



Residential CO₂ Heat Pump Water Heater Cold Climate Field Testing

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Sanden International USA

Sanden Profile

Founded in 1943 / Revenue: \$2.8 billion / Employees: > 10,000

 Global network: 54 sites in 23 countries, 3 sites in the US



Automotive



Refrigeration



HVAC

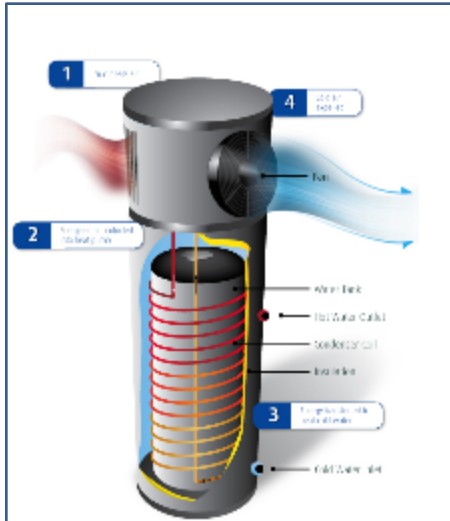


Project Overview

Standard HPWH

VS

Sanden HPWH



- R134a/R410a
- Indoor installation
- Noise >50dB
- Electric backup element required
- Cools home even in the winter



- CO₂ (R744)
- Heat Pump installed Outside, Tank Inside
- Noise <40dB
- NO electric backup element
- No Energy loss to home

#1 : Replacing Electric Resistance Water Heaters field test

- Homes across the NW from the Coast to Montana; Min family size 4, Maximum of 7
- Partners — Washington State University, NEEA, BPA, Avista, Energy Trust of Oregon, Ravalli Electric Coop, and Tacoma Power

#2 : Demand Potential Comparison

- What is the energy storage capacity in long-term field use when subject to high hot water use – 130+ Gallons per 24 hours
- Partners : Washington State University, NEEA, Bonneville Power Authority, PNNL & DOE

Field Test Monitoring

Sample Site	Sampled Days (n)	kWh/Day	Total Household Hot Water (Gal/day)	Mean OAT (°F)	Minimum OAT (°F)
Addy, WA	266	6.8	98.7	34.2	2.1
Corvallis, MT	340	6.0	75.6	33.0	-15.7
Portland	280	3.5	45.4	44.2	17.9
Tacoma	367	5.0	80.5	43.4	22.7

Units were monitored for Energy and Water use, along with multiple temperature sensors in the system

The energy needed to heat the cold water supply for each flow event was calculated as:

Supply Water BTU = Volume (Supply water) x 8.34 x (Avg. hot water temp. – Avg. cold water temp.) x 1 Btu/lb./oF, where 8.34 lb./gal is the density of water

