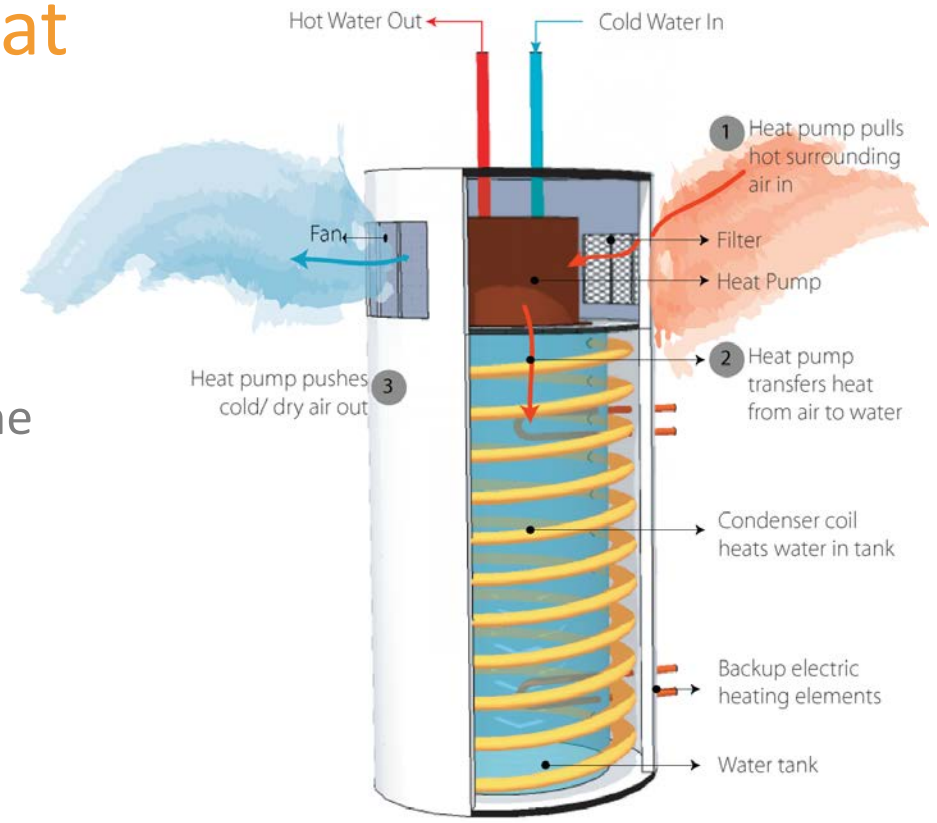
Predicting Real World Heat Pump Water Heater Performance

Based on Performance of 14 sites in the Northeast



Carl Shapiro
Steven Winter Associates, Inc.

Industry Research Teams

BA-PIRC

BARA
BUILDING AMERICA RETROFIT ALLIANCE

ARIES
Collaborative

CARB
Consortium for Advanced Residential Buildings

Alliance for Residential Building Innovation

NorthernSTAR

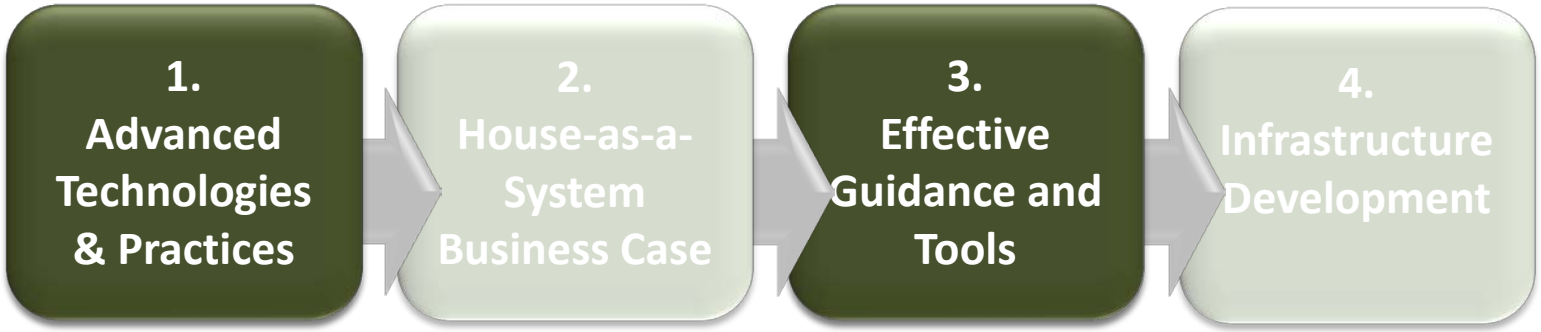
bsc Building Science Corporation

IBACOS
Home Quality + Performance

NAHB RESEARCH CENTER

PARR
The Partnership for Advanced Residential Retrofit

Building America Innovations



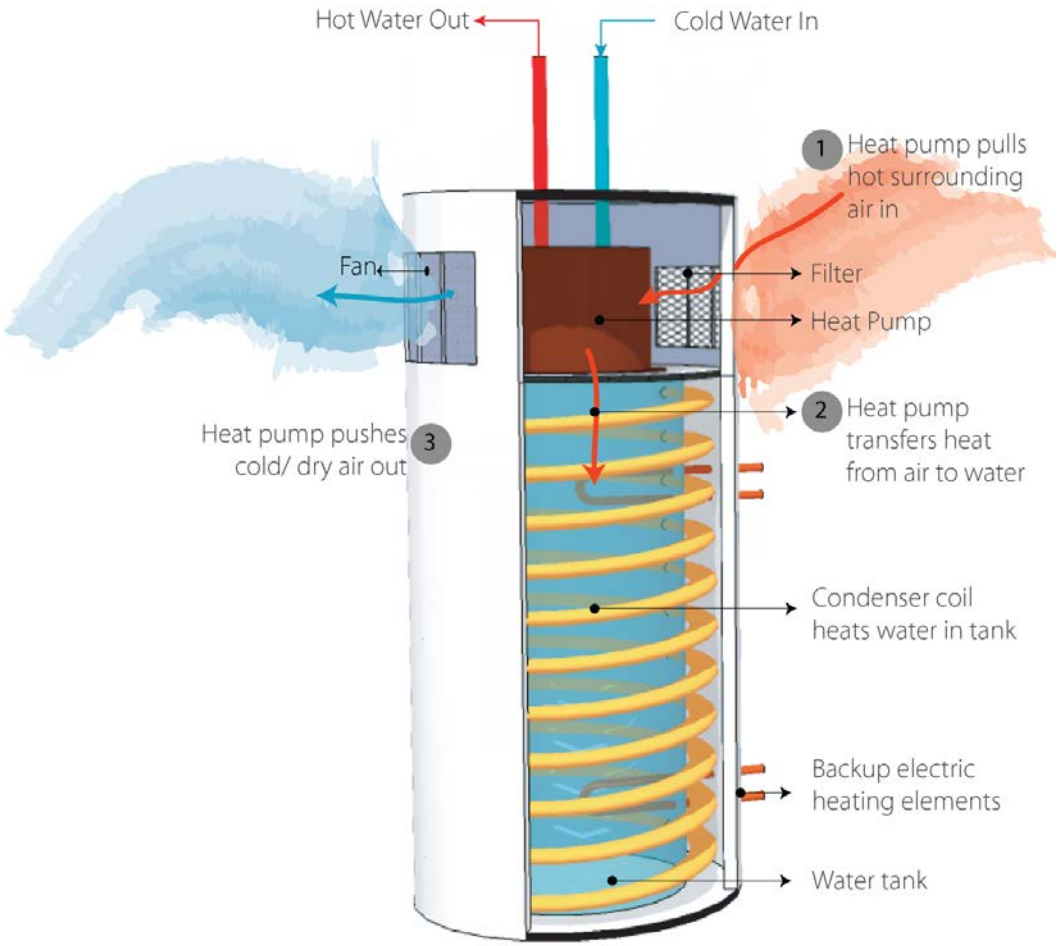
This research is paving the way for key innovations:

- Understanding in-field HPWH performance
- Developing guidelines for industry partners to ensure best practice HPWH installation

Outline

- What are HPWHs and how well do they perform?
- Modeling the real world performance of HPWHs
- Installation issues associated with HPWHs and recommendations

What is a HPWH?



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New Products

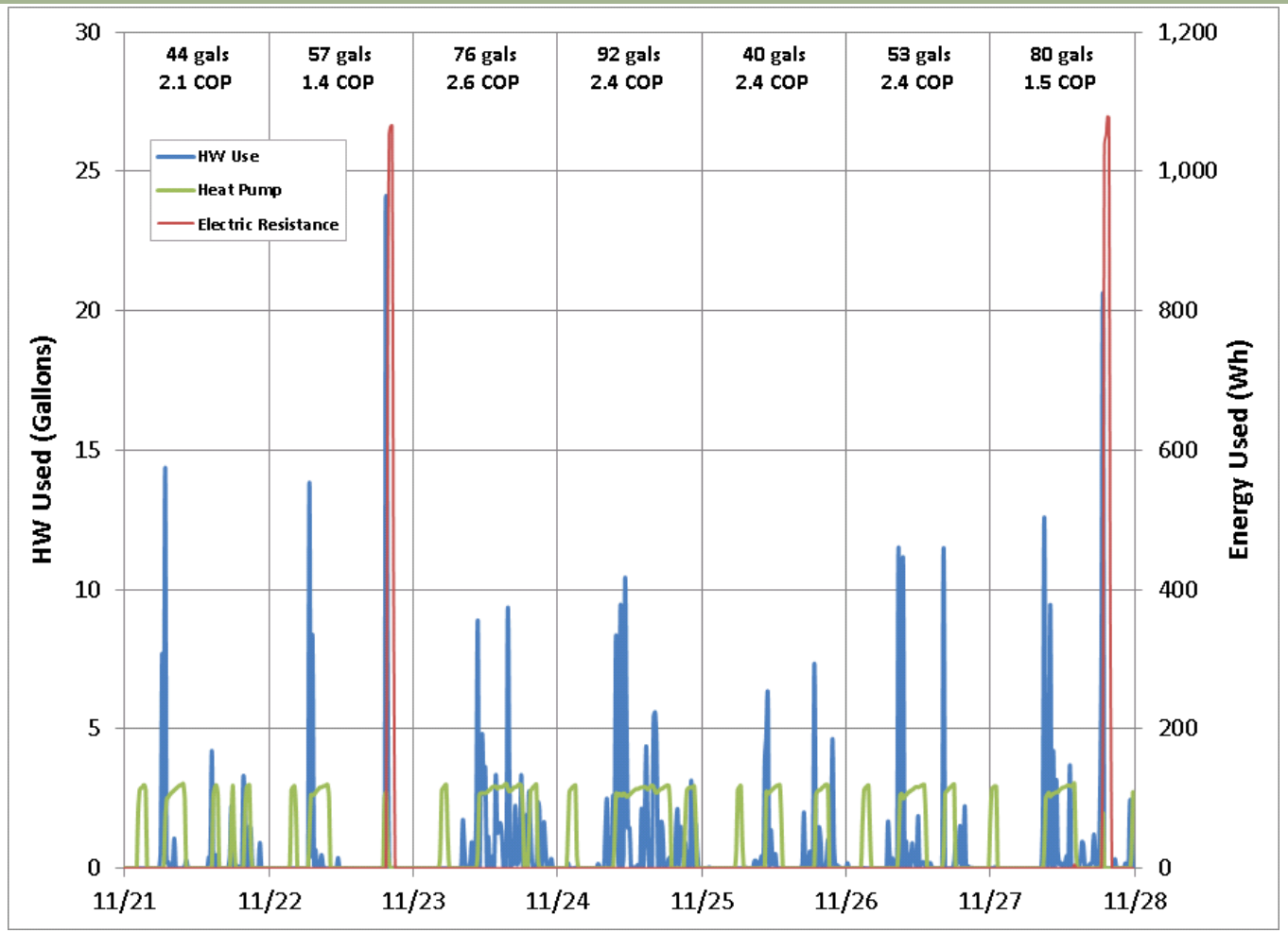
HPWH Monitoring

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

	No. Monitored	Capacity (gal)	Energy Factor	First Hour Rating (gal)	COP	% Electric Resistance
AO Smith	2	60/80	2.33	68.0/84.0	2.0 - 2.6	0% - 11%
General Electric	10	50	2.35	63.0	1.0 - 2.1	5% - 78%
Stiebel Eltron	2	80	2.51	78.6	2.0 - 2.3	2% - 8%

