Cost Summary

<table>
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<th>Resist. Tankless</th>
<th>Solar Therm.</th>
<th>HPWH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approx. Cost</strong></td>
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<td>$3,000*</td>
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<td><strong>Ann. DHW Cost</strong></td>
<td>$400</td>
<td>$375</td>
<td>$160</td>
<td></td>
</tr>
</tbody>
</table>

### Assumptions
- 30 gal/day
- 70°F temp rise
- $0.20/kWh
- 55% solar fraction
New Systems to Watch For:

1. Split HPWHs

2. Packaged outdoor HPWHs

3. Commercial/MF HPWHs for cold climates
Split HPWHs

Refrigerant Line Set

Heat Pump
Compressor, Evaporator

Condenser, Storage Tank

WH
Packaged Outdoor HPWH (CO$_2$)
Commercial/ MF HPWHs

- Available now
- Not for cold climates (below 50°F)
- Cold-climate CO₂ systems DO exist overseas...
Other Options

• Ground-source heat pumps (expensive, generally used for all heating and cooling)
Thank you!

Thanks to:
• U.S. DOE Building America Program
• Efficiency Vermont
• Massachusetts & Rhode Island Utilities
• NEEP
• Homeowners participating in the studies
• NESEA

Evaluation report:

NEEP database:

SWA Blog (search for “heat pumps”):
http://blog.swinter.com/

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