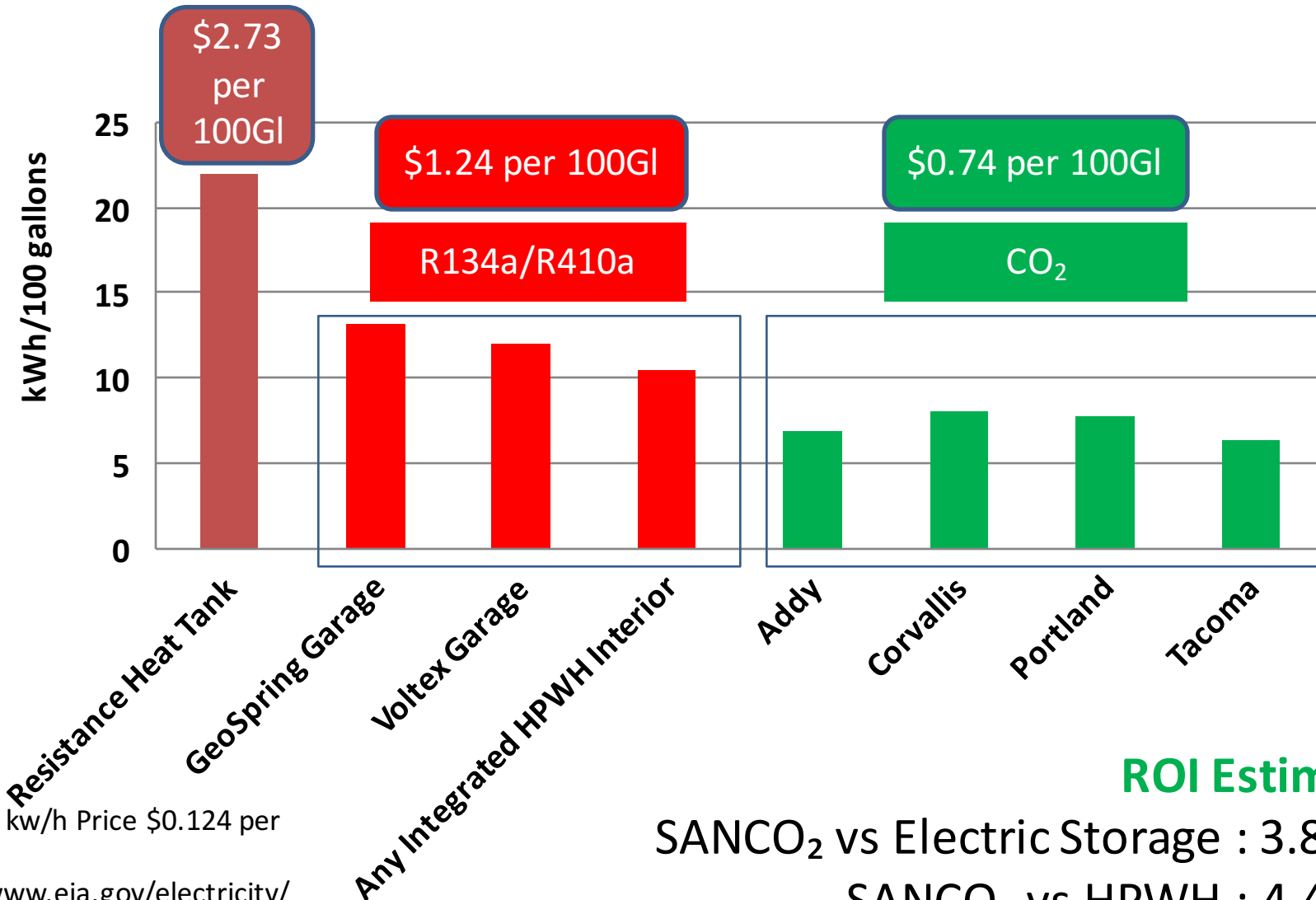
A Field Energy Factor (Energy Factor being the official DOE Water Heater Descriptor) was calculated :

