Energy and Indoor Air Quality Impacts of DOAS Retrofits in Small Commercial Buildings

15TH CANADIAN CONFERENCE ON BUILDING SCIENCE AND TECHNOLOGY

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PRESENTED BY:

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RDH CELEBRATING 20 YEARS EST. 1997

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Outline

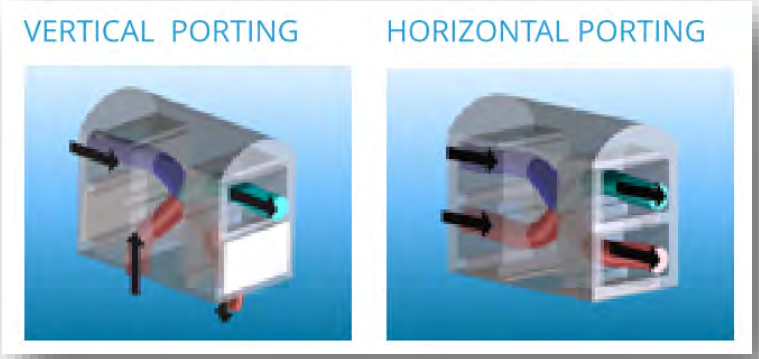
- → Background
- → Methodology
- → Results
- → Lessons Learned (to date)

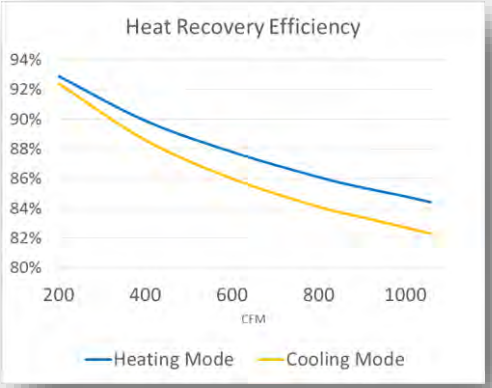
Background

Pilot Project Overview

→ Early pilot work funded by the Northwest Energy Efficiency Alliance (NEEA)

- → New high efficiency Heat Recovery Ventilation (HRV) unit
- → Vertical mounting for existing RTU ductwork
- → 1000 cfm max flow
- → Greater than 80% sensible heat recovery efficiency



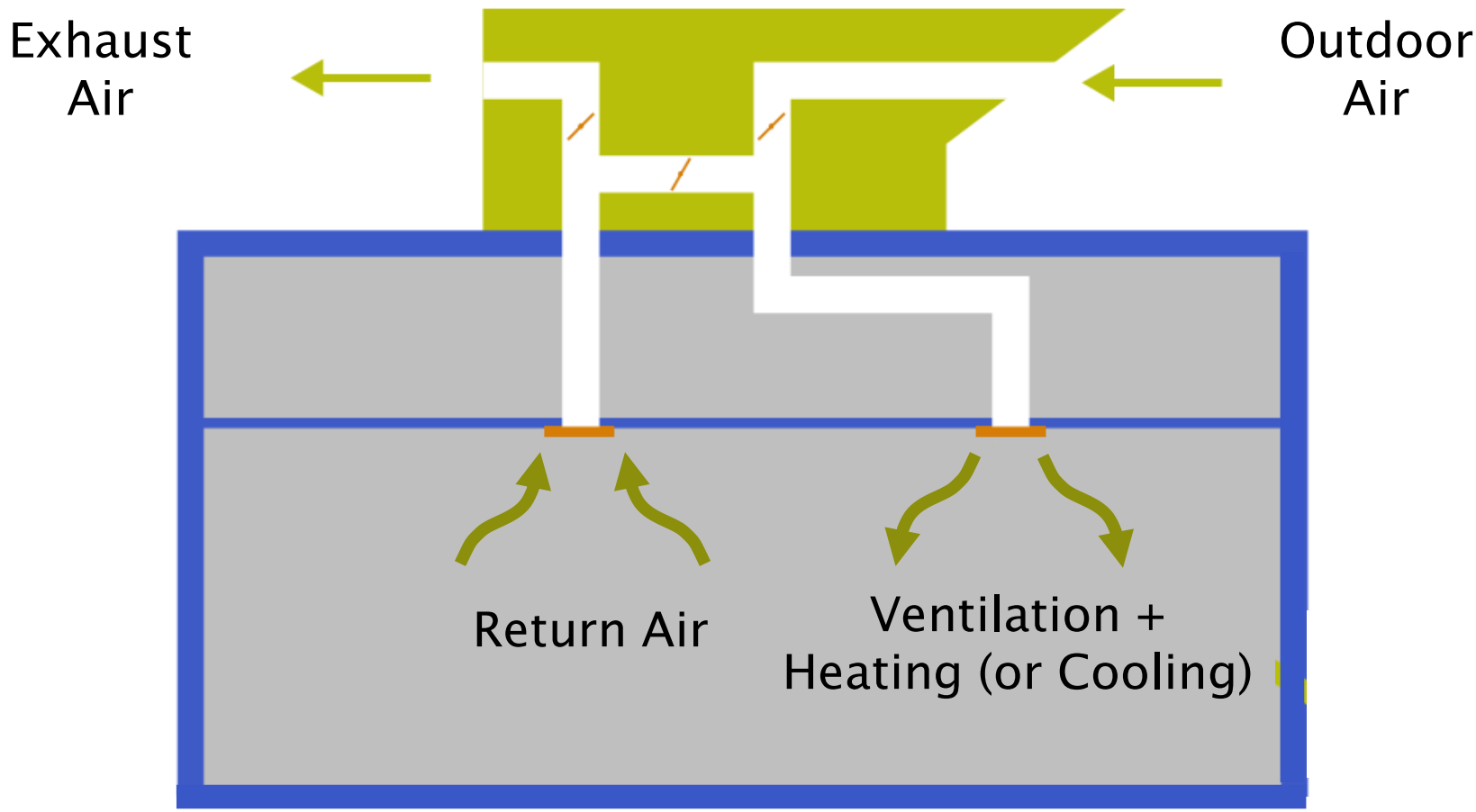


Pilot Project Overview

→ Target Building Sector:

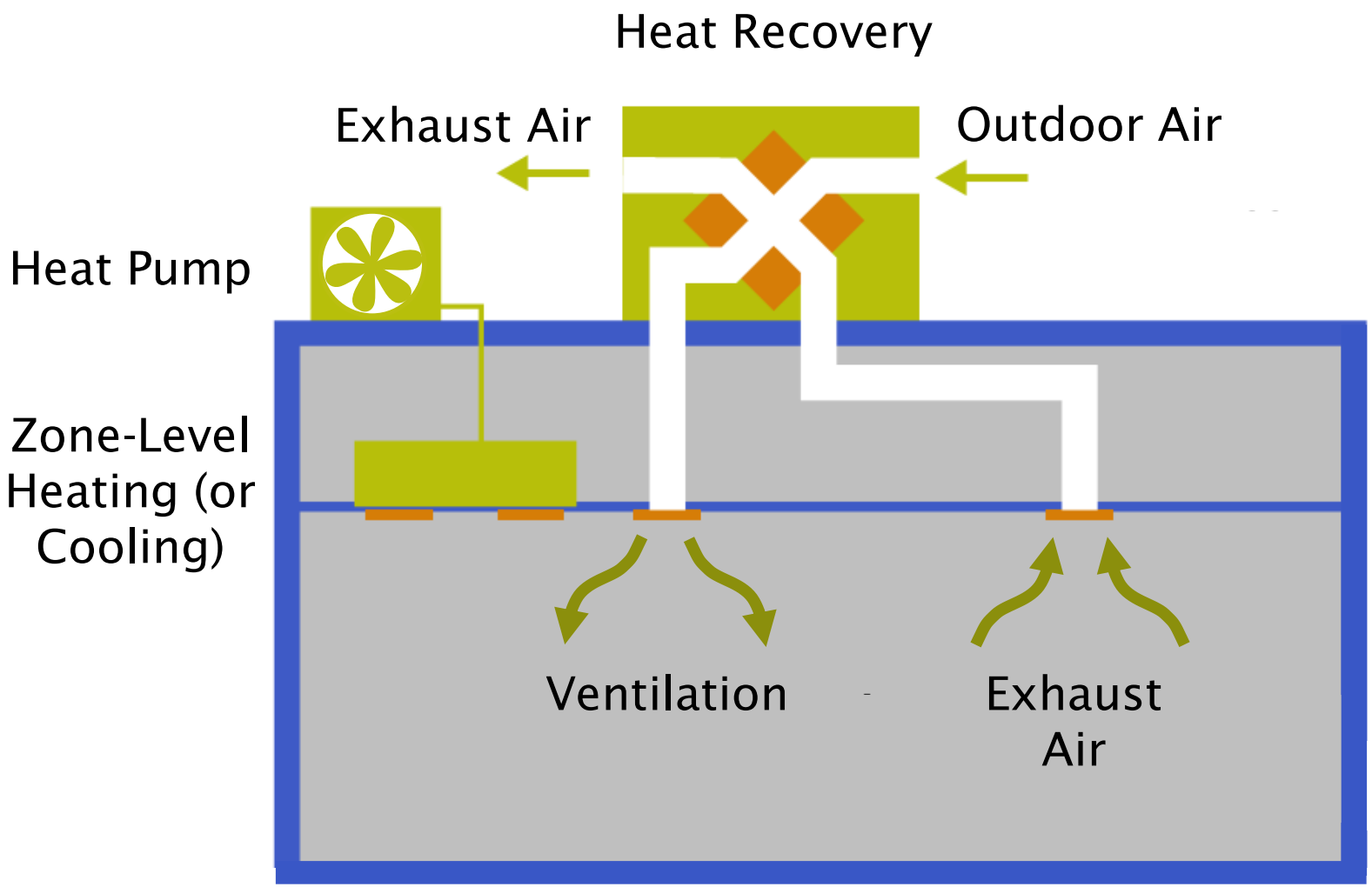
- → Small commercial (< 25,000 ft^2)
- → Includes small office, retail, schools, restaurants, small assembly
- → Makes up approx. half of the commercial building floor area in the Pacific Northwest.
- → Smaller HVAC systems; typically not engineered.