GE: Typical Operation

2 adults + 2 kids
120°F HW setpoint
Avg. of 41 gals/day
Total Calculated COP = 2.0



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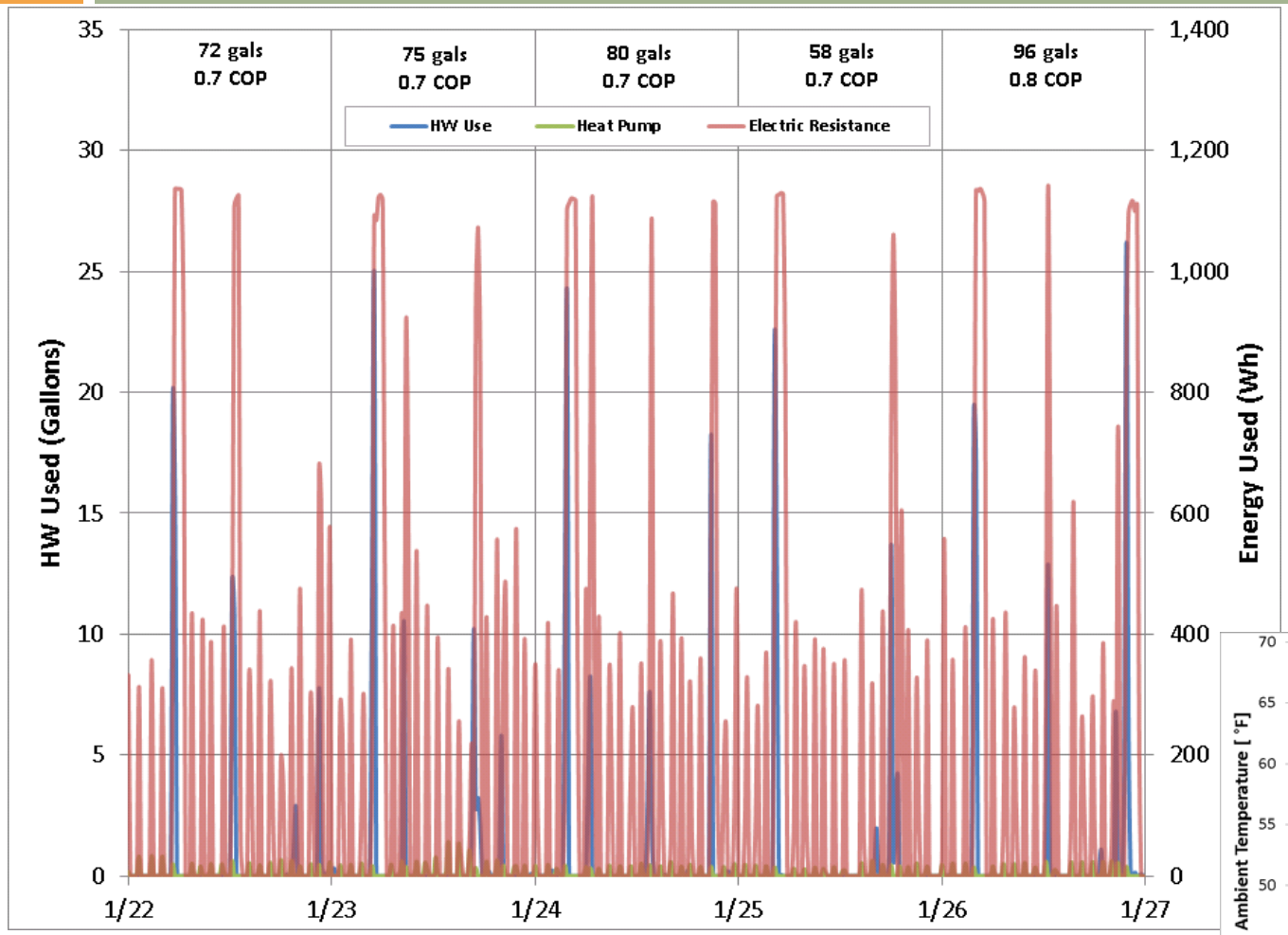
Standby loss heating:
~622 Wh @ $0.17/kWh =
$0.11/day

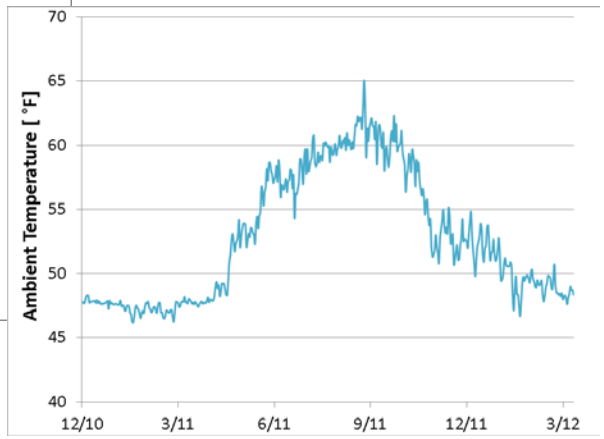
GE: Cold Basement

2 adults
130°F HW setpoint
Avg. of 64 gals/day
Total Calculated COP = 1.0



Avg. ambient temp = 53°F

Month COP ranges from 0.7-1.6.



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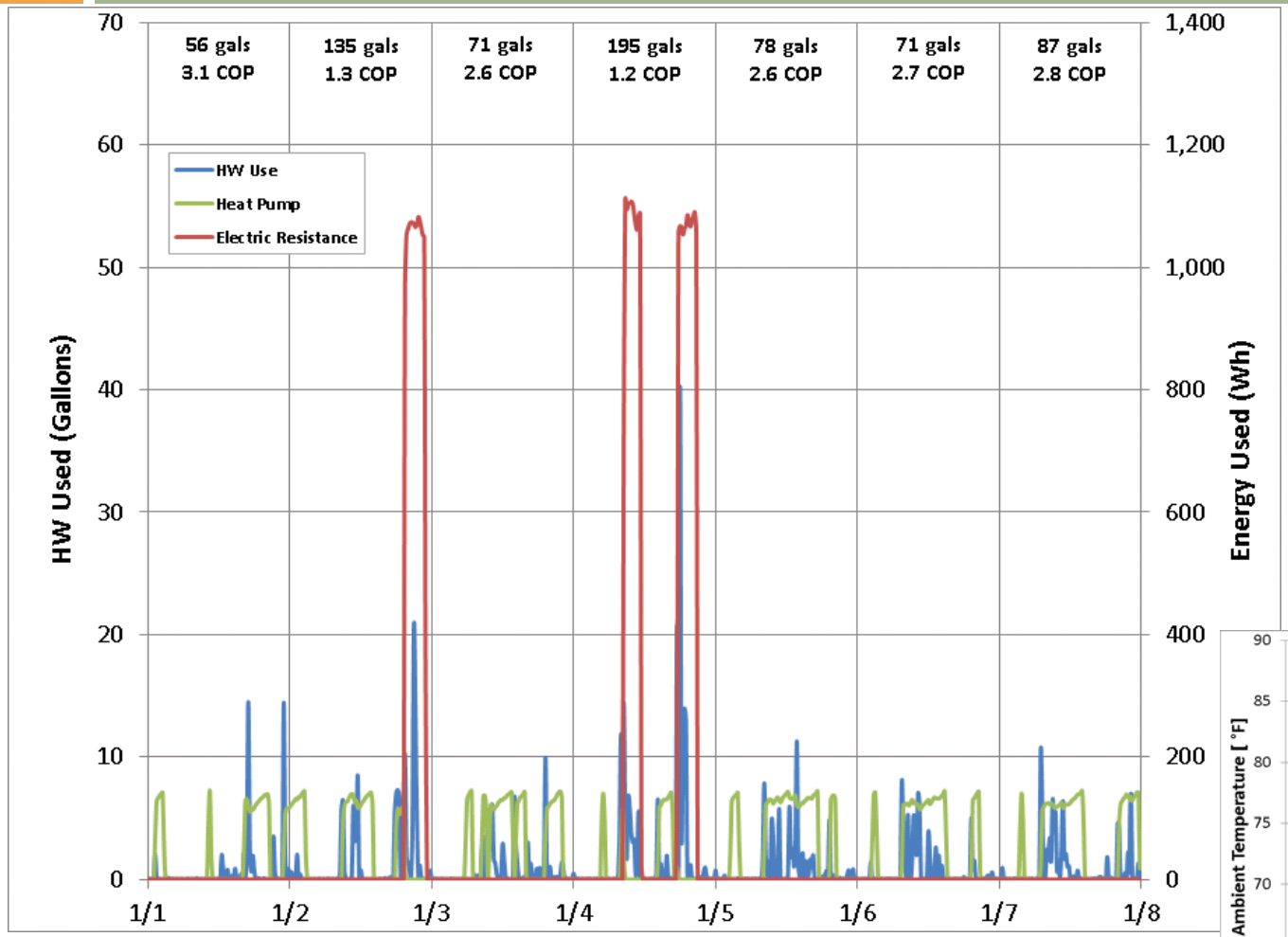
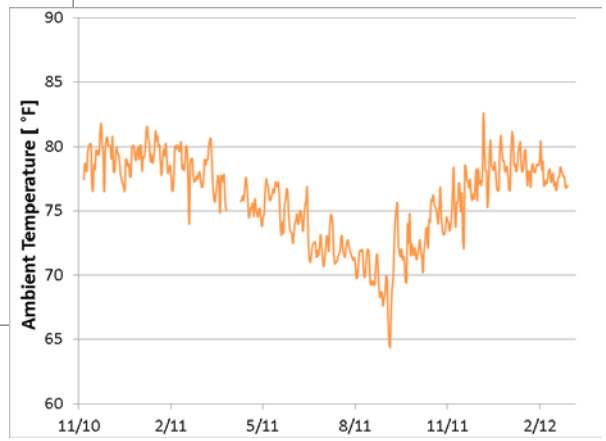
GE: Warm Basement

2 adults + 3 kids
140°F HW setpoint
Avg. of 72 gals/day
Total Calculated COP = 1.5



