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Putting CO_2 to Work

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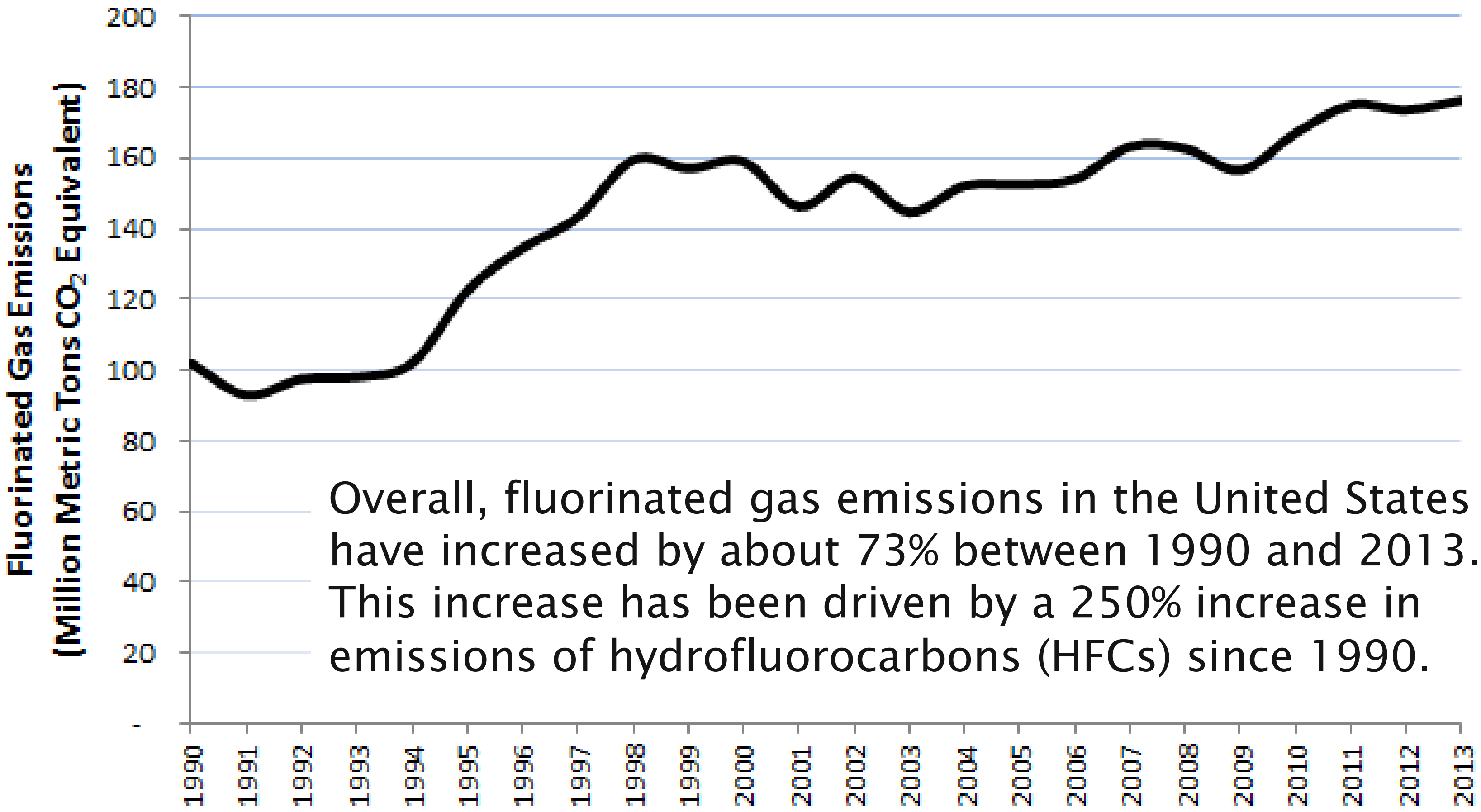
HFC Refrigerants Matter



Overall, fluorinated gas emissions in the United States have increased by about 73% between 1990 and 2013. This increase has been driven by a 250% increase in emissions of hydrofluorocarbons (HFCs) since 1990.

