How to Heat Water in All-Electric Homes & Apartments?

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Learning Objectives

- Appreciate various options available for non-fossil fuel water heating.
- Understand how new heat pump water heating systems work and where they can (and where the can't) be applied.
- Better appreciate potential benefits and challenges of solar water heating in various applications.
- Be better able to select water heating systems as part of a whole-building strategy.

Why All-Electric Homes?

- New heat pumps can work well – even in cold climates
- No access to gas
- Expensive to bring gas to site
- Oil & LP can be very expensive*
- No on-site fossil fuels
- Avoid meter fees
- **LOW LOADS!**

Greenfield, MA

Apartment Design heating loads: 5,500 – 11,500 Btu/h

Average DHW Consumption

In a single-family home,

Rule of thumb: 60-70 gallons per day

This is dropping!

Now: 30-45 gal/day more typical

Option 1: Elec. Storage Tanks

- Better insulation now (some better than others)
- Low first cost
- Readily available
- EF_{min} = 0.90 (50 gal)

Resistance Tank Drawbacks

- Resistance is expensive!
- Space
- Standby losses
  - Well-insulated tank
  - Use heat traps
  - Insulate pipes

Option 2: Tankless Electric

- No standby loss
- Systems available with modulation & temp control (not staged elements)
- Modest first-cost
- Compact

Current Draw!
1 gpm: 9 kW, 40 A
4 gpm: 35 kW, 150 A
(60°F rise)
Cost: ~$1,000

www.hubbellheaters.com

Option 3: Solar Thermal

- 65-80% of DHW load for a typical family
- High first cost - $8,000-$12,000 for system with 80 ft^2 **before incentives**
- Not cost-effective in most homes w/ gas water heater.

Solar Thermal

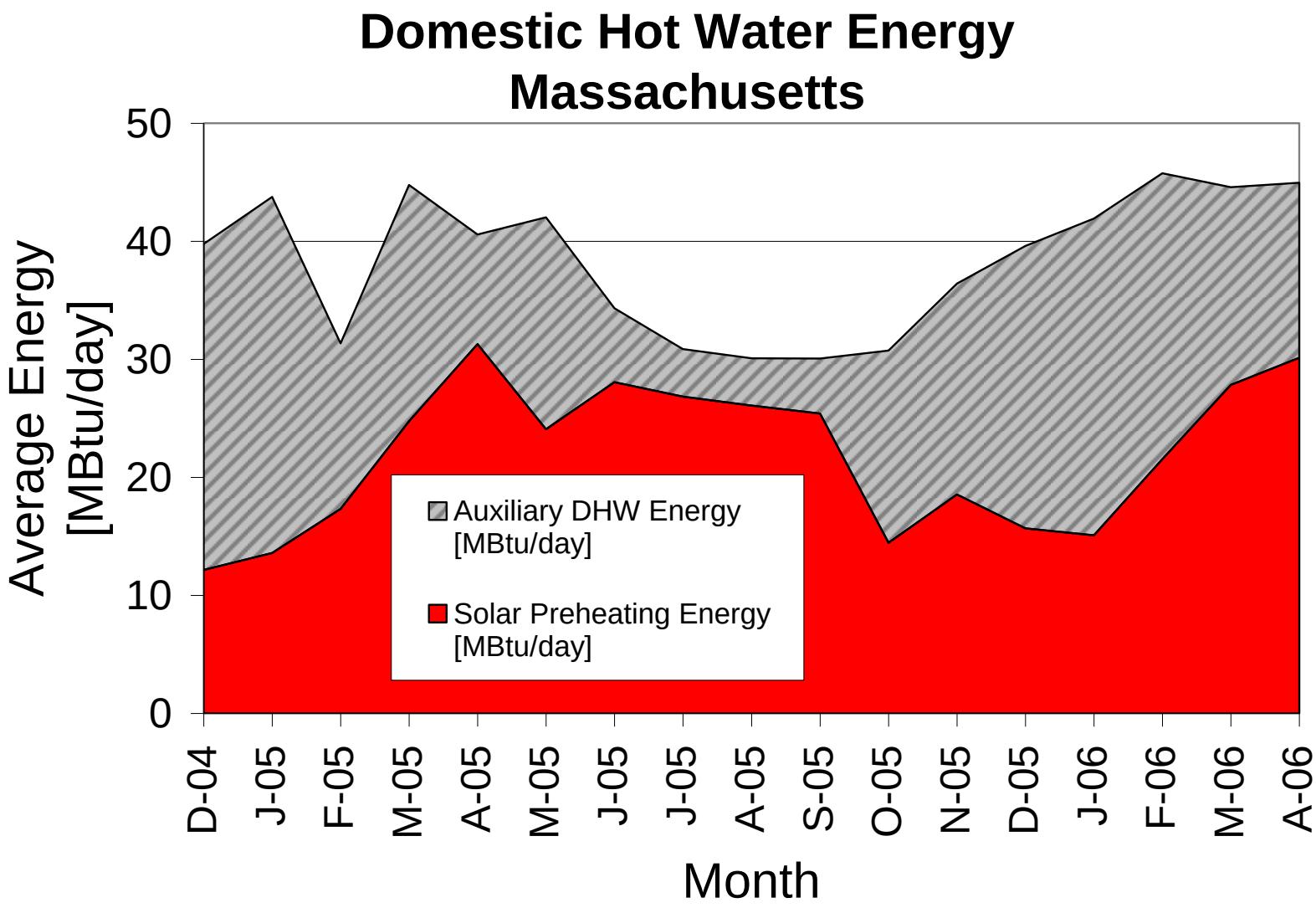
Western MA

- Two, 32-ft^2 flat-plate collectors
- 80-gallon storage tank

Hot Water Use: 64 gal/day

Annual Solar Fraction: 61%

Solar Thermal



Solar Thermal

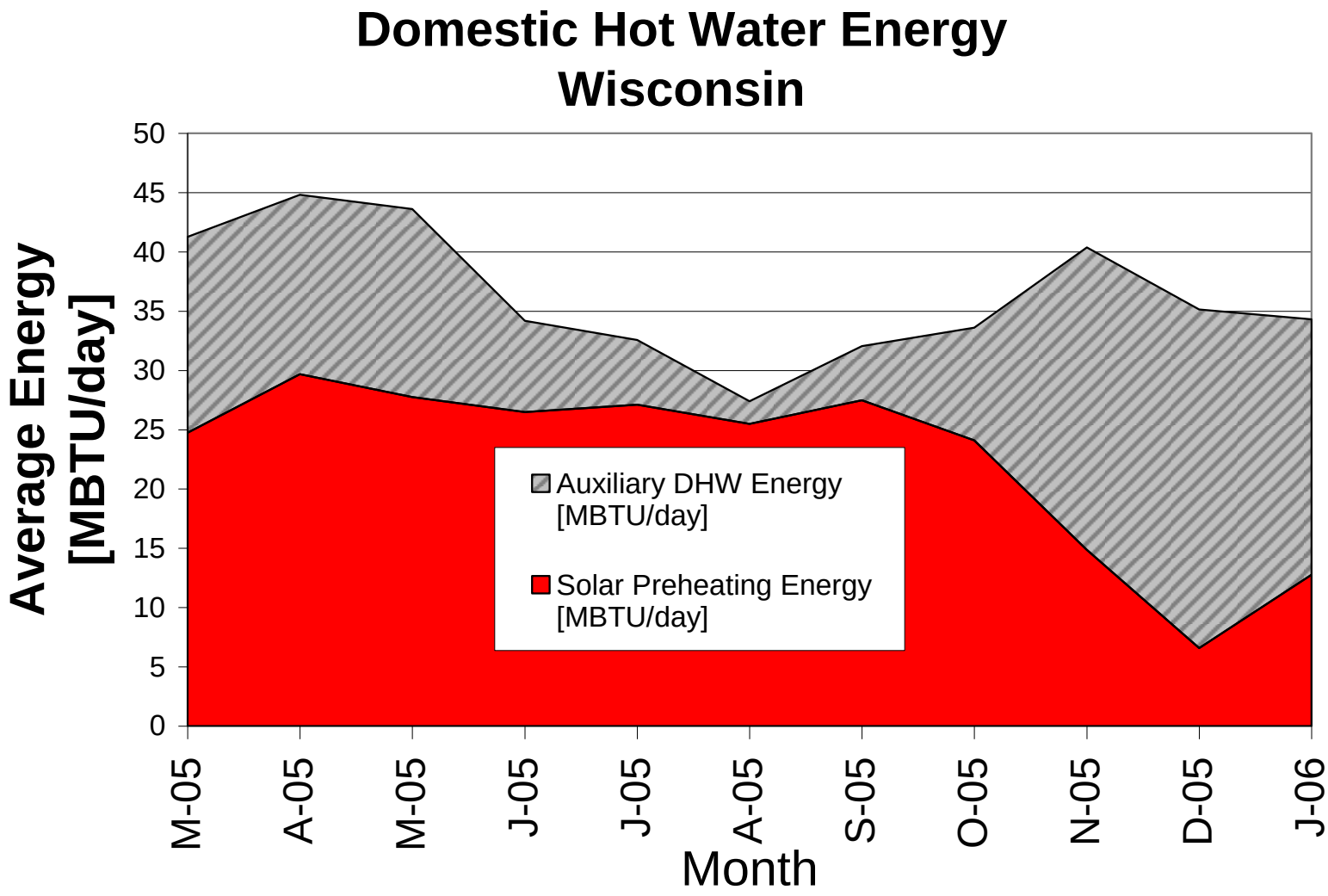
- Two, 32-ft^2 flat-plate collectors
- 80-gallon storage tank

