Energy Modeling of Dedicated Outdoor Air Systems for a Small Commercial Pilot Project

BUILDING ENERGY SIMULATION FORUM, JUNE 19, 2019

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RDH BUILDING SCIENCE

Overview

→ Pilot project: energy efficient replacement options for end-of-life packaged rooftop units on small commercial buildings

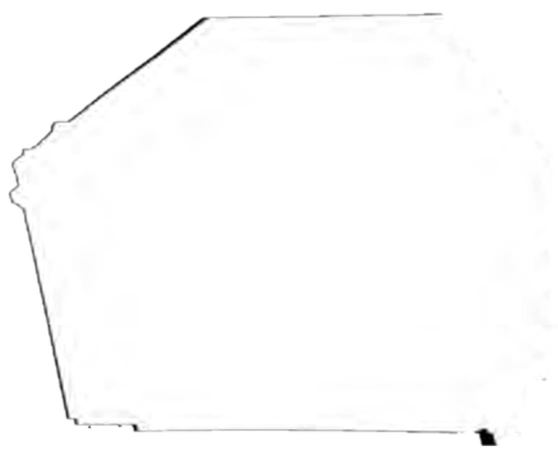
→ Dedicated Outdoor Air Systems (DOAS) with Heat Recovery Ventilation (HRV)

→ Energy modeling as a tool to quantify savings

→ Share progress and lessons learned

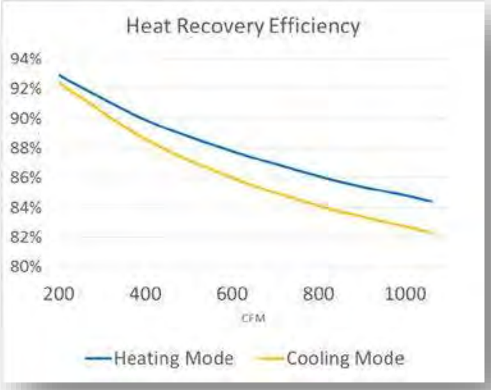
Pilot Project Overview

- 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.

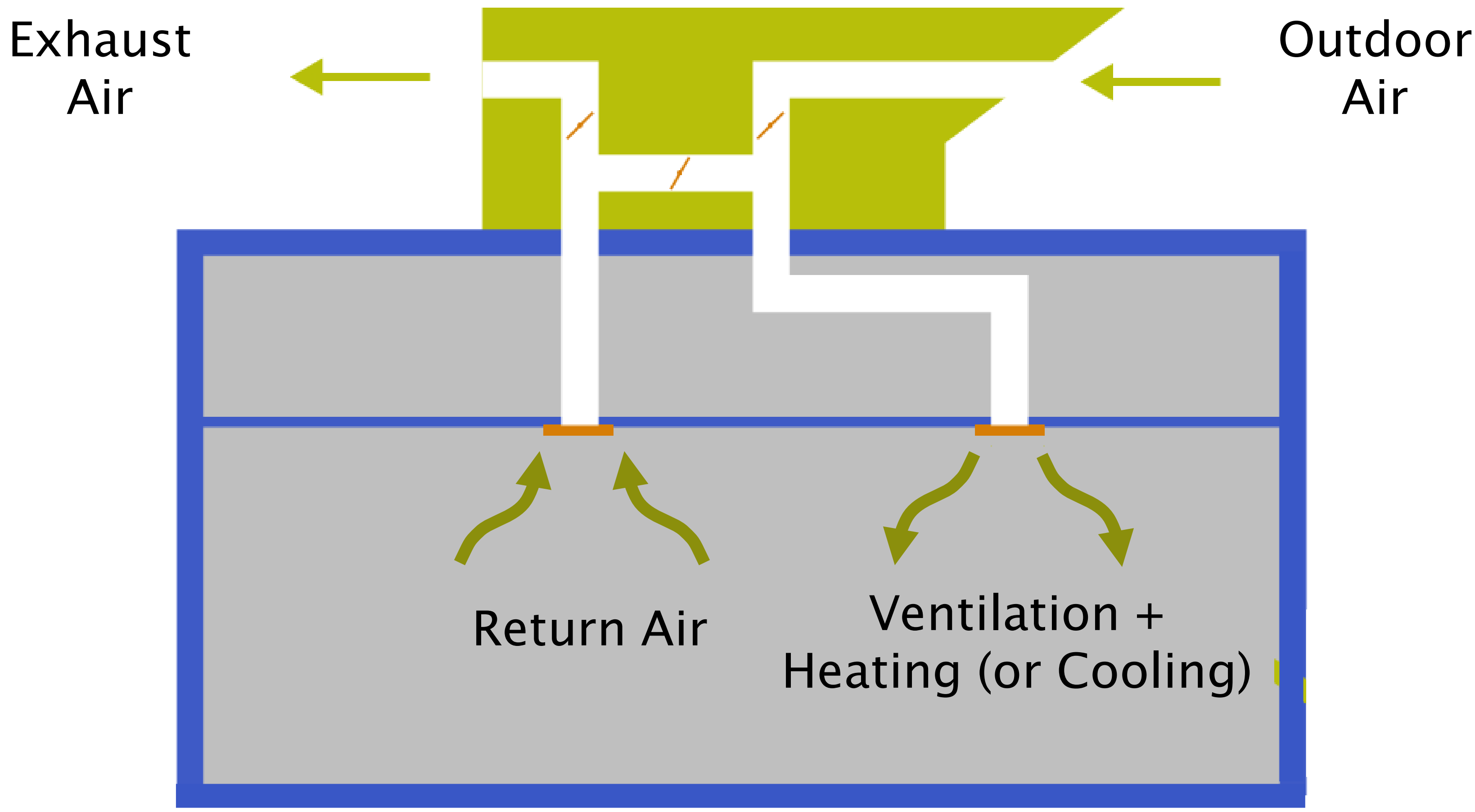


Pilot Project Overview

- Dedicated Outdoor Air System (DOAS) with Heat Recovery in Small Commercial Building Sector
- Early pilot work funded by the Northwest Energy Efficiency Alliance (NEEA)
  - New high efficiency HRV (> 0.85 eff @ 75% max flow)

