CO_2 Heat Pump Research Update

Presented by Ken Eklund and Charlie Stephens

ACEEE 2018 Hot Water Forum

Portland, Oregon

Session Roadmap

Split Systems

- Gen3 compared to original hot water sites
- Combi field sites in Grass Valley and Nevada City, CA and Olympia, WA compared to each other and to standard heat pumps and heat pump water heaters plus a billing analysis

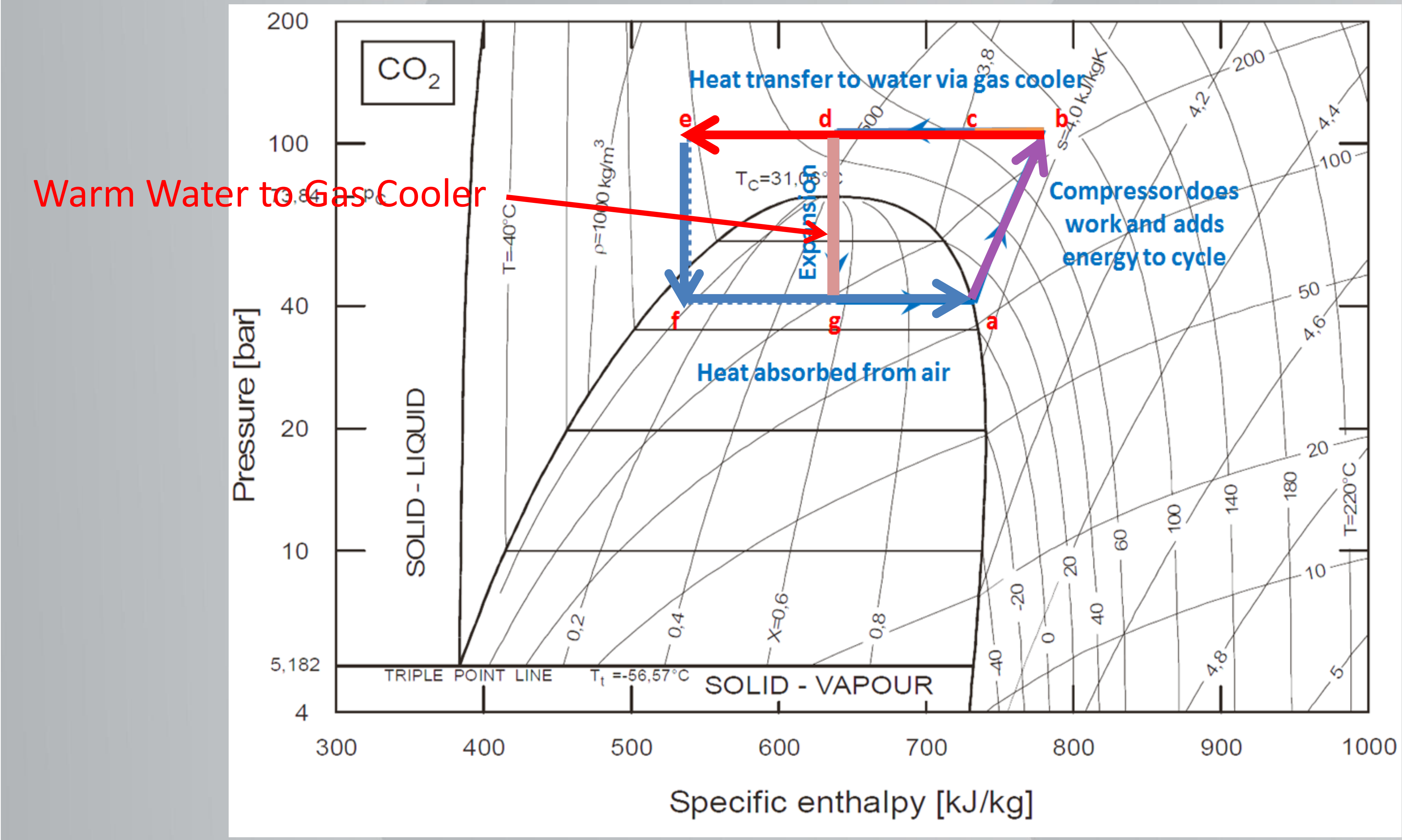
Eco Runo

- Installations in multiple climate zones, for multiple energy delivery systems
- Early performance
- A few early lessons