Hot Water Use: 71 gal/day

Annual Solar Fraction: 63%

Madison, WI

Solar Thermal



Solar Thermal

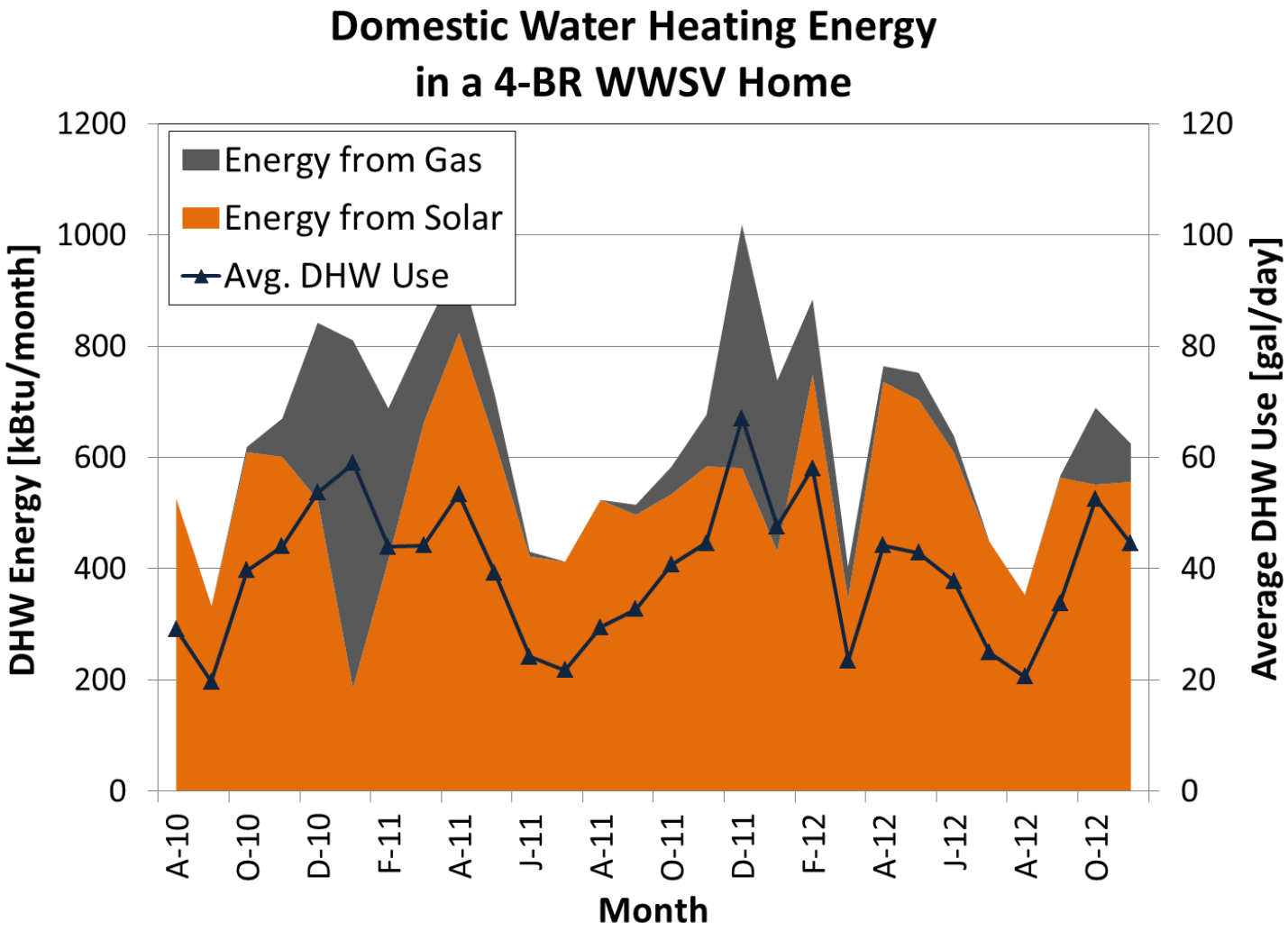
- 90 ft^2 flat plate collector
- 110 gallon storage

Hot Water Use: 39 gal/day

Annual Solar Fraction: 80%

Greenfield, MA

Greenfield Solar Performance



Greenfield Economics

Installed cost: $9,600

- 80% solar fraction
- 40 gal/day

Ann gas use: 24 therms

Ann cost ($1.40/therm): $34

Annual Solar Savings:

- 88 therms, $123

Solar DHW on SF homes with efficient gas WH & modest water usage… not a great investment.

What about an Elec. Home?

With an Elec. Resist tank,

Cost of heating 40 gal/day

- 2,700 kWh/y, **$513** ($0.19/kWh)

With Solar Thermal (80% solar fraction)

- Savings of 2,160 kWh, **$410**/y

Is that worth $9,600?

…or $4,000 - $6,000 after incentives?

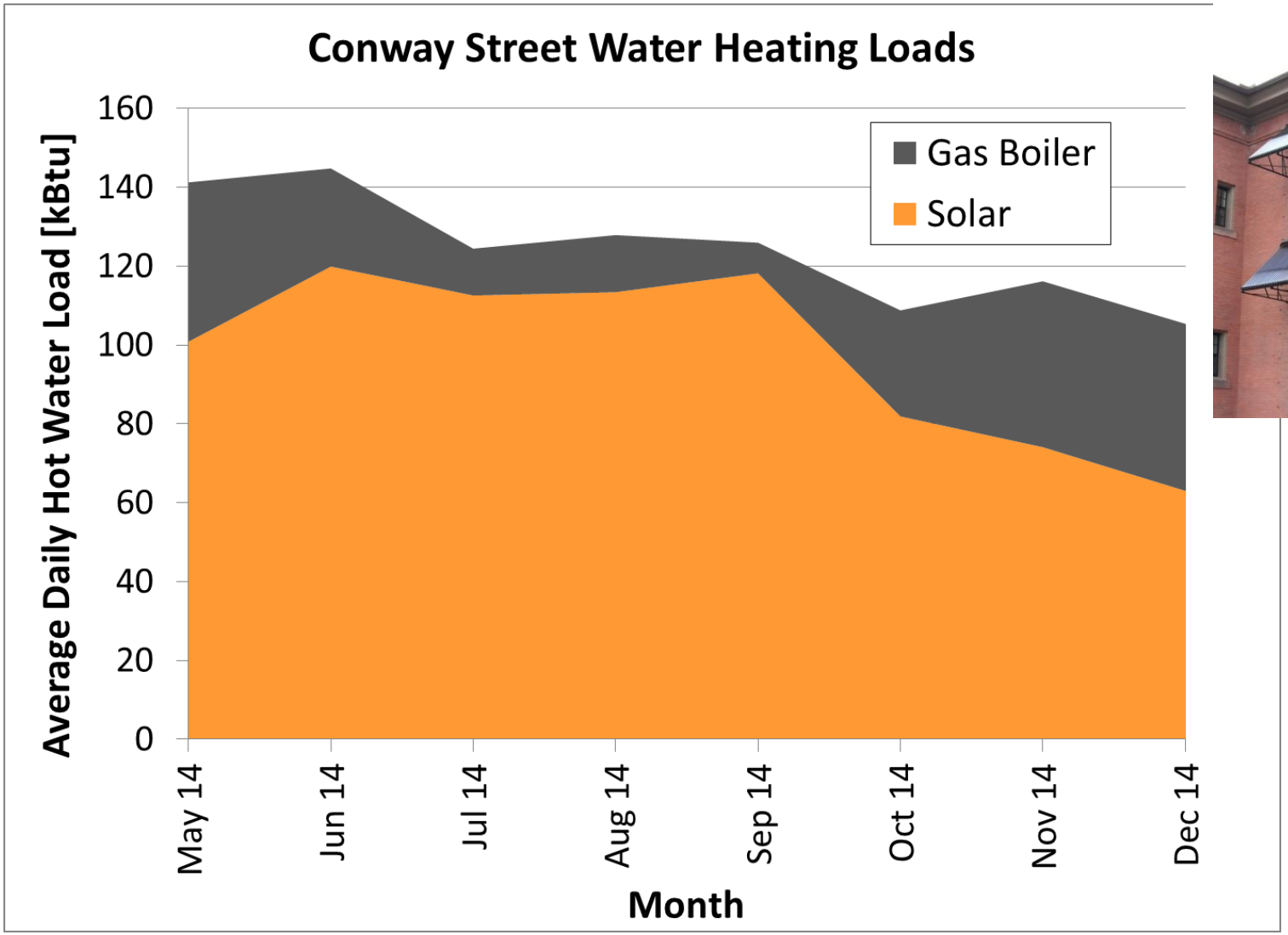
Where might Solar DHW make sense?

- Offsetting electric resistance
- High consumption
- Multi-family

Multifamily Solar Thermal

- Installed cost: $31,000
- 372 ft^2 evac. tube collectors
- 3 Major incentives
  - State rebate
  - Federal tax credit
  - Accel. depreciation
- ~$9,000 (pres. value) after incentives

Solar Savings



Solar Costs & Benefits

Hot Water use: ~20 gal/unit-day

Gas cost w/o solar:	$1,000/y
w/ solar:	$ 300/y
Solar savings:	$ 700/y

Elec. cost w/o solar:	$3,600/y
w/ solar:	$1,100/y
Solar savings:	$2,500/y

Costs: $31,000 before; ~$9,000 after incentives

http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/conwayst-apartments-multifamily-retrofit.pdf