Pilot Project Overview



Packaged Rooftop Unit

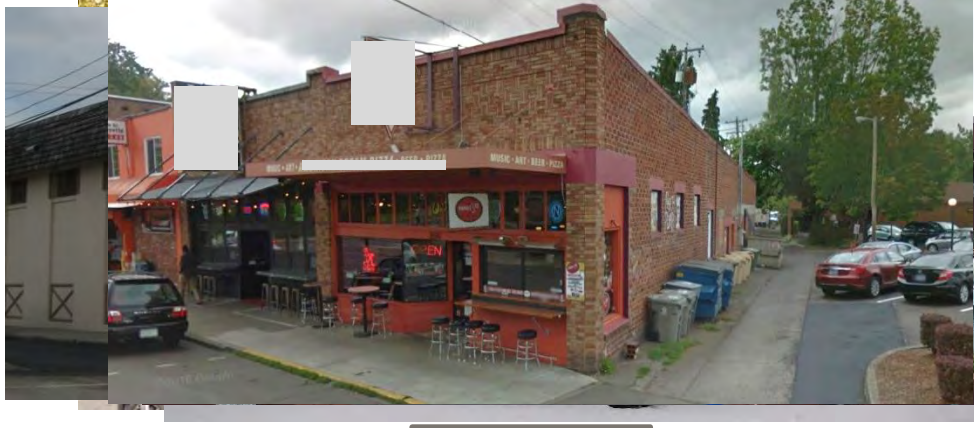
Pilot Project Overview

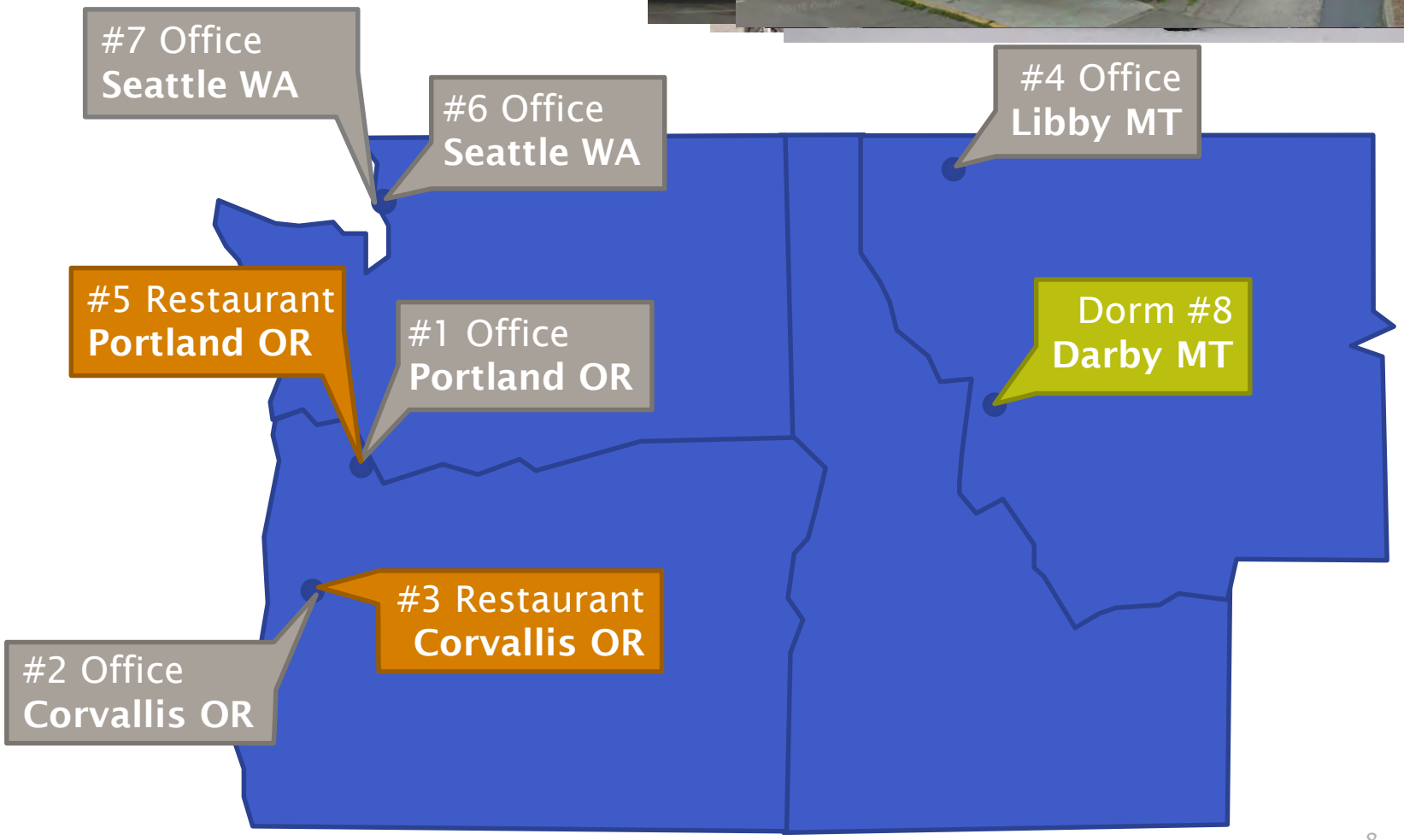


Dedicated Outdoor Air System

Pilot Projects

→ 8 pilot projects to date





#	Location	Building Type	Occupied Hours	Conditioned Area, ft² (m²)
1	Portland, OR	Office	M-F, 7am-6pm	11,600 (1,080)
2	Corvallis, OR	Office	M-F, 8am-5pm	13,200 (1,225)
3	Corvallis, OR	Restaurant	Su-W, 11am-11pm Th-Sa, 11am-12am	1,600 (162)
4	Libby, MT	Office w/ Garage	M-F, 9am-5pm	5,600 (520)
5	Portland, OR	Restaurant	M-F, 11am-9pm Sa-Su, 9am-9pm	1,150 (110)
6	Seattle, WA	Office	M-F, 9am-5pm	5,900 (550)
7	Seattle, WA	Office	M-F, 8am-5pm	24,300 (2,260)

Wide range of climates

Applicable to most building types

Size ranges from ~1,150ft² to 24,300ft²

Pilot Project Overview

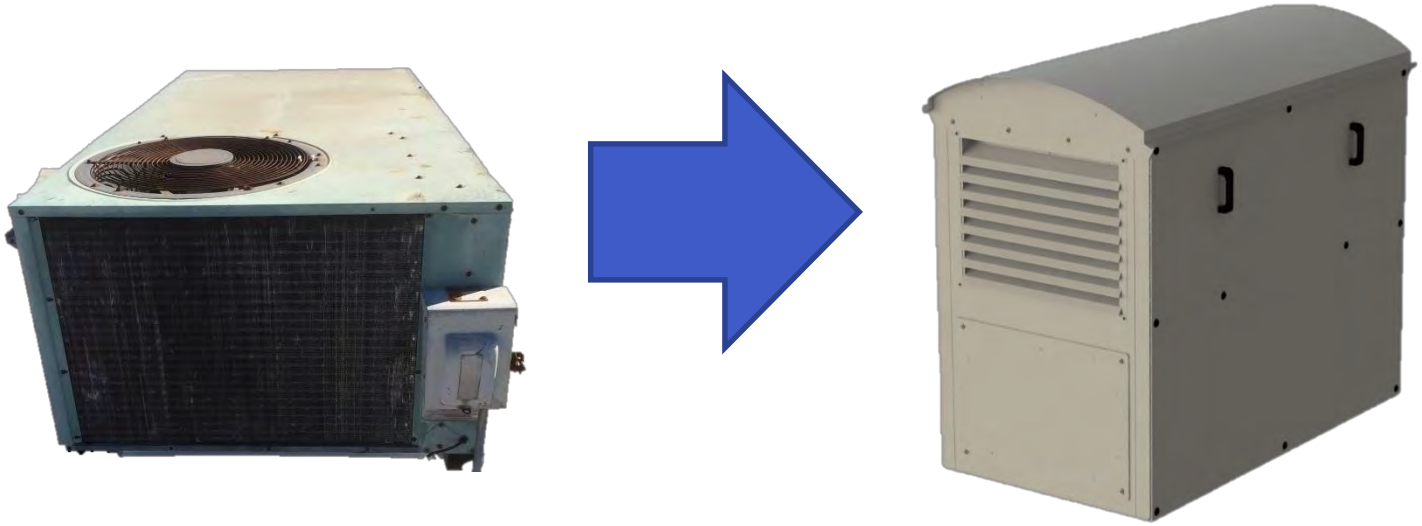
→ **PART 1:** Establish Baseline Conditions