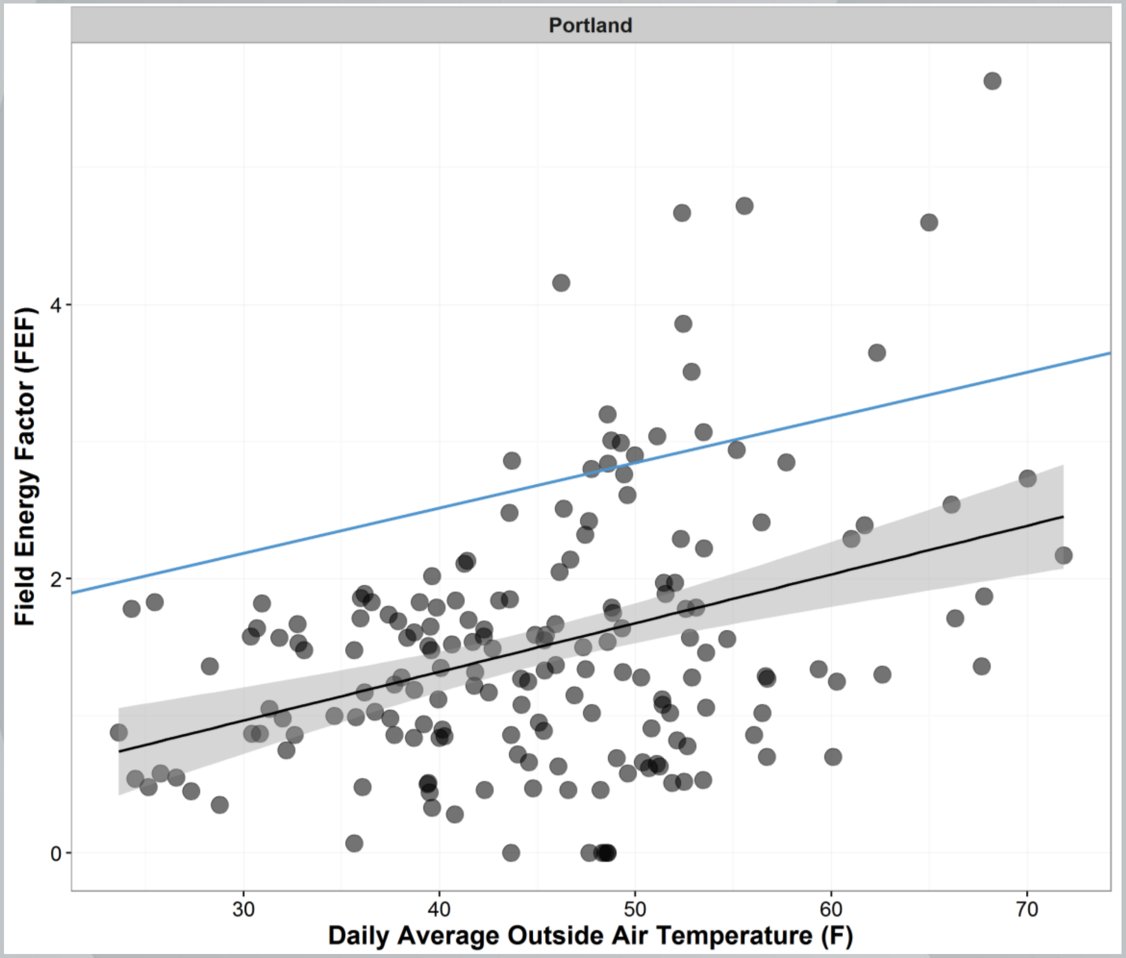
Quick Fixes

- Systems work best where design load is within heat pump limits
- Backup heat placed on domestic hot water line can keep hot water users happy
- Destratification hurts space and water heating performance. Use larger tank for large loads
- Reducing system temperature ups efficiency
- Reducing return temperature ups efficiency
- Cross flow results in reduced operating efficiency. Spring-loaded check valves stop it
- Volume of hot water use is related to system efficiency
- Programming heat pump to run off the time of peak increases efficiency
- Check controls, setup and programming

How CO_2 Heating Works (& Is Defeated)



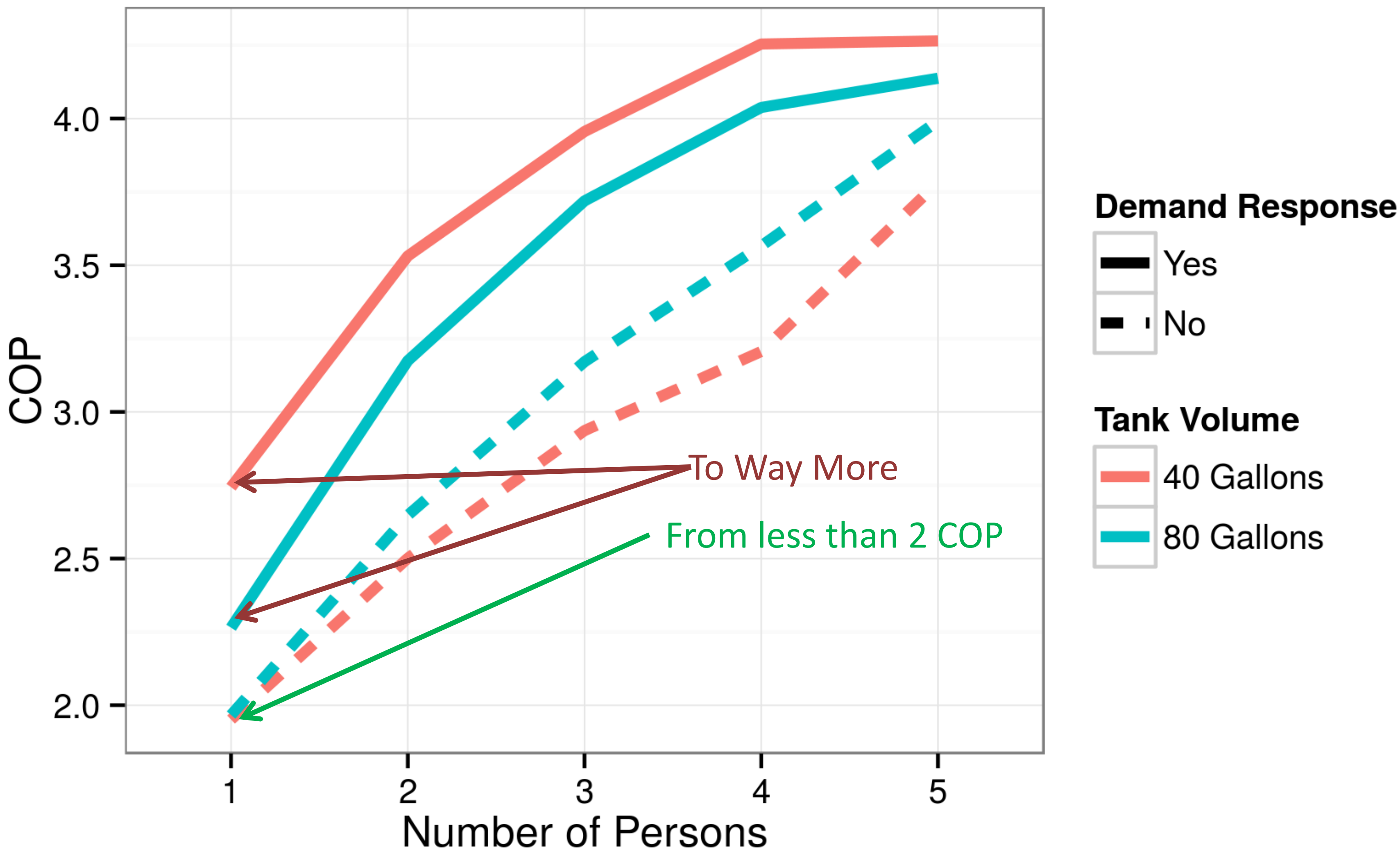
Hot Water Use is a Plus for Efficiency



Relating Efficiency to DHW Use

Site	KWh/Day	Gal/Day	Av. FEF	KWh/Gal
Addy, WA	6.8	98.7	2.42	0.07
Corvallis, MT	6	75.6	1.88	0.08
Portland, OR	3.5	45.4	2.30	0.07
Tacoma, WA	5	80.5	2.83	0.06
G3	3.4	23.8	1.50	0.15

