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Multifamily Central Heat Pump Water Heating

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The work presented in this presentation does not represent performance of any product relative to regulated minimum efficiency requirements.

The field site used for this work was not a certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

Overview

- Background
- Objective
  - Measure in-situ field performance and document reliability of central HPWH
    - When does central HPWH fail to meet load, and frequency
  - Compare economics of system to conventional options
- Monitoring performance
- Develop and validate TRNSYS model and develop results for other climates

Why Heat Pump Water Heaters?

- More than 40% of US households use electric resistance
- In single family homes HPWHs have been shown to provide 50%+ energy savings
- Little data available on MF Central HPWH systems

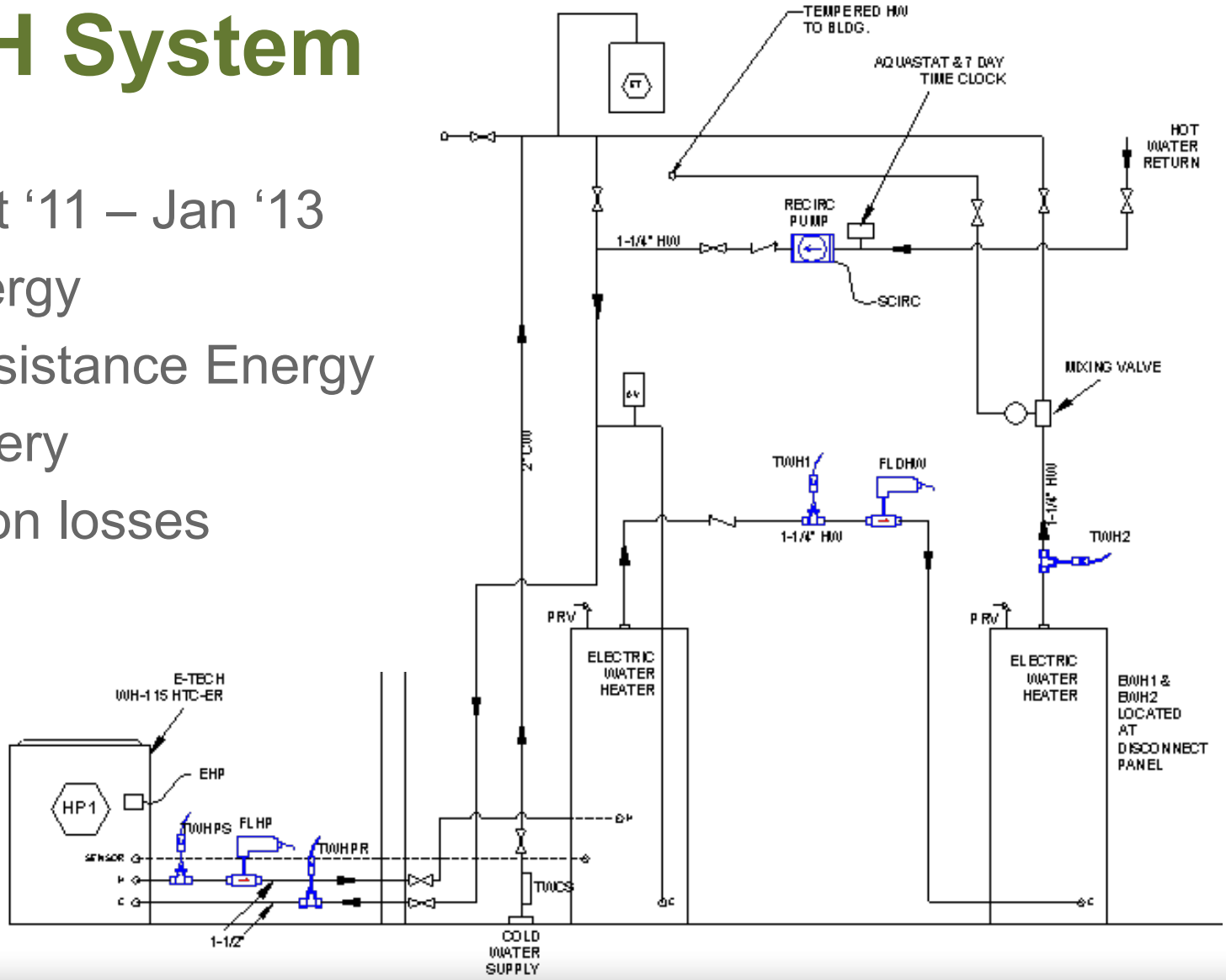
Background

- University of California Davis, West Village Student Housing
- Hot-dry climate
- 45 Student apartment buildings
- 14,200 ft^2 12 unit apt building with 10.5 ton HPWH
- Two 120-gal storage tanks; each with 54 kW back-up electric heat
- Time/temperature recirc loop