→ **PART 2:** Calibrate Baseline Energy Model

→ **PART 3:** DOAS Conversion

→ **PART 4:** Establish Post-Conversion Conditions

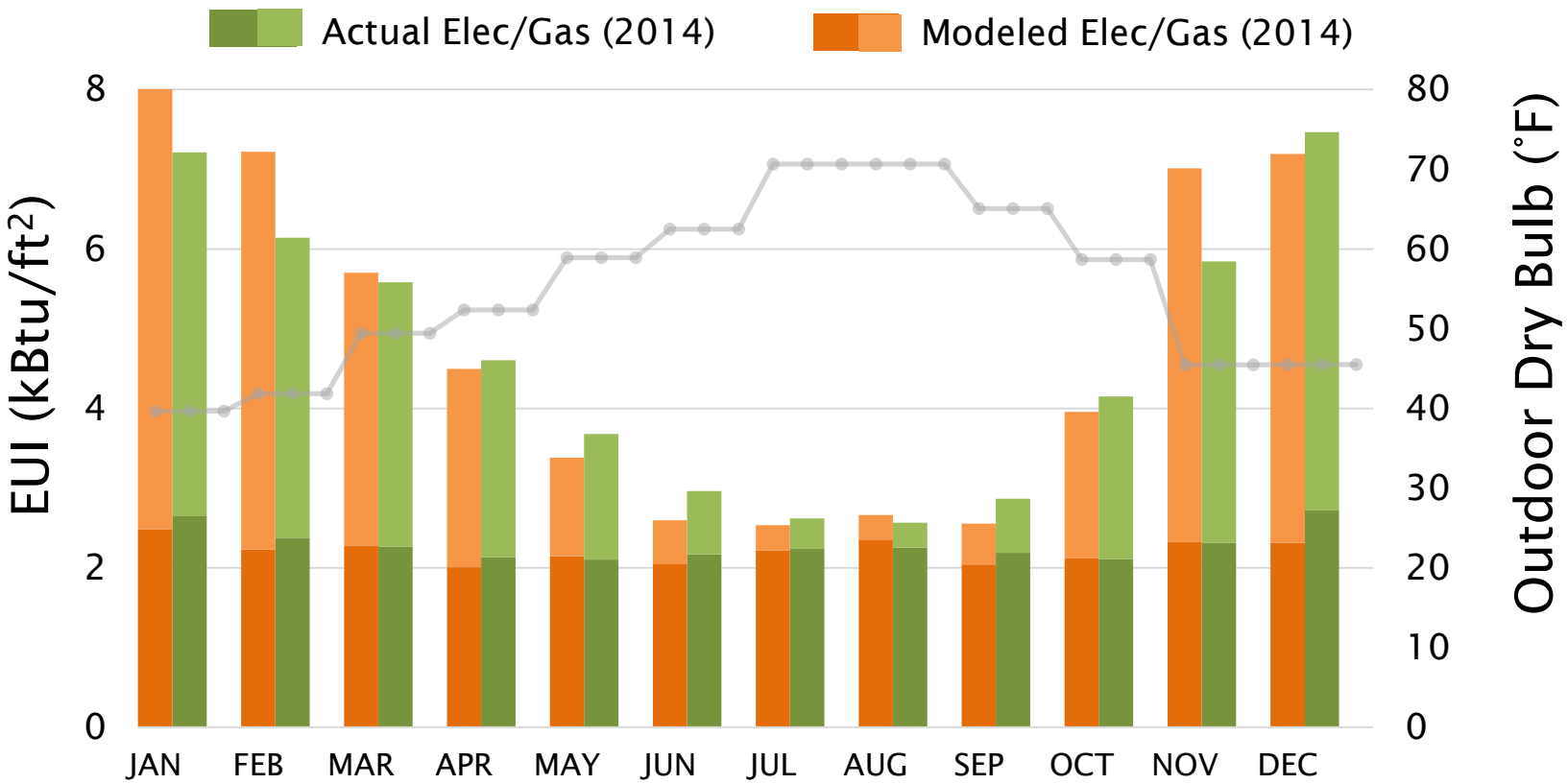
→ **PART 5:** Calibrate Post-Conversion Energy Model



Methodology

Pre-Conversion Baseline Model Calibration

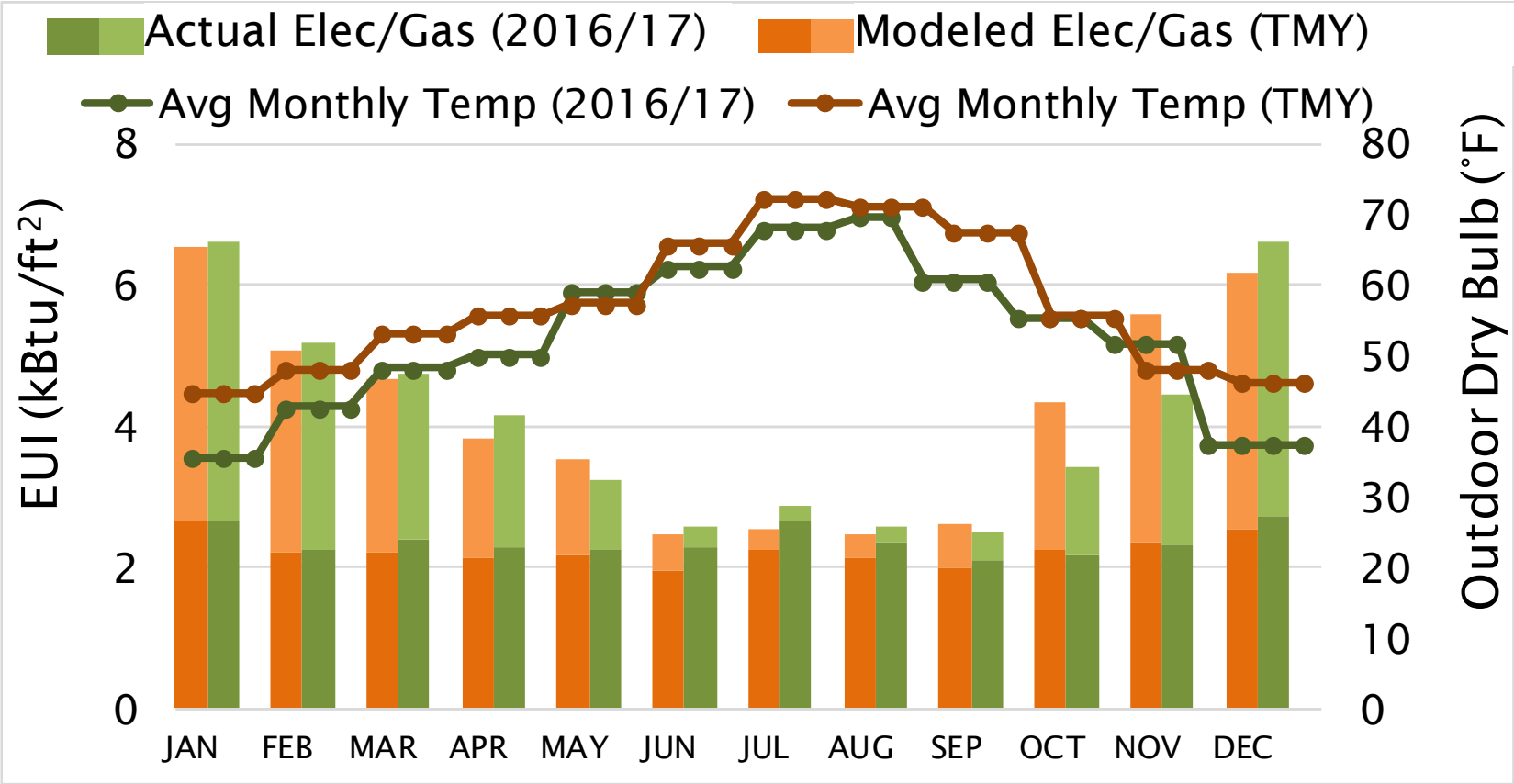
→ Calibration based on monthly electricity and natural gas bills



CVRMSE: 2.1 (elec) / 6.4 (gas)
NMBE: 3.8 (elec) / 2.1 (gas)
Coefficient of Variation of the Root Mean Squared Error (CVRMSE) < 10% and Normalized Mean Bias Error (NMBE) < 5% as per ASHRAE Guideline 14 for calibration of whole building energy simulation to monthly utility data.