Phase-outs are Imminent

- Europe is phasing out HFC refrigerants now
  - Depending on end use, phase-out will occur from 2017 through 2022.
  - Many manufacturers (automotive, commercial refrigeration) are choosing CO_2 and/or propane as their new refrigerant.
- U.S. is a couple of years behind Europe
  - But some markets are moving now (e.g. CARB proposal for R-410a phase-out by 2022, Whole Foods).

Refrigerant GWPs

- R-410a (small hvac, HPWH): 2,030
- R-134a (auto AC, ref/frzrs, HPWH): 1,430
- R-404a (groc. & conv. store refrig.): 3,920
- R-507a (commercial refrigeration): 3,990
- R-32 (proposed replacement for R-410a): 675
- R-290 (Propane): 3
- R-744 (CO_2; auto AC, hvac, refrig., HPWH) 1

Relevant End Use Equipment

- Water heating/chilling (air-to-water heat pump, R-744 / R-290)
- Space heating/cooling (air-to-water heat pump, R-744 / R-290)
- Grocery store refrigeration (packaged and rack-based; R-290, R-744, cascade systems using more than one refrigerant, including ammonia)
- Vending machines (R-744, R-290, R-600a)

CO_2 as an Alternative

Heating

CO2 heat pump warm water room heater specifications

	CO_2ヒートポンプ温水暖房機 仕様	
Model	形 式	EDS-C110A
phase/volts/hz	電 源	単相200V 50/60Hz
Max Amps	最 大 電 流	25A
Design Heating Capacity(1)	定格加熱能力※1	3.5kW
gn Electricity Consumption(1)	定格消費電力※1	0.80kW
:nergy Efficiency(1)	エネルギー消費効率※1	4.3 COP?
Heating Capacity (2)	加熱能力※2	11.0kW
Max Power Consumption(2)	最大消費電力※2	4.0kW
nti Freezing Wattage	ドレン凍結防止ヒーター	0.1kW
)perating Noise	運 転 音	47dB
External Dimensions	外形寸法(H×W×D)	1280×828×283mm(突起部除く)
Weight	製 品 質 量	98kg
refrigerant	使 用 冷 媒	R744(CO_2)
Design Water Temp.	温水温度設定	45℃~70℃の3段階 (3 stage)
rm Water Connection Fitting	温水配管接続口	R3/4

※1.外気温7℃/6℃(DB/WB)入水温度23℃
※2.外気温7℃/6℃(DB/WB)入水温度30℃

1. Outdoor temp 7 deg C/6 deg C (DB/WB), supply water 23deg C
2. Outdoor temp7 deg C/6 deg C (DB/WB), supply water 30deg C

Refrigeration

Natural Refrigerant Energy Savings

Heating (CO_2)

- High COPs (4.0 – 6.0)
- Cold-climate capable (down to -25F OAT)
- Can make very hot water (up to 195 F)
- Split system, so no impact on indoor environment
- High system pressures (~1,450 psi)
- Energy storage

Cooling (R-290)

- Modestly to much better efficiency (20-30% better than HFC-based systems)
- Non-transcritical CO_2 systems not so capable at very high ambient air temperatures (above 80F); R-290 should fill this gap
- Typically packaged systems
- More modest system pressures (~400 psi for propane and non-transcritical CO_2)