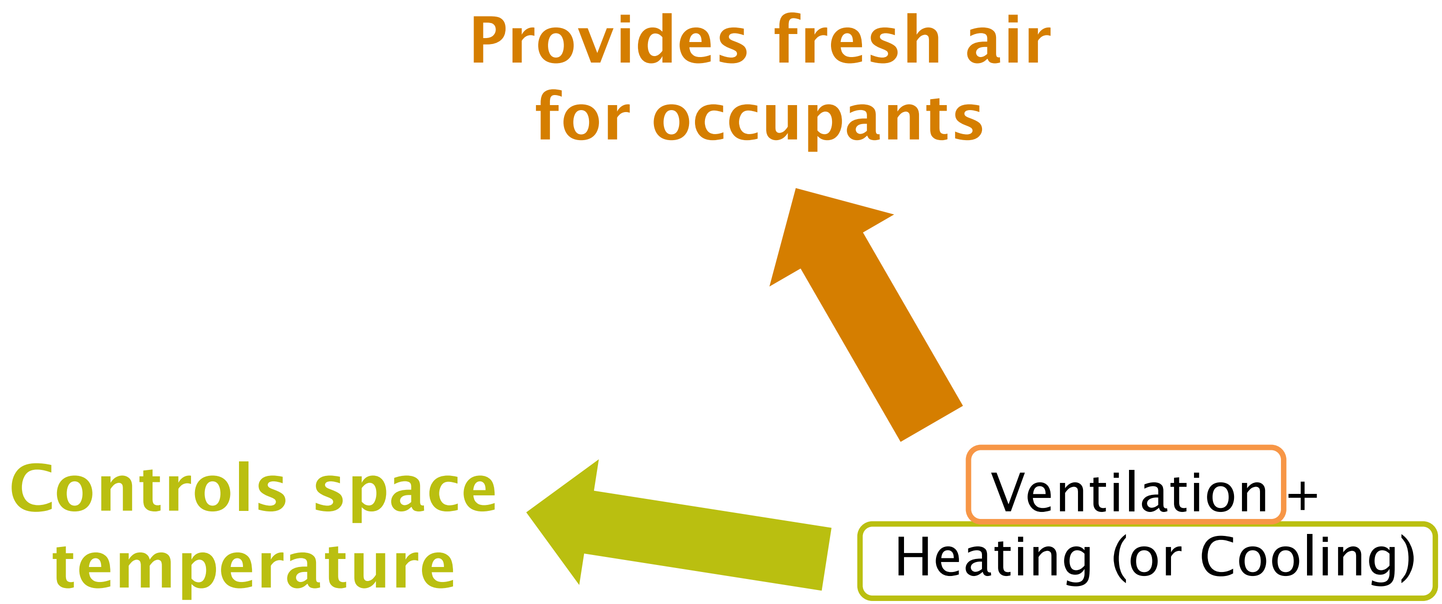


Pilot Project Overview

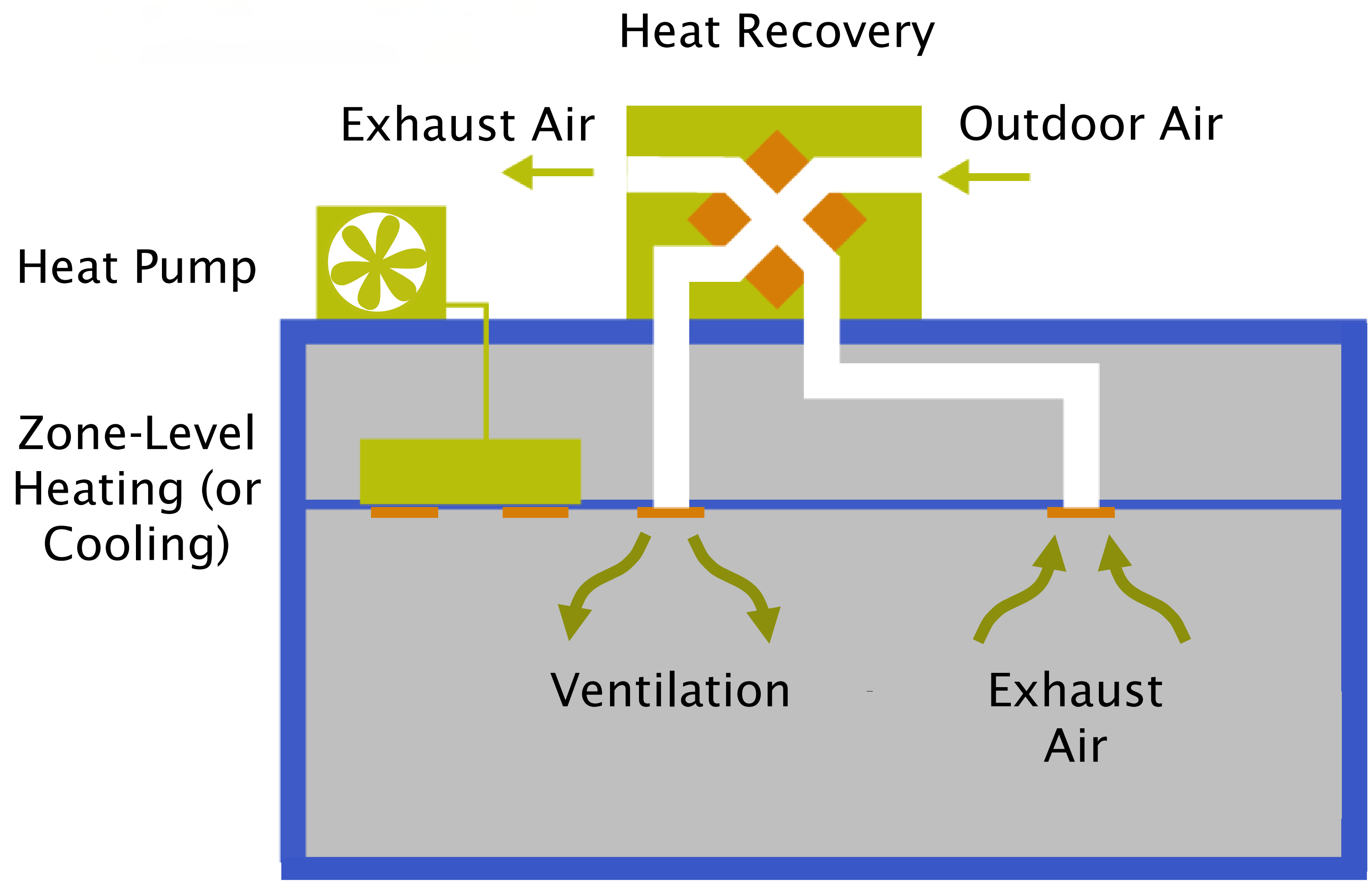


Packaged Rooftop Unit

Pilot Project Overview



Pilot Project Overview



Dedicated Outdoor Air System

Pilot Project Overview

Controls space temperature

Zone-Level Heating (or Cooling)

Provides fresh air for occupants

Ventilation

Pilot Project Overview

→ **PART 1:** Establish Baseline Conditions

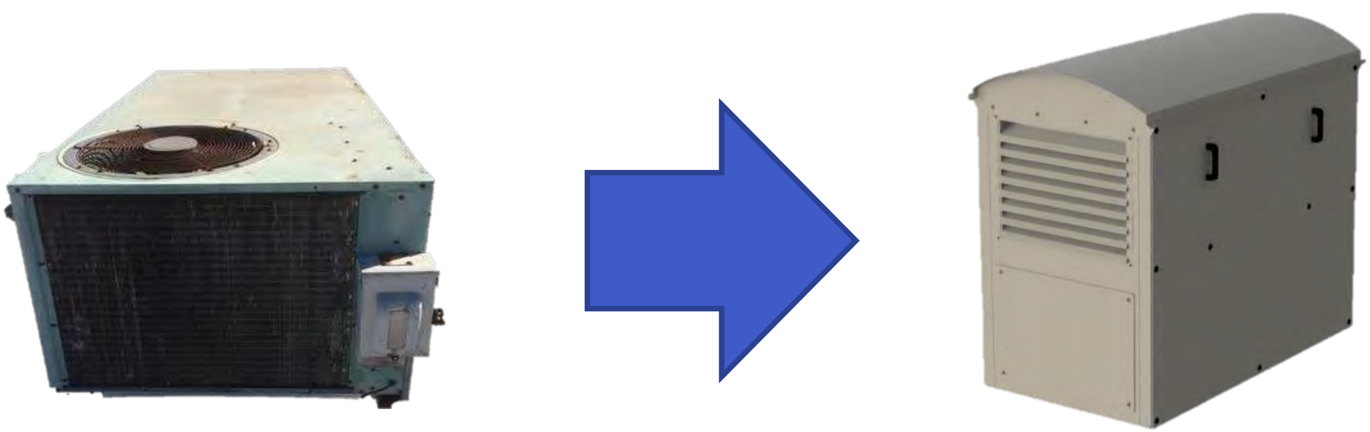
→ **PART 2:** Calibrated Baseline Energy Model

→ **PART 3:** DOAS Conversion

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

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

→ **PART 6:** Calculate Energy Savings



Pilot Project Overview

→ **PART 1:** Establish Baseline Conditions

- → Site Review
- → Baseline Air Leakage Testing
- → Installation of Monitoring Equipment

Pilot Project Overview

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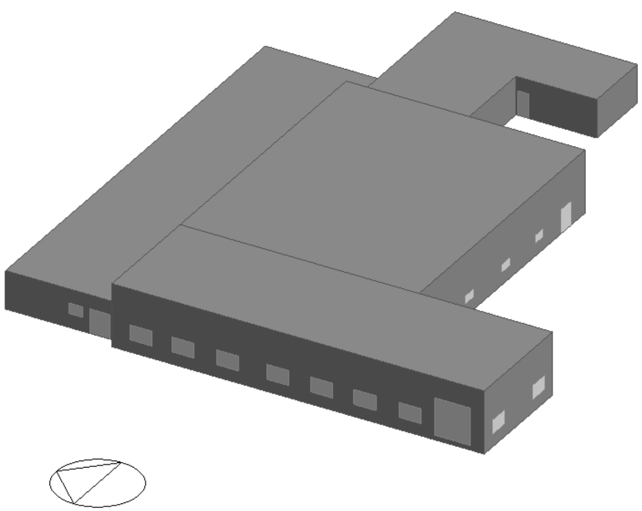
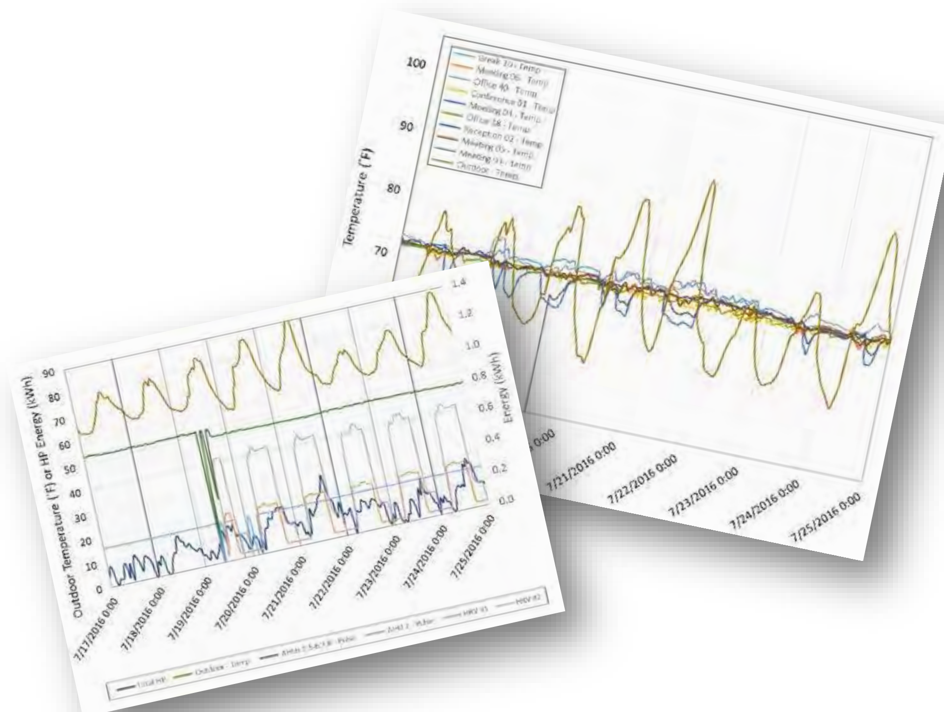
→ **PART 2:** Calibrated Baseline Energy Model

- → Actual Operating Conditions (occupancy, schedules, heating and cooling setpoints, etc.)
- → Baseline Air Tightness
- → Monitoring Data
- → Historic Utility Data





Pilot Project Overview

→ **PART 3:** DOAS Conversion

- → New HRV unit
- → Zone-level heating and cooling
- → Local design teams and contractors

