
- A.O. Smith
- Bradford White
- Rheem
- Sanden
- Home Upgrade
- Stiebel Eltron

Hosting thanks to:
City of Berkeley Office of Energy & Sustainable Development
& City of Palo Alto Utility
TODAY’S AGENDA

• Introductions
• Why Heat Pump Water Heaters?
• How to Install them
• Manufacturers Tell All
• Programs & Subsidies
• Q & A
• Networking & Refreshments
OUR NEXT BIG EVENT

PASSIVE + RENEWABLES
October 4-8, 2017 | Oakland, California

The goal of NAPHN17 ‘Passive + Renewables’ is to promote and accelerate the adoption of Passive House building strategies in North America, and to work with others who share our vision for a POST CARBON ALL-RENEWABLE ENERGY FUTURE.

- 2 DAYS of WORKSHOPS
- 2 DAYS of PROGRAM
- 5 PROJECT TOURS

KEYNOTE:
Scott Foster, Director, Sustainable Energy Division of United Nations Economic Commission (includes USA & Canada.)

SOURCE: http://www.naphnconference.com/
Tackling the Ghost in your Heating Closet

Why Electrify Water Heating in California Homes

Pierre Delforge, NRDC
May 23 - Berkeley
May 24 - Palo Alto
Direct emissions from residential and commercial buildings ≈ emissions from all in-state power plants

- In CA, 12% GHGs from residential and commercial buildings (mostly from natural gas burned for water and space heating)
- Similar to all in-state power plants!
  + fugitive emissions from gas distribution
  + gas use in industry

Source: [www.arb.ca.gov/cc/inventory/data/data.htm](http://www.arb.ca.gov/cc/inventory/data/data.htm)
As CA’s and the Bay Area’s electricity is getting cleaner, emissions from burning natural gas are becoming the majority of energy-related emissions from buildings.

Average Household CO2 emissions from energy use

- US: 2.2 metric tons CO2/year from electricity, 7.2 metric tons CO2/year in total
- California: 2.1 metric tons CO2/year from natural gas, 2.3 metric tons CO2/year from electricity, 4.4 metric tons CO2/year in total
- Bay Area: 2.0 metric tons CO2/year from natural gas, 1.0 metric tons CO2/year from electricity, 3.0 metric tons CO2/year in total

Note including emissions from methane and other high global warming potential gases.

Heat pump technology can electrify over 90% of thermal end uses.

Figure ES-6: Statewide Natural Gas Energy Consumption
354 therms per household

Source: 2010 California Residential Appliance Saturation Survey
Heat pump 101: 2 to 4x as efficient as conventional electric heaters

Moves (or “pumps”) heat from ambient air into a tank or the building, instead of generating it with a resistive element. Like a fridge or A/C in reverse.
HPWH’s triple value proposition

Electrified heat

- Energy efficiency
- Grid balancing & renewables integration
- Emissions: CO2, CH4, NOx...
Water heater CO2 emissions*
As CA grid gets cleaner, HPWH offer pathway to very low-GHG hot water

1) Not including fugitive methane emissions
2) 45%-efficient combined cycle gas plant (build margin)
Grid-interactive heat pump water heaters can help deep renewable integration

- NRDC et. al. study in-progress to quantify the load shifting capacity and value of HPWH, results planned for Sep. 2017
Unitary HPWH

Heat pump water heaters are a mature technology with a wide range of affordable models in the market

Popular models:

AO Smith  Bradford White  Rheem  Stiebel Eltron  Sanden

100+ ENERGY STAR models
Two heat pump-based solutions for domestic hot water (DHW) in multi-family:

- Unitary, as in single family
- Centralized: larger tank, shared between multiple units
How about solar thermal?

- GHGs roughly similar to heat pumps (need gas or electric backup in winter)

- Currently much more expensive than HPWH + PV

- Costs need to come down significantly to be able to scale up
How much does it cost?* (in retrofits)

Baseline gas water heater (EF 0.6)

- Equipment: ≈$500
- Installation: $700-$1,000
- Total: $1,200 - $1,500

Heat pump water heater (EF 3+)

- Equipment: $1,000-$1,500
- Electrical conduit: $300-$750
- (panel upgrade: $0 - $2,500)
- Installation: $900-$1,500
- Total: $2,200 - $3,750

- Near-parity in upfront cost is critical to scale HPWH deployment, hence need for rebates

- SMUD and Palo Alto offer a $1,500 rebate for HPWH fuel switching, PG&E $300 (but not for fuel switching)

* Costs vary widely by home, contractor, market. Indicative only.
How to make it cost-effective

- Upfront costs (equipment + installation) often higher than natural gas appliances in retrofits, but not always:
  - New construction: similar cost for gas tankless/HPWH
  - All-electric homes: avoid gas piping costs + venting + monthly gas fixed fee

- Lower operating costs can offset the higher upfront costs, under right conditions:
  - Rooftop PV
  - Low off-peak time-of-use rates + controls
  - Highest efficiency heat pumps
  - Utility rebates
  - Propane, electric resistance (often rural, low-income communities, trailer parks…)

[Image]
What will it take to transform the market?