Avg. ambient temp = 76°F



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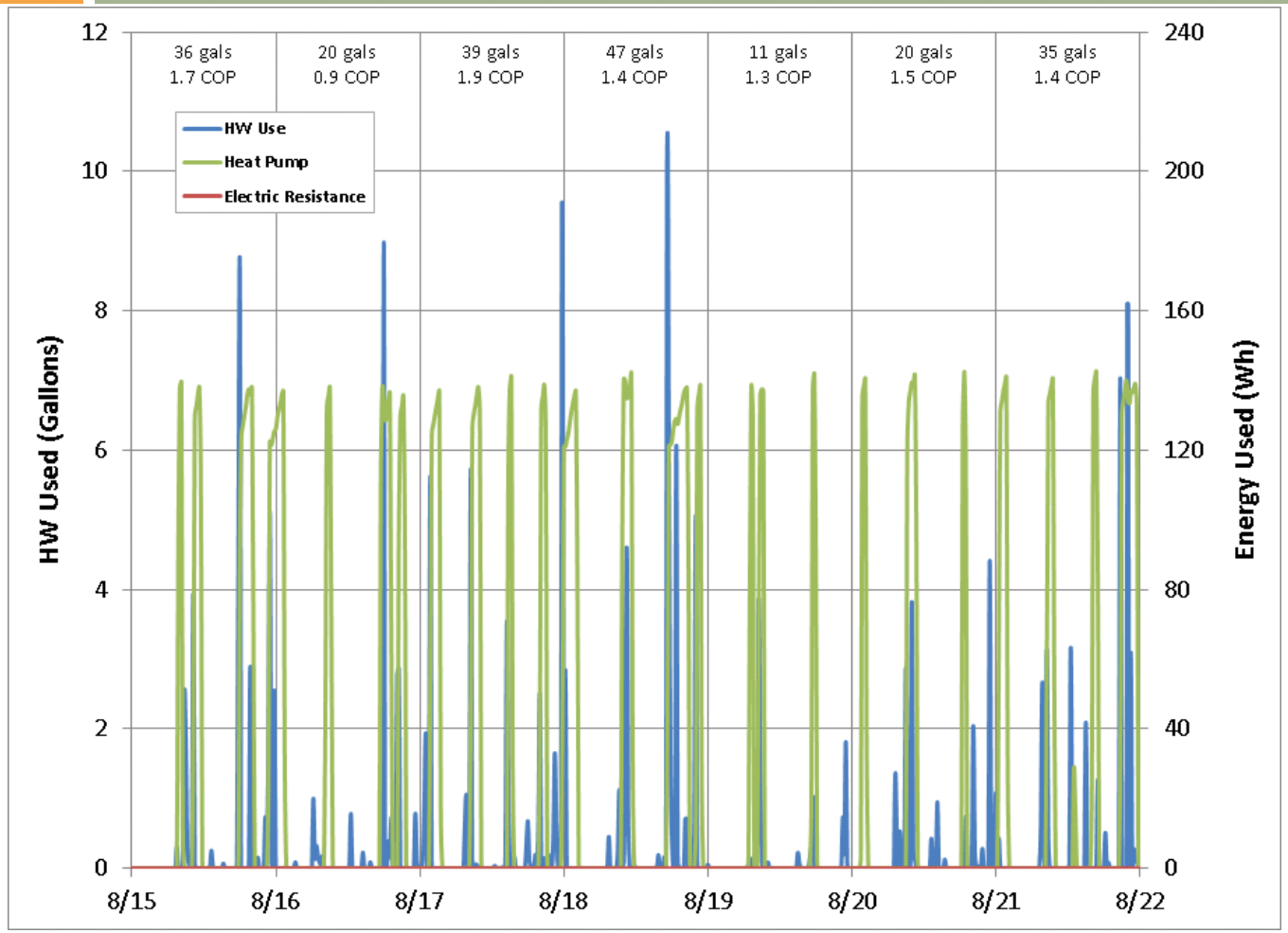
GE: Low HW Use

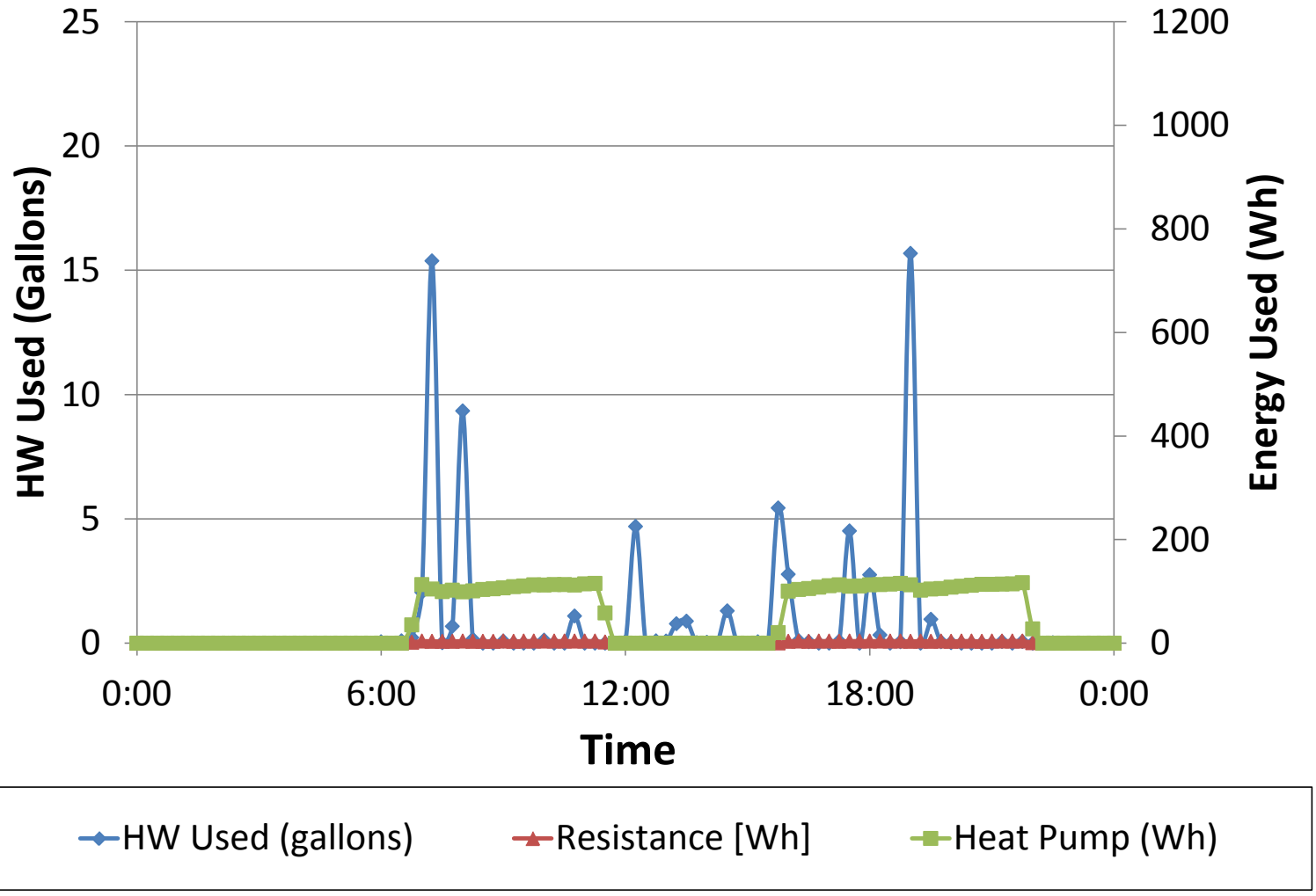
2 adults
130°F HW setpoint
Avg. of 32 gals/day
Total Calculated COP = 1.4



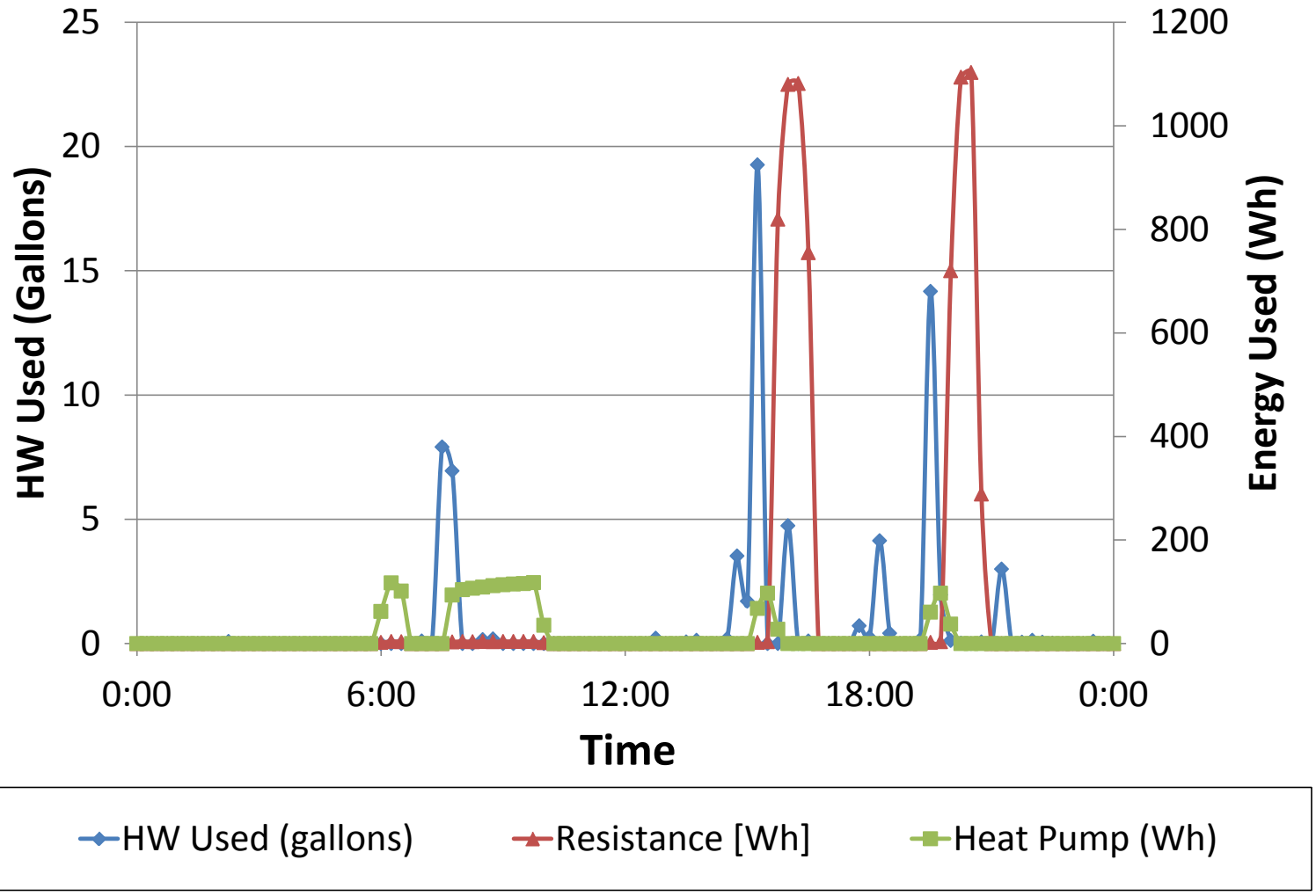
Avg. ambient temp = 70°F

Minimal electric resistance use over monitoring period.

