WASHINGTON STATE UNIVERSITY
EXTENSION ENERGY PROGRAM

Advanced Heat Pump Water Heater Research Update

Conducted by WSU Energy Program

Funded by Bonneville Power Administration

BPA Technology Innovation Projects 292, 302 and 326

Current Status
Pacific Northwest CO_2 HPWH Research

- Lab test of Sanden French manufactured unitary 40 gallon HPWH sponsored by NEEA
- Lab test of Sanden Australian manufactured split 84 gallon HPWH sponsored by BPA
- Field test of split system at 4 sites
- Demand Response assessment of Sanden unitary and split systems currently underway sponsored by BPA
- Field test for combined space and water heat in Next Step Homes sponsored by NEEA and BPA and lab test sponsored by BPA

Project Teams

(For All Projects)

WSU

- Ken Eklund, Principal Investigator and General Project Manager
- David Hales, Field Monitoring Installation and Maintenance
- Adria Banks, Data Analyst

Lab Tests

- Ben Larson, Ecotope, Test Manager and Analyst
- Kumar Banerjee, Cascade Engineering, Lab Test Director

Field Installations

- Mark Jerome, Clear Result, System Installation Coordinator

BPA

- Janice Peterson, Project Manager
- Stephanie Vasquez, Project Technical Representative

Sanden

- Maho Ito, CO_2 Product Line Manager
- Charles Yao, Project Engineer

Project Teams Continued

Demand Response Controlled Field Study (TIP 302)

- Graham Parker, PNNL – Lab Homes Project Lead
- Joe Petersen, PNNL – Technical Lead
- Greg Sullivan, Efficiency Solutions – Technical Consultant
- Austin Winkelman, PNNL – Engineering Intern
- Tony Koch, BPA – Demand Response Engineer
- Frank Brown, BPA – Demand Response and Efficiency
- Thor Hinckley, BPA – Smart Grid and Demand Response

Combi System Research

- Charlie Stephen, NEEA – Project Manager
- Thomas Anreise and Dan Wildenhaus, Clear Result – Next Step Home site analysis and recruitment

TIP 292 Project Overview

Performance test of split system CO_2 refrigerant Heat Pump Water Heater manufactured by Sanden

Lab test to DOE and Northern Climate Specification

Field test in partnership with NEEA and:

Avista	Heating Zone 2
Energy Trust of Oregon	Heating Zone 1
Ravalli Electric Coop	Heating Zone 3
Tacoma Power	Heating Zone 1

One install in each territory. 12-18 month monitoring.

TIP 302 Project Overview

Demand Response tests of Sanden unitary and split system Heat Pump Water Heater

Controlled Field Study at PNNL Lab Homes in Richland, WA – Currently underway

Demand Response Lab tests at Cascade Engineering Services in Redmond, WA – Protocol under development by Ben Larson

Combi System Research

WSU, NEEA and BPA are engaged in research in the use of the Sanden split system unit for combination space and water heating in highly efficient Next Step Homes

The partners are currently recruiting builders and sites through the Next Step Home project

NEEA will provide all the monitoring plus incentives

BPA has agreed to fund the lab test and analysis and reporting of data from both the field and lab research

Quick Specifications

Equipment currently built and sold in Australia
Outdoor Unit Model: GAU-A45HPA
Power Input: 240V, 15 A circuit
Tank Model: GAU-315EQTA
Storage Capacity: 315L (83 gallons)
Tank Set Point: 65°C (149°F) – not adjustable