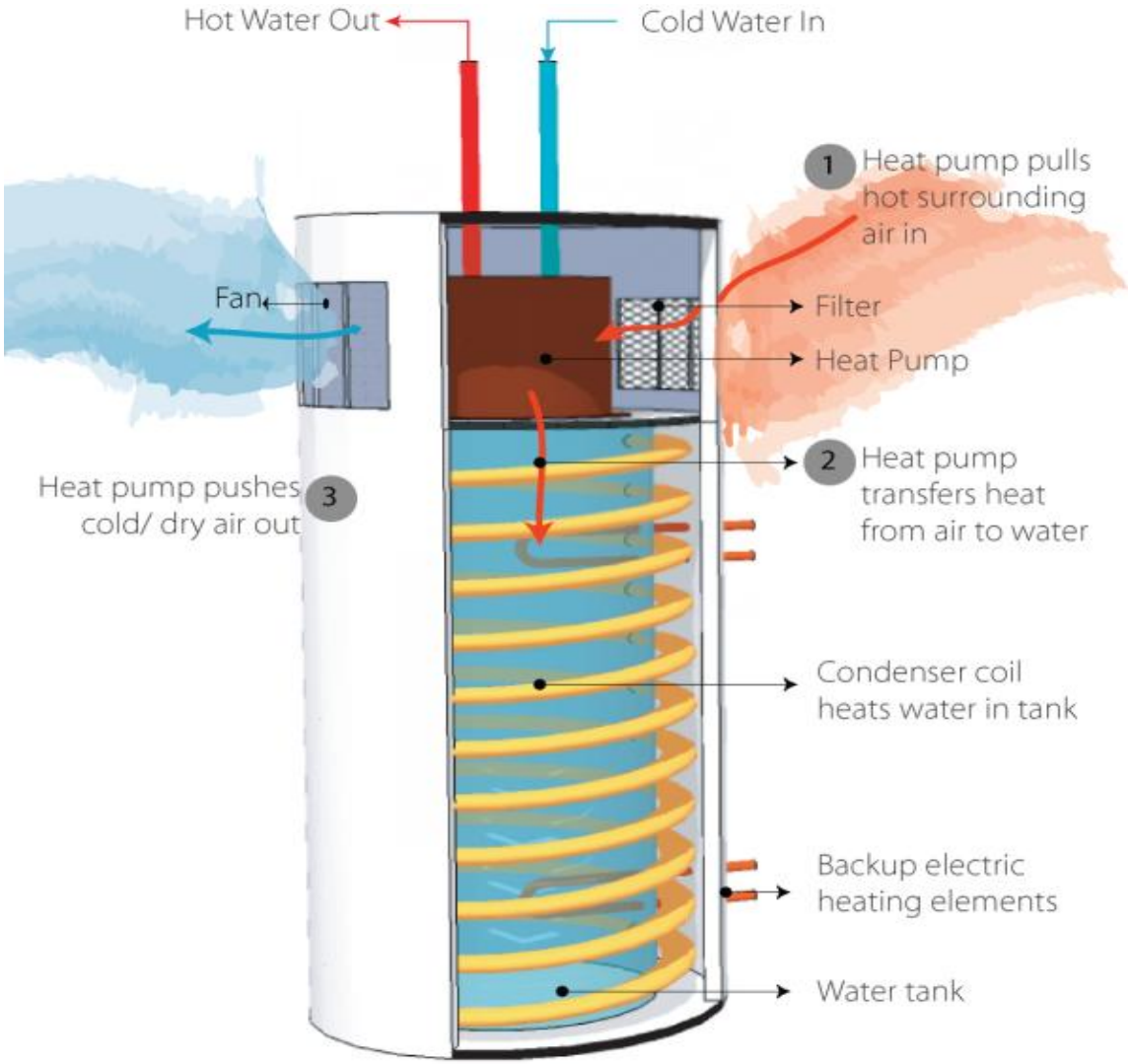
Solar "Issues"

- Operation & Maintenance
  - Smooth operation the exception?
- Monitor performance
- Clear O&M Instructions
- Explore service contracts
- Explore PPAs

Brooklyn Project

- 24 40-ft^2, flat-plate collectors
- 1,500-gallon storage tank
- Initial Cost: ~$105,000

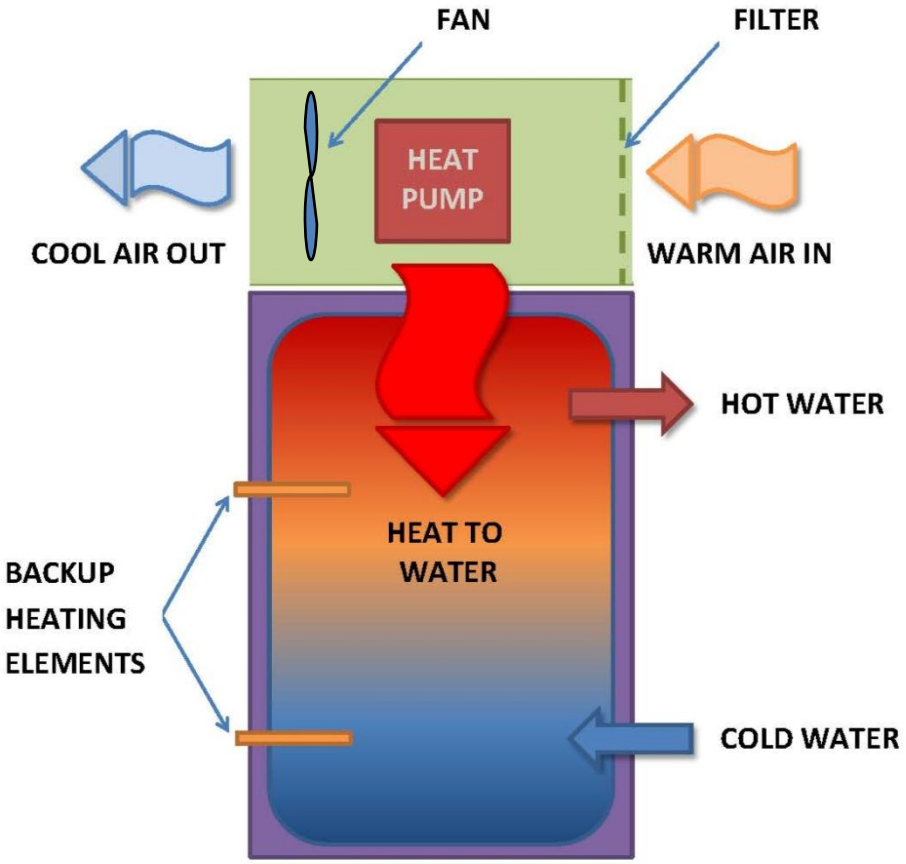
Option 4: Heat Pump Water Heaters



How do they Work?

- Moves heat from surrounding air into water.

- Cools & dehumidifies the surrounding air.



HPWH Monitoring

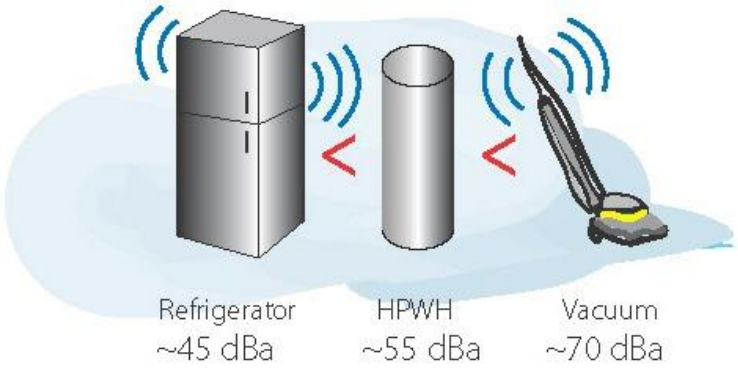
- Monitored 14 HPWHs at sites in MA and RI for over 1 year (2010-11)
- COPs ranged from 1.0 to 2.6

HPWH model	No. Monitored	Capacity (gal)	Energy Factor	Avg. COP	% Electric Resistance
GE	10	50	2.35	1.82*/ 1.64	33%*/ 41%
AO Smith	2	60/80	2.33	2.13	5%
Stiebel Eltron	2	80	2.51	2.35	6%

HPWHs

Advantages

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



Limitations:

- Needs volume (~1,000 ft^3)
- Cools surrounding space
- >45°F
- Condensate draining
- Noise

Where can HPWHs Work Well?

- In basements
- Down south

Where may HPWHs NOT work well?

- Closets
- Finished or occupied basements (noise, cold)
- Apartments (space, noise, comfort)

HPWHs in Apartments

HPWH Costs (MA,RI Study)

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

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

Solar Option: PV + HPWH?

PV needed to power HPWH in efficient home:

1-1.5 kW_{STC}

Cost @ $5/Watt:

$5,000 - $7,500

*All HPWH caveats still apply.