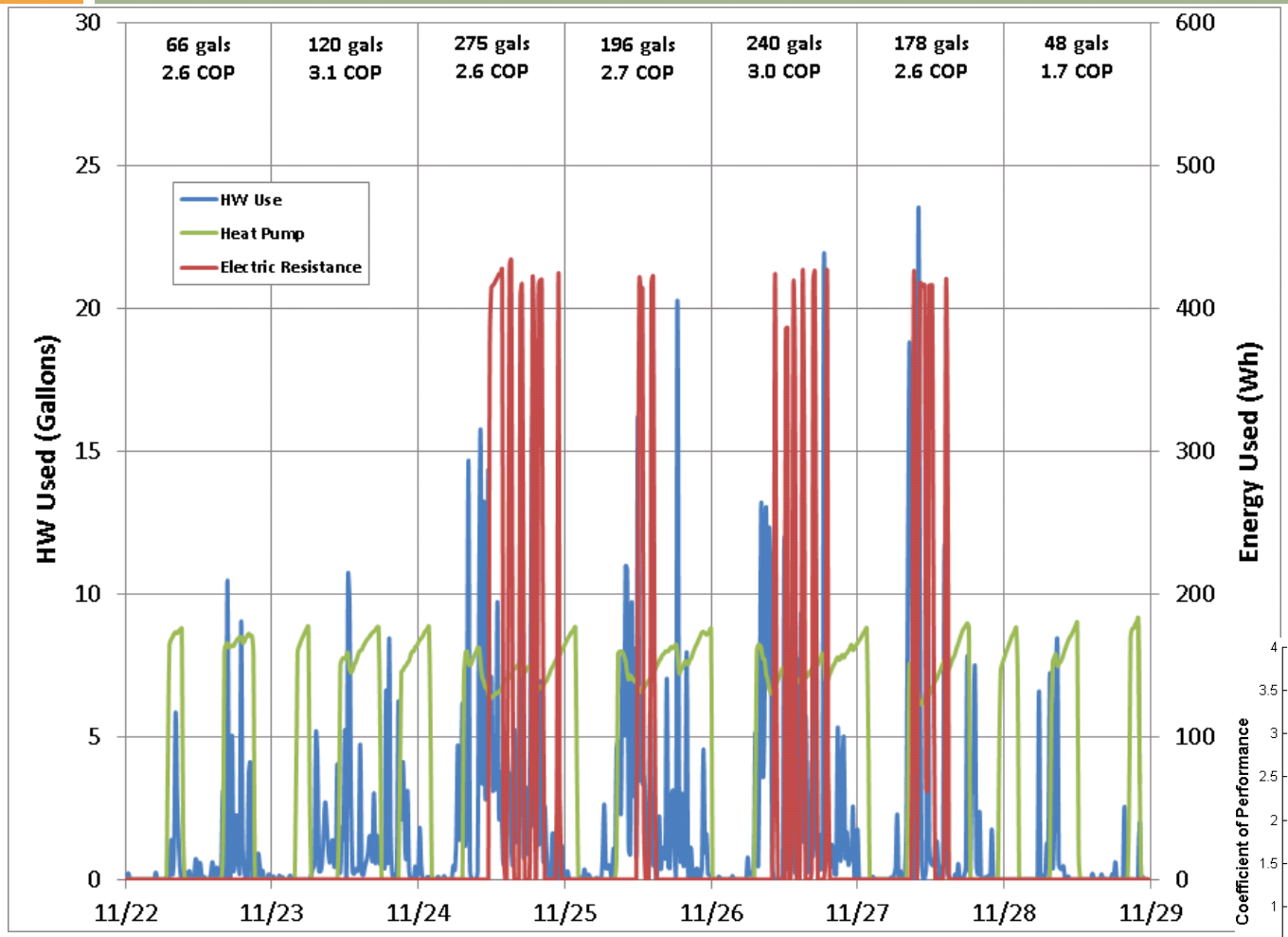
Dec. 6: 70 gallons, 0% Elec. Res.



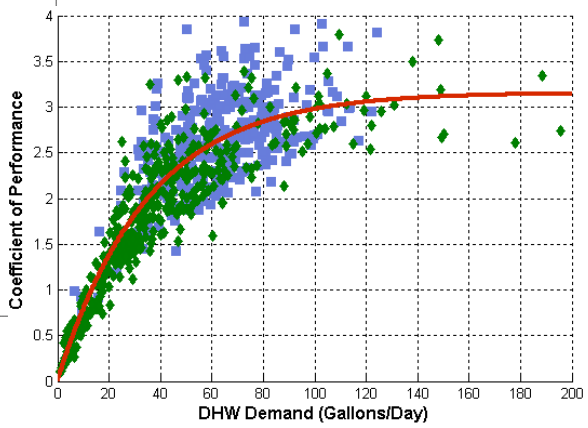
Nov. 30: 71 gallons, 81% Elec. Res.



Stiebel-Eltron: High HW Use



2 adults
140°F HW setpoint
Avg. of 41 gals/day
Total Calculated COP = 2.0
Avg. Ambient Temp = 68°F



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Model Goals

- Want to develop model to accurately predict COP
  - Identify variables that affect performance
  - Identify best period for analysis
  - Find equation that easily and accurately predicts COP
- Ongoing project

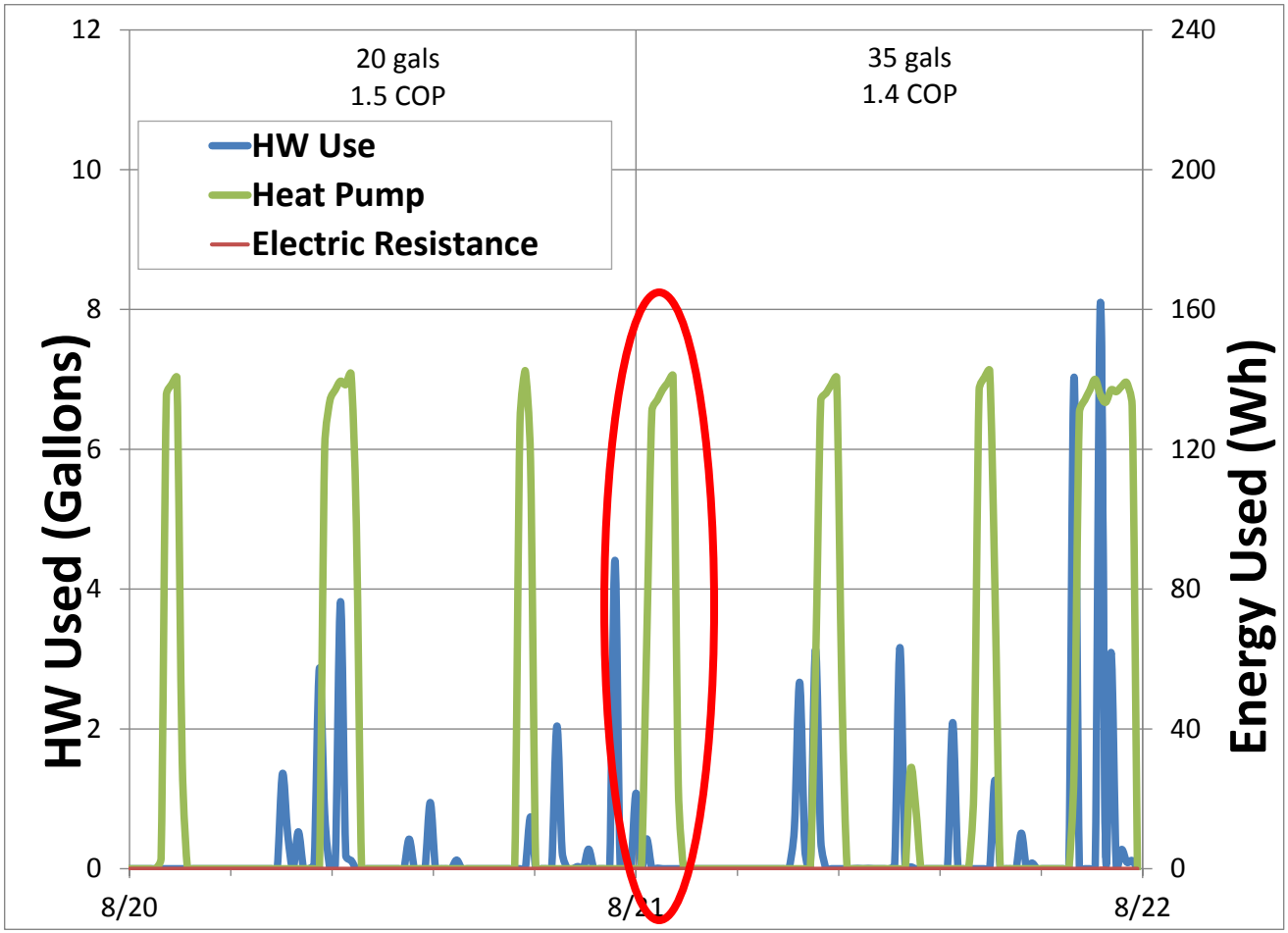
What Affects Performance

- COP depends on:
  - Ambient Temperature
  - Ambient Relative Humidity
  - Setpoint Temperature
  - Mains Temperature
  - Water Draw Profile
    - Total Volume
    - Draw Pattern

Choosing an Analysis Period

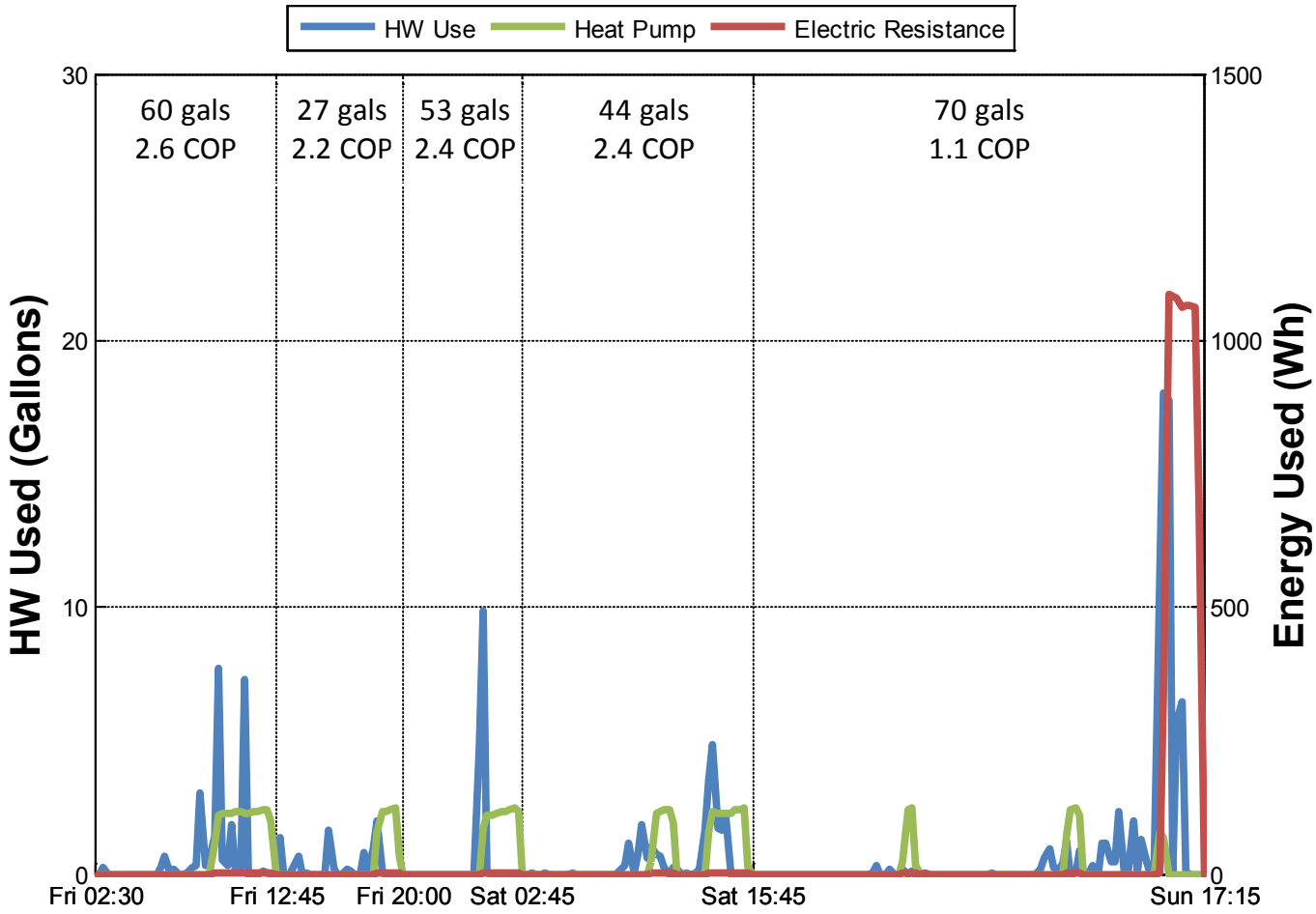
- Yearly
  - Sample size too small
  - No discernible patterns from data
- Daily
  - HPWHs have slow recovery and heating can flow into next day