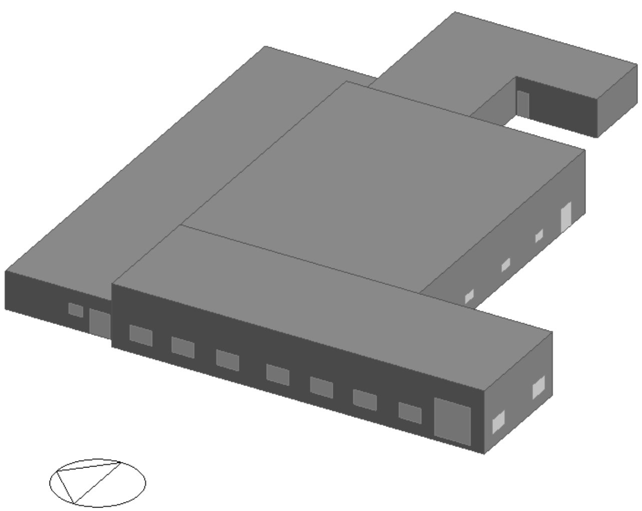
Pilot Project Overview

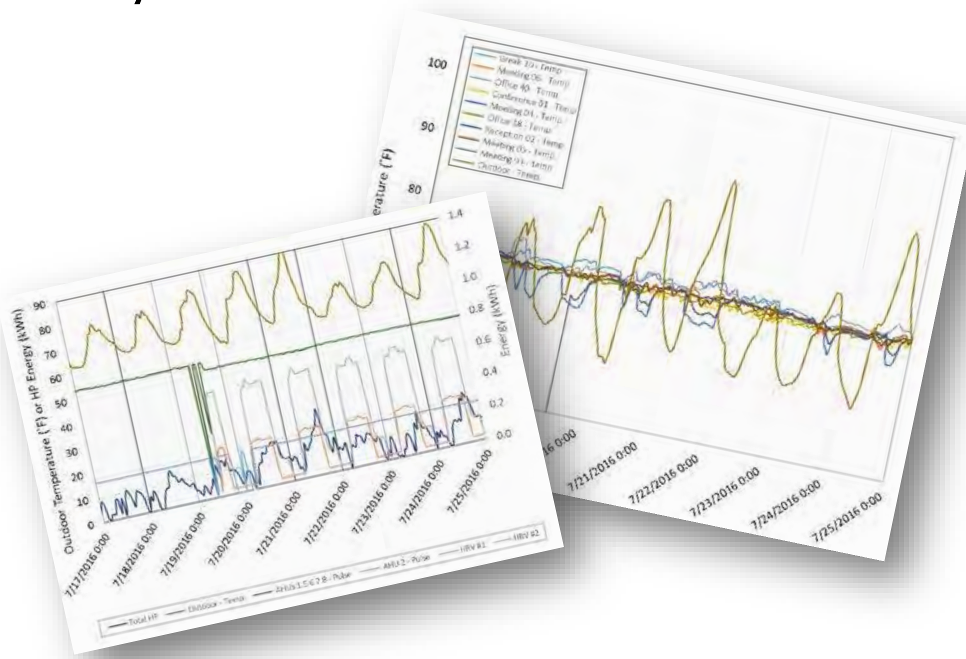
→ **PART 4:** Establish Post-Conversion Conditions

- → Site Review
- → Post-Conversion Air Leakage Testing
- → Additional Monitoring Equipment

Pilot Project Overview

- **PART 5:** Calibrated Post-Conversion Energy Model
  - Maintain Baseline Operating Conditions
  - Post-Conversion Air Tightness
  - Monitoring Data
  - 1 Year Post Conversion Utility Data

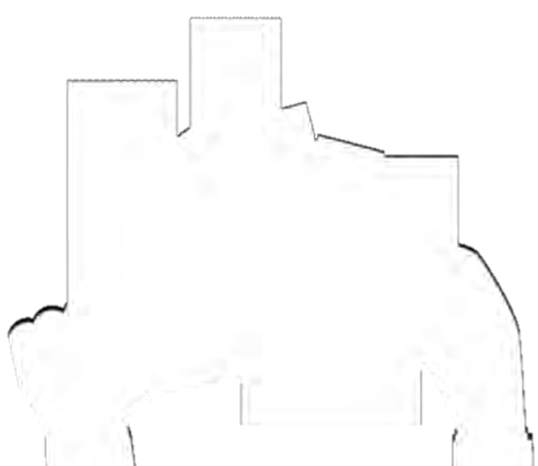




Pilot Project Overview

→ **PART 6:** Calculate Energy Savings

- → Overall Savings vs. Existing System
  - › i.e. owner utility bills
- → Incremental Savings vs. New Like-for-Like Replacement
  - › New equipment = higher efficiency, better controls, opportunity to commission, etc.
  - › Aligns with utility incentive programs (& other programs)



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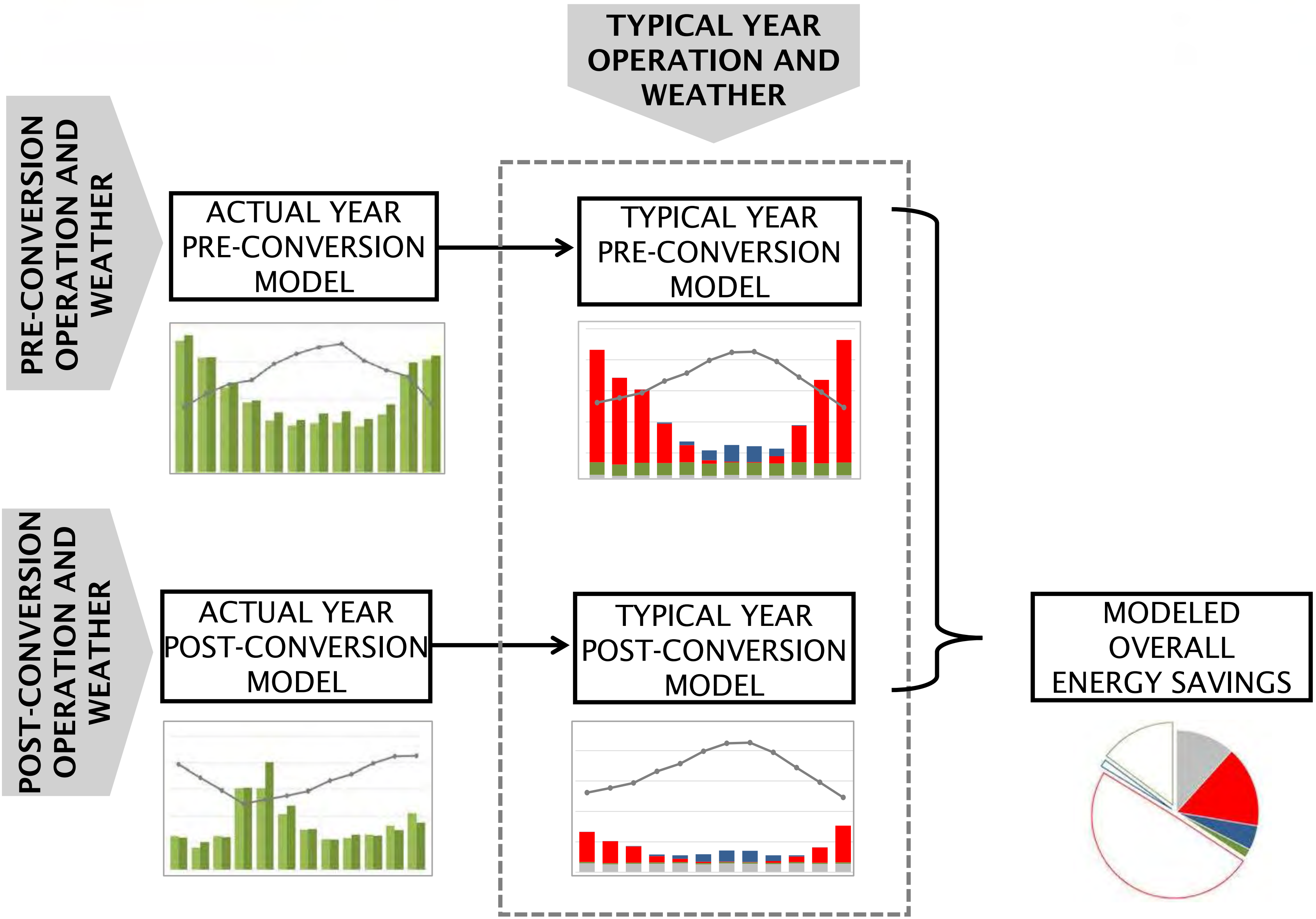
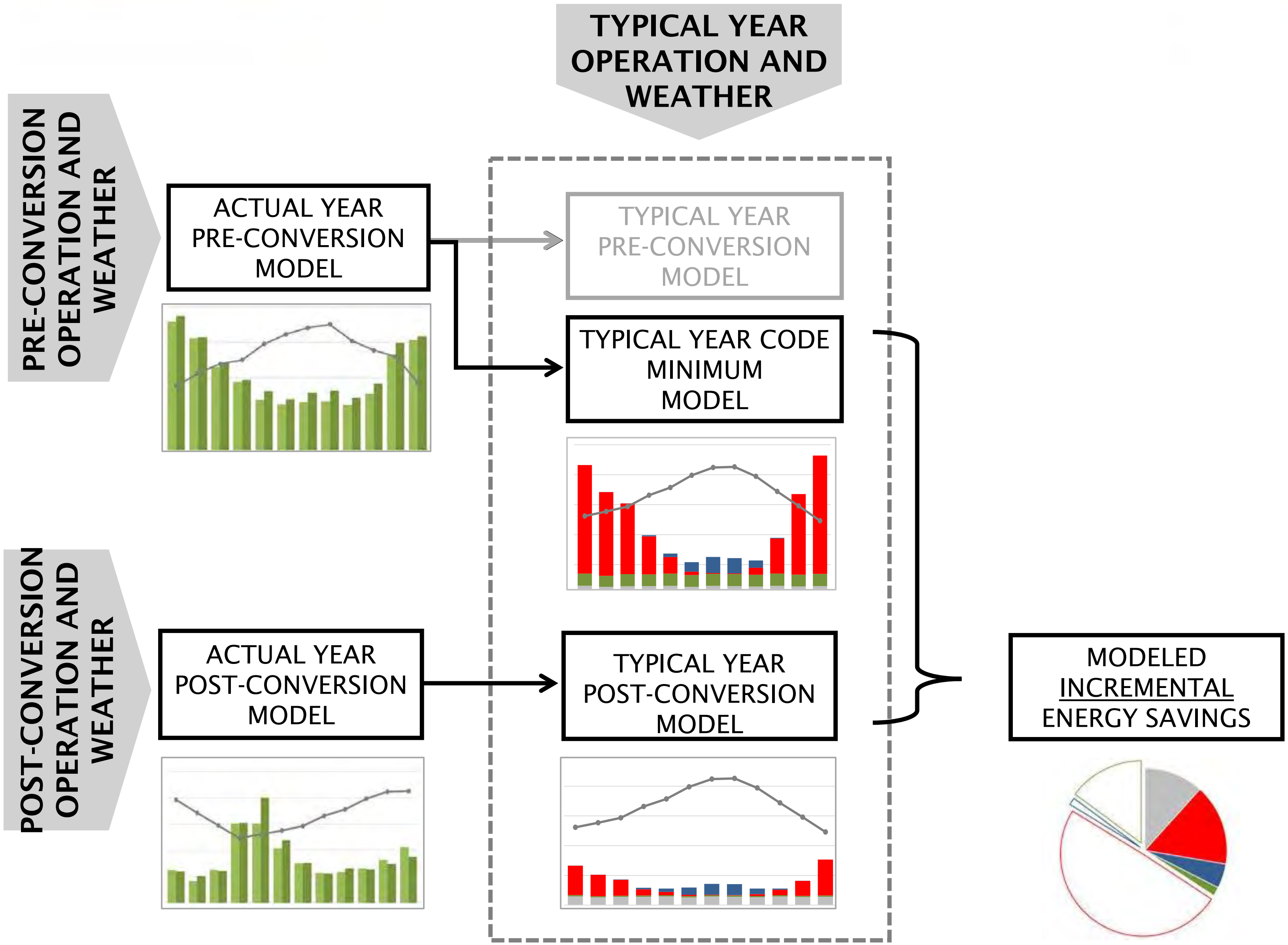
Pilot Project Overview