Climate-Responsive Space & Water Heating

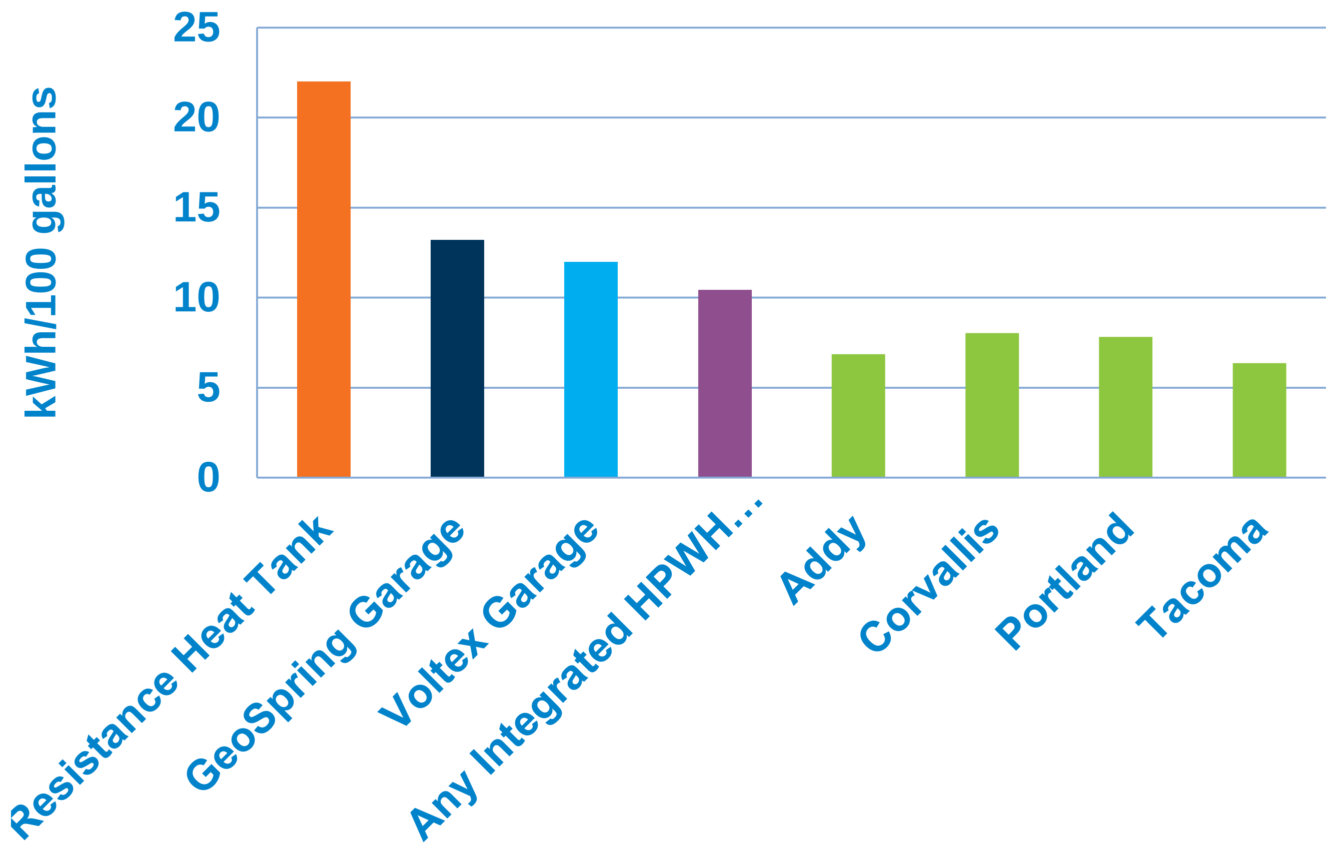
Work in Which NEEA is a Partner

- Extensive lab testing of packaged and split CO_2 DHW systems (2013 – 2014)
- Field tests of 4 split CO_2 DHW systems (late 2013 to present; one 8,800 DD site in Montana)
- Field tests of 9 combined space & water heating systems (CO_2 split systems, late 2014 to present)
- Lab & field tests of new 11 kW (35 kBtu/hr) combined space & water heating systems (2016/17)
- Investigation of grocery refrigeration system conversion (Whole Foods, Target) (2016/17)