Choosing an Analysis Period



Choosing an Analysis Period

- Yearly
  - Sample size too small
  - No discernible patterns from data
- Daily
  - HPWHs have slow recovery and heating can flow into next day
- Solution: find Periods > 4hrs with energy balance = 0
  - Tank Fully Heated -> Fully Heated



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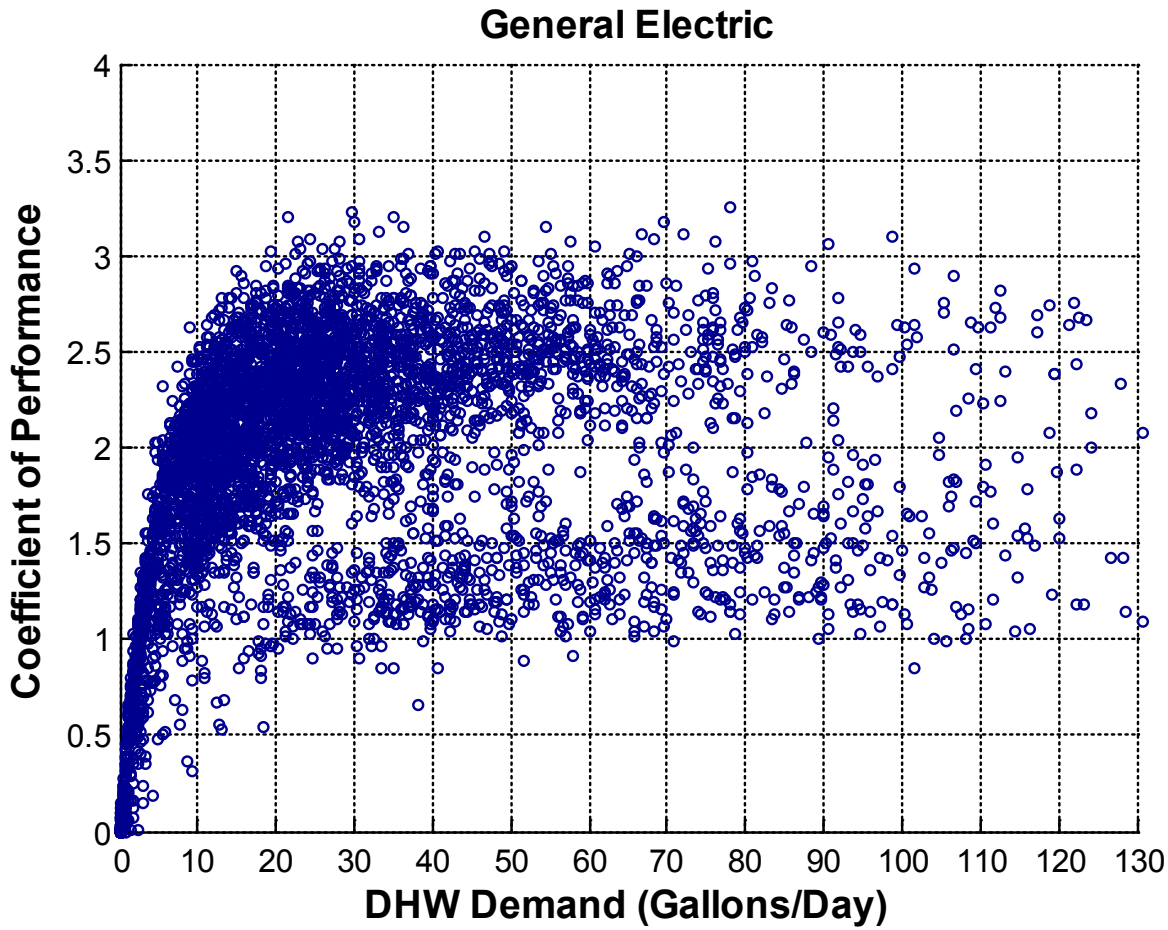
Performance Data



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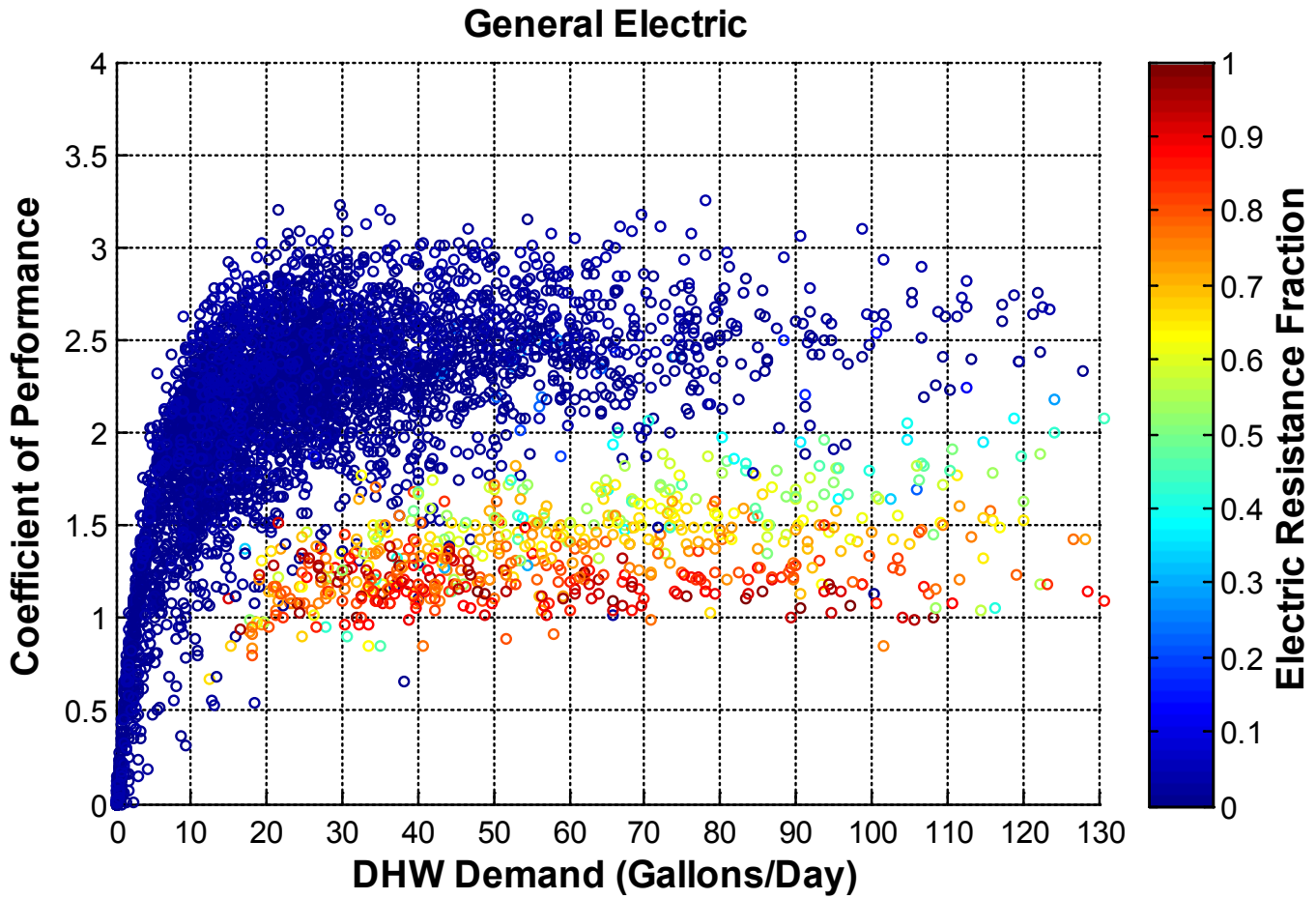

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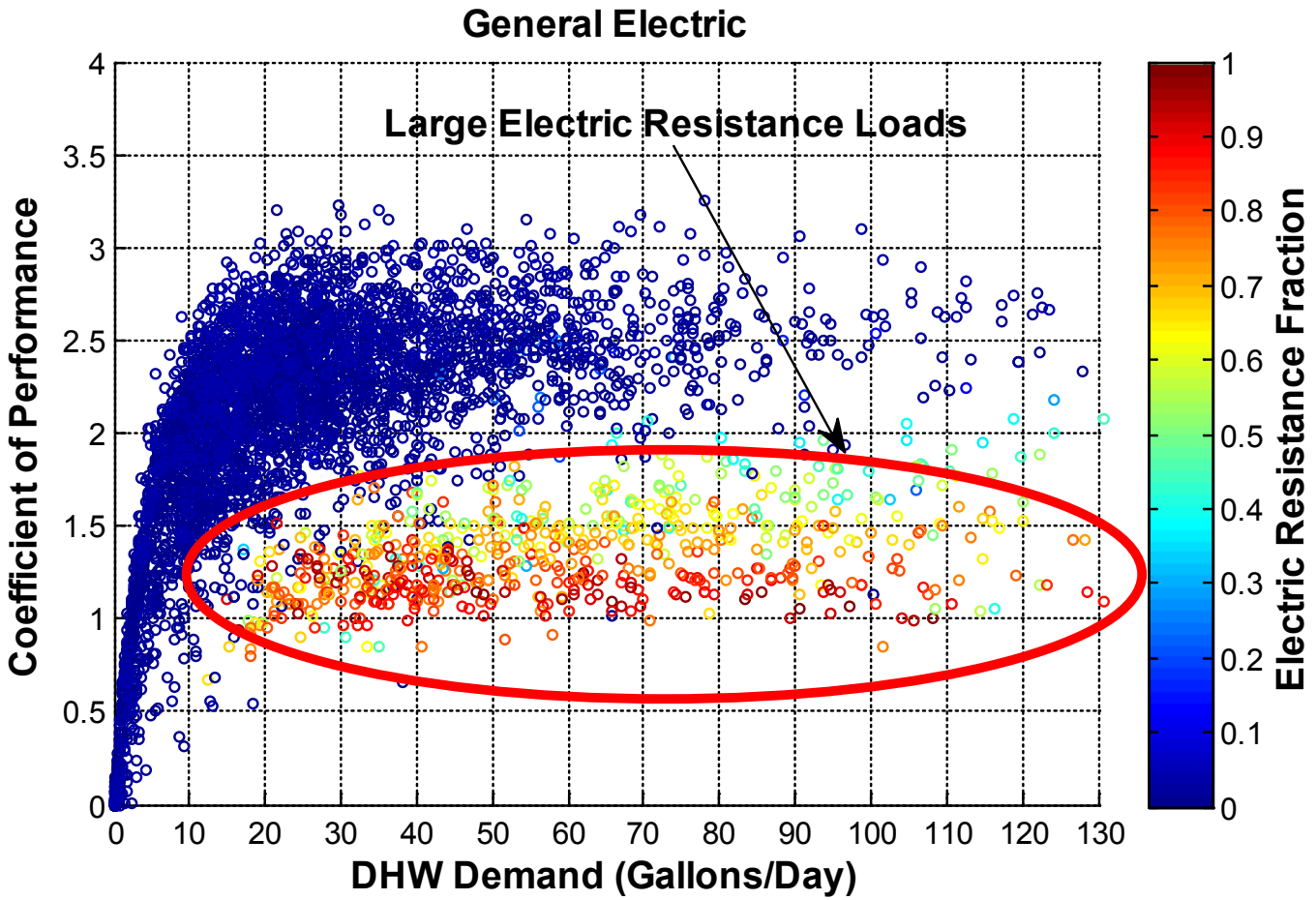

