HIGH PERFORMANCE VENTILATION for Commercial Buildings

BEST PRACTICES FOR PASSIVE HOUSE, NZE AND OTHER GREAT COMMERCIAL, MULTI-FAMILY AND INSTITUTIONAL PROJECTS

Presented by
Barry Stephens

28 May 2020

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

Chapter 1: High Performance Buildings

High Performance Buildings

- Energy efficient
- Durable
- Resilient
- Healthy
- Comfortable

Energy Efficient

- Highly insulated
- Superior verified air-sealing
- Thermal bridges eliminated
- Low u-value windows
- Efficient heating & AC systems
- Heat Recovery Ventilation (HRV)

Durable

- Durable long-lasting materials
- High integrity water barrier
- Verified air-sealing
- Superior workmanship
- Quality control

Resiliant

- Designed to withstand flooding
- Drought tolerant
- Buffer temperature extremes in power outage
- Operable windows
- Daylighting

Healthy

- Exceptional indoor air quality
- Source control of pollutants
- No/low VOC materials
- Daylighting
- Humidity control
- Noise reduction
- High water quality

Comfortable

- Exceptional indoor air quality
- Temperature zones and control
- Window surface temperature
- Daylighting
- Humidity control
- Noise reduction
- Aesthetic

High Performance Rating Systems

- Passive House
- LEED
- Living Building Challenge
- Well Building Standard

Side Benefits of High Performance Buildings

- Happy occupants
- Higher productivity
- Higher rent and/or lower vacancy rate
- Increased building value
- Hedged energy costs

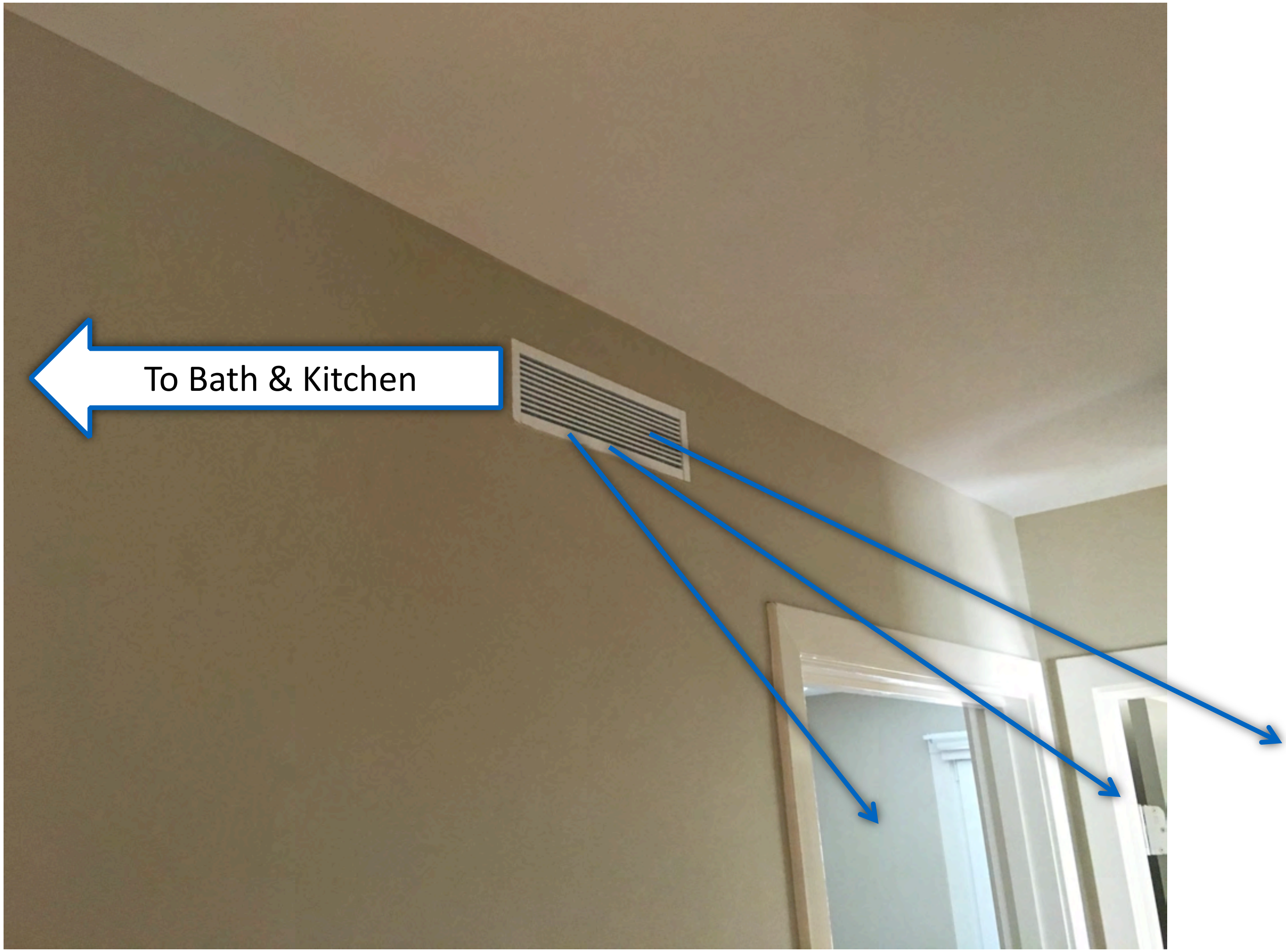
A Very Busy Roof

Plenty of Hot Air!

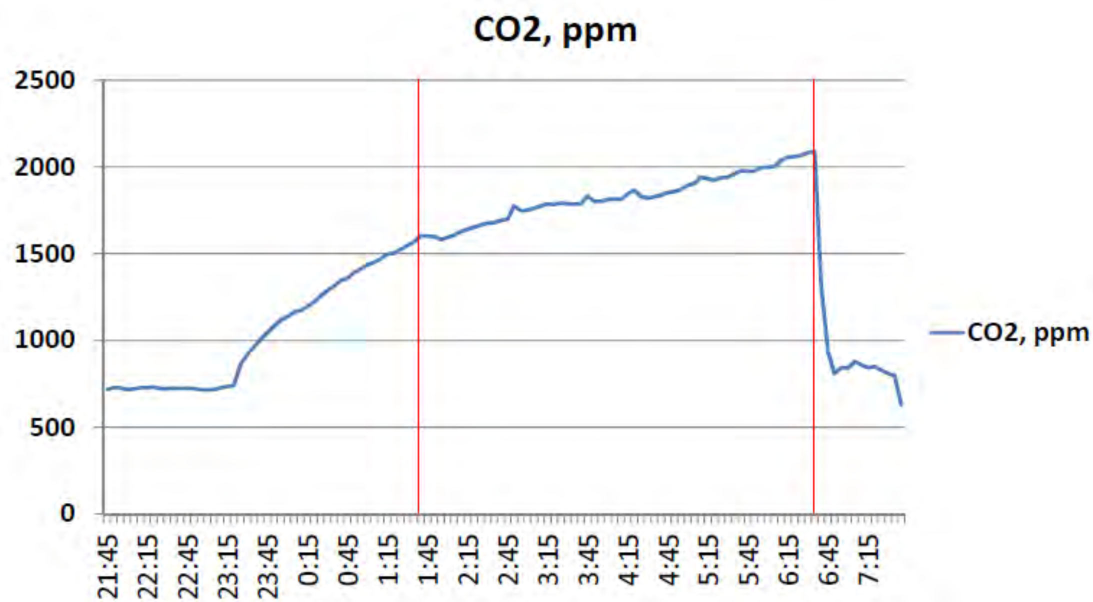
Exhaust the Kitchen (and suck up some grease)

Exhaust the Bathroom

Single Supply for Two or Three Bedrooms



Application: Multifamily Residential Traditional Design



- Bedroom occupied at 11:15 pm with door closed
- Exhaust fan turned on at 1:30 am at 88 CFM (ASHRAE 62.2 Rate for house is 62 CFM
- Exhaust fan off at 6:00 am
- Door open at 6:30 am

What is the ACH in the Bedrooms?

NOT ENOUGH!

Chapter 2: Why Ventilation Matters

Chapter 2: Why Ventilation Matters

Why Ventilate? Air is Life

For breath is life, and if you breathe well you will live long on earth. ~Sanskrit Proverb

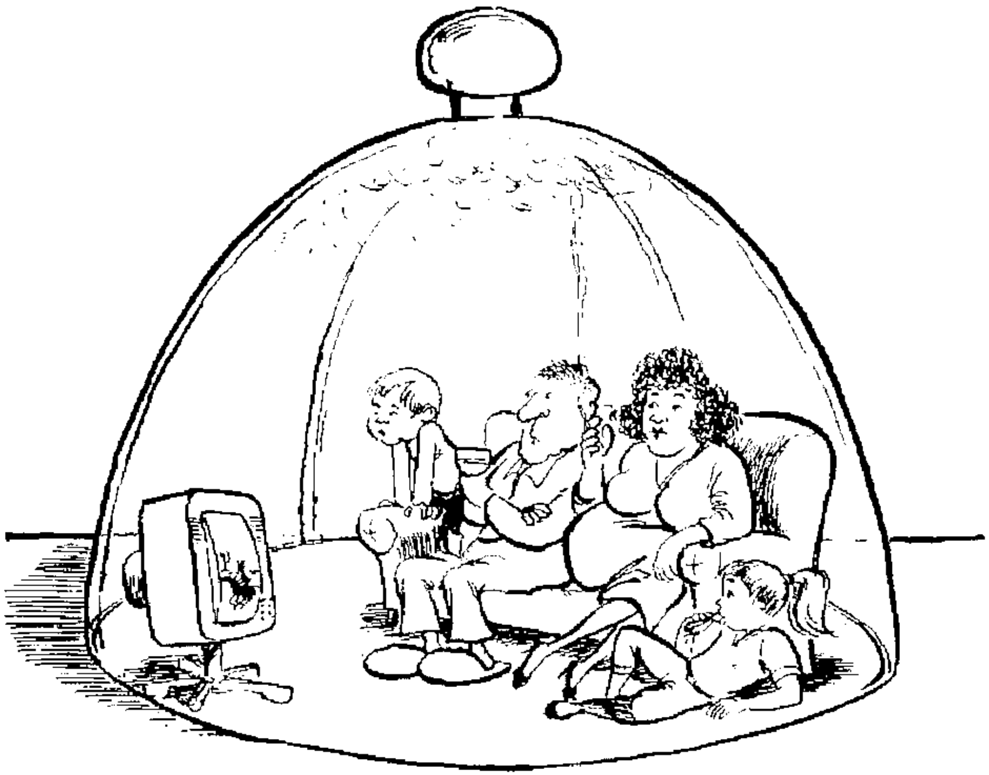
Why Ventilate? Air is Important

People can survive:

- 21 - 40+ days without food
- 4-7 days without water
- Only minutes without air!

Fresh air is critical to our health and survival

Why Ventilate? Better Indoor Environment



- Air Humidity
- CO_2 Concentration
- VOC's
- Smells
- Allergens
- Temperature

Why Ventilate? Healthier Conditions

- Lawrence Berkeley National Laboratory study of California classrooms
- Increasing ventilation from 8 CFM/student to 15 CFM/student
- Reduced sickness related absenteeism by almost 4%

Why Ventilate? Lower Risk of Virus Spread

Indoor Air 2003; 13: 237–245
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INDOOR AIR
ISSN 0905-6947

Risk of indoor airborne infection transmission estimated from carbon dioxide concentration

Abstract The Wells–Riley equation, which is used to model the risk of indoor airborne transmission of infectious diseases such as tuberculosis, is sometimes problematic because it assumes steady-state conditions and requires measurement of outdoor air supply rates, which are frequently difficult to measure and often vary with time. We derive an alternative equation that avoids these problems by determining the fraction of inhaled air that has been exhaled previously by someone in the building (rebreathed fraction) using CO_2 concentration as a marker for exhaled-breath exposure. We also derive a non-steady-state version of the Wells–Riley equation which is especially useful in poorly ventilated environments when outdoor air supply rates can be assumed constant. Finally, we derive the relationship between the average number of secondary cases infected by each primary case in a building and exposure to exhaled breath and demonstrate that there is likely to be an achievable critical rebreathed fraction of indoor air below which airborne propagation of common respiratory infections and influenza will not occur.

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Key words: Carbon dioxide; Infectious disease risk modeling; Wells–Riley equation; Basic reproductive number; Communicable disease control; Respiratory tract infections; Indoor air pollution.

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Why Ventilate? Lower Risk of Virus Spread

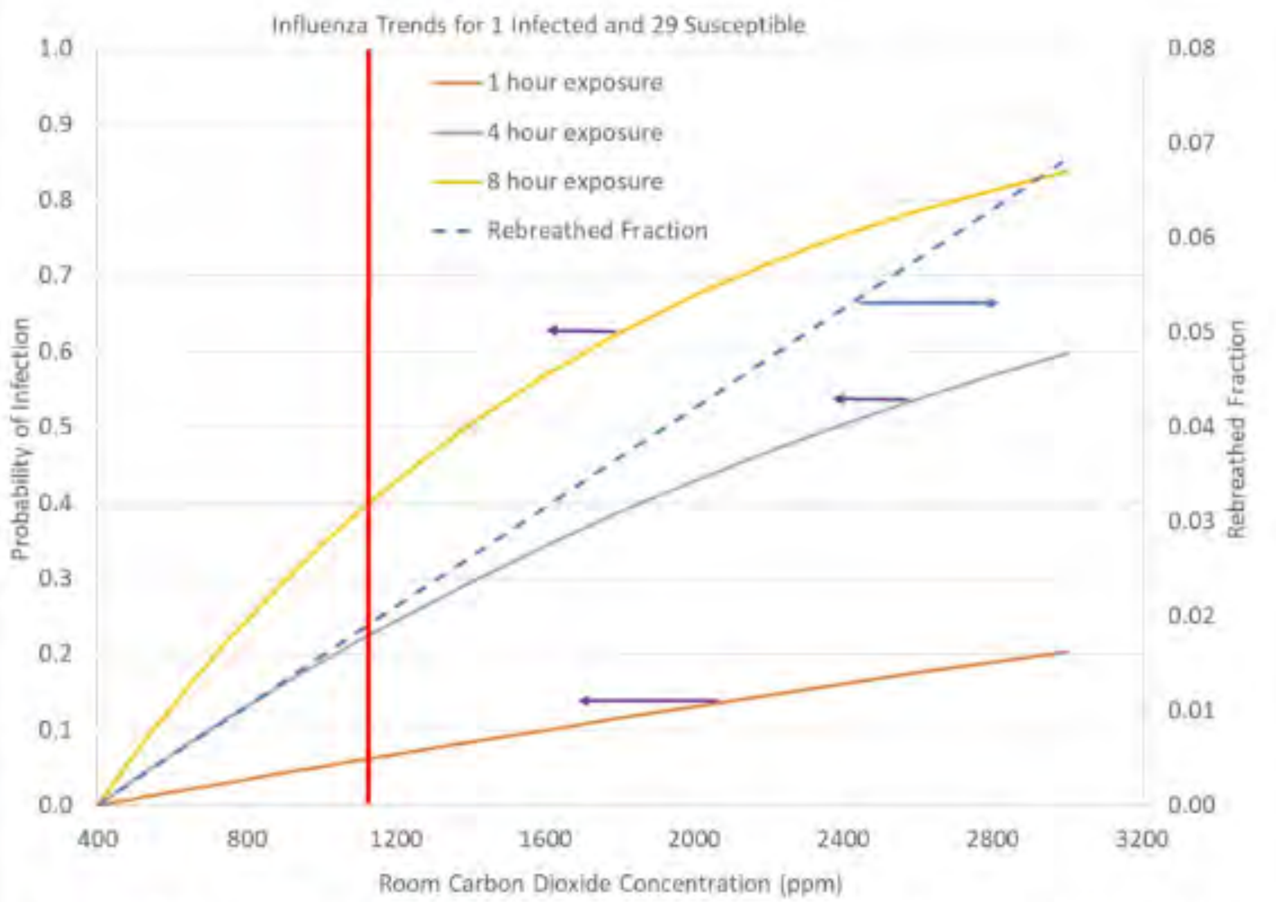


Figure 6 Probability of infection in a room with 1 infected person and 29 susceptible persons.

Evidence That Better Ventilation Provides Lower Risk For Viruses

CORONAVIRUS NEWS

Rethinking IAQ: Critical Advice from Harvard Healthy Buildings Guru

'Healthy Buildings' author Joe Allen offers insight about what the future may hold for building operations and maintenance.

APR 27, 2020

GAZETTE: Can you say more about how to specifically make a building a better barrier against the spread of coronavirus? Specifically hospitals, nursing homes, and grocery stores that are on the front lines right now.

ALLEN: You want to try to get to 100 percent outdoor air being brought into your system with no recirculated air. If you don't have a central air system, you want to open up your windows as much as you can. You want to make sure that if you are recirculating air, that it's being filtered through upgraded filters. Typically you have a MERV 8 — MERV is a rating system for filters — and those capture less than 50 percent, it could be down to 20 percent of small particles. Filters like a MERV 13 get you closer to 80 or 90 percent, or HEPA filters capture 99.97 percent of particles, so upgraded filters can be effective.

DOAS Is Better

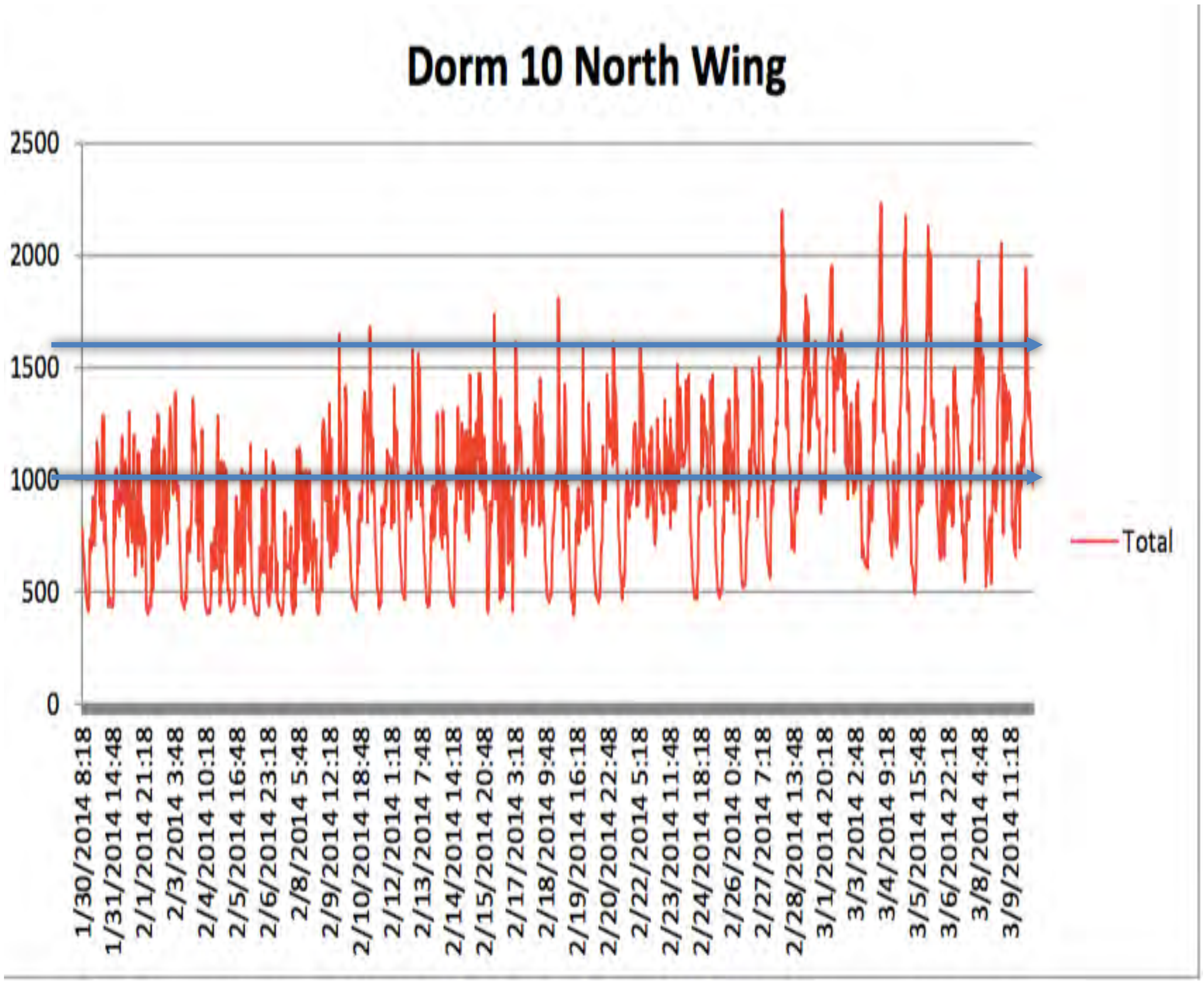
DOAS Is Better

Why Ventilate? Better Performance

- Harvard/Syracuse study of cognitive function in office workers:
- Green days 61% better
- Green+ days 101% better
- Most effected categories were ***crisis response***, ***information usage***, and ***strategy***

Retrofit For Improved IAQ

HEALTHY AND EFFICIENT



- WITHOUT PROPER VENTILATION, IAQ SUFFERS
- UNDERVENTILATING IS UNHEALTHY
- DESIGN TO OPTIMIZE

Chapter 3: Emerging Commercial Codes

Proposed Changes to the Canadian National Codes for Buildings (2017)

5.2.10.1. Heat-Energy Recovery Systems

Table 5.2.10.1.-A
Supply Fan Airflow Rate Threshold Values at which an Energy Recovery System is Required for the Exhaust Air System: NON-CONTINUOUSLY OPERATING VENTILATION SYSTEMS[(1)]
Forming Part of Sentence 5.2.10.1.(1)

Heating Degree-Days of *Building* Location,[(3)] in Celcius Degree-Days	Percentage of Outdoor Air at Design Airflow Conditions							
	≥ 10% and < 20%	≥ 20 and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
	Design Supply Fan Airflow Rate Threshold Values,[(2)] L/s							
Zone 4:[(4)] < 3000	NR	NR	NR	NR	NR	NR	NR	NR
Zone 5:[(4)] 3000 to 3999	≥ 12 270	≥ 7 550	≥ 2 600	≥ 2 120	≥ 1 650	≥ 940	≥ 470	R
Zone 6:[(4)] 4000 to 4999	≥ 12 270	≥ 7 550	≥ 2 600	≥ 2 120	≥ 1 650	≥ 940	≥ 470	R
Zones 7A and 7B:[(4)] 5000 to 6999	≥ 2 120	≥ 1 890	≥ 1 180	≥ 470	R	R	R	R
Zone 8:[(4)] ≥ 7000	≥ 2 120	≥ 1 890	≥ 1 180	≥ 470	R	R	R	R

Notes to Table 5.2.10.1.-A:

(1) Ventilation systems that operate less than 8 000 hours per year are considered "non-continously operating."

(2) NR = energy recovery system is not required at any design supply fan airflow rate
R = energy recovery system is required at all design supply fan airflow rates

(3) See Sentence 1.1.4.1.(1).

(4) See Note A-Table 3.2.2.2.

Proposed Changes to the Canadian National Codes for Buildings (2017)

5.2.10.1. Heat-Energy Recovery Systems

Table 5.2.10.1.-B
Supply Fan Airflow Rate Threshold Values at which an Energy Recovery System is Required for the Exhaust Air System: CONTINUOUSLY OPERATING VENTILATION SYSTEMS[1]
Forming Part of Sentence 5.2.10.1.(1)

Heating Degree-Days of *Building* Location,[3] in Celcius Degree-Days	Percentage of Outdoor Air at Design Airflow Conditions							
	≥ 10% and < 20%	≥ 20 and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
	Design Supply Fan Airflow Rate Threshold Values,[2] L/s							
Zone 4:[4] < 3000	NR	≥ 9 200	≥ 4 250	≥ 2 360	≥ 1 890	≥ 1420	≥ 710	R
All other zones:[4] ≥ 3000	R	R	R	R	R	R	R	R

Notes to Table 5.2.10.1.-B:

(1) Ventilation systems that operate 8 000 hours or more per year are considered "continously operating."
(2) NR = energy recovery system is not required at any design supply fan airflow rate
R = energy recovery system is required at all design supply fan airflow rates
(3) See Sentence 1.1.4.1.(1).
(4) See Note A-Table 3.2.2.2.

Adopted Washington State Commercial Mechanical Code 1 July 2018

TABLE C403.3.5
OCCUPANCY CLASSIFICATIONS REQUIRING DOAS

Occupancy Classification[a]	Inclusions	Exempted
A-1	All occupancies not specifically exempted	Television and radio studios
A-2	Casinos (gaming area)	All other A-2 occupancies
A-3	Lecture halls, community halls, exhibition halls, gymnasiums, courtrooms, libraries, places of religious worship	All other A-3 occupancies
A-4, A-5		All occupancies excluded
B	All occupancies not specifically exempted	Food processing establishments including commercial kitchens, restaurants, cafeterias; laboratories for testing and research; data processing facilities and telephone exchanges; air traffic control towers; animal hospitals, kennels, pounds; ambulatory care facilities.
F, H, I, R, S, U		All occupancies excluded
E, M	All occupancies included	

a. Occupancy classification from the *International Building Code* Chapter 3.

C403.3.5.1 Energy recovery ventilation with DOAS. The DOAS shall include *energy recovery ventilation*. The energy recovery system shall have a 60 percent minimum sensible recovery effectiveness or have 50 percent enthalpy recovery effectiveness in accordance with Section C403.7.6.1. For DOAS having a total fan system motor nameplate hp less than 5 hp, total combined fan power shall not exceed 1 W/cfm of outdoor air. For DOAS having a total fan system motor hp greater than or equal to 5 hp, refer to fan power limitations of Section C403.8.1. This fan power restriction applies to each dedicated outdoor air unit in the permitted project, but does not include the fan power associated with the zonal heating/cooling equipment. The airflow rate thresholds for energy recovery requirements in Tables C403.7.6.1(1) and C403.7.6.1(2) do not apply.

Exceptions:

1. Occupied spaces with all of the following characteristics: complying with Section C403.7.6.1, served by equipment less than 5000 cfm, with an average occupant load greater than 25 people per 1000 square feet (93 m^2) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) that include demand control ventilation configured to reduce outdoor air by at least 50% below design minimum ventilation rates when the actual occupancy of the space served by the system is less than the design occupancy.
2. Systems installed for the sole purpose of providing makeup air for systems exhausting toxic, flammable, paint, or corrosive fumes or dust, dryer exhaust, or commercial kitchen hoods used for collecting and removing grease vapors and smoke.

Adopted Washington State
Commercial Mechanical Code 1 July 2018

SECTION C406
EFFICIENCY PACKAGES

C406.1 Additional energy efficiency credit requirements. New buildings and changes in space conditioning, change of occupancy and building additions in accordance with Chapter 5 shall comply with sufficient packages from Table C406.1 so as to achieve a minimum number of six credits. Each area shall be permitted to apply for different packages provided all areas in the building comply with the requirement for six credits. Areas included in the same permit within mixed use buildings shall be permitted to demonstrate compliance by an area weighted average number of credits by building occupancy achieving a minimum number of six credits.

EFFICIENCY PACKAGE CREDITS

Code Section	Commercial Building Occupancy					
	Group R-1	Group R-2	Group B	Group E	Group M	All Other
	Additional Efficiency Credits					
1. More efficient HVAC performance in accordance with Section C406.2	2.0	3.0	3.0	2.0	1.0	2.0
2. Reduced lighting power: Option 1 in accordance with Section C406.3.1	1.0	1.0	2.0	2.0	3.0	2.0
3. Reduced lighting power: Option 2 in accordance with Section C406.3.2[a]	2.0	3.0	4.0	4.0	5.0	4.0
4. Enhanced lighting controls in accordance with Section C406.4	NA	NA	1.0	1.0	1.0	1.0
5. On-site supply of renewable energy in accordance with C406.5	3.0	3.0	3.0	3.0	3.0	3.0
6. Dedicated outdoor air system in accordance with Section C406.6	4.0	4.0	4.0	NA	NA	4.0
High performance dedicated outdoor air system in accordance with Section C406.7	4.0	4.0	4.0	4.0	4.0	4.0
heating in accordance with Sections C406.8.1 and C406.8.2	4.0	5.0	NA	NA	NA	8.0
9. High performance service water heating in multi-family buildings in accordance with Section C406.9	7.0	8.0	NA	NA	NA	NA
10. Enhanced envelope performance in accordance with Section C406.10[c]	3.0	6.0	3.0	3.0	3.0	4.0
11. Reduced air infiltration in accordance with Section C406.11[c]	1.0	2.0	1.0	1.0	1.0	1.0
12. Enhanced commercial kitchen equipment in accordance with Section C406.12	5.0	NA	NA	NA	5.0	5.0 (Group A-2 only)

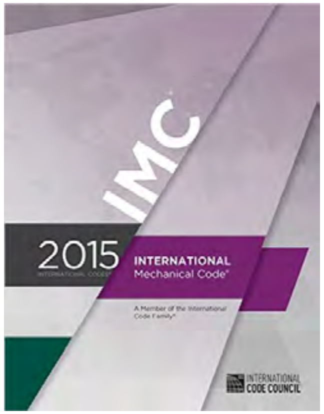
a. Projects using this option may not use Item 2.
b. This option is not available to buildings subject to the prescriptive requirements of Section C403.3.5.
c. Buildings or building areas that are exempt from thermal envelope requirements in accordance with Sections C402.1.1 and C402.1.2 do not qualify for this package.

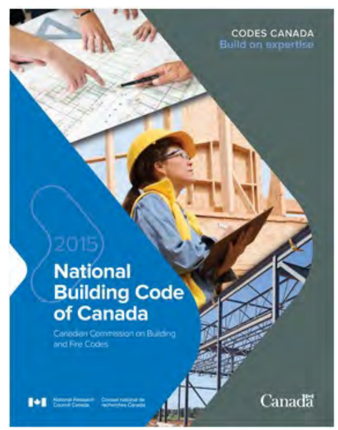
Adopted Washington State Commercial Mechanical Code 1 July 2018

C406.7 High performance dedicated outdoor air system (DOAS). A whole building, building addition or tenant space which includes a DOAS complying with Section C406.6 shall also provide minimum sensible effectiveness of heat recovery of 80 percent and DOAS total combined fan power less than 0.5 W/cfm of outdoor air. For the purposes of this section, total combined fan power includes all supply, exhaust, recirculation and other fans utilized for the purpose of ventilation.

Chapter 4: Ventilation Requirements

How Much Ventilation is Needed?



