DO AS We Say (and As We Do):
Energy 350 Office HVAC System Conversion

June 28th, 2022

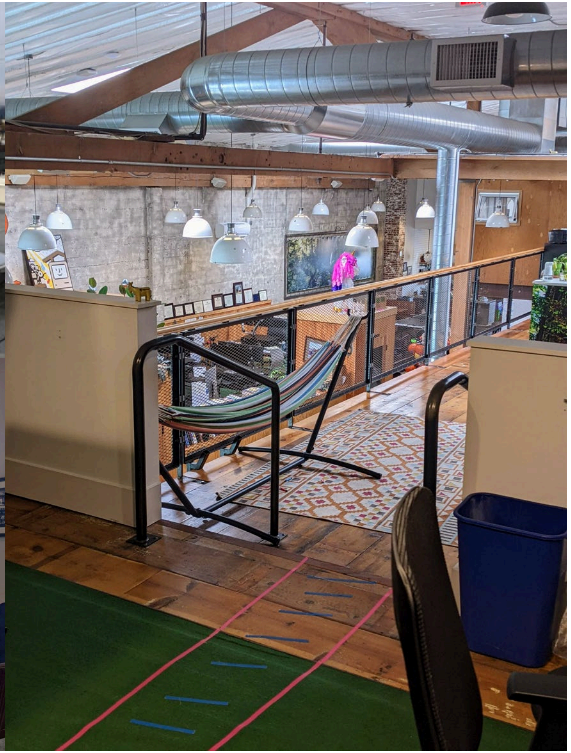
Discussion Topics

ENERGY350

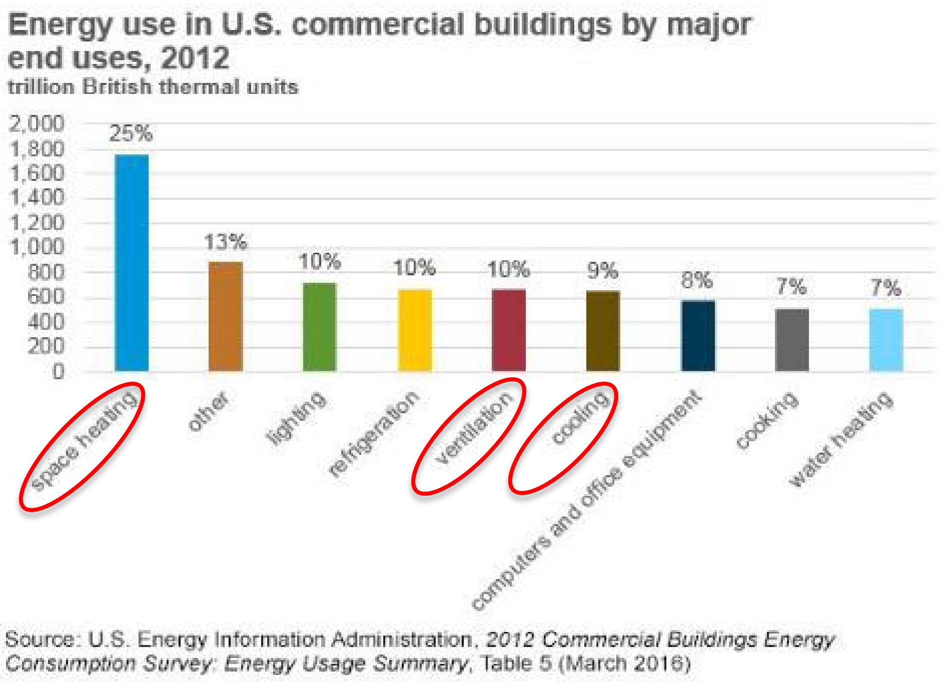
- **WHY** Energy 350 upgraded our HVAC?
- **WHAT** is a very high efficiency DOAS?
- **RESULTS** from our HVAC conversion
  - Energy, comfort, IAQ
  - Design decisions, system optimizations
  - Lessons learned

Why E350 upgraded our HVAC

1. Increase thermal comfort
2. Improve indoor air quality
3. Decrease our carbon footprint
4. Improve energy efficiency (lower energy costs)
5. Have a cool shiny new system to show off to clients
   a) Industry events
   b) NEEA anytime
   c) Hands on testing



WHY HVAC? …It's Expensive & Energy Intensive



....But energy in the Northwest is cheap!

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Compared to our Utility Bills, Energy 350 spends:

- 34x on rent
- 800x on our annual operating expenses

Expenditure	$/month	$/year	% of total	x HVAC
HVAC Energy Pre-Conversion	$699	$8,384	0.12%	1
HVAC Energy Post-Conversion	$498	$5,979	0.08%	0.7
Rent	$24,000	$288,000	4%	34
Total Operating Expenses	$600,000	$7,200,000	100%	859

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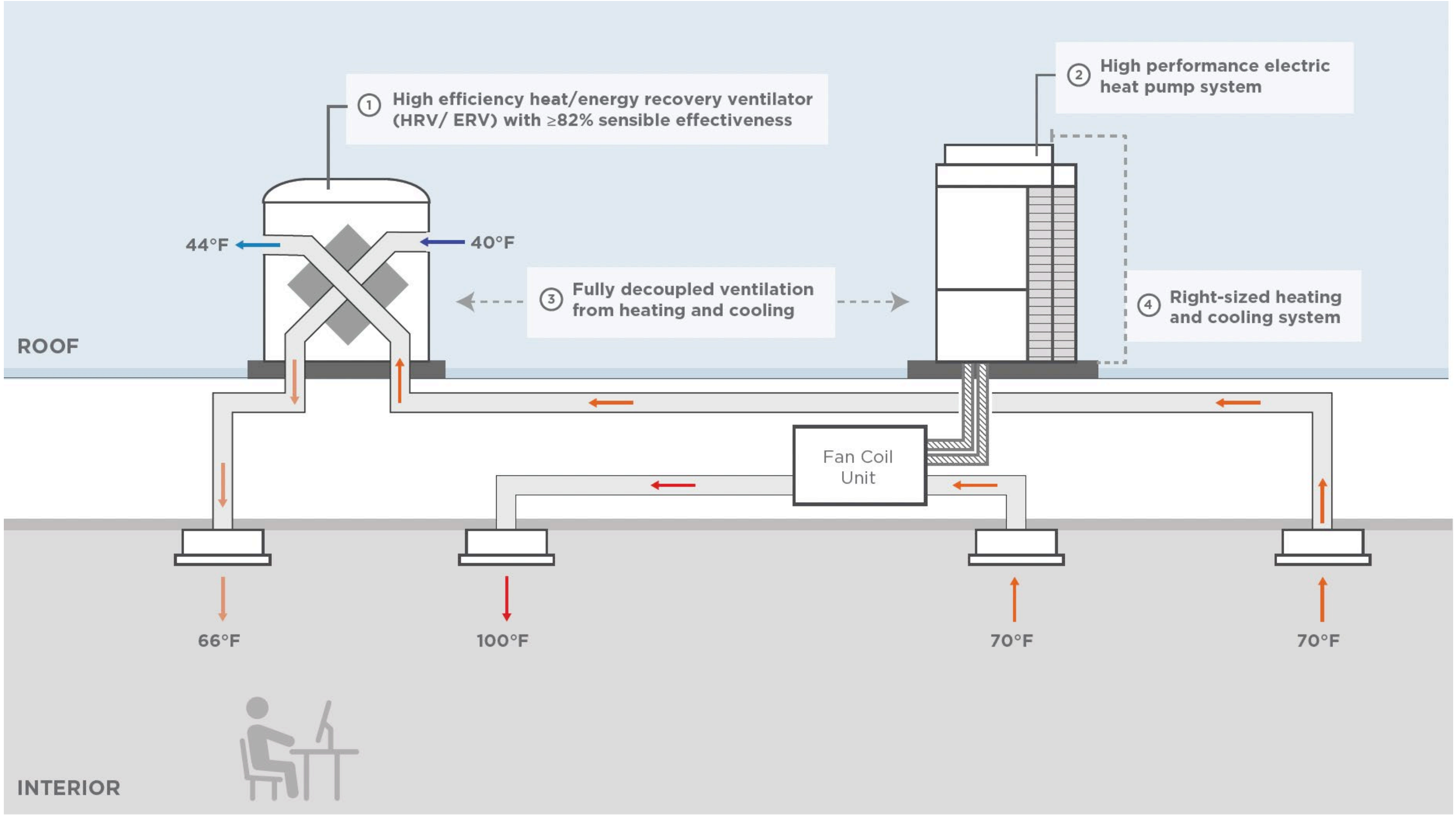
What is very high efficiency DOAS?

Very high efficiency dedicated outdoor air system



Energy 350 VHE DOAS Conversion

System conversion

1. Added VRF with (7) indoor units

2. Removed (2) RTUs

3. Added (2) HRVs

Comfort conditioning system (VRF)

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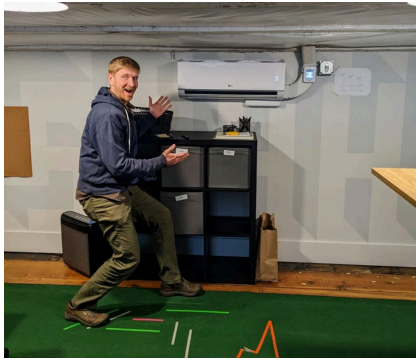
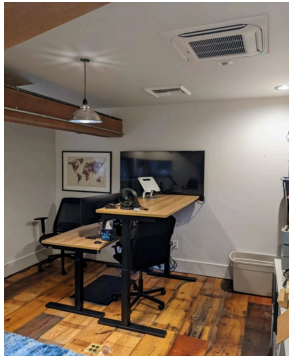
Nerd nest