Space Conditioning Impacts

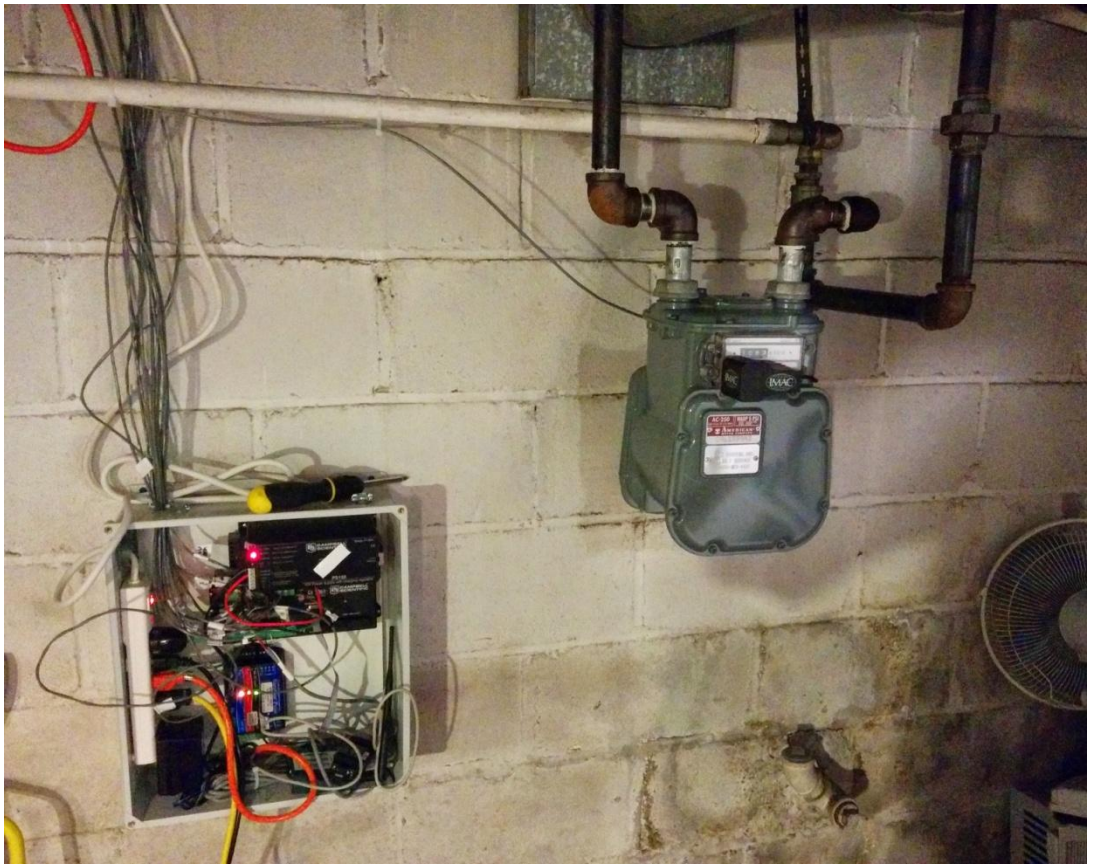
Study currently underway

- 3 AO Smith HPWHs
- 3 CT basements

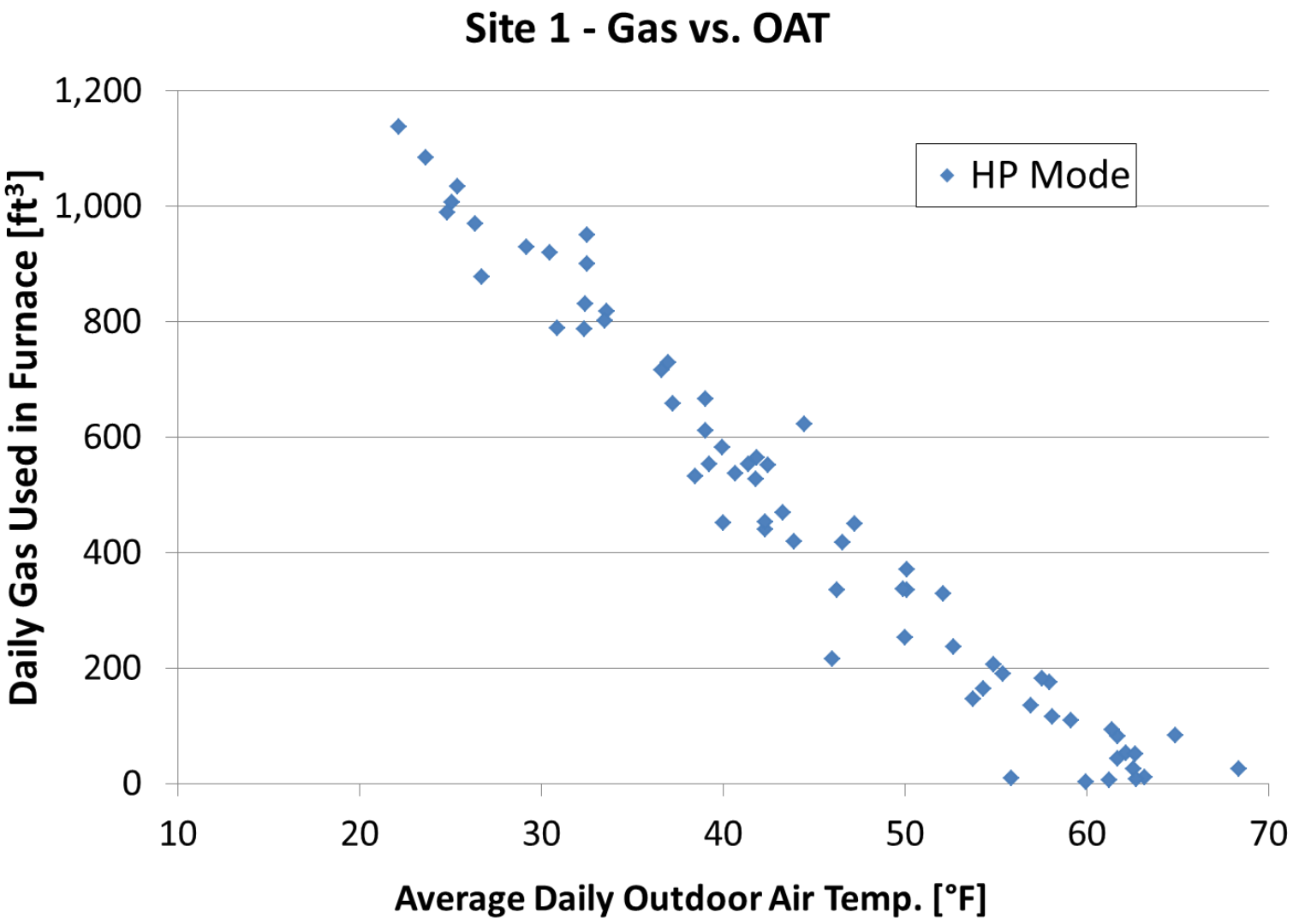
Monitoring Heating Fuel

Cycle between:

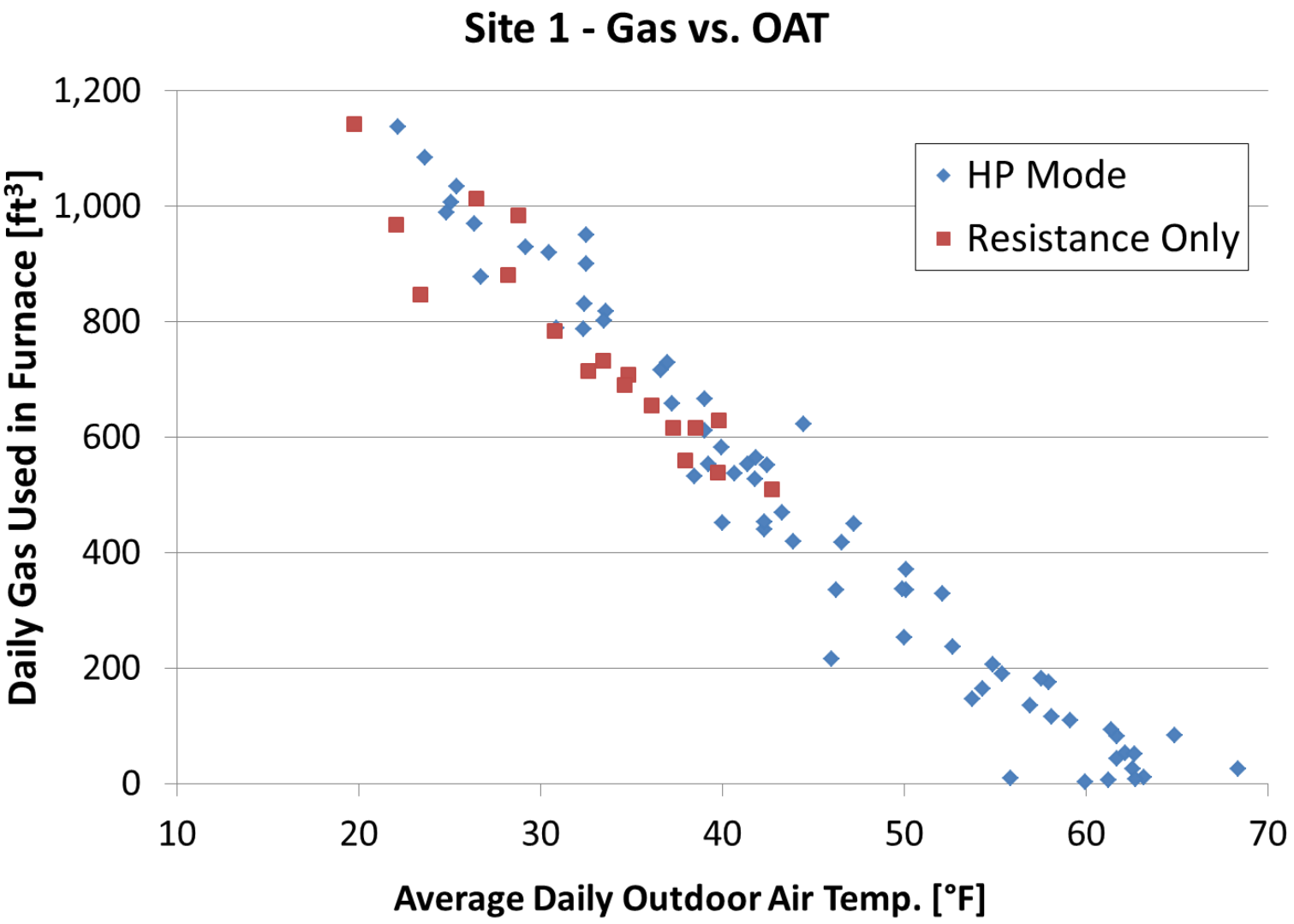
- HP (hybrid) mode
- Resistance mode



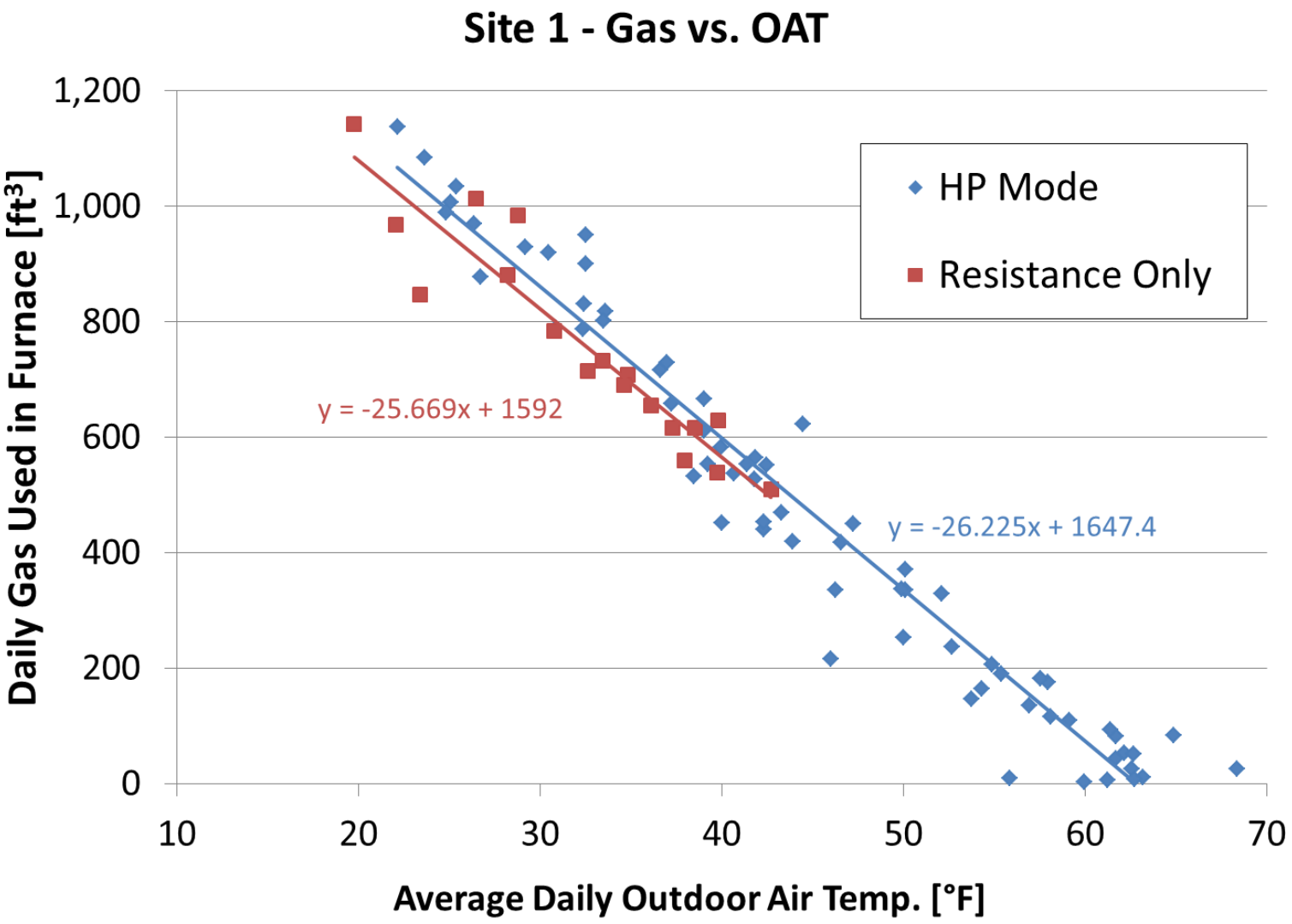
Furnace Gas in HP Mode



Furnace Gas in **Resist.** Mode



Furnace Gas in **Resist.** Mode



Site A

Extra Gas Use with HPWH: **5%**

Over 5,500 HDD: 60 therms

$60 (@ $1.00/therm)

Increased Heating Fuel (5,500 HDD)

Site A	5%	60 therms gas	$60
Site B	7%	65 gal oil	$190
Site C	6%	40 gal oil	$120

* Not final!
* Only additional fuel for heating
* Not including WH savings, cooling/dehumidification benefits
* Monitoring is ongoing.

	COP in HP	COP in Resistance	Avg. Use
Site A	1.84	0.60	42 gal/d
Site B	1.86	0.82	27 gal/d
Site C	1.06	0.51	26 gal/d

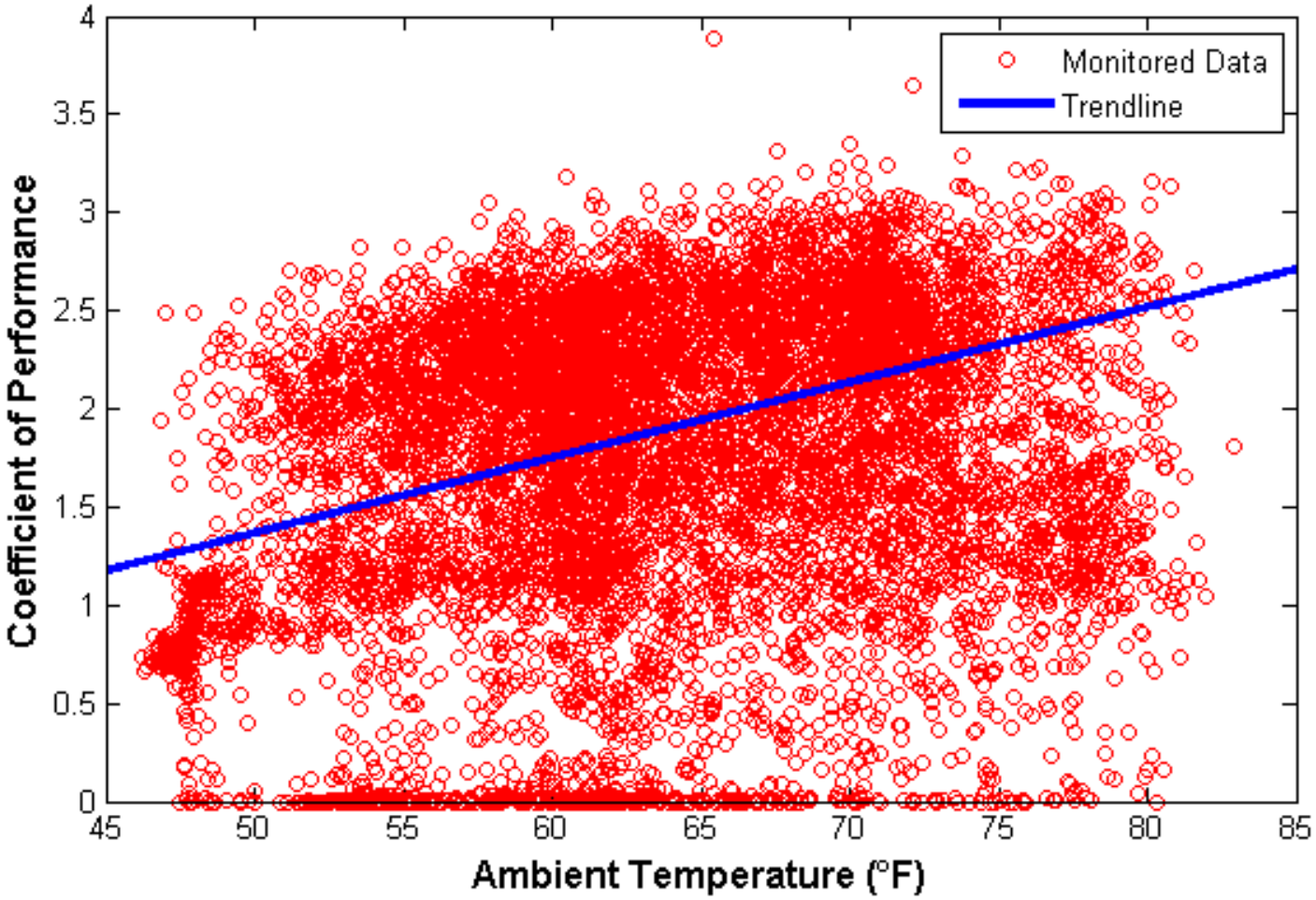
* Late Fall/Winter only; COPs will likely go up in summer

What Affects HPWH Performance

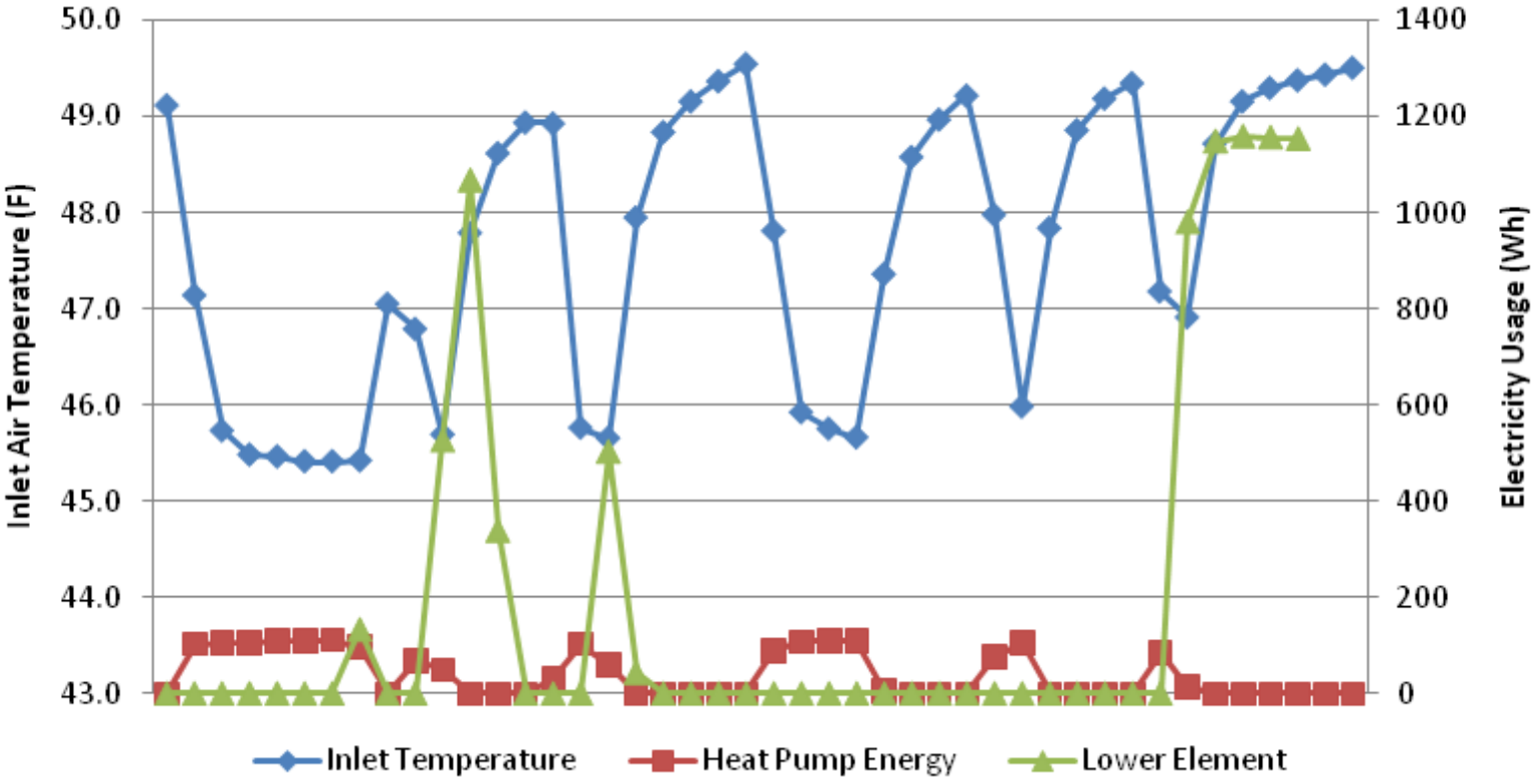
For a given HPWH, COP varies with:

- Ambient Temp (air surrounding WH)
- Total water consumption
- Water draw profile

Temperature Dependence

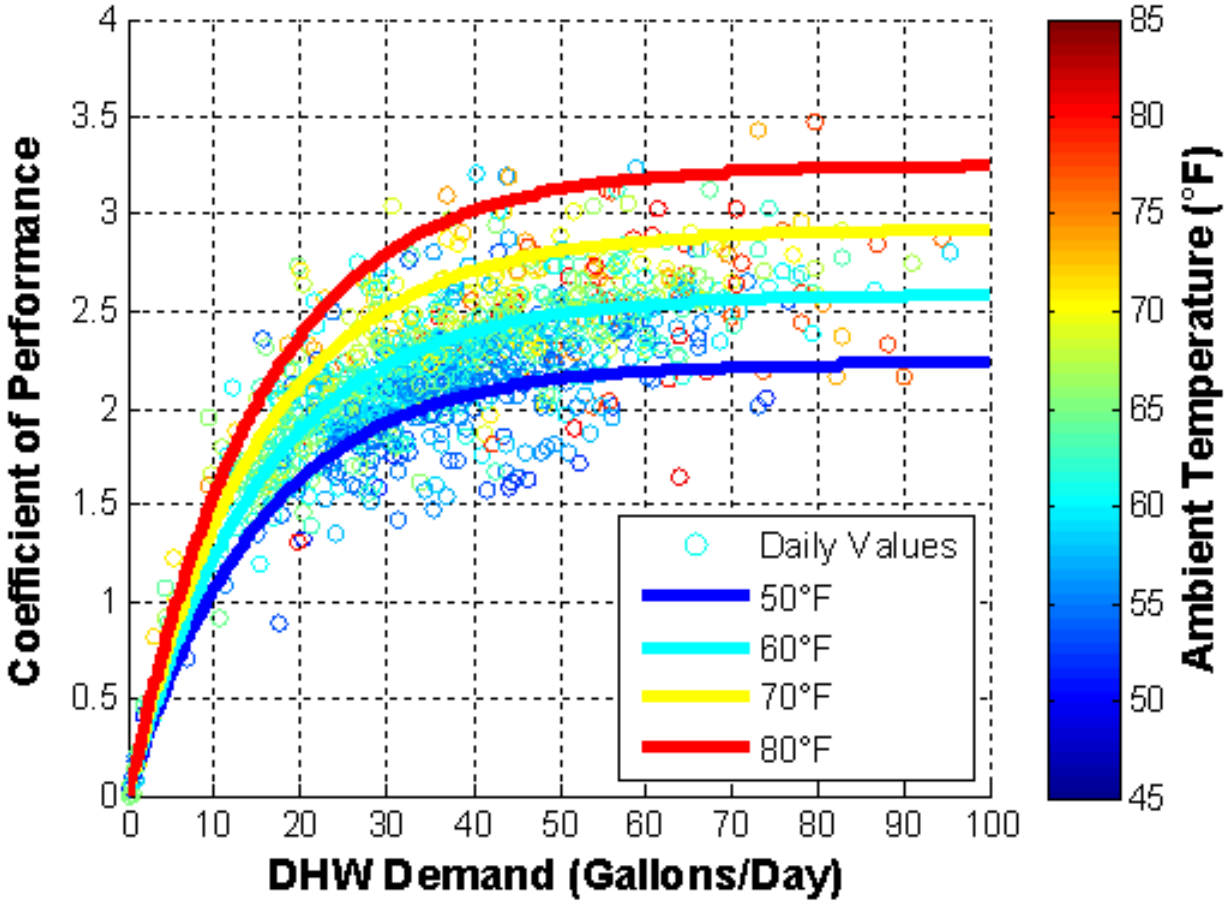


Site 5: Low Ambient Temps

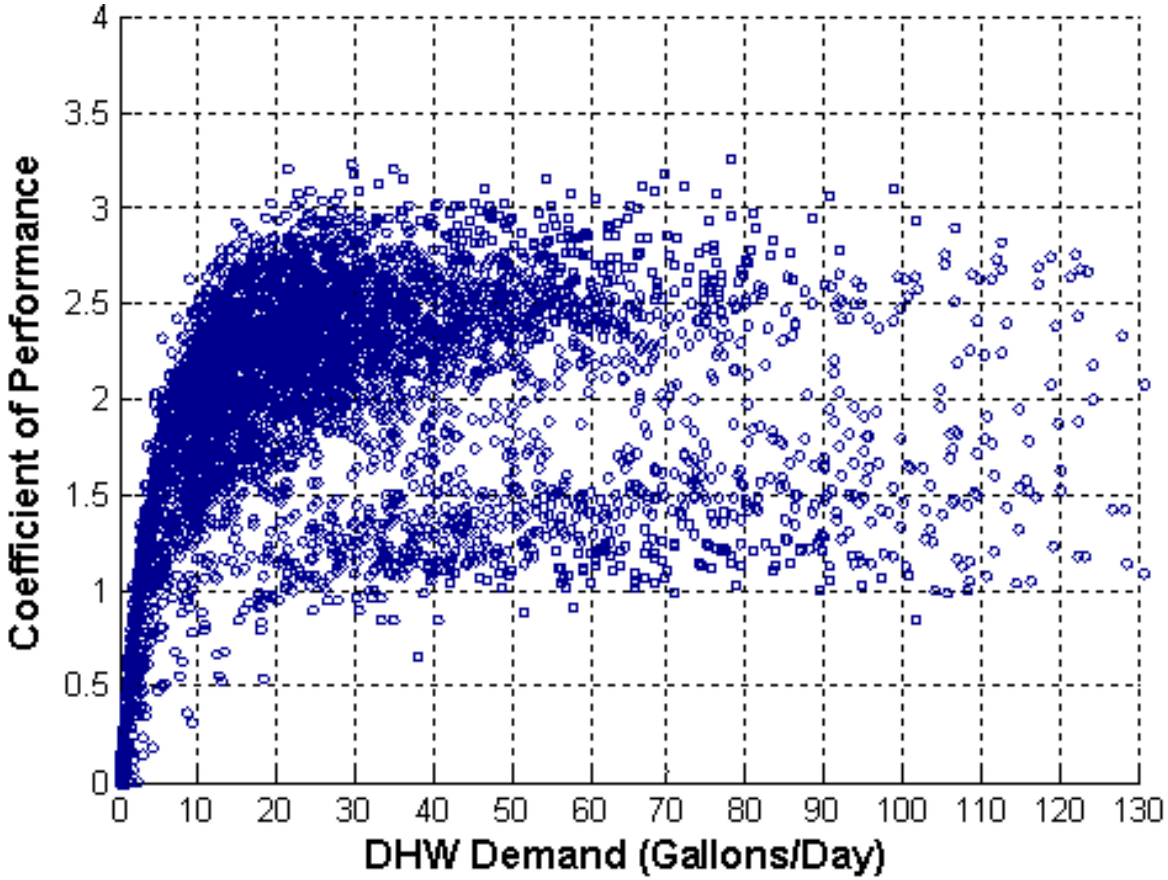


Site 5: GE Unit; COP = 0.77; Average Ambient Temperature = 48°F

