Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

CO2 Combi System Compared to Other Systems in the PNNL Lab Homes

Cheryn Metzger, Joe Petersen, Josh McIntosh
Pacific Northwest National Laboratory

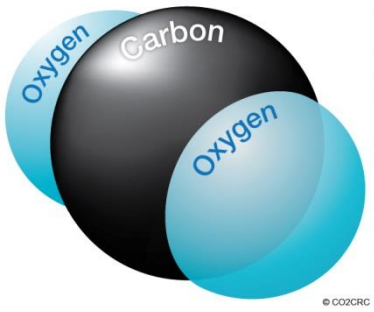
Ken Eklund
Washington State University

March 21st, 2018
Portland, OR

BACKGROUND

Benefits: CO_2 as a Refrigerant (R744)

- Thermal lift at cold temperatures exceeds standard refrigerant capacity
- Flexible in different climate zones
- Non-flammable
- Global Warming Potential of 1 (vs 2,088)



Past Lab Home Demand Response Experiments with Sanden CO_2 HPWHs

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Experiment Metric	Unitary System	Split-System
Dispatchable Power (kW)	1.3	1.2
Recovery Energy Shift (kWh)*	2.65	2.95
Oversupply duration (hours)	6	6
Maximum off period while delivered temperature is met (hours)	6	12

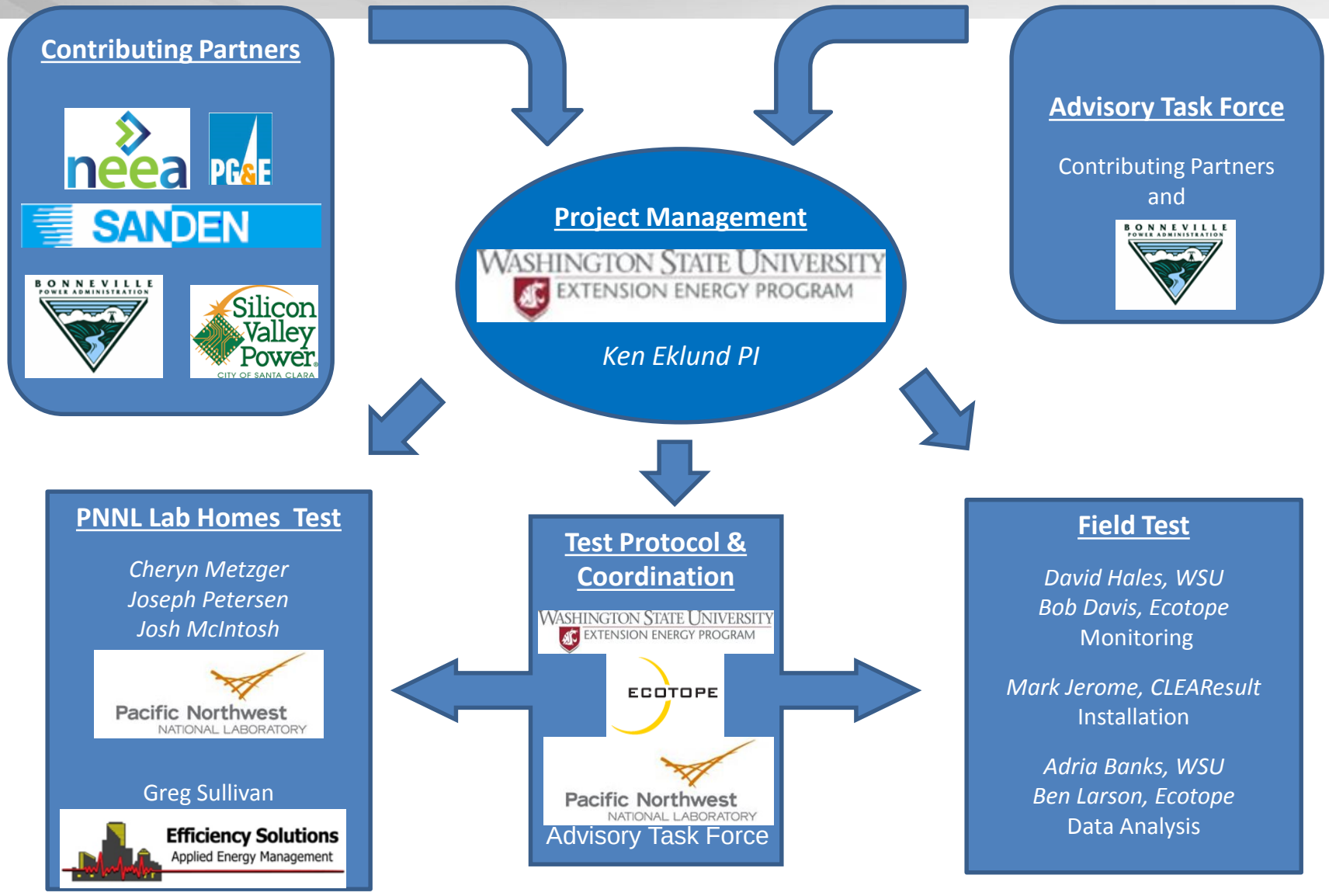
*Energy required to recover tank to set point after DR event