Impact of Off Peak Operation on Efficiency



3 Combi Systems

- Split System combined systems in existing homes with identical monitoring systems were studied with support from BPA, PG&E and NEEA
- They are compared with each other and with homes in NEEA's Residential Building Stock Assessment for space heat and with NEEA's Heat Pump Water Heater Model Validation Study for heat pump water performance. Both studies are the work of Ecotope of Seattle
- One of the homes had analyzable utility data prior to the combined system installation and the resulting variable degree day analysis is presented

Climate

Site Location	Heating Zone	Site HDD
Grass Valley , CA	CEC CZ11	3,521
Nevada City, CA	CEC CZ16	4,536
Olympia, WA	IECC Z5	5,579

Site Characteristics

Site Location	Grass Valley	Nevada City	Olympia
Design T	19	14	22
Heating system	CO_2 Split	CO_2 Split	CO_2 Split
Distribution system	Forced Air Furnace	Forced Air Furnace	Radiant Panels
DHW T°F	143	121	120
Number of occupants	2	2	2
Conditioned Floor Area	1,680	1,690	1,152
UA incl. Infiltration	407	210	281

Design Load and System Needs

Location	Grass Valley	Nevada City	Olympia
Set Point	70	70	70
Design Temp.	19	14	22
ΔT	51	56	48
UA + Infiltration	407	210	281
Design Load Btu/hr.	20,757	11,760	13,488

Design Load & Heat Pump Capacity

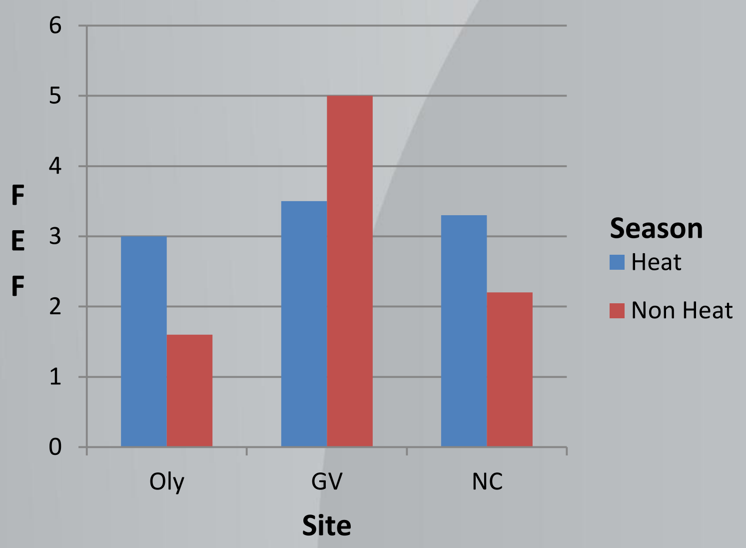
- Design load should be within the cold weather capacity of the heat pump
- If design load exceeds that capacity by a small margin, auxiliary heat will be needed. If the difference is substantial a larger heat pump is recommended.
- Auxiliary heat must be carefully designed to supplement the heat pump without harming its performance

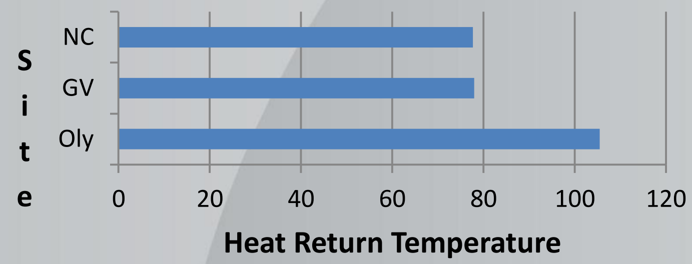
Energy Measurements

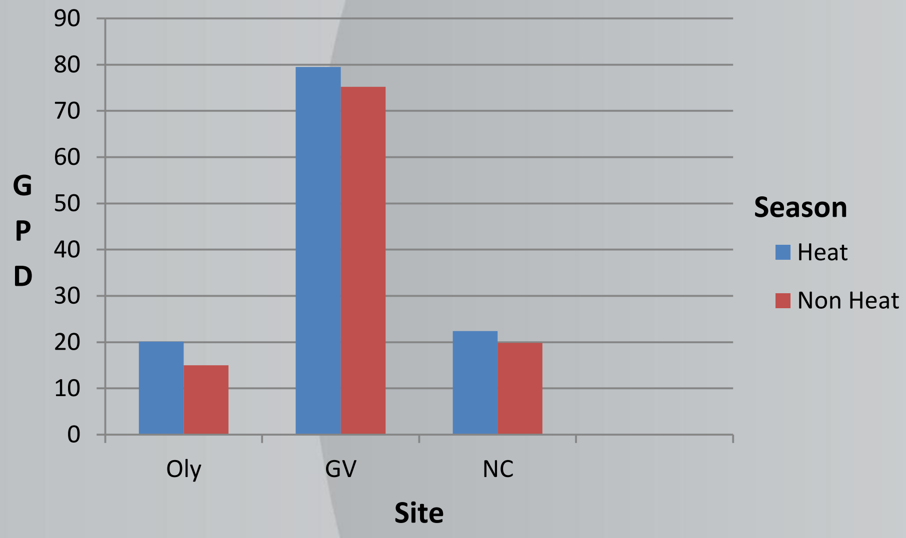
	HP (kWh)		Aux (kWh)		Pump & Control (kWh)		Total kWh	
Season	H	NH	H	NH	H	NH	H	NH
Olympia	521	49	0	0	120	6	641	55
Grass Valley	1,669	927	312	371	306	176	2,287	1,475
Nevada City	926	526	0	0	105	43	1,031	569