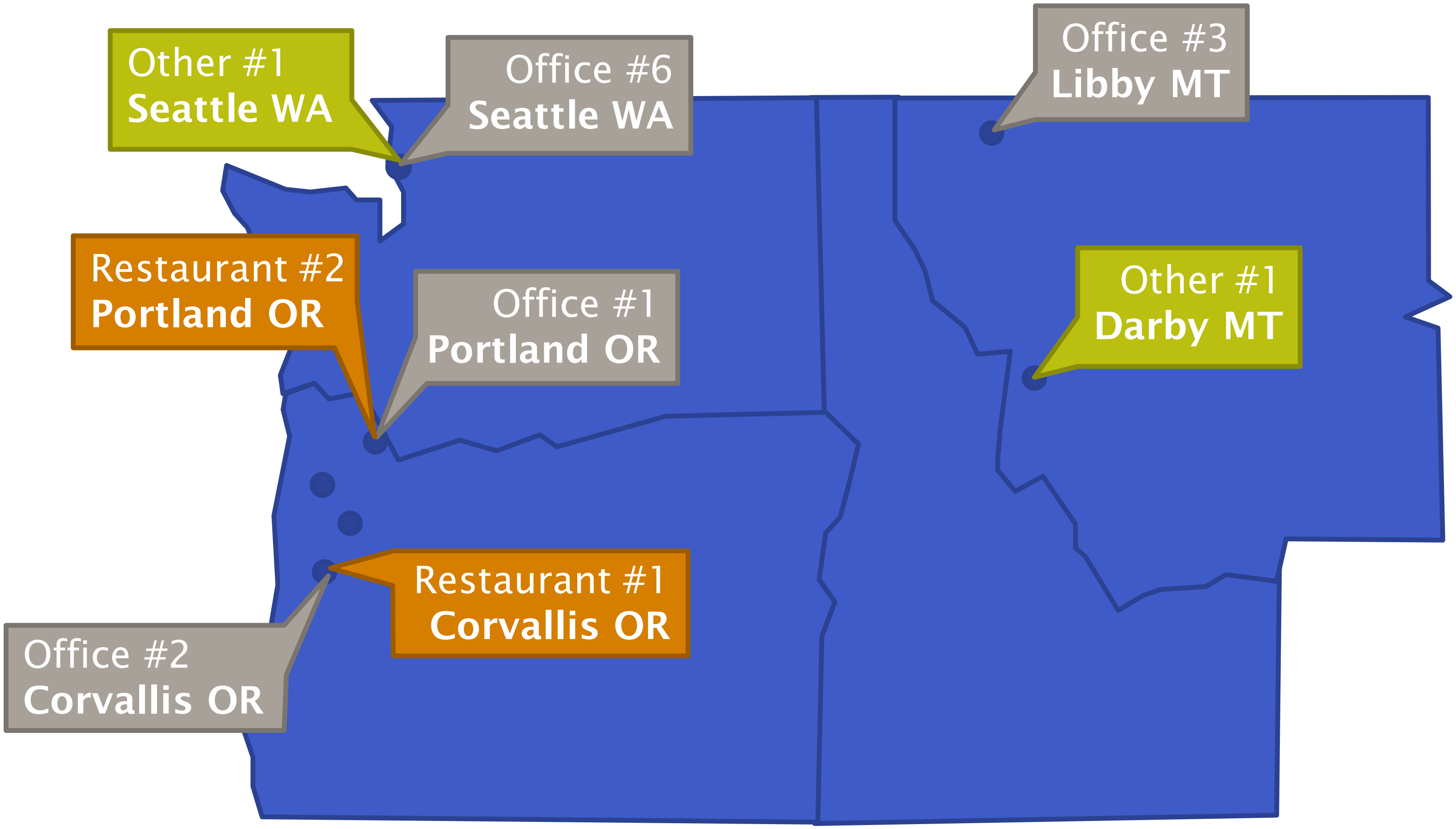
Pilot Project Overview



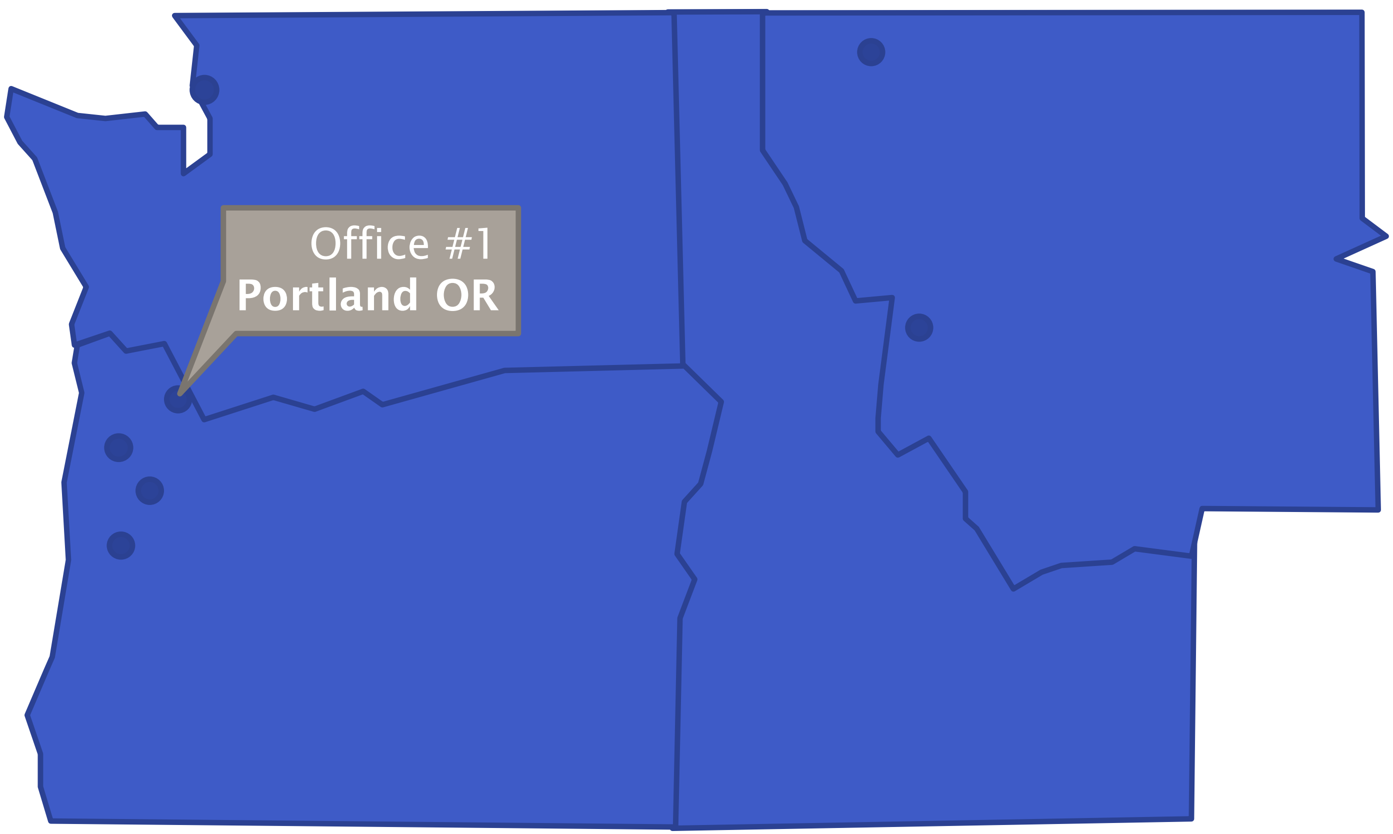
Pilot Projects

Pilot Projects

→ 8 pilot projects



Pilot Projects



Pilot Projects

→ **Office 1**

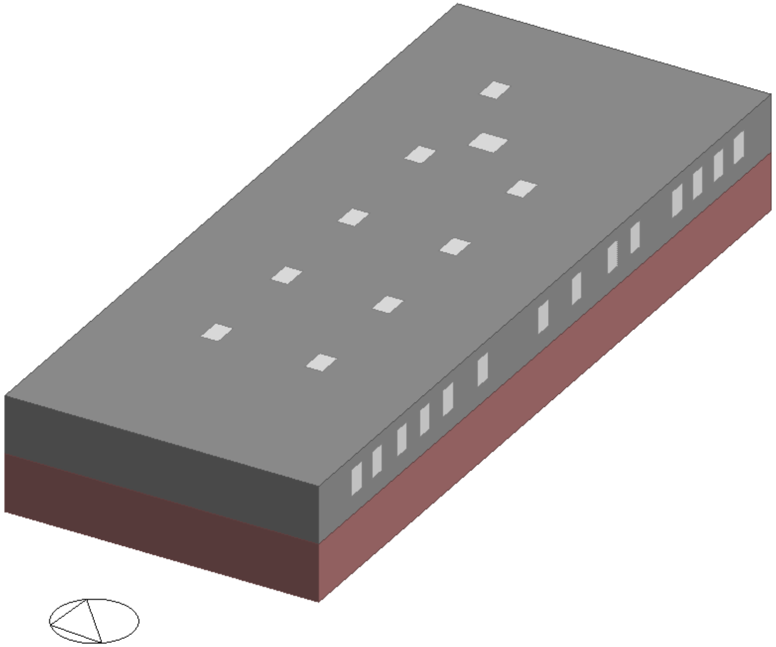
→ Existing heritage building

→ Second floor of a 2 storey building

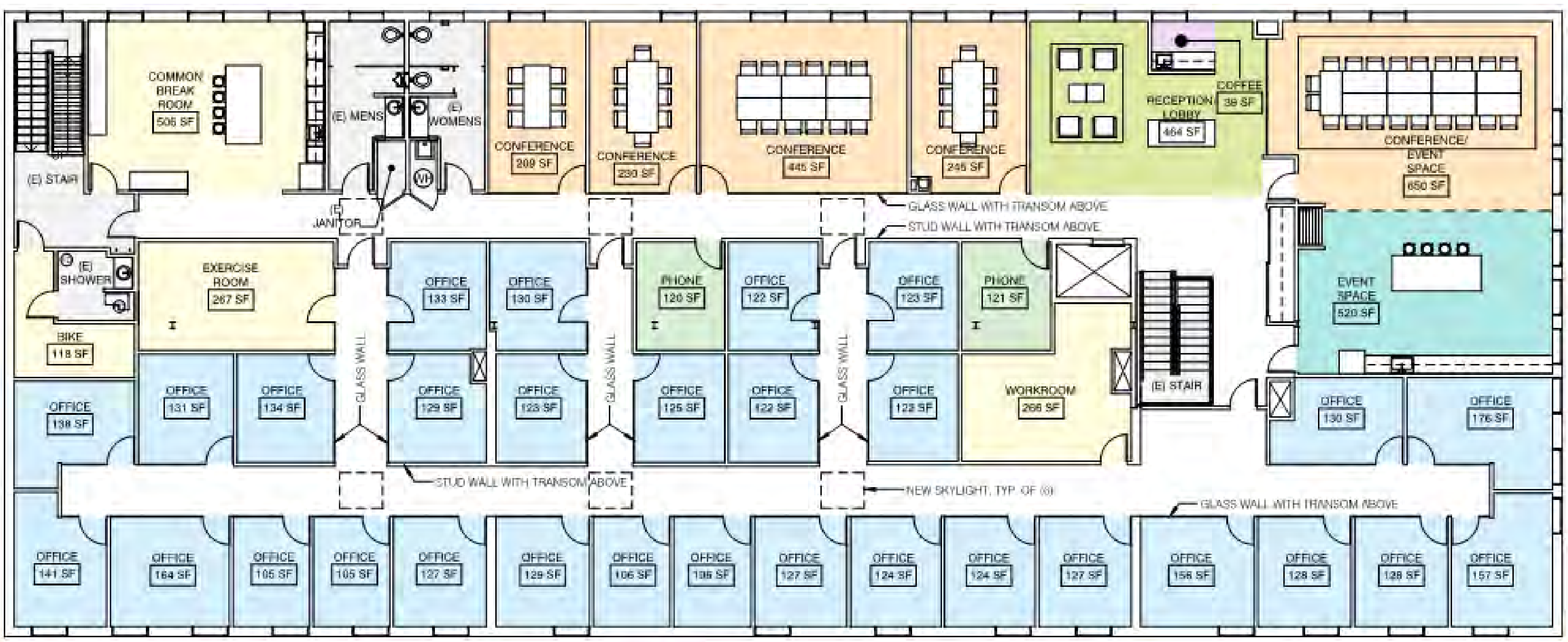
→ Private offices

→ Intermittent occupancy in meeting and conference rooms

→ Monday through Friday day time operation



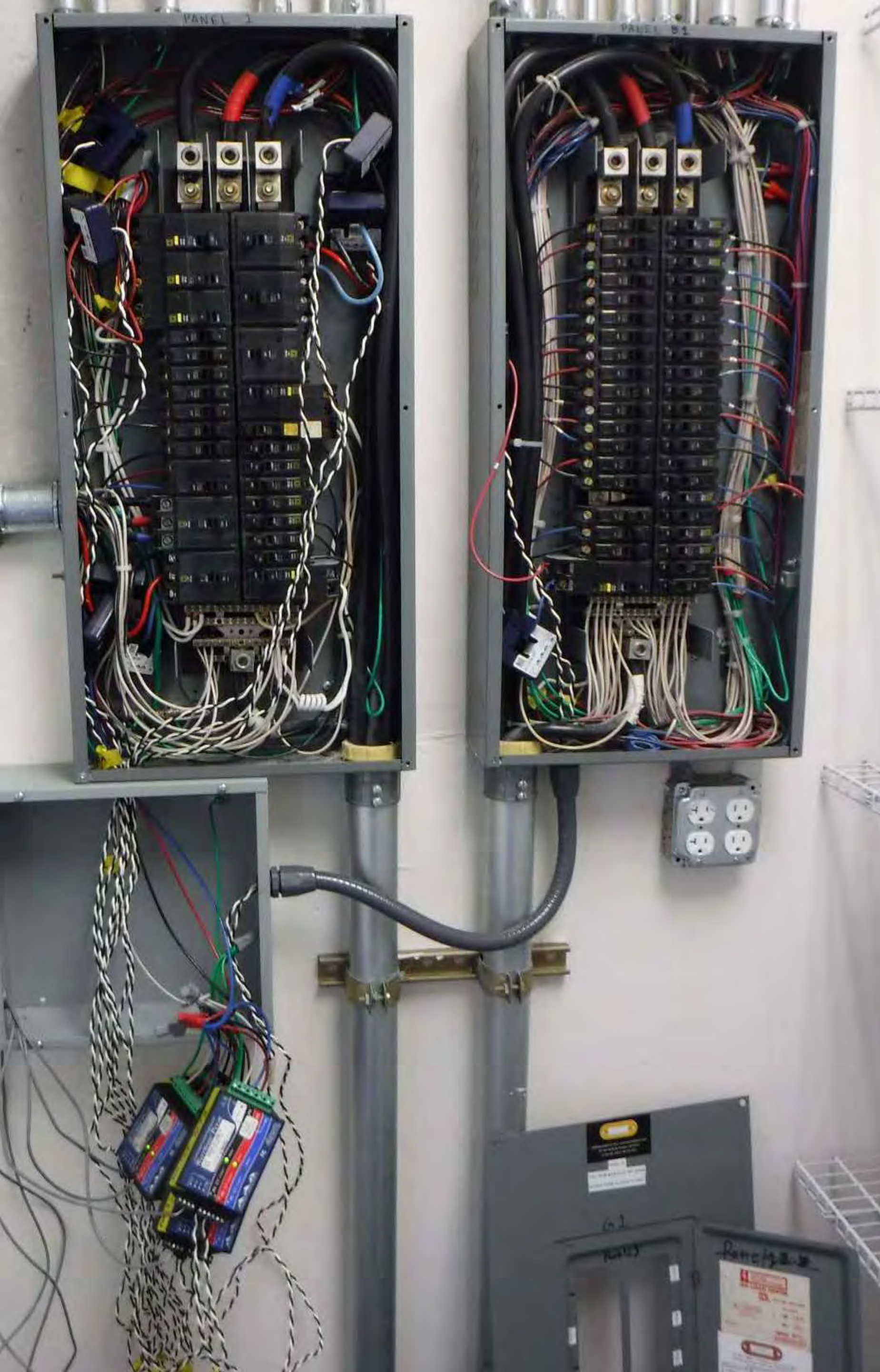
Pilot Project



Pilot Project

- **Office 1**
- Baseline
  - 9 RTUs, total 35 tons cooling, 650,000 Btu/h heating
- Conversion
  - 4 HRVs
  - 2 VRF outdoor heat pump units + 8 zone-level VRF fan coil units, 16 tons cooling, 210,000 Btu/h heating


Weathermaker
FILTER SECTION
RTU 7
AC 7
2ND FLOOR




WARNING
WARNING

Pilot Project