FEF = Energy Contained in Total Useful Hot Water/Total Energy In

Data from installation through 10/31/2014

Field Test Results

kWh/100 gallons – Standard HPWH results from a NW Test



ROI Estimation

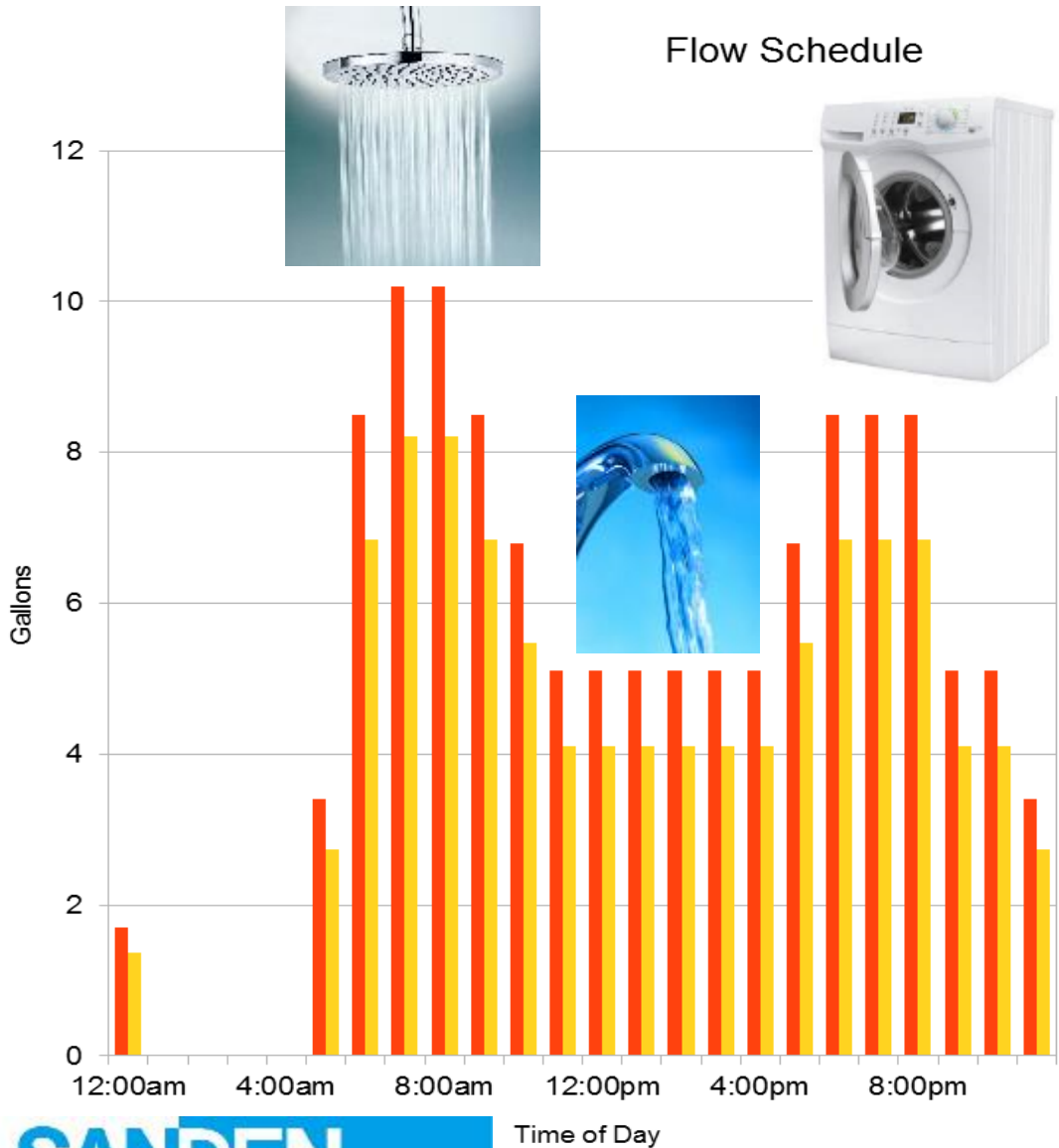
SANCO₂ vs Electric Storage : 3.8 Years

SANCO₂ vs HPWH : 4.4 Years

Average kw/h Price \$0.124 per kwh

http://www.eia.gov/electricity/monthly/update/end_use.cfm

Demand Potential Monitoring



Approx. 130 Gallons used per 24 Hour Period using varying Flow Rates and Length of Draw

System potential test :
 Outdoor unit is turned off for varying periods of time to determine if the system can meet Hot Water demand

Over Supply Schedule

	Off Time	On Time
Day 1	None	None
Day 2	5PM	Midnight
Day 3	4PM	Midnight
Day 4	3PM	Midnight
Day 5	2PM	Midnight
Day 6	1PM	Midnight
Day 7	Noon	Midnight