Opportunity!

GP Sullivan and JP Petersen. July 2015. *Demand-Response Performance of Sanden Unitary and Split-System Heat Pump Water Heaters* . PNNL - 24224, Pacific Northwest National Laboratory, Richland, WA.

Project Participants

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



EXPERIMENTAL PLAN

Lab Homes Characteristics

- Represent existing homes
  - 3 BR/2BA 1493-ft^2 double-wide, factory-built to HUD code
  - All-electric with 13 SEER/7.7 HSPF heat pump central HVAC + alternate Cadet fan wall heaters throughout
  - R-22 floors, R-11 walls & R-22 ceiling with composition roof
  - Incandescent lighting
  - Bath, kitchen, whole-house exhaust fans
  - Carpet + vinyl flooring
  - All electric
- Modifications include end-use metering, sensors, weather station, and three electric vehicle charging stations

Research Questions

During the heating season:

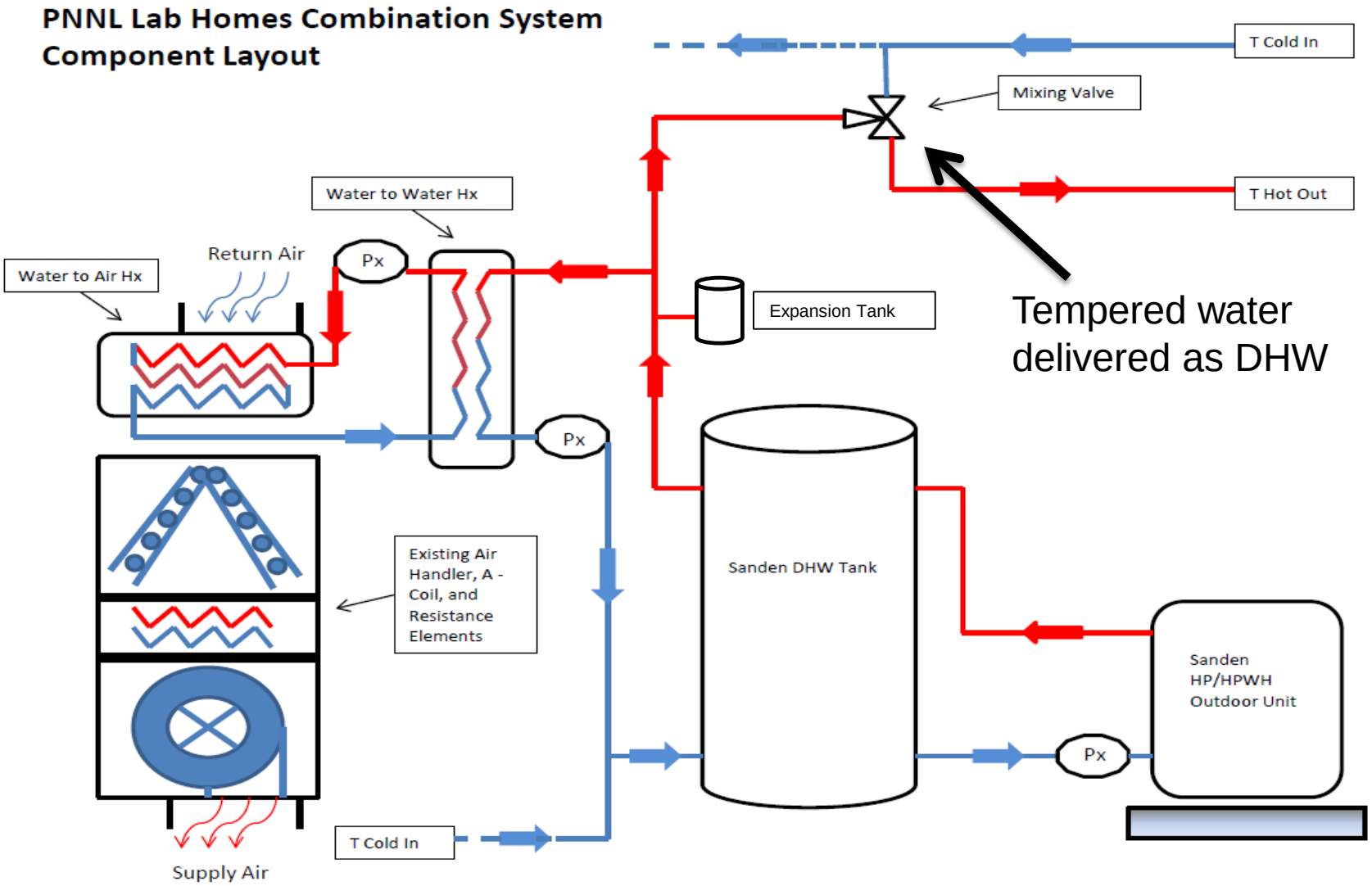
1. Does the system meet common space and water heating loads in these homes?
2. What is the impact on the system's ability to meet space and water heating needs when occupant-controlled variables such as thermostat settings, hot water draws, and hot water temperature settings are moved beyond average?
3. What is the DR oversupply mitigation capability and its ability to meet space and water heating loads?
    a. When occupant-controlled variables are moved beyond average?