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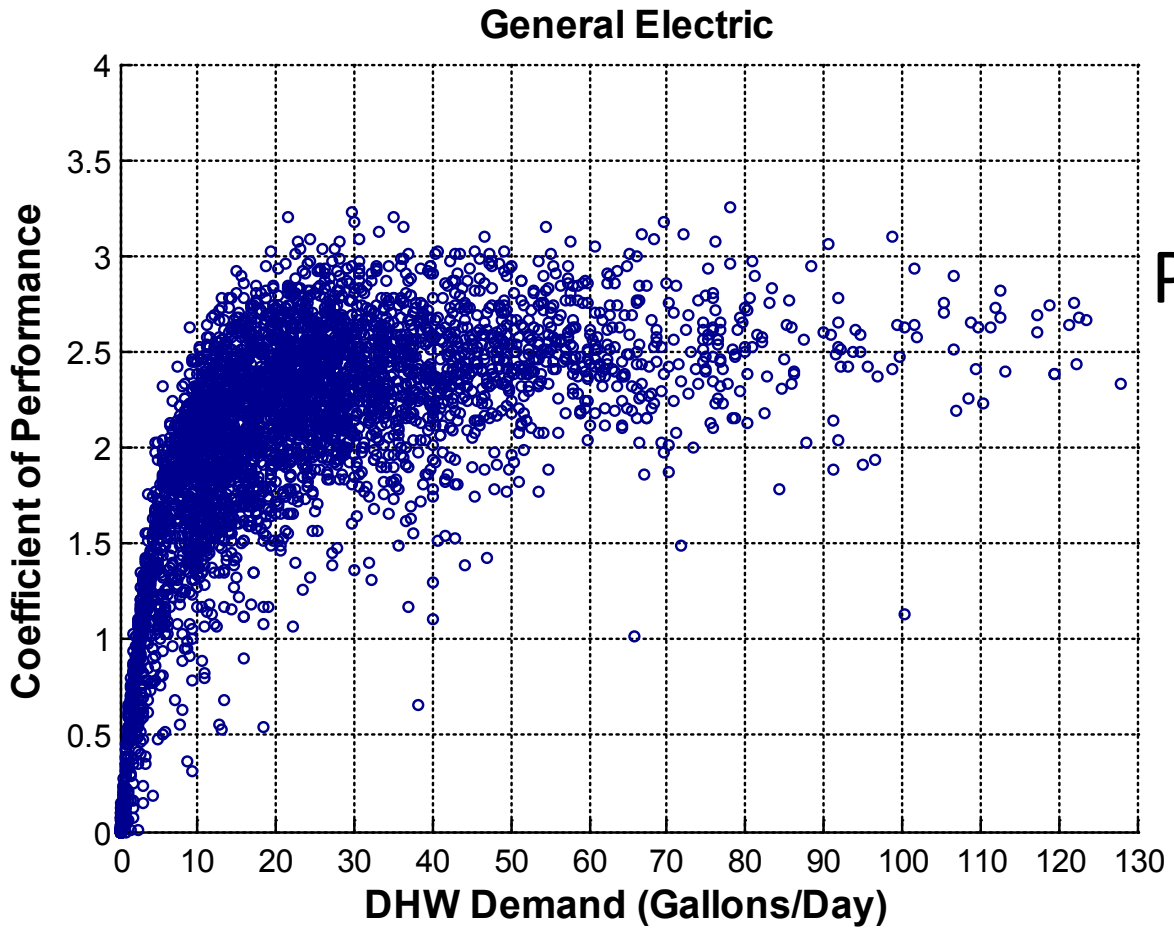
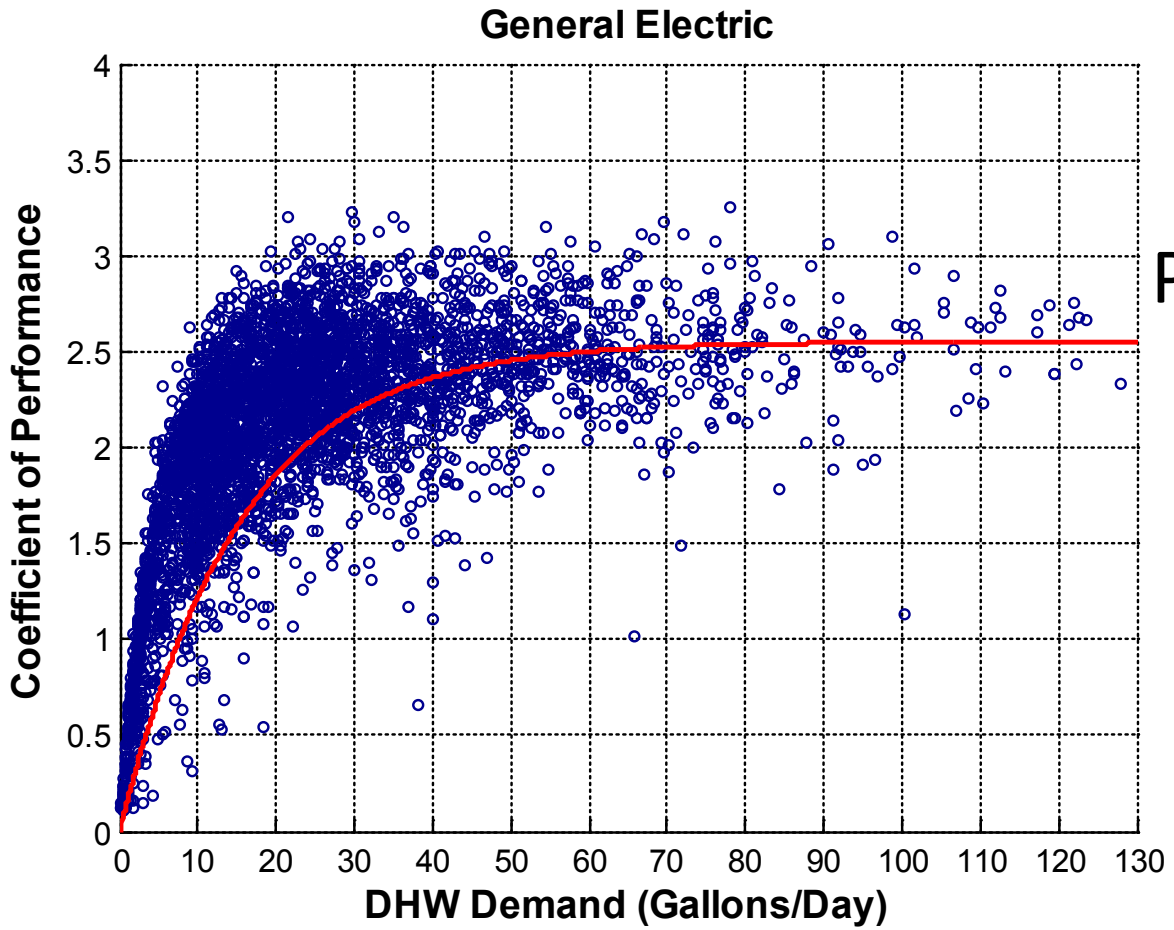


Periods with electric resistance fractions < 0.04

Performance Data



Periods with electric resistance fractions < 0.04

Performance Model Overview

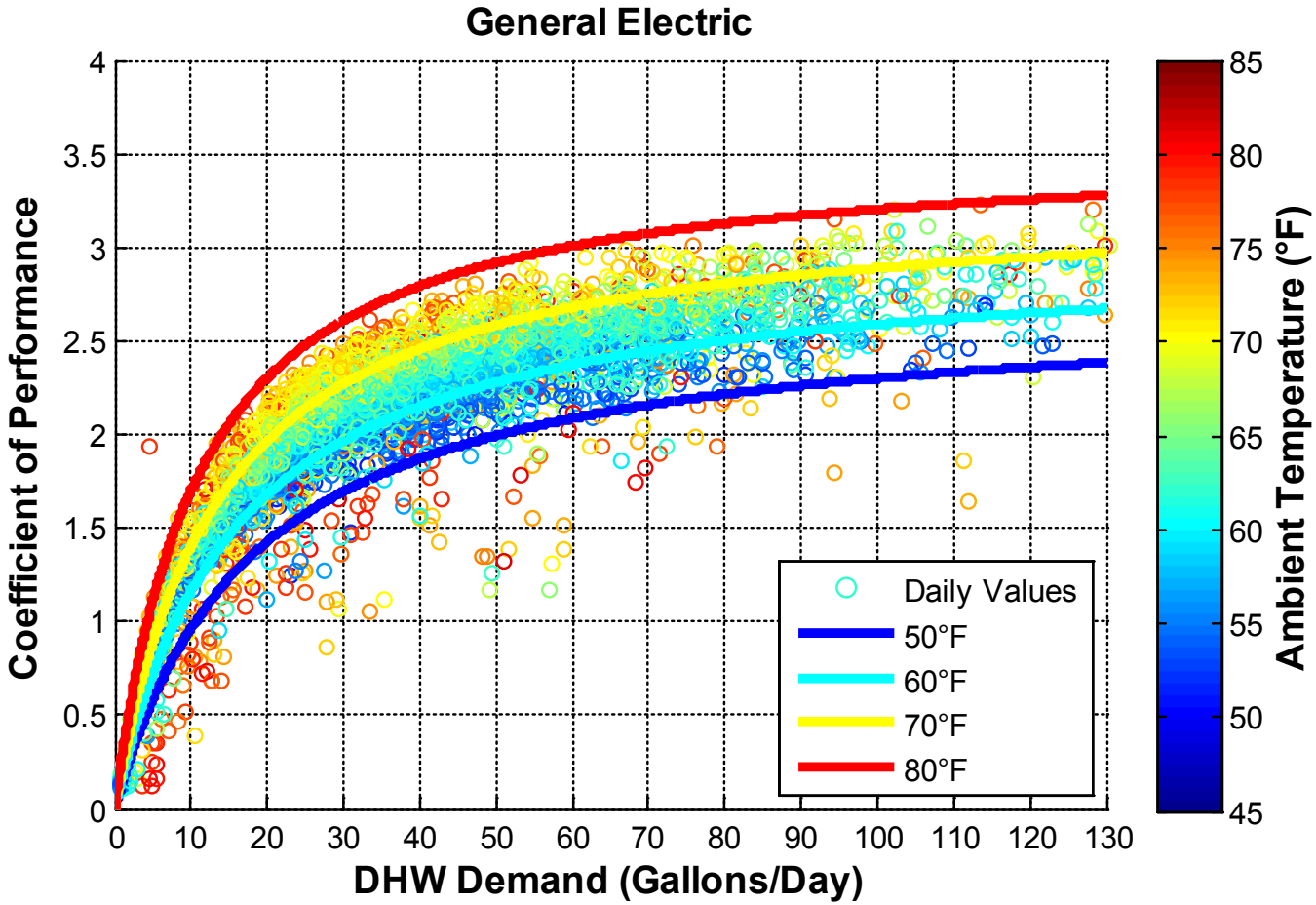
- Model based on first principles and performance curves
- 5 independent variables (previously mentioned)
- 1 dependent variable (COP)
- 4 regression coefficients
  - a_1, a_2, and a_3 describe heat pump efficiency[1]
  - UA describes tank losses