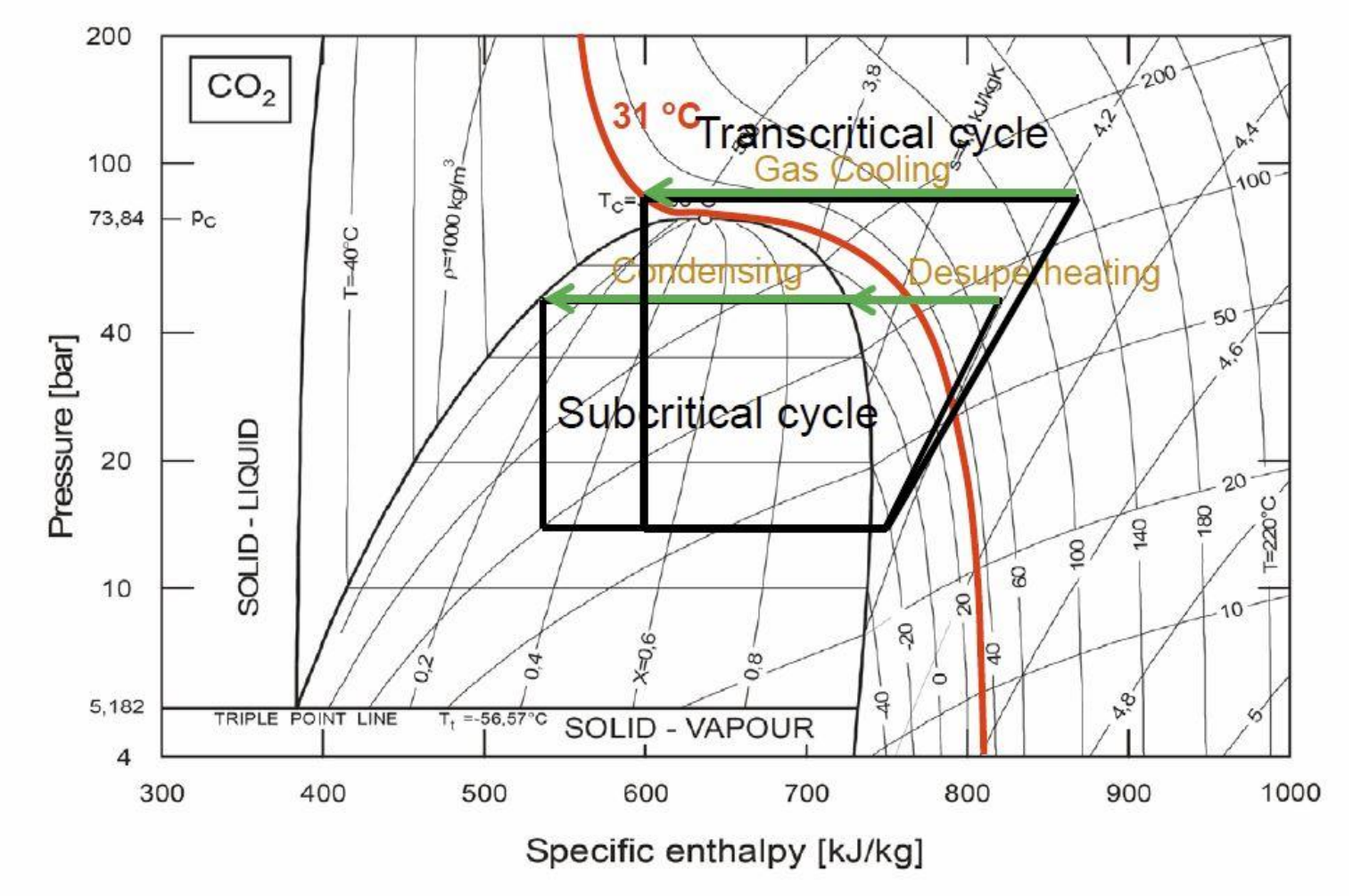
Outdoor unit has a variable speed inverter driven compressor, fan and pump

Water is heated at the outdoor unit. A pump circulates water from the bottom of the tank, to the outdoor unit heat exchanger, heating the water in one pass, and re-injecting the hot water near the top of the tank