Post-Conversion Comparison

→ Comparison of modeled TMY to actual post-conversion use



→ Re-calibration done after 1-year post-conversion data

Monitoring Equipment

→ Energy Data

- → Utility Billing
- → Electricity Sub-metering

→ Indoor Environmental Quality

- → Carbon Dioxide
- → Temperature
- → Relative Humidity

Air Leakage Testing

→ Conducted pre- and post-conversion

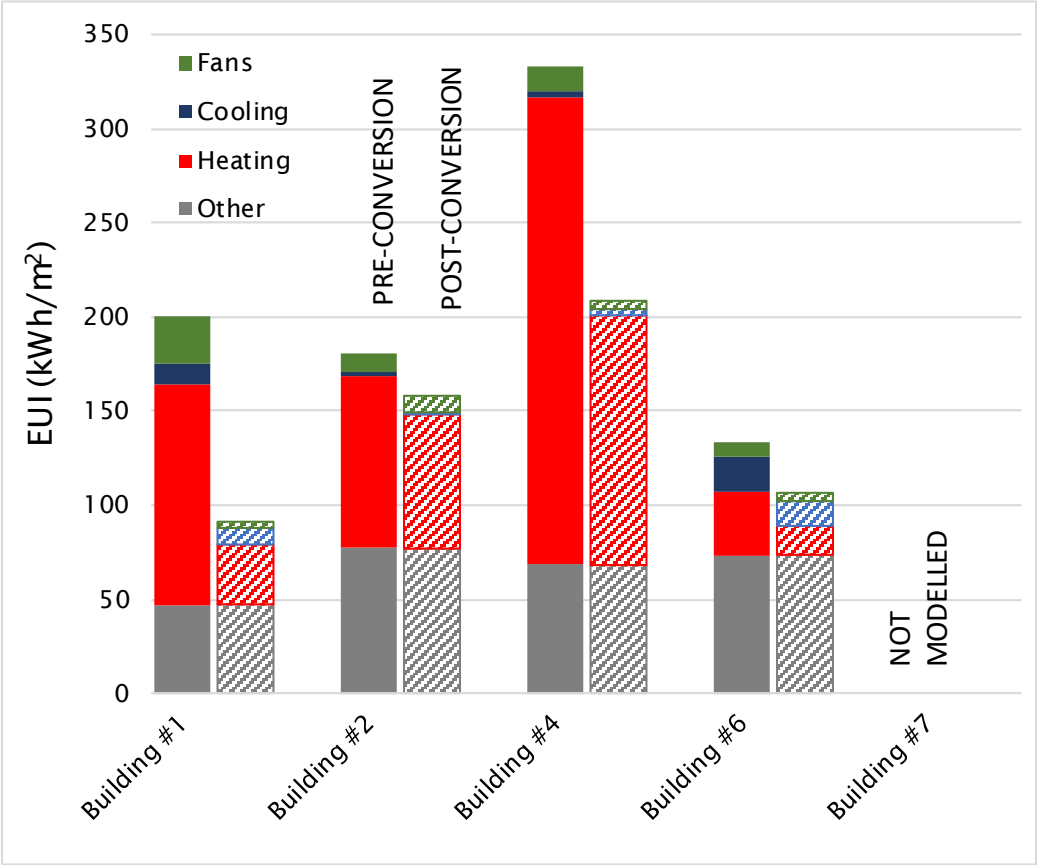
→ US Army Corps of Engineers (USACE) test protocol

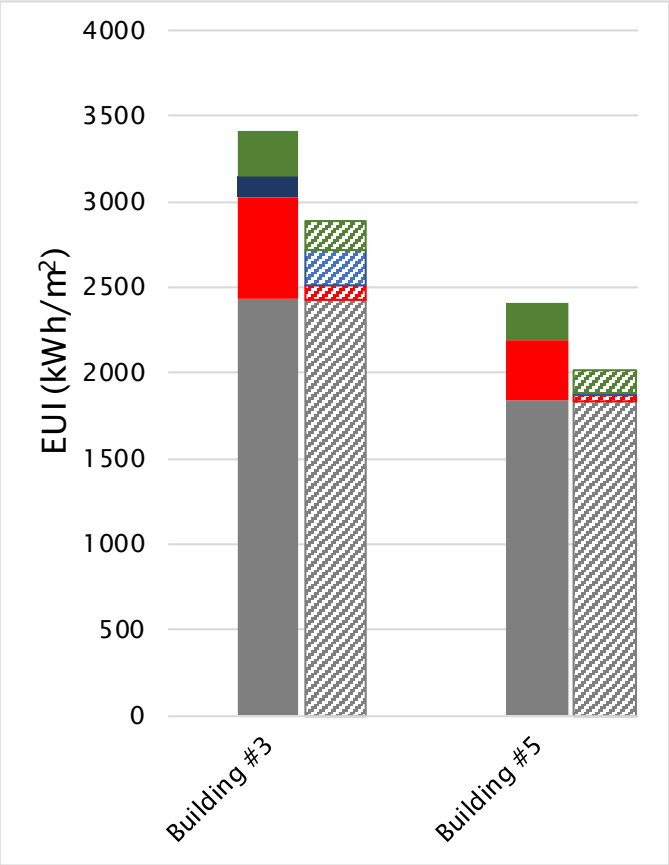
Summary of Project Results

→ Energy Savings

Summary of Energy Savings

→ Pre and Post-Retrofit energy end use breakdown compared





Offices

Restaurants

Summary of Energy Savings

#	Location	Occupancy	HVAC			Total		
			Pre, kBtu/ft² (kWh/m²)	Post, kBtu/ft² (kWh/m²)	Savings	Pre, kBtu/ft² (kWh/m²)	Post, kBtu/ft² (kWh/m²)	Savings
1	Portland, OR	Office	48 (153)	14 (44)	71%	63 (200)	29 (91)	54%
2	Corvallis, OR	Office	33 (103)	25 (80)	22%	57 (180)	50 (158)	13%
3	Corvallis, OR	Restaurant	313 (990)	146 (461)	53%	1,082 (3,418)	914 (2,890)	15%
4	Libby, MT	Office/Garage	84 (265)	45 (141)	47%	105 (333)	66 (209)	37%
5	Portland, OR	Restaurant	193 (609)	58 (182)	70%	773 (2,444)	638 (2,017)	17%
6	Seattle, WA	Office	19 (60)	10 (33)	45%	42 (133)	34 (106)	20%
7	Seattle, WA	Office	TBD	TBD	TBD	TBD	TBD	TBD