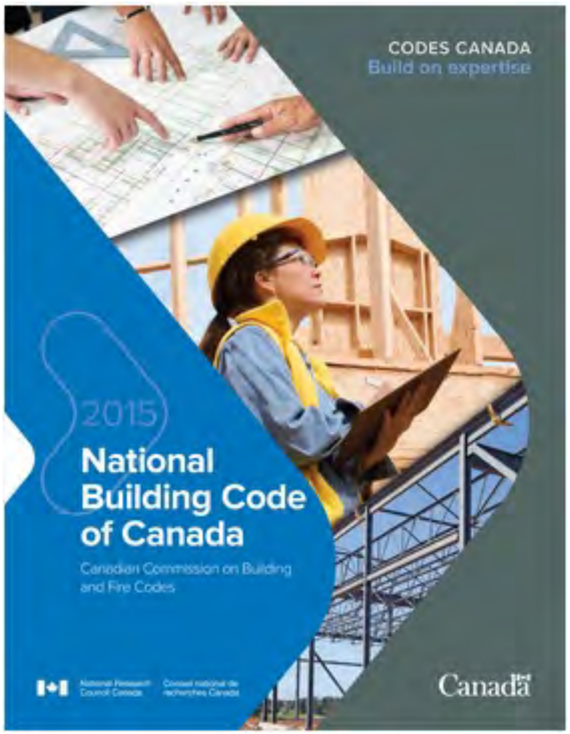


- International Mechanical Code (IMC)
- ASHRAE 62.1
- Passive House
- National Building Code of Canada

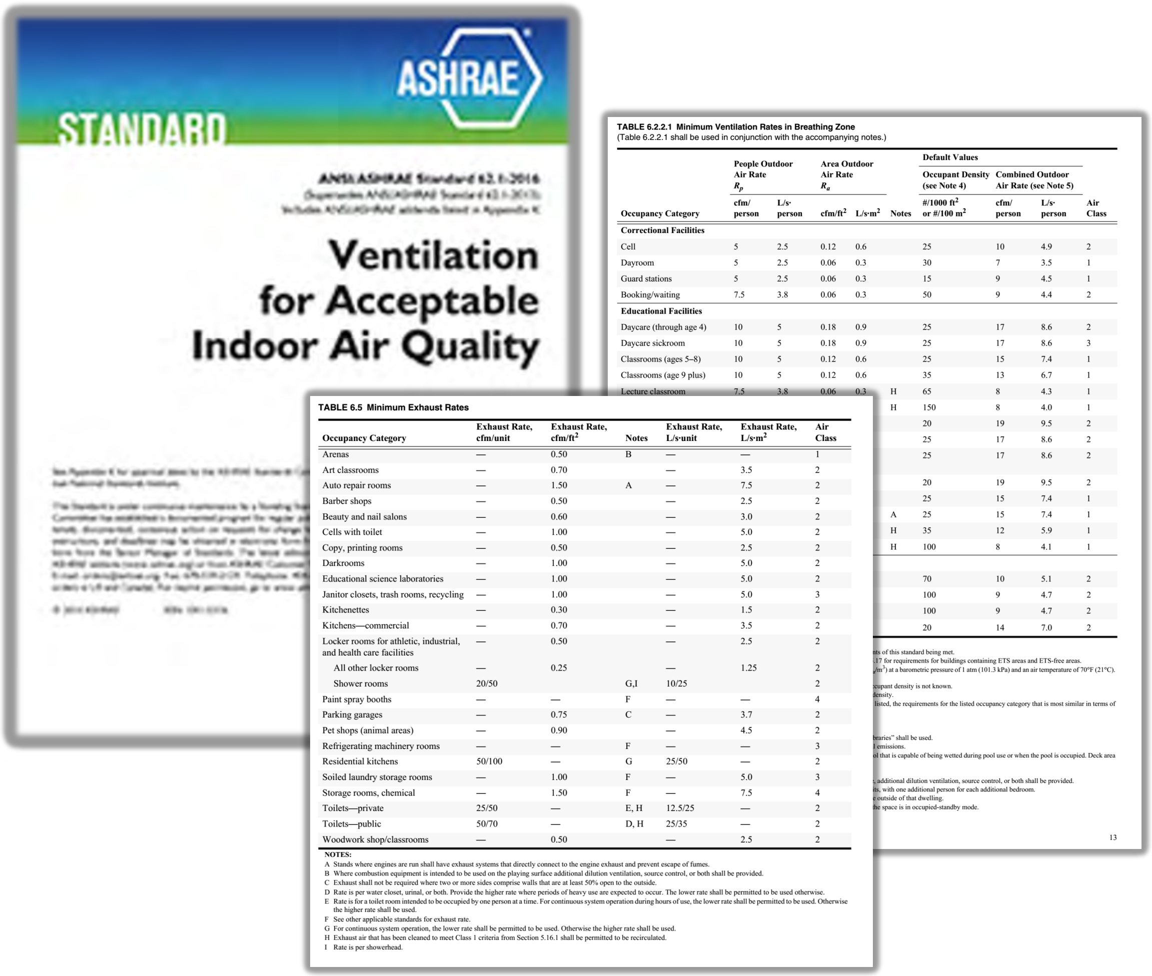
How much Ventilation is needed?
2015 National Building Code of Canada

[T]he rates at which outdoor air is supplied in *buildings* by ventilation systems shall be not less than the rates required by *ANSI/ASHRAE 62, "Ventilation for Acceptable Indoor Air Quality"*

- National Building Code of Canada
- References ASHRAE 62.1 for flow rates



How Much Ventilation is Needed?
ASHRAE Standard 62.1 2016



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.1-2016

Ventilation for Acceptable Indoor Air Quality

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p cfm/person	People Outdoor Air Rate R_p L/s·person	Area Outdoor Air Rate R_a cfm/ft²	Area Outdoor Air Rate R_a L/s·m²	Notes	Default Values: Occupant Density (see Note 4) #/1000 ft² or #/100 m²	Default Values: Combined Outdoor Air Rate (see Note 5) cfm/person	Default Values: Combined Outdoor Air Rate (see Note 5) L/s·person	Air Class
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3	H	65	8	4.3	1
					H	150	8	4.0	1
						20	19	9.5	2
						25	17	8.6	2
						25	17	8.6	2
						20	19	9.5	2
						25	15	7.4	1
					A	25	15	7.4	1
					H	35	12	5.9	1
					H	100	8	4.1	1
						70	10	5.1	2
						100	9	4.7	2
						100	9	4.7	2
						20	14	7.0	2

TABLE 6.5 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft²	Notes	Exhaust Rate, L/s·unit	Exhaust Rate, L/s·m²	Air Class
Arenas	—	0.50	B	—	—	1
Art classrooms	—	0.70		—	3.5	2
Auto repair rooms	—	1.50	A	—	7.5	2
Barber shops	—	0.50		—	2.5	2
Beauty and nail salons	—	0.60		—	3.0	2
Cells with toilet	—	1.00		—	5.0	2
Copy, printing rooms	—	0.50		—	2.5	2
Darkrooms	—	1.00		—	5.0	2
Educational science laboratories	—	1.00		—	5.0	2
Janitor closets, trash rooms, recycling	—	1.00		—	5.0	3
Kitchenettes	—	0.30		—	1.5	2
Kitchens—commercial	—	0.70		—	3.5	2
Locker rooms for athletic, industrial, and health care facilities	—	0.50		—	2.5	2
All other locker rooms	—	0.25		—	1.25	2
Shower rooms	20/50		G,I	10/25		2
Paint spray booths	—	—	F	—	—	4
Parking garages	—	0.75	C	—	3.7	2
Pet shops (animal areas)	—	0.90		—	4.5	2
Refrigerating machinery rooms	—	—	F	—	—	3
Residential kitchens	50/100	—	G	25/50	—	2
Soiled laundry storage rooms	—	1.00	F	—	5.0	3
Storage rooms, chemical	—	1.50	F	—	7.5	4
Toilets—private	25/50	—	E, H	12.5/25	—	2
Toilets—public	50/70	—	D, H	25/35	—	2
Woodwork shop/classrooms	—	0.50		—	2.5	2

NOTES:
A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B Where combustion equipment is intended to be used on the playing surface additional dilution ventilation, source control, or both shall be provided.
C Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.
D Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.
E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during hours of use, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
F See other applicable standards for exhaust rate.
G For continuous system operation, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
H Exhaust air that has been cleaned to meet Class 1 criteria from Section 5.16.1 shall be permitted to be recirculated.
I Rate is per showerhead.

- Table 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
- Table 6.5 Minimum Exhaust Rates

How Much Ventilation is Needed?
ASHRAE Standard 62.1 – Table 6.2.2.1

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a			Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		
Occupancy Category	**cfm/ person**	**L/s· person**	**cfm/ft^2**	**L/s·m^2**	**Notes**	**#/1000 ft^2 or #/100 m^2**	**cfm/ person**	**L/s· person**	**Air Class**
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3	H	65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3	H	150	8	4.0	1

- People Outdoor Air Rate
- Area Outdoor Air Rate
- Default Occupancy
- Air Class

$V_{bz} = (R_p \times P_z) + (R_a \times A_z)$

Zone Airflow = (People Rate x Number People) + (Area Rate x Area)

How Much Ventilation is Needed?
ASHRAE Standard 62.1 – Table 6.2.2.2

TABLE 6.2.2.2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level (See Note 6)	1.0
Floor supply of cool air and ceiling return, provided that the vertical throw is greater than 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) or more above the floor	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification, or underfloor air distribution systems where the vertical throw is less than or equal to 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust, return, or both.	0.8
Makeup supply drawn in near to the exhaust, return, or both locations.	0.5

$V_{oz} = V_{bz}/0.8 = 1.25V_{bz}$

25% Increase!

$V_{oz} = V_{bz}/E_z$

$$\text{Outdoor Airflow} = \frac{\text{Zone Airflow}}{\text{Effectiveness}}$$

- Zone Air Distribution Effectiveness
- Amount of outdoor airflow depends upon distribution configuration
- Cool air supply by DOAS system minimizes amount of outside air required

How Much Ventilation is Needed?
ASHRAE Standard 62.1 – Table 6.5

TABLE 6.5 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft^2	Notes	Exhaust Rate, L/s·unit	Exhaust Rate, $L/s \cdot m^2$	Air Class
Arenas	—	0.50	B	—	—	1
Art classrooms	—	0.70		—	3.5	2
Auto repair rooms	—	1.50	A	—	7.5	2
Barber shops	—	0.50		—	2.5	2
Beauty and nail salons	—	0.60		—	3.0	2
Cells with toilet	—	1.00		—	5.0	2
Copy, printing rooms	—	0.50		—	2.5	2
Darkrooms	—	1.00		—	5.0	2
Educational science laboratories	—	1.00		—	5.0	2
Janitor closets, trash rooms, recycling	—	1.00		—	5.0	3
Residential kitchens	50/100	—	G	25/50	—	2
Soiled laundry storage rooms	—	1.00	F	—	5.0	3
Storage rooms, chemical	—	1.50	F	—	7.5	4
Toilets—private	25/50	—	E, H	12.5/25	—	2
Toilets—public	50/70	—	D, H	25/35	—	2
Woodwork shop/classrooms	—	0.50		—	2.5	2

NOTES:

A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B Where combustion equipment is intended to be used on the playing surface additional dilution ventilation, source control, or both shall be provided.
C Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.
D Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.
E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during hours of use, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
F See other applicable standards for exhaust rate.
G For continuous system operation, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
H Exhaust air that has been cleaned to meet Class 1 criteria from Section 5.16.1 shall be permitted to be recirculated.
I Rate is per showerhead.

- Exhaust Rate per Unit
- Exhaust Rate per Area
- Air Class
- Private Toilets: single toilet
- Public Toilets: multiple toilets

How Much Ventilation is Needed?
Passive House Institute

Passive House Institute

Passive House Non-Residential Air Flow Rate Guidelines			
	Rate [CFM/P]	Rate [CMH/P]	Note
Schools	9 to 12	15 to 20	CO_2 limit between 1200 -1500 PPM
Office	18	30	
Gymnasium	36	60	Demand control recommended

- Very little prescriptive rates available
- Generally follow code/ASHRAE requirements.
- Demand control whenever feasible to minimize airflow to meet occupancy

How Much Ventilation is Needed?
Other High-Performance Standards

LEED
LEARDERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

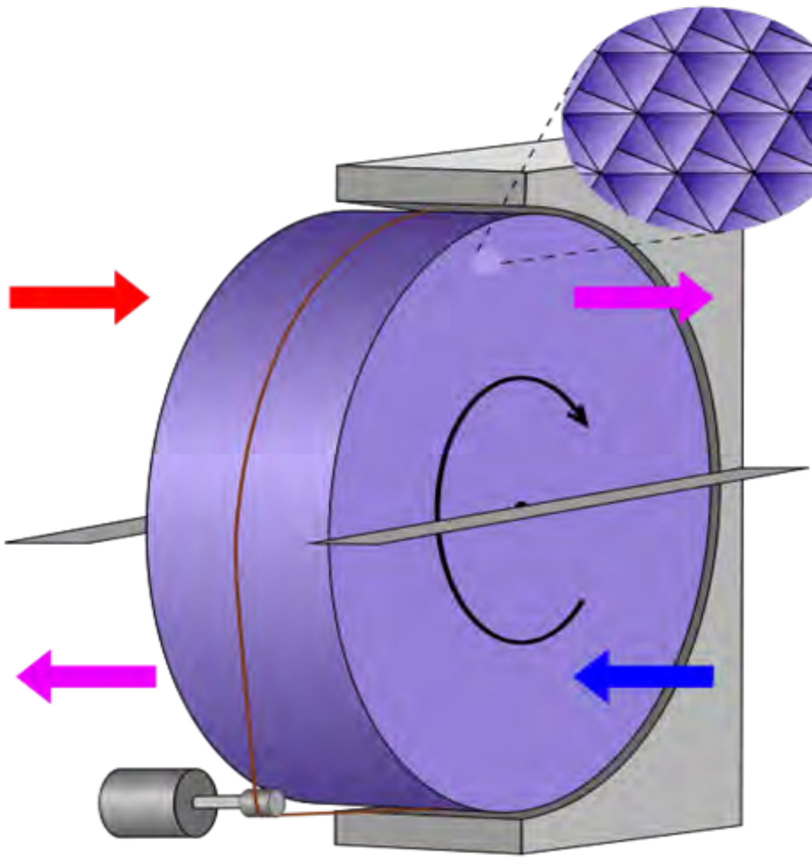
LIVING BUILDING CHALLENGE

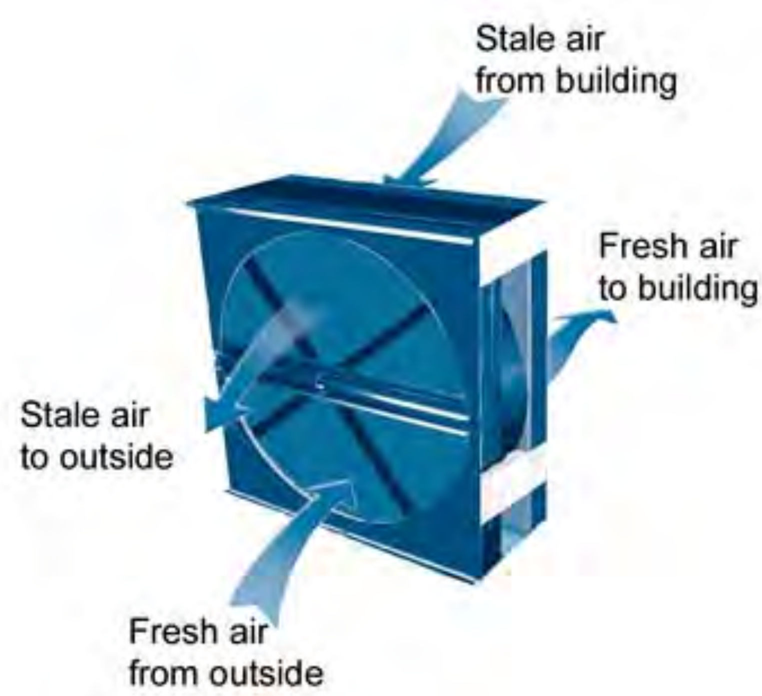
INTERNATIONAL WELL BUILDING INSTITUTE

- All these standards reference ASHRAE 62.1
- LEED and Well Building Standard offer points for 30% higher airflow than ASHRAE 62.1

Chapter 5: What's In The Box?

Enthalpy Wheel ERV





Ventilation in the Age of COVID-19

CIBSE JOURNAL

NEWS CIBSE NEWS TECHNICAL CPD JOBS CASE S

Preventing Covid-19 spreading in buildings

In response to the coronavirus pandemic, REHVA experts have published a guidance document on how to operate and use building services to minimise the spread of Covid-19. Alex Smith provides a summary of their findings

Posted in March 2020

Increase air supply and exhaust ventilation

The general advice is to supply as much outside air as possible. Expanded operation times are recommended for buildings with mechanical ventilation. Consider keeping the ventilation on 24/7 with lower ventilation rates when people are absent.

If employee numbers reduce, do not place remaining staff in smaller areas.
Exhaust ventilation systems of toilets should always be left on 24/7, and relatively negative pressure must be maintained in the room air to help avoid faecal-oral transmission.

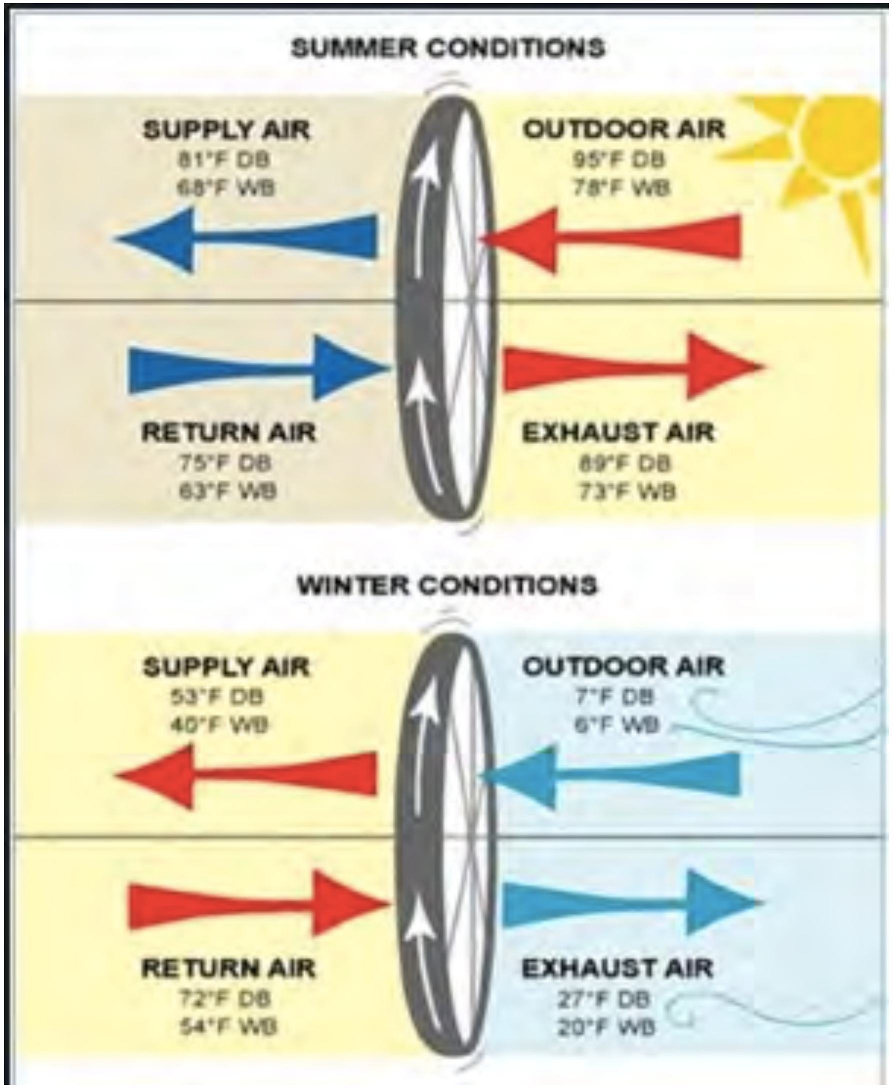
Ventilation in the Age of COVID-19

Safe use of heat-recovery devices

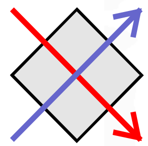
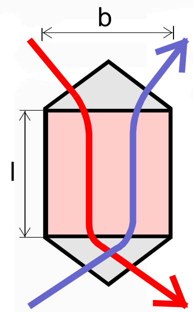
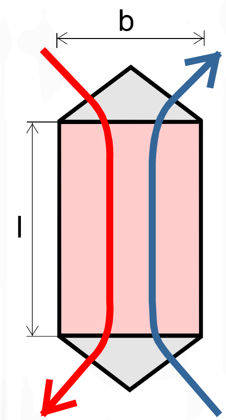
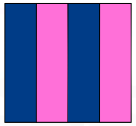
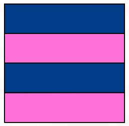
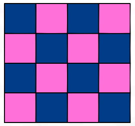
Virus particles in extract air can re-enter the building. Heat-recovery devices may carry over the virus attached to particles from the exhaust airside to the supply airside via leaks. In rotary heat exchangers (including enthalpy wheels) particles deposit on the return airside of the heat exchanger surface, after which they might be resuspended when the heat exchanger turns to the supply airside.

Based on current evidence, REHVA recommends turning off rotary heat exchangers temporarily during SARS-CoV-2 episodes. Its document goes on to state: if leaks are suspected in the heat-recovery sections, pressure adjustment or bypassing can be an option to avoid a situation where higher pressure on the extract side causes air leakages to the supply side.

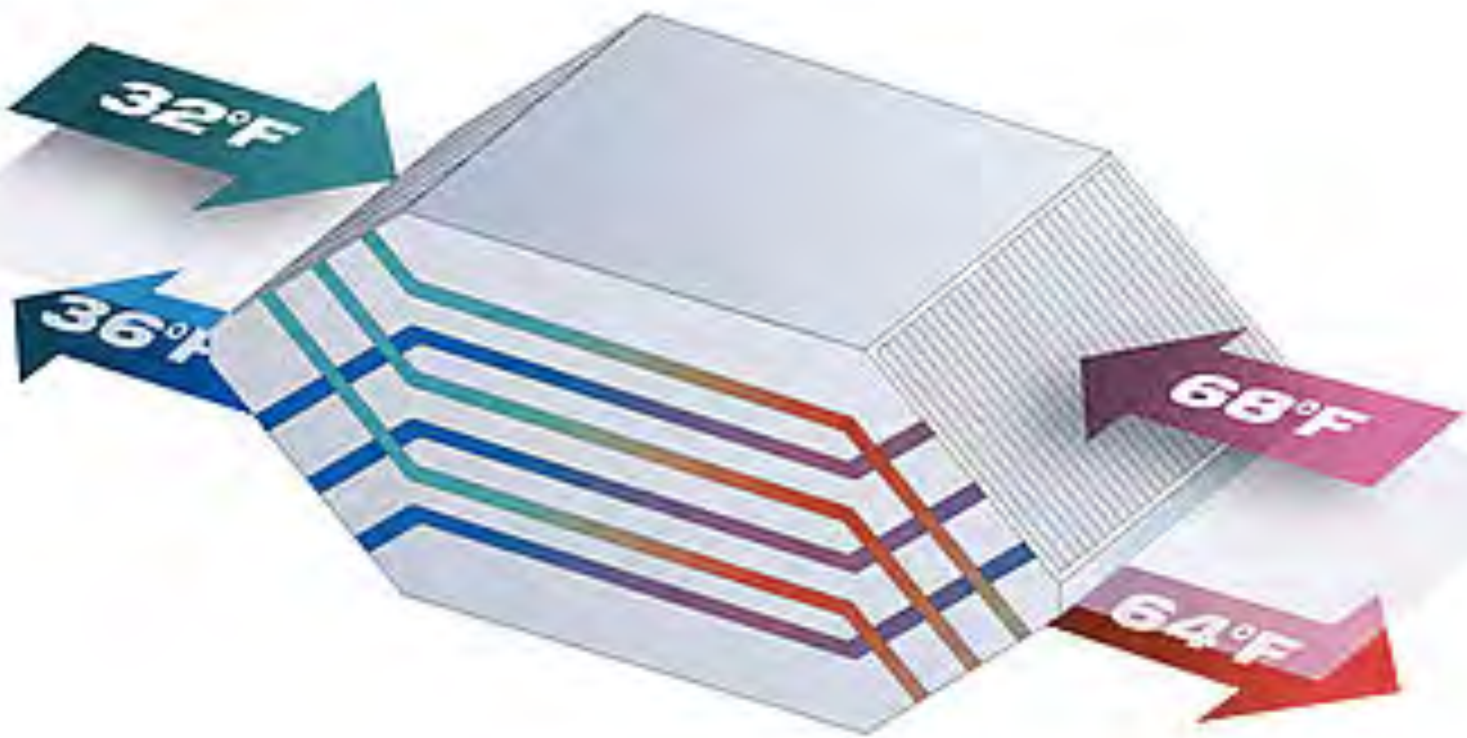
Enthalpy Wheel ERV



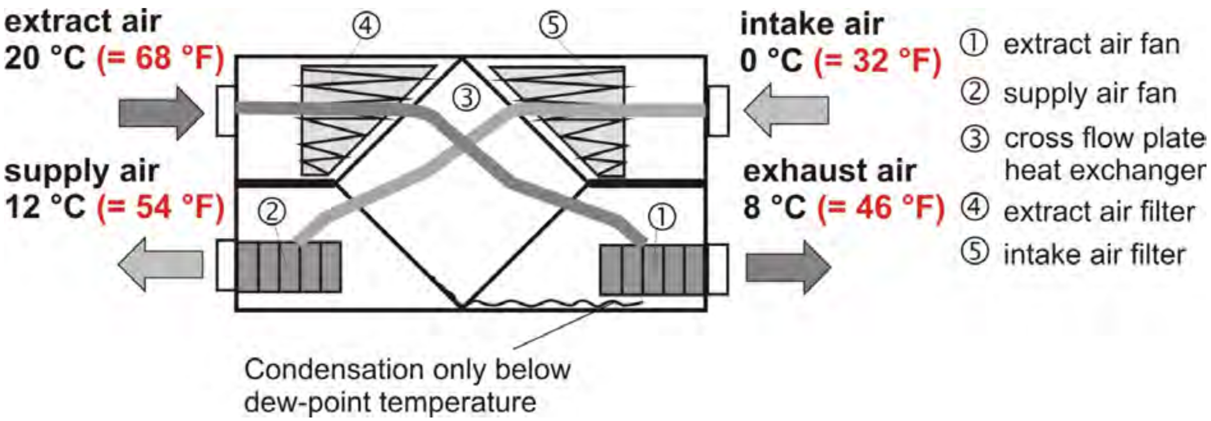
Options for H/ERV Cores

Schematic diagram				cross flow counter flow
	cross flow heat exchanger	cross counter flow heat exchanger	counter flow heat exchanger	
heat exchanger surface [m²] [ft²]	4 – 10 0,4 – 0,9	6 – 14 0,6 – 1,3	17 – 60 1,6 – 5,6	
flow profile				
heat recovery [%] effective like in PHPP	50 – 70	70 – 80	85 – 99 (92)	

High Efficiency Counter-Flow Heat Exchanger



Cross-Flow Heat Exchanger



Counter-Flow Heat Exchanger

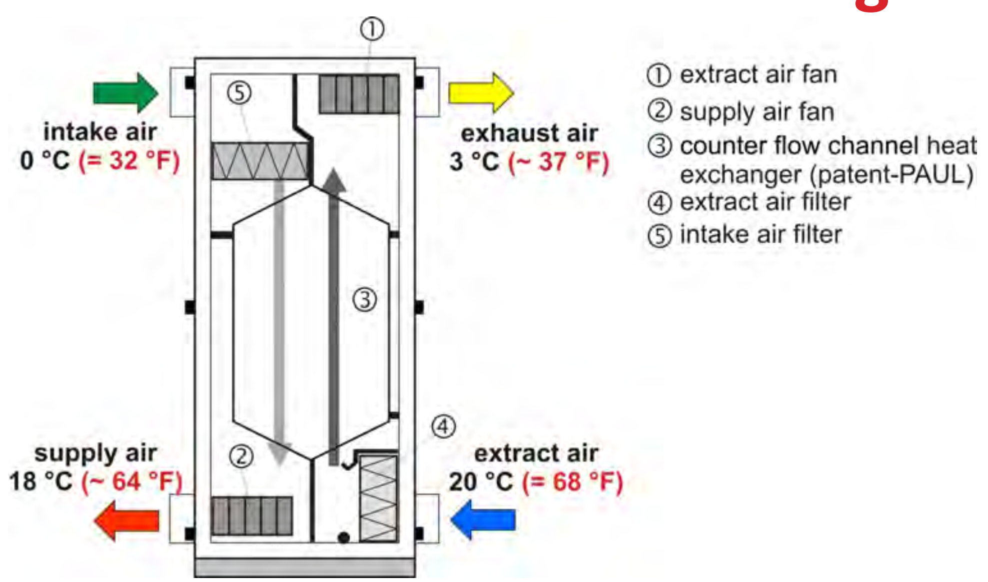
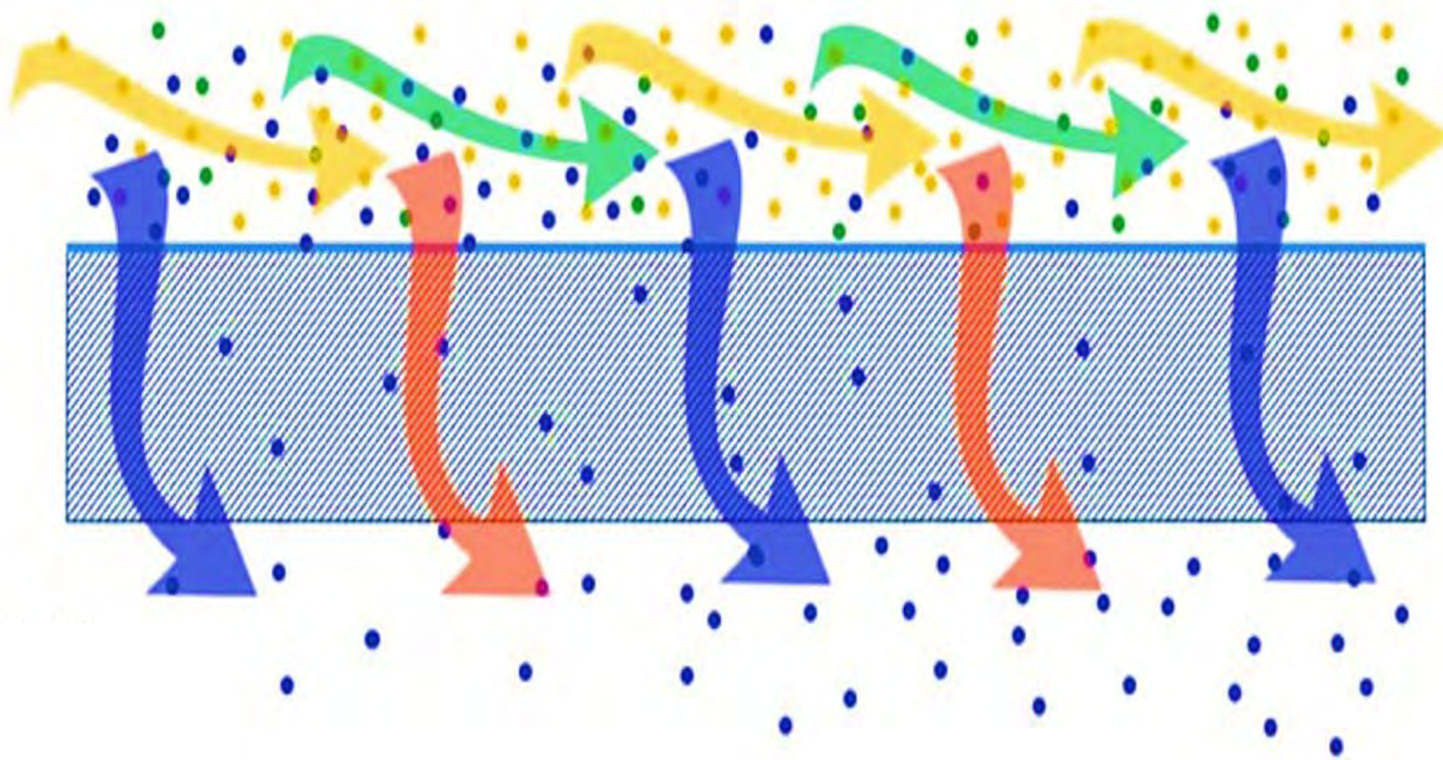


Plate Exchanger with Enthalpy Recovery



- water vapor
- heat
- odors
- gases, contaminants

Plate Exchanger with Enthalpy Recovery

1. Exhaust air transfer (EATR)

There is much debate about the high exhaust air transfer with rotary heat exchangers at unfavorable pressure ratios. However, even with favorable pressure ratios (low-pressure in exhaust air) adhesion of substances on the surface of the rotating heat storages is possible. Wanted are water molecules for humidity recovery, unwanted are other substances, such as odors. Whether viruses can be transferred is under investigation by producers of such systems.