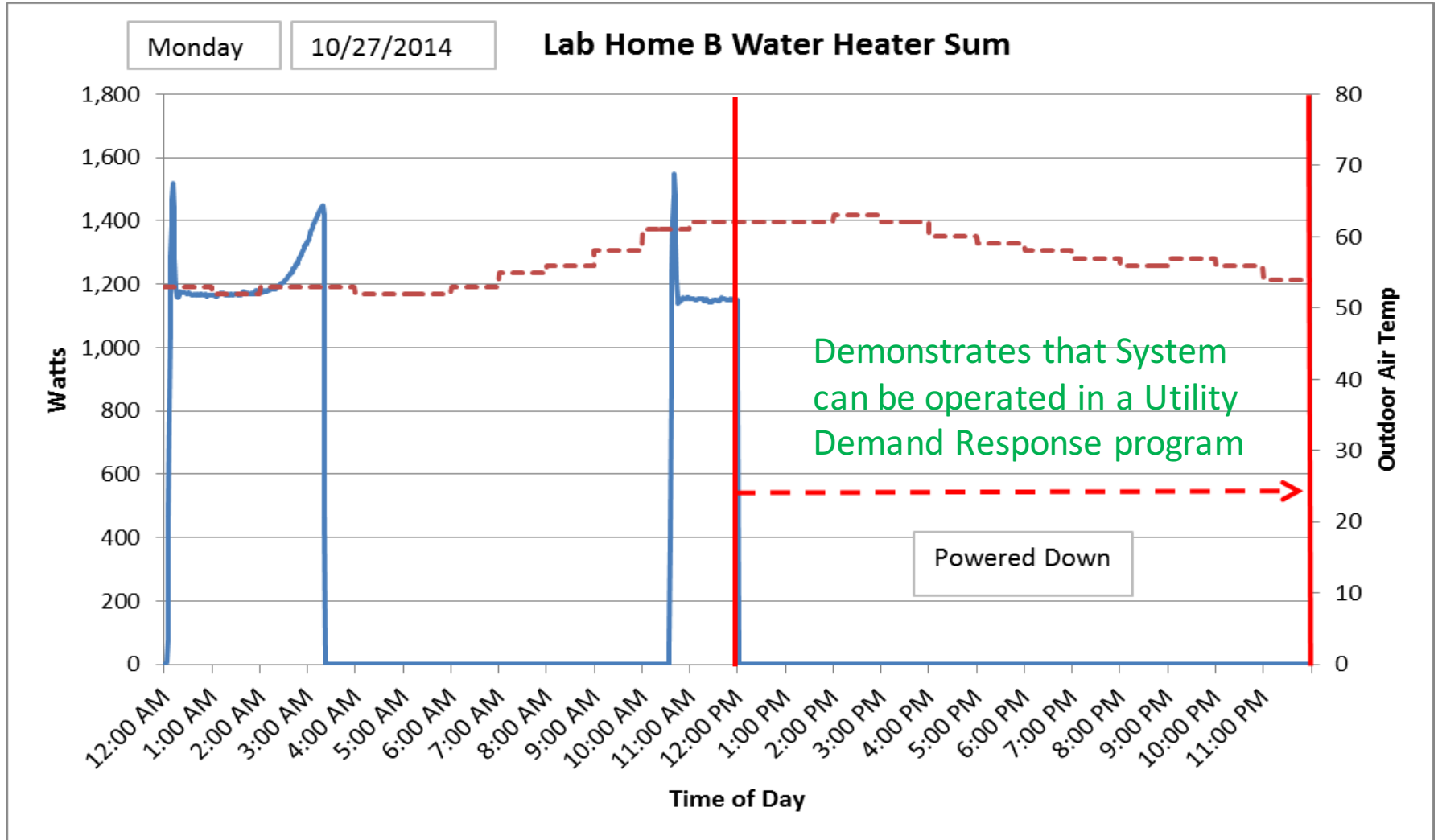
SANDÉN

Delivering Excellence

Demand Potential Power Usage

This graph shows the unit was shut off for 12 hours

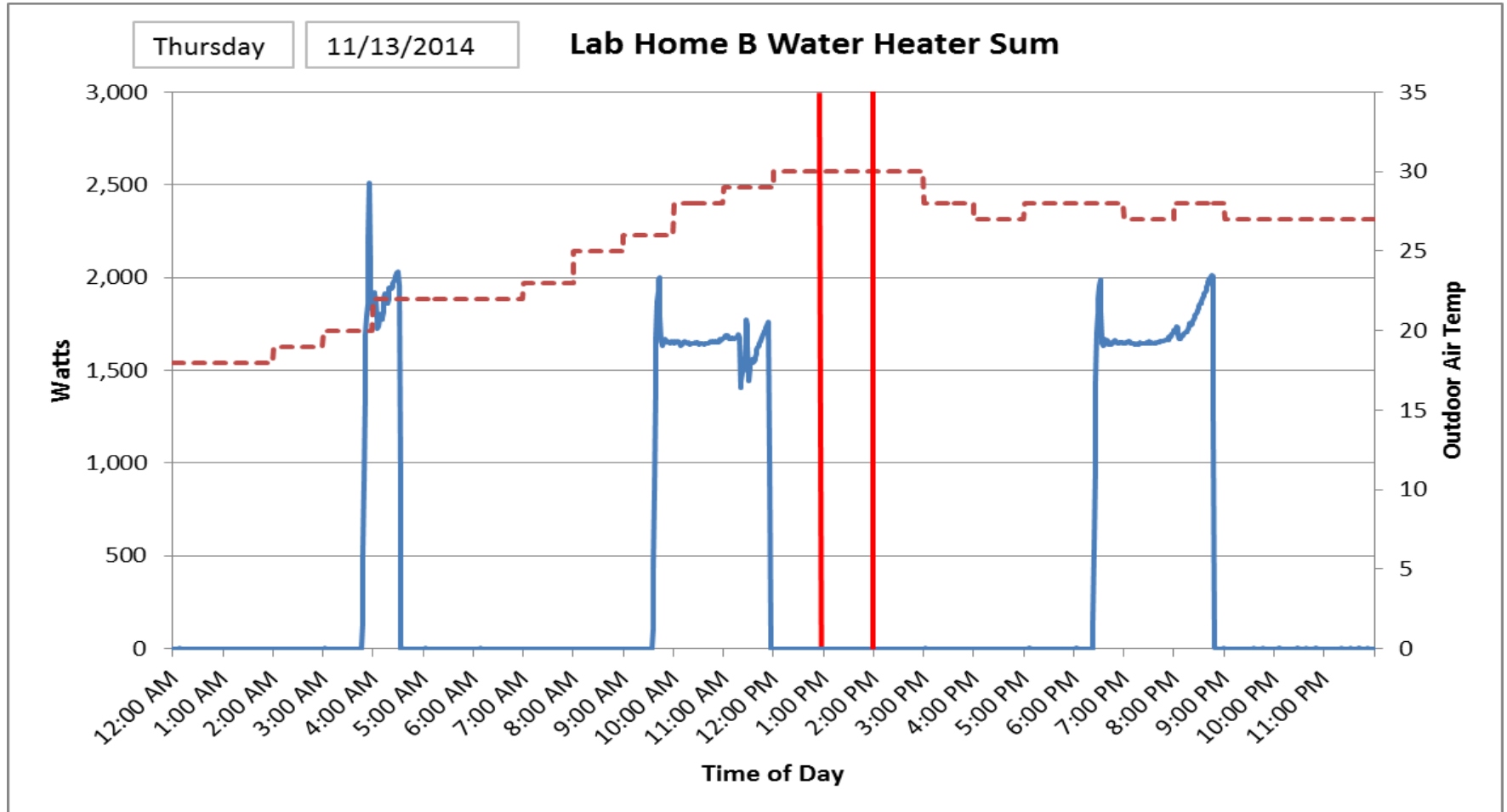
Total Energy use 5.63 kw, no reduction in HW performance