No resistance heating element

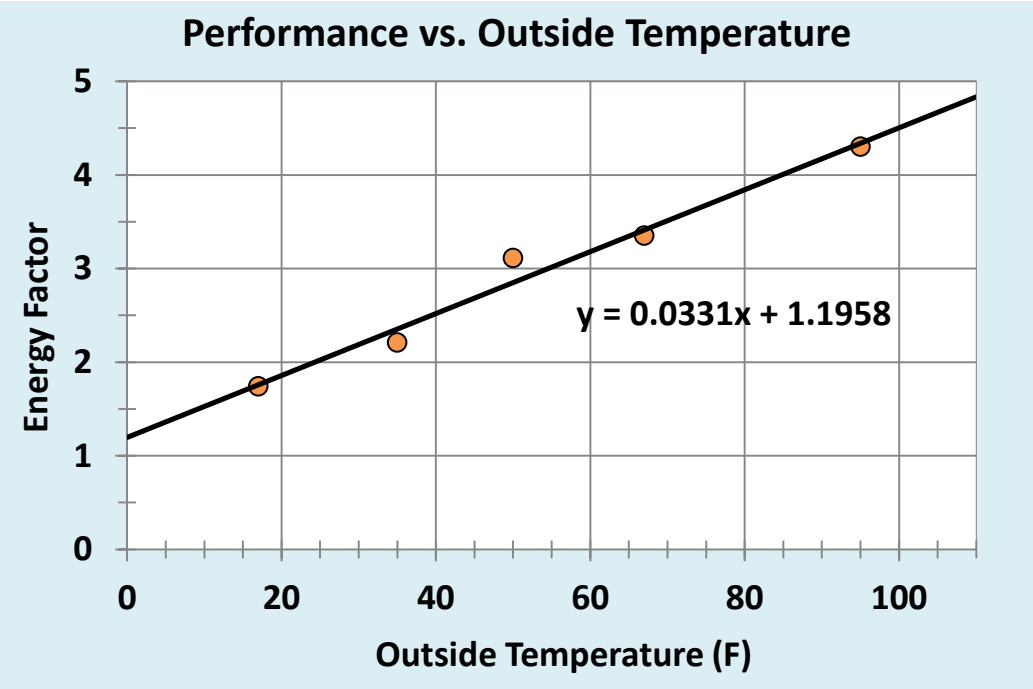
CO_2 Refrigerant Function

Source: Rolf Christensen, ATMOsphere 2014



Performance vs. Temperature

Outside Air Temperature (F)	Energy Factor (EF)	COP	Output Capacity (kW)	Input Power (kW)
17	1.74	2.1	4.0	1.9
35	2.21	2.75	3.6	1.3
50	3.11	3.7	4.0	1.1
67	3.35	4.2	4.1	0.97
95	4.3	5.0	4.6	0.93



- Linear fit of EF to temperature
- Use TMY temperature bins to calculate an annual EF:

Climate	Annual EF
Boise	2.9
Kalispell	2.6
Portland	3.0
Seattle	2.9
Spokane	2.8

Installation-Tacoma-10-15-13

TIP 292 Field Site Characteristics

Site Location	Site HDD	Climate Area
Portland, OR	4,461	Western Oregon
Tacoma, WA	4,696	Puget Sound
Addy, WA	6,842	Inland Washington
Above Corvallis, MT	8,156	Mountain Region