Heat Pump Temp. Dependence



Performance Data



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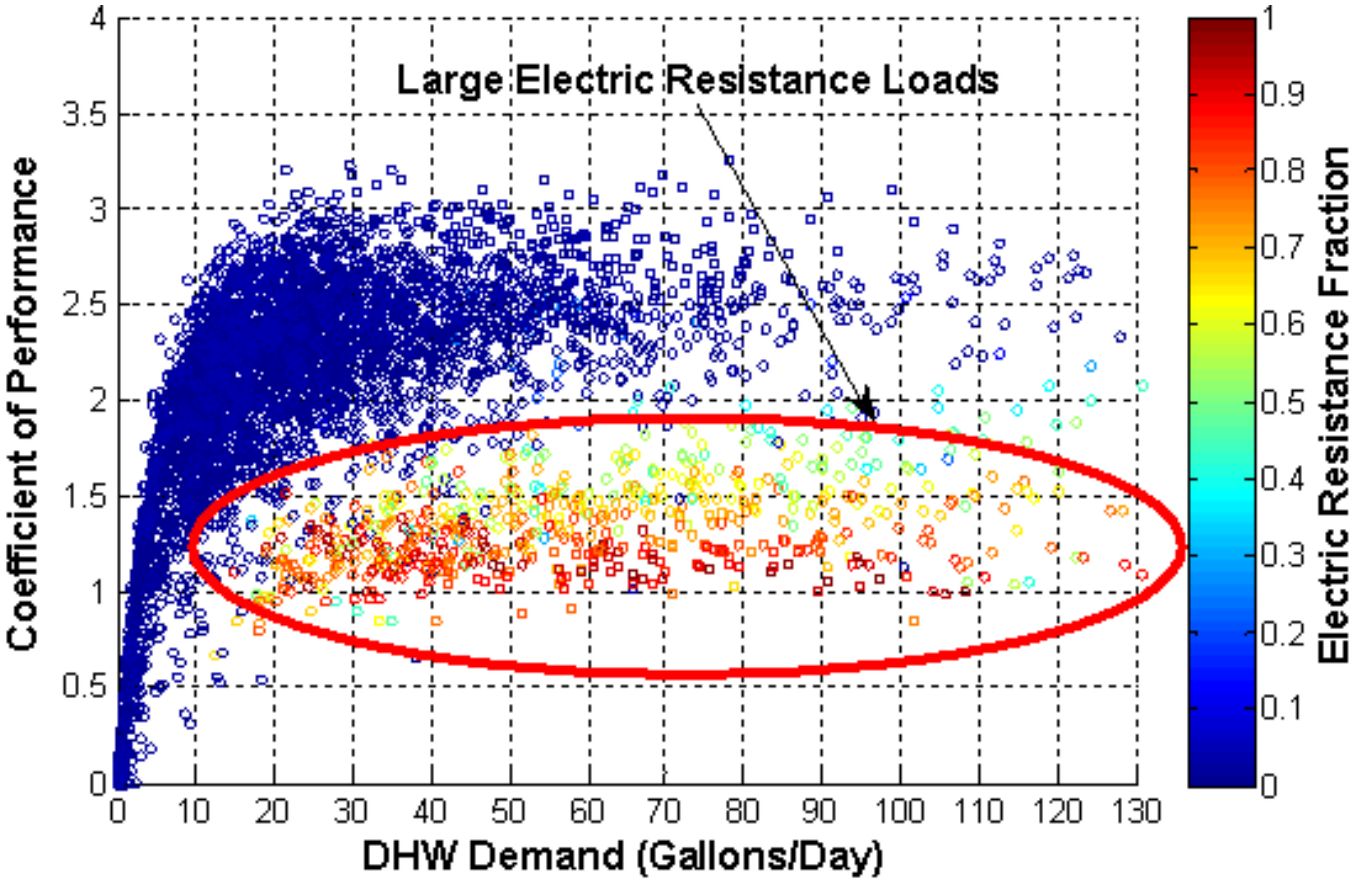
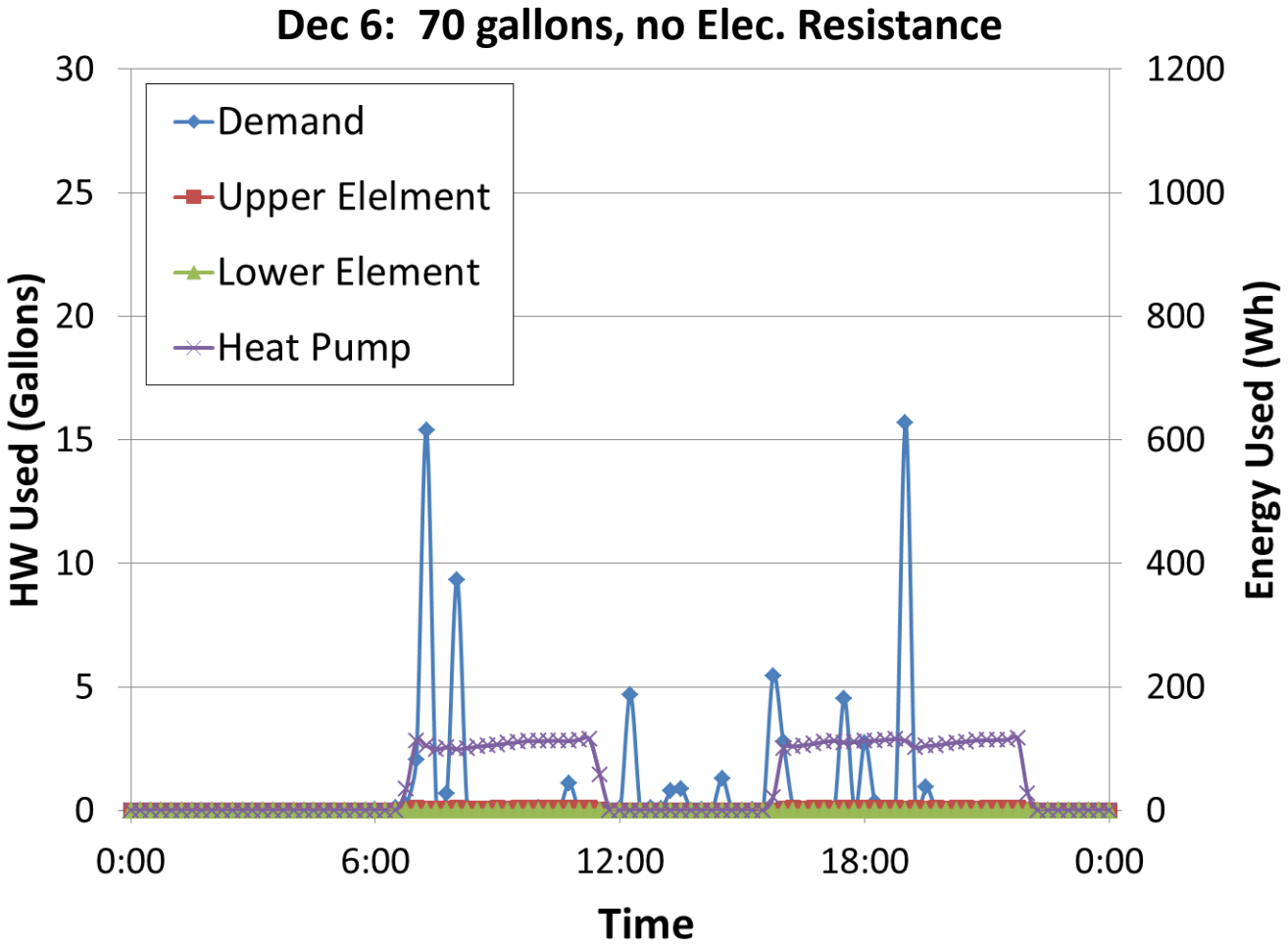


Site 3: Concentrated Draws



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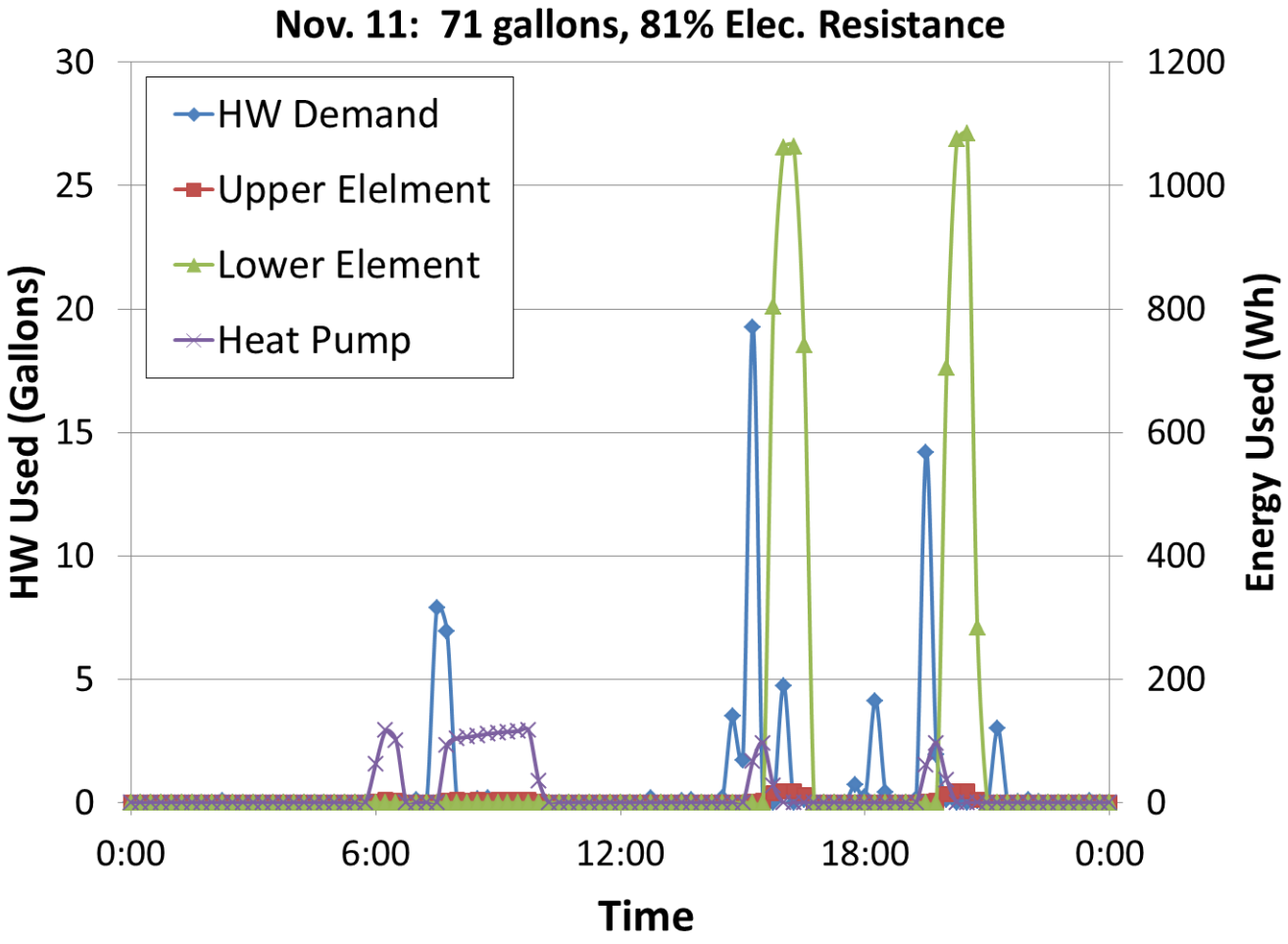