- → **Office 1**
- → Pre-Conversion Air Leakage Testing
  - → Air Leakage Test Result: 0.616 cfm/ft^2 at 75 Pa
    - › Air leakage noted at operable windows, HVAC dampers, and mechanical chases between floors.

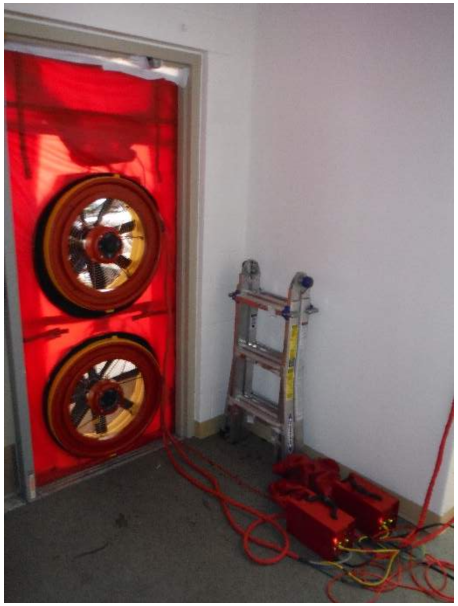


TABLE 1– SUMMARY OF AIR LEAKAGE TEST RESULTS			
Test Condition	Depressurize	Pressurize	Average
Enclosure Airtightness [cfm/ft^2@75Pa]	0.615	0.617	0.616
Equivalent Leakage Area [ft^2 @ 75Pa]	14.9	15.0	14.95
Air Changes [per Hour @ 50Pa]	5.71	5.84	5.77
Air Leakage Test Coefficient (C) [cfm/Pa^n]	1431.3	1761.1	N/A
Flow Exponent (n) [dimensionless]	0.611	0.564	N/A
Squared Correlation Coefficient (r^2) [dimensionless]	0.9964	0.9977	N/A

Pilot Project

- → **Office 1**
- → Post-Conversion Air Leakage Testing
  - → Air Leakage Test Result: 0.506 cfm/ft^2 at 75 Pa
    - › Improved air leakage between floors