Load Definitions

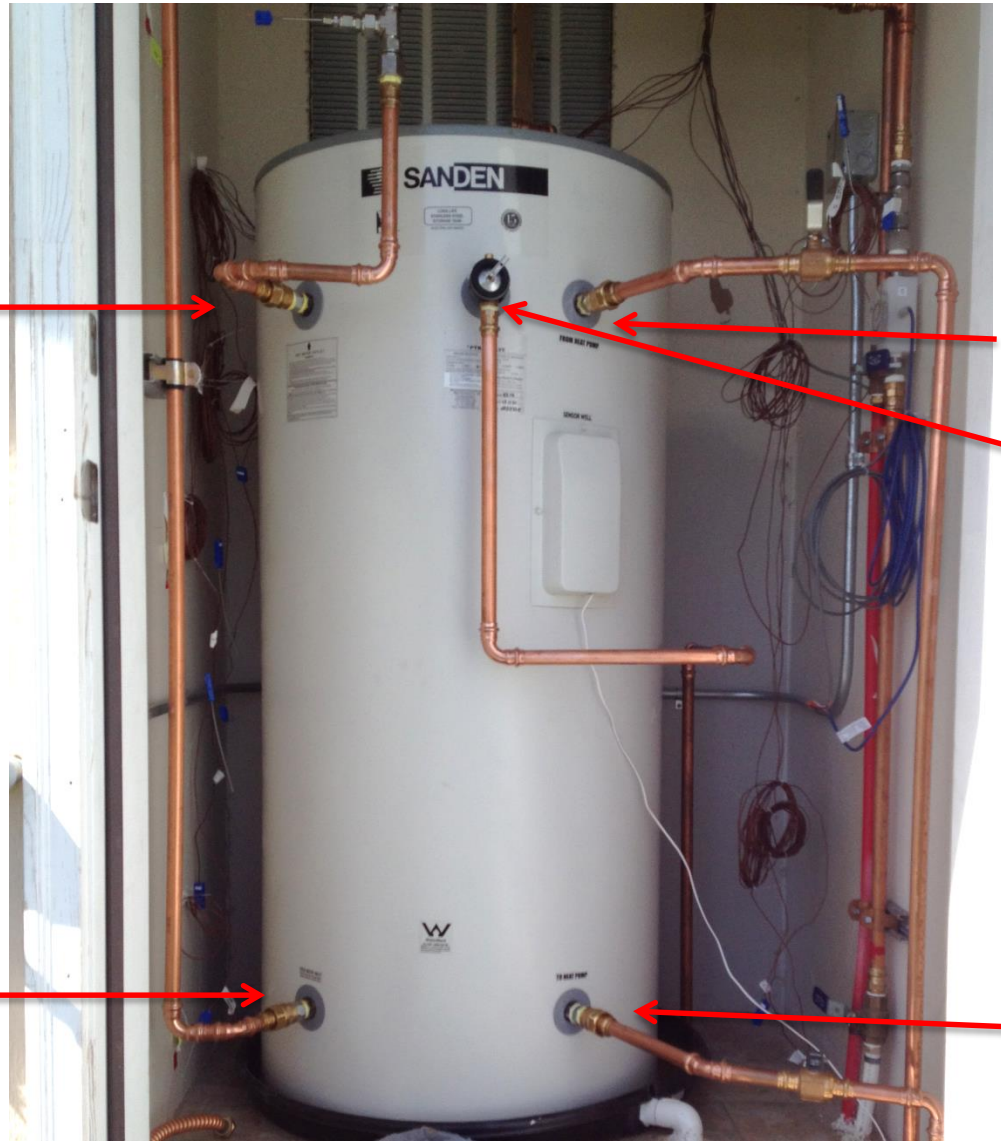
- Thermostat settings
  - Low: 65°F
  - Medium: 71°F
  - High: 80°F
- Water Temperature settings:
  - Low: 125°F
  - High: 135°F
- Water Load settings:
  - Low: 24 gpd
  - Medium: 46 gpd
  - High: 85 gpd