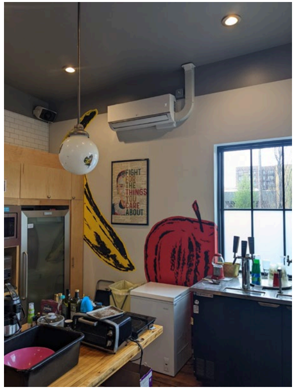
Closed office

Meeting room

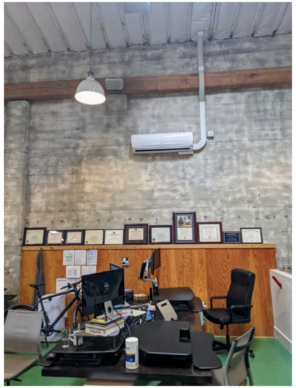


Mezzanine

Kitchen

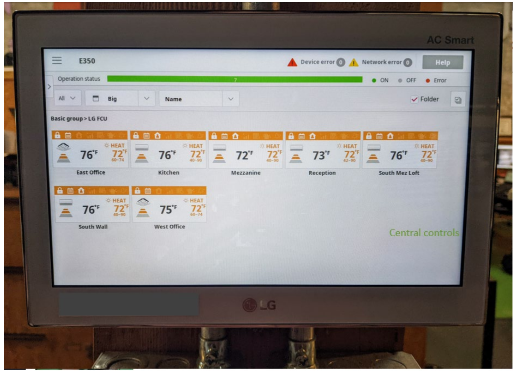


West wall/reception



West wall/south windows

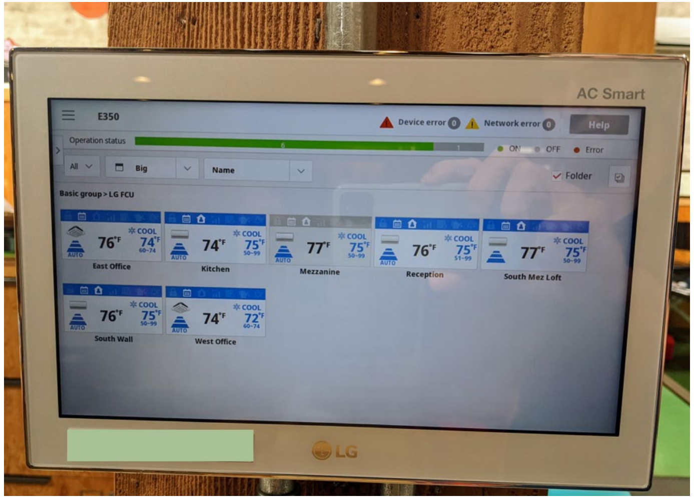
Central controls



Heating/cooling controls (VRF)

Upstairs thermostats

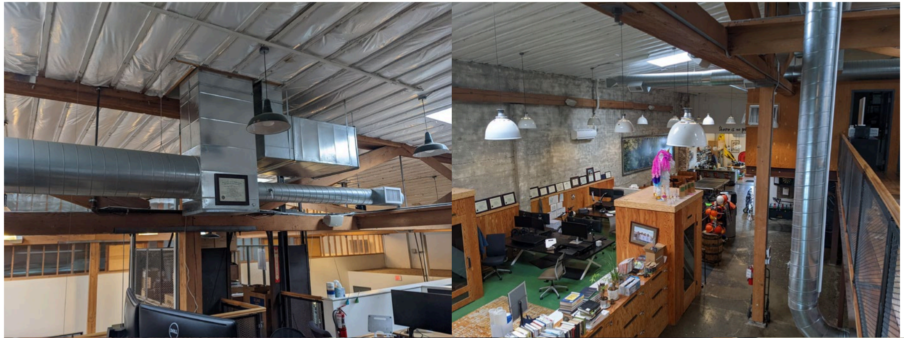
Central VRF controls



Ventilation system (HRVs)

Heat recovery ventilators

Repurposed ductwork for ventilation air



Dedicated control system

Equipment schedule

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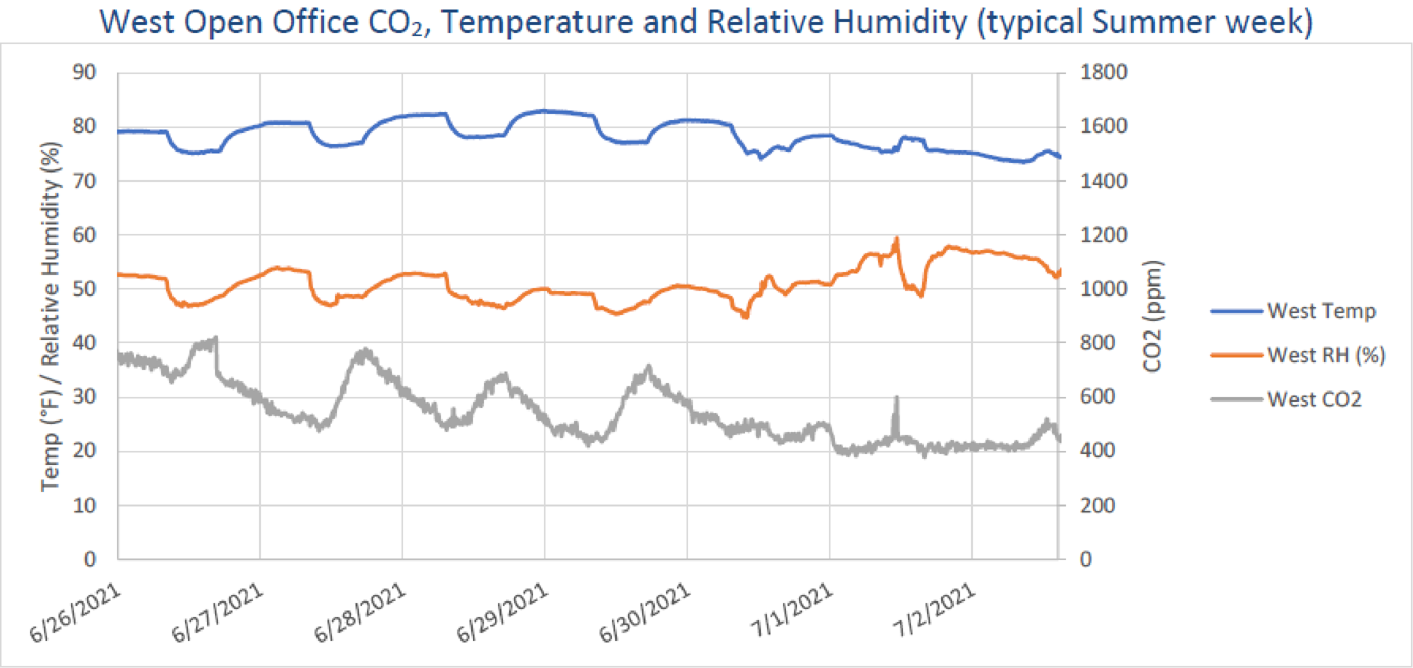
	Quantity / Make / Model	Cooling Capacity	Heating Capacity	Zones
Pre-Conversion System				
Packaged Single-Zone Rooftop Units (Gas Heat)	(2) Carrier 48TCED09	17 tons	25 tons (296 MBH)	2
Post-Conversion System				
VRF Heat Pump	(1) LG ARUM121BTE5	10 tons	11 tons (135 MBH)	7
Heat Recovery Ventilators	(2) Ventacity VS1000RTh	1,500 cfm (design) / 2,100 cfm (max)		2

41% reduction in cooling capacity!

Results

Thermal comfort and IAQ



Peak load analysis ("right-sizing")