HPWH System

Monitored Oct ‘11 – Jan ‘13

- HPWH Energy
- Electric Resistance Energy
- DHW Delivery
- Recirculation losses

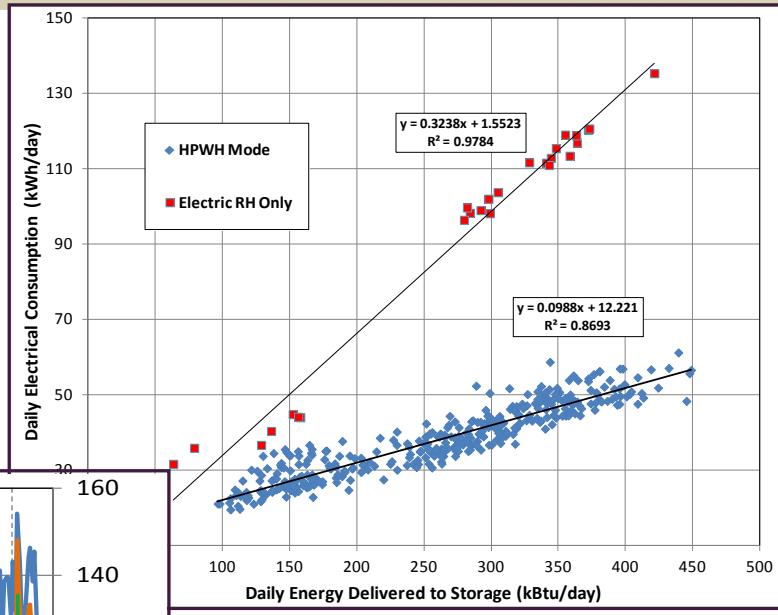


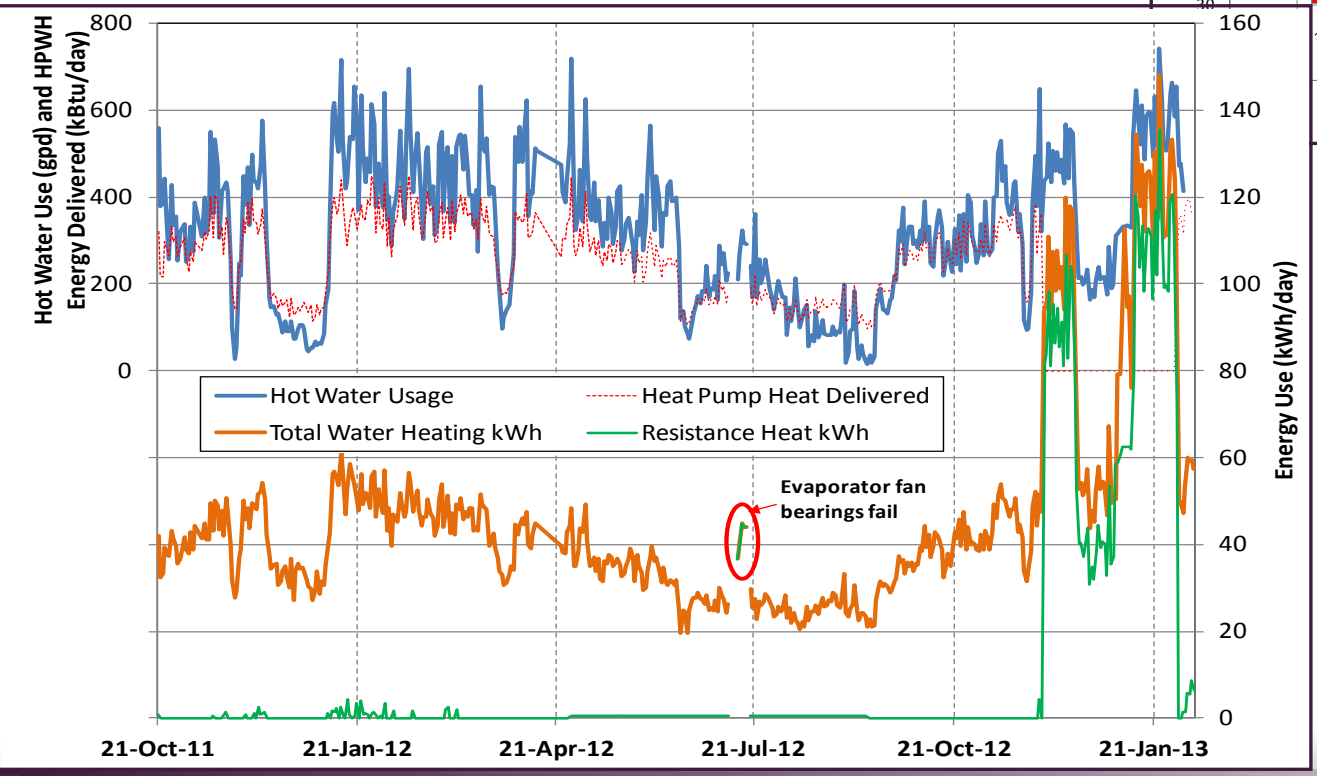
The case for monitoring

- Document in-situ field performance
- Monitoring as a commissioning aide
  - Compressor not running, circulating pump and fan gave impression of operation
  - Incorrect sensor placement