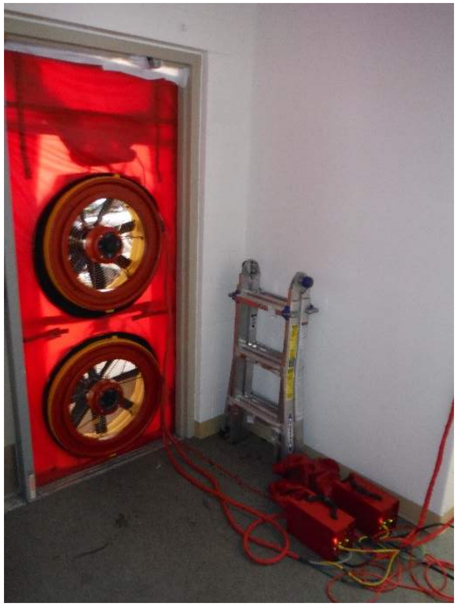


TABLE 1 – SUMMARY OF AIR LEAKAGE TEST RESULTS			
Test Condition	Depressurize	Pressurize	Average
Enclosure Airtightness [cfm/ft^2@75Pa]	0.481	0.531	0.506
Equivalent Leakage Area [ft^2 @ 75Pa]	11.87	12.72	12.30
Air Changes [per Hour @ 50Pa]	4.53	4.96	4.74
Air Leakage Test Coefficient (C) [cfm/Pa^n]	1299.4	1306.5	N/A
Flow Exponent (n) [dimensionless]	0.577	0.598	N/A
Squared Correlation Coefficient (r^2) [dimensionless]	0.9956	0.9980	N/A

Pilot Project

→ Overall Savings

- → Existing System: 56 kBtu/ft^2
- → DOAS HRV System: 19 kBtu/ft^2

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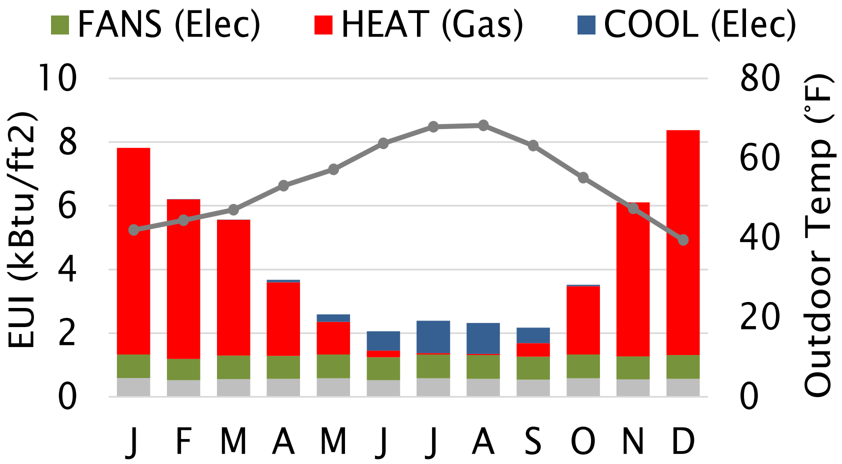
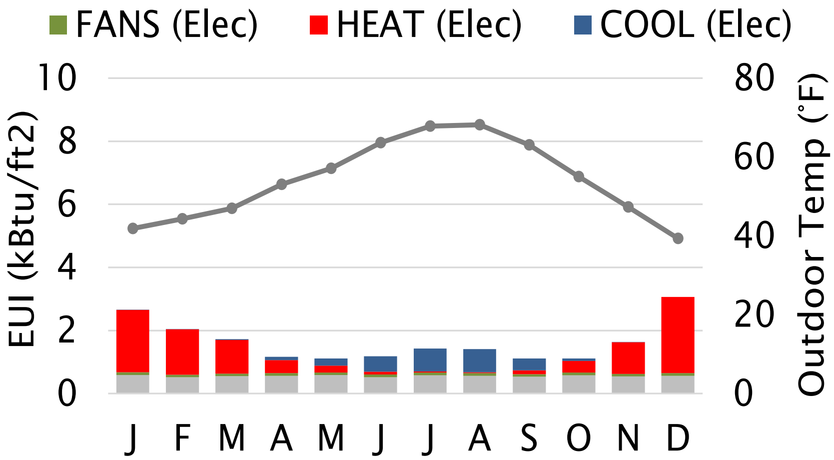
37 kBtu/ft^2

66% Total Savings

75% HVAC Savings





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→ Incremental Savings

→ New RTU System: 51 kBtu/ft²

→ DOAS HRV System: 19 kBtu/ft²

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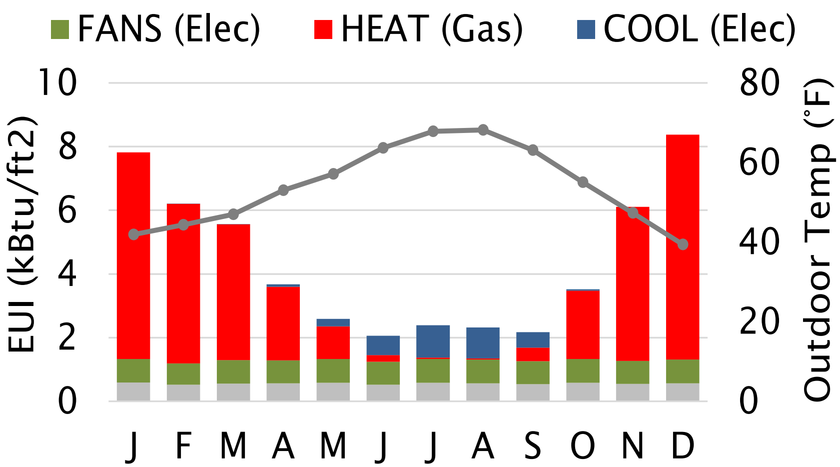
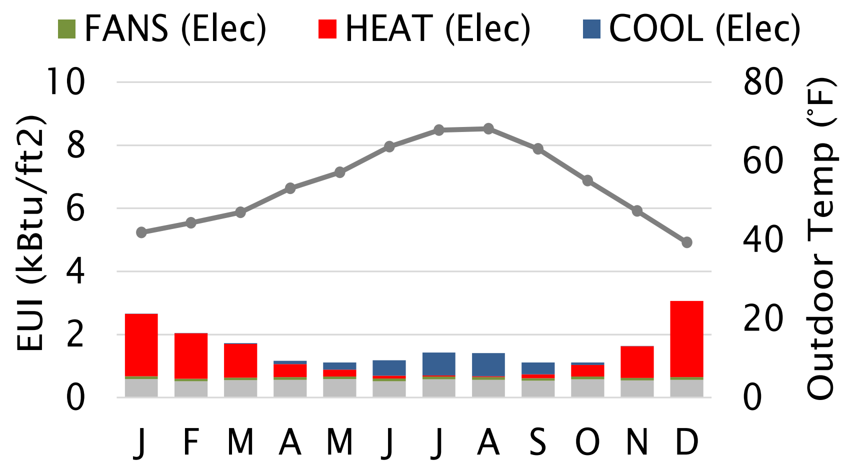
32 kBtu/ft²

63% Total Savings

72% HVAC Savings





Pilot Project

→ Incremental Savings

- → New gas-fired RTUs vs new electric heat pump RTU
- → Some utility incentive programs require electric vs electric

~70% HVAC Savings → ~40% HVAC Savings

Energy Modeling as a Tool to Quantify Savings

Energy Modeling Discussion

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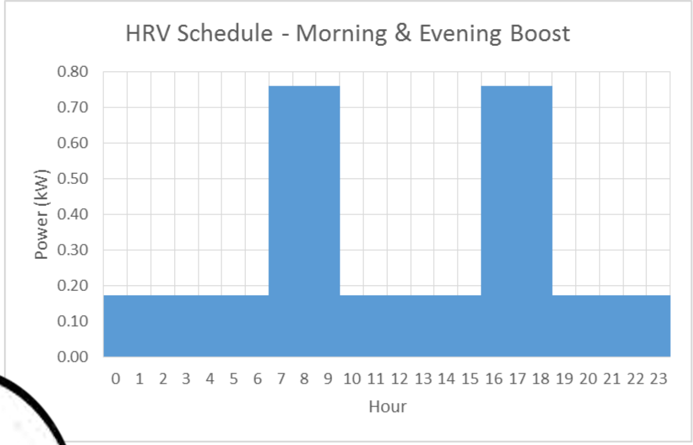
- What we learned:
  - Normal model calibration things apply
  - Low HRV fan power
  - Core bypass & economizer controls
  - VAV DOAS
  - Winter heat pump operation

  - Sidebar: Poor in-service RTU performance

Energy Modeling Discussion

→ Normal model calibration things apply



Energy Modeling Discussion

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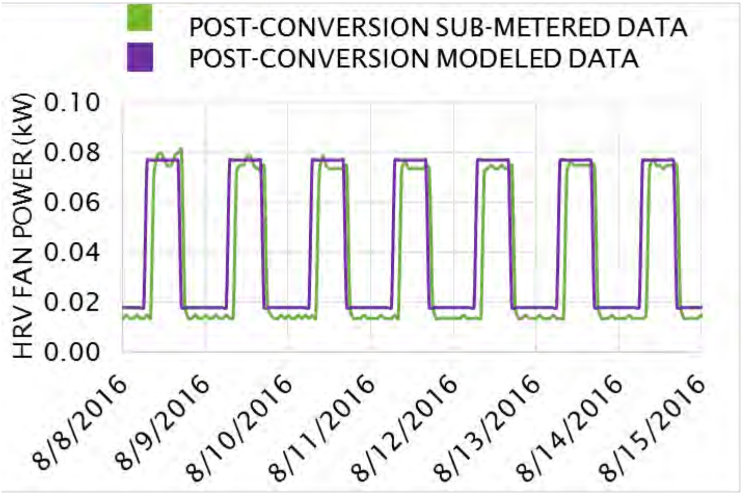
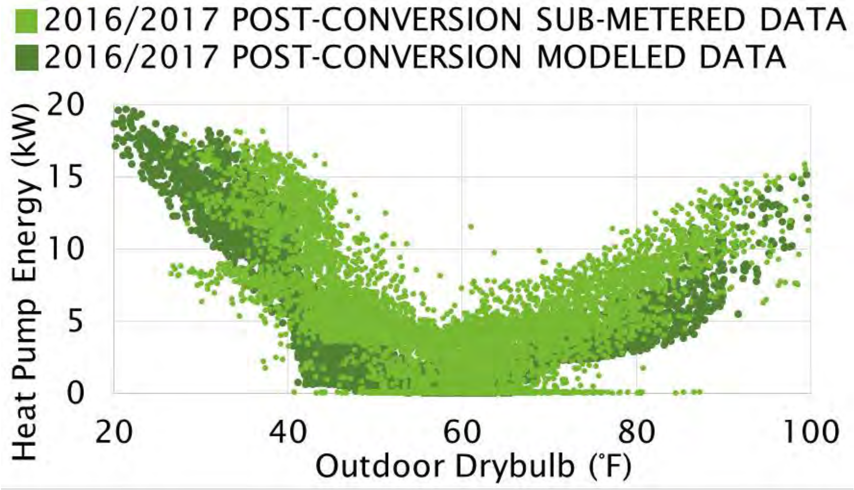
→ Monitoring data