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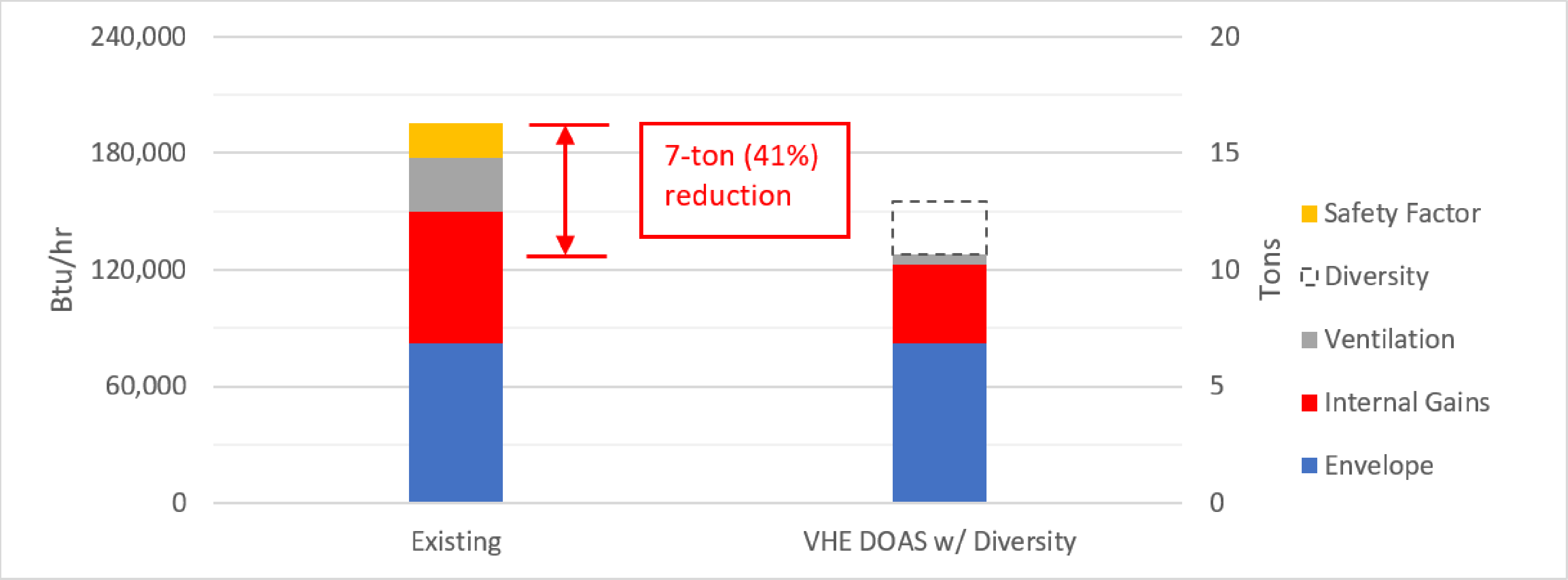
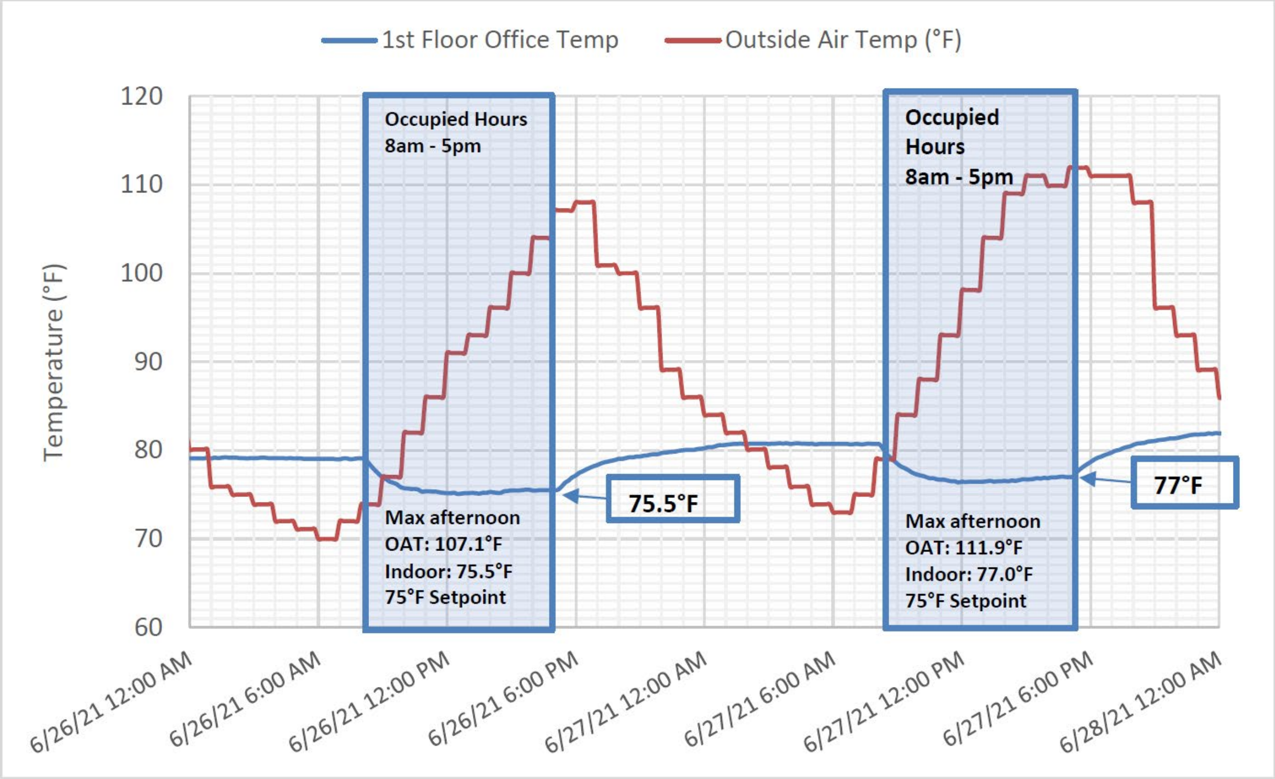
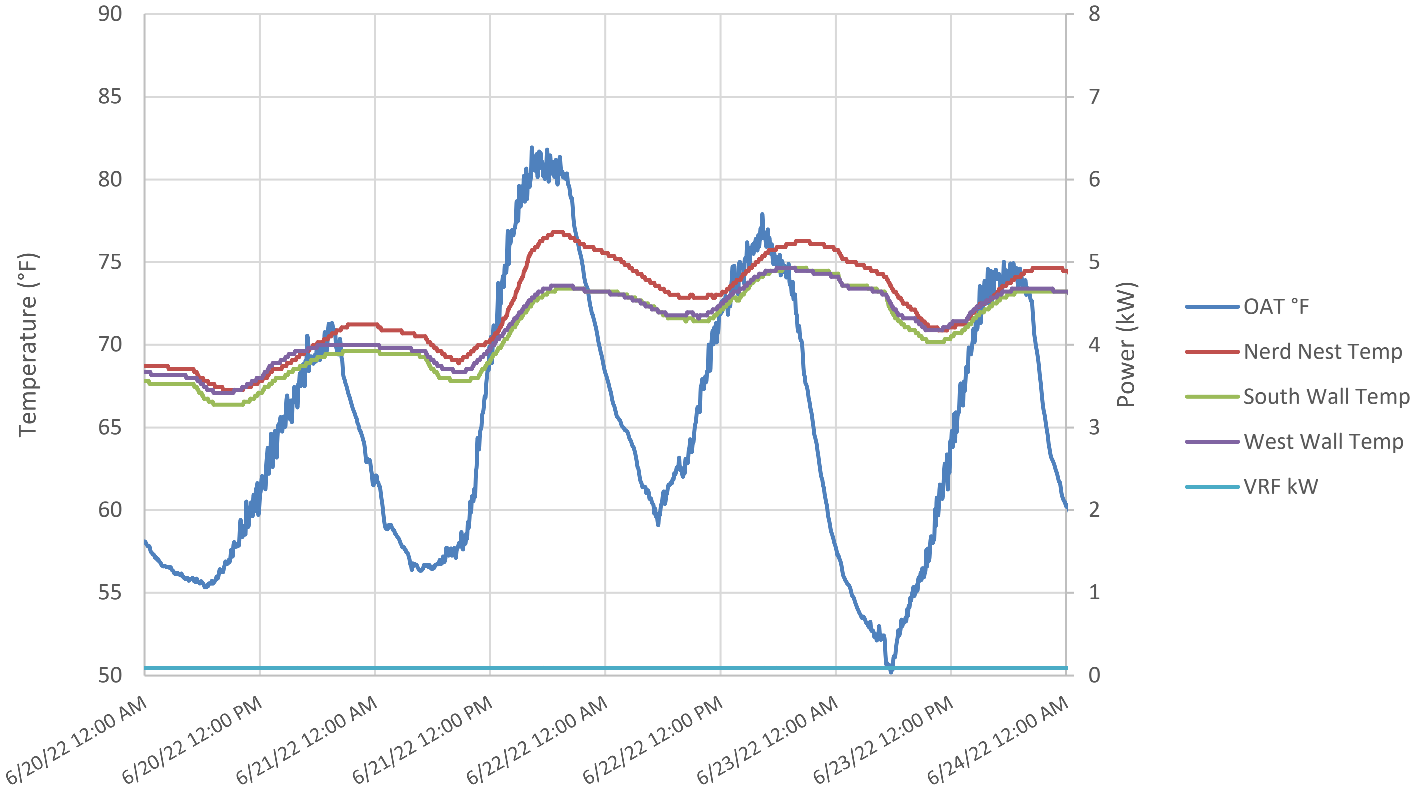


Heat dome event



More recent (typical) warm weather



Cooling in Portland

ENERGY350

2017 ASHRAE Handbook - Foundamentals (IP)

PORTLAND INTL, OR, USA (WMO: 726980)

Lat:**45.596N** Long:**122.609W** Elev:**19** StdP: **14.69** Time zone:**-8.00** Period:**90-14** WBAN:**24229**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
12	**25.0**	**29.0**	**9.8**	**9.1**	**30.7**	**16.2**	**12.5**	**34.1**	**30.5**	**37.2**	**27.3**	**39.1**	**10.0**	**120**

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
8	**21.4**	**91.2**	**67.5**	**87.1**	**66.4**	**83.4**	**65.2**	**69.5**	**86.8**	**68.0**	**84.2**	**66.2**	**80.9**	**10.3**	**310**

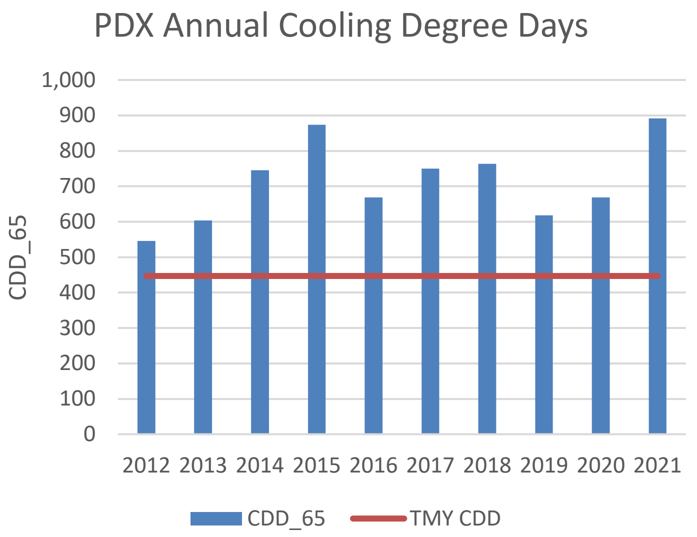
Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
63.2	**86.8**	**75.2**	**61.8**	**82.4**	**73.3**	**60.4**	**78.4**	**71.6**	**33.5**	**87.6**	**32.1**	**84.1**	**30.8**	**80.9**	**77.2**

Extreme Annual Design Conditions

Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
23.7	**19.7**	**17.4**	DB	**20.8**	**99.0**	**5.2**	**3.3**	**17.1**	**101.4**	**14.0**	**103.3**	**11.0**	**105.1**	**7.2**	**107.5**
			WB	**19.1**	**72.8**	**5.2**	**1.8**	**15.3**	**74.1**	**12.3**	**75.2**	**9.3**	**76.2**	**5.5**	**77.6**

Monthly Climatic Design Conditions

		Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	DBAvg	**54.6**	**41.5**	**43.8**	**47.9**	**52.3**	**58.4**	**63.2**	**69.5**	**69.9**	**65.3**	**55.3**	**46.7**	**40.9**
	DBStd	**11.57**	**5.68**	**5.34**	**4.75**	**5.28**	**6.05**	**5.46**	**5.36**	**4.79**	**5.22**	**5.16**	**5.73**	**6.24**
	HDD50	**1005**	**267**	**179**	**98**	**32**	**3**	**0**	**0**	**0**	**0**	**13**	**127**	**286**
	HDD65	**4232**	**728**	**594**	**529**	**383**	**221**	**96**	**15**	**9**	**59**	**304**	**548**	**746**
	CDD50	**2695**	**4**	**6**	**34**	**101**	**264**	**397**	**605**	**616**	**459**	**176**	**29**	**4**
	CDD65	**447**	**0**	**0**	**0**	**1**	**17**	**43**	**155**	**160**	**69**	**2**	**0**	**0**
	CDH74	**4349**	**0**	**0**	**1**	**33**	**254**	**477**	**1485**	**1373**	**694**	**32**	**0**	**0**
	CDH80	**1622**	**0**	**0**	**0**	**4**	**75**	**168**	**605**	**530**	**237**	**3**	**0**	**0**