Demand Potential Power Usage

Showing effect of Ambient temperature below freezing and a shut down period on power use

9.4kw total use over a 6 hours run time, no loss of HW performance



The Sanden CO₂ HPWH

- Provides Domestic Hot Water to any home in **Ambient temperatures down to -15°F**
- **Does not require a Back up Electric Element** for the Storage Tank
- **Only needs to operate 25%** of the time, when compared to Synthetic Refrigerant HPWH's
- Is **over 3 x more efficient** than electric resistance water heating and **40% more efficient IN COLD AMBIENTS** than Synthetic Refrigerant HPWH's
- **Can produce over 135 gallons of Hot Water per day**, including a 12 hour shut down period

Barrier

- Product concept, refrigerant is different to the market

Countermeasure

- Education at all levels of the market about advantages of CO₂, Efficiency, Performance, Reliability, & Split type HPWH's is required – Pilot Sales program underway (Buy one!)

Barrier

- Price point is higher than current NA market place

Countermeasure

- Cost reduction process underway to reduce price differential

Barrier

- UL/AHRI/Energy Star Certification required

Countermeasure

- Testing underway to certify product to all standards

SanCO₂

Launching Q3 2015

www.Sandenwaterheater.com

Facebook : Sanden Water Heater

Twitter : @SandenCO2HPWH



ATMO
sphere
business case
natural refrigerants
25 & 26 June - Atlanta, Georgia

Thank you

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Back Up Slides



Akagi Plant – Sanden Forest

**Environmental
Preservation**



**Eco-friendly Technology
Development & Manufacturing**
Heating, Cooling &
Electronics



GREEN PRODUCTS



Hybrid Compressor



**Electric Driven
Compressor**



CO₂ Compressor



CO₂ Heat Pump



CO₂ Cassette



Water Heater



**Vending
Machine**



Showcase

Sanden International (USA)



Automotive business (Wylie, TX & Plymouth, MI)

- Established 1985
- OEM market
- Heavy Duty Truck market
- Agricultural market
- After market



Compressors

Piston
Scroll



Auto HVAC



HVAC business (Plymouth, MI)