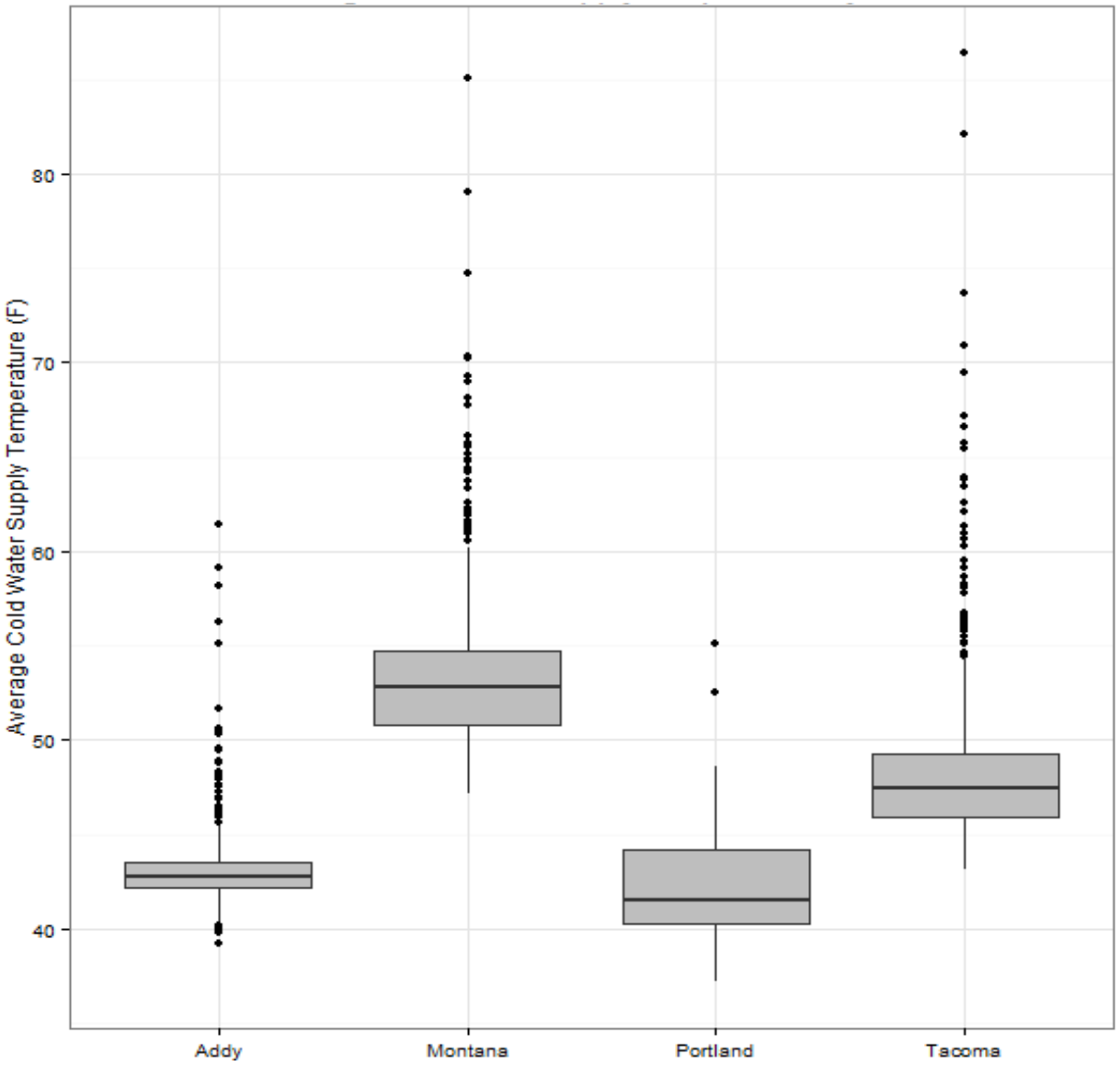
- **Each site has at least 4 occupants**
- **At least 3 years of electric hot water use**
- **Represents a climate within the Pacific Northwest**