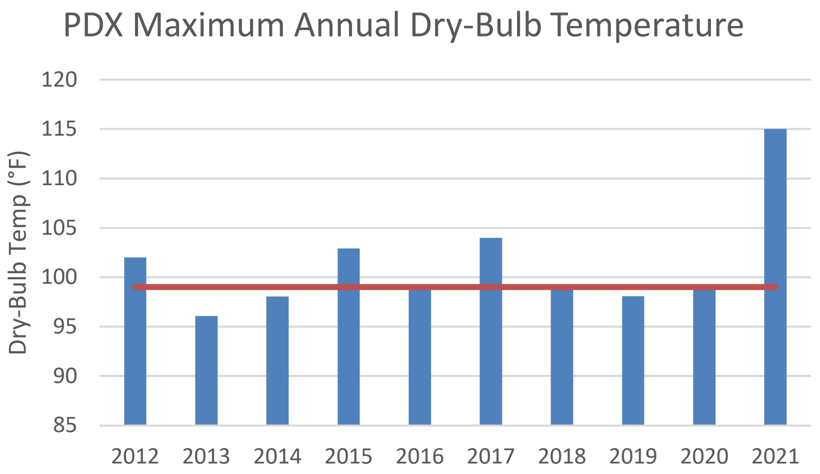


Cooling in Portland

	Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
	Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
DB	**20.8**	**99.0**	**5.2**	**3.3**	**17.1**	**101.4**	**14.0**	**103.3**	**11.0**	**105.1**	**7.2**	**107.5**
WB	**19.1**	**72.8**	**5.2**	**1.8**	**15.3**	**74.1**	**12.3**	**75.2**	**9.3**	**76.2**	**5.5**	**77.6**

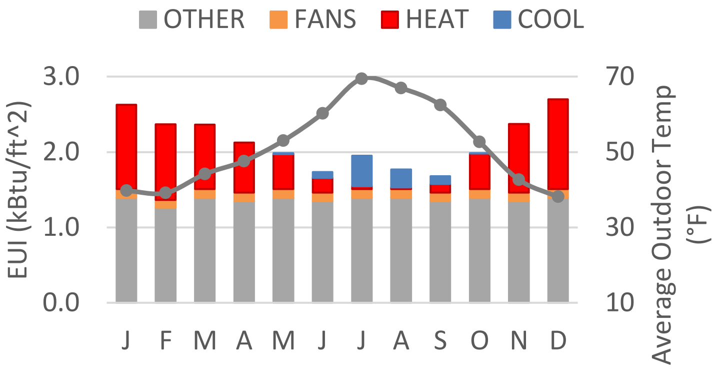
Annual Cooling, Dehumidification, and Enthalpy Design Conditions

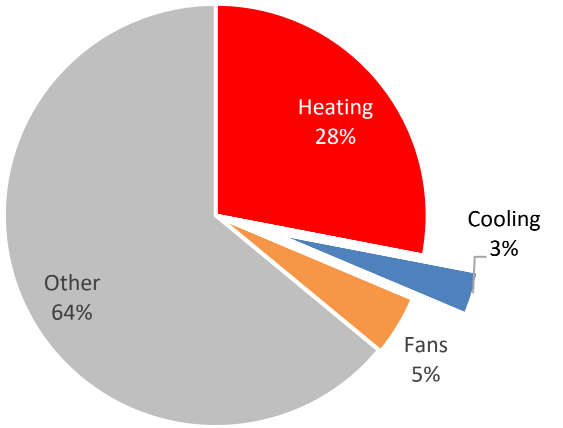
Hottest Month	Hottest Month DB Range	Cooling DB/MCWB			
		0.4%		1%	
		DB	MCWB	DB	MCWB
8	**21.4**	**91.2**	**67.5**	**87.1**	**66.4**



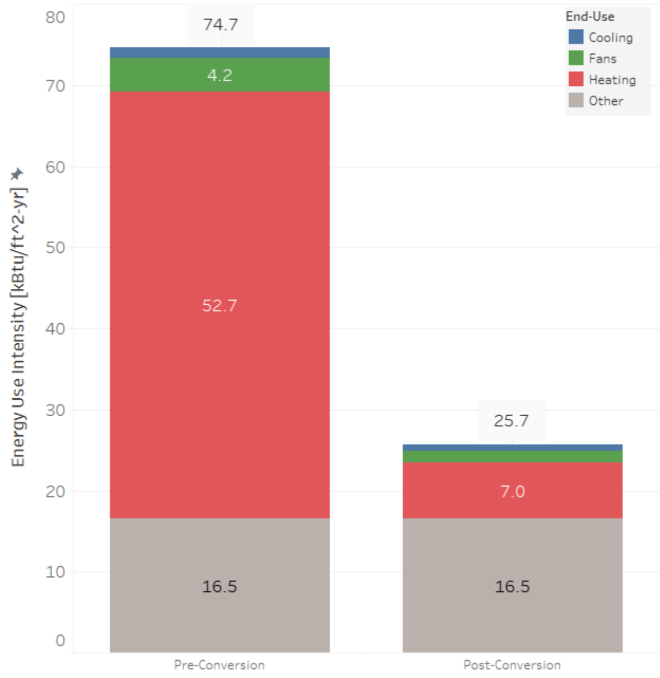
Cooling at Energy 350

- **Cooling in NW commercial buildings is becoming more important but…**
- **Cooling is still only 1,850 kWh/yr**
  – 9% of HVAC
  – 3% of building
- **VHE DOAS is more resilient in Extreme weather events**
  – High efficiency heat recovery nearly eliminates ventilation load
  – Zonal heating and cooling
  – Modern heat pump technology performs well in a range of conditions





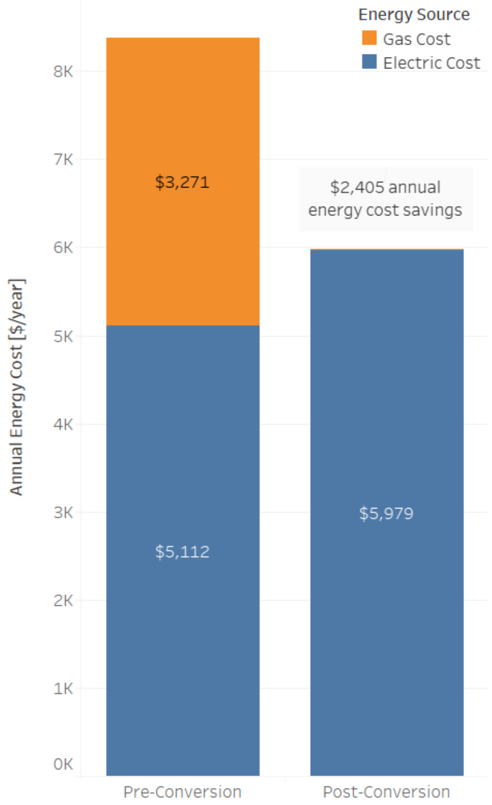
Energy results



Building Savi..	HVAC Savings	Fan Savings	Heat Savings	Cool Savings
66%	84%	67%	87%	38%

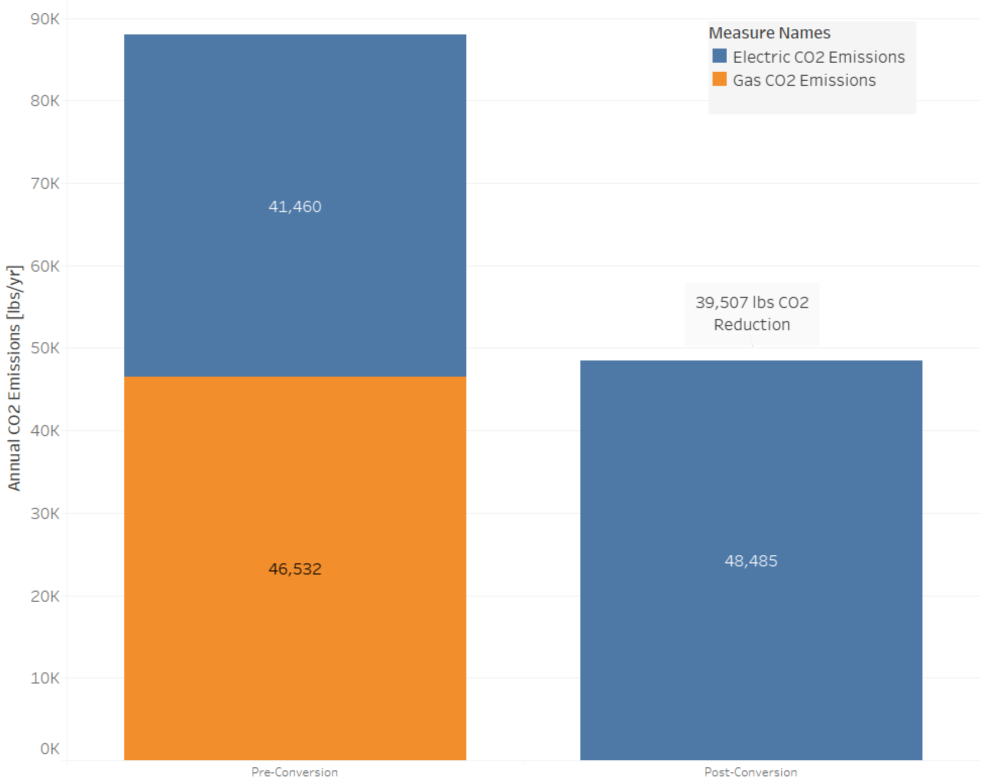
EUI (site)