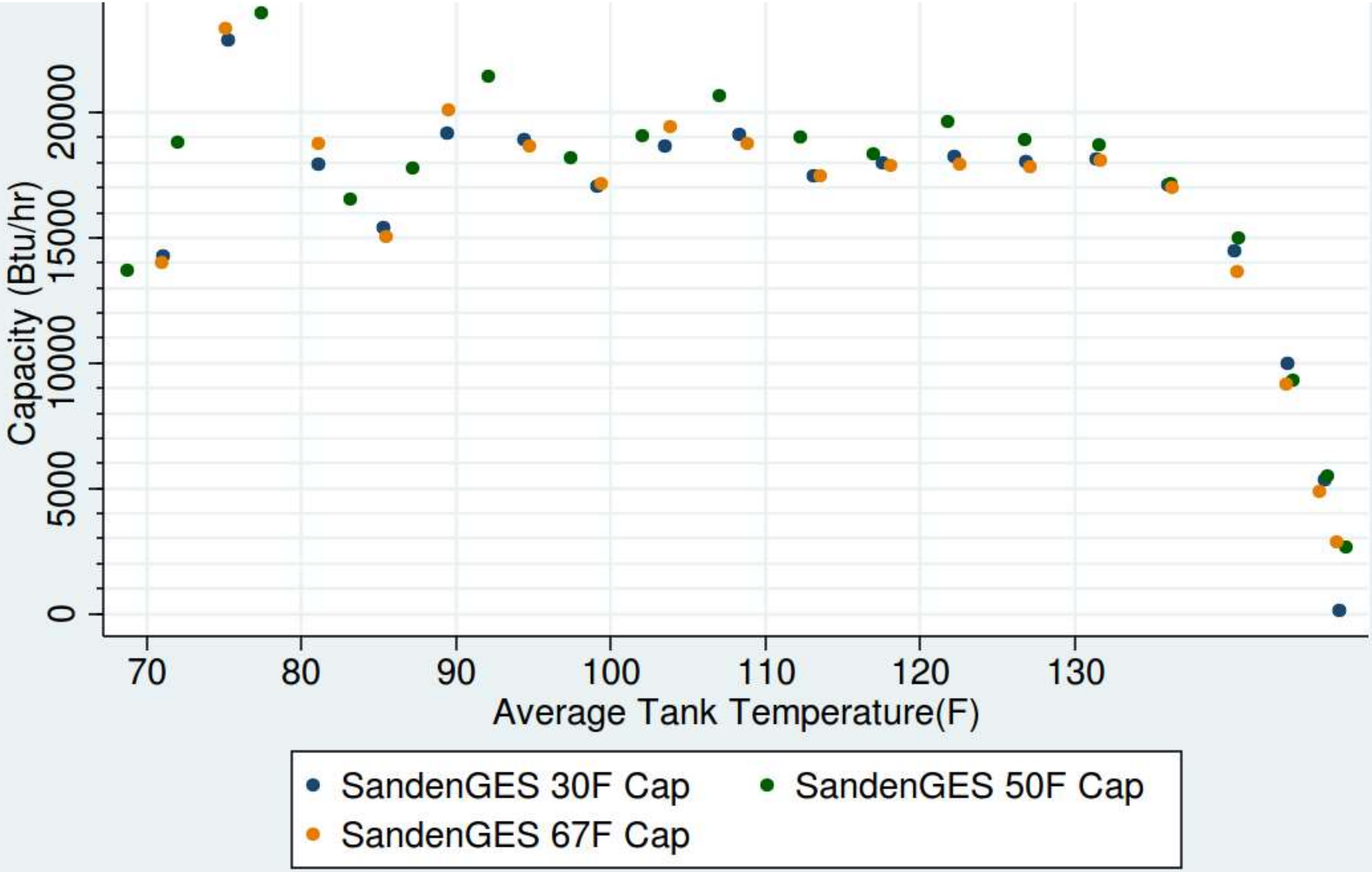
HPWH Performance

kWh per 100 gallons water delivered