- Auxiliary Heat is only at Grass Valley
- The auxiliary system is an air to air heat pump that was rarely used to backup
- The non heating season auxiliary use is mostly for air conditioning

Performance Factors







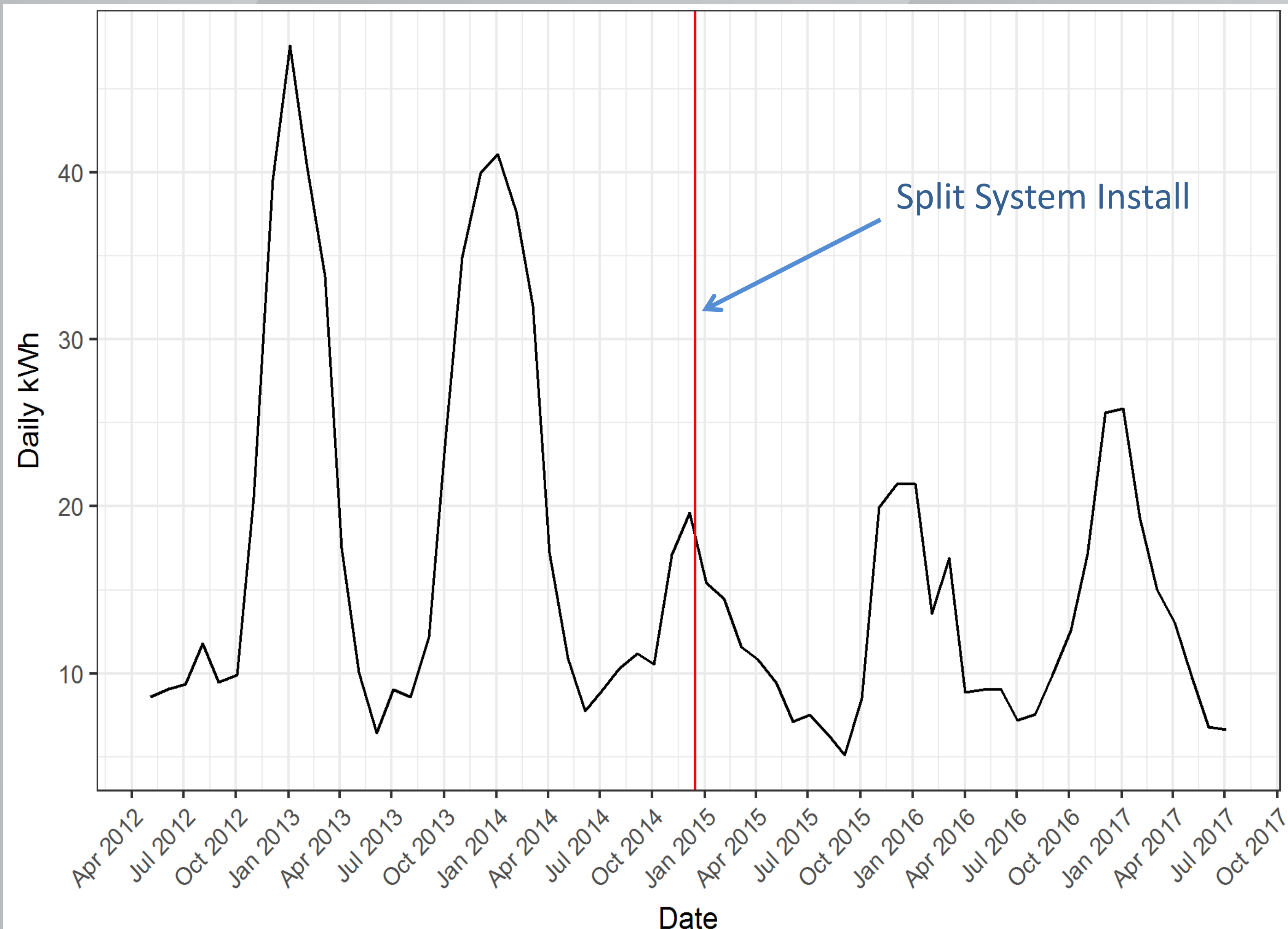
- Lowest Heating FEF correlates with highest return water temperature (Oly)
- Where DHW use drops, performance during Non Heating drops (Oly & NC)
- Largest daily water use correlates with highest FEF due to cold water (GV)

Comparison of Energy Use per Sq. Ft. Based on Field Measured Data

	CO_2 Split System Combi, kWh/ft^2	Air-to-Air Heat Pump & Tier 2 HPWH in Garage, kWh/ft^2
Olympia	2.4	5.2
Grass Valley	2.9	3.2
Nevada City	1.4	4.1

- Space Heat Comparison from 2012 Residential Building Stock Assessment—Ecotope
- Heat Pump Water Heater Comparison from HPWH Model Validation Study—Ecotope