- 84% HVAC reduction
- 66% Building reduction

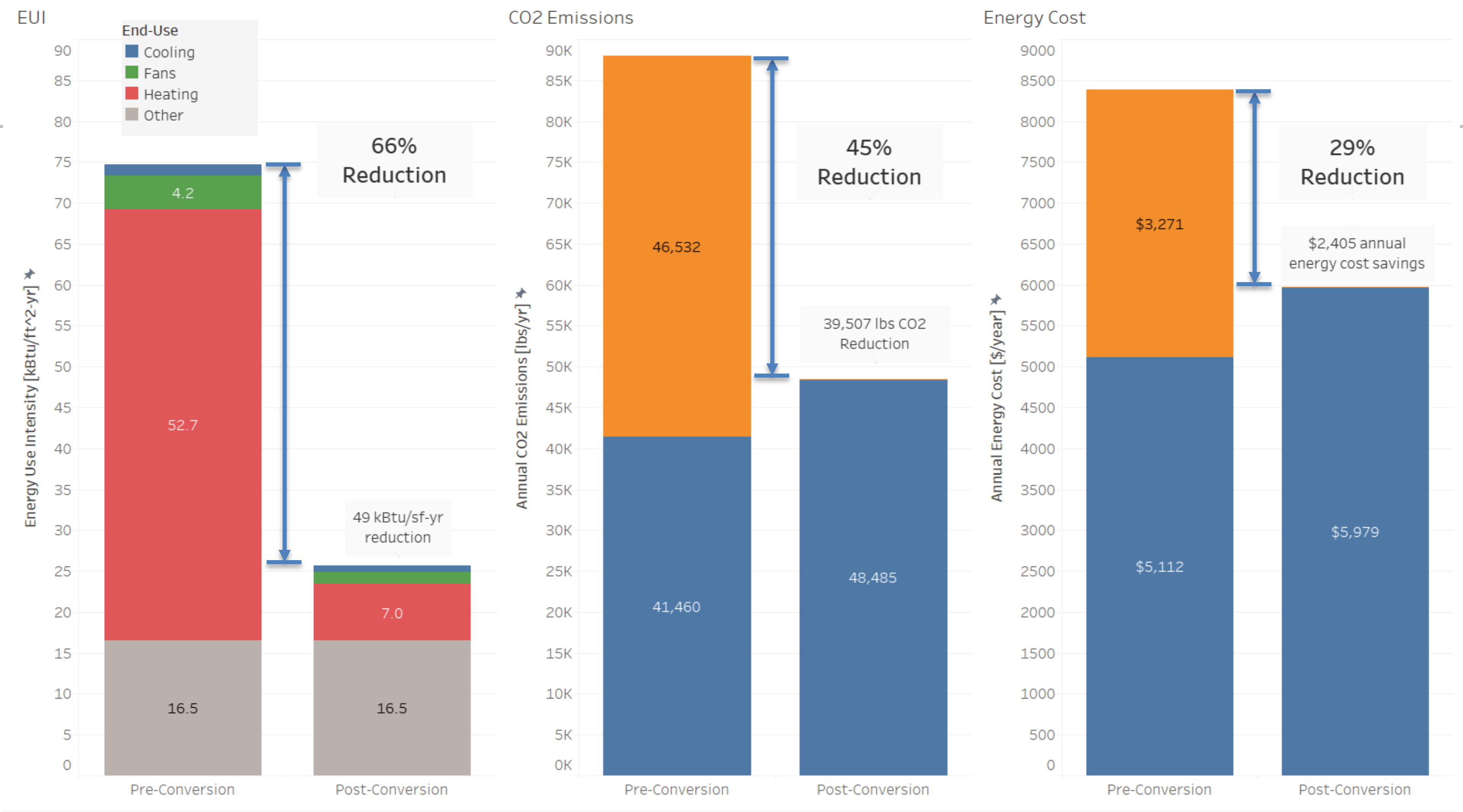


Carbon emissions

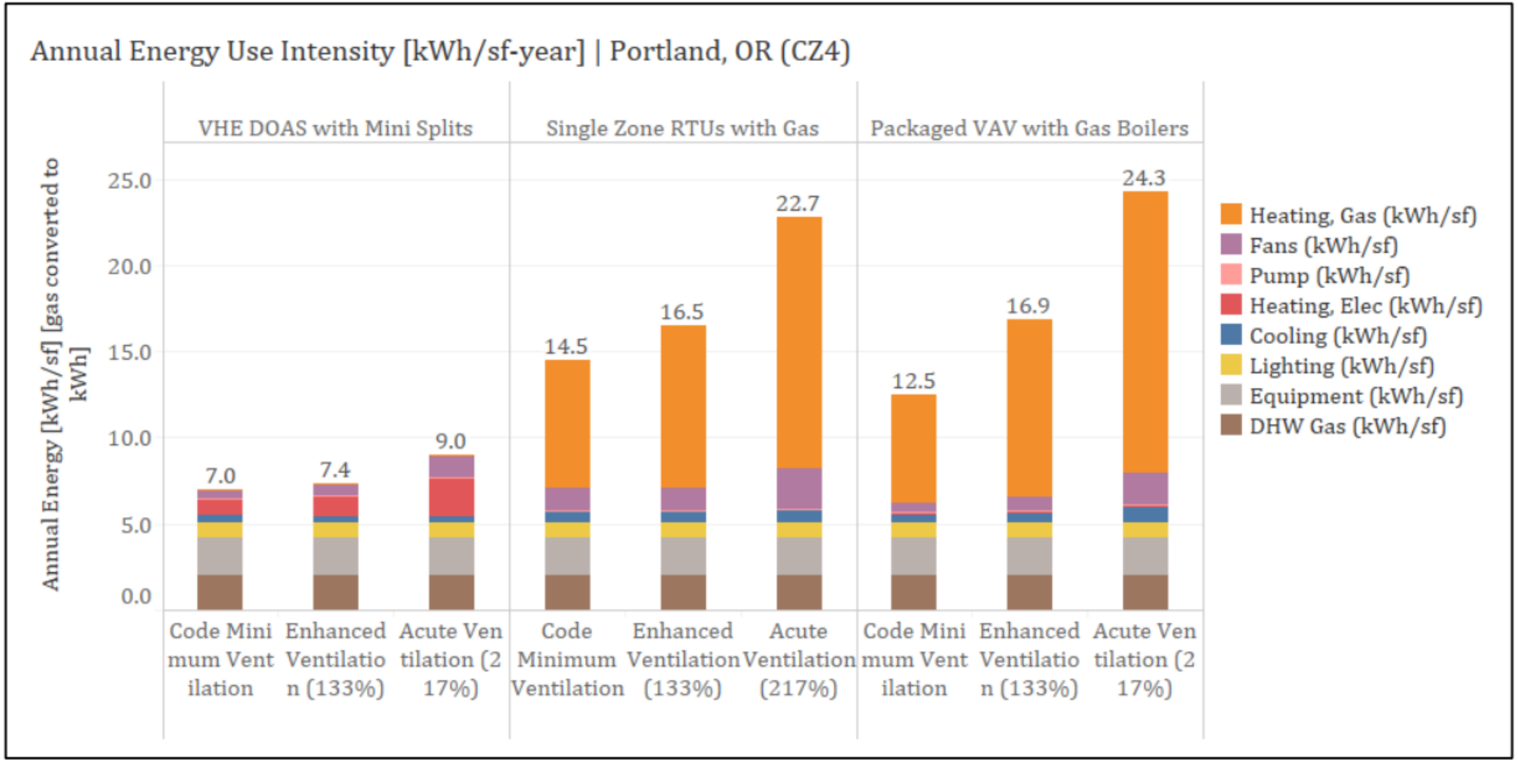
Annual CO_2–eq emission reduction of 39,703 lbs (19.9-tons)



Note: CO2-eq emissions assume an incremental rate of 851.53 lbs CO2-eq/MWh for electricity and 116.65 lbs CO2-eq/MMBtu of natural gas.

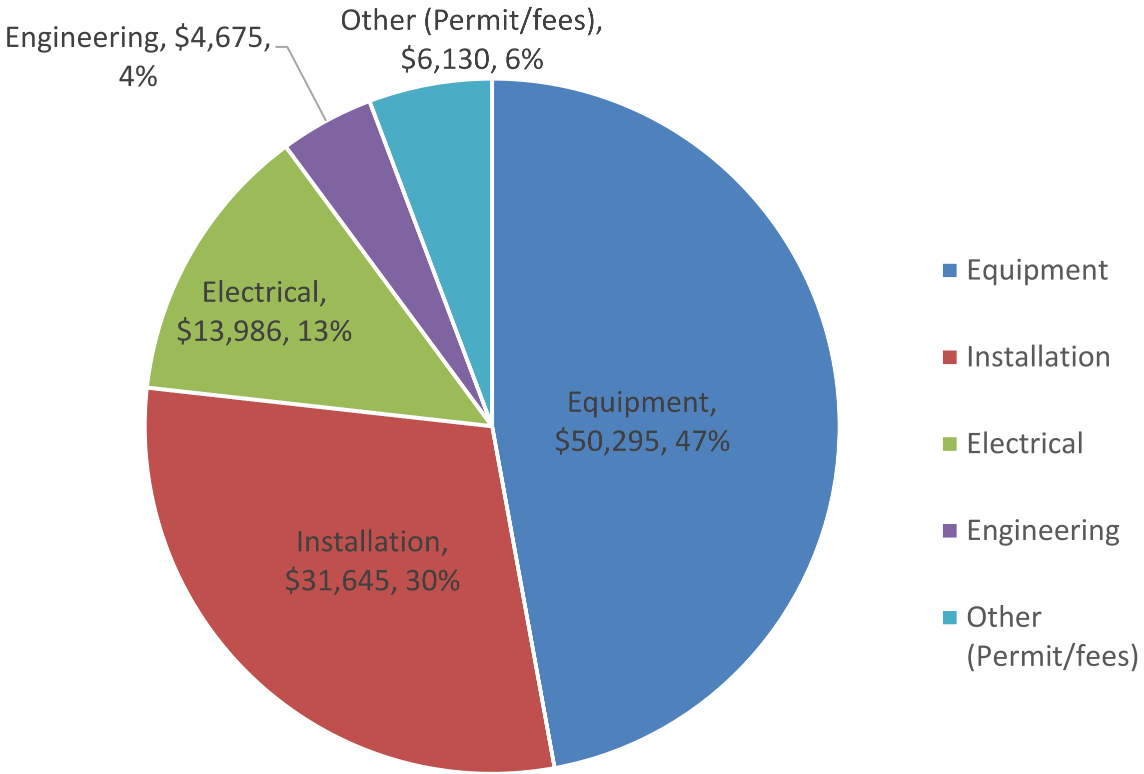

EUI
End-Use
Cooling
Fans
Heating
Other
Energy Use Intensity [kBtu/ft^2-yr]
66% Reduction
49 kBtu/sf-yr reduction
4.2
52.7
16.5
7.0
16.5
Pre-Conversion
Post-Conversion
CO2 Emissions
Annual CO2 Emissions [lbs/yr]
45% Reduction
39,507 lbs CO2 Reduction
46,532
41,460
48,485
Pre-Conversion
Post-Conversion
Energy Cost
Annual Energy Cost [$/year]
29% Reduction
$2,405 annual energy cost savings
$3,271
$5,112
$5,979
Pre-Conversion
Post-Conversion

Enhanced Ventilation



[Source: BetterBricks | Covid-19 Risk Reduction Strategies and HVAC System Energy Impact]()

Project Costs

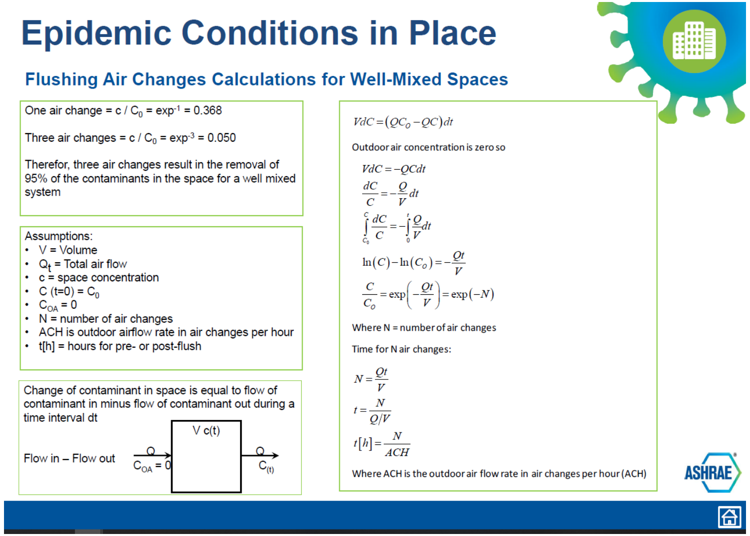


$13.94/sf

Results may vary!!!
This is not a good number to use for all VRF/DOAS projects in commercial buildings. I would use $33/sf or more if I know nothing else.