With aluminum and enthalpy exchangers from Polybloc, transfer of exhaust air is only possible by leakage. Eurovent certified products have a maximum leakage of 0.5% at nominal conditions. **In case of lower pressure in the exhaust air, 0% exhaust air transfer is guaranteed.** In practice, this is ensured by positioning both fans to draw air through the energy exchangers.

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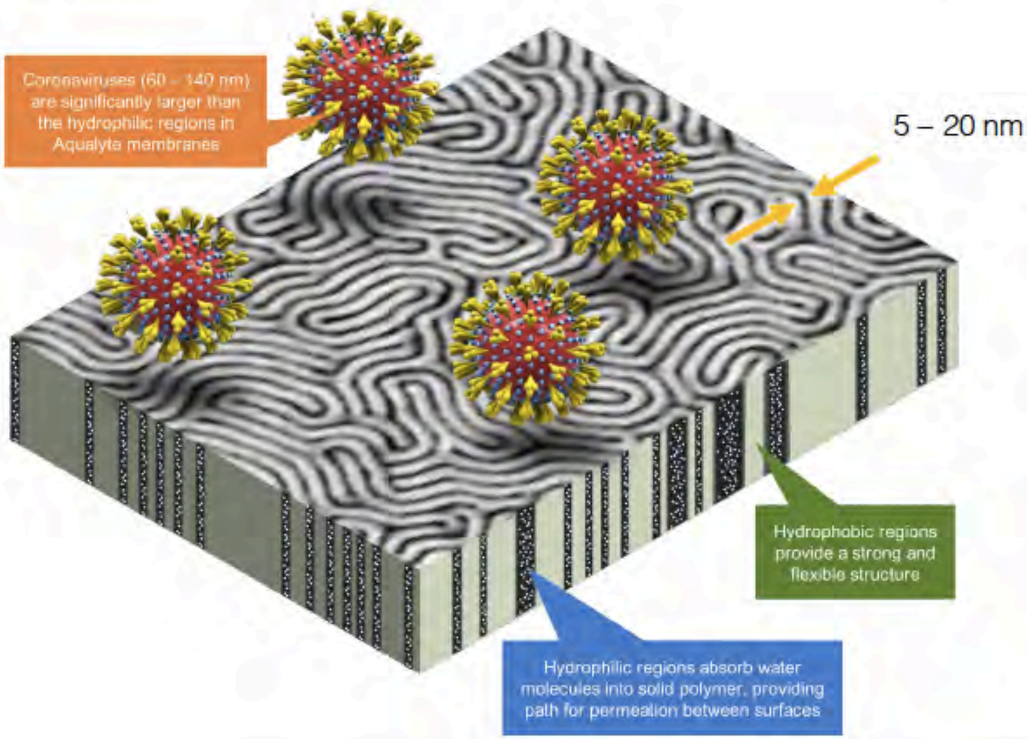
Plate Exchanger with Enthalpy Recovery

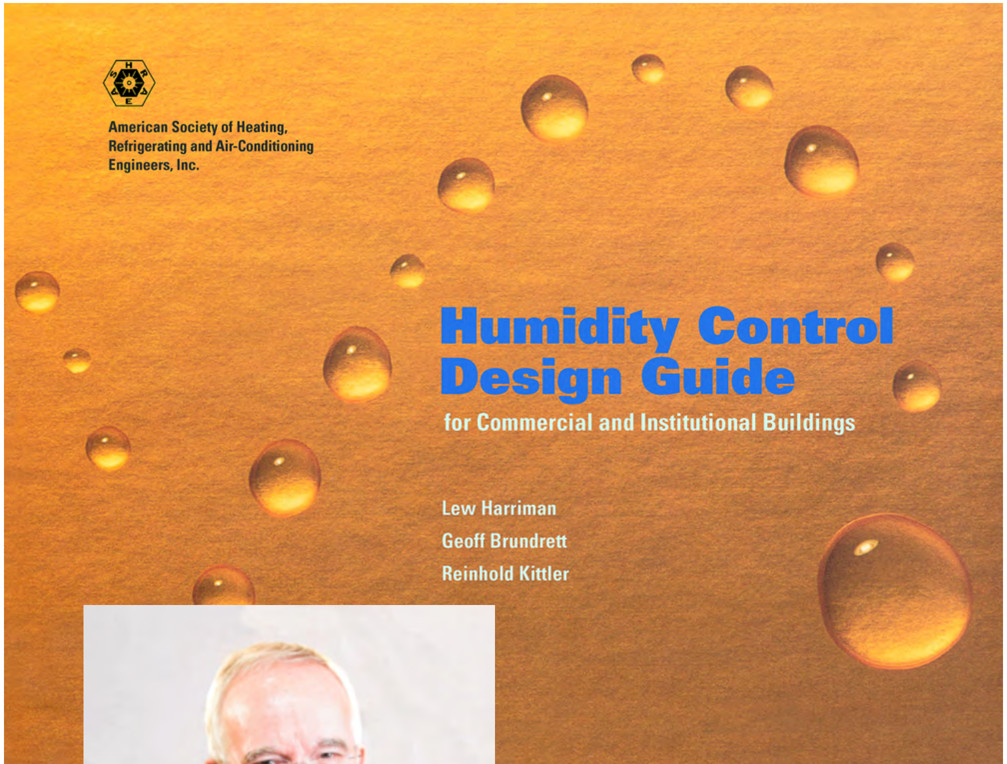
2. Diffusion through the membrane

Enthalpy exchangers are produced of widely varying materials. In Asia and North America, cellulose paper is often used. These enthalpy exchangers are usually very cheap, but as they are very sensitive to water, it is very hard to get a hygiene certification for these models. It is also challenging to get hygiene certifications for porous plastic foils.

The multilayer membrane developed by Polybloc and its partners allows water molecules to transfer without using porous foils.



Should you use an HRV or an ERV?



Tight, well-built buildings in cold and mixed climates need dry outside air in the wintertime to mitigate the interior latent loads. Otherwise moisture related problems could occur.

THE EFFECT OF ENTHALPY RECOVERY VENTILATION ON THE RESIDENTIAL INDOOR CLIMATE

Bart Cremers

Zehnder Group Nederland
Lingenstraat 2
8028 PM Zwolle, The Netherlands
bart.cremers@zehndergroup.com

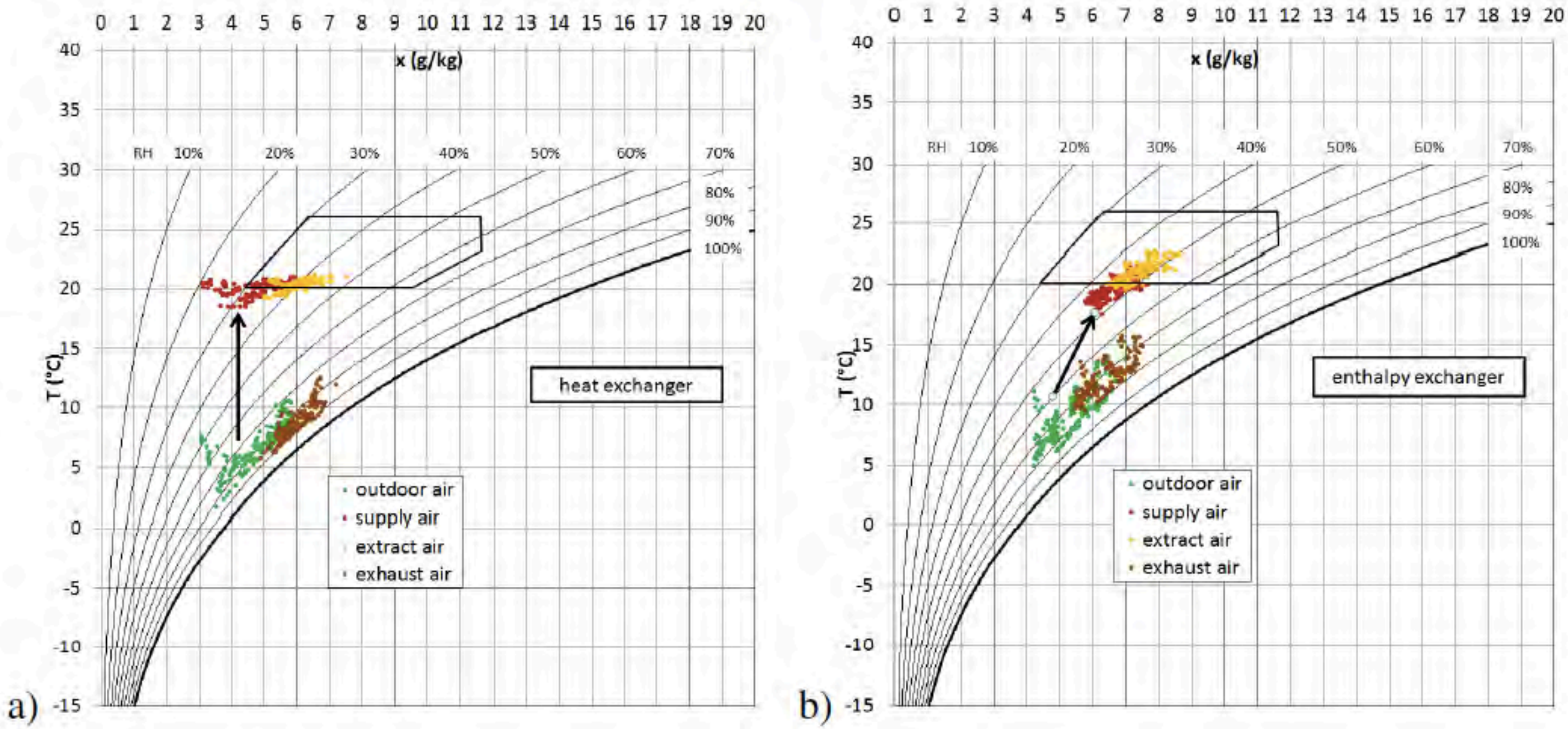
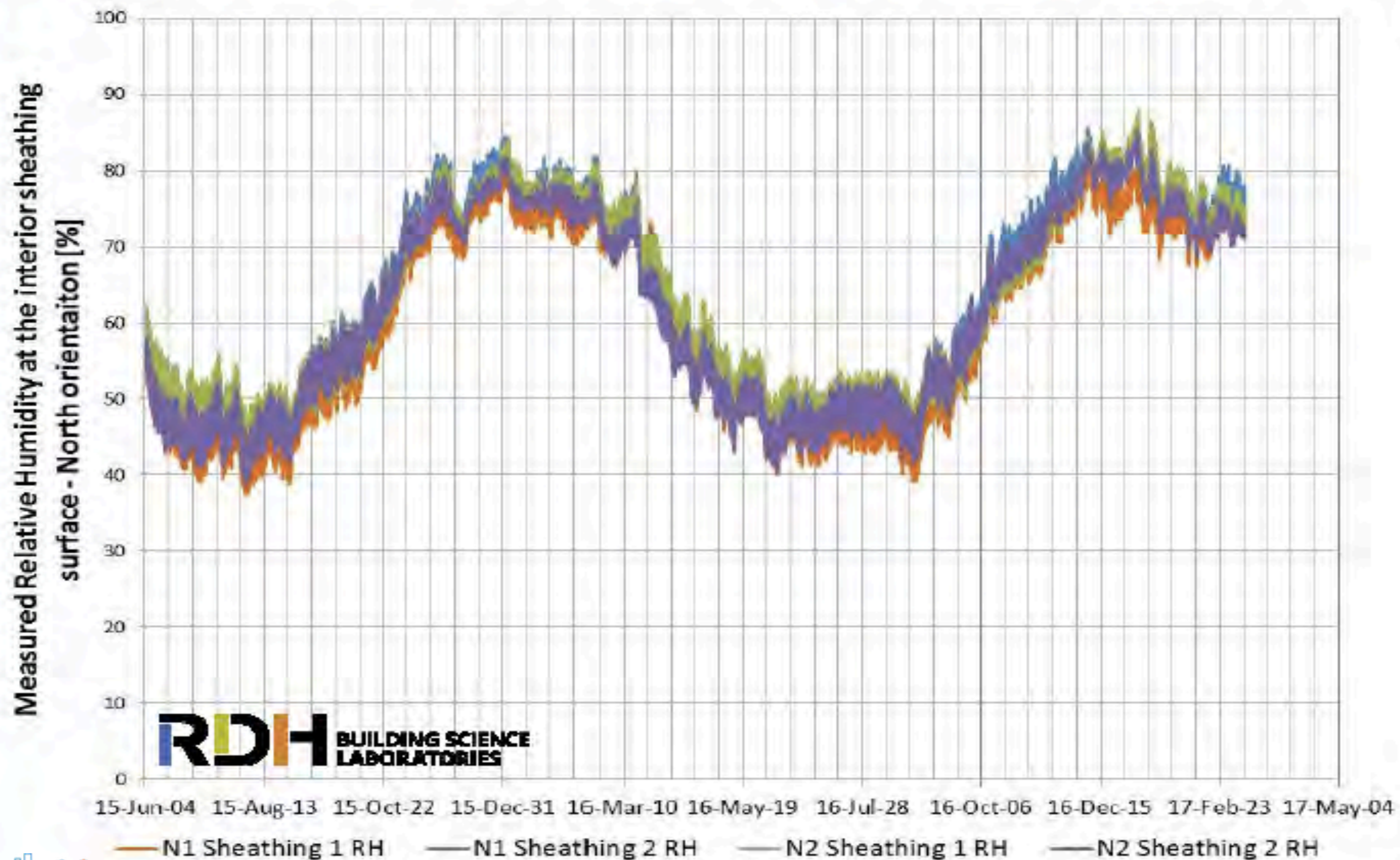


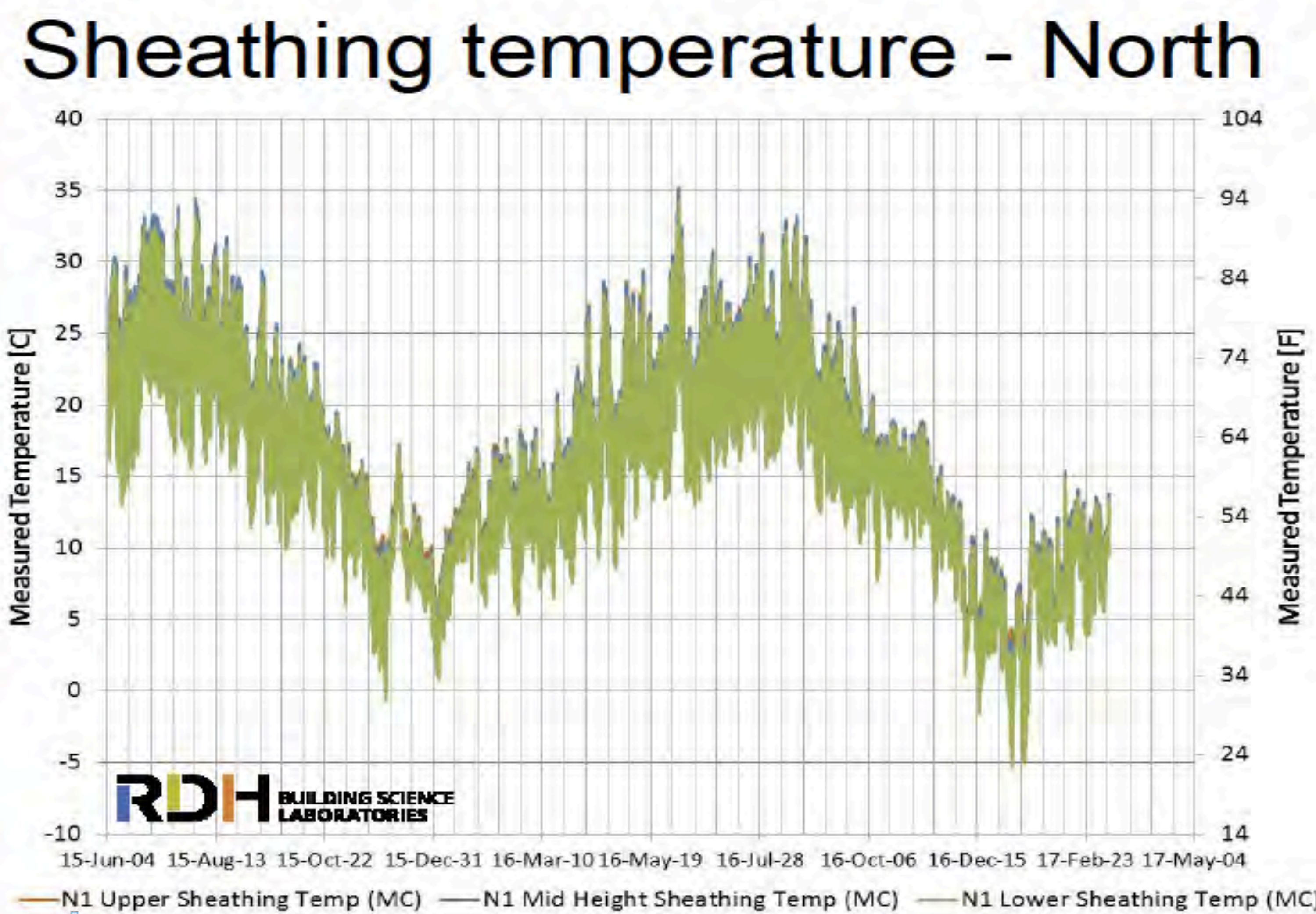
Figure 3: The effect of a heat exchanger (a) and an enthalpy exchanger (b) on the supply air and the indoor air.

Should you use an HRV or an ERV?

Sheathing relative humidity - North



Should you use an HRV or an ERV?



Should you use an HRV or an ERV?

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

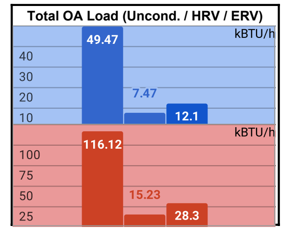
Project Information

Project Name:	Example Project Name
City:	Portland
State/Province:	OR
Org Name:	Customer Co, Inc.
Org Contact Name:	John Doe
Org Contact Phone:	800-555-1212
Org Contact Email:	john@buildingowner.com
Created By:	You
Created On:	1/1/2020

Quick Selector

Ventacity HRV / ERV

Ventacity Model	**VS3000**	
Altitude	**100**	ft
Supply Flow	**2400**	CFM
Exhaust Flow	**2400**	CFM



HRV	ERV	REDUX
-42.00	-37.4	kBTU/h
-100.89	-87.8	kBTU/h

Project Conditions

Summer Conditions Cooling

Outside DBT	**91.4**	°F	
Outside WBT	**67.3**	°F	
or Outside RH		%	28.0
Design Inside DBT	**73.0**	°F	
Design Inside WBT		°F	
or Design Inside RH	**50.0**	%	50.0

Unconditioned OA Cooling Load

Supply DBT	91.4	°F
Supply WBT	67.3	°F
Supply RH	28.0	%
Total Load	**49.47**	**kBTU/h**
Sensible Load	47.69	kBTU/h
Latent Load	1.78	kBTU/h

HRV OA Cooling Load

Supply DBT	75.2	°F
Supply WBT	61.9	°F
Supply RH	47.2	%
Efficiency (S)	87.9	%
Total Load	**7.47**	**kBTU/h**
Sensible Load	5.76	kBTU/h
Latent Load	1.71	kBTU/h

ERV OA Cooling Load

Supply DBT	77.4	°F
Supply WBT	62.5	°F
Supply RH	43.5	%
Efficiency (S)	76.1	%
Efficiency (L)	57.2	%
Total Load	**12.1**	**kBTU/h**
Sensible Load	11.4	kBTU/h
Latent Load	0.7	kBTU/h

Winter Conditions Heating

Outside DBT	**25.2**	°F	
Outside WBT	**23**	°F	
or Outside RH		%	72.4
Design Inside DBT	**70**	°F	
Design Inside WBT			
or Design Inside RH	**50**	%	50.0

Unconditioned OA Heating Load

Supply DBT	25.2	°F
Supply WBT	23.0	
Supply RH	72.4	%
Total Load (Sensible)	**116.12**	**kBTU/h**

HRV OA Heating Load

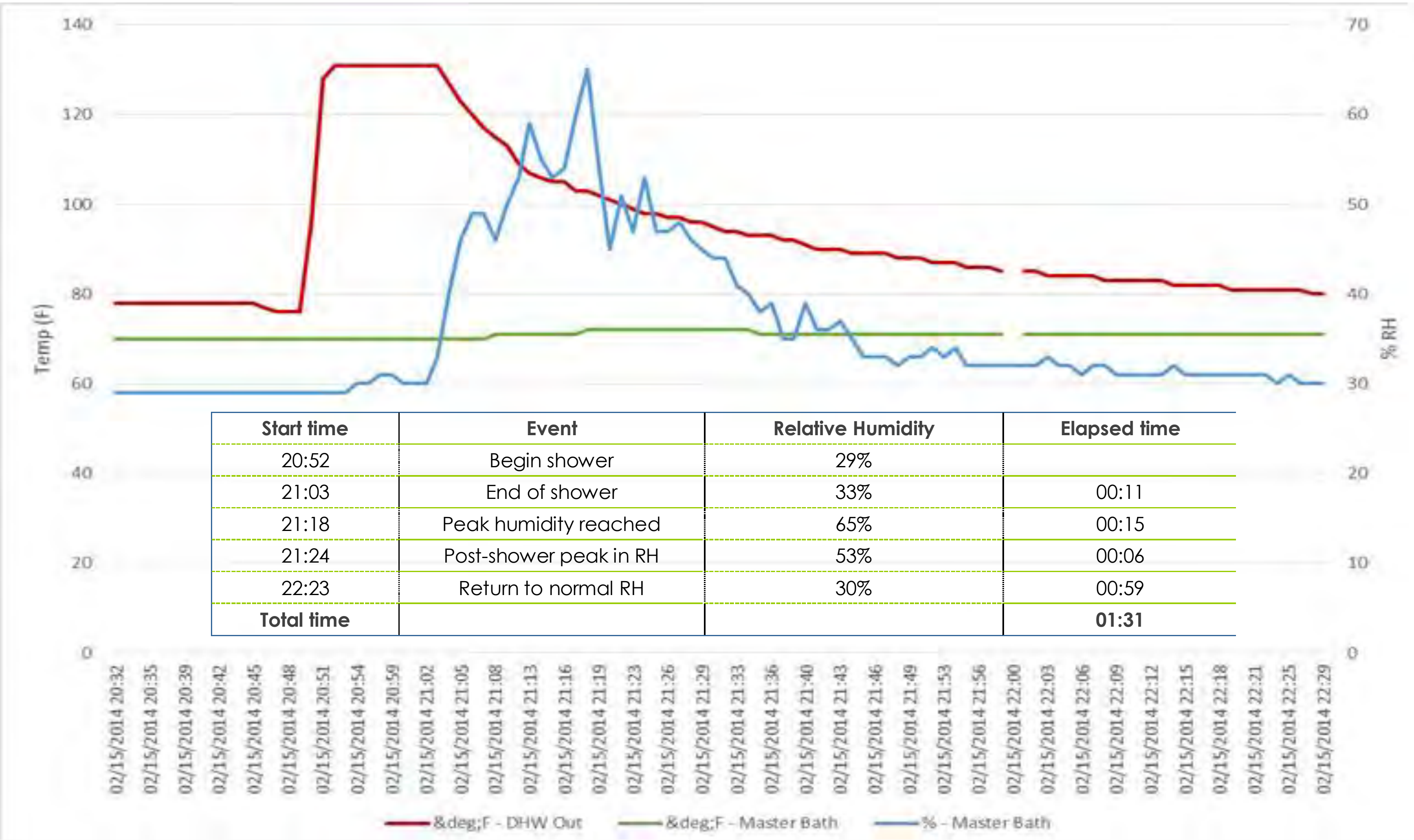
Supply DBT	64.1	°F
Supply WBT	45.1	°F
Supply RH	16.3	%
Efficiency (S)	86.9	%
Total Load (Sensible)	**15.23**	**kBTU/h**

Warning: Condensation (1)

ERV OA Heating Load

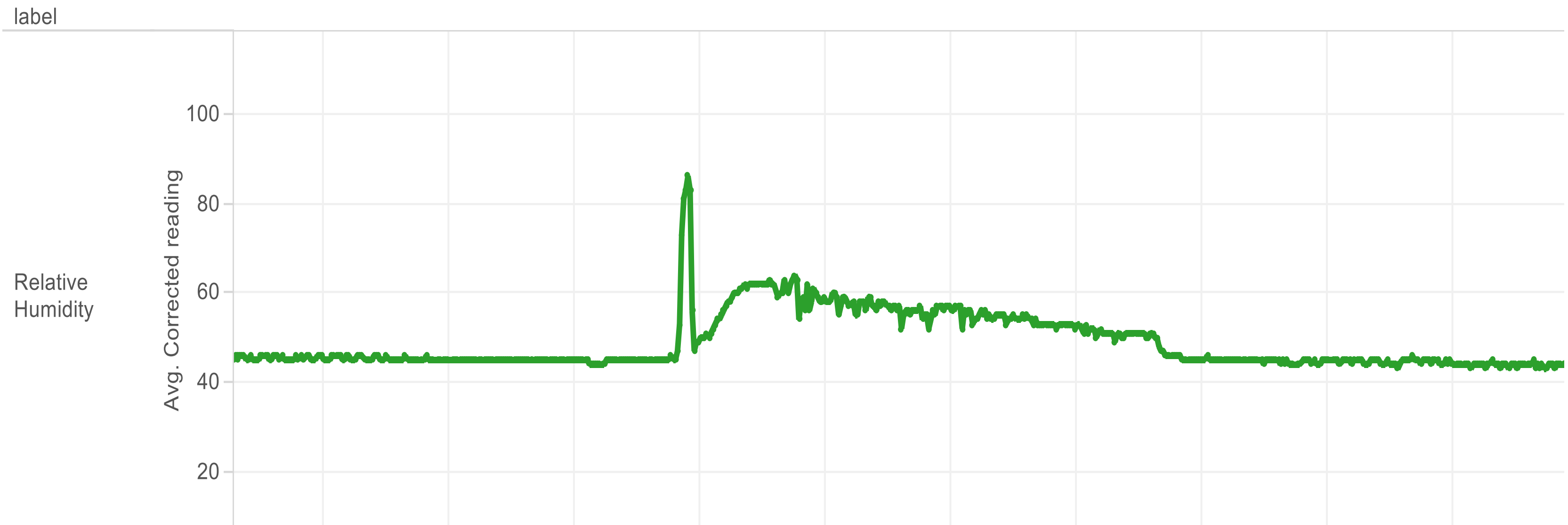
Supply DBT	59.1	°F
Supply WBT	50.3	°F
Supply RH	54.1	%
Efficiency (S)	75.6	%
Efficiency (L)	64.6	%
Total Load (Sensible)	**28.3**	**kBTU/h**

Continuous Exhaust Ventilation With Balanced HRV System



Start time	Event	Relative Humidity	Elapsed time
20:52	Begin shower	29%	
21:03	End of shower	33%	00:11
21:18	Peak humidity reached	65%	00:15
21:24	Post-shower peak in RH	53%	00:06
22:23	Return to normal RH	30%	00:59
Total time			**01:31**

Exhaust Only Utilizing HRV



Start time	Event	Relative Humidity	Temperature	Elapsed time
05:44:00	Begin shower	45%	66.0 F	
05:54:00	Peak humidity reached	86%	68.0 F	00:10
06:06:00	End of shower	52%	68.0 F	00:12
06:34:00	Second peak	62%	67.0 F	00:28
10:56:00	Return to normal RH	44%	66.0 F	04:22
Total				**05:12**

