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San Francisco Bay Area Net Zero Urban Infill

2011 ASHRAE Annual Conference, June 25-29, 2011, Montreal, QC

Building Science Corporation

Sustainability Knows No Borders!

Learning Objectives for this Session

- Compare the present and predicted future affordability of net-zero energy homes.
- Provide an estimate of required PV price for NZEH to be an optimal solution in 2030.
- Describe measures leading to market-rate net-zero houses.
- Describe the temperature distribution due to minimally distributed heating.
- Explain that whether or not an overall net-zero balance is achieved is highly dependent on the user.
- Describe that in very efficient homes, standby loads become more and more important and unnecessary standby losses (for example a crankcase heater for a heat pump) can sum up to a significant part of the overall energy consumption

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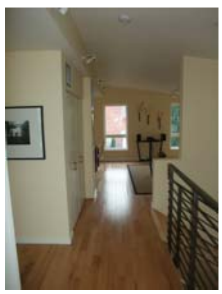
Live/Work Urban Infill Townhome



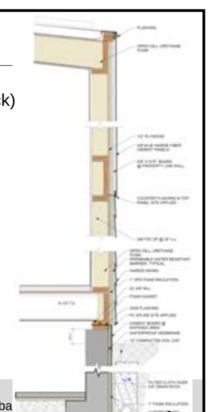
1540 sf, 2 bedroom, 2 story
Oakland, CA; ½ mile from train station (BART)
USGBC LEED Platinum Rating
2009 Green Builder Home of the Year

Modular Construction

Modular Construction

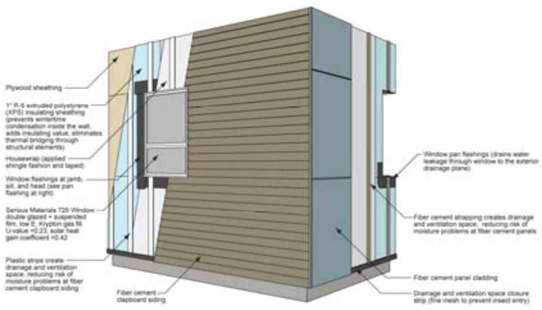
Enclosure Design

- R-32 Roof (nominal)
  Low density urethane foam under roof deck)
- R-23 Walls (nominal)
  2x6 framing at 24" o.c. w. low density urethane foam or denim batt + 1" R-5 XPS
- Foundation
  R-7.5 XPS on crawl space walls;
  R-5 under crawl space slab
- Windows
  Low-E double pane + film / krypton filled, U=0.23 SHGC=0.42
- Airtightness
  964 CFM 50 (3.1 ACH 50) measured



Wall Section (c/o DSA Architecture)

Exterior Enclosure Features



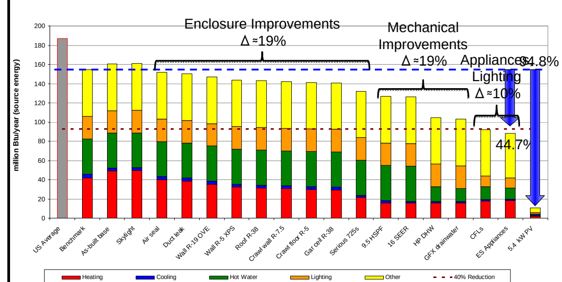
Mechanical Design, Lights, Appliances

- 16 SEER/9.5 HSPF air source heat pump
- Heat pump water heater in mechanical room/garage (2.11 EF rating) w. electric backup
- HRV (“minimally” ducted) ventilation
- Central fan integrated supply-only ventilation
- Residential-scale economizer (off the shelf components, custom controller)
- CFL/LED lighting, Energy Star appliances
- Drainwater heat recovery system

Renewable Energy

- 5.4 kW$_p$ photovoltaic system
- Inverter in garage
- System covers ~½ of roof
- Covered 90%+ predicted energy use (simulation)
- California net metering laws

Parametric Energy Simulations



Valuing energy upgrades relative to PVs

Extended Cost Effectiveness Analysis			
Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)

Energy saved over lifetime of measure

Component lifetime

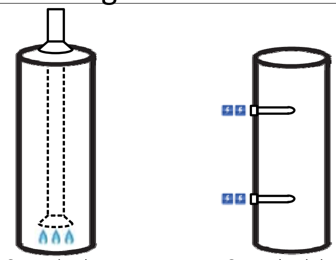
“Cost per unit of energy saved”

Source Energy Savings (from typical analysis)