Nevada City Energy Use Over Time



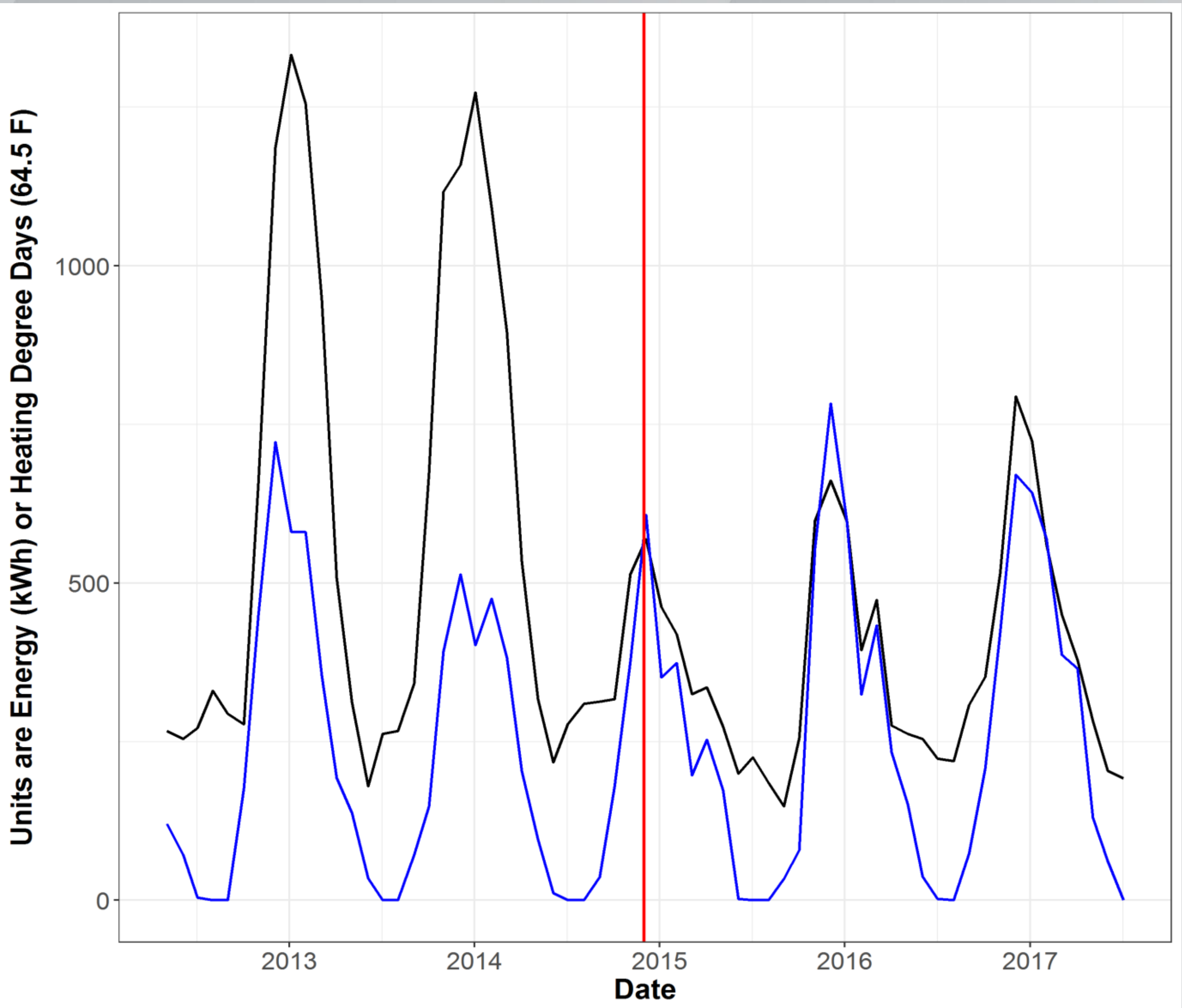
Weather Normalization

Blue line is Heating Degree Days at the VDD base of 64.5

Black line is energy used at Nevada City

Red line is date of Sanden Combi install

Normalized slope shows savings of 3,191 kWh/yr.



Case Study in Optimization

- The comparison case in Olympia, WA originally had a heating FEF of .6. It is now 3
- The average heating loop return temperature was reduced from 111.4°F to 105.5°F by lowering the heat pump output from 150 to 130°F
- A replaced sensor reduced average pumps and control energy use from 2.7 average kWh per heating season day to 2.3
- A new check valve prevented cross-flow of hot water from flowing through the mixing valve to the bottom of the tank and flowing to the heat pump

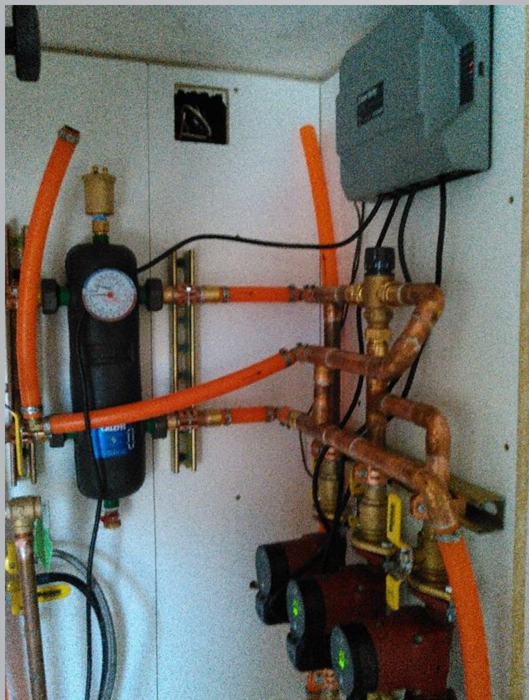
Implications

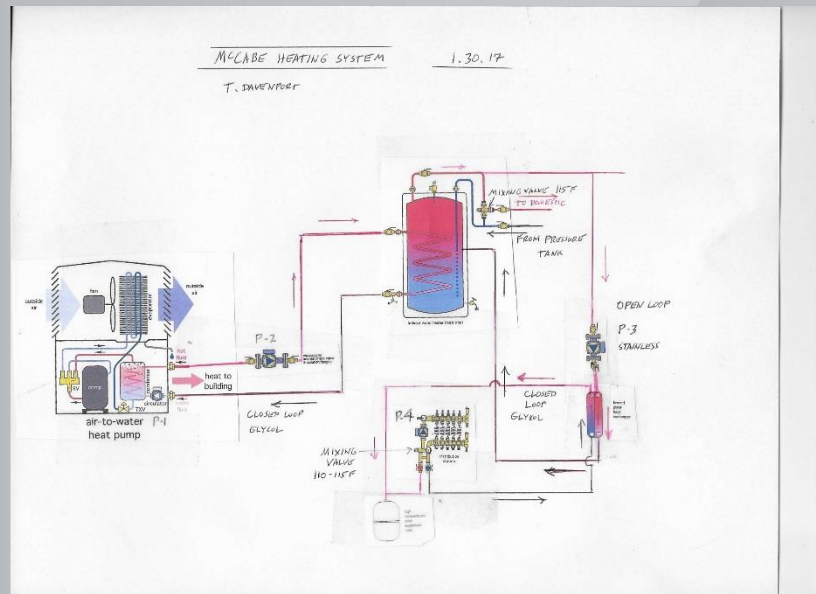
- The results show great potential for retrofit combined space and water heating in California climates and coastal locations to Canada
- The flexibility allows many types of distribution—in this study we had forced air and radiators
- Combining end uses in one heat pump in this project is more efficient than separate heat pumps for each end use