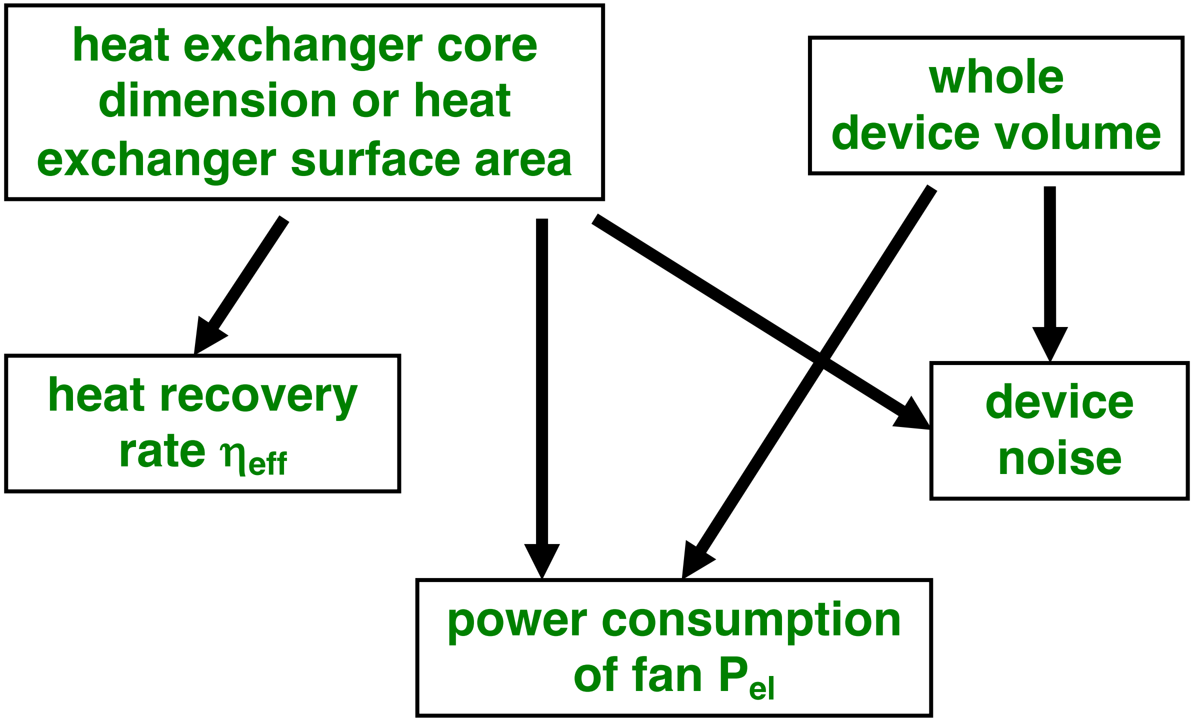
Metrics Of Performance

heat recovery rate

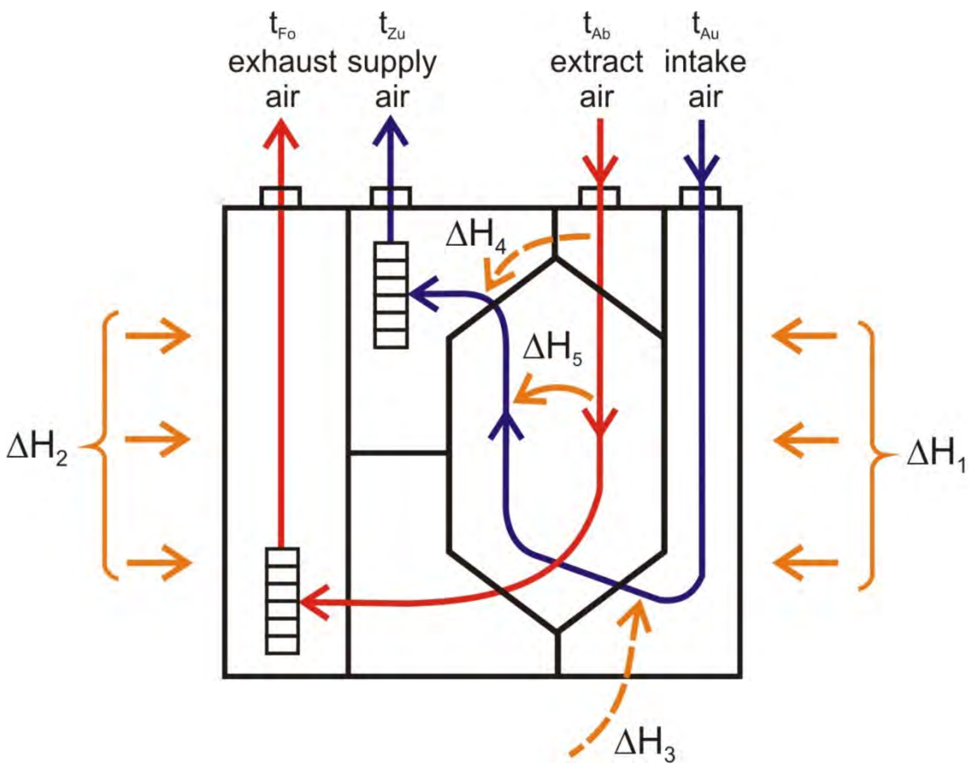
power consumption

noise

Performance Metrics Are Inter-Related

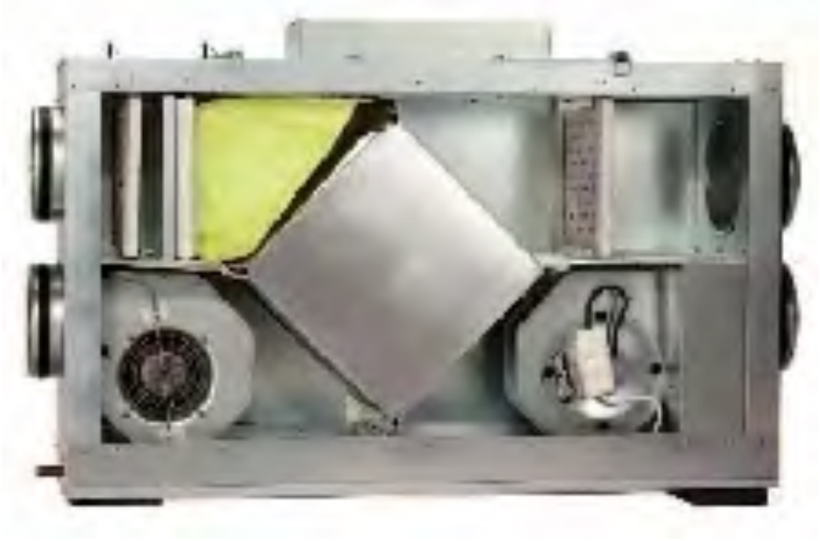


Conventional Measurement Of Efficiency Has A Lot Of Issues

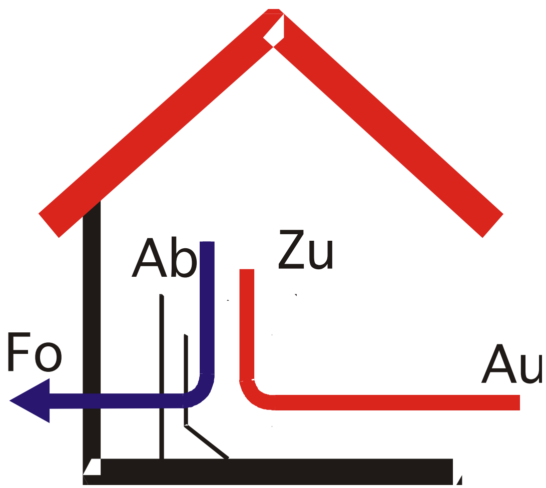


additional heat flow
from installation roomum into intake air (ΔH_1)
or into exhaust air (ΔH_2)
+
leakage hot air flows into intake/supply air:
external (from installation room ~ 20 °C (= 68 °F)) → ΔH_3
internal (from extract air ~ 21 °C (~70 °F)) → ΔH_4

Unit With Thermal Bridging – Casing Leakage



PHI vs North American Protocols For Measurement Of Efficiency

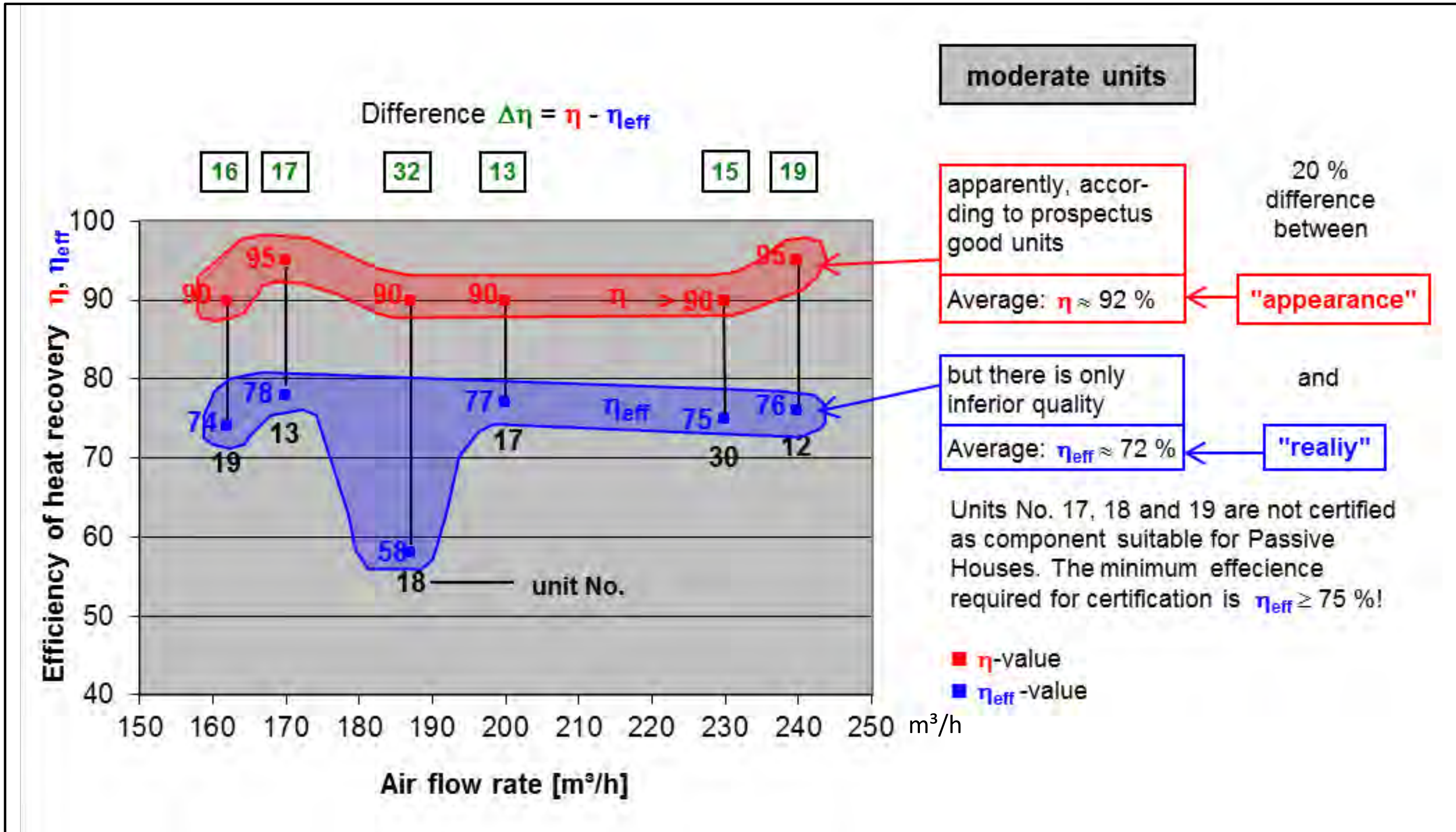


Manufacturer	η_{eff}	η
	$\eta_{Ext} = \frac{t_{Ext} - t_{Exh} + \frac{P_{el}}{\dot{m} \cdot c_P}}{t_{Ext} - t_{In}}$	$\eta_{Su} = \frac{t_{Su} - t_{In}}{t_{Ext} - t_{In}}$
1	69.9 %	90 %
2	59.2 %	95 %
3	93.0 %	94 %

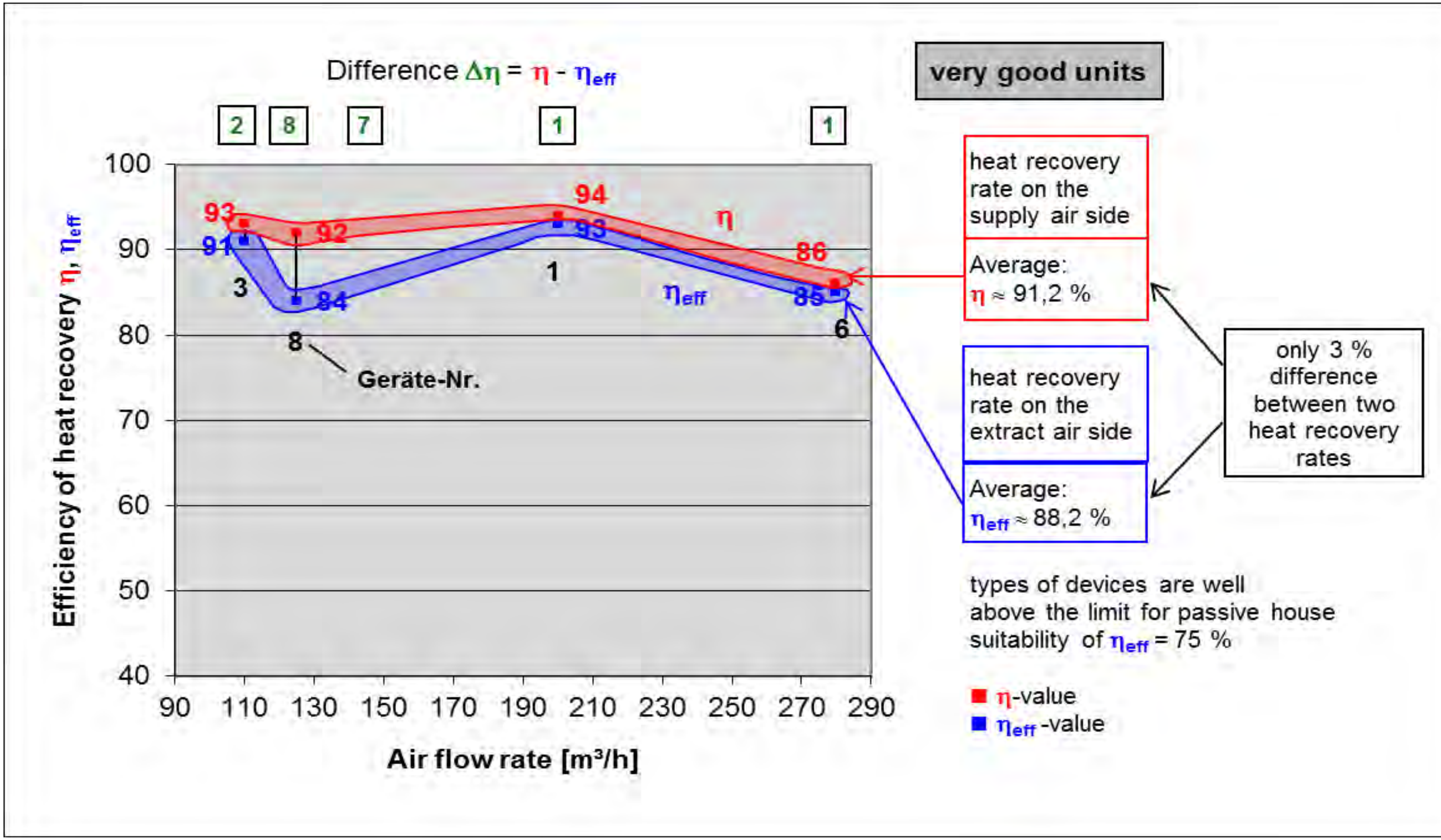
Test method as per:
HVI, AHRI, TUV
η_{Su} is mostly used for brochure data

GE	Test method according to Passive House Institute Dr. Wolfgang, Feist Darmstadt PH certified device see www.passiv.de
GE	DIN V 18599-6:2007-02 and DIN EN 13141-7:2004(D) the included test report requires, among others:
CH	HTA Luzern Prüfreglement für Energie-Etikette (ohne $P_{el}/\dot{m} \cdot c_P$)
AT	e. g. in Lower Austria for LA energy performance certificate $\eta_{V,eff} = \eta_V - 12\ \%$

Significant Discrepancies Between Measured Efficiencies



Better Units Have Smaller Discrepancy, But Still Need To Be Measured



ERV ≠ HRV

CERTIFICATE

Certified Passive House Component

Component-ID 1008vs03 valid until 31st December 2018

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category: **Air handling unit with heat recovery**
Manufacturer: **Zehnder Group Nederland B.V. Netherlands**
Product name: **ComfoAir Q600 ERV, Comfort Vent Q600 ERV**

Specification: Airflow rate < 600 m³/h
Heat exchanger: Recuperative

This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥	75 %
Specific electric power	$P_{el,spec}$	≤	0.45 Wh/m³
Leakage		<	3 %

Comfort: Supply air temperature ≥ 16.5 °C at outdoor air temperature −10 °C

Airflow range
70–460 m³/h
Heat recovery rate
η_{HR} = 80 %
Specific electric power
$P_{el,spec}$ = 0.22 Wh/m³
Humidity recovery
η_x = 68 %

- At an airflow of 90 m³/h, a heat recovery of η_{HR} = 91 % is reached.
- Due to the frost protection strategy at outdoor temperatures of -15 °C the air flow rate is reduced to about 280 m³/h.

cool, temperate climate
CERTIFIED COMPONENT
Passive House Institute

www.passivehouse.com

CERTIFICATE

Certified Passive House Component

Component-ID 0975vs03 valid until 31st December 2018

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Category: **Air handling unit with heat recovery**
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Product name: **ComfoAir Q600 HRV, Comfort Vent Q600 HRV**

Specification: Airflow rate < 600 m³/h
Heat exchanger: Recuperative

This certificate was awarded based on the product meeting the following main criteria

Heat recovery rate	η_{HR}	≥	75 %
Specific electric power	$P_{el,spec}$	≤	0.45 Wh/m³
Leakage		<	3 %

Comfort: Supply air temperature ≥ 16.5 °C at outdoor air temperature −10 °C

Airflow range
70–460 m³/h
Heat recovery rate
η_{HR} = 87 %
Specific electric power
$P_{el,spec}$ = 0.24 Wh/m³

- At an airflow of 223 m³/h, a heat recovery of η_{HR} = 91 % is reached.
- Due to the frost protection strategy at outdoor temperatures of -15 °C the air flow rate is reduced to about 280 m³/h.

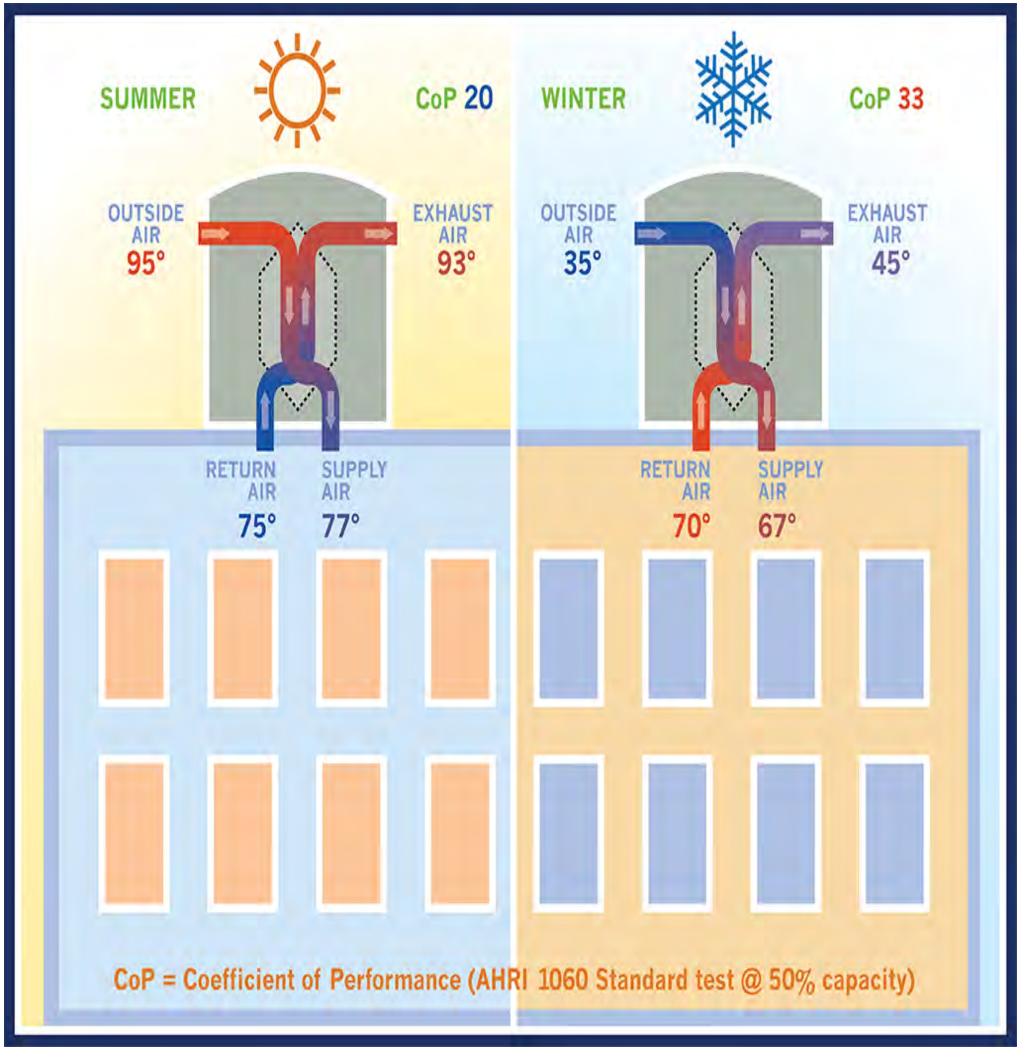
cool, temperate climate
CERTIFIED COMPONENT
Passive House Institute

www.passivehouse.com

BETTER METRIC, BUT LOWER EFFICIENCY NUMBER

- NET RECOVERY EFFICIENCY
- POWER EFFICIENCY
- CROSS-FLOW TRANSFER/ CONTAMINATIOIN
- SOUND LEVEL

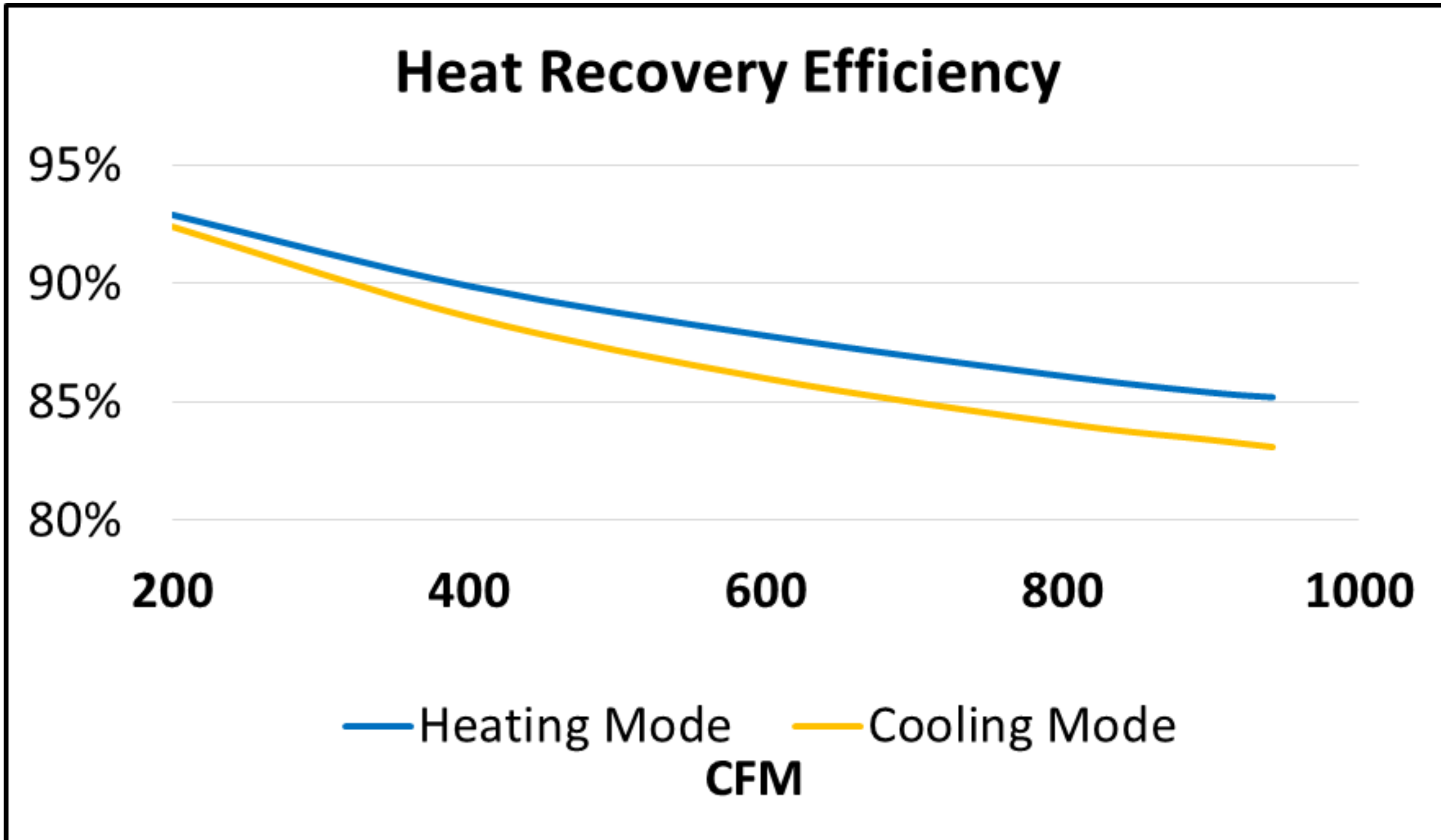
Efficiency, Efficiency, Efficiency!



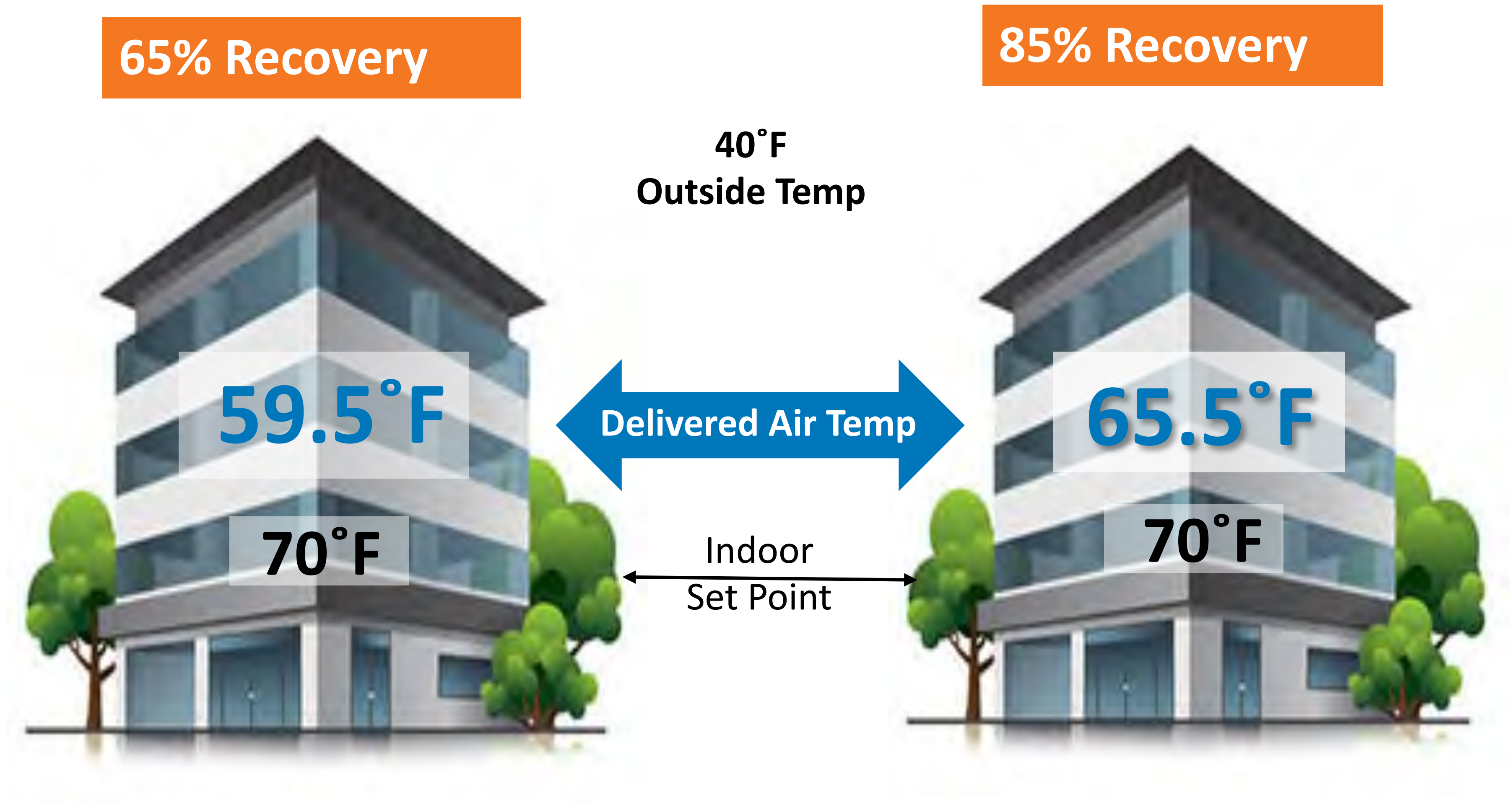
NET EFFICIENCY MATTERS!

- **BUILDING LOAD REDUCTION**
- **HIGH COMFORT LEVEL**
- **NO NEED TO REHEAT**
- **SIMPLER CONTROLS**
- **HIGH RETURN (COP)**

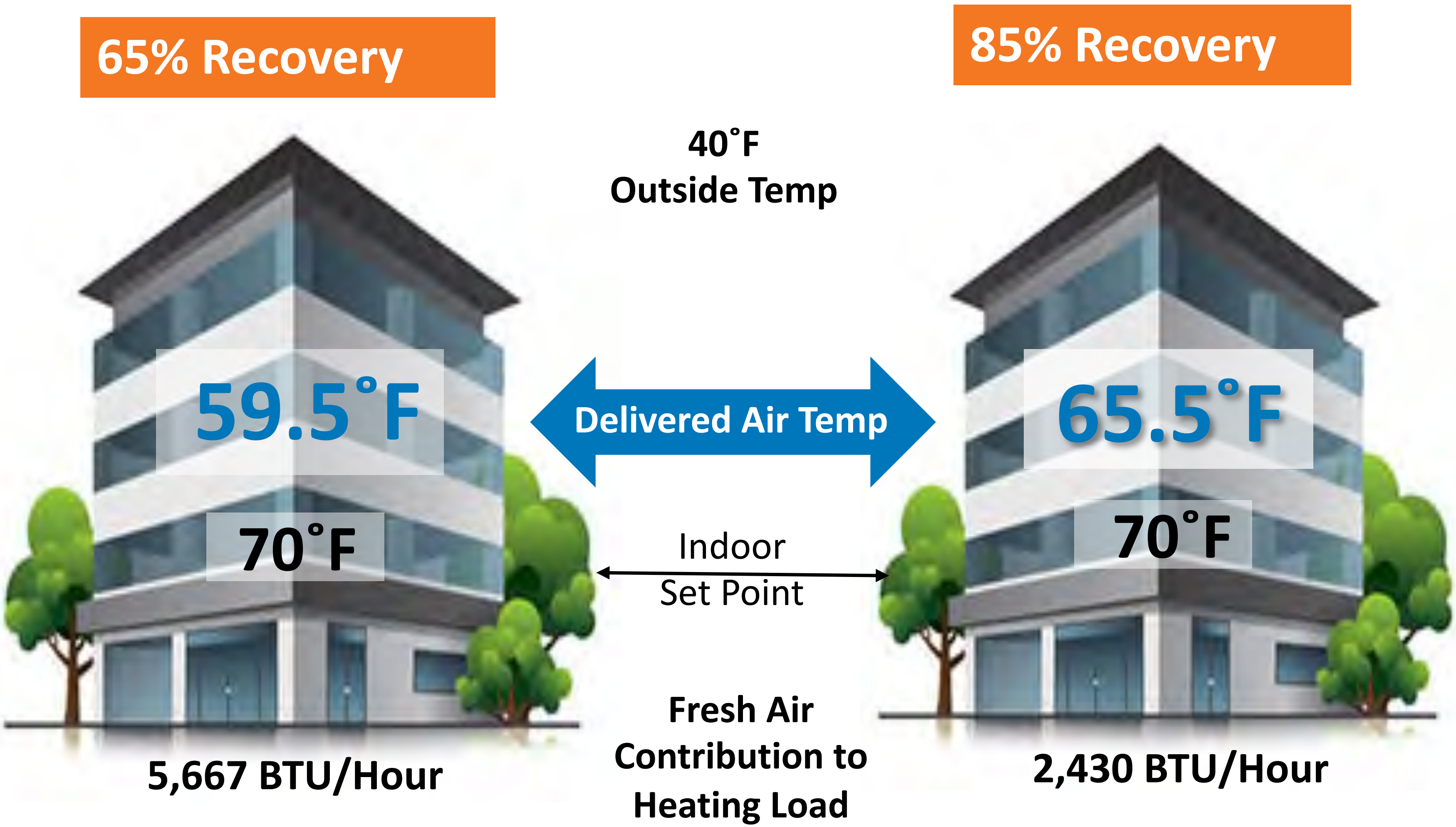
Heat Exchanger Core Efficiency – VS1000 RT



Efficiency Means Comfort



Efficiency Means Comfort



Assume 500 cfm

With a higher efficiency, the yearly cost of operation is nearly half!

	Ventacity		
	 VS1000 RT		
Recovery Efficiency	85%	70%	72%
Tempering Energy			
Incoming Air Temp	65.5˚F	61˚F	61.6˚F
BTUs/Hour	2,430	4,860	4,536
kBTUs/Year	21,286	42,573	39,735
Fan Efficiency			
CFM/WATT	2.9	1.3	1.6
Power Used	172	384	312
kWH/Year	1,507	3,364	2,733
Operating Cost			
Total kWH/Year	**6,238**	**12,477**	**11,654**
Yearly Cost	$998	$1,996	$1,865

Assuming 500 cfm & .25 inches water column OA 40F / IA 70F; $.16/kw

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT™

TRUTH IN ADVERTISING?