EXPERIMENTAL SETUP

Experimental Setup



System design credit to Mark Jerome, CLEAResult



Hot water out

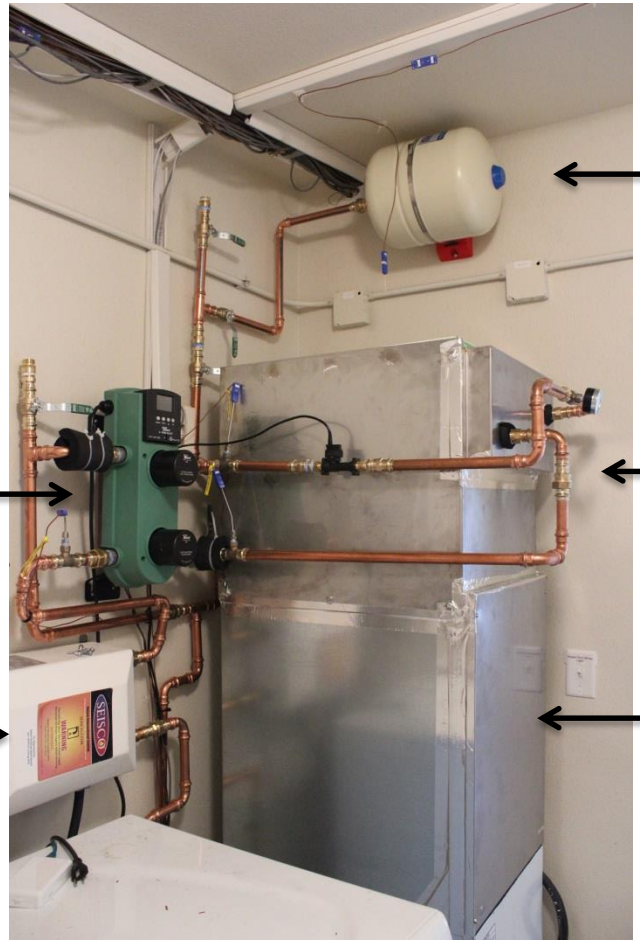
From heat pump

Pressure relief valve

Cold water supply

To heat pump

Interior Heat Exchange System with Electric Forced Air Furnace



Expansion Tank

Taco water to water heat exchanger

Custom water to air heat exchanger

Backup heater

Existing air handler for forced air furnace

HIGH LEVEL RESULTS