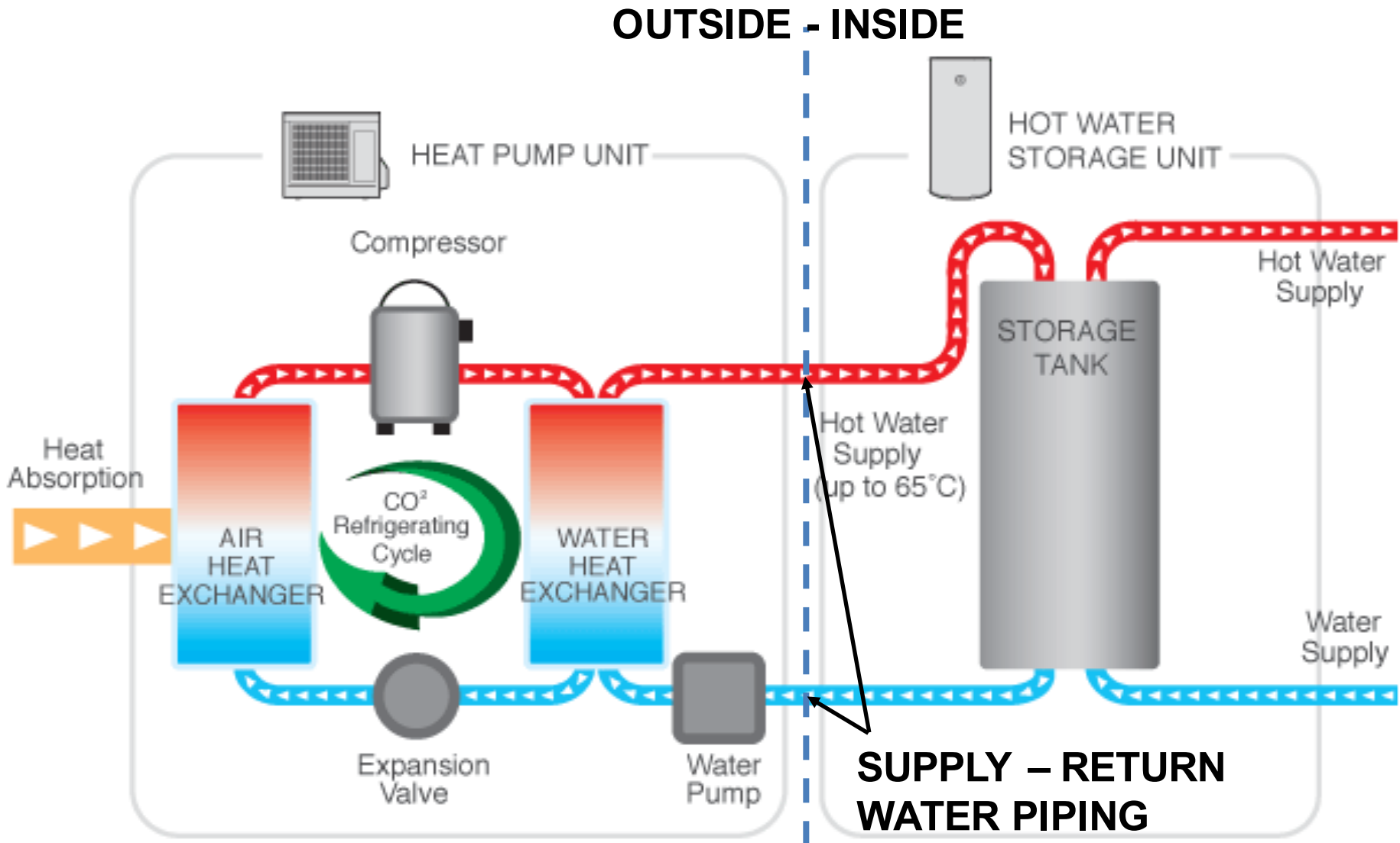
- Living Environment Division headquarters
- CO2 HPWH debut at AHR, Pilot sales program started
- R&D & Market Research on Heat Pump Space Heating
- Distribution channel development and lab/field testing of CO2 water heater.
- Micro Channel Coil Sales



CO₂ Split Type HPWH - History

- CO₂ Split HPWH were first designed in collaboration between Industry and University/Government Research programs in Japan during the late 90's
- Term Eco Cute was coined to describe this type of product
- First commercially available product was introduced in 2000 and Sanden launched our version of the Eco Cute product in 2006
- Eco Cute products and controls differ significantly from our Global product as cultural differences require features that are unnecessary outside of the core market