22% to 71%

13% to 54%

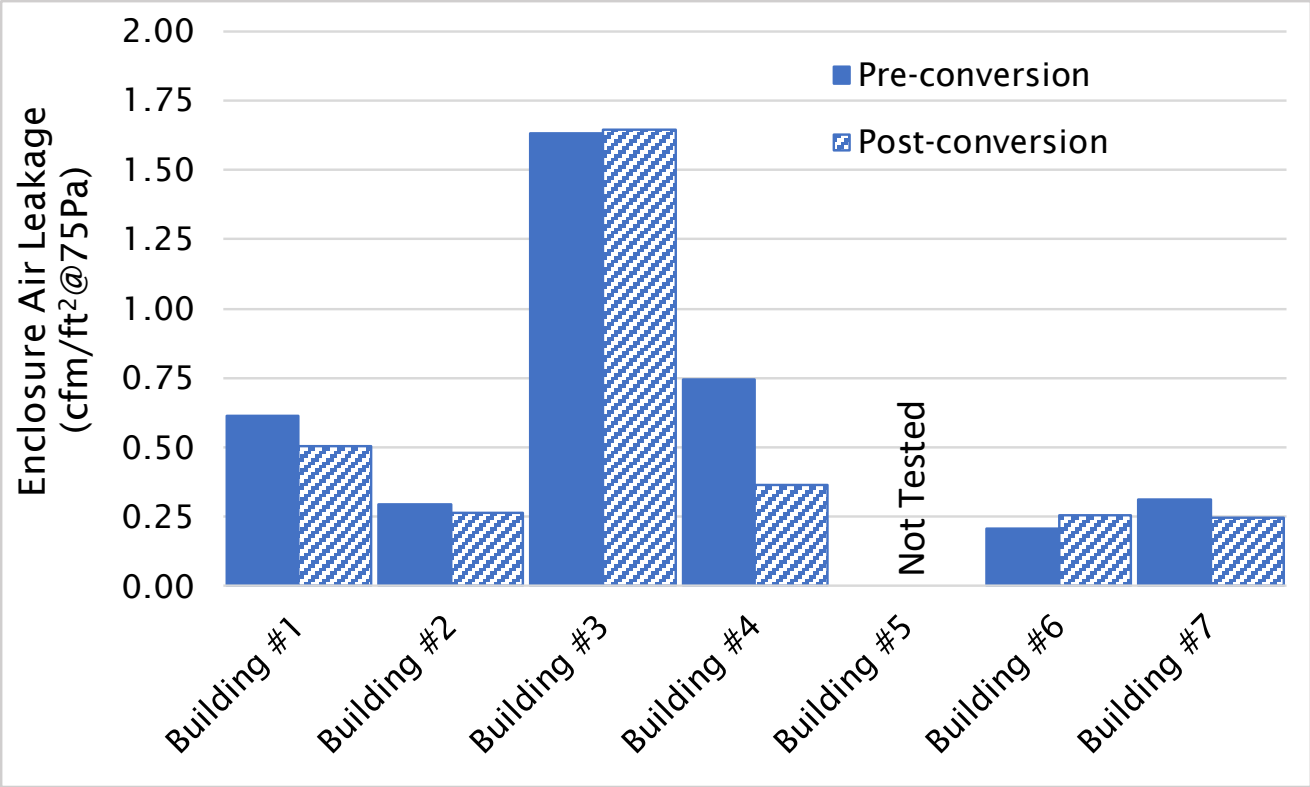
Summary of Project Results

→ Air Leakage

Air Leakage Testing

→ Typical leakage ~0.2 to 0.5 cfm/ft^2 @75Pa (1.0 to 2.5 L/s·m^2)

- → Building #3 (restaurant) was an outlier <1.6 cfm/ft^2 @75Pa (8.1 L/s·m^2) due to kitchen equipment openings
- → 51% decrease in Building #4: removal of two swamp coolers
- → 23% increase in Building #6: difficulty sealing ductwork between floors