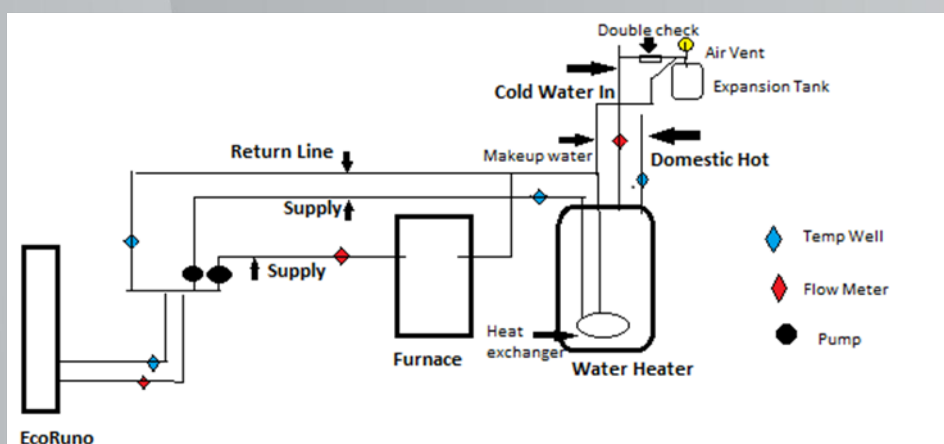
Eco Runo Field Demonstrations

Combined Systems Field Demos

Multiple Distribution System Types





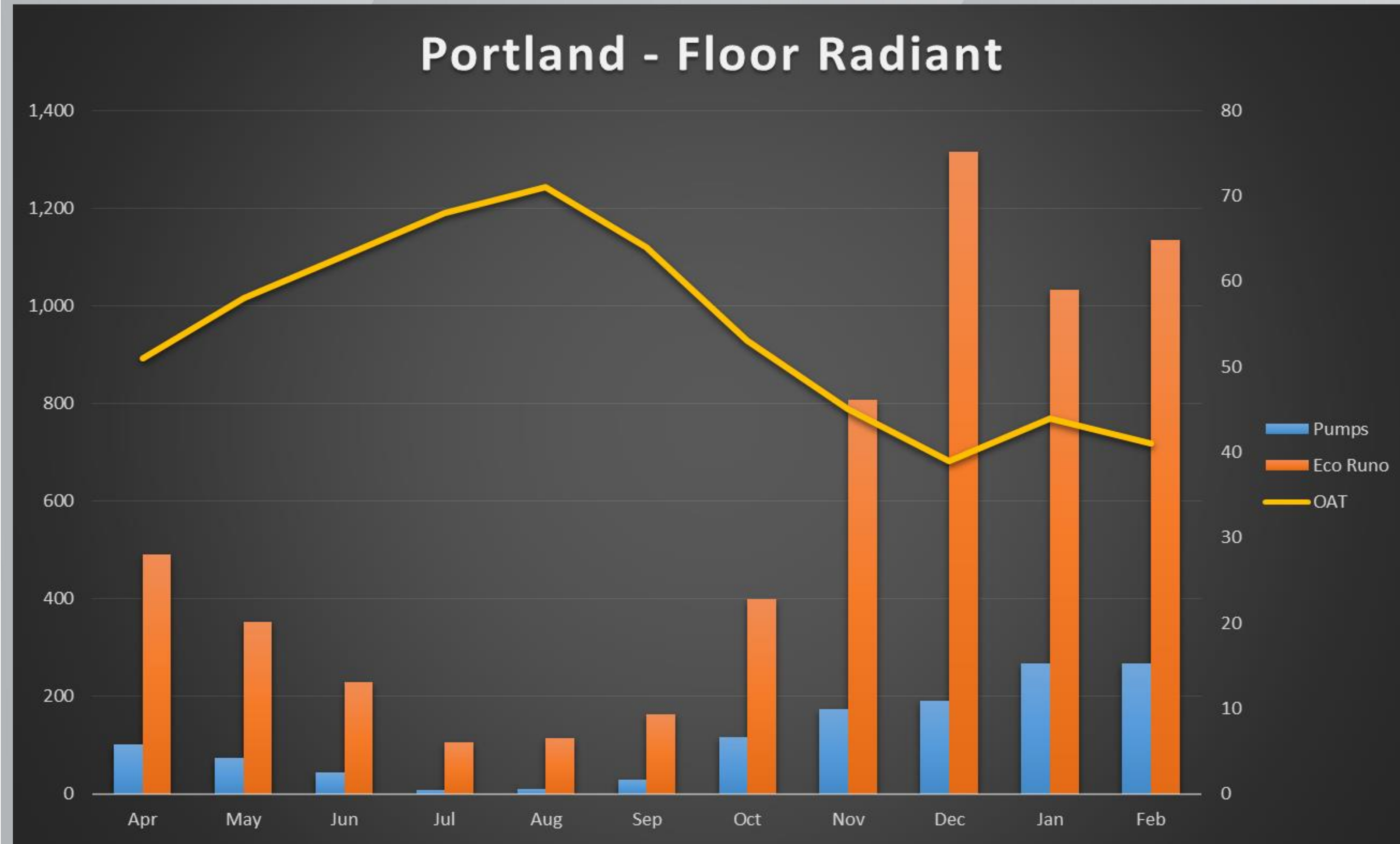


Floor systems are inherently complex – and expensive.