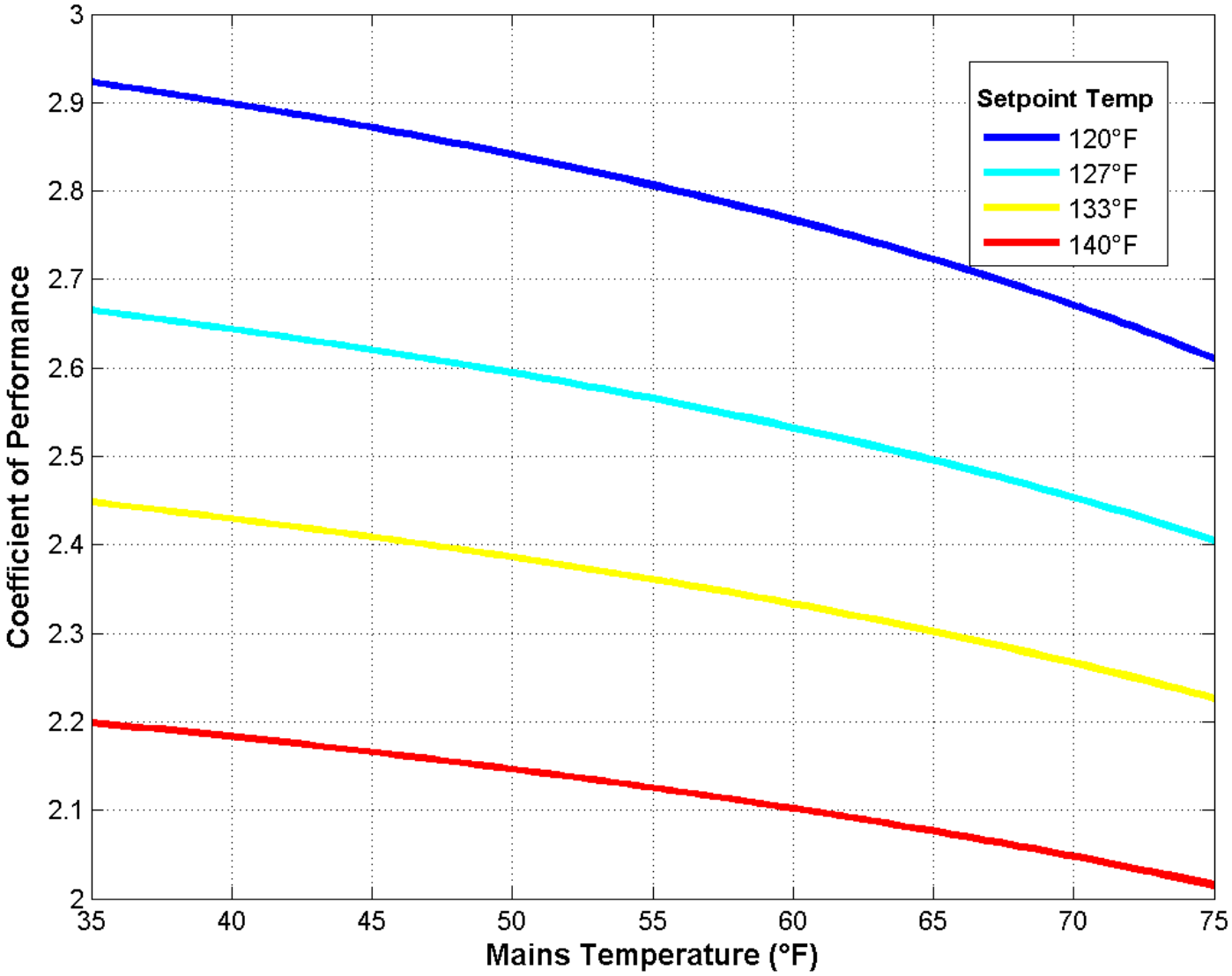
[1] Morrison, G.L.; Anderson, T.; Behnia, M. (2004). "Seasonal Performance Rating of Heat Pump Water Heaters." Solar Energy, 76, pp. 147-152.

Model Regression Results

	UA	a_1	a_2	a_3	N	R^2	z
AO Smith 80 gallon	8.72	4.91	-2.85E-2	-2.23E-9	386	0.980	137
AO Smith 60 gallon	6.49	4.31	-2.17E-2	-1.71E-10	247	0.930	56.7
General Electric	6.14	4.80	-2.78E-2	-5.46E-11	4121	0.917	213
Stiebel Eltron	15.0	7.49	-4.96E-2	-4.12E-11	742	0.967	148

Model Regression Results





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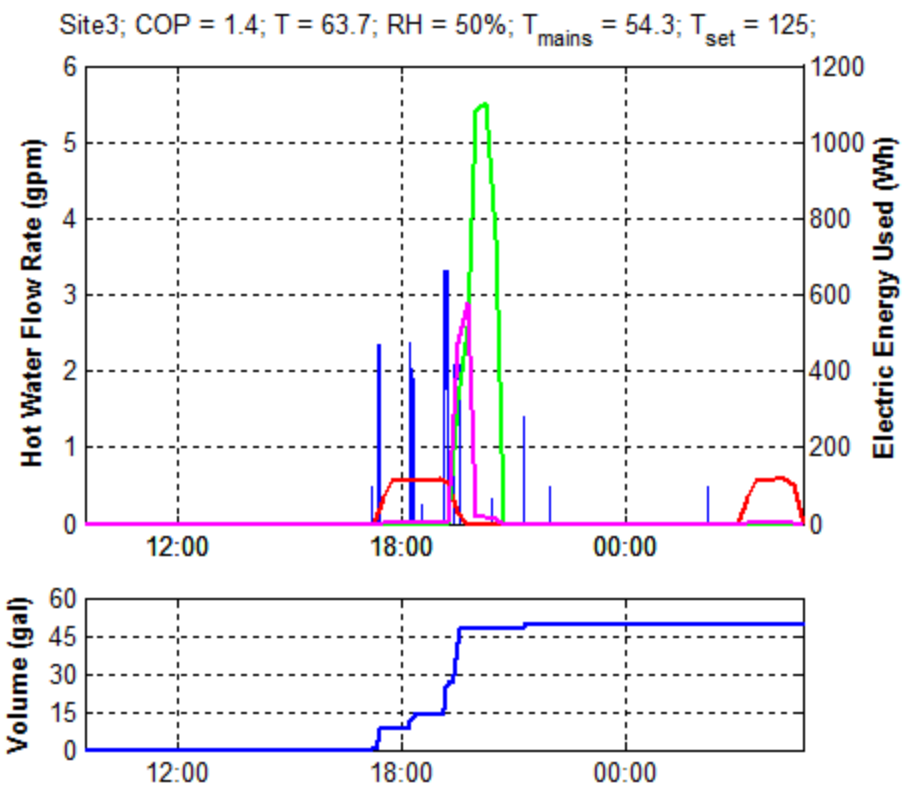
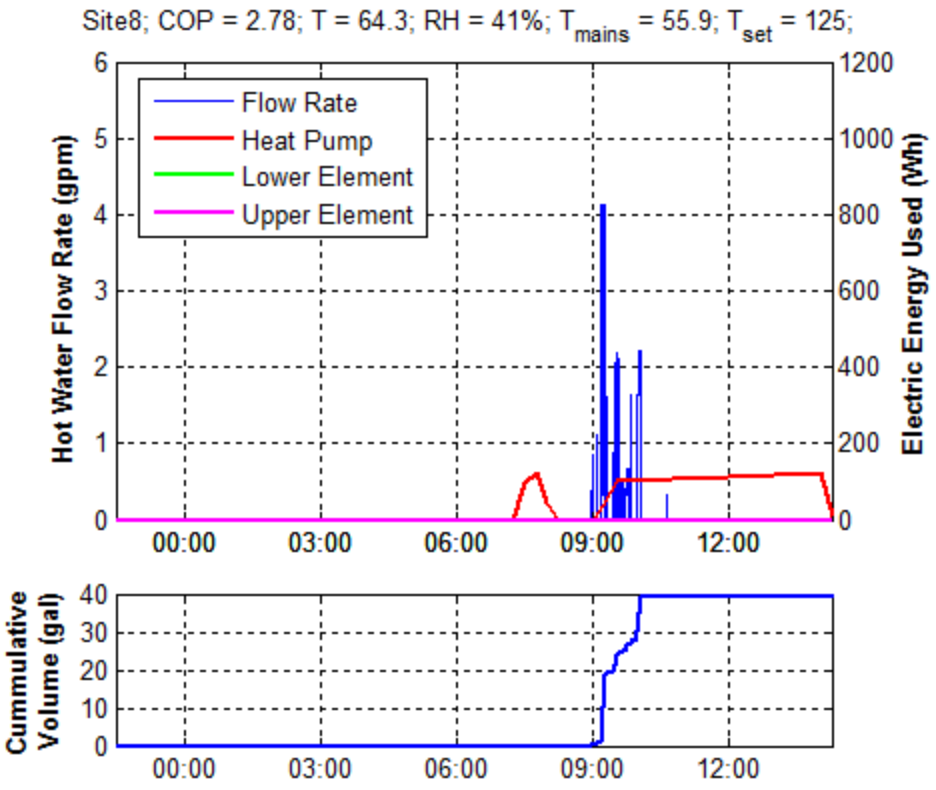
HPWH Performance - Unpredictable





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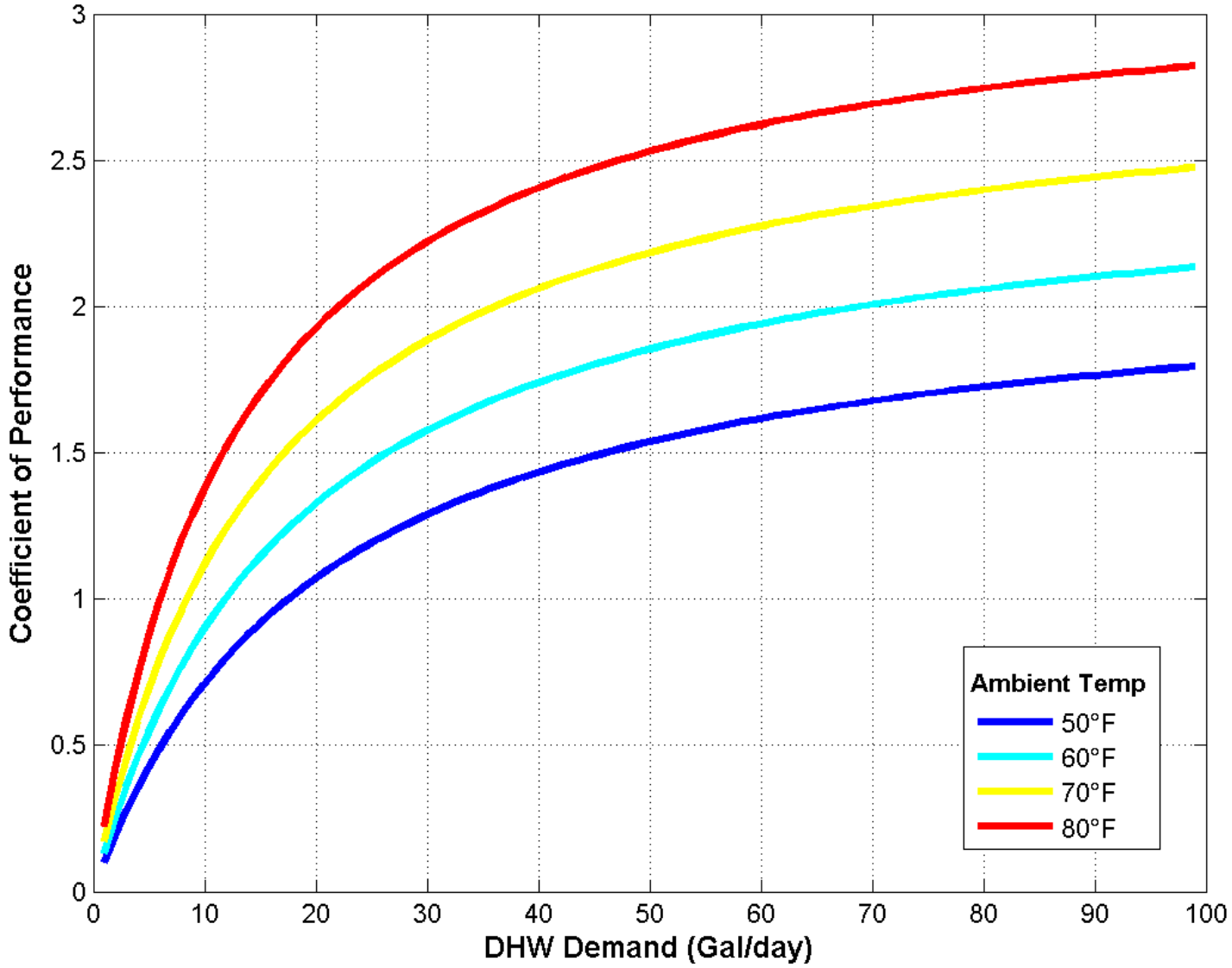