Energy Modeling Discussion

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- → Low HRV fan power
  - → Measured HRV fan power is generally low
    - › 0.2 W/cfm to 0.6 W/cfm
  - → Fan power increases if:
    - › Complicated rooftop install
    - › Complicated downstream ductwork
    - › Downstream tempering coils (i.e. HRV "post heater")

Energy Modeling Discussion

Energy Modeling Discussion

→ Core bypass & economizer controls

- → Supply air outlet temperature control
  - › No heat recovery when it is detrimental for cooling
- → “Boost” mode operation approximated by post-process calculation
  - › Run model at HRV design flow for ventilation (say, 450 cfm)
  - › Run model at HRV “boost” flow for cooling (say, 1000 cfm)
  - › Compare hourlies and swap cooling and fan power

Energy Modeling Discussion

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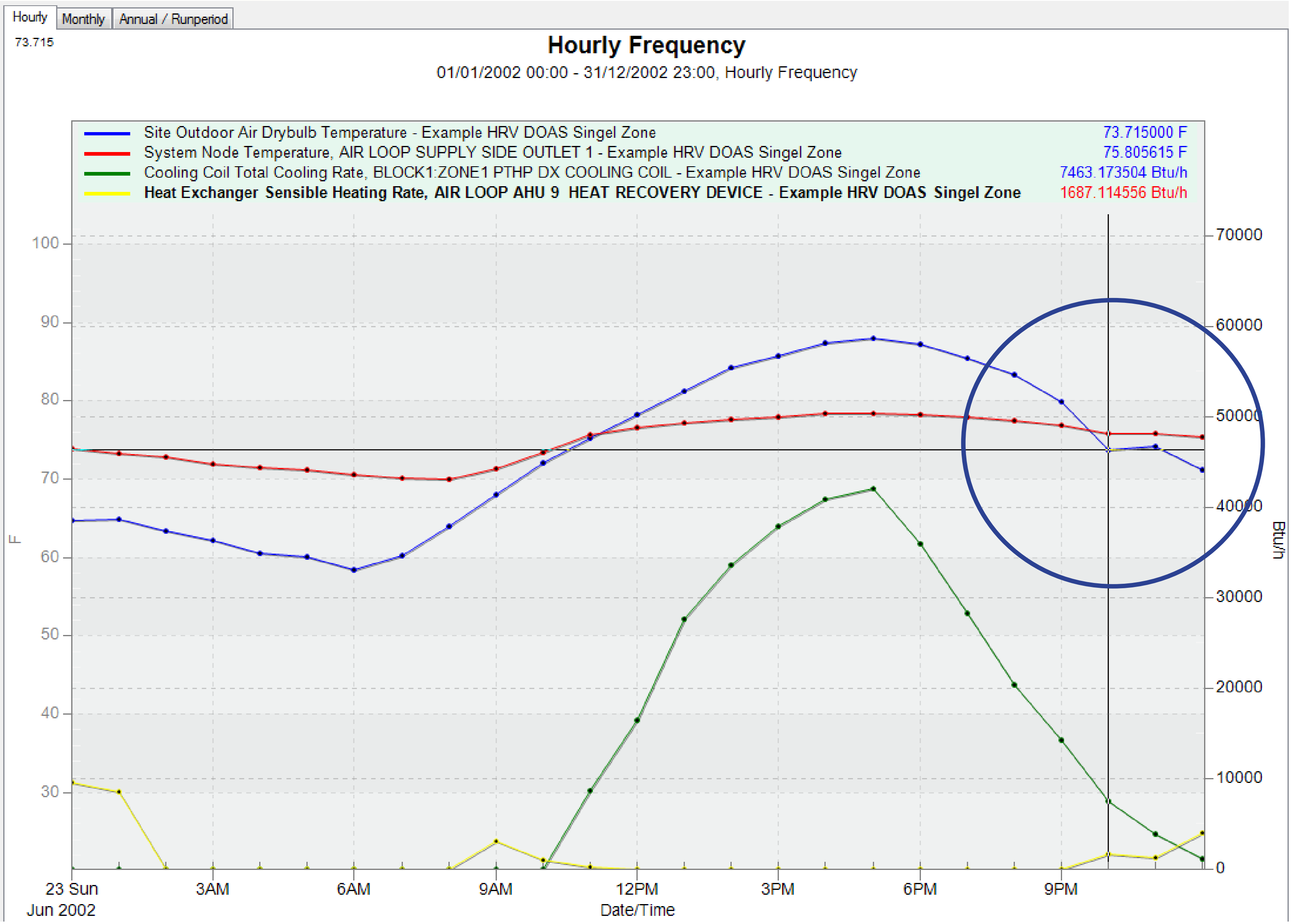
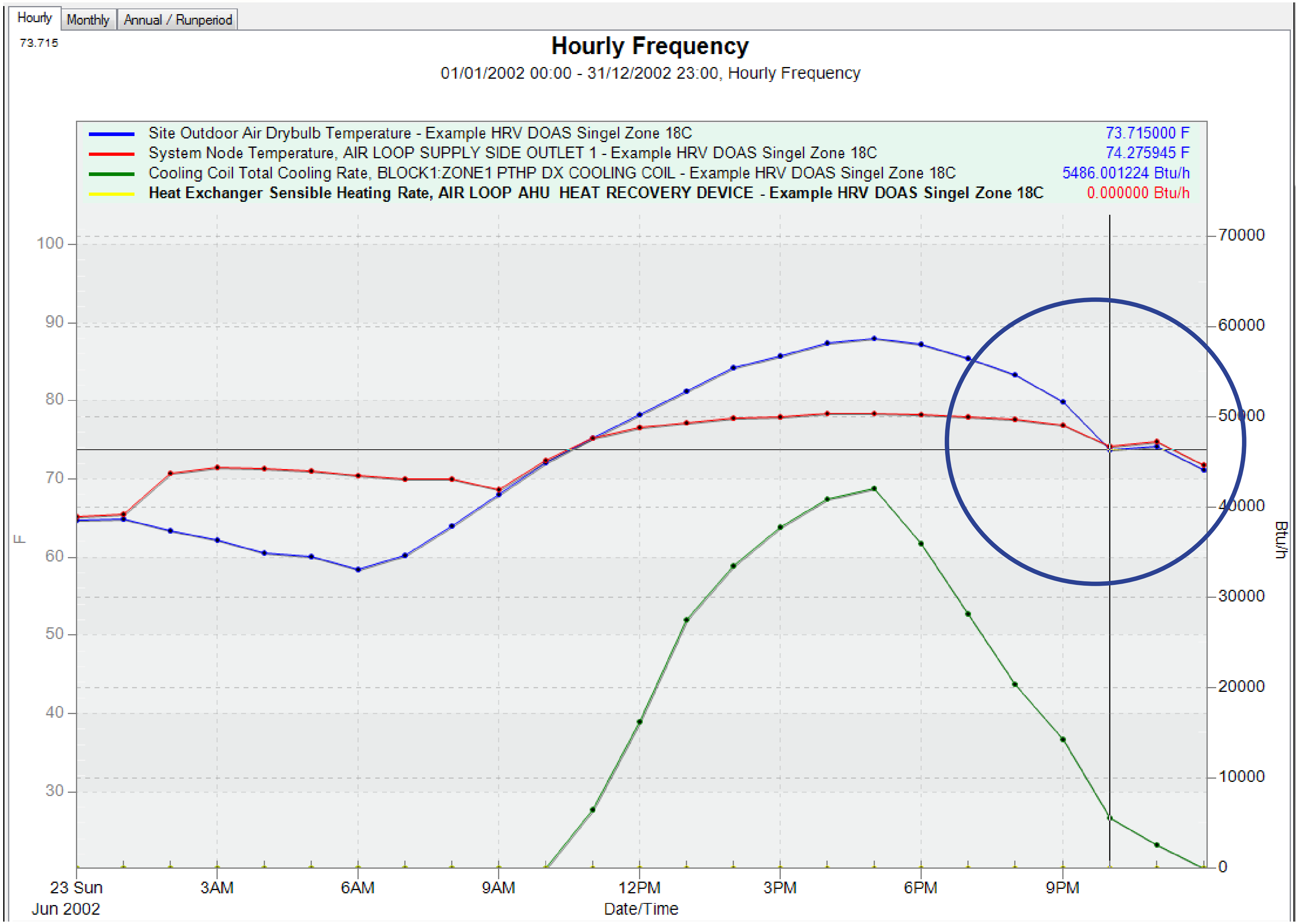
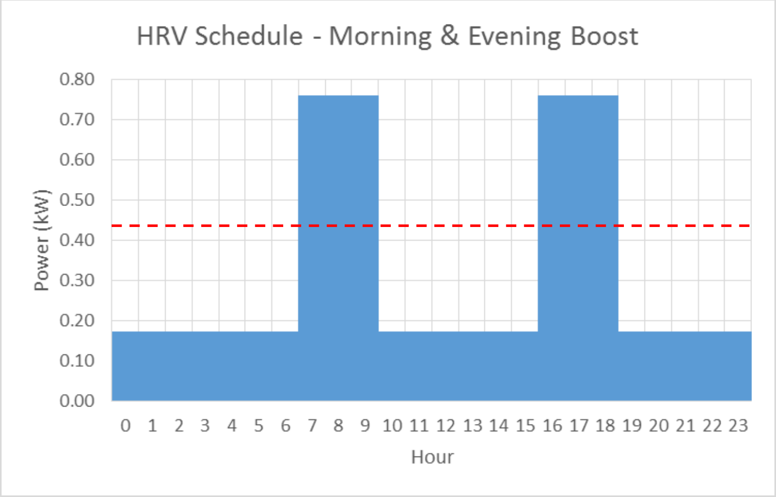