Performance

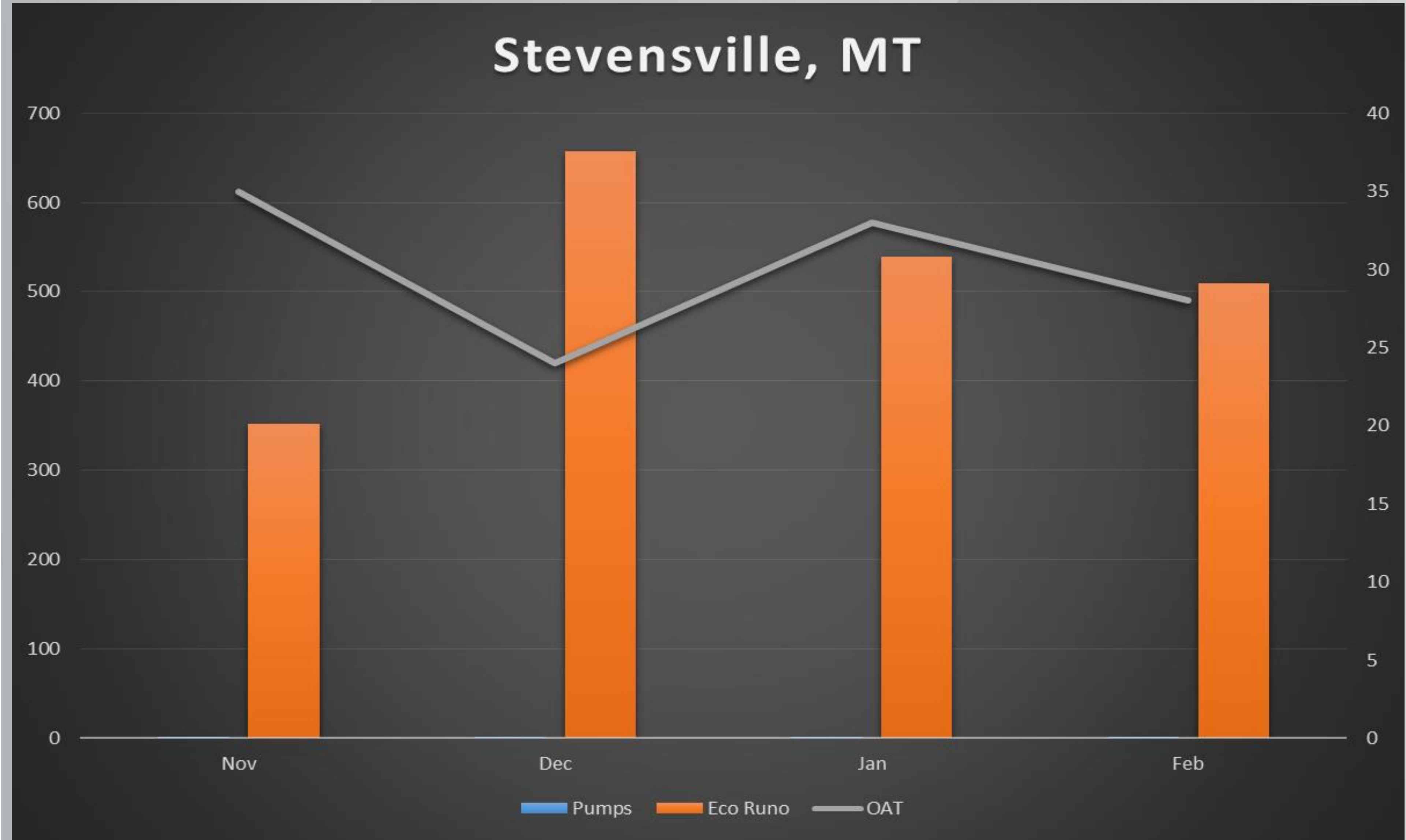
Energy Use

Pumps: 1,282 kWh
Eco Runo: 6,140 kWh



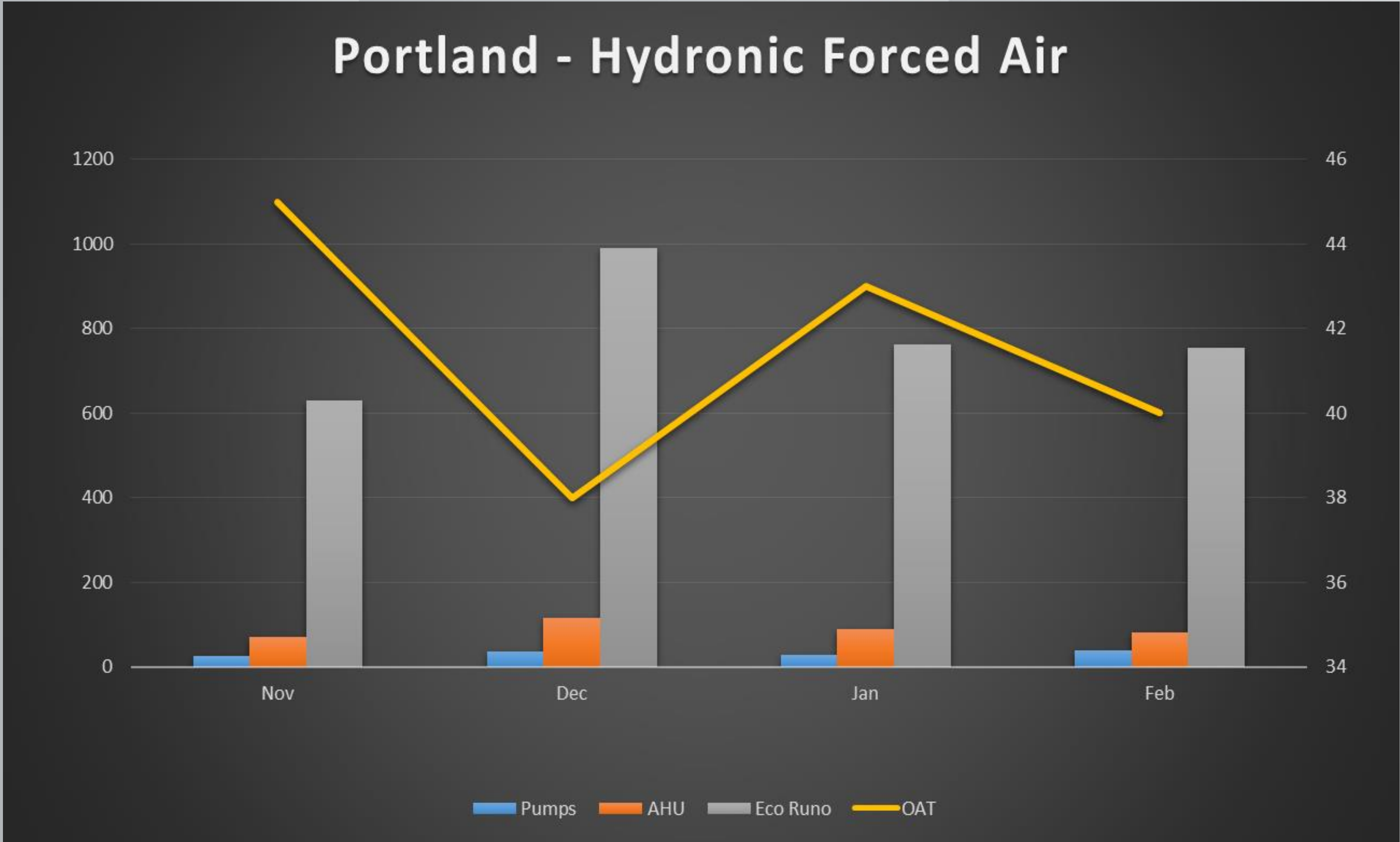
Energy Use

Pumps: 6.4 kWh
Eco Runo: 2,058 kWh