  - Non-optimal setpoints
    - 140° F heat pump upper limit set point (5° F dead band)
    - 120° F resistance heat set point in each tank
    - 120° F setting on the tempering valve that feeds the recirculation loop.
- Monitoring for early equipment failure
  - Evaporator fan failure

Monitored Data

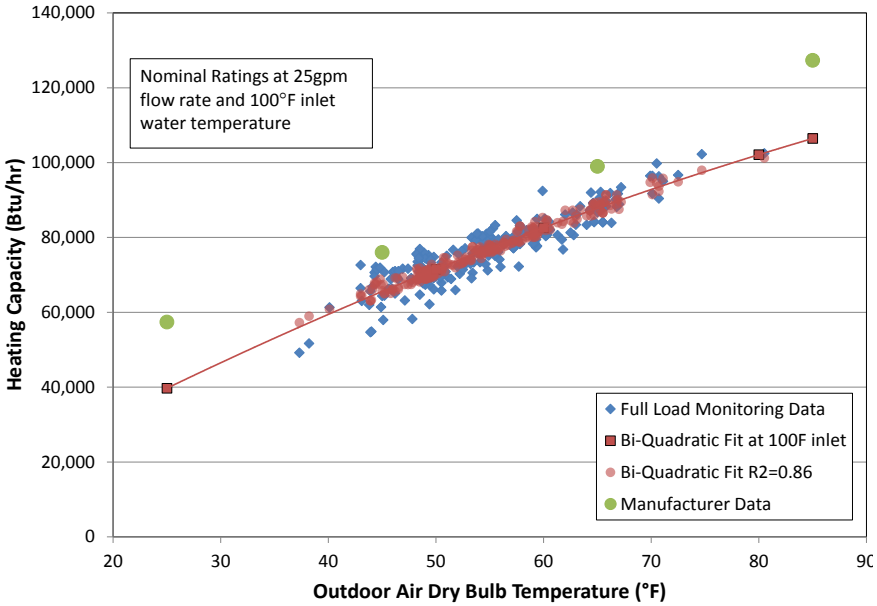
- Student occupancy patterns atypical with multifamily 60 – 450 kBtu/day