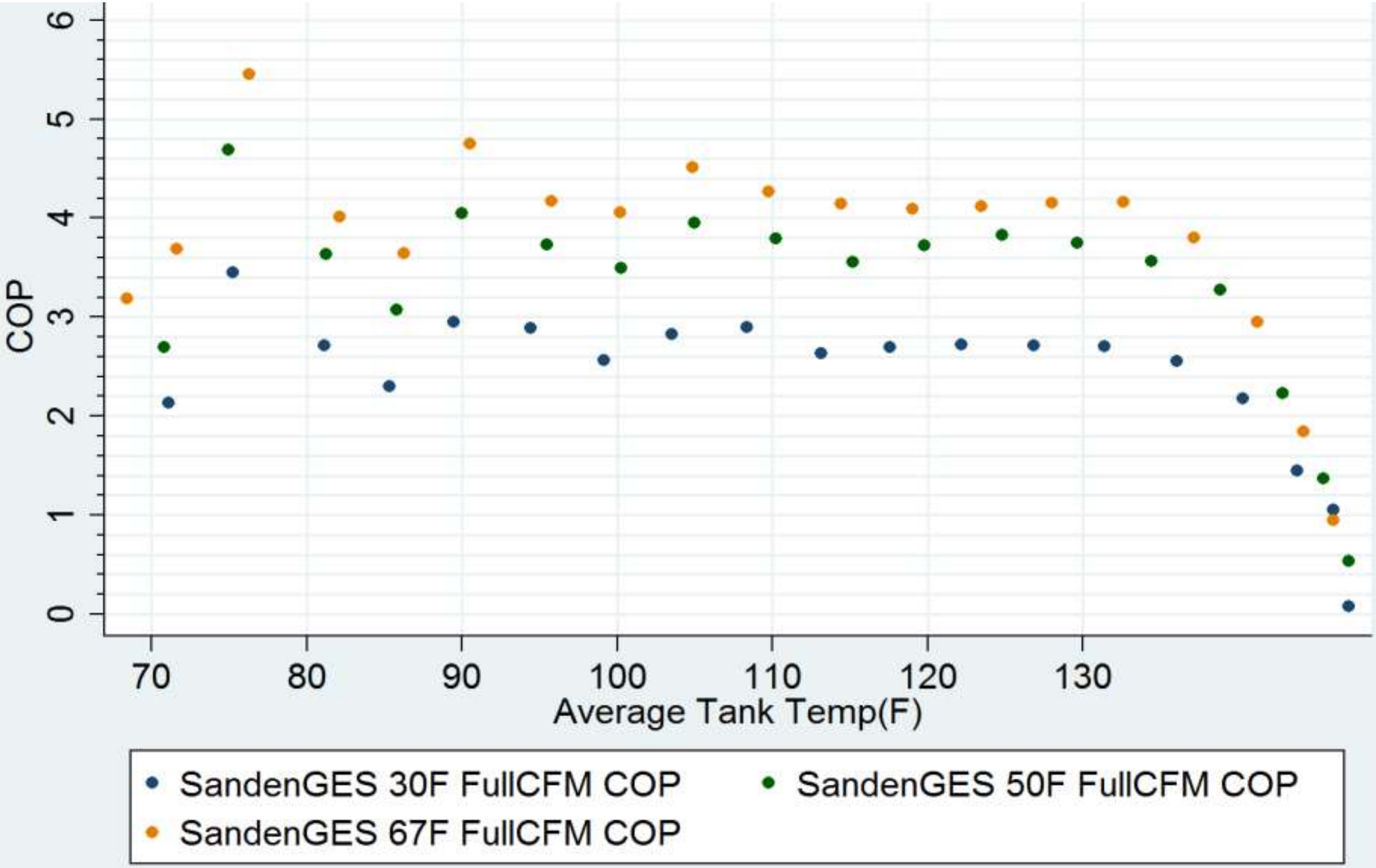
Note: Performance for CO_2 sites is for cold weather months only; other sites are annual.