Climate Data

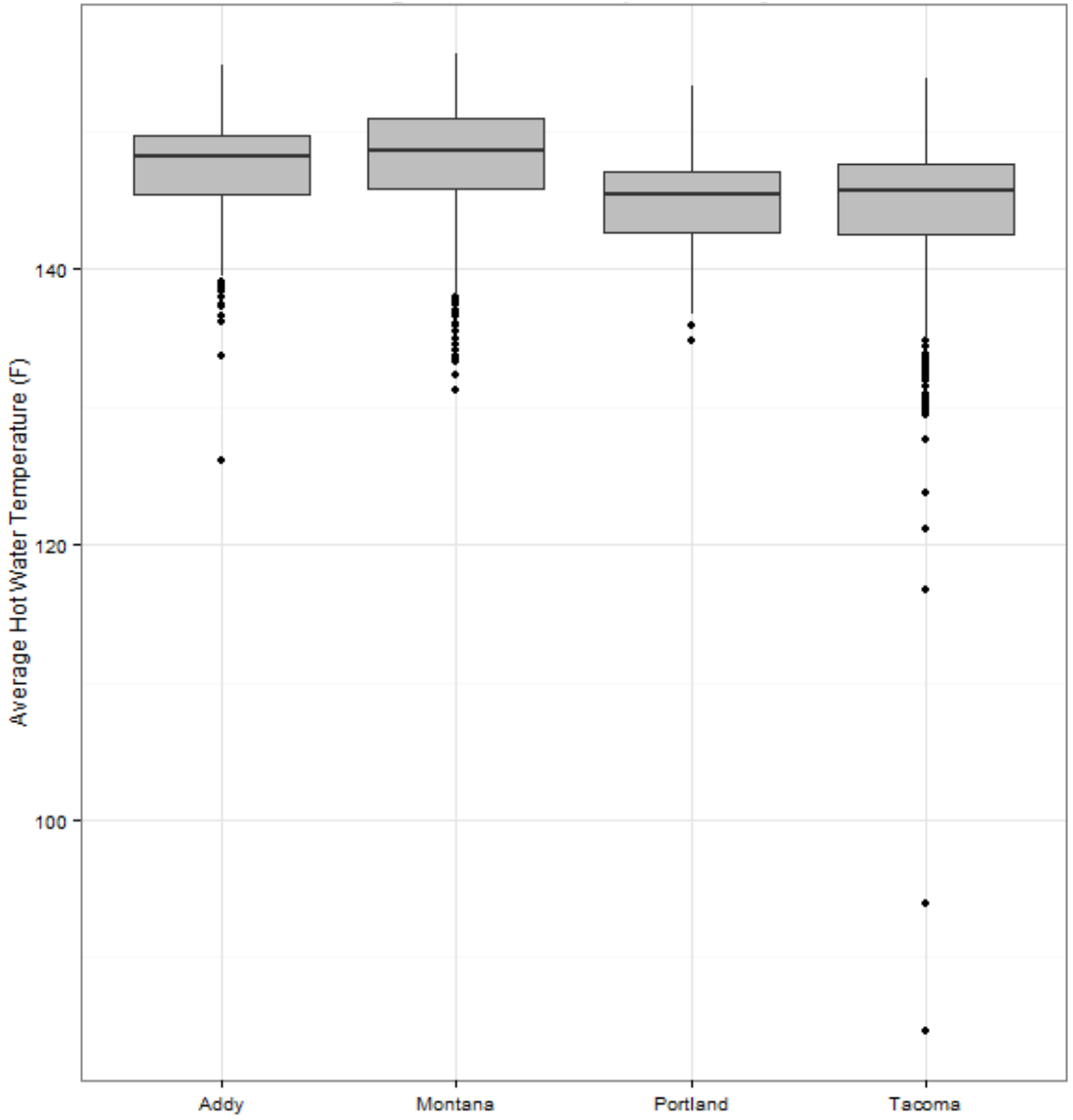
From Installation through March 31, 2014

Site	Minimum OAT (F)	Mean OAT (F)	Standard Deviation (F)
Portland	17.89	44.23	± 8.88
Tacoma	22.20	43.35	± 5.33
Addy	2.08	34.17	± 8.64
Montana	-15.68	32.96	± 11.74