- Resistance heat typically 2.5 times higher energy use than HPWH

System Performance Mapping

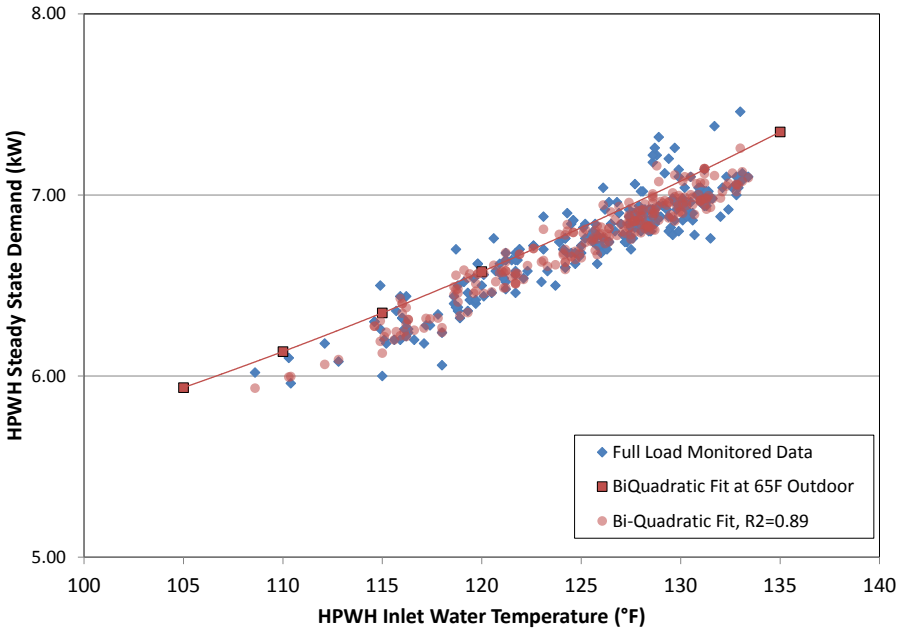


Monitored data:

Avg. inlet 125.4 F, Flow rate 19.6 GPM

Manufacturer Data:

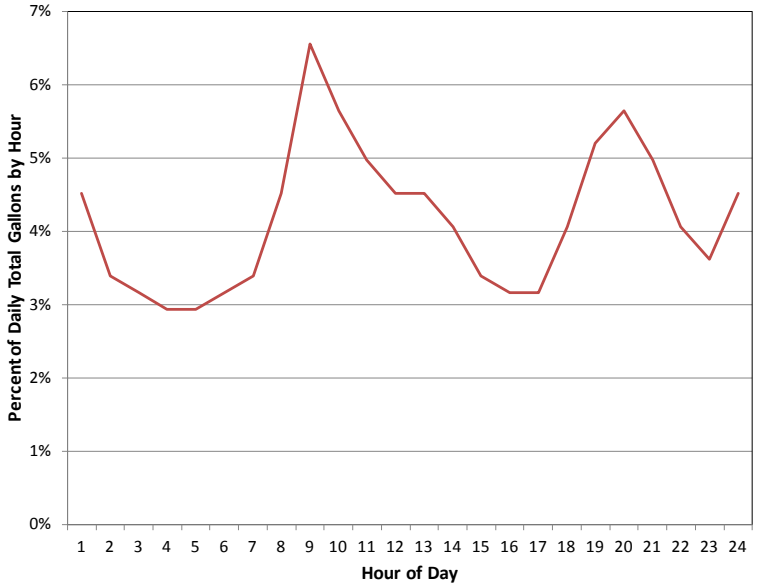
Inlet 100 ° F, Flow Rate 25 GPM

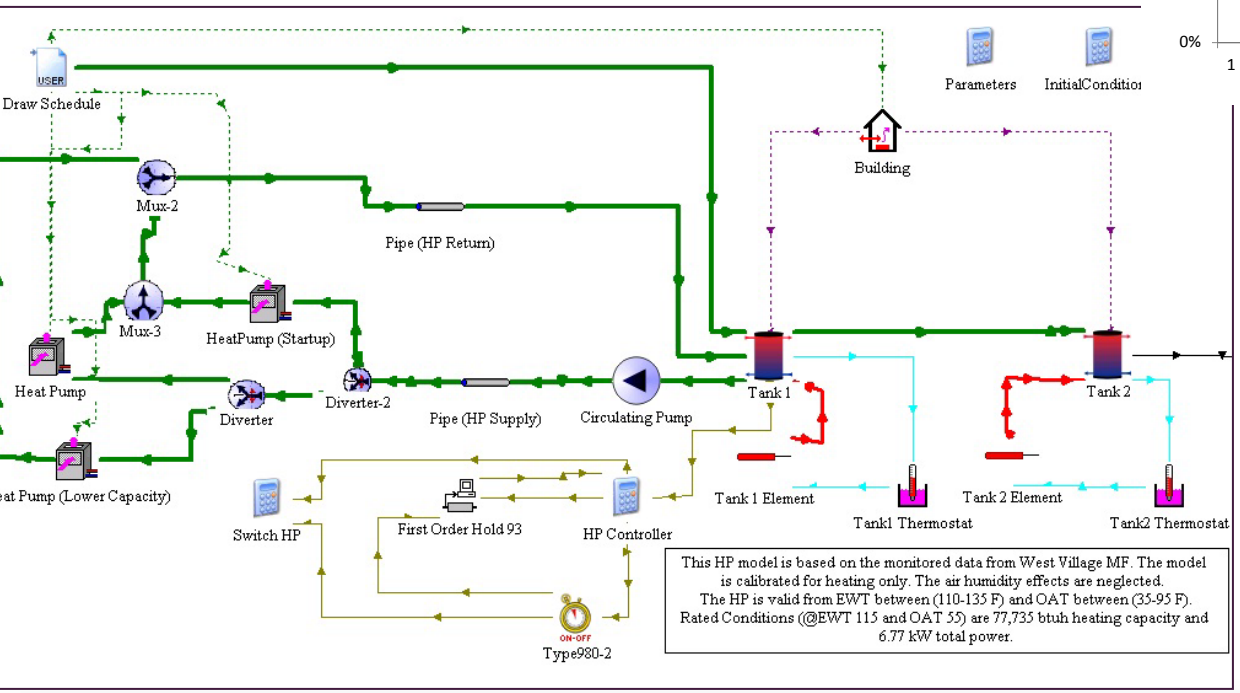


HPWH Performance Map developed using linear regression. Result is biquadratic relationship of power and capacity to outdoor dry bulb and entering water temperature.

TRNSYS Model

- Validated with monitored data
- Hourly draw profile from ASHRAE service water heating guidelines