Anatomy of CO₂ Split type Heat Pump



Sanden Split System Installation

Similar to a Mini Split, but easier

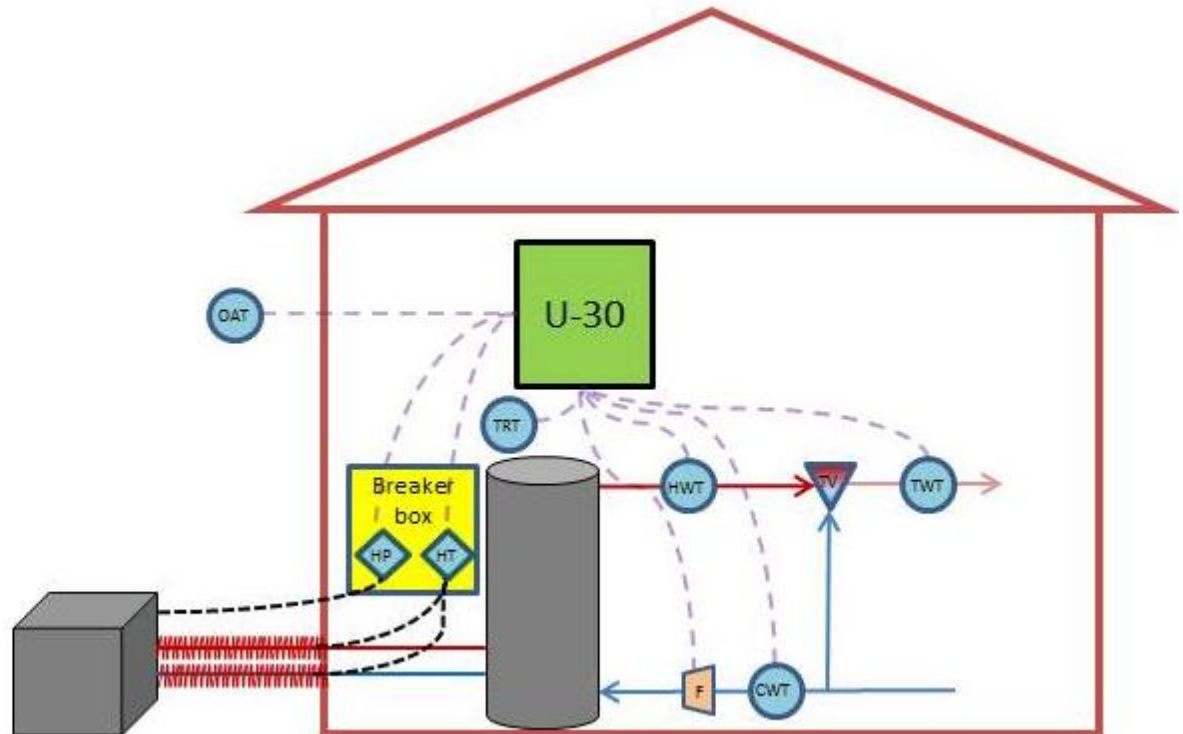
- 2 x water lines – ½”
Copper/PEX from the tank connections to the Outdoor
- No Refrigeration connections
- 208/230V-1Ph @ 15A Power – thermistor cable provided
- 50ft distance between Outdoor and Tank
- Tank has similar connections to a standard North American Tank (just 2 more of them)