Design & Operational Challenges (Lessons Learned)

Air Flushing



- ASHRAE ETF recommends 3 Air Changes – 95% of contaminants removed
- Based off our office and HRV flow rate, we need 3.5 hours to meet 3 air changes
- Run 2 hours before and after typical office hours
- 300 watts (ea.) – 1,040 hrs/yr
- 624 kWh/yr
  - $50/yr
  - 3% of HVAC

Night Flush ("Freecooling")

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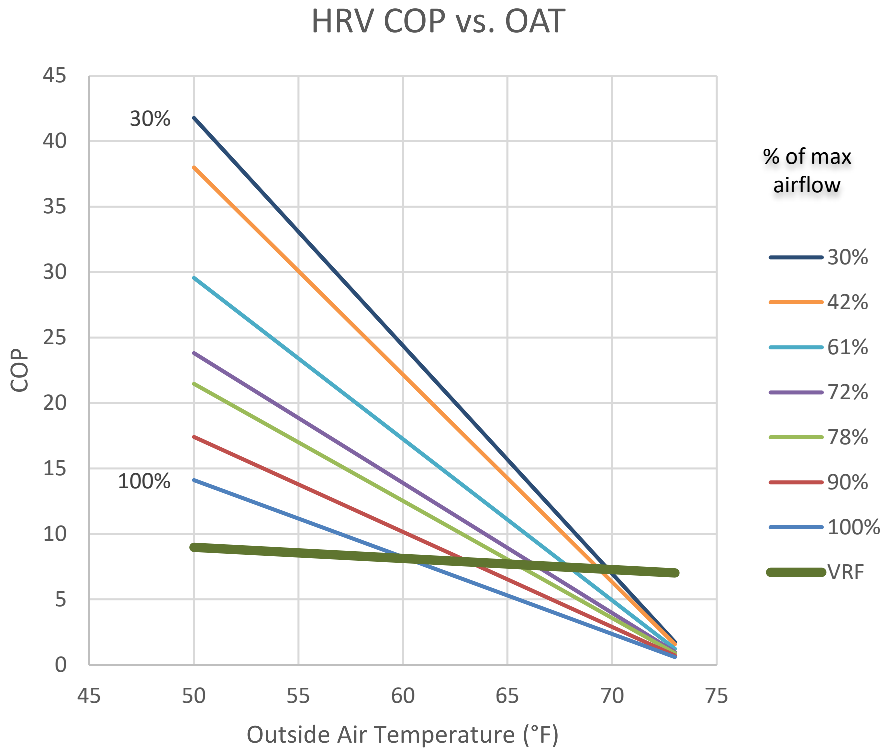

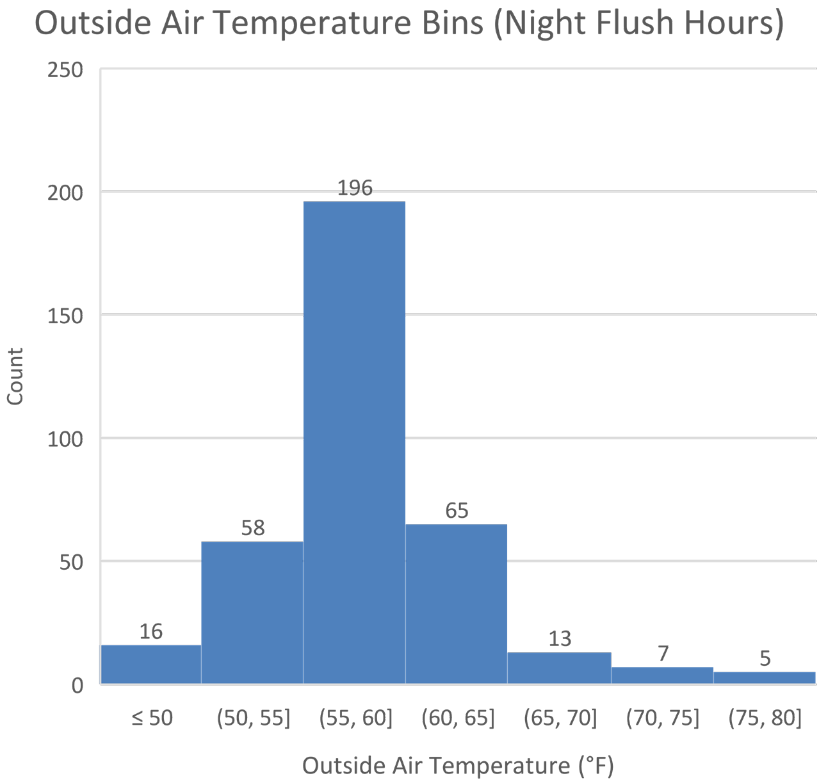

Vampire power draws

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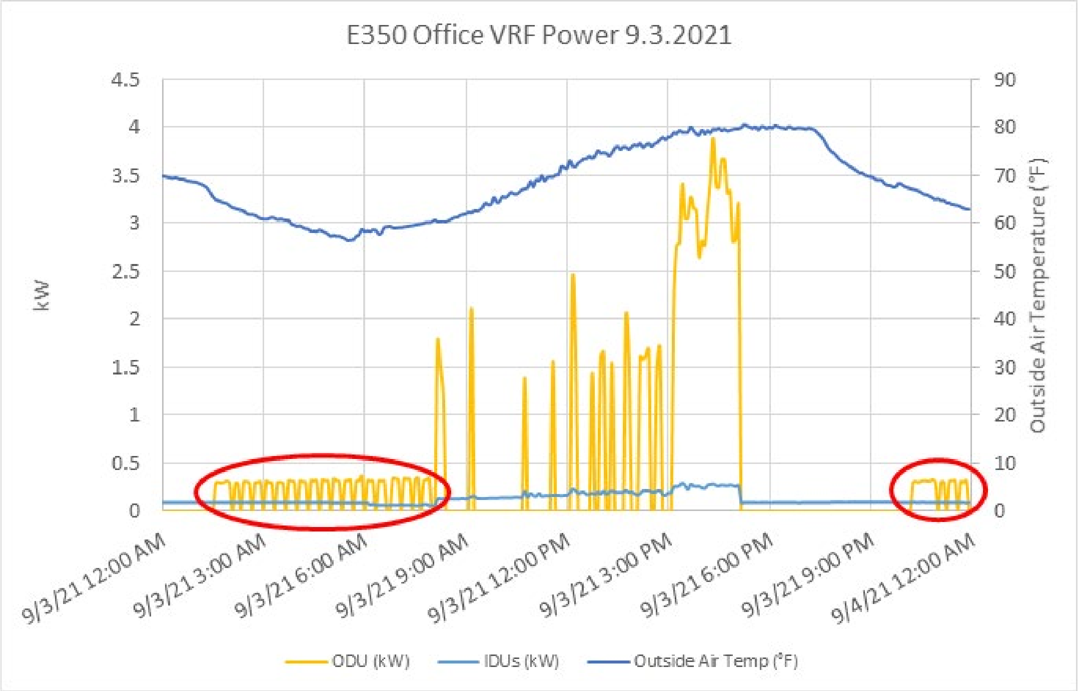

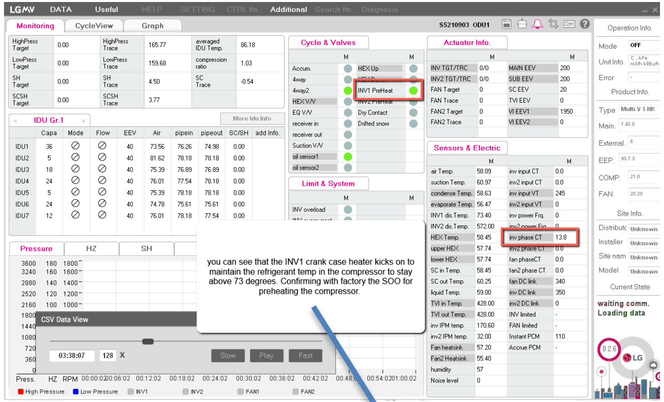

you can see that the INV1 crank case heater kicks on to maintain the refrigerant temp in the compressor to stay above 73 degrees. Confirming with factory the SOO for preheating the compressor.

Lessons Learned

1. Occupant comfort and safety > energy
2. Night flush @ 100% airflow was wasting Energy! (a little)
3. Running VRF on weekends for café
4. It’s pretty difficult to screw up a well-designed VHE DOAS

Did we accomplish our goals?