MEASUREMENTS	SUMMER		WINTER	
	Outdoor (OA)	Room (RA)	Outdoor (OA)	Room (RA)
Flow Rate **scfm**	1400	1110	1400	1110
Dry Bulb °F	82	75	23	70
Wet Bulb °F	63	62.6	22	54.4
Enthalpy (H) **BTU/lb**	28.4	28.1	7.8	22.7
Moisture Ratio (MR) **grains/lb**	55.5	64.7	15.0	38.0
	Exhaust (EA)	Fresh (FA)	Exhaust (EA)	Fresh (FA)
Flow Rate **scfm**	-	1400	-	1400
Dry Bulb °F	-	77.3	-	54.6
Wet Bulb °F	-	62.4	-	44.8
Enthalpy (H) **BTU/lb**	-	27.9	-	17.5
Moisture Ratio (MR) **grains/lb**	-	60.0	-	28.1

	SUMMER	WINTER
Fresh Air - External Static Pressure **w.g.**	1.4	1.4
Exhaust Air - External Static Pressure **w.g.**	1.4	1.4
Sensible effectiveness %	84.9	84.9
Total effectiveness %	74	81.7
Load savings ratio %	58.7	64.8
Moisture removed **grains/lb**	-4.5	-13.1

	Sen	Lat	Tot	Sen	Lat	Tot
Original load **BTUH [T]**	10584 [0.9]	8850 [0.7]	19434 [1.6]	71064	22921	93985
Load w/ RenewAire **BTUH [T]**	3461 [0.3]	4566 [0.4]	8027 [0.7]	23239	9862	33102
Total energy saved **BTUH [T]**	7123 [0.6]	4284 [0.4]	11407 [1]	47825	13059	60883

- WINTER

1. OA = 23F
2. RA = 70F
3. FA = 54.6 F

AHRI = 70-23 (47)
54.6-23 (31.6)

= 31.6/47 - 67%

CLAIM SENSIBLE 84.9%

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

Project Information

Project Name:	Example Project Name
City:	Portland
State/Province:	SFO
Org Name:	Customer Co, Inc.
Org Contact Name:	John Doe
Org Contact Phone:	800-555-1212
Org Contact Email:	john@buildingowner.com
Created By:	BST
Created On:	6/4/2019

Project Conditions

Summer Conditions Cooling

Outside DBT	82.0	°F	
Outside WBT	63.0	°F	
or Outside RH		%	34.2
Design Inside DBT	75.0	°F	
Design Inside WBT		°F	
or Design Inside RH	50.0	%	50.0

Winter Conditions Heating

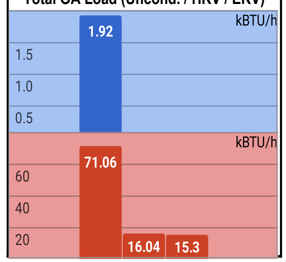
Outside DBT	23	°F	
Outside WBT	22	°F	
or Outside RH		%	86.4
Design Inside DBT	70	°F	
Design Inside WBT			
or Design Inside RH	35	%	35.0

Quick Selector

Ventacity HRV / ERV

Ventacity Model	VS3000	
Altitude	100	ft
Supply Flow	1400	CFM
Exhaust Flow	1110	CFM

Total OA Load (Uncond. / HRV / ERV)



	HRV	ERV	REDUX
	-8.28	-2.3	kBTU/h
	-55.03	-55.8	kBTU/h

Unconditioned OA Cooling Load

Supply DBT	82.0	°F
Supply WBT	63.0	°F
Supply RH	34.2	%
Total Load	**1.92**	**kBTU/h**
Sensible Load	10.58	kBTU/h
Latent Load	-8.66	kBTU/h

HRV OA Cooling Load

Supply DBT	76.5	°F
Supply WBT	61.1	°F
Supply RH	40.9	%
Efficiency (S)	78.2	%
Total Load	**-6.36**	**kBTU/h**
Sensible Load	2.31	kBTU/h
Latent Load	-8.67	kBTU/h

ERV OA Cooling Load

Supply DBT	76.9	°F
Supply WBT	62.5	°F
Supply RH	44.4	%
Efficiency (S)	72.2	%
Efficiency (L)	78.5	%
Total Load	**-0.3**	**kBTU/h**
Sensible Load	2.9	kBTU/h
Latent Load	-3.3	kBTU/h

Unconditioned OA Heating Load

Supply DBT	23.0	°F
Supply WBT	22.0	
Supply RH	86.4	%
Total Load (Sensible)	**71.06**	**kBTU/h**

HRV OA Heating Load

Supply DBT	59.4	°F
Supply WBT	44.9	°F
Supply RH	28.3	%
Efficiency (S)	73.3	%
Total Load (Sensible)	**16.04**	**kBTU/h**

Preheater: 7.2F / 36.8F
Warning: Condensation (1)

ERV OA Heating Load

Supply DBT	59.9	°F
Supply WBT	48.8	°F
Supply RH	43.7	%
Efficiency (S)	72.0	%
Efficiency (L)	82.4	%
Total Load (Sensible)	**15.3**	**kBTU/h**

Preheater: 10.8F / 36.8F

TRUTH IN ADVERTISING?

- WINTER

1. OA = 23F
2. RA = 70F
3. FA = 59.9 F

AHRI = 70-23 (47)
59.9-23 (36.9)

= 36.3/47 - **79%**

TRUTH IN ADVERTISING?

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

Project Information

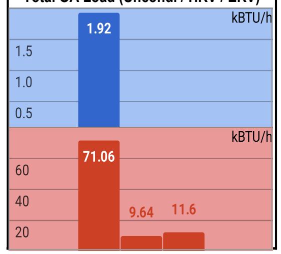
Project Name:	Example Project Name
City:	Portland
State/Province:	SFO
Org Name:	Customer Co, Inc.
Org Contact Name:	John Doe
Org Contact Phone:	800-555-1212
Org Contact Email:	john@buildingowner.com
Created By:	BST
Created On:	6/4/2019

Quick Selector

Ventacity HRV / ERV

Ventacity Model	**VS3000**	
Altitude	**100**	ft
Supply Flow	**1400**	CFM
Exhaust Flow	**1400**	CFM

Total OA Load (Uncond. / HRV / ERV)



	HRV	ERV	REDUX
	-9.52	-2.8	kBTU/h
	-61.42	-59.5	kBTU/h

Project Conditions

Summer Conditions Cooling

Outside DBT	**82.0**	°F
Outside WBT	**63.0**	°F
or Outside RH		% 34.2
Design Inside DBT	**75.0**	°F
Design Inside WBT		°F
or Design Inside RH	**50.0**	% 50.0

Unconditioned OA Cooling Load

Supply DBT	82.0	°F
Supply WBT	63.0	°F
Supply RH	34.2	%
Total Load	**1.92**	**kBTU/h**
Sensible Load	10.58	kBTU/h
Latent Load	-8.66	kBTU/h

HRV OA Cooling Load

Supply DBT	75.7	°F
Supply WBT	60.8	°F
Supply RH	42.1	%
Efficiency (S)	89.8	%
Total Load	**-7.60**	**kBTU/h**
Sensible Load	1.08	kBTU/h
Latent Load	-8.67	kBTU/h

ERV OA Cooling Load

Supply DBT	76.3	°F
Supply WBT	62.3	°F
Supply RH	45.8	%
Efficiency (S)	81.8	%
Efficiency (L)	68.0	%
Total Load	**-0.9**	**kBTU/h**
Sensible Load	1.9	kBTU/h
Latent Load	-2.8	kBTU/h

Winter Conditions Heating

Outside DBT	**23**	°F
Outside WBT	**22**	°F
or Outside RH		% 86.4
Design Inside DBT	**70**	°F
Design Inside WBT		
or Design Inside RH	**35**	% 35.0

Unconditioned OA Heating Load

Supply DBT	23.0	°F
Supply WBT	22.0	
Supply RH	86.4	%
Total Load	**71.06**	**kBTU/h**
(Sensible)		

HRV OA Heating Load

Supply DBT	63.6	°F
Supply WBT	46.0	°F
Supply RH	21.0	%
Efficiency (S)	85.3	%
Total Load	**9.64**	**kBTU/h**
(Sensible)		

Preheater: 3.6F / 36.8F
Warning: Condensation (1)

ERV OA Heating Load

Supply DBT	62.3	°F
Supply WBT	49.8	°F
Supply RH	39.9	%
Efficiency (S)	81.6	%
Efficiency (L)	74.1	%
Total Load	**11.6**	**kBTU/h**
(Sensible)		

Preheater: 5.4F / 36.8F

- WINTER

1. OA = 23F
2. RA = 70F
3. FA = 62.3 F

AHRI = 70-23 (47)
62.3-23 (39.3)

= 39.3/47 - **84%**

British Columbia Daycare Project

Efficiency Leads to Additional Savings

	Typical Competitor	Ventacity Product
Heat Recover Ventilator	RenewAire 1000 CFM	Ventacity VS1000 RT
Re-Heat of Outdoor Air	100,000 BTUH gas fired duct heater used. As configured will maintain 55˚F supply air temperature.	Not needed, provides supply air temperature at design temeprature at 65°F.
Add-Ons	1. Outdoor Insulation Package 2. Intake/exhaust Dampers 3. By-pass For Free-cooling	All included as standard.

Significant reduction possible for costs of installation of gas lines, duct heaters and controls.

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT™

EFFICIENCY = SAVINGS

MICHIGAN MIXED USE BUILDING 26,409 SQ FT

STANDARD HVAC SYSTEM	PROPOSED HVAC²
H&C WITH CONVENTIONAL SYSTEM	FUJITSU/VENTACITY HVAC
OUTSIDE AIR DELIVERED = 2,772 CFM EXHAUST AIR REQUIREMENT = 400 CFM	BALANCED VENTILATION NOMINAL 85% SENSIBLE HEAT RECOVERY
OA HEATING LOAD = 203,657 BTUH OA COOLING LOAD = 93,031 BTUH	OA HEATING LOAD = 31,369 BTUH OA COOLING LOAD = 67,799 BTUH

- **UTILIZING HIGH PERFORMANCE HRV RESULTS IN SIGNIFICANT LOAD REDUCTION**
- **173,032 BTUH HEATING LOAD REDUCTION**
- **EQUAL TO 18 NOMINAL HEAT PUMP TONS**
- **AT $1,800/TON EQUIPMENT COST RESULTS IN SAVINGS OF $32,400**

PHI Certification Matters

- 4 Storey Apartment Building in Ottawa
- Offers 42 Apartments (40m2 each) for men and women with mental illness
- Interior and Exterior Amenity areas
- 1 community worker office

Certified Passive House
Passive House Institute

LEED Platinum 2015
Candidate

Specific building demands with reference to the treated floor area

				Requirements	Fulfilled?*
	Treated floor area	2082.2	m^2		
Space heating	Heating demand	14	$kWh/(m^2a)$	15 $kWh/(m^2a)$	yes
	Heating load	11	W/m^2	10 W/m^2	-
Space cooling	Overall specif. space cooling demand	1	$kWh/(m^2a)$	16 $kWh/(m^2a)$	yes
	Cooling load	4	W/m^2	-	-
	Frequency of overheating (> 25 °C)		%	-	-
Primary energy	Heating, cooling, auxiliary electricity, dehumidification, DHW, lighting, electrical appliances	114.40	$kWh/(m^2a)$	120 $kWh/(m^2a)$	yes
	DHW, space heating and auxiliary electricity	53	$kWh/(m^2a)$	-	-
	Specific primary energy reduction through solar electricity		$kWh/(m^2a)$	-	-
Airtightness	Pressurization test result n_{50}	0.3	1/h	0.6 1/h	yes

* empty field: data missing; '-': no requirement

Passive House?	yes

- Radical energy efficiency
- Exemplary comfort
- Exceptional indoor air quality
- A performance that lasts

Salus Clementine… *Ottawa, Ontario, Canada*

PHI Certification Matters

Lesson #4: We need to use PH-Certified Components!

Non-CSA Approved Certified PH ventilation system was not allowed by local Code – this drove up heating demand in the building, increased costs significantly and cost us delays. This has to change!

Using Canadian-made Ventilation unit (7

		kWh/a	kWh/(m²a)
$Q_L - Q_G$	=	28305	14

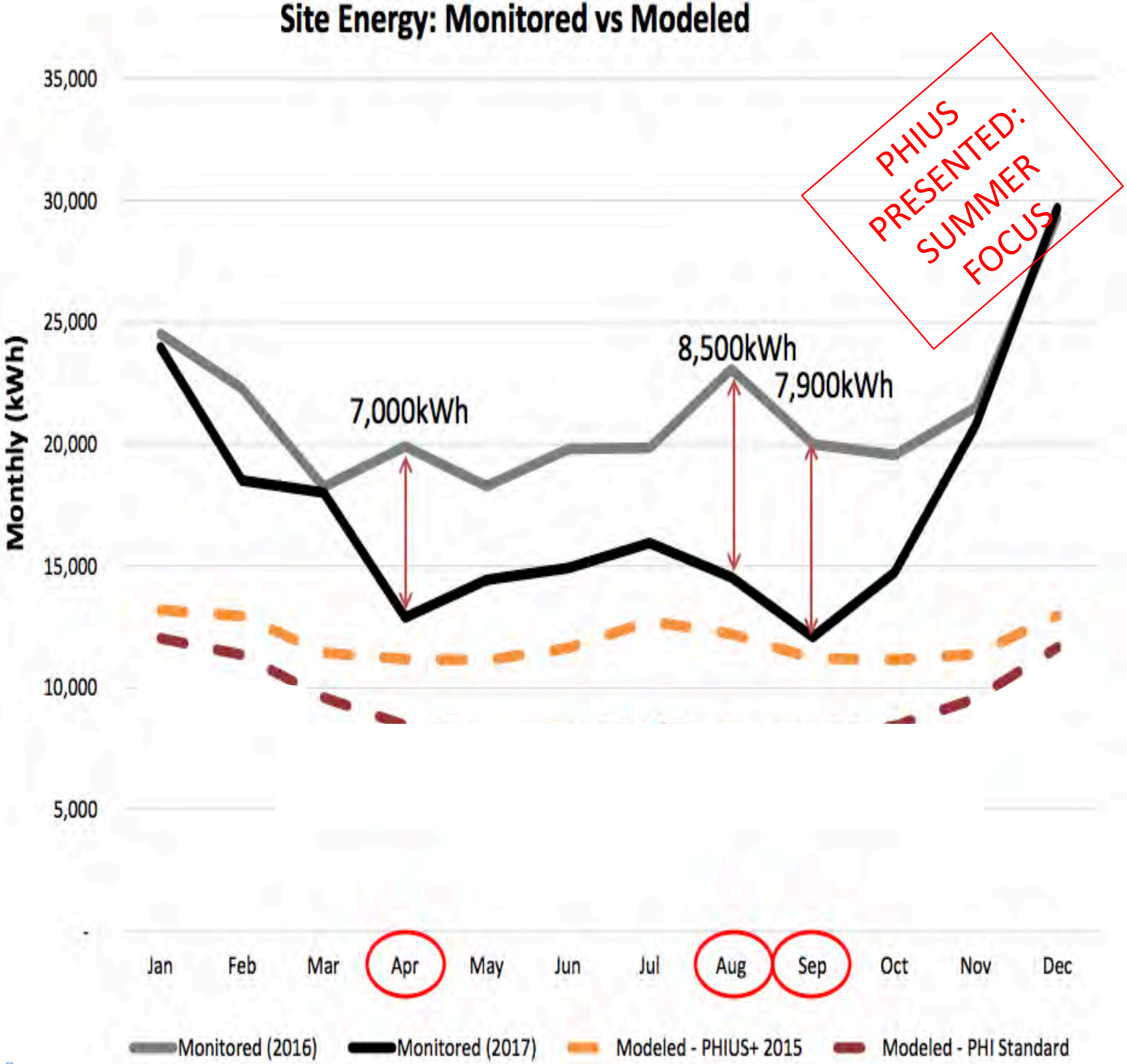
Using PHI-Certified Ventilation unit (85

		kWh/a	kWh/(m²a)
$Q_L - Q_G$	=	21625	10

PENALTY = 6680 kWh/y

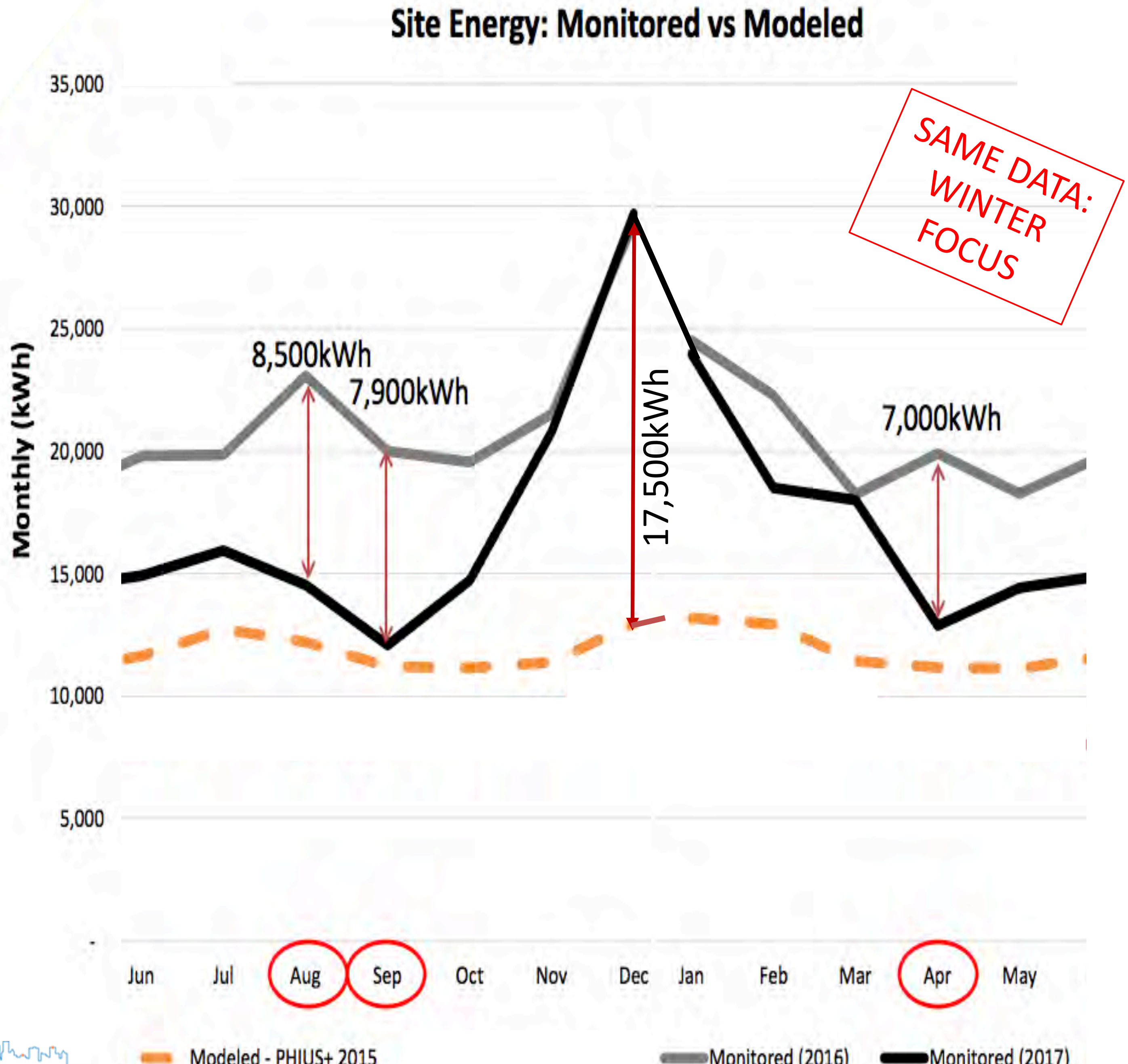
Transmission Losses, Exterior Walls = 12281 kWh/y

UPTOWN LOFTS, Pittsburgh, PA



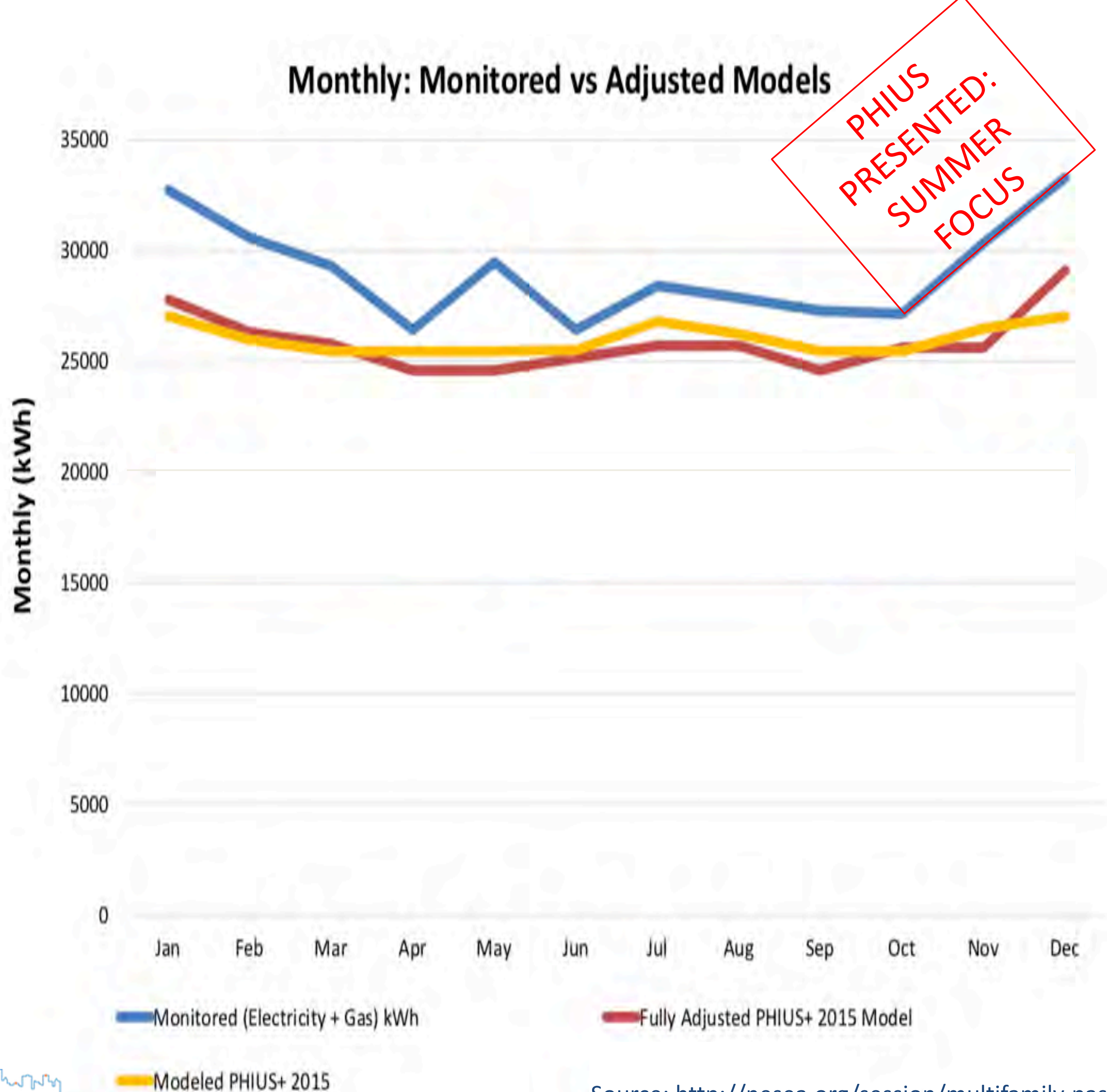
Source: http://nesea.org/session/multifamily-passive-buildings-evaluation-measured-performance

UPTOWN LOFTS, Pittsburgh, PA



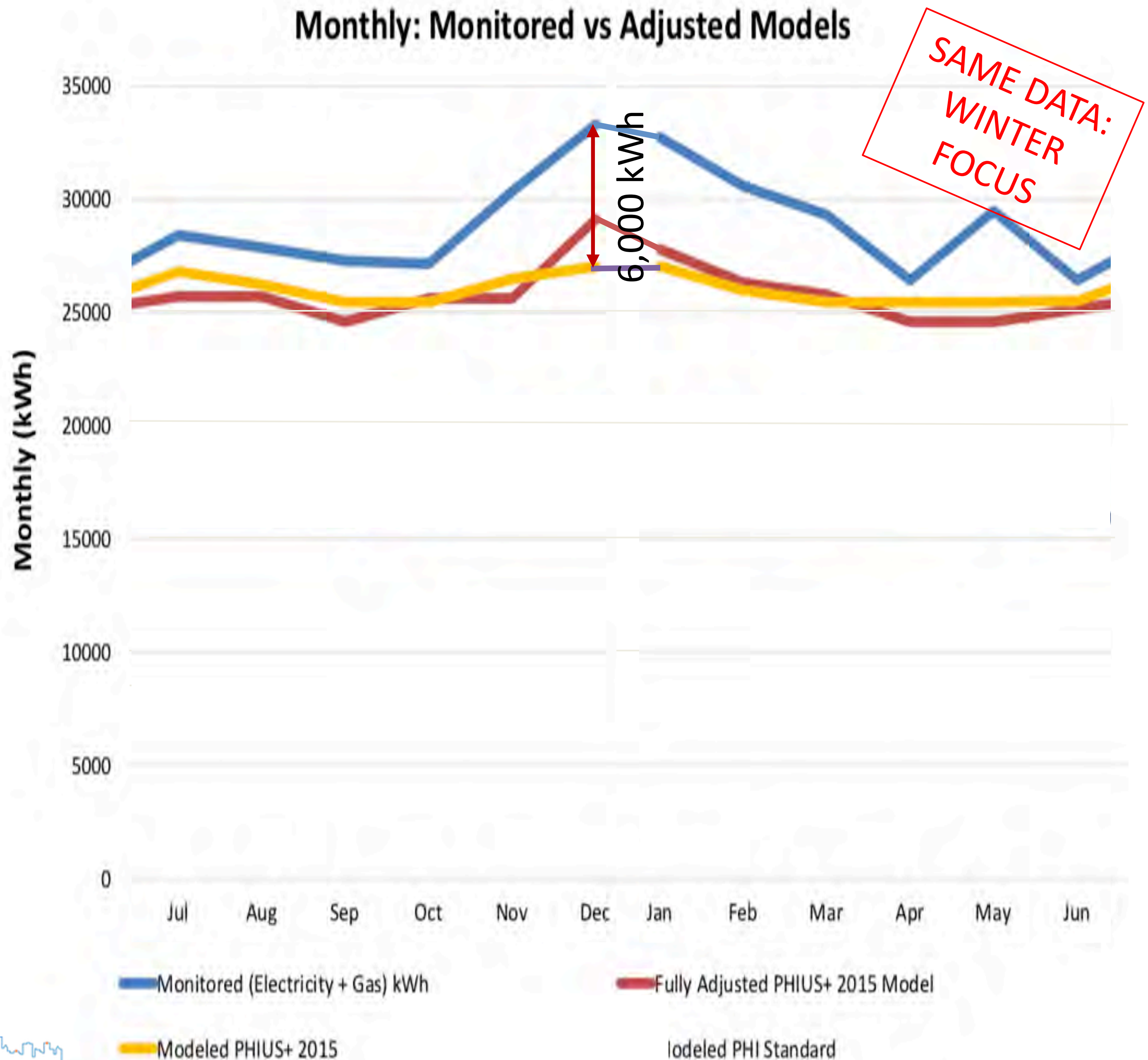
Source: http://nesea.org/session/multifamily-passive-buildings-evaluation-measured-performance

ORCHARDS AT ORENCO, OR



Source: http://nesea.org/session/multifamily-passive-buildings-evaluation-measured-performance

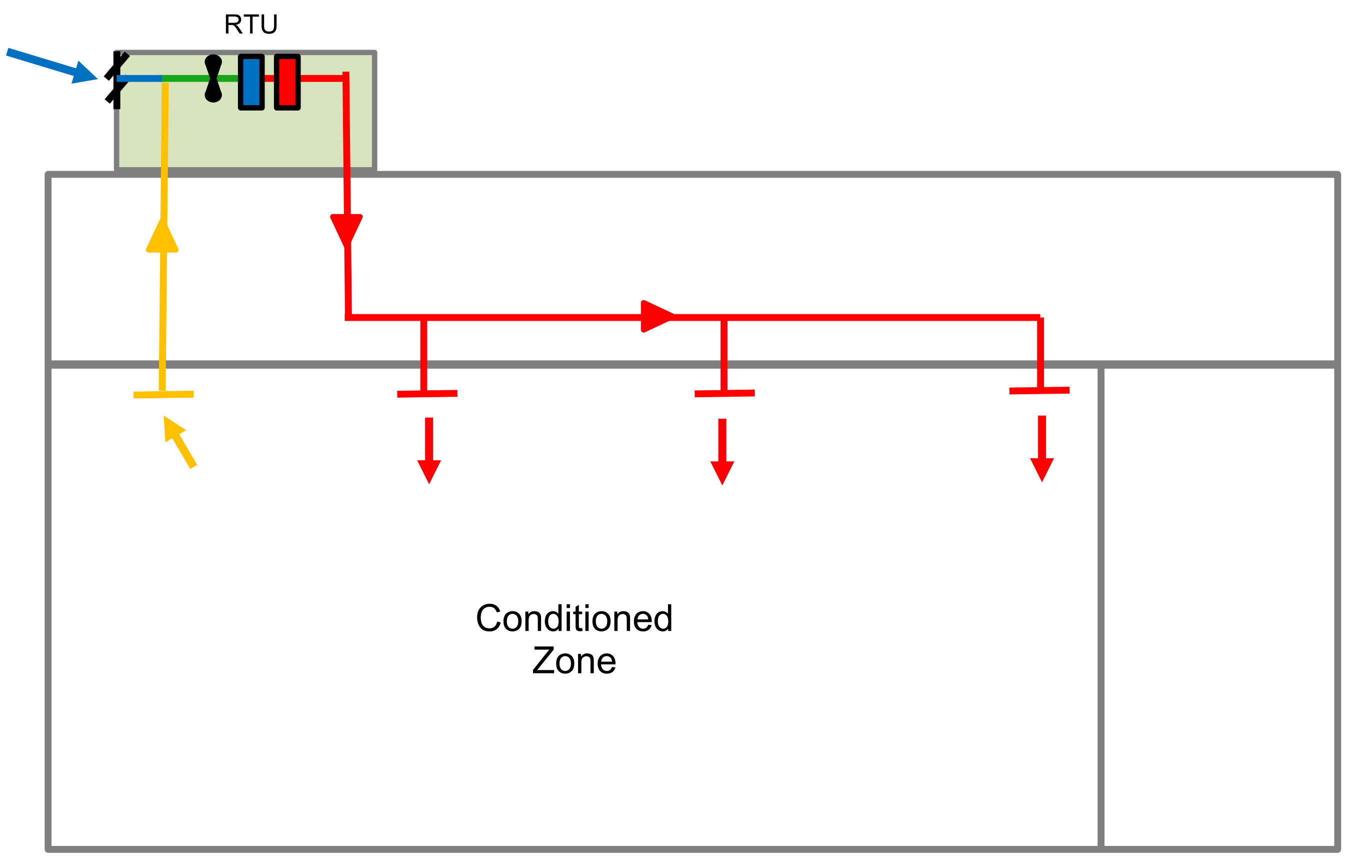
ORCHARDS AT ORENCO, OR



Source: http://nesea.org/session/multifamily-passive-buildings-evaluation-measured-performance