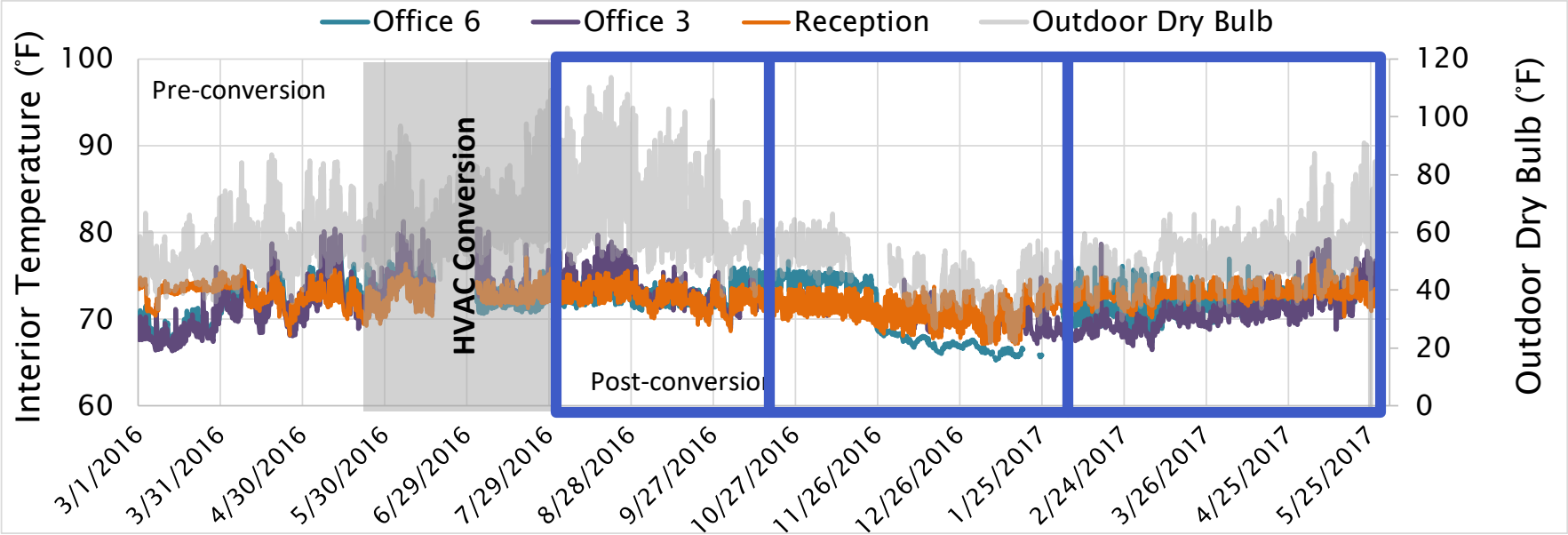
Summary of Project Results

→ Temperature

Drybulb Temperature – Building #2 – Office, Oregon

→ Primary use: confirm space setpoint/setback being met

→ Secondary use: troubleshooting and optimizing operation



→ Initially tight control of space temperature

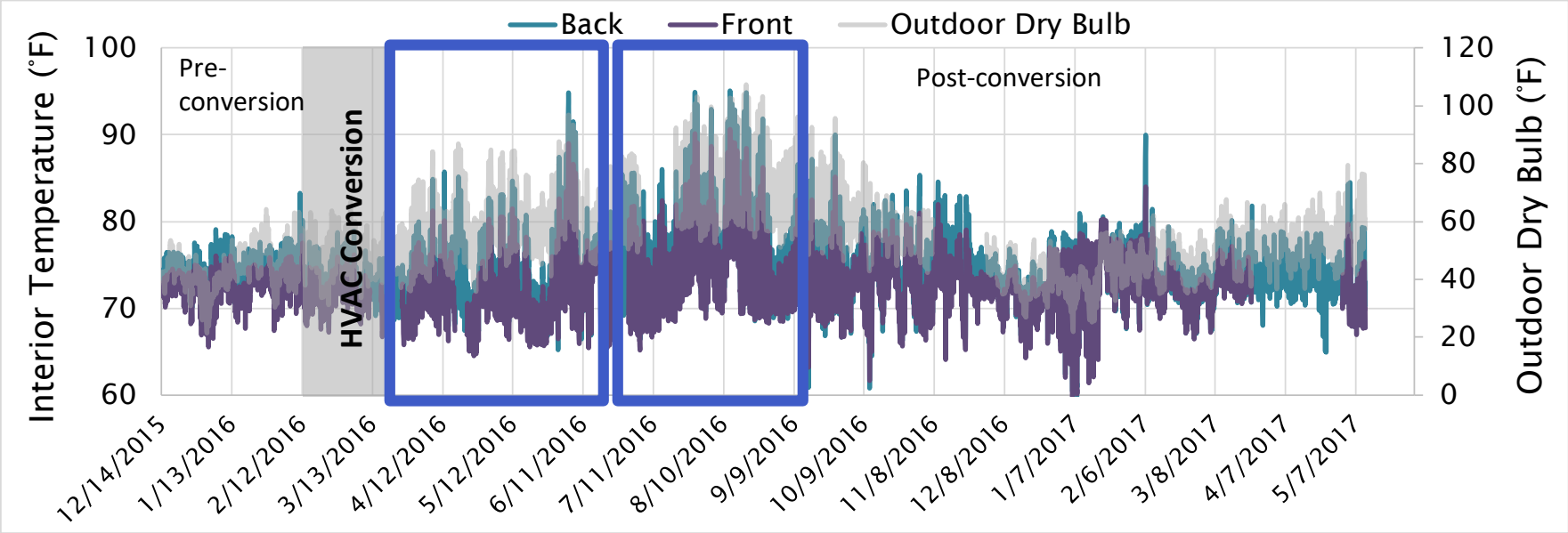
→ Occupant adjustments causes deviation

→ Spaces deviate but small temperature band in each

Drybulb Temperature – Building #3 – Restaurant, Oregon

→ Primary use: confirm space setpoint/setback being met

→ Secondary use: troubleshooting and optimizing operation



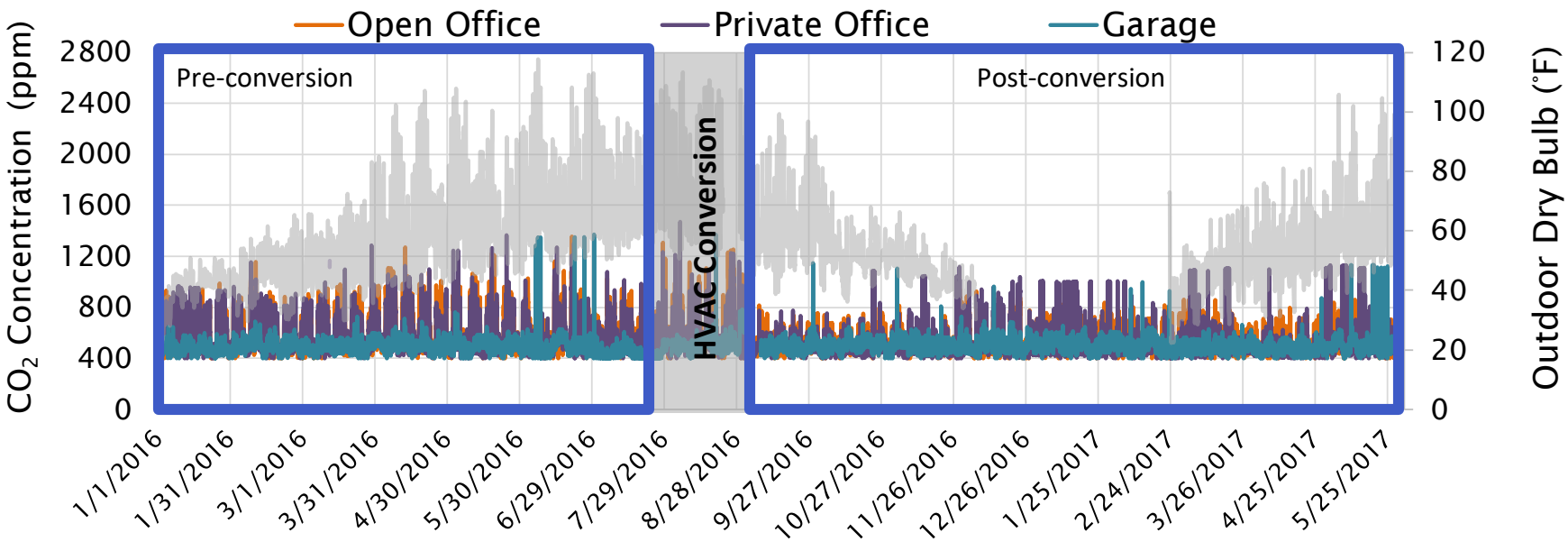
→ Significant daily variations in space temperature