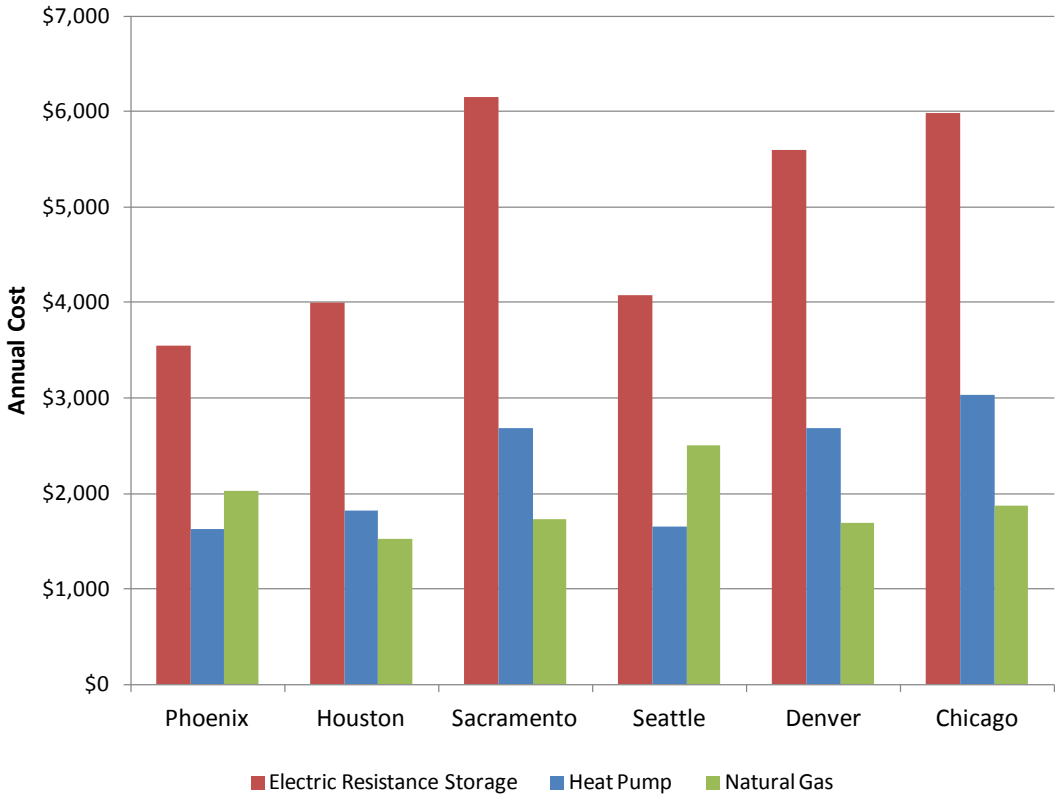




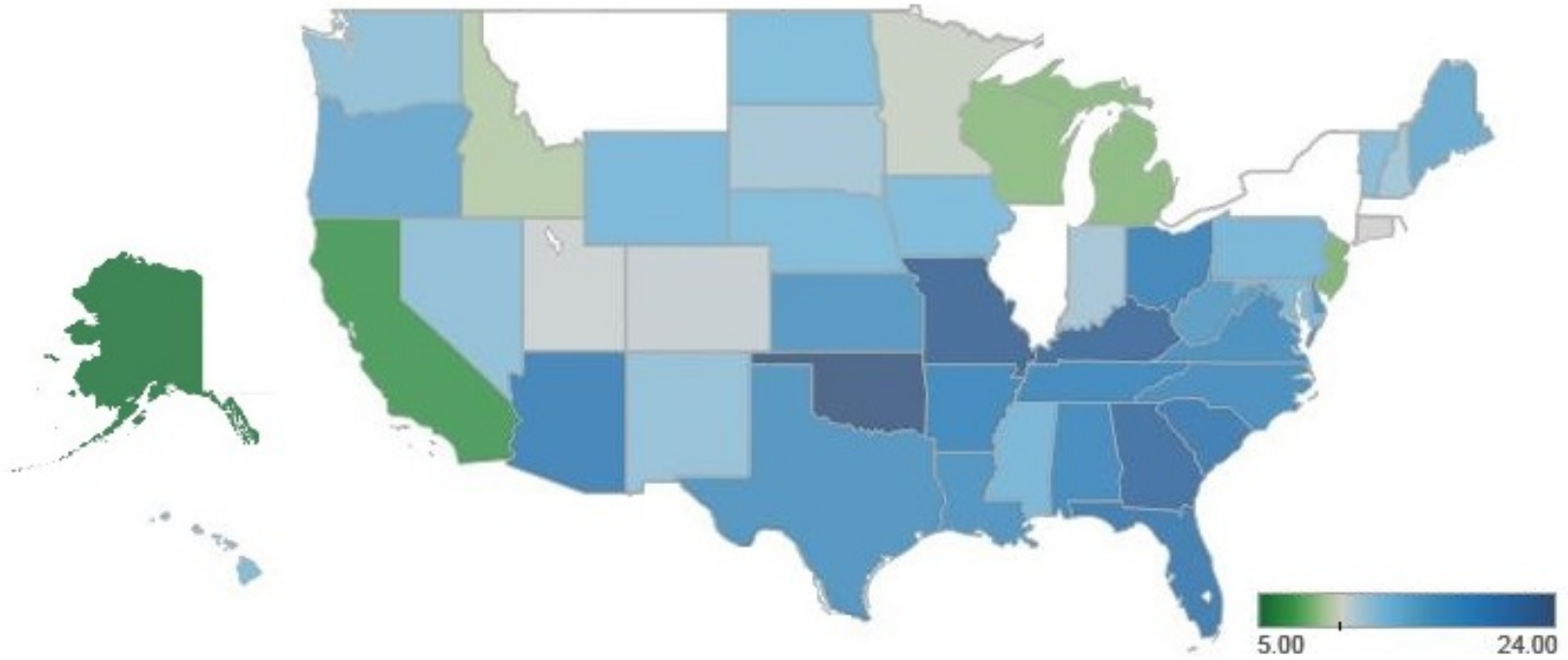
- Hot water usage varied by climate to account for variation in distribution losses

Cross-climate Comparison

- Compared with TRNSYS all-electric and natural gas storage unit models
- Natural gas storage
  nominally rated
  309 kBTU/h,
  80% efficiency
- EIA state average utility rates



Utility Rate Comparison



Ratio of Natural Gas ($/Therm) to Electricity ($/kWh)

Summary

- System performance impacted by lower flow rate and higher inlet temperatures from recirculation mixing
- Control dead-band should be widened to improve steady-state operation, or multi-stage HPWH
- Installation and commissioning training is critical
- Sizing of 2,500 Btu/h compressor capacity per person was sufficient to meet the load with little need for resistance backup (for this application)
  - 3-person single family typically sized for 6,000-8,000 Btu/h
- Savings relative to resistance heaters projected to be 49%-59% based on climate
  - Local utility rates and natural gas availability can strongly impact economics