Home Owners
• Go electric!
• Talk to friends and neighbors
• Host open house

Building Professionals
• Contractors
• Builders
• Architects
• Energy consultants
• Raters
• Distributors
• Retailers
• Manufacturers
• Help raise awareness and build demand!

City/County
• Ordinances: reach code, time-of-sale…
• Train building department
• Bulk buy programs
• Outreach
• Financing
• Munis/CCEs: rates, incentives

Region
• Air quality and GHG regs
• Incentives

State
• CEC: building code, energy planning (IEPR)
• CPUC: incentive programs, rates
• ARB: AB 32 scoping plan
• Legislation
• Governor leadership
THANK YOU!

QUESTIONS / COMMENTS?
Heat Pump Water Heaters

On-the-Ground Perspective

John Neal: Senior Project Manager
Pierre discussed the “why…”

Now, “how?”

Challenges and lessons learned:

• Unitary (single family & apartment installs)

• Central system installs
Unitary

Electrical

– All heat pump water heaters require a 220v circuit
  
  • Tank type models typically require 30amp 220v
  
  • Stiebel Eltron tank type and Sanden split system requires 15amp 220v
Electrical Challenges

My very own, very vintage, 120v 30 amp service!
Electrical Challenges

• Sufficient service capacity?
  – Equipment from 1970’s or older could trigger service or panel upgrades
  – 100amp panels usually OK for some added load
  – Where capacity is at a premium, Sanden and Stiebel Eltron system add the least load
Electrical Challenges

• Wiring
  – Breaker space in panel?
  – Access to run wiring to the new water heater without lots of demo?
    • Usually easy in single family homes with attics or crawl spaces
    • Can be difficult in multistory apt bldgs.
Electrical Opportunities

• Consider future electrification!
  – Heat Pump HVAC
  – Electric car charger
  – Induction stove, etc.

• If owner has existing AC consider freeing up load through whole building approach...

...a brief digression...
• If replacing existing AC, opportunity to drop load through equipment and envelope improvements (example project went from 50 to 30 amp equipment disconnect)
  – “Traditional” scroll equipment might require electric resistance strip backup
  – Inverter equipment likely will not

• Lots of flavors, including high static air handlers
Back to heat pump water heating...
Condensate Drain

- Equipment requires a condensate drain
- Can drain by gravity or with condensate pump
- Different jurisdictions treat condensate differently, usually the following work:
  - Exterior planter
  - Washing machine drain
  - Share with AC drain
Locating the water heater

• Tank type units draw heat from and reject cold air to their surroundings
• Reducing access to outdoor air (heat source) will reduce efficiency
• Most tank models can duct exhaust and/or intake (8” duct, keep runs short, use hard pipe if possible!)
• Sanden system uses outdoor compressor location (requires piping between compressor and tank)
Locating the water heater

Review clearance requirements (eg: 6” on all sides)

– Water heater closets can be small
– Sufficient room volume required when not vented (garage)
– Filter/compressor access

Heat Pump Space Requirements

<table>
<thead>
<tr>
<th>Configuration (see Note 1)</th>
<th>Enclosed Room</th>
<th>Single Louver in Door (Note 2)</th>
<th>Double Louver in Door (Note 3)</th>
<th>Inlet or Outlet Ducting and a Single Louver in Door (Note 4)</th>
<th>Inlet and Outlet Ducting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Space (FT²)</td>
<td>700</td>
<td>300</td>
<td>120</td>
<td>No minimum space requirement</td>
<td>No minimum space requirement</td>
</tr>
<tr>
<td>Space Example H x L x W (FT)</td>
<td>8 x 8-3/4 x 10</td>
<td>5 x 6 x 10</td>
<td>3 x 4 x 10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Minimum louver size is 24” x 14” or 336 in²
Note 2: When one louver is installed, please install the louver at the location where is close to the top of the heater.
Note 3: When two louveres are installed, install one louver just over the top of the heater and the other one where is close to the center of the heater’s top shroud.
Note 4: When one duct adapter is used, locate the louver close to the non-ducted grill. (eg if outlet is ducted, place louver near inlet grill)
Locating the water heater

• **Interior closet**
  – Cold air would be a nuisance in winter and adds load to HVAC.
  – Check clearances
  – Duct intake/exhaust

• **Exterior closet**
  – Check clearances
  – Duct exhaust, use fully louvered door for intake
Locating the water heater