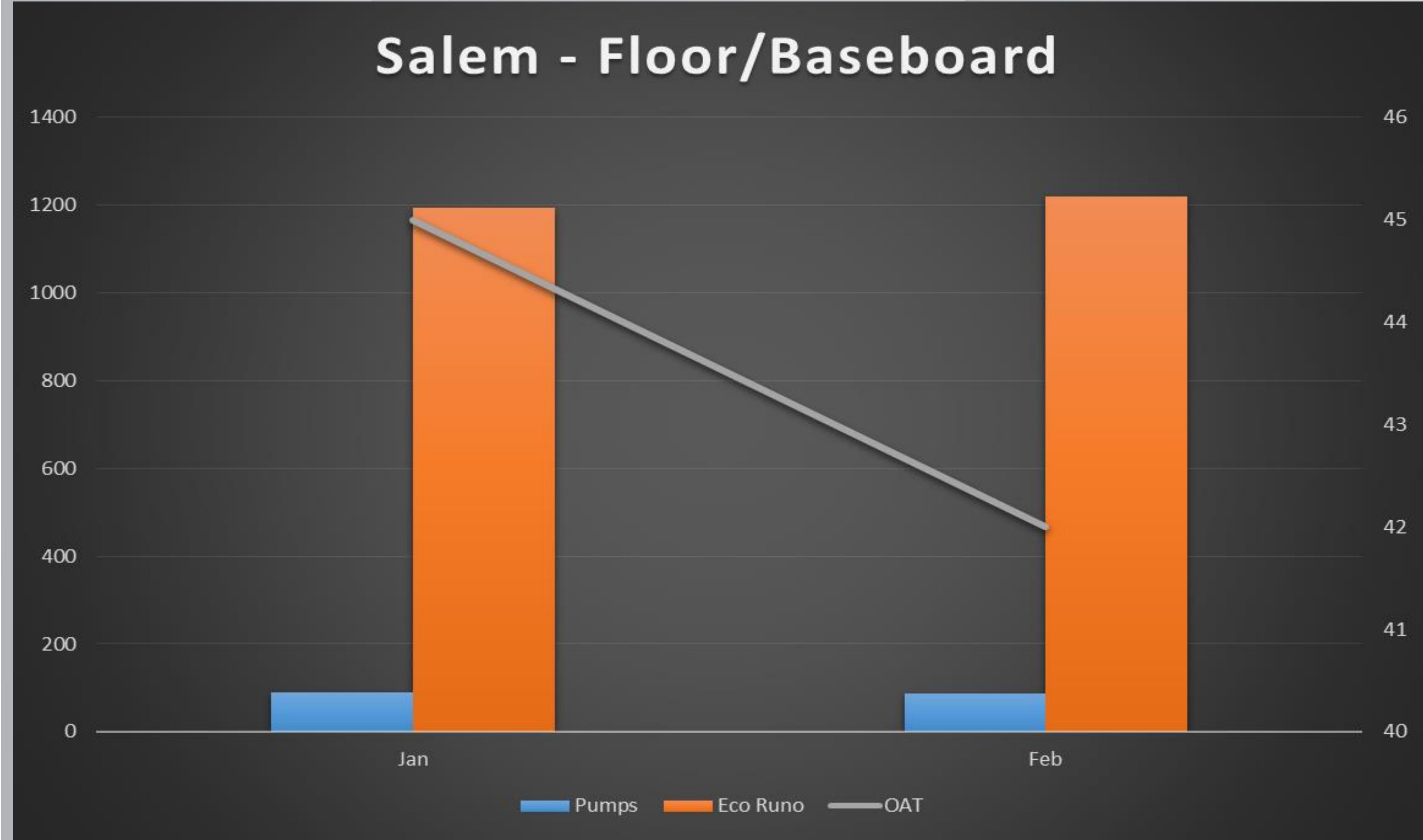
Energy Use

Pumps: 129 kWh
AHU: 356 kWh
Eco Runo: 3,139 kWh



Energy Use

Pumps: 177 kWh
Eco Runo: 2,413 kWh



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