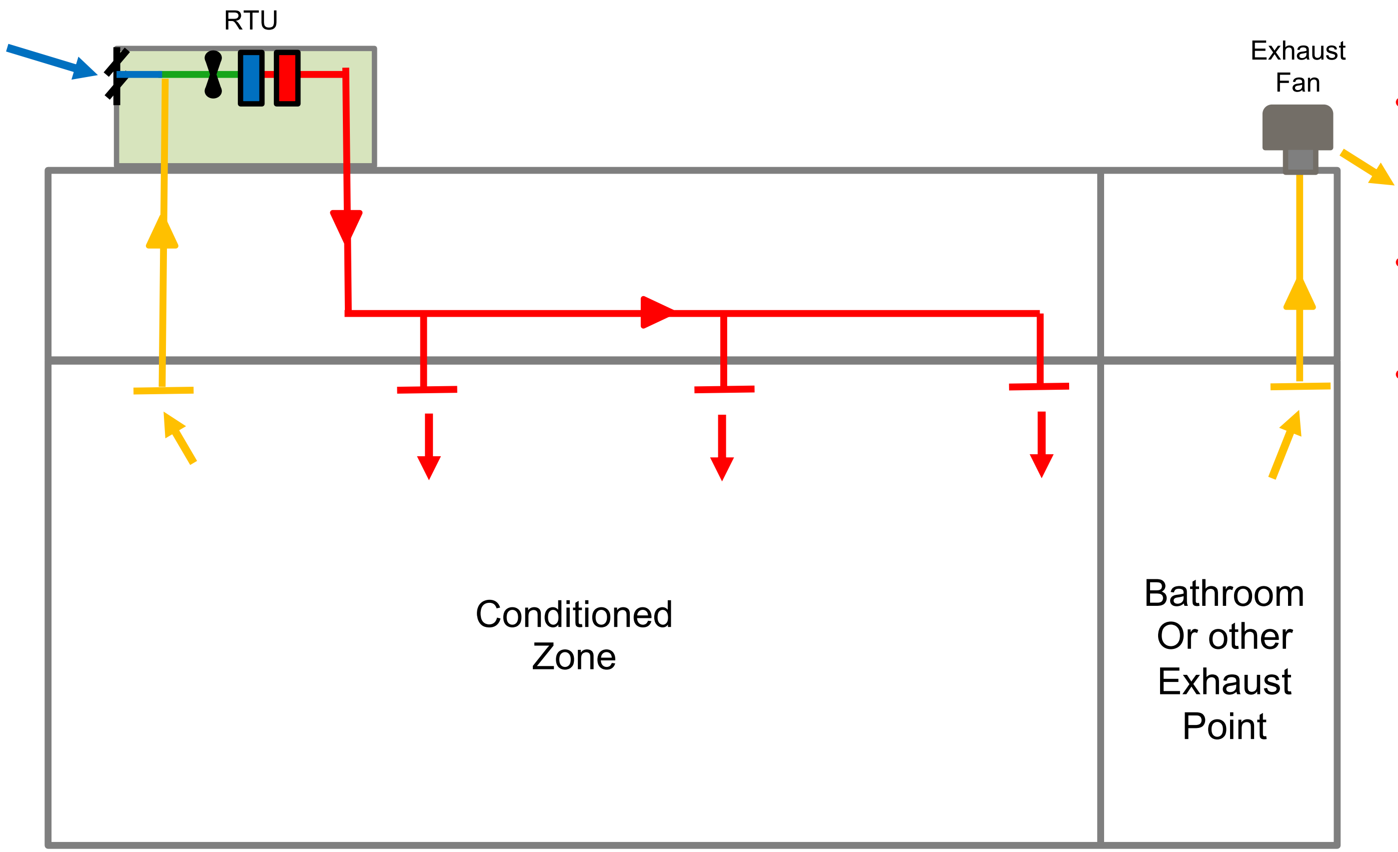
Chapter 6: Traditional Ventilation Methods

Traditional Ventilation Methods: Outside Air Inlet to Roof Top Unit



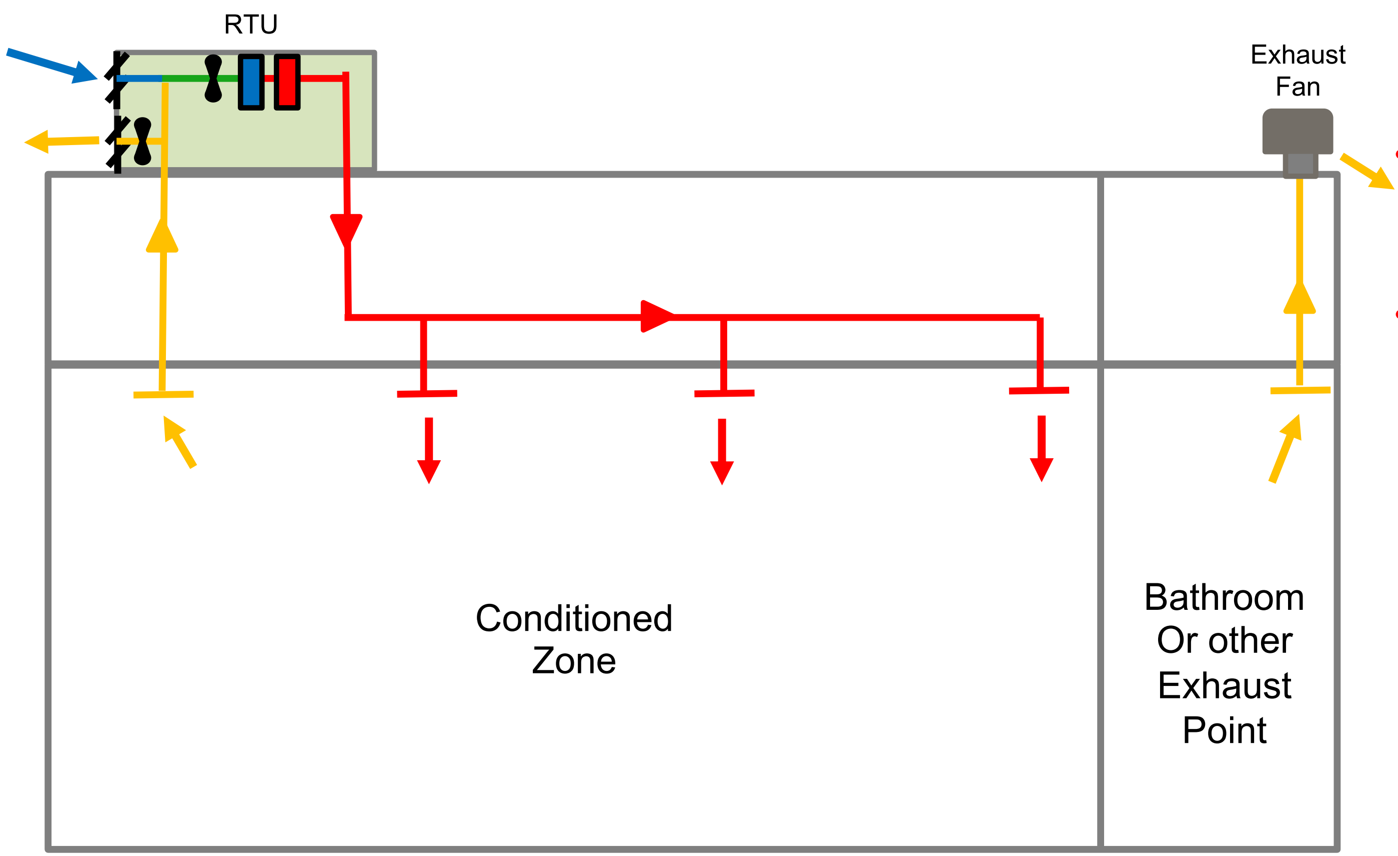
- RTU primarily for H&AC
- System designed around H&AC loads
- Need full fan operation for OA distribution
- Often pressurizes the building and leads to exfiltration
- OA dampers often closed to save energy

Traditional Ventilation Methods: Exhaust Fans



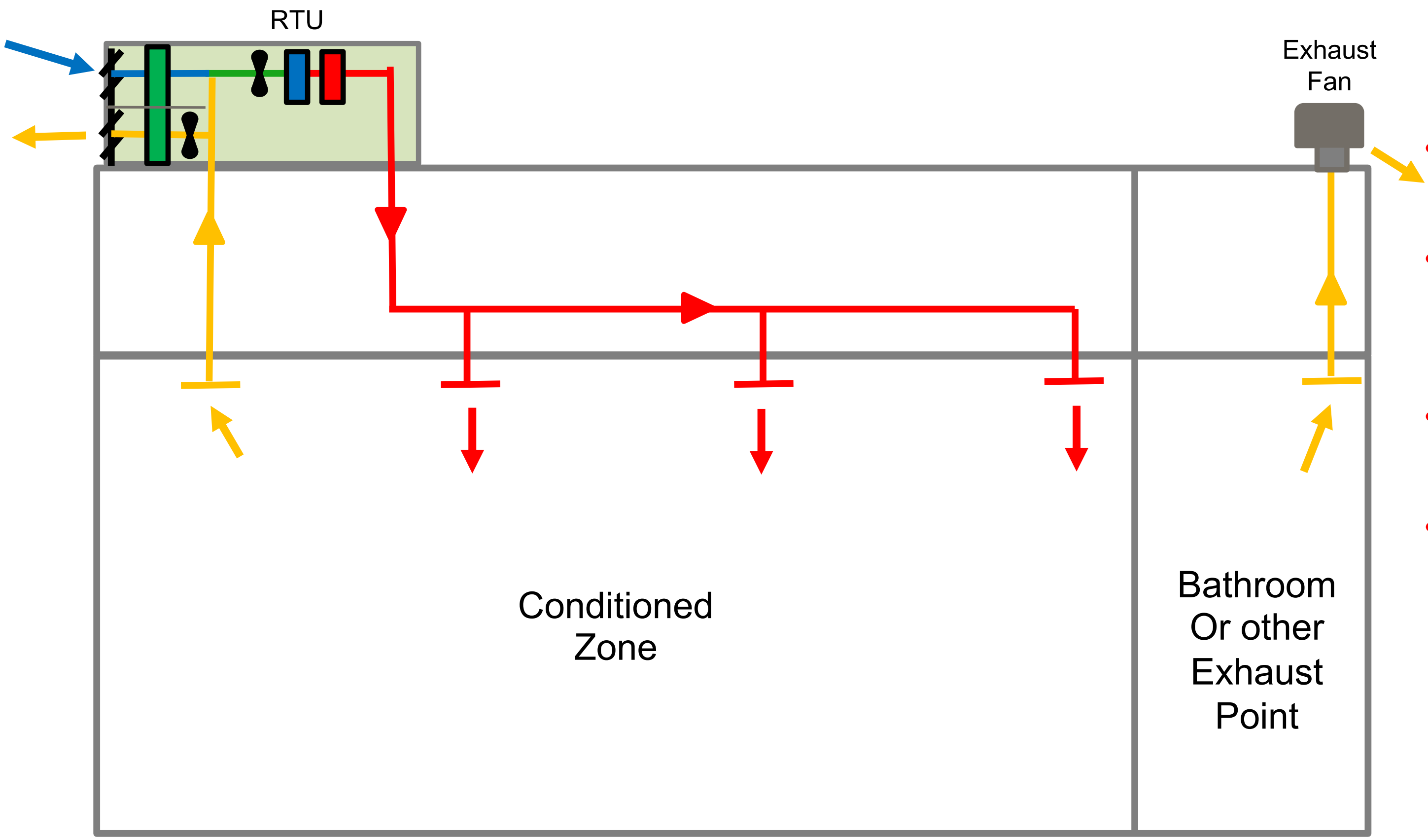
- Usually RTUs coupled with dedicated exhaust fans for bathrooms, etc
- Meets exhaust requirements but energy wasted
- Usually not balanced to OA airflows
- If OA damper closed to save energy, promotes infiltration

Traditional Ventilation Methods: Relief Fan for Balance



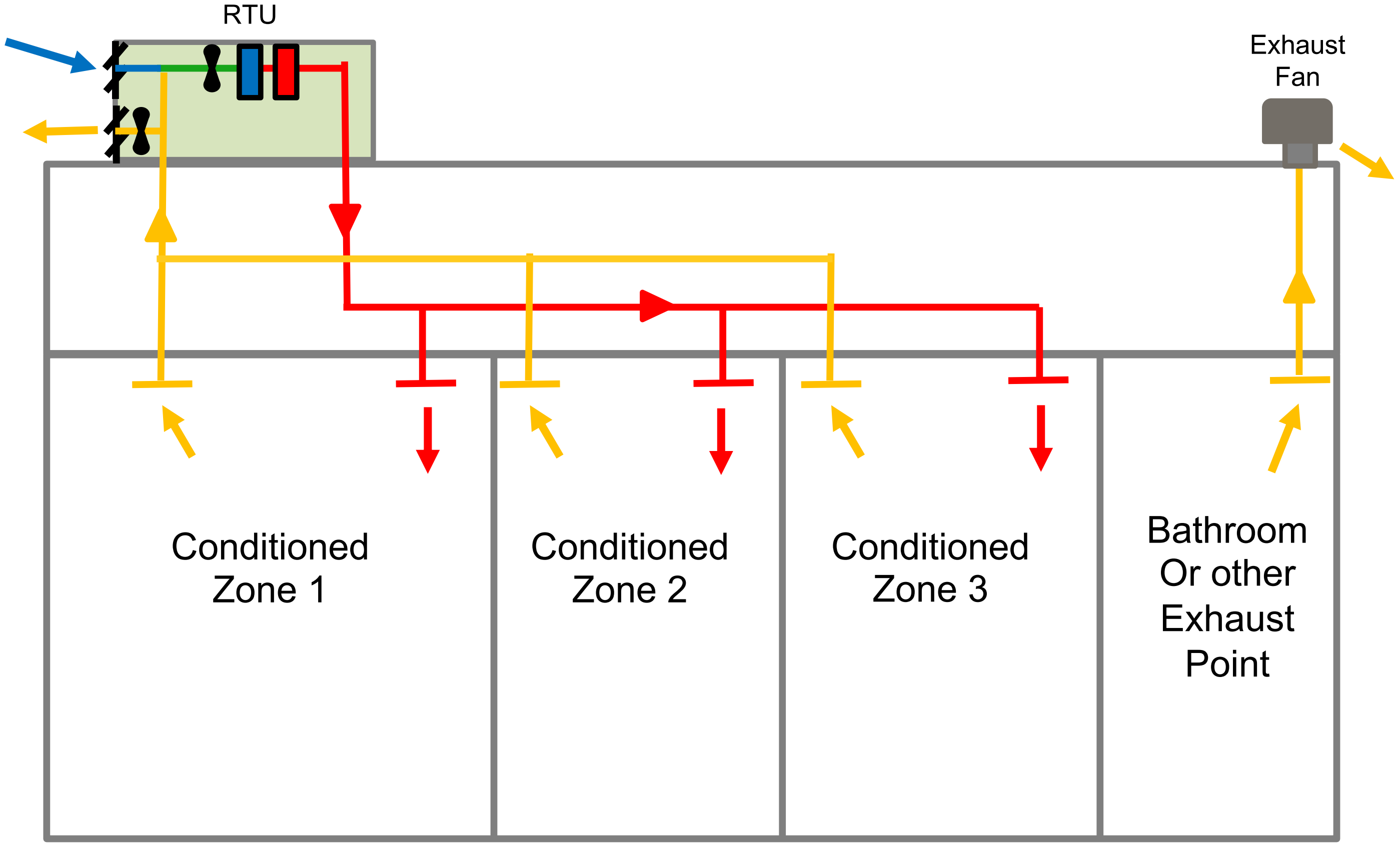
- Addition of relief air damper and fan can help properly balance the system
- Reduces amount of infiltration and exfiltration potential
- Energy still wasted in exhausting air

Traditional Ventilation Methods: Include an ERV Wheel



- ERV heat recovery wheel sometimes added to recover heat from relief air to OA
- Reduces amount of heat wasted.
- Still waste all heat from the dedicated exhaust fans
- Can have significant cross-flow leakage
- Other challenges of coupled systems remain

Traditional Ventilation Methods
Multiple Zones



- International

Traditional Ventilation Methods
Multiple Zones (Alphabet Soup)

Multi-zone Systems

$V_{bz} = (R_p \times P_z) + (R_a \times A_z)$

$V_{oz} = V_{bz}/E_z$

$Z_{pz} = V_{oz} / V_{pz}$

Use Max Z_{pz} to find E_v

$D = P_s / \Sigma_{all\ zones} P_z$

$V_{ou} = D\Sigma_{all\ zones} (R_p \times P_z) + \Sigma_{all\ zones} (R_a \times A_z)$

$V_{ot} = V_{ou} / E_v$

Single Zone Systems

$V_{bz} = (R_p \times P_z) + (R_a \times A_z)$

$V_{oz} = V_{bz}/E_z$

$V_{ot} = V_{oz}$

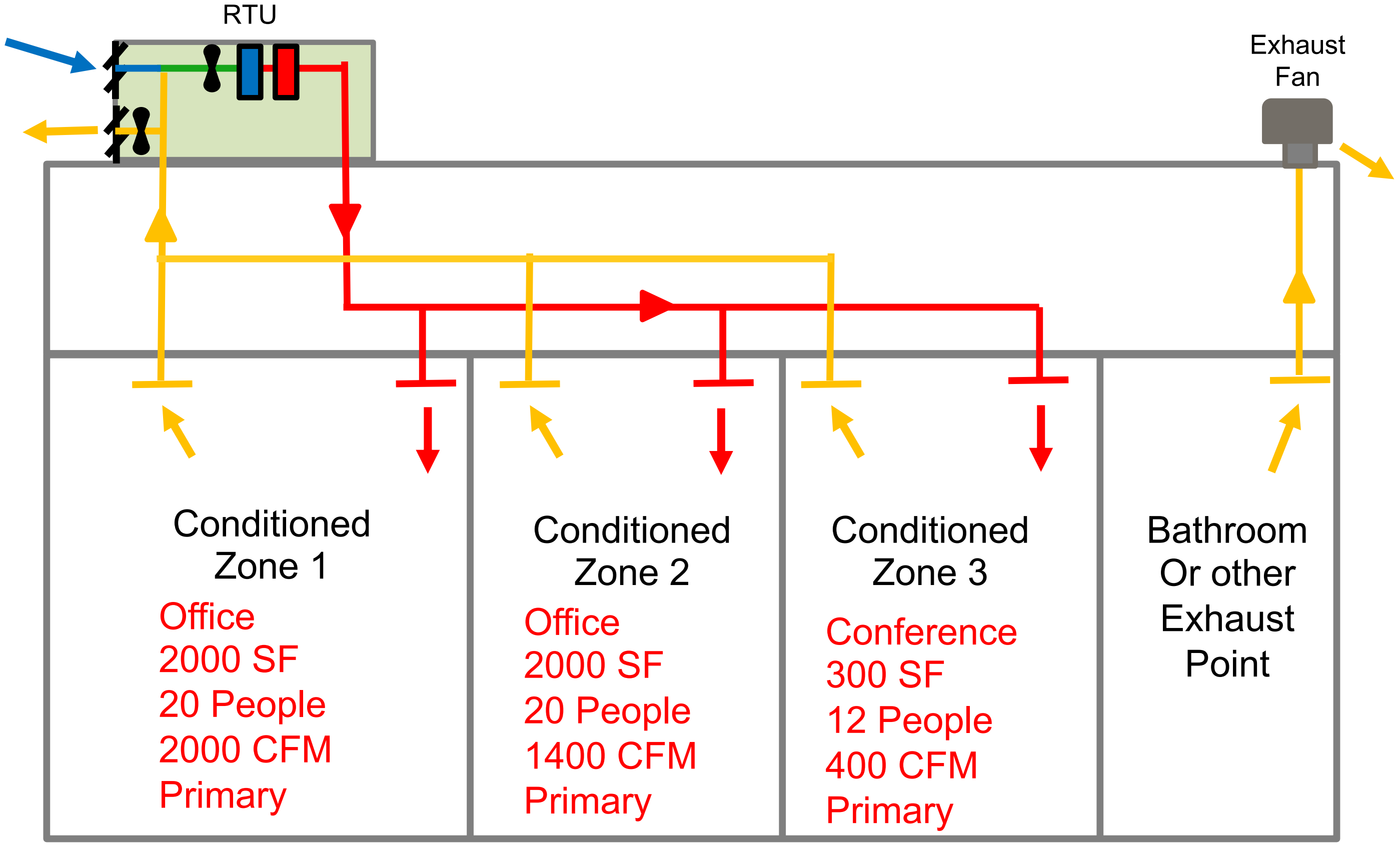
OA Intake Flow = Zone Airflow

TABLE 6.2.5.2 System Ventilation Efficiency

Max (Z_{pz})	E_v
≤0.15	1.0
≤0.25	0.9
≤0.35	0.8
≤0.45	0.7
≤0.55	0.6
>0.55	Use Normative Appendix A

- Single zone systems are simple
- Multi-zone systems are complicated and lead to compromise of ventilation

Traditional Ventilation Methods
Multiple Zones – Example Case



- Basic 3-zone office occupancy
- 2 open offices and conference room

Traditional Ventilation Methods
Multiple Zones – Example Case

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a			Default Values			
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
Occupancy Category	cfm/ person	L/s· person	cfm/ft^2	L/s·m^2	Notes	#/1000 ft^2 or #/100 m^2	cfm/ person	L/s· person	Air Class
General									
Break rooms	5	2.5	0.06	0.3	H	25	7	3.5	1
Coffee stations	5	2.5	0.06	0.3	H	20	8	4	1
Conference/meeting	5	2.5	0.06	0.3	H	50	6	3.1	1
Corridors	—	—	0.06	0.3	H	—			1
Occupiable storage rooms for liquids or gels	5	2.5	0.12	0.6	B	2	65	32.5	2
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3	H	10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
Office space	5	2.5	0.06	0.3	H	5	17	8.5	1
Reception areas	5	2.5	0.06	0.3	H	30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3	H	60	6	3.0	1

- Step 1: Consult the Tables
- Office 5 CFM/Person 0.06 CFM/SF
- Conference 5 CFM/Person 0.06 CFM/SF
- Default densities are different

Traditional Ventilation Methods
Multiple Zones – Example Case

Office & Conference: 5 CFM/Person 0.06 CFM/SF

Breathing Zone Outdoor Airflow (V_{bz})

$V_{bz} = (R_p \times P_z) + (R_a \times A_z)$

Office 1:

V_{bz1} = (5 CFM/P x 20P) + (0.06 CFM/SF x 2000SF)

V_{bz1} = 100 CFM + 120 CFM

V_{bz1} = **220 CFM**

Office 2:

V_{bz2} = (5 CFM/P x 20P) + (0.06 CFM/SF x 2000SF)

V_{bz2} = 100 CFM + 120 CFM

V_{bz2} = **220 CFM**

Conference Room:

V_{bz3} = (5 CFM/P x 12P) + (0.06 CFM/SF x 300SF)

V_{bz3} = 60 CFM + 18 CFM

V_{bz3} = **78 CFM**

- Step 2 Calculate the Breathing Zone Outdoor Airflows for each zone
- Do people and area calcs as intermediate step, will need later.

Traditional Ventilation Methods
Multiple Zones – Example Case

Zone Outdoor Airflow (V_{oz})

$V_{oz} = V_{bz}/E_z$

In this case ceiling supply of Warm air and ceiling return
$E_z = 0.8$

Office 1:
V_{oz1} = 220 CFM / 0.8
V_{oz1} = 275 CFM

By similar process:

Office 2:
V_{oz2} = 275 CFM

Conference:
V_{oz3} = 98 CFM

TABLE 6.2.2.2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level (See Note 6)	1.0
Floor supply of cool air and ceiling return, provided that the vertical throw is greater than 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) or more above the floor	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification, or underfloor air distribution systems where the vertical throw is less than or equal to 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust, return, or both.	0.8
Makeup supply drawn in near to the exhaust, return, or both locations.	0.5

NOTES:
1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling supply" includes any point above the breathing zone.
4. "Floor supply" includes any point below the breathing zone.
5. As an alternative to using the above values, E_z may be regarded as equal to air-change effectiveness determined in accordance with ASHRAE Standard 129 [16] for air distribution configurations except unidirectional flow.
6. For lower velocity supply air, E_z = 0.8.

- Step 3 Calculate the Zone Outdoor Airflows for each zone using Air Distribution Effectiveness
- E_z can be different for each zone

Traditional Ventilation Methods
Multiple Zones – Example Case

Primary Outdoor Airflow Fraction (Z_{pz})

$Z_{pz} = V_{oz}/V_{pz}$

V_{pz} is primary airflow from RTU for heating and cooling.

Office 1:
Z_{pz1} = 275 CFM / 2000 CFM
Z_{pz1} = 0.14

Office 1 V_{pz} = 2000 CFM
Office 2 V_{pz} = 1400 CFM
Conference V_{pz} = 400 CFM

By similar process:

Office 2:
Z_{pz2} = 0.20

Conference:
Z_{pz3} = 0.25

Max Z_{pz}

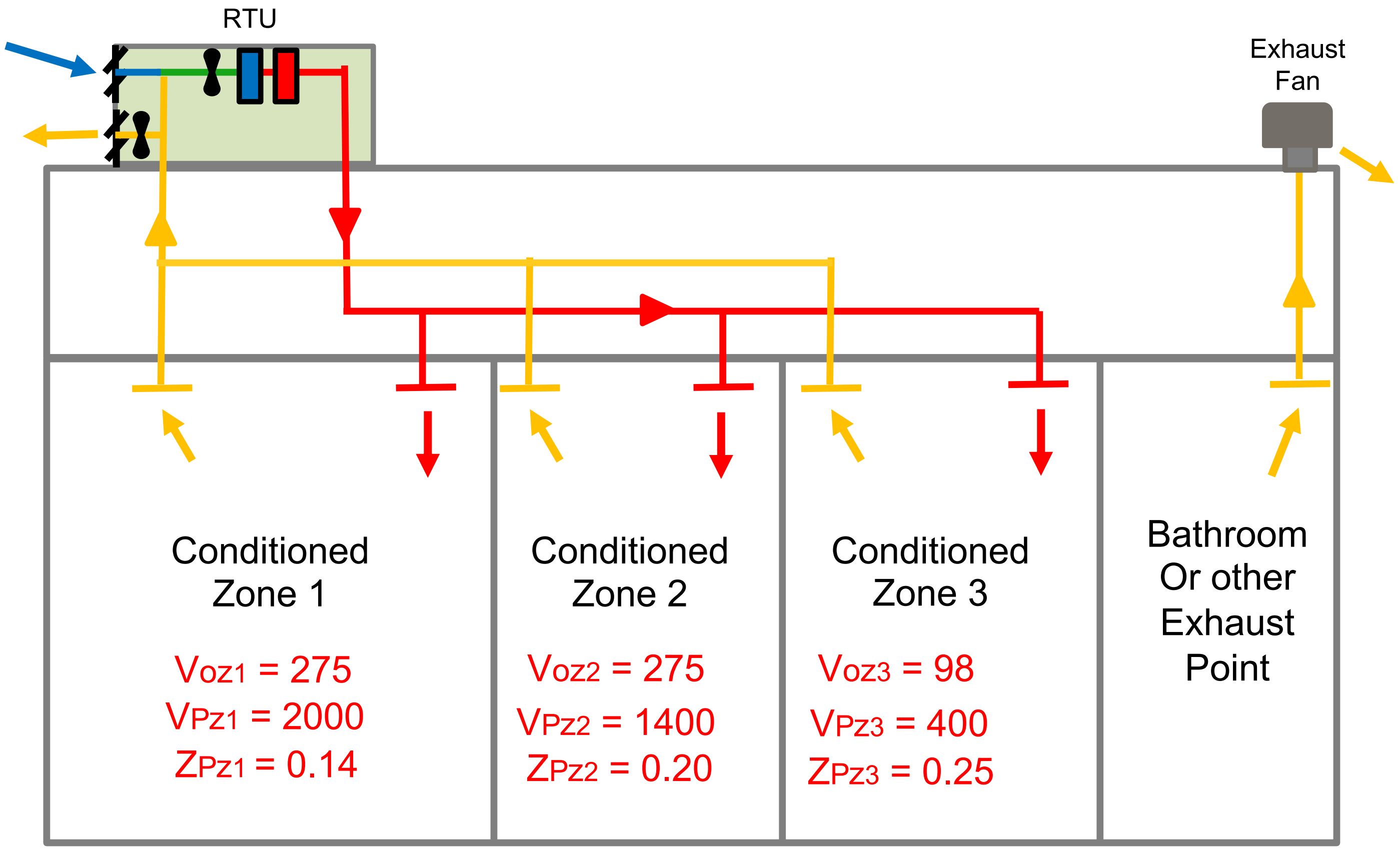
TABLE 6.2.5.2 System Ventilation Efficiency

Max (Z_{pz})	E_v
≤0.15	1.0
≤0.25	0.9
≤0.35	0.8
≤0.45	0.7
≤0.55	0.6
>0.55	Use Normative Appendix A

$E_v = 0.9$

- Step 3 Calculate the Primary Outdoor Airflow Fraction for each zone using V_{pz} primary airflow
- Max Zpz used to determine System Ventilation Efficiency

Traditional Ventilation Methods
Multiple Zones – Example Case



- Done all zone by zone calculations
- Next steps system level calculations

V_{oz} - Zone Outdoor Airflow
V_{pz} - Zone Primary Airflow (heating & AC)
Z_{pz} - Primary Zone Air Fraction

System Ventilation Efficiency
$E_v = 0.9$

Traditional Ventilation Methods
Multiple Zones – Example Case

<u>Occupant Diversity (D)</u>

$D = P_s / \Sigma_{all\ zones} P_z$

P_s is the total amount of people in the area at one time
P_z is the total possible in a given zone.

In this case assume only people in conference room
Would otherwise be in one of the offices,

Ps = 40 people

D = 40 P / (20 + 20 + 12) P

D = 0.77

- Step 4 Calculate occupant diversity of the zones covered.
- Total people at one time versus the total possible people per zone.

Traditional Ventilation Methods
Multiple Zones – Example Case

Uncorrected Outdoor Air Intake (V_{ou})

$V_{ou} = D\Sigma_{\text{all zones}} (R_p \times P_z) + \Sigma_{\text{all zones}} (R_a \times A_z)$

Apply the occupant diversity factor to the people rate part of the Breathing Zone Outdoor Airflow equation

$V_{ou} = 0.77(100 + 100 + 60) + (120 + 120 + 18)$

$V_{ou} = 458$ CFM

- Step 5 Calculate Uncorrected Outdoor Air Intake
- Sum of all the zone ventilation taking occupant diversity into account

Traditional Ventilation Methods
Multiple Zones – Example Case

Design Outdoor Air Intake (V_{ot})

$V_{ot} = V_{ou} / E_v$

From Step 3, $E_v = 0.9$

$V_{ot} = 458$ CFM / 0.9

$V_{ot} = 508$ CFM

$\Sigma V_{bz} = 518$ CFM

$\Sigma V_{oz} = 648$ CFM

Pretty close to breathing zone value and accounts for diversity so everything is good right?

- Step 6: adjust the uncorrected outdoor air intake for the system ventilation efficiency
- This is the design outdoor air intake

Traditional Ventilation Methods
Multiple Zones – Example Case

What does this mean to the individual zones?

Only one mix of OA to primary air
The Primary Outdoor Air Fraction

$V_p = \Sigma V_{pz}$

V_p = 2000 CFM + 1400 CFM + 400 CFM

V_p = 3800 CFM

V_{ot} = 508 CFM

Z_p = 508 CFM / 3800 CFM

$Z_p = 0.134$ 13.4%

- One rooftop unit supplies all zones with a fixed percentage of outside air.
- How does this percentage meet the needs of each zone while in use?