→ Challenges maintaining setpoint during summer

Summary of Project Results

→ Carbon Dioxide

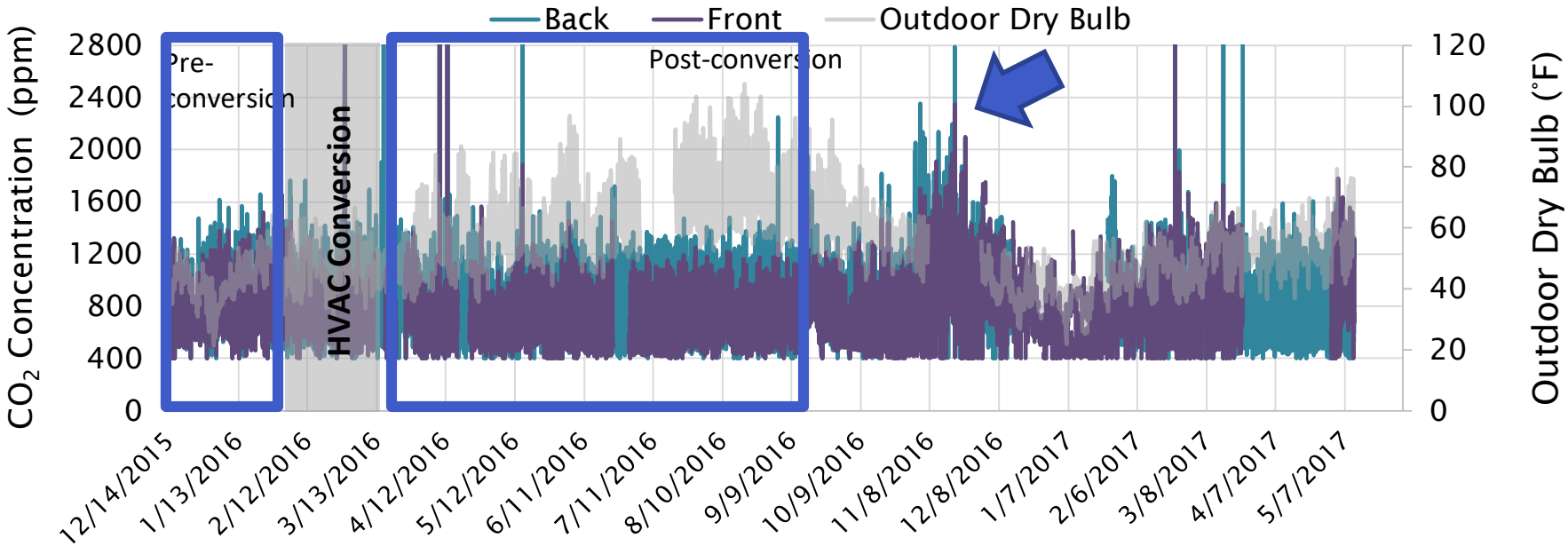
Building #4 – Office, Montana



→ Pre-conversion ventilation system provided good IAQ

→ Reduction in peak CO_2 concentration post-conversion

Building #3 – Restaurant, Oregon



→ Pre-conversion CO_2 variation is significant, concentration often in excess of 1,000ppm

→ Post-conversion concentration shows minor reduction in peak concentration

→ Greatest concentration is after HRV operating hours (staff clean-up)

Carbon Dioxide Concentration

Project Number	Occupancy	Frequency above 1000ppm Pre	Frequency above 1000ppm Post	Average Occupied Pre	Average Occupied Post
1	Office	N/A	0.2%	N/A	500
2	Office	0.7%	0.1%	615	565
3	Restaurant	23%	15%	900	740
4	Office/Garage	2.6%	0.1%	620	545
5	Restaurant	7.2%	N/A	760	N/A
6	Office	N/A	0.0%	N/A	500
7	Office	0.0%	2.7%	480	560

0% to 24%

0% to 15%

480 to 900ppm

500 to 740ppm

Lessons Learned

Lessons Learned

- → Successful DOAS conversion depends on several factors, including:
  - → Reduction in ventilation air volumes; demand controlled ventilation (DCV)
  - → Very low ventilation fan power (0.5 Watts/cfm or less)
  - → **Very high ventilation heat/energy recovery efficiency**
- → Can be a challenge due to limited equipment meeting required specifications

- → Implementation has led to a number of lessons learned:

Air Leakage

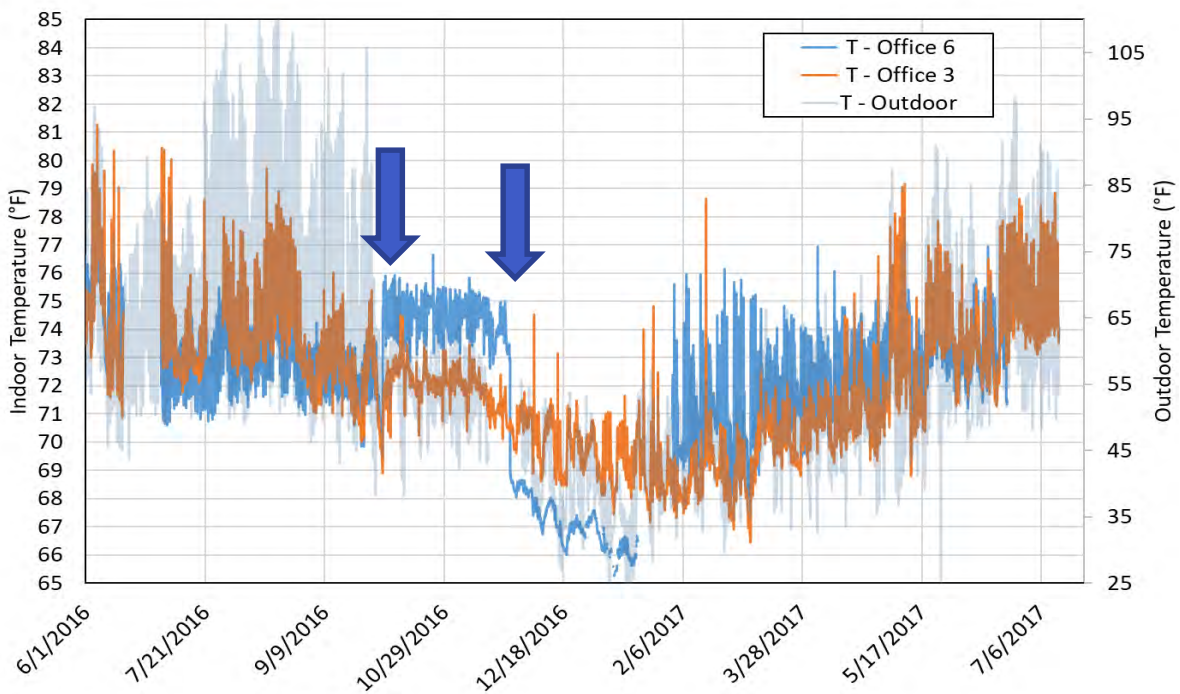
- → Commissioning of HRV airflow at diffusers found rates up to 25% below design conditions
- → Initial solution from contractors was to increase the airflow rate at the HRV until space supply flowrates were met
- → Root cause identified to be air leakage at ductwork at fittings
  - → Challenges repurposing existing ductwork due to the leaks
- → Care required at new duct joints

Contractor Education

- → Several pilots initially specified old equipment capacity
- → Relied heavily on design assistance from heat pump equipment suppliers
  - → Typically leads to extra features
- → Tools and/or technical support for selecting proper equipment required for broad scale implementation

Occupant Education

- → Operation changes required to account for the separation of the ventilation from A/C
- → Occupants initially hesitant to adjust setpoint temperature despite dissatisfaction with the indoor temperature
- → Others made changes without understanding the impact
- → Proper instruction around the intended system operation and periodic follow-up is required to ensure both comfort and energy goals are achieved



Discussion + Questions

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