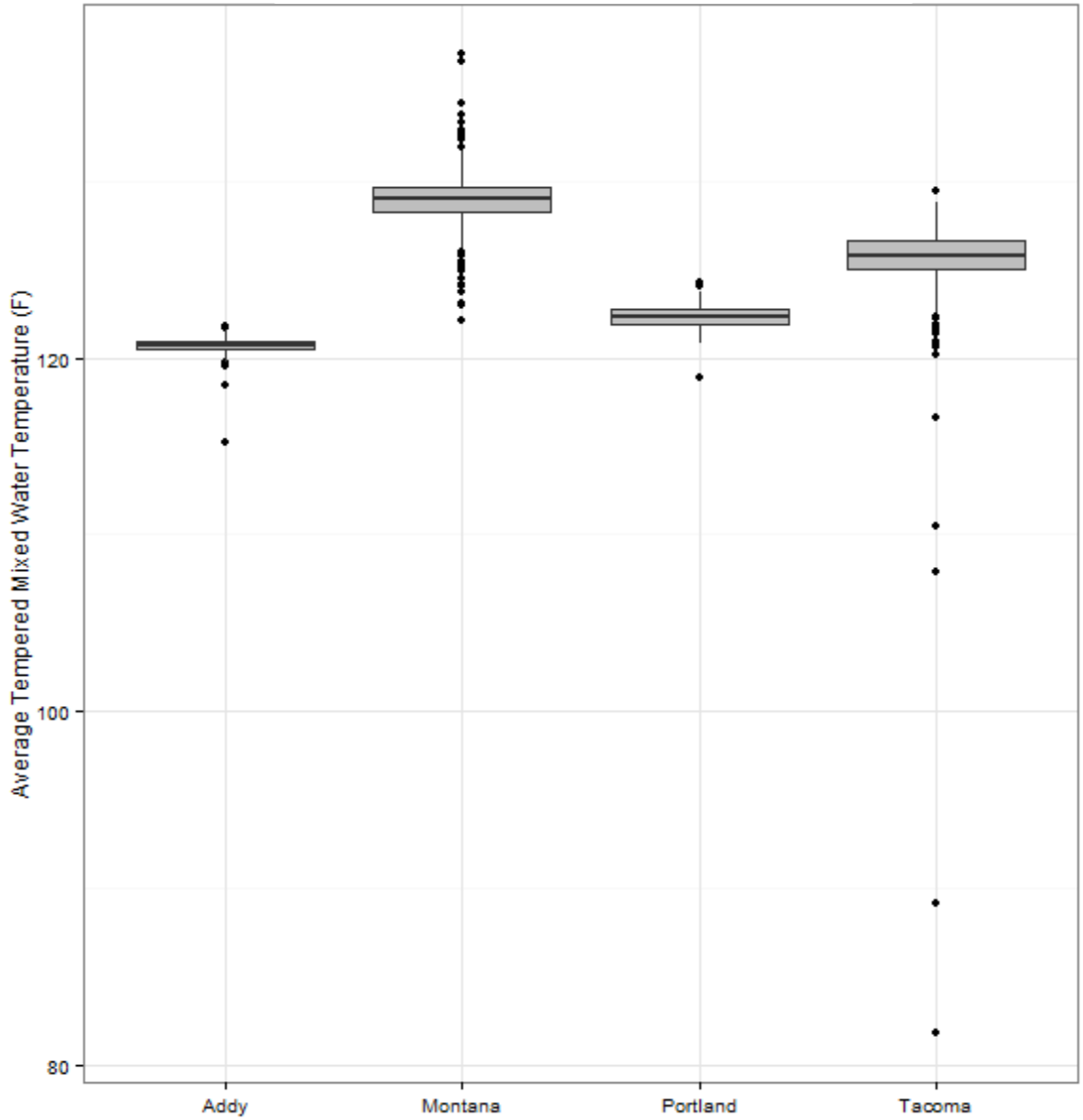
Average Cold Water Temp



Average Hot Water Supply Temp



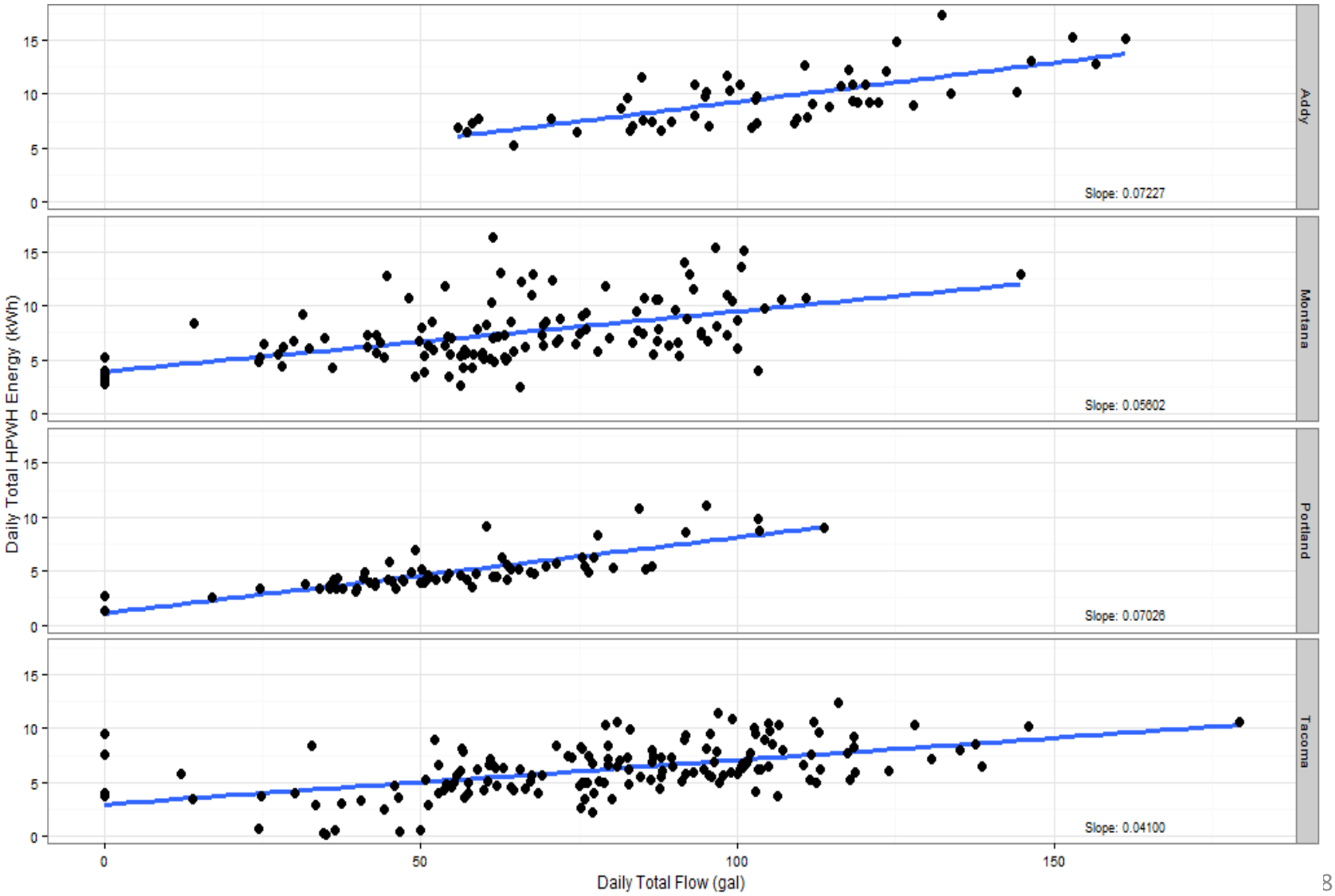
Average Tempered Water Temp



Water Use Per Site

Site	Total Cold Water Supply Water (Gal/day)	Calculated Total Water added to Tempering Valve (Gal/day)	Total Household Hot Water (Gal/day)
Addy	77.6	26.5	104.0
Montana	50.5	12.4	62.6
Portland	44.0	12.2	55.9
Tacoma	64.7	15.8	79.5