Traditional Ventilation Methods
Multiple Zones – Example Case

What does this mean to the individual zones?

Z_p = 0.134 13.4%

Air Supplied to Zone	Design Airflow	
Office 1: 2000 CFM x 0.134 = 268 CFM	275 CFM	-3%
Office 2: 1400 CFM x 0.134 = 187 CFM	275 CFM	-32%
Conference: 400 CFM x 0.134 = 54 CFM	98 CFM	-45%

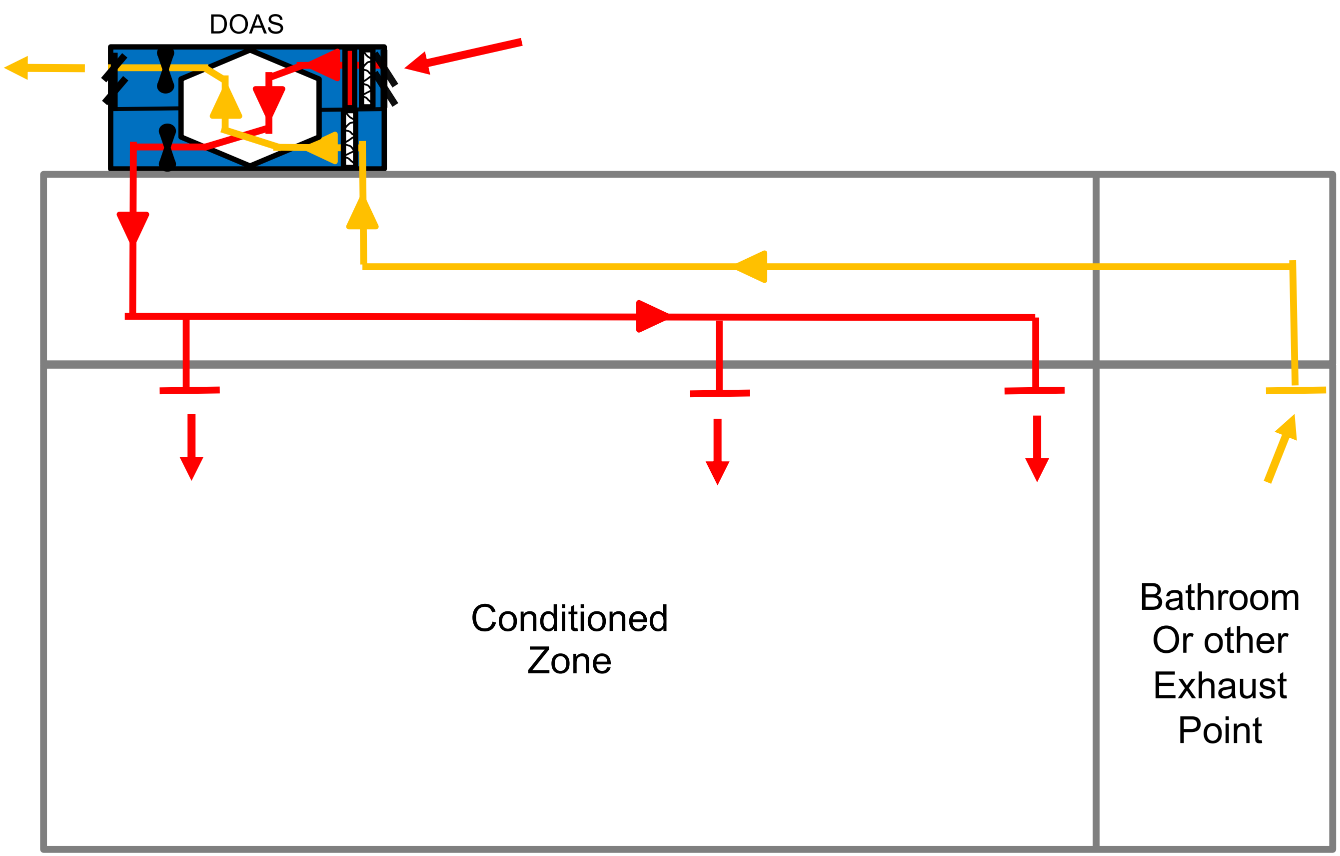
How good is the air in that conference room going to be
After a long meeting?

Poor IAQ shown to diminish decision making skills.
This space would not serve the organization well

- Potential Large discrepancies between design flows and provided flows in individual zones
- Worst for dense occupancies with low loads

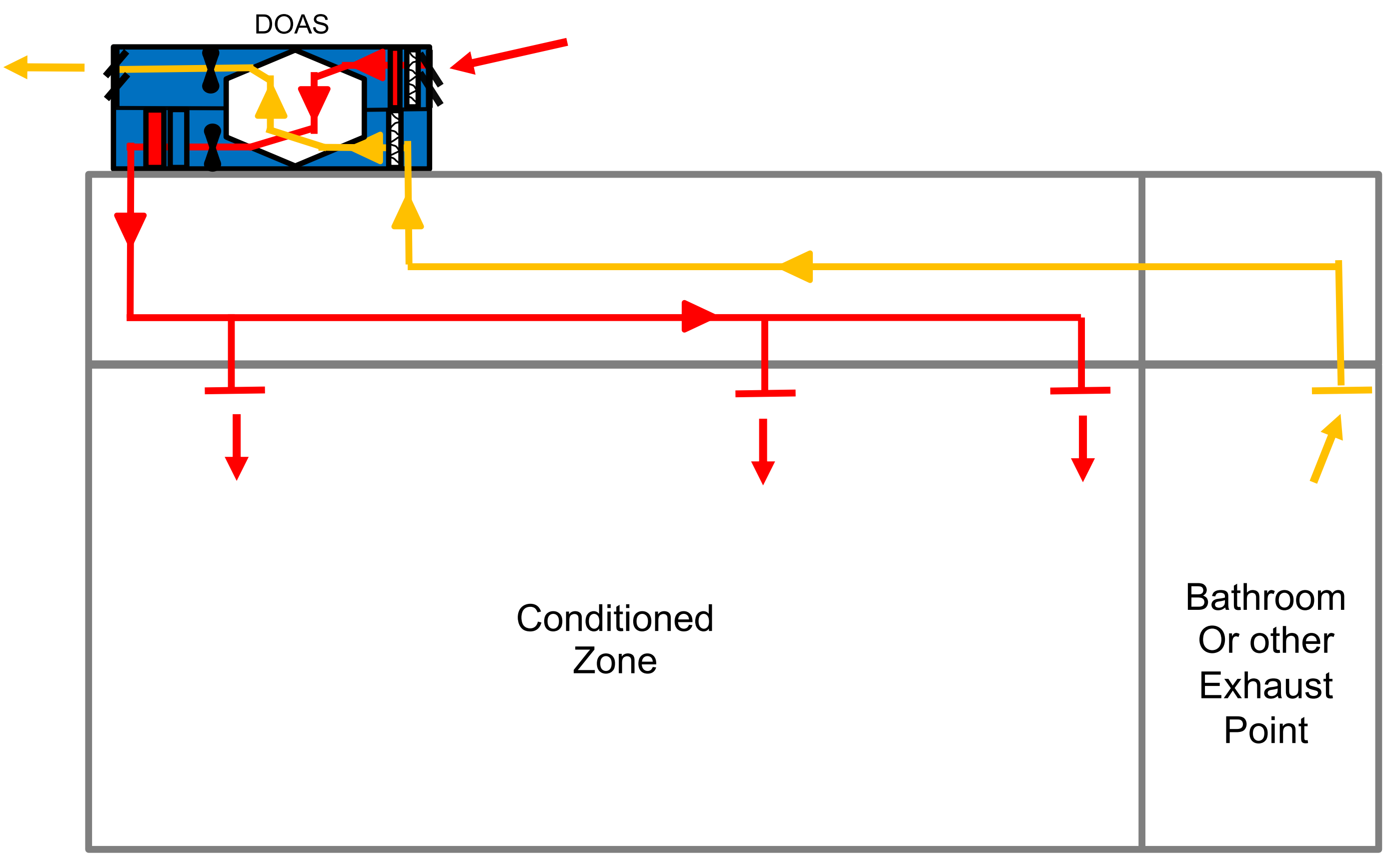
Chapter 7: DOAS
(Dedicated Outdoor Air Systems)

Dedicated Outdoor Air Systems (DOAS)
The High Performance Solution



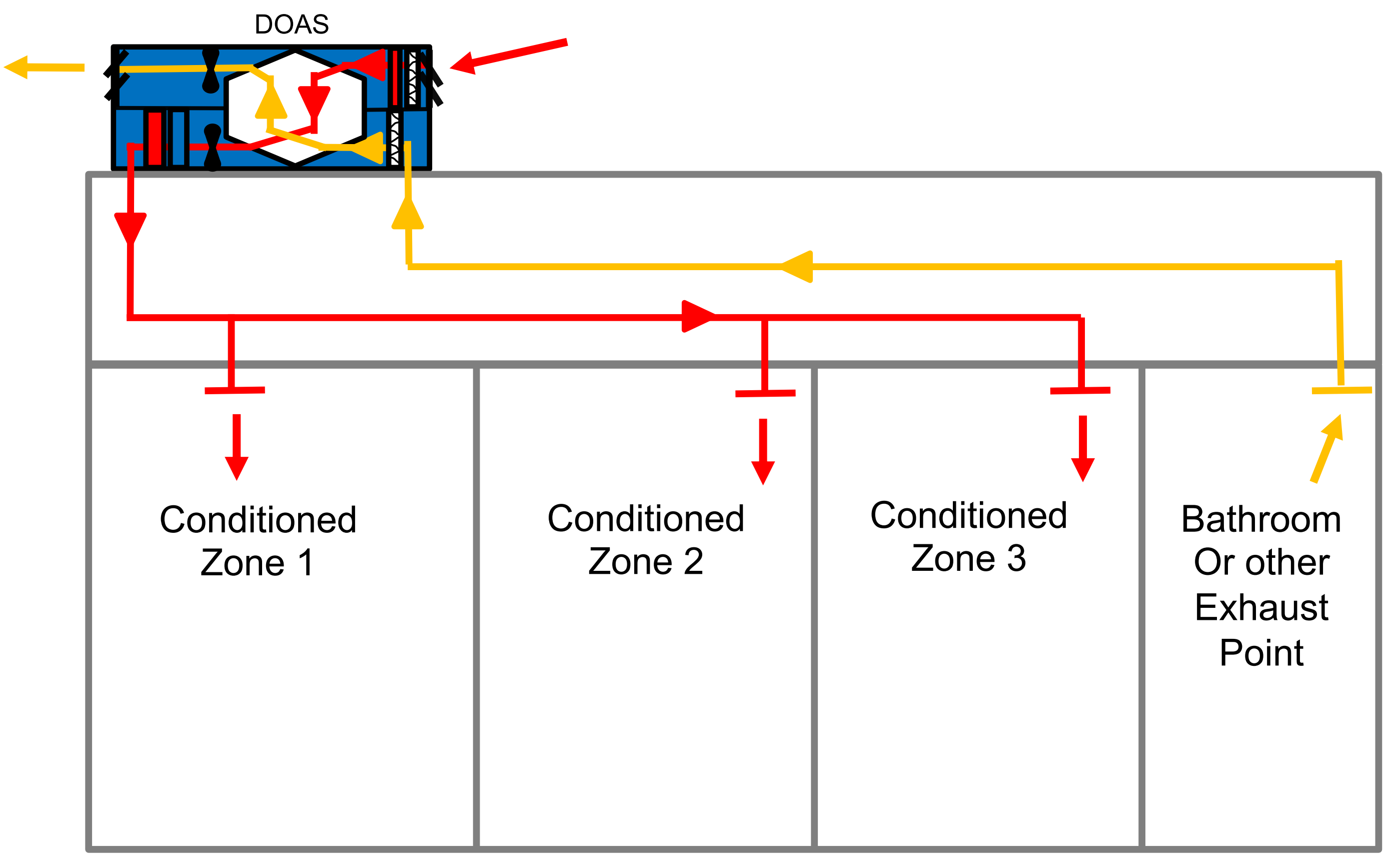
- DOAS ventilation is decoupled from the heating and cooling.
- Supply air is ducted independently to the conditioned zone(s).
- Exhaust air is ducted back to the DOAS H/ERV to recovery energy before exhausting.

Dedicated Outdoor Air Systems (DOAS)
Post Conditioning Possibilities



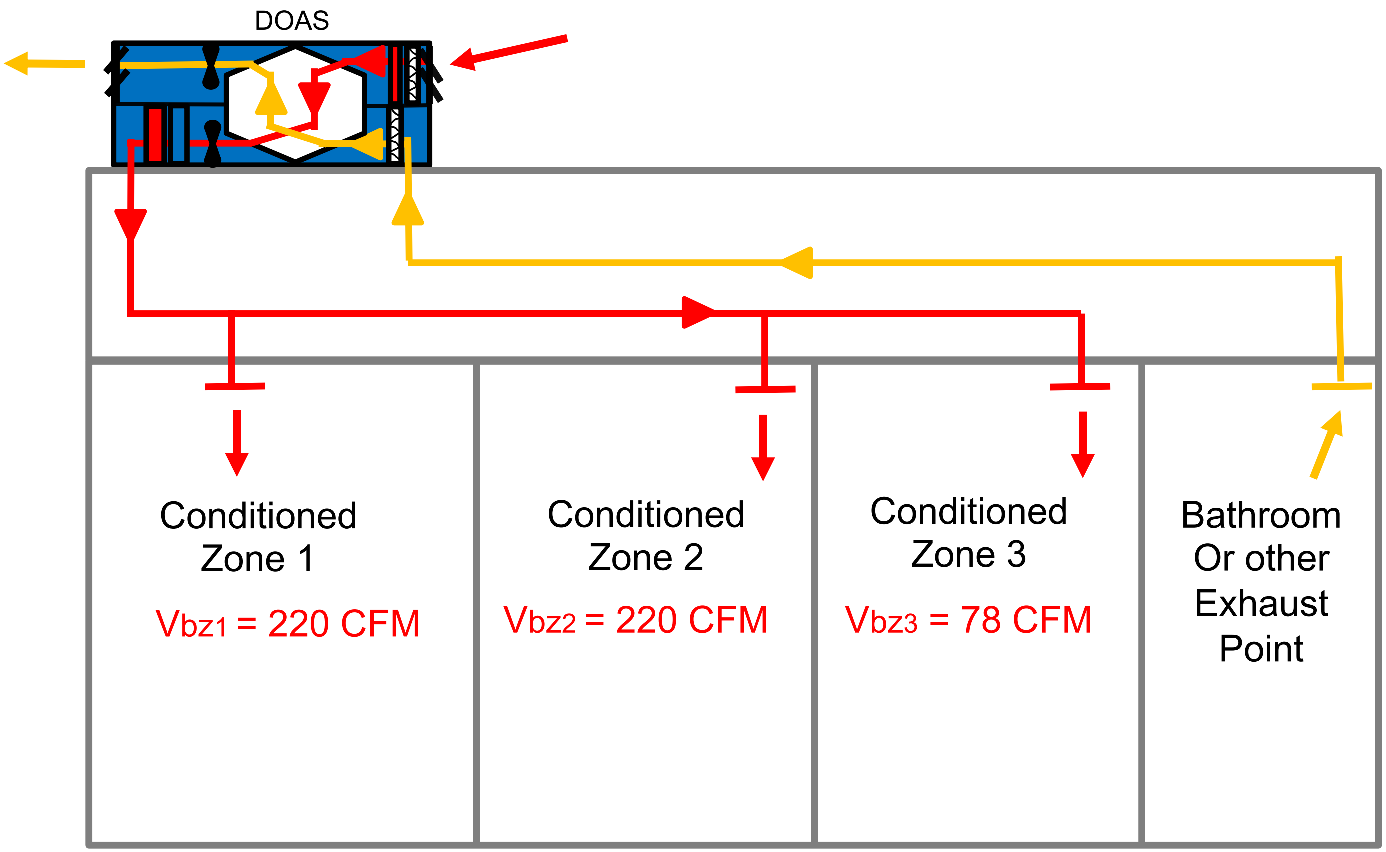
- Post heat exchanger conditioning coils possible for additional tempering to further heat, cool and/or dehumidify OA airstream.
- Sometimes internal to DOAS unit or installed downstream separately.

Dedicated Outdoor Air Systems (DOAS) Multiple Zones



- DOAS works better than traditional approach for multiple zone systems
- Supply air to zones, exhaust from bathrooms and other exhaust points.
- Balance flows to higher of the two design flows

Dedicated Outdoor Air Systems (DOAS)
Multiple Zones – Example Case



- Take same example case as used for traditional system
- 3 Zones
- 2 Offices
- 1 Conference Room

Dedicated Outdoor Air Systems (DOAS)
Multiple Zones – Example Case

Zone Outdoor Airflow (V_{oz})

$V_{oz} = V_{bz}/E_z$

In this case ceiling supply of Warm air and ceiling return
$E_z = 1.0$

Office 1:
V_{oz1} = 220 CFM / 1.0
V_{oz1} = 220 CFM

By similar process:

Office 2:
V_{oz2} = 220 CFM

Conference:
V_{oz3} = 78 CFM

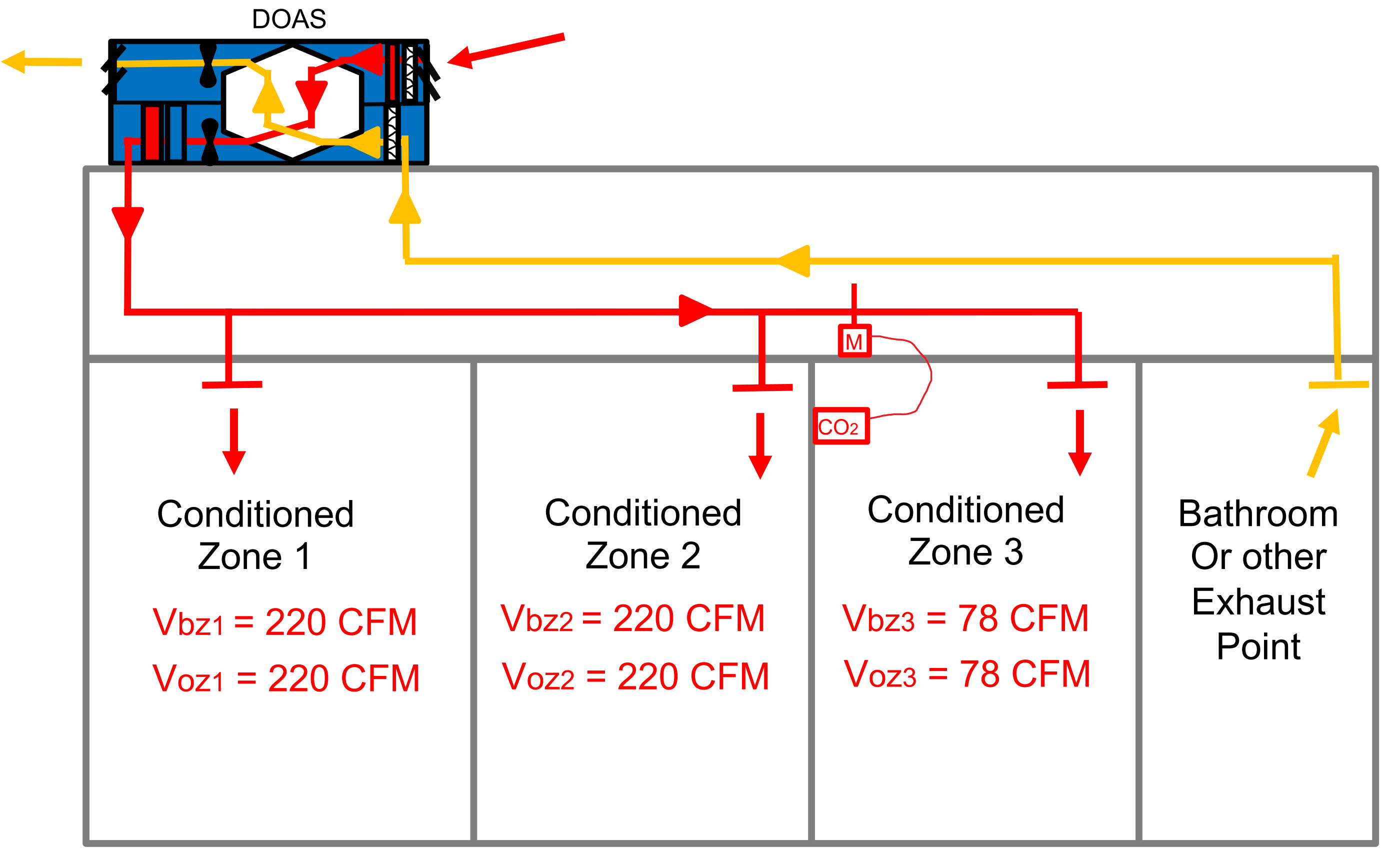
TABLE 6.2.2.2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level (See Note 6)	1.0
Floor supply of cool air and ceiling return, provided that the vertical throw is greater than 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) or more above the floor	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification, or underfloor air distribution systems where the vertical throw is less than or equal to 50 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust, return, or both.	0.8
Makeup supply drawn in near to the exhaust, return, or both locations.	0.5

NOTES:
1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling supply" includes any point above the breathing zone.
4. "Floor supply" includes any point below the breathing zone.
5. As an alternative to using the above values, E_z may be regarded as equal to air-change effectiveness determined in accordance with ASHRAE Standard 129 [16] for air distribution configurations except unidirectional flow.
6. For lower velocity supply air, $E_z = 0.8$.

- Without post heating air will be slightly cooler than ambient.
- Without post cooling air will be slightly warmer than ambient
- With proper diffuser selection can obtain distribution effectiveness of 1.

Dedicated Outdoor Air Systems (DOAS)
Multiple Zones – Example Case



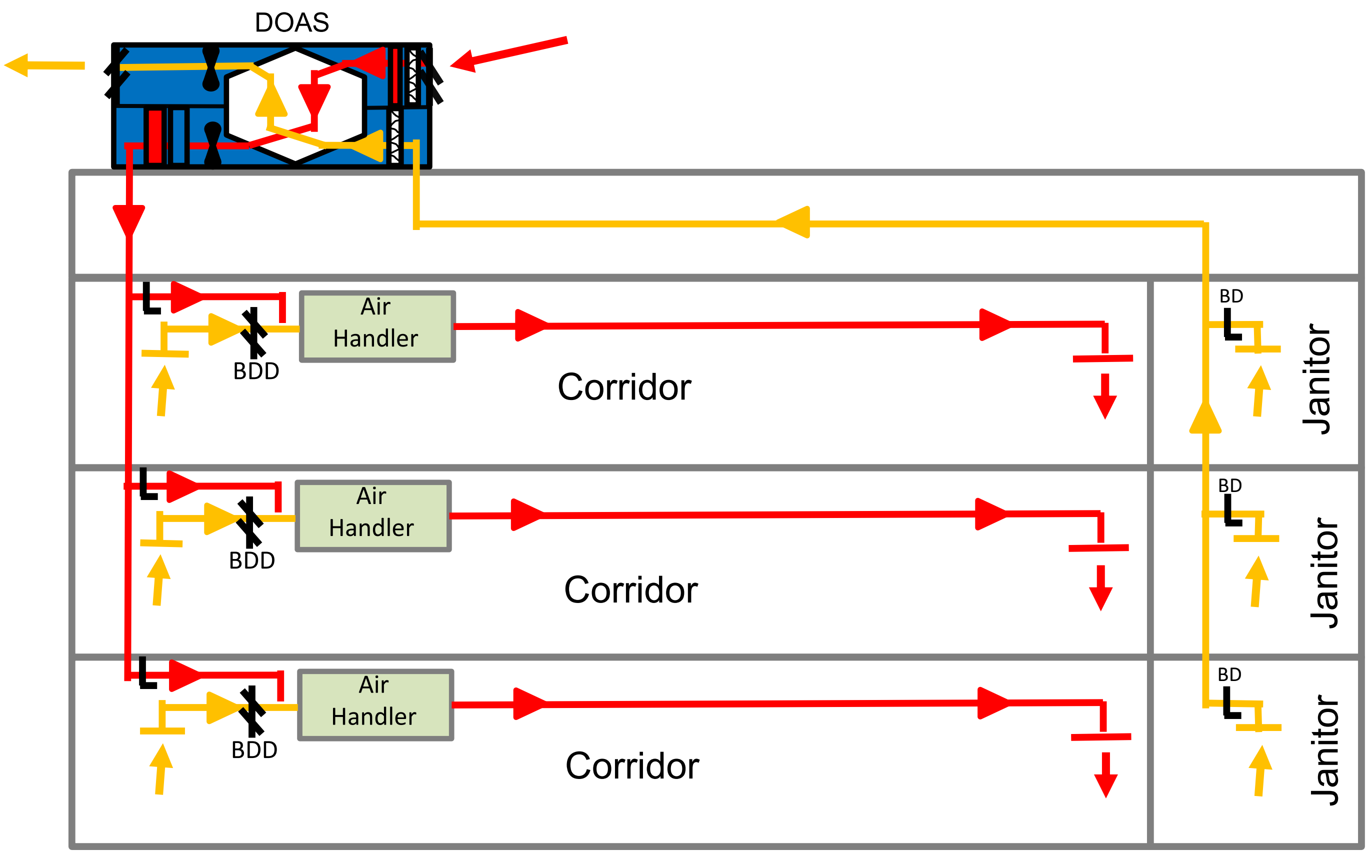
- For 100% OA systems the outdoor air intake flow is the sum of the zone outdoor airflows
- Each zone actually can be balanced to receive the design airflow.
- Controls can reduce flows to account for diversity if desired

$V_{ot} = \Sigma_{\text{all zones}} V_{oz}$

$V_{ot} = 220\text{ CFM} + 220\text{ CFM} + 78\text{ CFM}$

$V_{ot} = 518\text{ CFM}$

Dedicated Outdoor Air Systems (DOAS)
Multiple Zones – Connecting to Air Handlers



- For simple zones it is possible to connect supply to zone air handlers.
- Include back-draft damper so air flows out the supply network.
- Preferably keep exhaust independent.

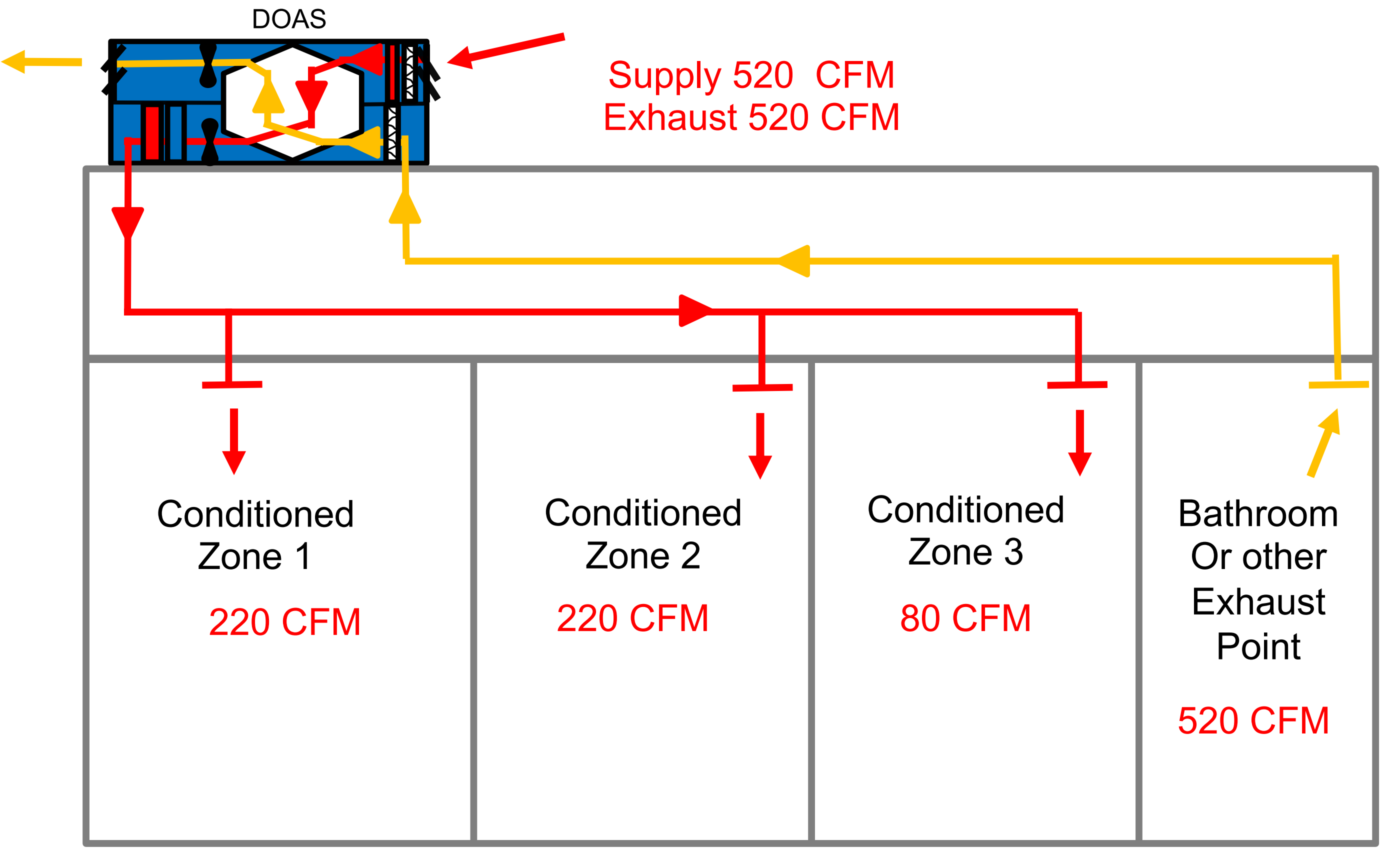
DOAS Control Strategies

Main Approaches:

- CAV – Constant Air Volume
- DCV – Demand Control Ventilation
- VAV – Variable Air Volume
- Economizer