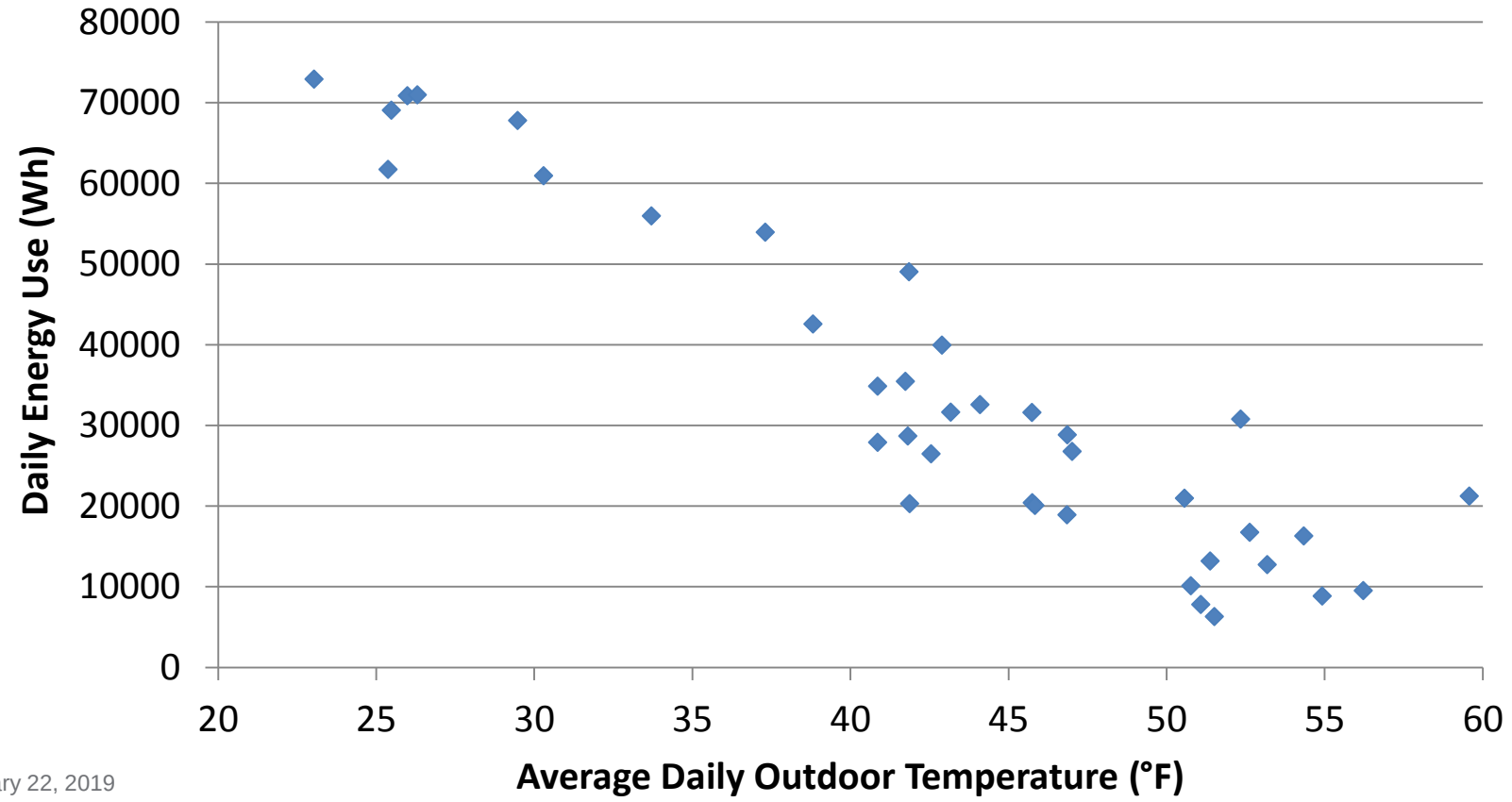
Occupancy Load Results

- When outdoor temp is above 40°F, system can meet loads:
  - 85 GPD
  - 80°F thermostat set point
  - 135°F water heater set point
- System cannot meet loads consistently:
  - When outdoor temperature is below 40°F
- Inconclusive if system can meet loads consistently following a DR event if temperatures are above 40°F
- System favors space conditioning temperature over water heating temperature