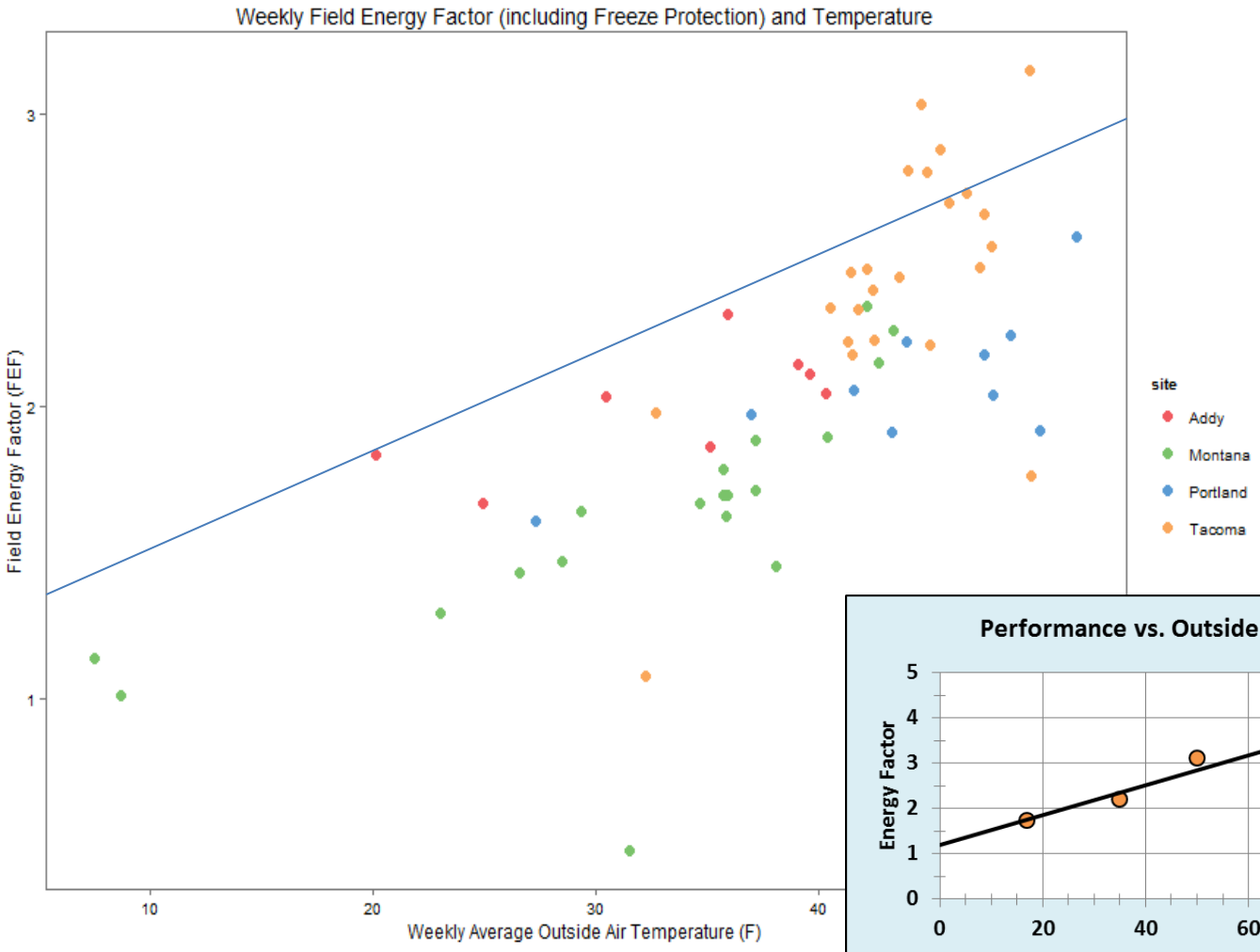
Daily Water Flow and Energy



Field Energy Factor

- Is the Energy Contained in Total Useful Hot Water / Total Energy In
- Contains all the invested energy including compressor and freeze protection
- Also includes the energy losses from the tank and the piping
- Plus variable such as the ground water temperature—which varied significantly

Field Energy Factor & Outside Air Temp.



Interim Conclusions

From Installation Through March 31, 2014

- The largest performance factors appear to be amount of daily water use and outside air temperature
- The Sanden system is capable of providing 150^{o}F water in minus zero weather and can operate to minus 15.7^{o}F
- The weekly Field Energy Factors ranged from 1.1 during a week averaging below 10^{o}F OAT to 2.5 at 40^{o}F OAT

Next Steps

Performance Research

- Second Interim Report
  - Data from April 1 through July 31, 2014
  - Report due September 30, 2014
- Final Analysis and Report
  - Data through February, 2015
  - Report due summer, 2015

Demand Response Research

- Complete PNNL study, analyze and report
- Finalize lab protocol, conduct test, analyze and report

Combi System Research

- Recruit, qualify, install systems and monitoring at NSH sites
- Collect data for at least one year, analyze and report