Results of Economic Comparison

- Shows value of long-lived measures (e.g., enclosure upgrades)
- PVs $9 per 10^6 Btu Saved (Lifetime)
- Assumed 30 year lifespan, $4/installed W$_p$ (peak watt) (actual cost with rebates)
- Losing items in energy simulation analysis:
  - Heat recovery ventilator ($64 per 10^6 Btu Saved)
  - 16 SEER air conditioner ($44)
  - Triple glazed (double + film) fiberglass windows ($19)
  - Drainwater heat recovery ($11)

Water Heating: Conventional Options



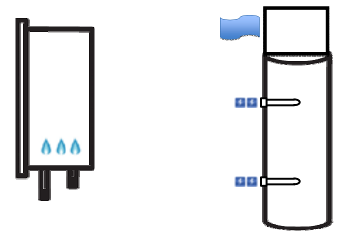
Conventional gas tank (~0.59 EF) site

"Source Efficiency" ≈ 54%

Conventional electric tank (~0.92 EF) site

"Source Efficiency" ≈ 27%

Water Heating: Best Options?



Condensing instantaneous tankless (~0.9 EF) site

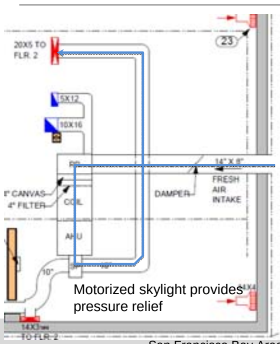
"Source Efficiency" ≈ 82%

ASHP (electric) water heater (2.11 EF) site

"Source Efficiency" ≈ 63%

California Title 24 Requirements: Time Dependent Valuation (TDV) Energy Calculations

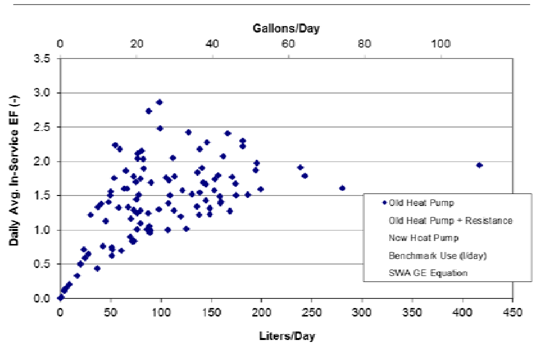
Residential Economizer



Residential Economizer Results

- Air handler efficiency 6.2 CFM/W total flow (vs. 2.5 CFM/W typical for ECM)
- 170 CFM outside air drawn, 120 W → 1.4 CFM/W outside air
- Cooling efficiency calculated at various ΔT; compared to DX cooling
- DX cooling more efficient than economizer when indoor-outdoor ΔT < 13° F
- Damper design vs. commercial economizers
- Risk of duct system leakage to outside in future

Heat Pump Water Heater Performance



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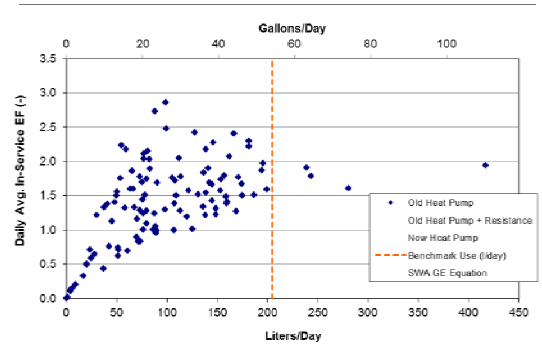

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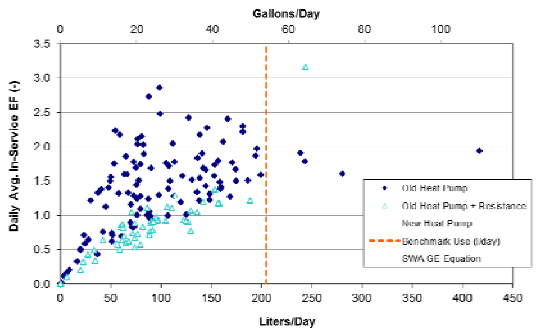