ENERGY USE DATA

Combi Energy Use

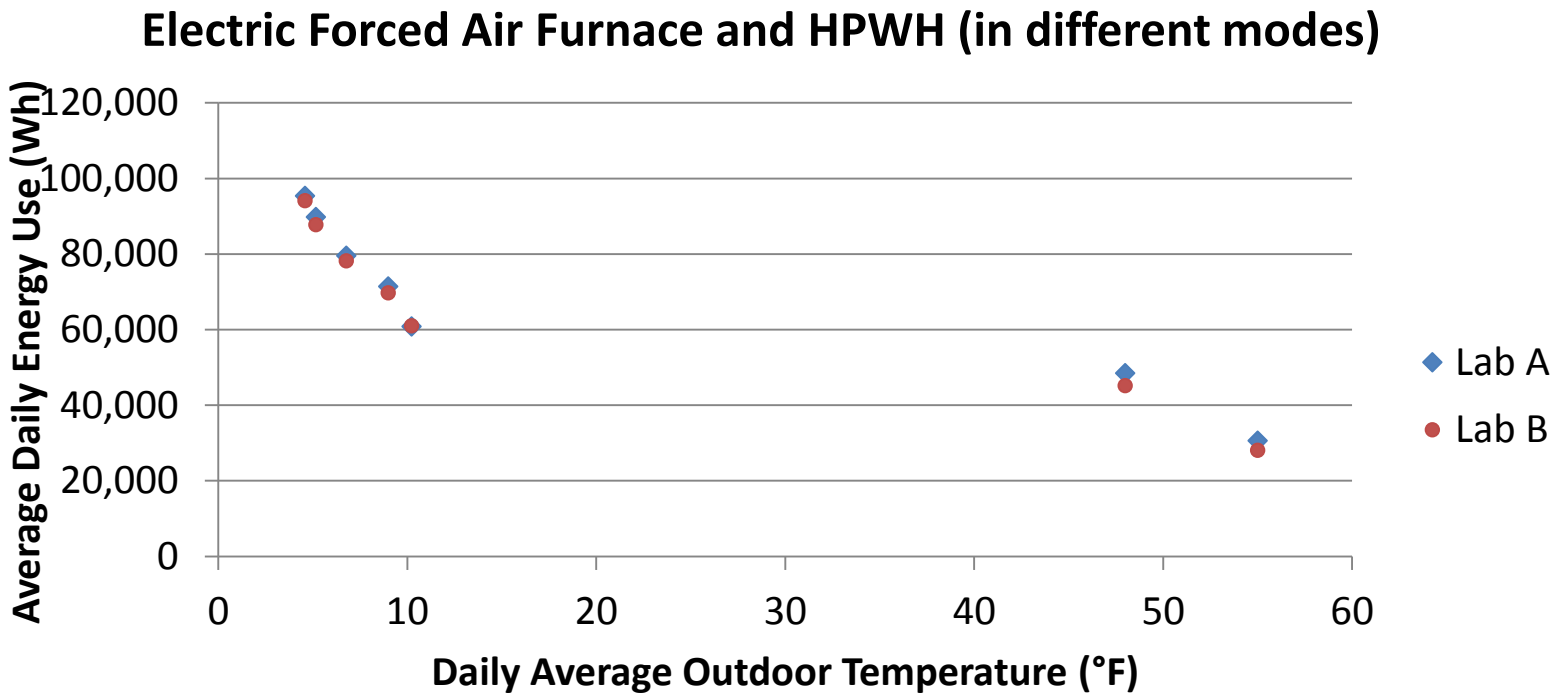
- 71°F Indoor temperature set point
- 125°F Hot water set point
- 46 gallons per day