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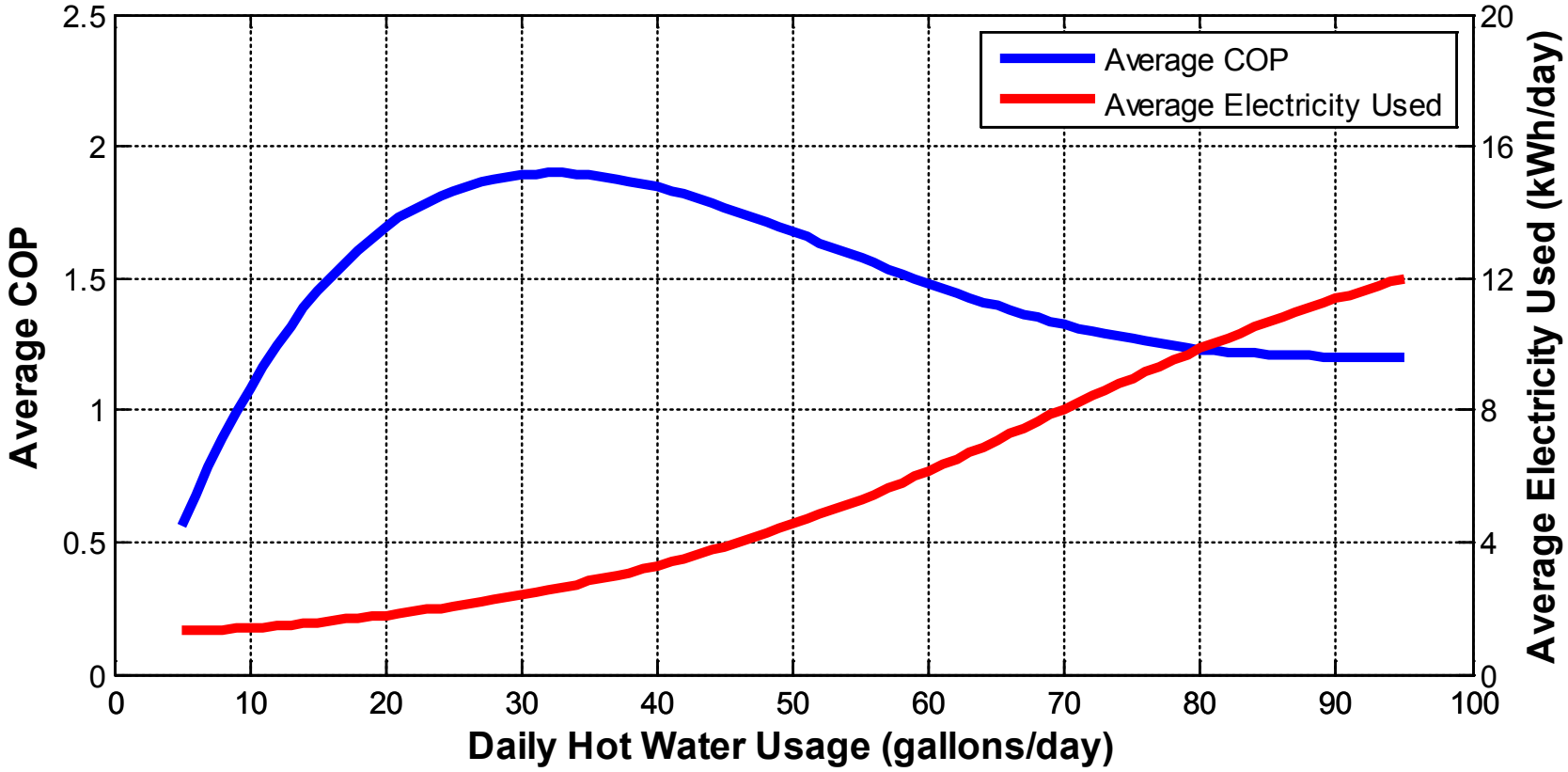

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Proper HPWH Installation

- Space Requirements
- Tank Volume
- Comfort & Noise
- Managing Condensate
- Mixing Valves and Setpoint Temperature
- Filter Maintenance
- Heat Traps (any tank water heater)

Space Requirements

- Most manufacturers specify 750 to 1000 ft^3 of space
- Vents should not be obstructed.

Yes!

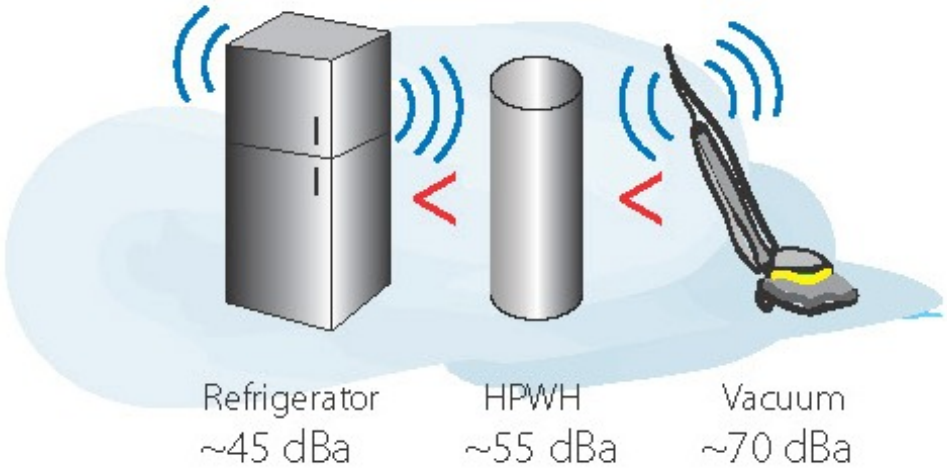
No!

Tank Volume

BIGGER IS BETTER

Comfort & Noise

- HPWH cools space – comfort problems in winter.
- Creates more noise than other water heaters.



Managing Condensate

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

HPWH Sitting in Water

Proper Installation

Mixing Valves and Temperature

- Unlike most water heaters, increasing the setpoint of HPWHs can increase efficiency
- Mixing Valves are needed if the setpoint is greater than 130°F
- Good practice below 130°F

Filter Maintenance

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

Heat Traps

- Heat traps should be installed to prevent thermosiphoning
- Thermospihoning can significantly increase thermal losses from tank!
- Insulate your pipes

No Heat Traps Installed

Heat Traps Correctly Installed

Builder Resources

- Code Considerations
  - By 2015, all electric water heaters > 55 gallons must be HPWH.
  - Utilities have rebates (up to $1000)
- References:
  - BA Measure Guideline
  - QI Guideline for Northeast
  - Recent Home Energy Article

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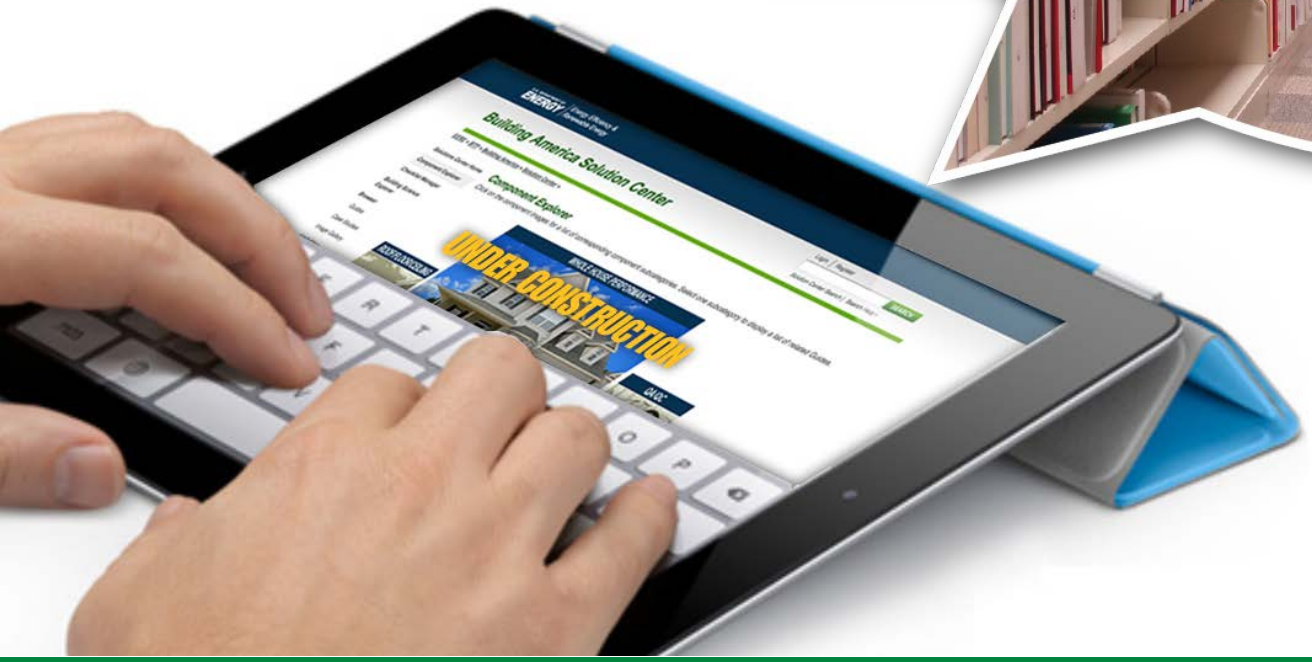
COMING IN JANUARY



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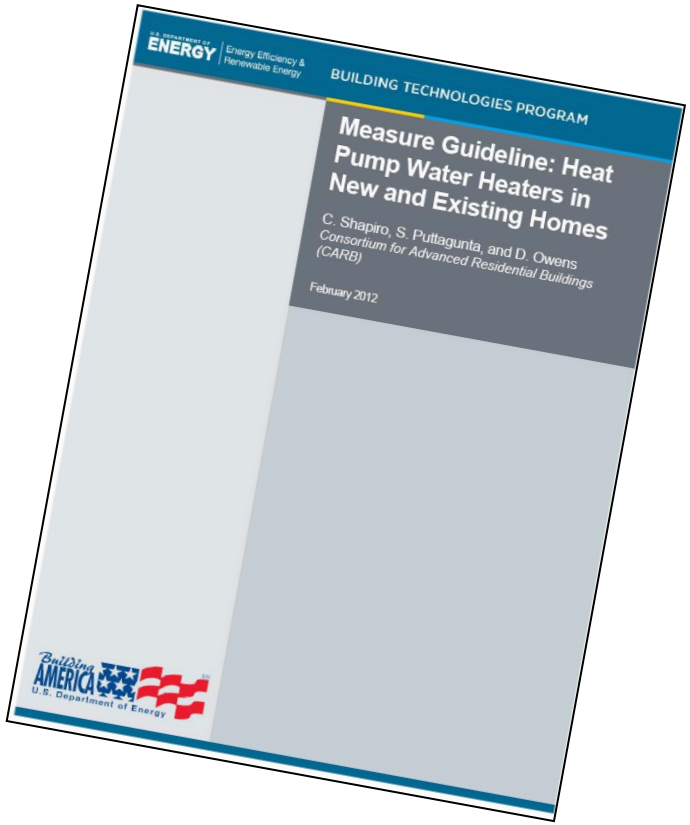

http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_hpwh.pdf

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