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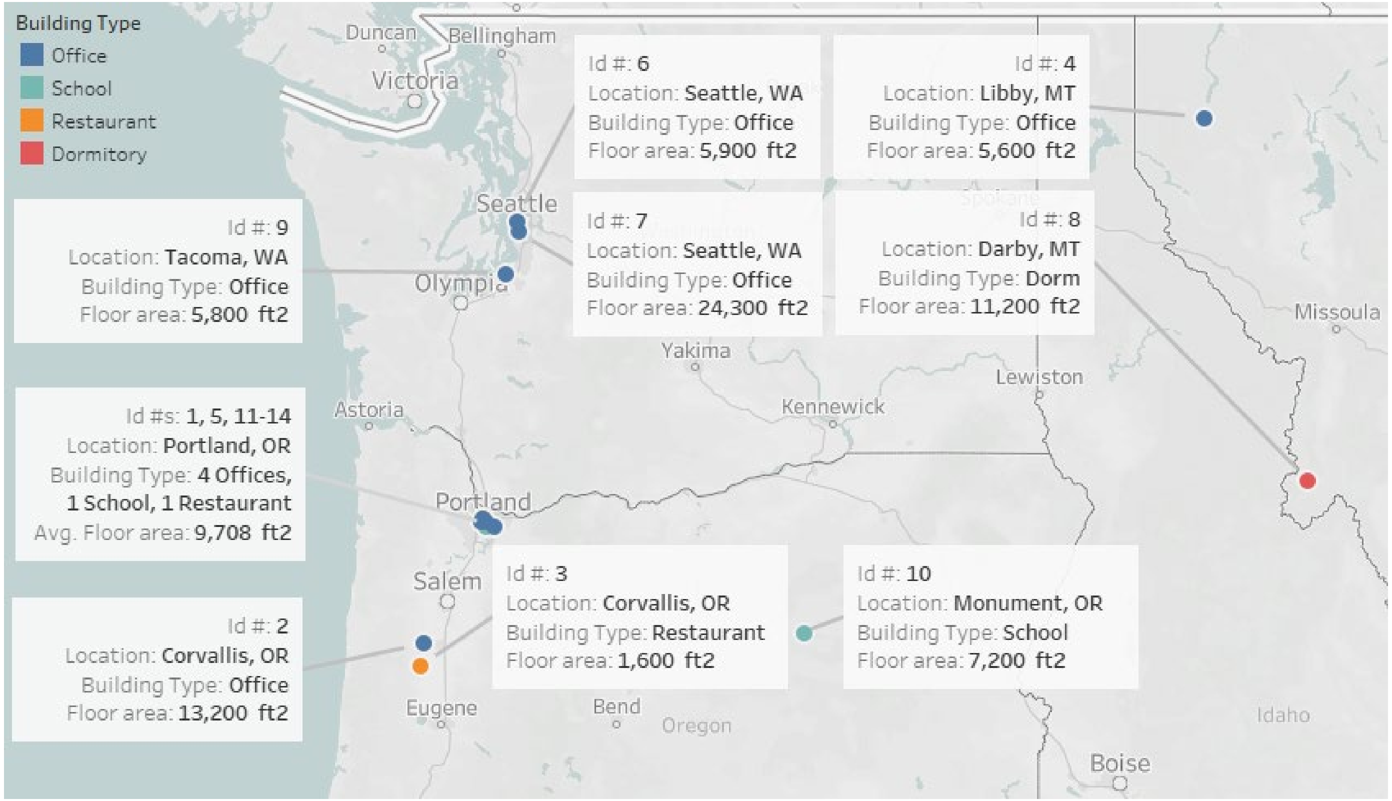
❑ Thermal comfort?	✓ Anecdotally and quantitatively
❑ IAQ?	✓ Doubled ventilation rates
❑ Carbon footprint?	✓ 20-ton emissions reduction
❑ Energy efficiency?	✓ 66% reduction in EUI (29% $$$)
❑ Showcase system?	✓ 5 events
❑ Hands on testing?	✓ Weekly

Other NEEA Demonstration Projects

Providing "technical support" since 2018



Pilot demonstration project results

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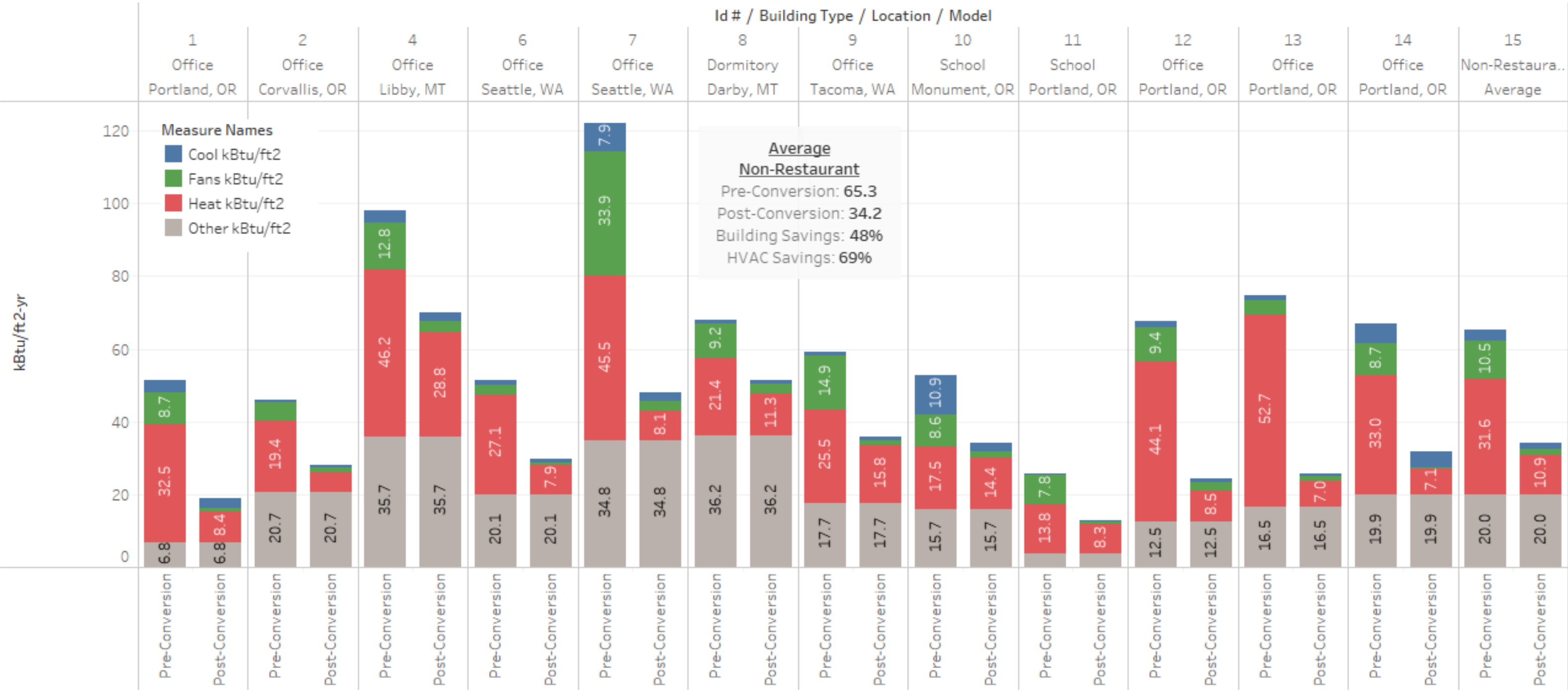

Building Savings	63%	39%	29%	42%	61%	24%	40%	35%	50%	64%	66%	53%	48%
HVAC Savings	73%	71%	45%	69%	85%	52%	57%	50%	58%	79%	84%	75%	69%

69% HVAC savings across 12 non-restaurant demonstration projects

THANK YOU NEEA!

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Questions?

Appendix

Energy STAR Score

ENERGY350

11 Main

1033 SE Main St., Portland, OR 97214 | Map It
Portfolio Manager Property ID: 4859993
Year Built: 1943
Edit

Not currently eligible for ENERGY STAR Certification

Years Certified (Score):
2016 (100), 2017 (98), 2018 (97), 2019 (94)

Change Metric

ENERGY STAR Score (1-100)

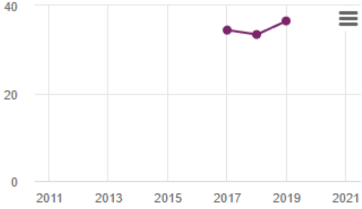
Current Score: 97

Baseline Score: N/A

Summary | Details | Energy | Water | Waste & Materials | Goals | Design

Site EUI Trend (kBtu/ft²)

Change Metric



(Chart current as of 03/31/2022 03:59 PM PDT)

Refresh Chart

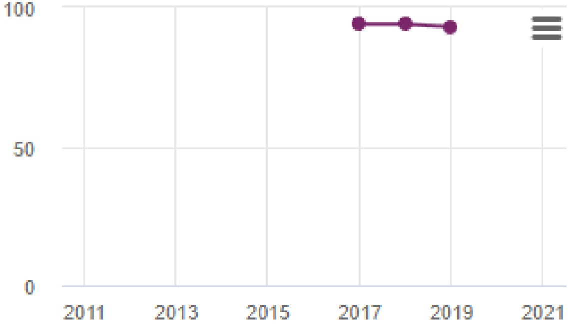
Change Metrics
Change Time Periods

Metrics Summary

Metric	Jan 2016 (Energy Baseline)	Aug 2020 (Energy Current)	Change
ENERGY STAR Score (1-100)	Not Available	97	N/A
Source EUI (kBtu/ft²)	Not Available	72.5	N/A
Site EUI (kBtu/ft²)	Not Available	31.2	N/A
Energy Cost ($)	Not Available	10,779.68	N/A
Total GHG Emissions Intensity (kgCO2e/ft²)	Not Available	2.6	N/A
Water Use (All Water Sources) (kgal)	Not Available	Not Available	N/A
Total Waste (Disposed and Diverted) (Tons)	Not Available	Not Available	N/A

ENERGY STAR Score Trend

Change Metric



(Chart current as of 03/31/2022 04:02 PM PDT)