COMPARED TO PAST DATA

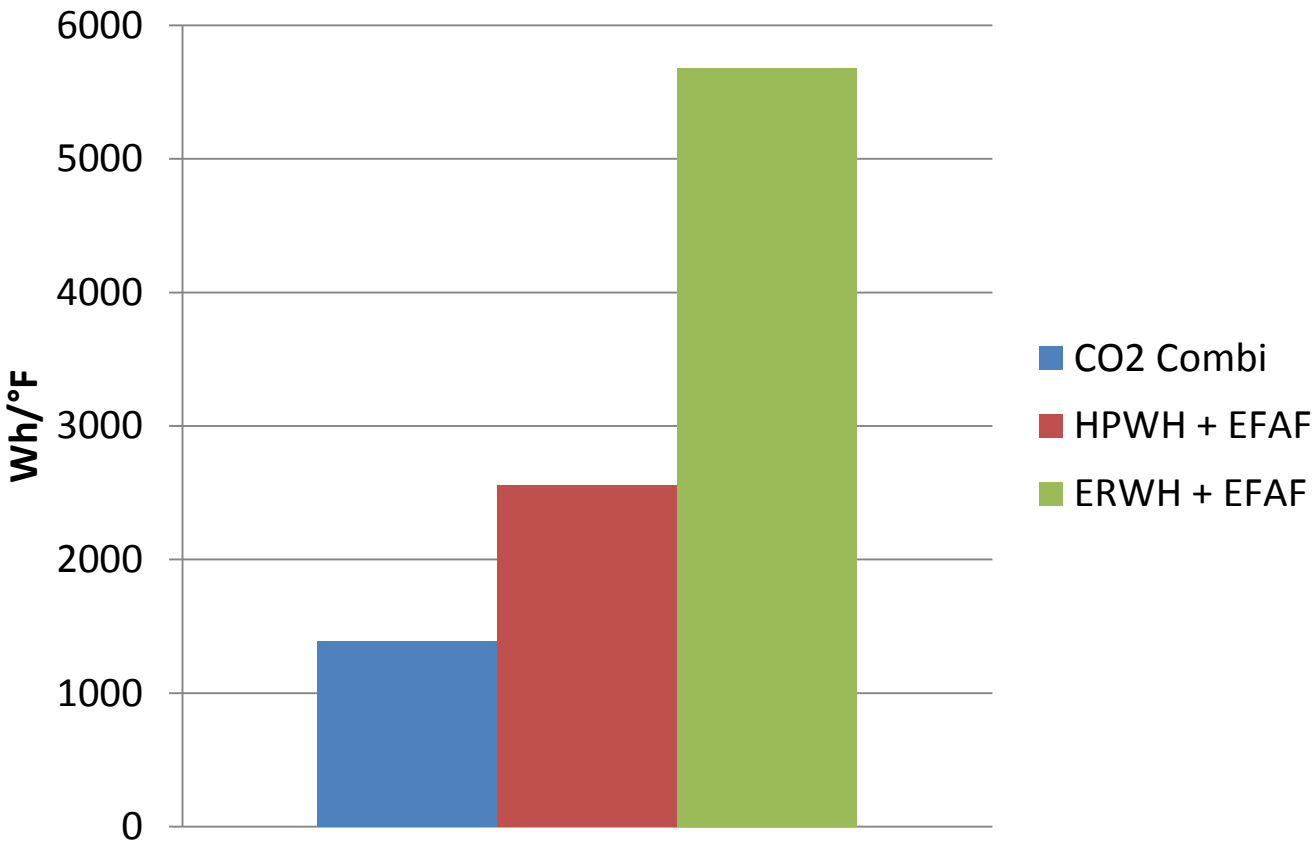
Past Experiment Results

- 71°F Indoor temperature set point
- 125°F Hot water set point
- 130 gallons per day