Output


Capacity (Btu/hr)
0
5000
10000
15000
20000
70
80
90
100
110
120
130
Average Tank Temperature(F)
SandenGES 30F Cap
SandenGES 50F Cap
SandenGES 67F Cap

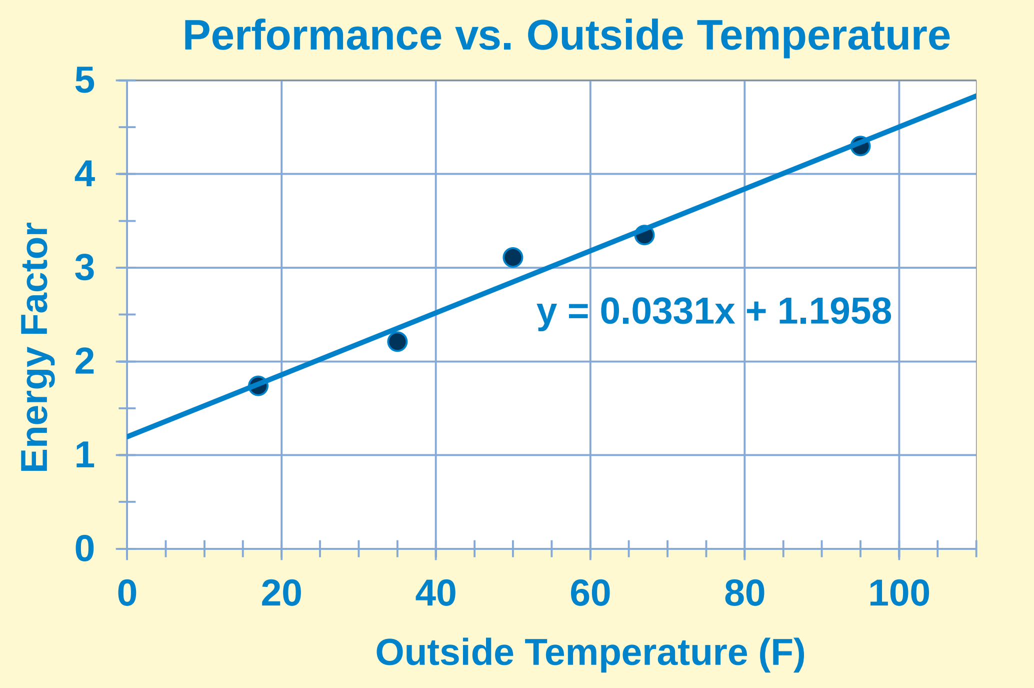
Efficiency



0
1
2
3
4
5
6
COP
70
80
90
100
110
120
130
Average Tank Temp(F)
SandenGES 30F FullCFM COP
SandenGES 50F FullCFM COP
SandenGES 67F FullCFM COP