Energy Modeling Discussion



Energy Modeling Discussion

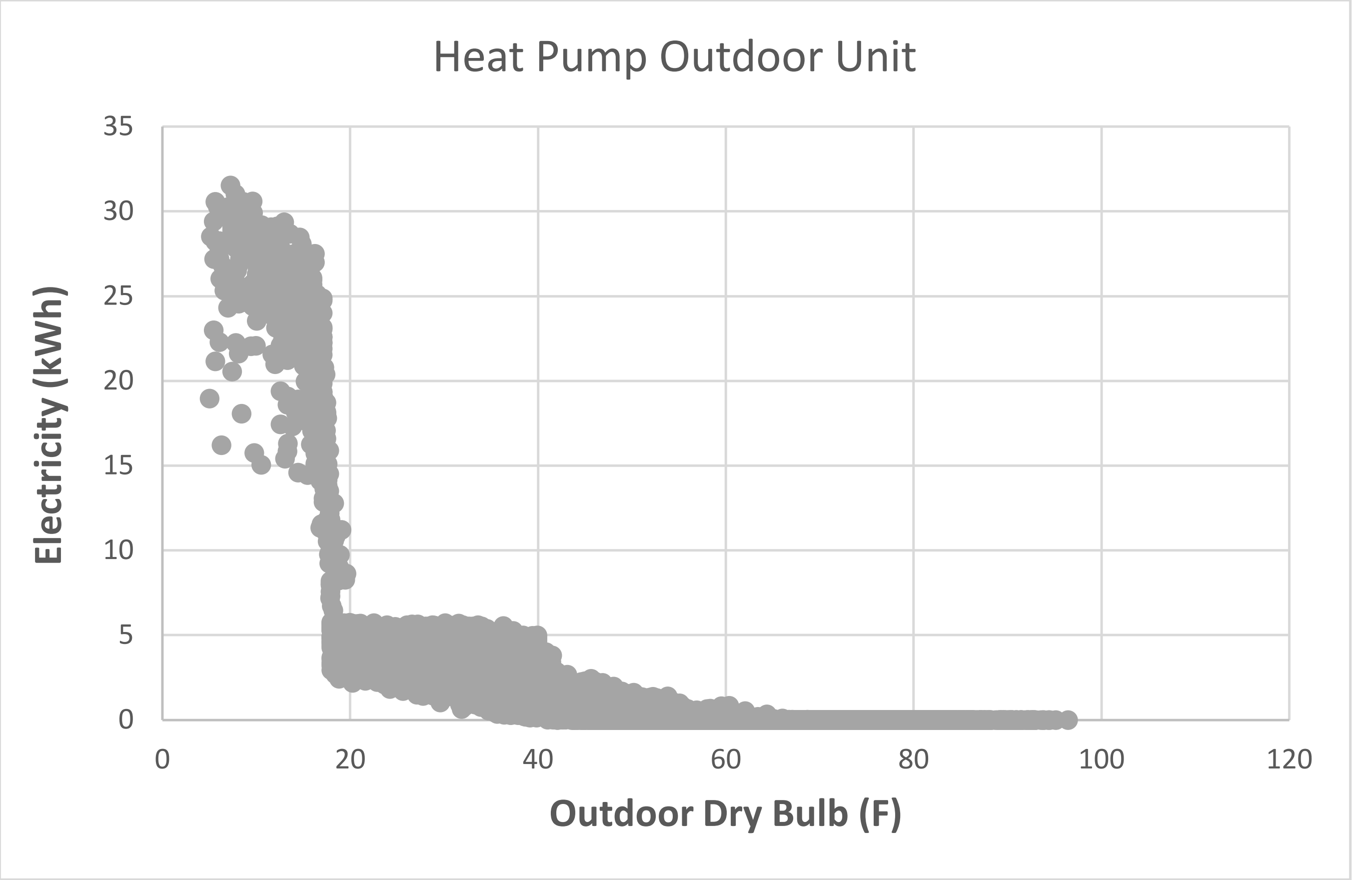
- → VAV DOAS
  - → Approximating VAV as “average” CV
  - → Consider impact on peak load



Hour	kW	cfm
0	0.17	589
1	0.17	589
2	0.17	589
3	0.17	589
4	0.17	589
5	0.17	589
6	0.17	589
7	0.76	970
8	0.76	970
9	0.76	970
10	0.17	589
11	0.17	589
12	0.17	589
13	0.17	589
14	0.17	589
15	0.17	589
16	0.76	970
17	0.76	970
18	0.76	970
19	0.17	589
20	0.17	589
21	0.17	589
22	0.17	589
23	0.17	589
	AVG	**684**

Energy Modeling Discussion

→ Winter heat pump operation



Energy Modeling Discussion

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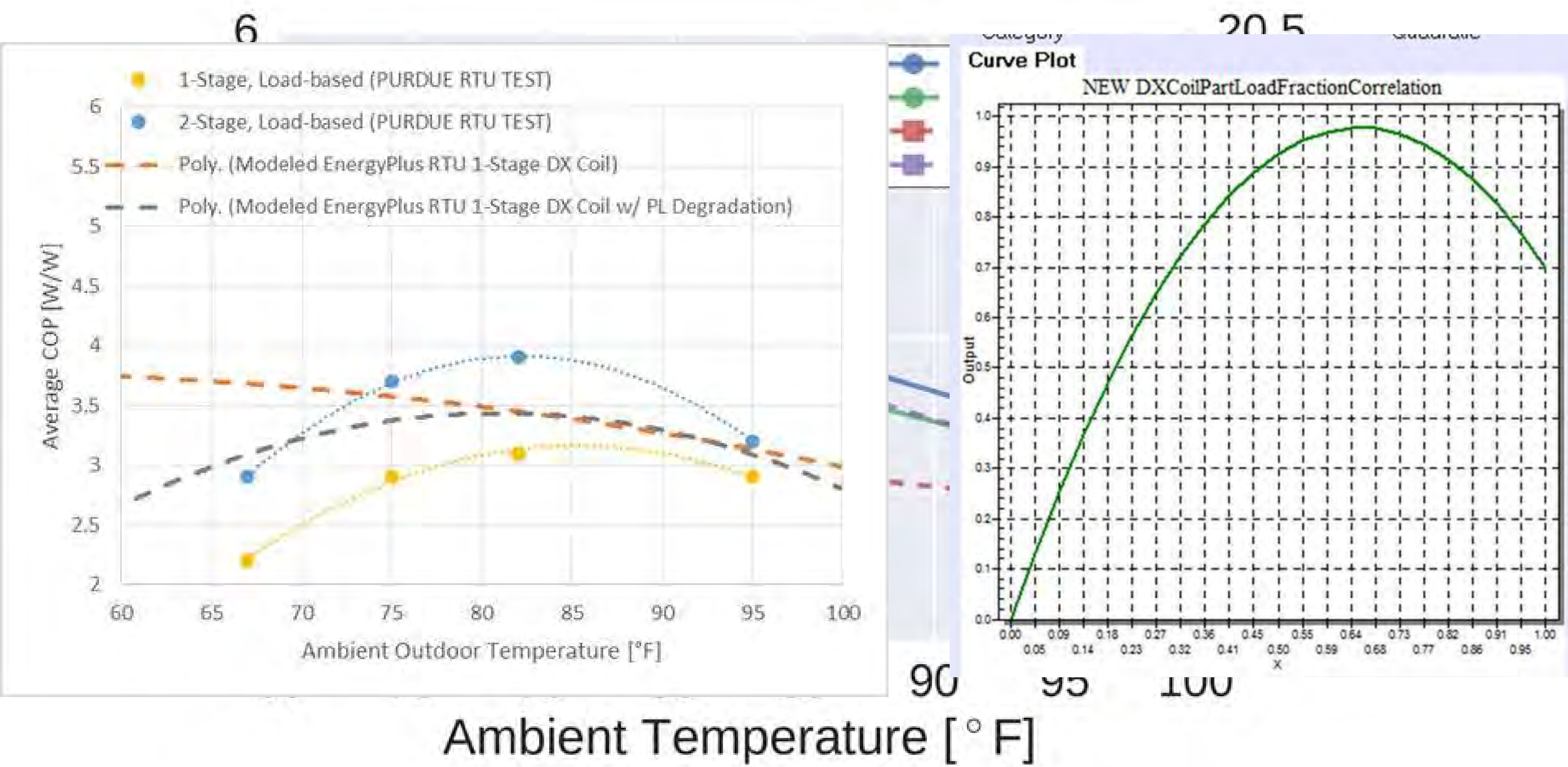
→ Sidebar: Poor in-service RTU performance



Questions

→ neea.org

→ betterbricks.com

Powerful Energy Ideas. Delivered by NEEA.

Discussion + Questions

FOR FURTHER INFORMATION PLEASE VISIT

→ rdh.com | buildingsciencelabs.com

RDH BUILDING SCIENCE

RDH Building Engineering Ltd. and Building Science Consulting Inc. have merged. Effective November 1, 2015, we now operate as one integrated firm. The merger brings two of the leading building science firms in North America together to provide a combination of cutting-edge research with leading design and implementation capabilities. The result is a unique offering for our clients–an ability to explore new and innovative ideas based on science and our practical knowledge of what can be built. We are excited about the possibilities as we launch the new firm.