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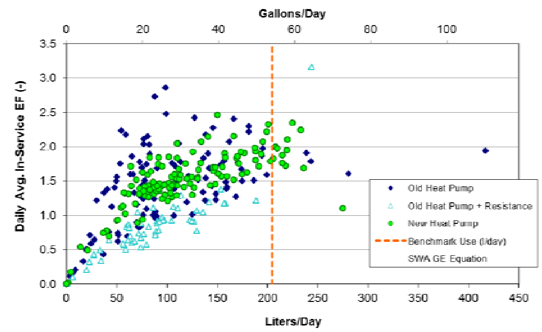
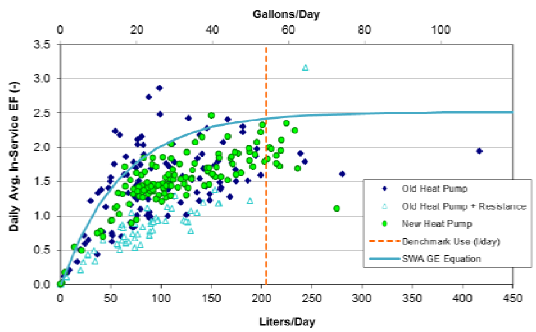
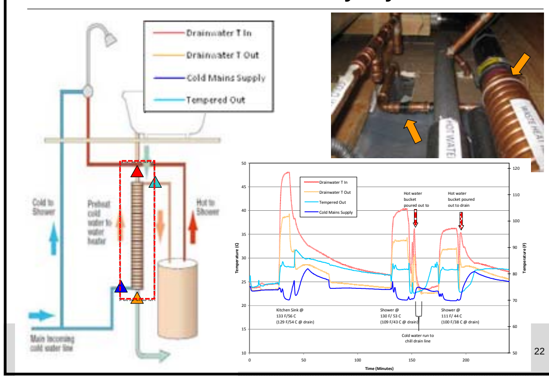


Heat Pump Water Heater Performance



Drainwater Heat Recovery System



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Drainwater Heat Recovery Results

$$\% \, recovery = \frac{energy \, recovered}{energy \, required} = \frac{\dot{m} \cdot (T_{in\,HX} - T_{out\,HX}) \cdot C}{\dot{m} \cdot (T_{DHW\,@\,tap} - T_{mains}) \cdot C} = \frac{(T_{in\,HX} - T_{out\,HX})}{(T_{DHW\,@\,tap} - T_{mains})}$$

- % recovery 19% at multiple temperatures
- Long term testing—0%-22% daily averages (13%±5%)
- Cast iron drain pipe thermal mass small effect (steady state ~5-6 minutes)
- Heat loss through pipe walls (3-5° F)
- Shower water temperature loss (130° F at the shower head to 109° F at the drain)

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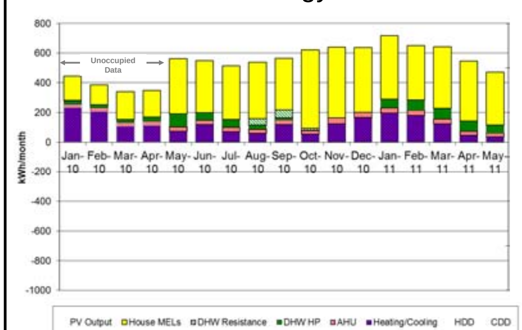
Submetered Net Energy Use



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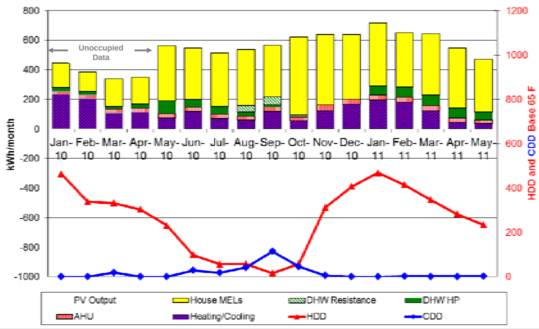
Submetered Net Energy Use



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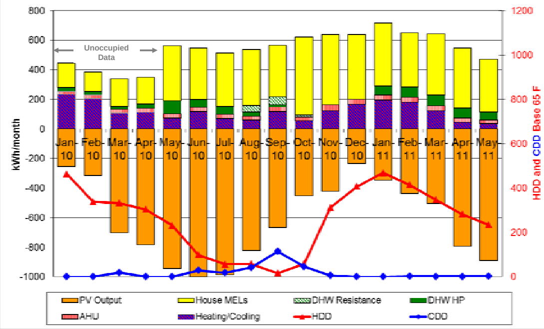
Submetered Net Energy Use



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Overall Performance (Summary)

- 17 months' data (13 months occupied data)
- 7560 kWh generated/7100 kWh consumed (past 12 months): 15% excess
- 10,556 kWh generated/9165 kWh consumed (all data): 7% excess
- Data collection continuing

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Questions?

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This presentation is based on a peer-reviewed paper (Paper 6733), which is available for sale in the onsite ASHRAE bookstore and the online ASHRAE bookstore following the conference.

A complete list of references can be found in this paper.

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