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

1.25-ton SanCO$_2$

- UL-listed
- Two tank sizes (40-, 80-gal)
- Became available July 2016

$*

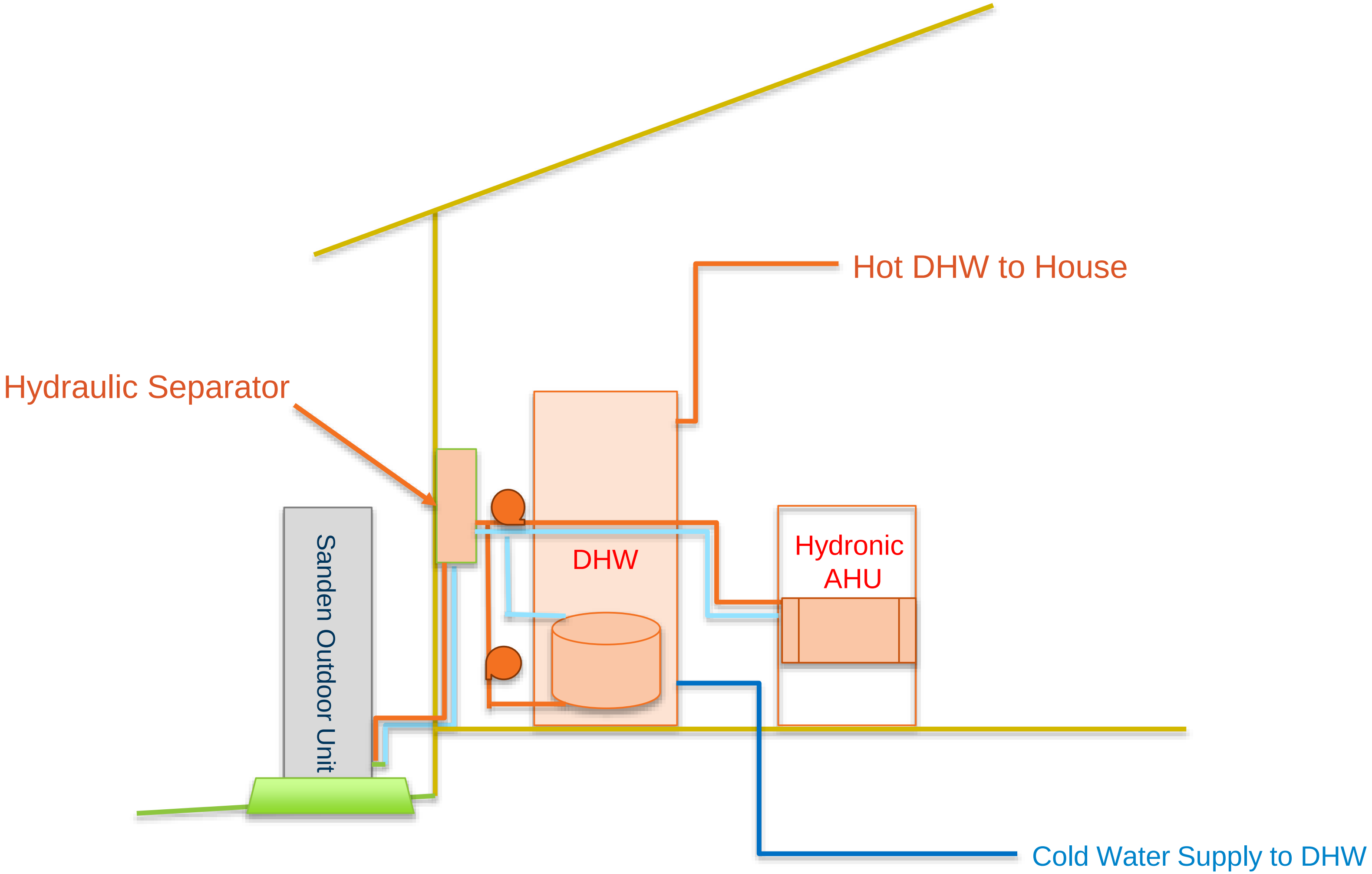
- Can be used in a combined space & water heating system, but heating loads must be small

* Now eligible for utility incentives in the PNW!