Volume & Temperature

BIGGER IS BETTER

HOTTER IS BETTER

Mixing Valves and Temperature

- Unlike most water heaters, increasing the setpoint of HPWHs can increase efficiency
- Tempering (anti-scald) valves are good practice

Managing Condensate

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

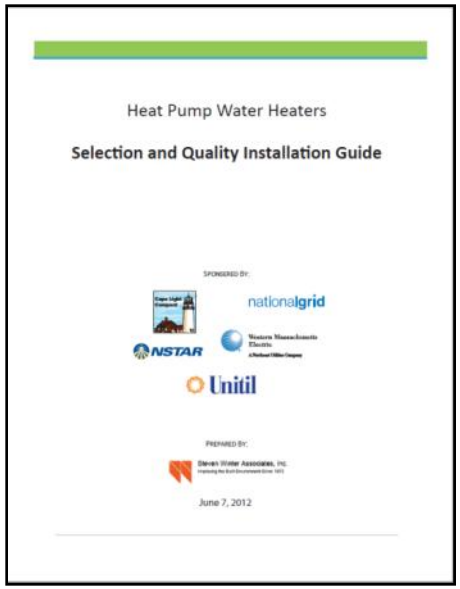
HPWH Sitting in Water

Proper Installation

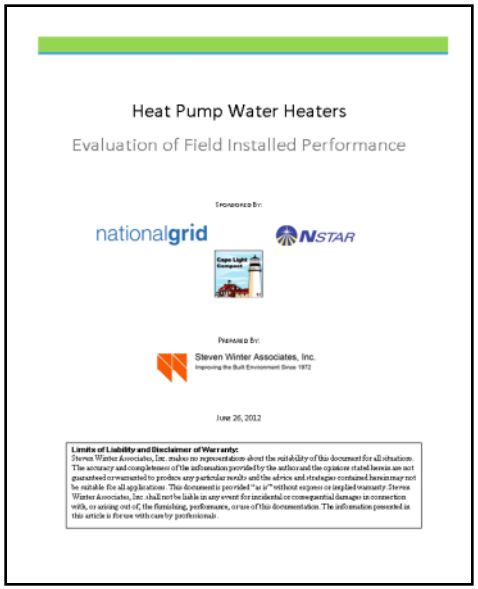
Maintenance

- Filters in HPWHs must be regularly cleaned.
- Educating the homeowners is crucial!

HPWH Resources



http://www.masssave.com/~/media/Files/Residential/Information-and-Edu-Docs/HPWH_QI_Guide.pdf



http://ma-eeac.org/wordpress/wp-content/uploads/Heat-Pump-Water-heaters-Evaluation-of-Field-INstalled-Performance.pdf

Systems So Far

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

SF Cost Summary

	Resist. Tank	Resist. Tankless	Solar Therm.	HPWH
Approx. Cost	$1,000	$1,000	$10,000*	$2,400*
Ann. DHW Cost	$530	$500	$160	$250

Assumptions

- 40 gal/day
- 70°F temp rise
- $0.20/kWh
- 70% solar fraction

Apartment Summary

	Resist. Tank	Resist. Tankless	Solar Therm.	HPWH
Approx. Cost	$800	$800	$3,000* +$800	Not Likely
Ann. DHW Cost	$400	$375	$160	

Assumptions

- 30 gal/day
- 70°F temp rise
- $0.20/kWh
- 55% solar fraction

Systems So Far

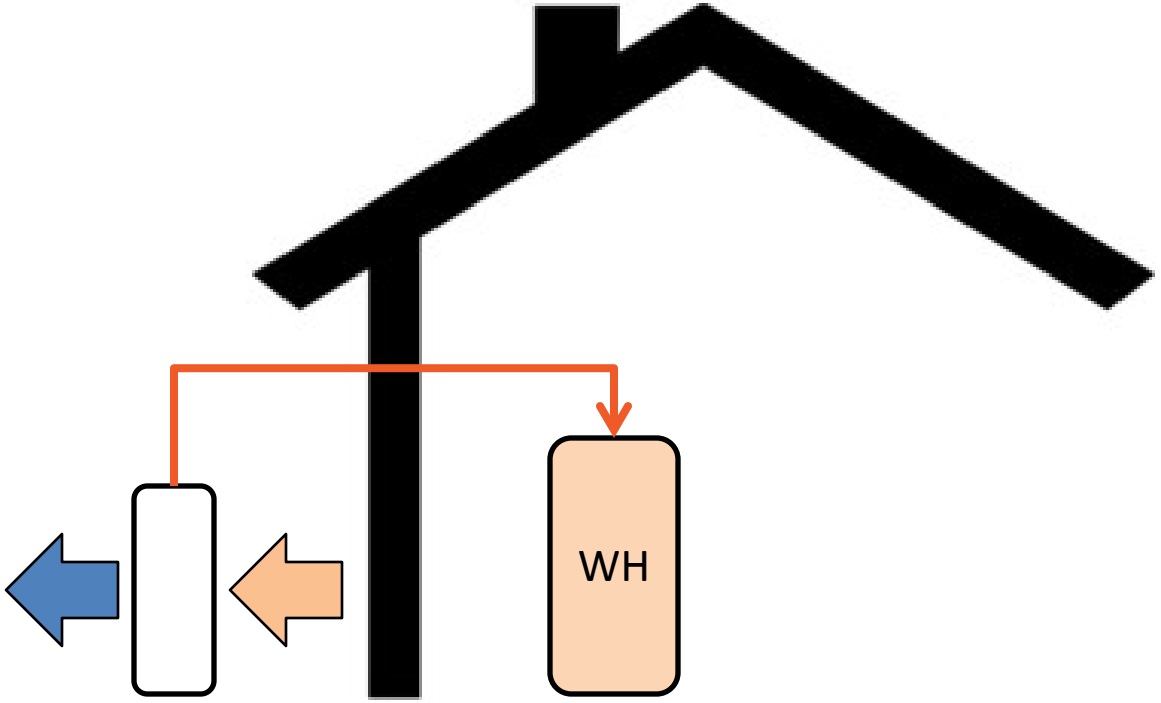
1. Resistance Tanks
2. Tankless Resistance
3. Solar Thermal
4. Heat Pump Water Heaters

- Multi family building
- Don't want fossil fuels (cost, etc.)
- Resistance WH would cost too much (op.)
- Not a good layout for solar
- MF – no good place for HPWHs

…what to do about water heating?

Split HPWHs

"Packaged" vs. "Split"



Other Options

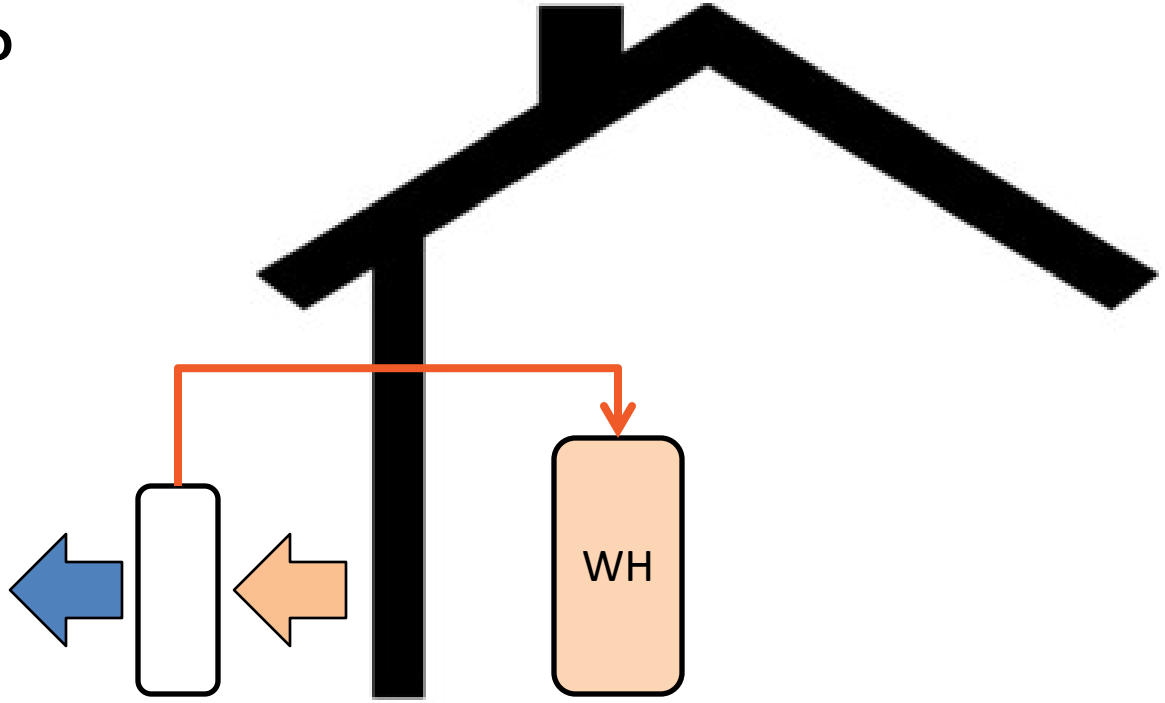
- Whole-house, split air-water heat pumps (e.g. Daikin Altherma)

- AO Smith Commercial HP
  - Not for cold climates
  - Below 50°F

Future Products

Split HPWHs available in Europe & Asia

Soon in US…?



Other Options

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

Questions?

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