Refresh Chart

Heating/Cooling equipment efficiency

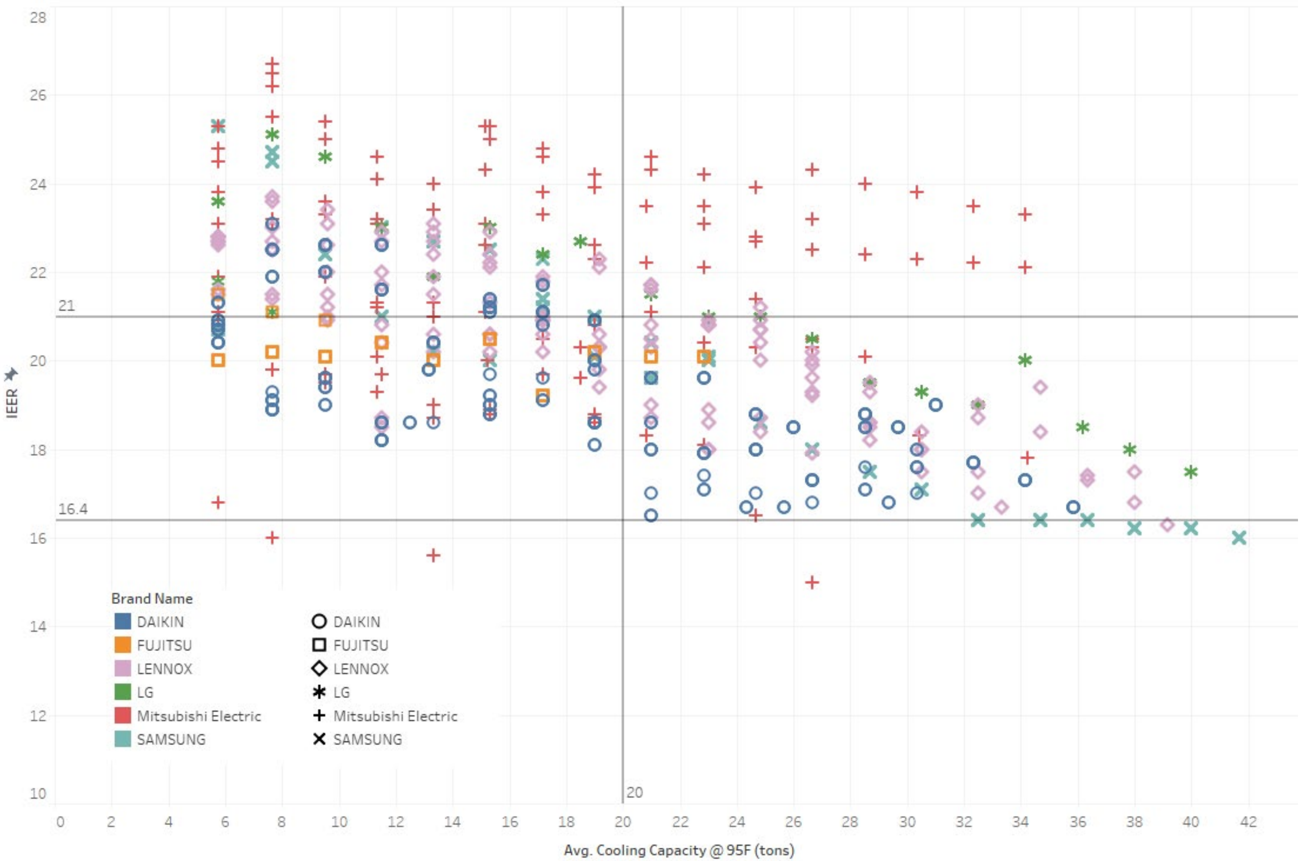
APPENDIX B:
HEATING/COOLING EQUIPMENT MINIMUM EFFICIENCY REQUIREMENTS

Where applicable, allowable space heating/cooling equipment shall meet ENERGY STAR minimum efficiency requirements. Where ENERGY STAR does not apply, the minimum efficiency requirements in Table B1, below, apply.

Table B1: Allowable Heating/Cooling Equipment and minimum efficiency requirements

Heating/Cooling Equipment	Minimum Heating Efficiency	Minimum Cooling Efficiency	Notes
Mini-split or ductless multi-zone heat pump (<65 kBtu/hr.)[15]	9.5 HSPF, or 7.8 HSPF2	16 SEER, or 15.2 SEER2	HSFP2 and SEER2 are optional until January 1, 2023[16].
Air-source VRF (≥65 kBtu/hr. and <135 kBtu/hr.)[17] without heat recovery	3.4 COP (47°F)	17.4 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥65 kBtu/hr. and <135 kBtu/hr.[17] with heat recovery	3.4 COP (47°F)	17.2 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥135 kBtu/hr. and <240 kBtu/hr.)[17] without heat recovery	3.3 COP (47°F)	16.4 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥135 kBtu/hr. and <240 kBtu/hr.)[17] with heat recovery	3.3 COP (47°F)	16.2 IEER	Applies to both ducted and non-ducted systems.
Air-source VRF (≥240 kBtu/hr.)	3.2 COP (47°F)	16.2 IEER	Applies to both ducted and non-ducted systems.
Air-to-water heat pump	1.7 COP		@ 5°F dry bulb and LWT of 110°F
Ground-source heat pump[18]	3.6 COP[19] at 32°F EWT	17.1 EER[20] at 77°F EWT	Closed loop water-to-air.
Groundwater-source heat pump[18]	4.1 COP[19] at 50°F EWT	21.1 EER[20] at 59°F EWT	Open loop water-to-air.
Heat recovery chiller		9.78 EER 15.8 IPLV	
Electric resistance heat (Low-energy spaces only)	1.0 COP	Not allowed	Allowed only when spaces demonstrate peak heating loads 30% less than allowed by PHIUS.

VRF cooling efficiency



CASE STUDY:

New Day Preschool

ENERGY350

LOCATION: Portland, OR

SQ. FT.: 2,900

COST/SQ. FT.: $22.80

EXISTING SYSTEM:

Constant volume 5-ton packaged heat pump RTU

NEW SYSTEM:

(2) 1.5-ton ductless heat pumps
(1) 2-ton ducted mini-split heat pump
(1) 1000 cfm HRV

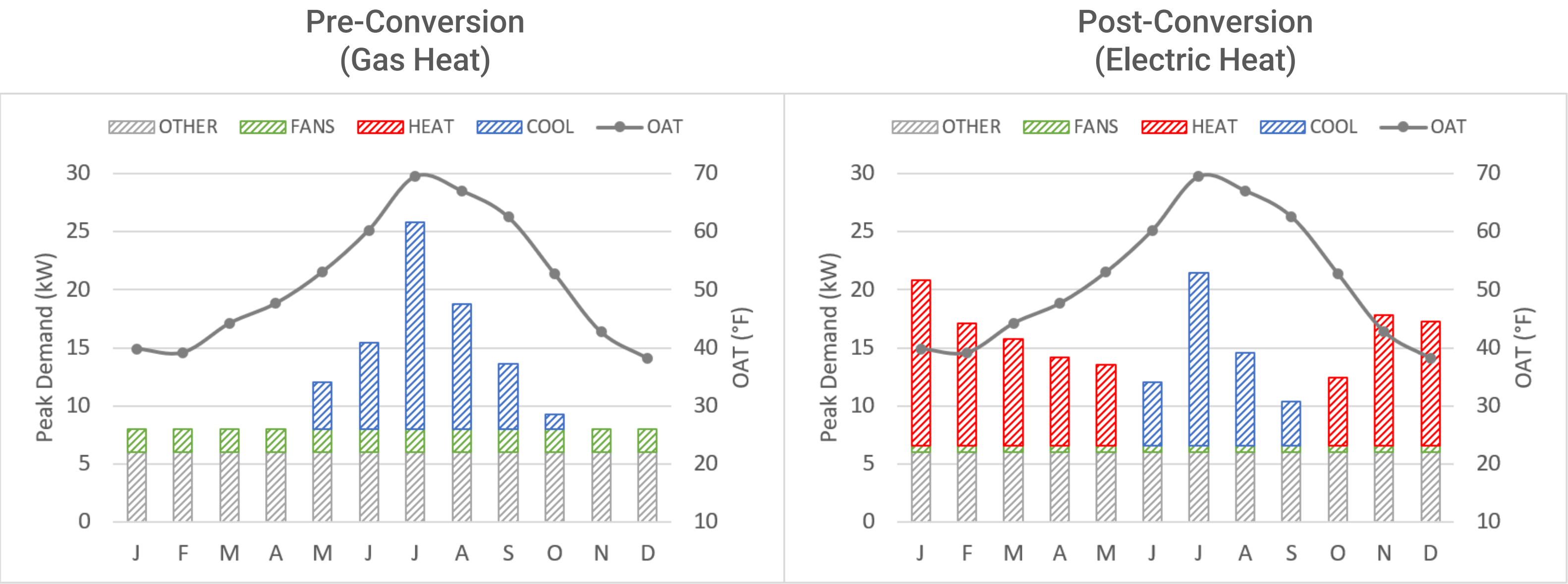
58%

reduction in total HVAC energy use

50%

reduction in total building energy use

Gas conversion peak demand impact



High-Efficiency HRV/ERVs

Greenheck	ERVe-20-15L1	ERV	82% at 75% flow (AHRI database)
Greenheck	ERV-20-15L1	ERV	
Greenheck	ERV-45-15L1	ERV	
Greenheck	ERCH-20-15L1	ERV	
Greenheck	ERCH-45-15L1	ERV	
Oxygen8	Ventum H05	HRV	82.8% at 75% flow (AHRI software)
Oxygen8	Ventum H10	HRV	82.9% at 75% flow (AHRI software)
Oxygen8	Ventum H15	HRV	83% at 75% flow (AHRI test data)
Oxygen8	Ventum H20	HRV	
Oxygen8	Ventum H25	HRV	83.11% at 75% flow (AHRI software)
Oxygen8	Ventum H30	HRV	
Swegon	Gold RX 05	HRV	>84% (PHI database)
Swegon	Gold RX 07	HRV	
Swegon	Gold RX 08	HRV	
Swegon	Gold RX 11	HRV	
Swegon	Gold RX 12 MTE	ERV	>83% per (AHRI software)

Swegon	Gold RX 14 MTE	ERV	>83% per (AHRI software)
Swegon	Gold RX 20 MTE	ERV	
Swegon	Gold RX 25 MTE	ERV	
Swegon	Gold RX 30 MTE	ERV	
Swegon	Gold RX 35 MTE	ERV	
Swegon	Gold RX 40 MTE	ERV	
Swegon	Gold RX 50 MTE	ERV	
Swegon	Gold RX 60 MTE	ERV	
Swegon	Gold RX 70 MTE	ERV	
Swegon	Gold RX 80 MTE	ERV	
Tempeff	RGL 5500	HRV	82.5% at 75% flow (third-party testing provided at 20 and 16.7 deg F performance software confirmation at 35 deg F)
Tempeff	RGL 6500	HRV	
Tempeff	RG 1000	HRV	
Tempeff	RG 1500	HRV	
Tempeff	RG 2000	HRV	
Tempeff	RG 3000	HRV	
Tempeff	RG 4000	HRV	
Tempeff	RG 5500	HRV	
Tempeff	RGL 1500	HRV	

Tempeff	RGL 2000	HRV	82.5% at 75% flow (third-party testing provided at 20 and 16.7 deg F performance software confirmation at 35 deg F)
Tempeff	RGL 3000	HRV	
Tempeff	RGL 4000	HRV	
Tempeff	RGL 5500	HRV	
Tempeff	RGL 6500	HRV	
Ventacity	VS1000 RTh	HRV	PHI Certified RTh hHR= 82% Rte hHR= 82%* *Includes latent recovery
Ventacity	VS1000 RTe	ERV	
Ventacity	VS3000 RTh	HRV	
Ventacity	VS3000 RTe	ERV	
Ventacity	VS1200CMh	HRV	Ventacity test summary shows 83.3% at 75% flow. PHI Test data: 81.1% th eff at 54% flow.
Ventacity	VS900CMh	HRV	PHI Certified Ventacity test summary: 84.3% at 57% airflow PHI data: 81.6% at 55% airflow
Ventacity	VS250CMh	HRV	Ventacity test summary shows 81.7% at 76% flow. PHI data: >78%

As of February 2022; Source: BetterBricks