3-ton Eco Runo

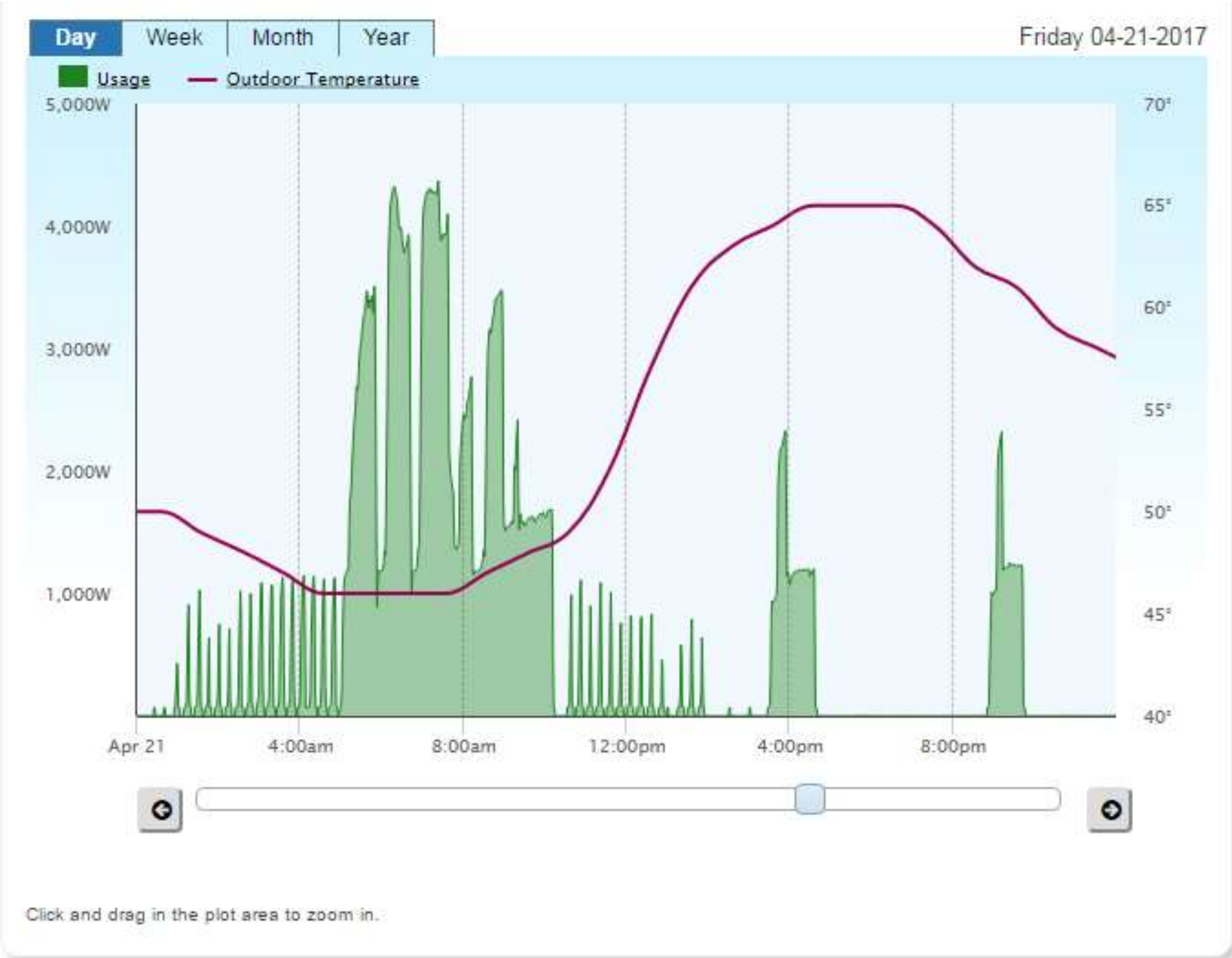
- Completed lab-testing phase
- Configured for space heating
- Can do sidearm water heating

Combined System Configuration



Field Performance – 1.25-ton

Field Performance – 3-ton



Controls

Next Steps

- Install 6 forced air combined systems & monitor for 15 months
- Complete new test & rating procedures
- Acquire 4-ton systems for combined heating, cooling & DHW
  - Low-pressure stage likely to use R-290 (chilled water and first stage hot water)
- Develop a program for replacing electric forced air and electric resistance water heating in existing homes

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Thank you!

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TOGETHER *We Are Transforming the Northwest*