• **Garage or Basement**
  – Well ventilated space may be sufficient
  – In Northern CA climates the location could get very cold in winter
  – Safer to duct exhaust, ensure sufficient room venting for intake
  – Dehumidification benefit?
Apartment Location Exercise
Two + story projects with interior water heaters require routing solutions
Two + story projects with interior water heaters require routing solutions
Additional Considerations

• Performance
  – HPWH typically operate at higher efficiencies when incoming water temperature is cold
  – Solar thermal pairing not ideal
  – Constant or temperature based recirculation pumps will reduce efficiency. Replace with demand-controlled pump
Additional Considerations

• Contractor options
  – Depends on electrical scope
  – If upgrading panel will need electrician
  – Running new wire only, providing exhaust/intake ducts - mechanical contractor
  – Knowledgeable plumber (electrical, ducting?)
Central Systems

Let’s start with pretty pictures
Central Systems

Pre-Install
Central Systems

Sanden System Mid-Install
Sanden Systems Mid-Install
Sanden Systems – Cold air baffle strategy
Lessons Learned - Advantages

• Pairing with PV attractive to owners
  – Solar thermal can have building limitations and is not price competitive with PV
  – Potential for load shifting can work well with Time-of-Use electric tariffs

• With or without PV, electric water heating can act as a cheap battery for bldg. or grid

• Much higher GHG reduction potential compared to gas equipment
Lessons Learned - Challenges

• Punch line on following challenges - most are easy hurdles, but folks need to pave the way

• Potential for a usage profile that can increase energy costs without education and/or controls (demand charges and TOU)
  – Problem becomes solution - with the right utility tariffs and demand response controls, HPWH systems could be another grid storage, load shifting strategy
Lessons Learned - Challenges

• Heat pump BTU output is very small relative to boilers
• Sanden equipment not initially designed for central application. They are currently working on controls, piping, storage configurations for larger applications
• Space constraints - larger storage needs, location for heat pumps
• Contractor knowledge – pricing
• Owner knowledge - hesitancy
Lessons Learned - Challenges

• Energy Code Challenges –
  – Low rise individual – easy, complies
  – Low rise central
    • No prescriptive compliance approach
    • Performance approach is broken (they’re working on it).
  – High rise
    • No electric standard water heating design
    • Selecting “no gas available” doesn’t change comparison
    • Proposed equip efficiency capped at .99
    • “Low on the list of things to be fixed”
Sizing Challenges

• Traditional gas sizing approach might be 50% of first hour load covered by storage, rest by recovery. This results in lots of heat pumps!

• Proposed 75% of first hour load covered by storage, rest by recovery. Results in less heat pumps and vulnerability to kW demand charges
Flow Monitoring to Verify Sizing
Central Heat Pump Chillers

- Simultaneous heating, cooling, DHW production
- Circulates hot and chilled water to building
- Designed to take the place of boiler (heating & DHW) + chiller
- Internal Heat Recovery
Efficiency

EER: 9.2
COP: 3.05
TER (Total Efficiency Ratio): 6.4

Heat recovery on condenser loop yields highly efficient operation while in simultaneous modes:

In this example (referring to unit size NRP 1250A) the total energy ratio is:

$$TER = \frac{(353 + 261)}{97} = 6.3 \quad (*)$$
Oversized internal pumps

Heating pump oversized for DHW only service

Control sequence based on temp, not optimal

Undersized Hx

3-way fan coil valves prevent pressure modulating pumping

No secondary CW pump

Tank location not optimized for thermal storage capacity

Very little guidance on control setup or SOO
Change Order Schematic: Project #1
CEC Research Project

**Meter and logging:**
- Heating energy production & consumption (kW, kWh, Btu)
- Cooling energy production & consumption (kW, kWh, Btu)
- DHW energy production & consumption (kW, kWh, Btu)
- Indoor Temperature Set-points (from visual inspection)
- Indoor Temperatures (°F)
- Pumping energy (kW, kWh)
- Distribution losses (Btu)
- Tank losses (standby) (Btu)
- Domestic hot water usage (gal, gal/person/day)
- Total (cold + hot) water usage (gal)

How does DHW production efficiency compare to the GeoSpring and Sanden projects?
How much benefit are we getting from the heat recovery process?
Can system be used effectively for thermal storage
CEC research project - What Have We Discovered So Far

- Not plug-and-play out of the box
- Many technical challenges (design & install)
- Still relatively new technology in US
- Issues with first 2 installs, unhappy residents, owners, management
Installation Challenges

• Complexity
• Noise levels
• Troubleshooting
• 2 compressors failed in a first year
• 1 year warranty!
• Parts availability
• Start-up
• Service
Thank You!

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