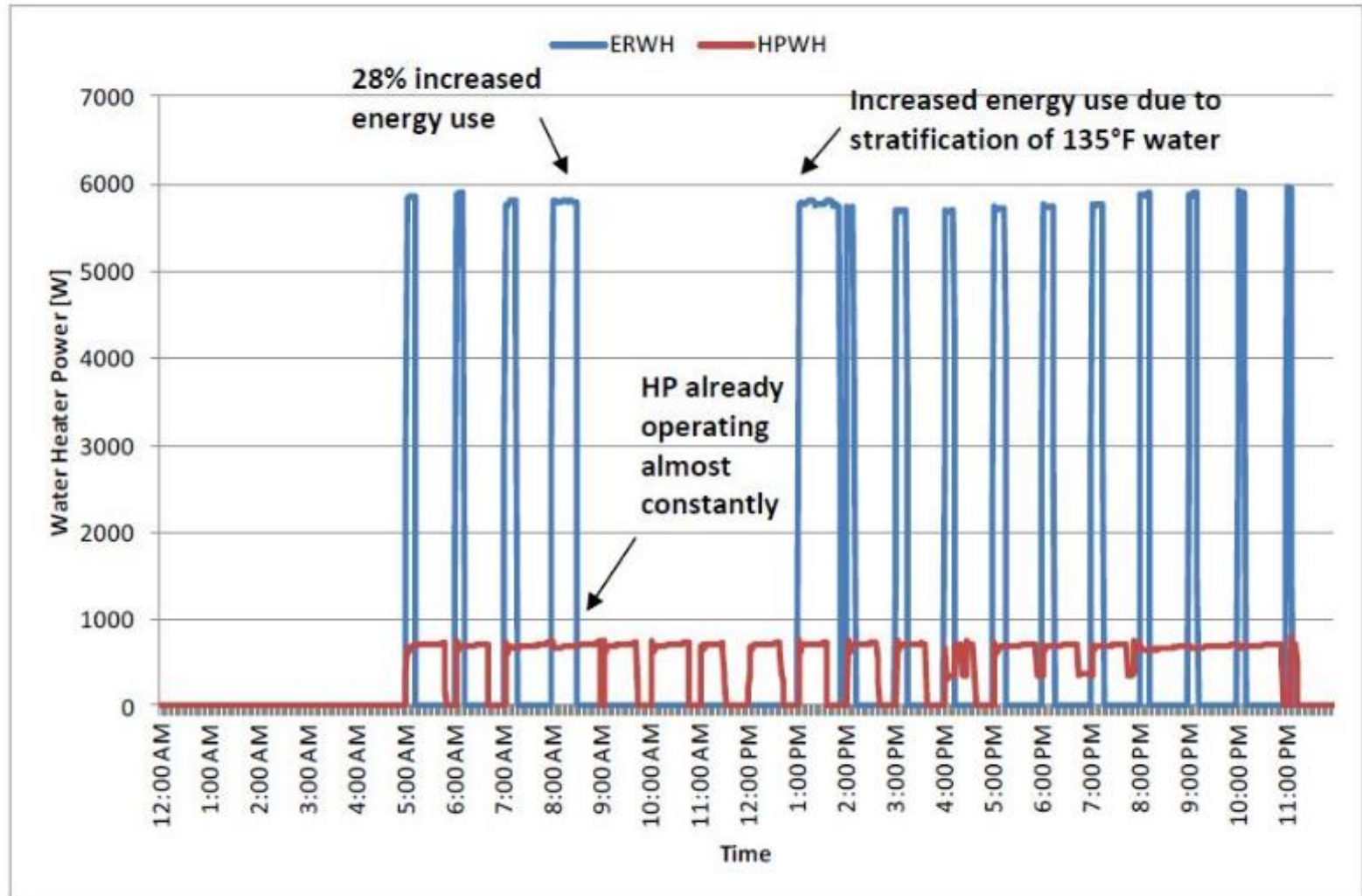
Field Test – Monitoring Layout

Key to Terms

- OAT – Outdoor Air Temp
- TRT – Tank Room Temp
- HP – Electricity to Heat Pump
- HT – Electricity to Heat Tape
- HWT – Hot Water Temp
- TWT – Tempered Water Temp
- CWT – Cold Water Temp
- F – Flow Meter
- TV – Tempering Valve
- U-30 – Monitoring System

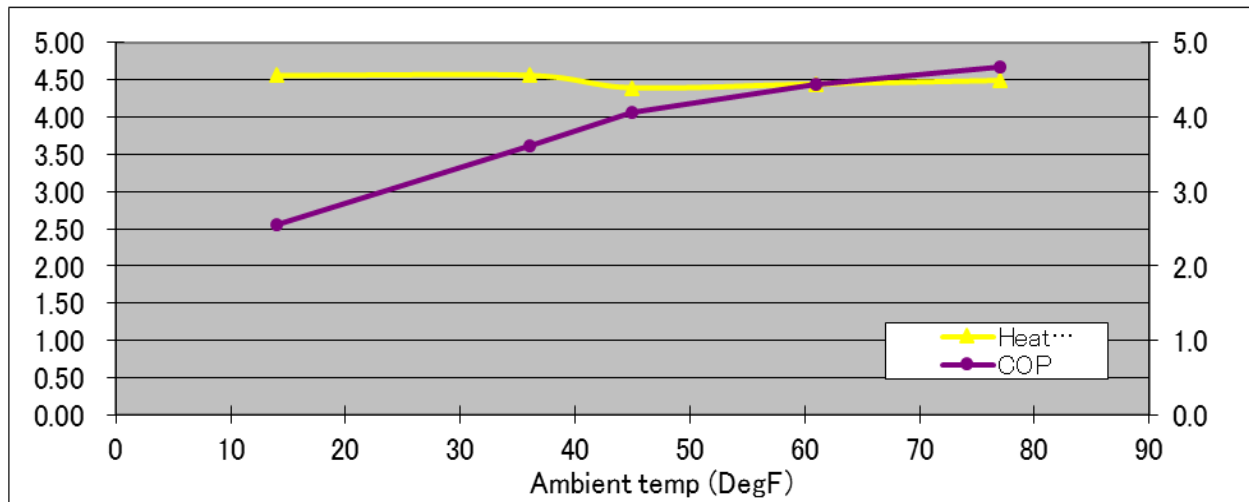


Standard and HPWH Water Heater – **72 Gallons usage only**



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



High efficiency and no capacity loss below freezing down to below zero

Design Changes made for North America

- Core Cold Weather (Hokkaido) global design currently unchanged – Compressor, Controller, Gas Cooler, Evaporator
- Product detail changes as needed to meet the regulatory standards
- “Line Set” length increased – larger residences
- Freeze Protection/Cold Weather line set protection being optimized
- Tank design to make it easier to retrofit into the North American home

Sanden Timeline

- 2006 Introduced CO₂ Eco Cute in Japan
- 2011 Introduced CO₂ unit in Europe (Integrated type)
- 2011 Introduced Global Split in Australia
- 2012 First Test units in US
- 2013/4 Successful Lab and Field trials
- 2014 Pilot Sales program started
- 2015 Q2/Q3 – Full Commercial Launch of SANCO₂ Split CO₂ HPWH
- 2016 on