In Summary

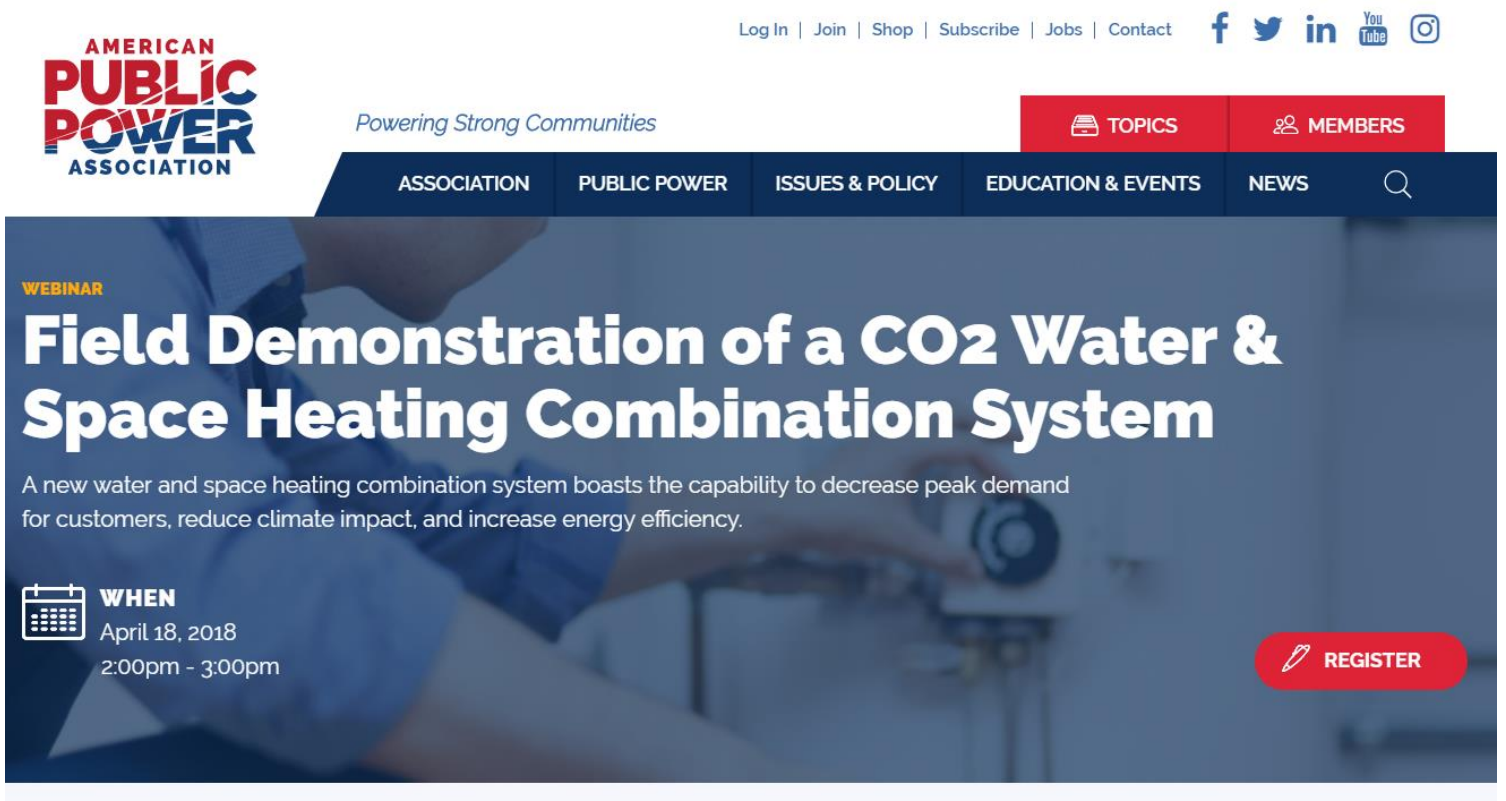
- Total energy use per degree increases



Upcoming Webinar!

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- https://www.publicpower.org/event/field-demonstration-co2-water-space-heating-combination-system



Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

THANK YOU!

Contact Information:
Cheryn Metzger PE PMP LEED AP
Cheryn.metzger@pnnl.gov
707-623-7091

https://labhomes.pnnl.gov/
Let me know if you would like to be added to the Lab Homes Newsletter!