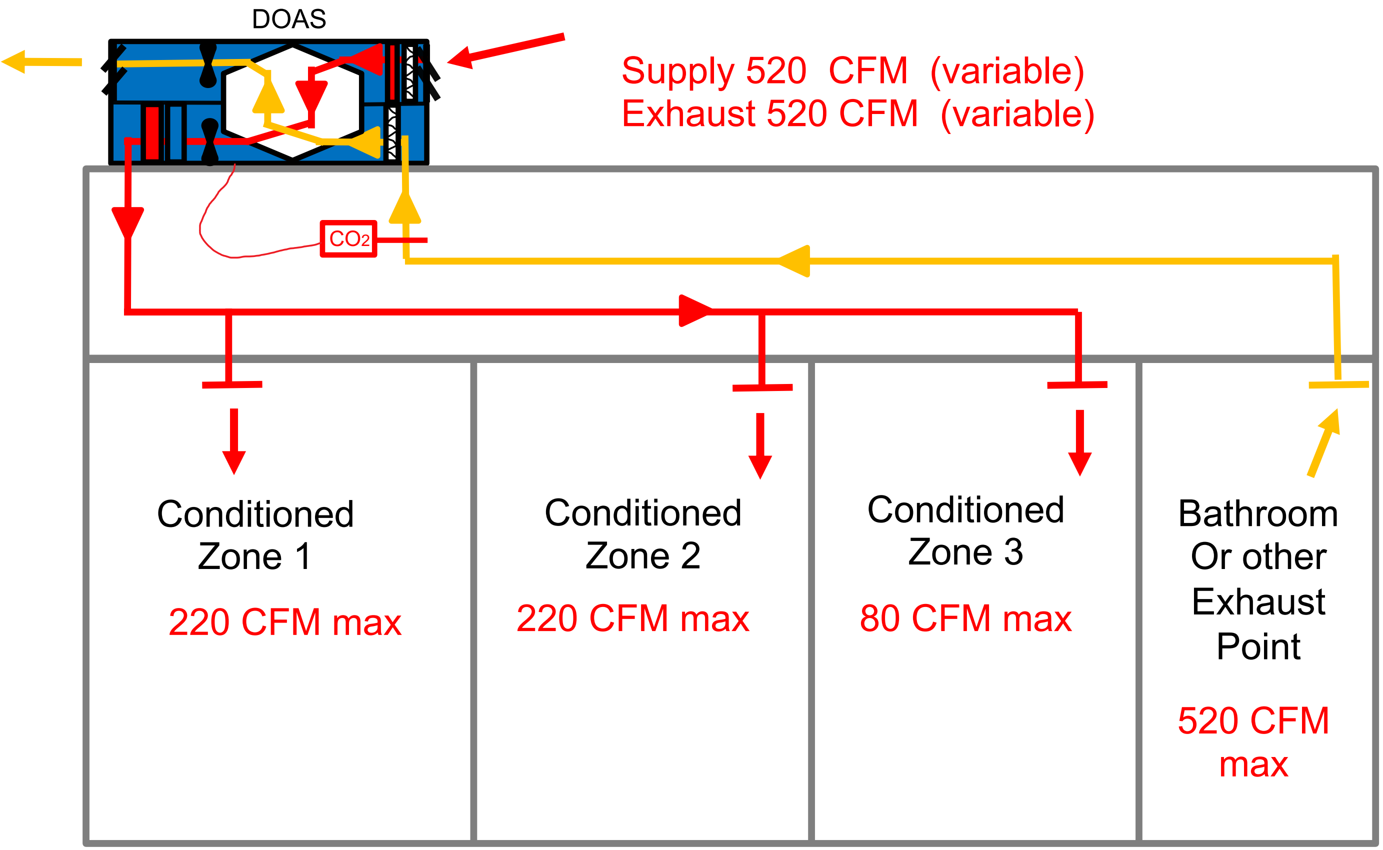
- Multiple strategies for controlling a DOAS from simple to sophisticated depending upon goals and budget.
- Some brands have flexible and elegant internal controls while others require a BMS system to do anything beyond basic control

DOAS Control Strategies: CAV – Constant Air Volume



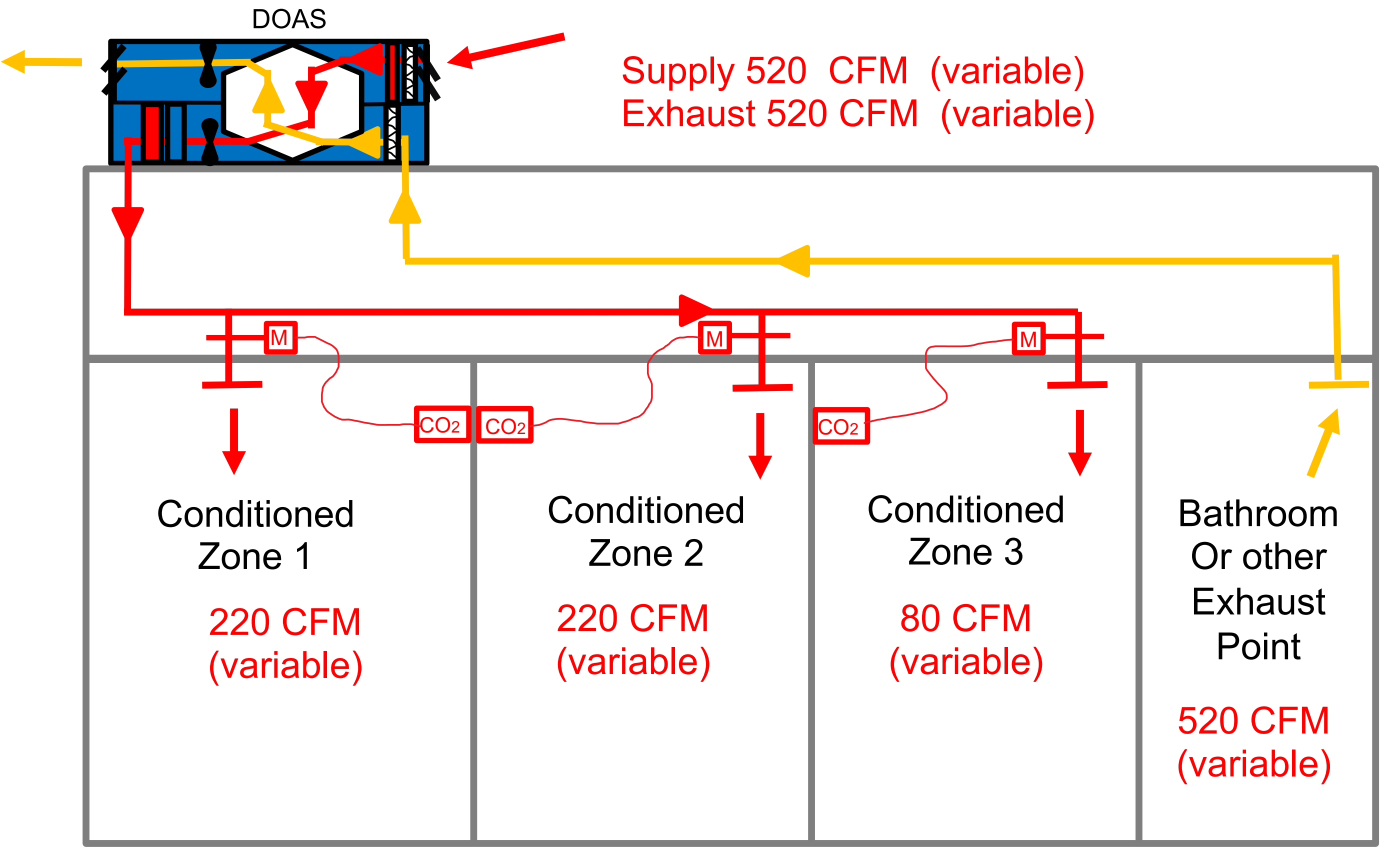
- During occupied hours DOAS runs at a constant single rate to meet the design airflows
- During unoccupied hours DOAS is in stand-by mode
- Schedule can be overridden for special events

DOAS Control Strategies:
DCV – Demand Control Ventilation



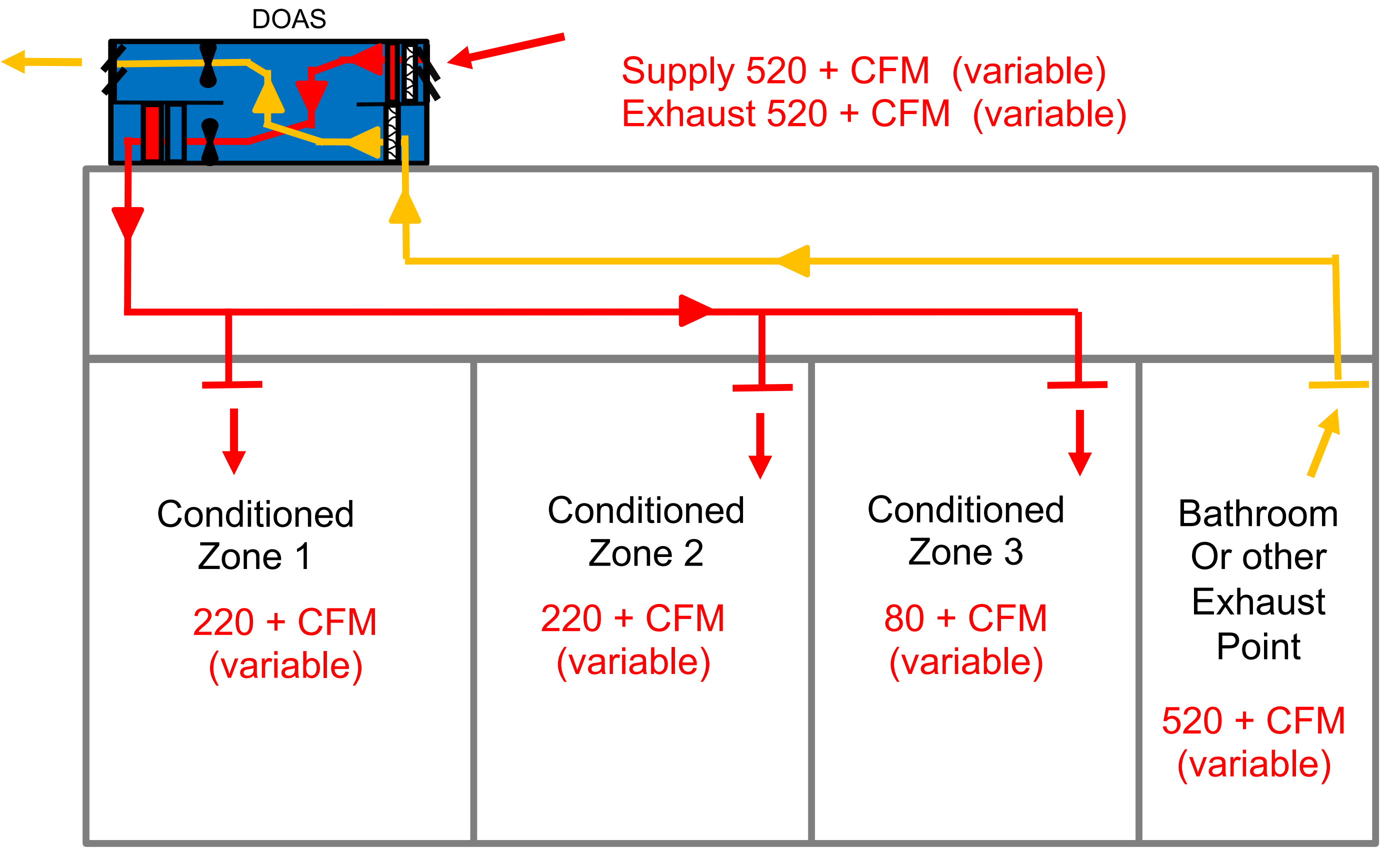
- Demand control ventilation allows system to ramp down during periods of lower occupancy
- Both supply and exhaust side fluctuate in parallel
- Lowest setting based on area rate or exhaust requirement.

DOAS Control Strategies: VAV – Variable Air Volume



- Variable Air Volume is a zone by zone demand control ventilation system
- Each zone flow controlled by CO_2, Occupancy, or other sensor
- Minimum flow to meet area flow rates
- DOAS run in constant pressure mode

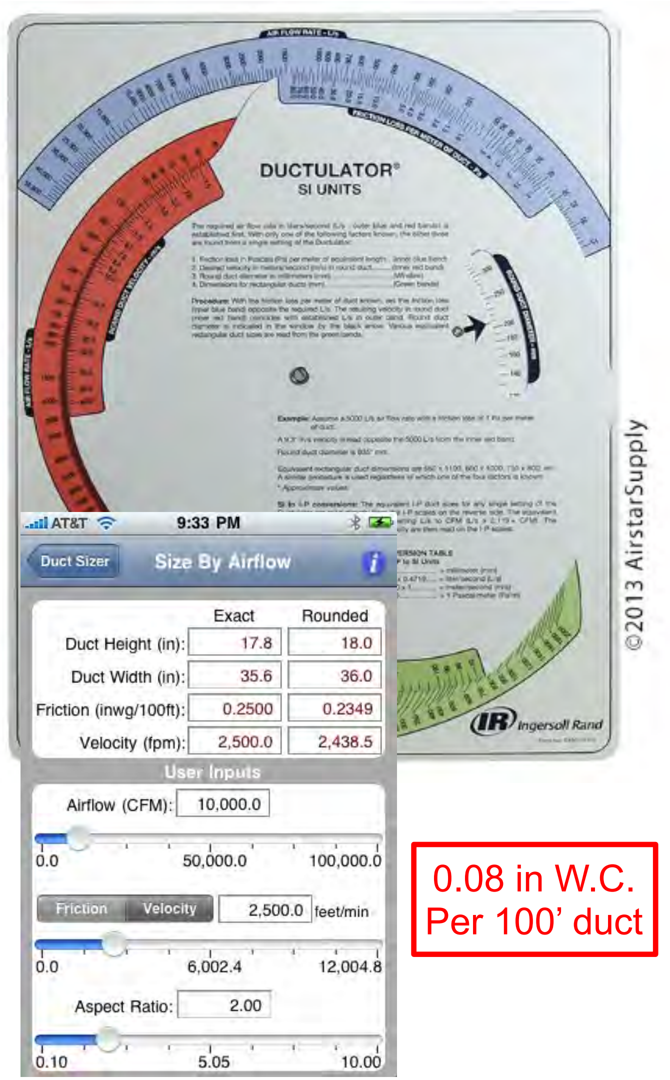
DOAS Control Strategies: Economizer



- A DOAS with an Economizer feature can bypass the heat exchanger and ramp up flow to take advantage of “free cooling” conditions.
- Smart systems can modulate bypass to control supply temperature.

Chapter 8:Duct Design Optimization

Ductwork Design: Duct sizing



0.08 in W.C.
Per 100' duct

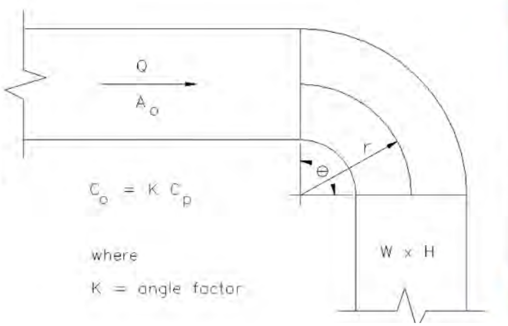
- Overall duct sizing done by friction loss for that airflow.
- Good rule of thumb less than 0.08 in W. C. of friction losses per 100 ft of ductwork
- Ductulators (paper or electronic) will have round and equivalent rectangular.
- Round most efficient.

Ductwork Design: Duct sizing

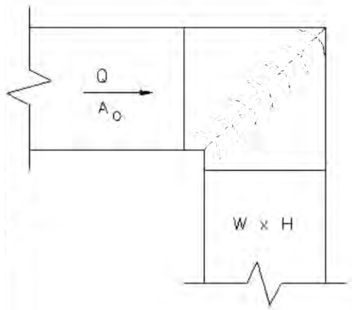
- Round ductwork is most efficient for airflow.
- Rectangular duct can sometimes fit in shallower height.
- Avoid aspect ratios of greater than 5:1 for most efficient flow.

Ductwork Design: Fittings

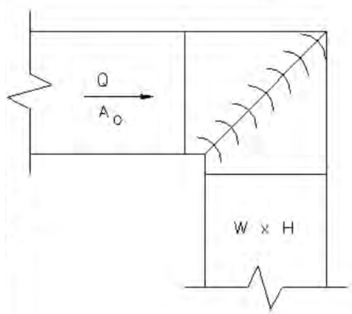
Example: 12"x12" duct with 800 CFM



Radius Elbow r = 1.5W
$C_o = 0.17$ $\Delta P = 0.01$ in WG
Approx equal to 13' of ductwork



Mitered Elbow
$C_o = 1.18$ $\Delta P = 0.05$ in WG
Approx equal to 63' of ductwork

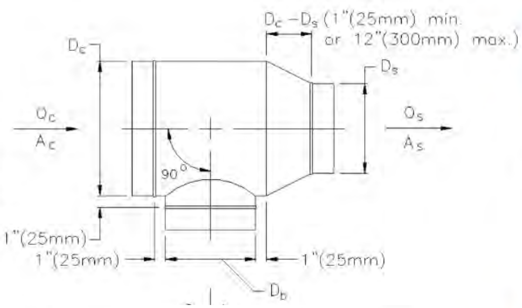


Mitered Elbow with vanes (1-1/2")
$C_o = 0.11$ $\Delta P = 0.00$ in WG
Approx equal to <6' of ductwork
Note: wider spacing and/ double Thickness vanes increase ΔP

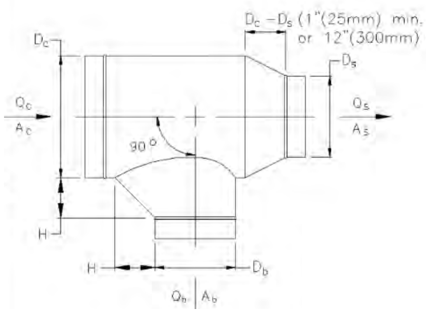
- Selection of fittings can make a big difference in system pressure drop.
- ASHRAE Ductwork Database and related App are good tools for selection and comparison

Ductwork Design: Fittings

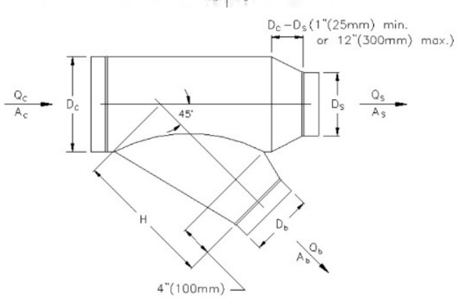
Example: 12” Φ duct with 600 CFM
and 200 CFM take-off
12” x 10” x 8” Fitting



90° Straight Tee
Branch ΔP = 0.04 in WG
Approx equal to 50’ of ductwork



90° Straight Tee w/ 45° Entry
Branch ΔP = 0.02 in WG
Approx equal to 25’ of ductwork



45° Conical Wye
Branch ΔP = 0.01 in WG
Approx equal to 13’ of ductwork

- Selection of fittings can make a big difference in system pressure drop.
- ASHRAE Ductwork Database and related App are good tools for selection and comparison

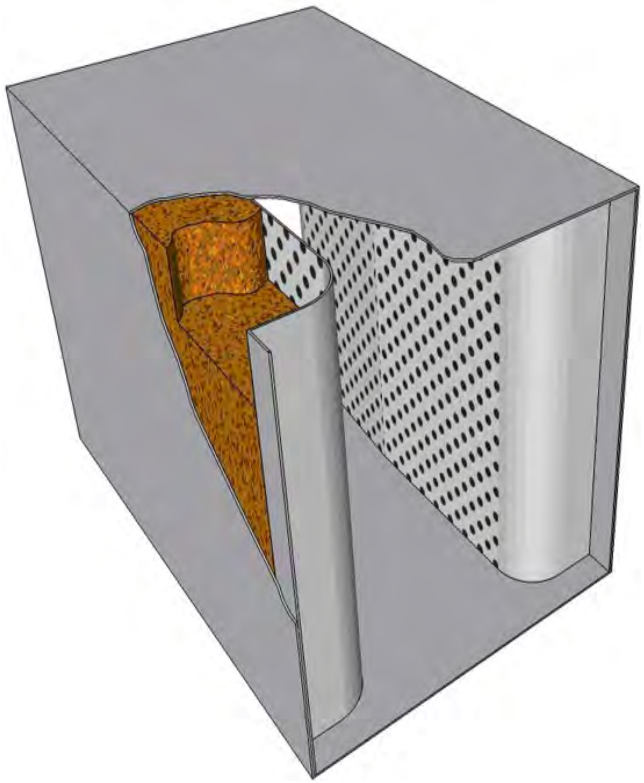
Ductwork Design: Air Sealing

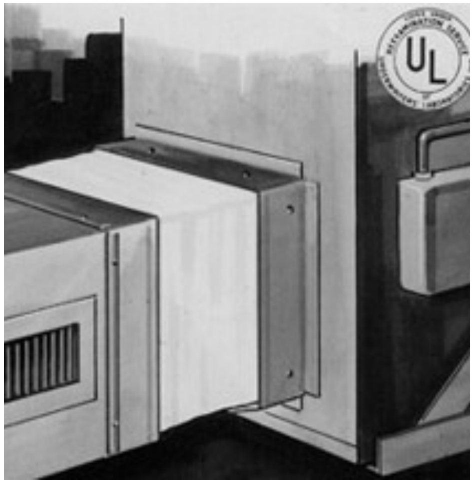
- Proper air sealing of ductwork is critical for efficient delivery of air to designed locations.
- Leakage causes fans to run harder to meet design airflows.
- Duct blaster testing important for confirmation.
- A duct is just a pipe for air. Plumbers can make their pipes 100% airtight!

Ductwork Design: Fire and Smoke Dampers

- Stops fire and smoke from moving through the ductwork.
- Required when ducts penetrate a fire rated assembly (with some exceptions).
- Coordinate with architects about what assemblies are fire and/or smoke rated.
- Access panel required for maintenance.

Ductwork Design: Acoustics and Vibration





- It is good design to connect ductwork to equipment with a flexible connector to isolate vibration from ductwork. Vibration isolating mounts may also be needed.
- Sound attenuation may be useful for critical environments (schools, auditoriums, sound studios)
- Quiet equipment important for high performance buildings

Ductwork Design: Challenges

- Connect through roof with shortest duct/curb possible.
- Avoid bends.
- Reduce or eliminate insulated ducts.
- Minimize leaks.

Ductwork Design: Challenges

- Connect through roof with shortest duct/curb possible.
- Avoid bends.
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Ductwork Design: Challenges

- Connect through roof with shortest duct/curb possible.
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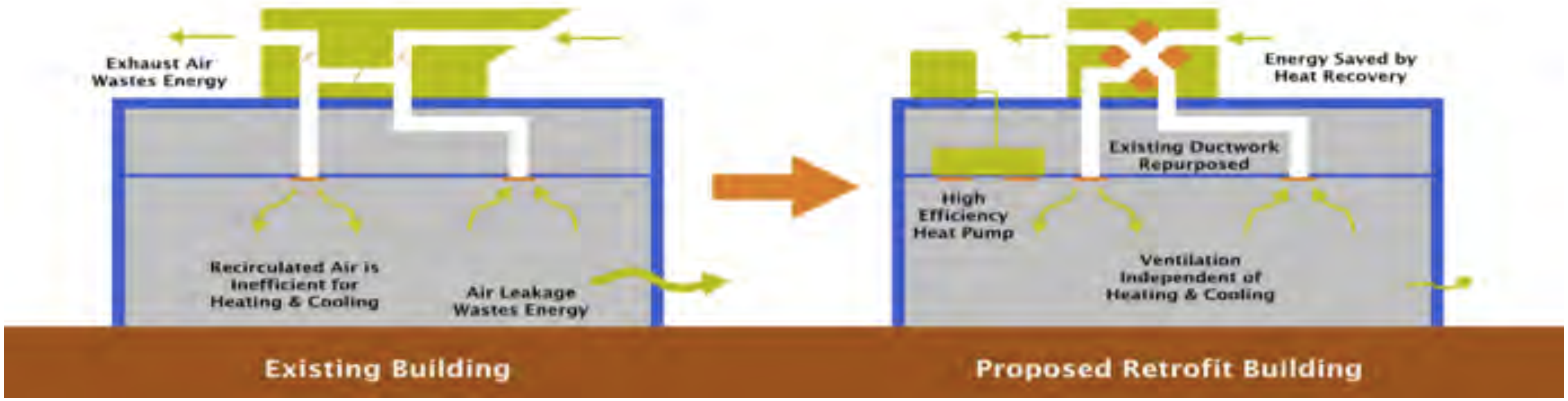
- Minimize leaks.


Change Order
ORANGE BEACH, AL


Change Order

Chapter 9: VHE DOAS Program



- Very Low Energy Savings (5% Typical)
- Same High Cost Maintenance
- 15 Year Life Span
- Same H/C Loads, Resulting in 1:1 Replacement
- Same Noise Level
- Same poor IAQ

- Significant Energy Savings (Proven 40-60+ %)
- 50% + Reduction In Maintenance Costs
- 25-30 Year Life Span
- Significant Reduction in H/C Loads, Reduced Equipment Sizing
- Improved Comfort & Quiet
- Great IAQ & Health

Retrofitting Existing Commercial Buildings to Achieve Significant Energy Savings & Better IAQ

AGING INSTALLATIONS

- Many aging gas packs
- Possible curb reuse

PROGRAM SPECIFICATION

https://betterbricks.com/resources/very-high-efficiency-doas-system-requirements

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Very High Efficiency DOAS System Requirements

ARTICLE

System Requirements and Recommendations Summary

These system requirements and recommendations are intended to provide guidance to manufacturers, designers and specifiers regarding the components of very high efficiency dedicated outside air systems (or very high efficiency DOAS). Developed over several years of research, market analysis, and demonstration project installations, these system requirements have been refined to decrease energy consumption, improve indoor-air quality, and improve occupant comfort over conventional systems.

Downloads

Vhe Doas Requirements Summary

PROGRAM SPECIFICATION

Table 1: Minimum Equipment Performance [learn more]	
Heat Recovery Ventilation [learn more]	
1.	Minimum efficiency: Passive House Institute[1] (PHI) certified, or minimum 82% Sensible Effectiveness[2] of heat exchanger (HX) at Air-Conditioning, Heating & Refrigeration Institute (AHRI) Standard 1060 winter conditions at 75% of rated flow[3] verified by independent third-party testing[4].
2.	Minimum fan efficacy: PHI-certified, or minimum 1.4 cubic feet per minimum per Watt (cfm/Watt) at 0.5" water gauge (w.g.) external static pressure (ESP) at 75% of rated full airflow[5].

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CASE STUDY

LEGAL FIRM OBJECTS TO OLDER BUILDING'S INEFFICIENCIES AND DISCOMFORT

OLD BUILDING COMES WITH AGE-OLD INDOOR COMFORT PROBLEMS

Local law firm Immix Law Group purchased the upper floor of a 1909, two-story historic building in the once-industrial area of Northwest Portland. Vacant for nearly three years, the 11,615-square-foot space presented many comfort challenges. Air leaked between floors, the fresh air dampers were all closed shut, and the oversized existing HVAC system was aging and inefficient.

Before they moved in, the law firm was committed to providing year-round indoor comfort for their team and their clients. To get there, they chose an HVAC configuration that would provide consistent temperatures and high indoor air quality across their approximately 30 office spaces, five conference rooms, lunch room, exercise room, two sets of restrooms, and open common and utility spaces.

Immix rooftop showing new equipment

PROJECT OVERVIEW

BUILDING TYPE
OFFICE

YEAR BUILT
1909

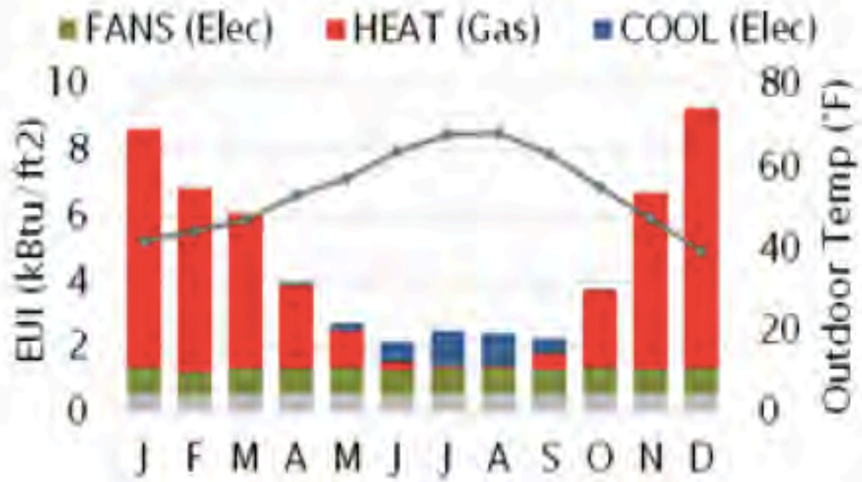
PROJECT FLOOR AREA
11,615 sq. ft.

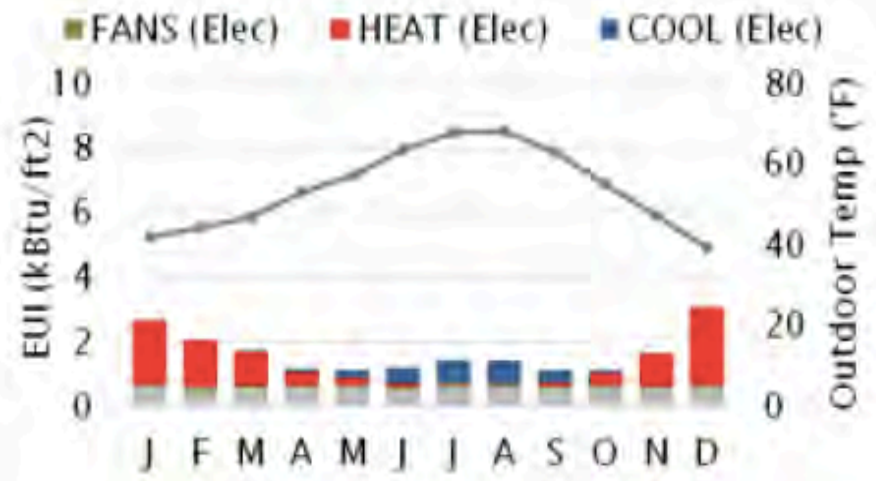
ENERGY UTILITY/PROGRAM
Energy Trust of Oregon

TOTAL PROJECT COST
$15.61 per sq. ft.

REDUCTION IN HVAC ENERGY USE
72%

IMPRESSIVE RESULTS





	ANNUAL EUI	---		ANNUAL EUI	ANNUAL SAVINGS
Total:	57.4 kBtu/ft²	---	**Total:**	19.7 kBtu/ft²	37.8 kBtu/ft²
Fans:	9.5 kBtu/ft²	---	**Fans:**	1.0 kBtu/ft²	8.5 kBtu/ft²
Heating:	37.6 kBtu/ft²	---	**Heating:**	9.2 kBtu/ft²	28.4 kBtu/ft²
Cooling:	3.6 kBtu/ft²	---	**Cooling:**	2.8 kBtu/ft²	0.8 kBtu/ft²
HVAC:	50.7 kBtu/ft²	---	**HVAC:**	13.0 kBtu/ft²	37.8 kBtu/ft²
Electricity:	19.8 kBtu/ft²	---	**Electricity:**	19.7 kBtu/ft²	0.1 kBtu/ft²
Gas:	37.6 kBtu/ft²	---	**Gas:**	0.0 kBtu/ft²	37.6 kBtu/ft²

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CASE STUDY

HIGH-PERFORMANCE HVAC GETS TO WORK FOR UTILITY OFFICE

UTILITY OFFICE UPGRADES FROM PIECEMEAL HVAC TO STATE-OF-THE ART SYSTEM

Flathead Electric's district office is a single-story 1960s-vintage building with offices at the front and a combination of storage space and garage bays for utility trucks in the back. Their former HVAC system had been pieced together from several years of changes and modifications and it was no longer providing indoor comfort or an adequate level of heating efficiency. Flathead Electric took advantage of an innovative approach to HVAC they knew all to well—a very high efficiency dedicated outside air system (also referred to as very high efficiency DOAS).

"We knew it was time to upgrade our HVAC," said Don Newton, Energy Services Supervisor at Flathead Electric. "This was the ideal time to take the very high efficiency DOAS approach to increase our comfort and greatly reduce our energy use. It was a very easy decision to make."

PROJECT OVERVIEW

BUILDING TYPE
OFFICE

YEAR BUILT
1960s

PROJECT FLOOR AREA
5,735 sq. ft.

ENERGY UTILITY/PROGRAM
Flathead Electric
in partnership with the Bonneville Power Administration

TOTAL PROJECT COST
$21.90 per sq. ft.

REDUCTION IN HVAC ENERGY USE
45%

1. SIGNIFICANT ENERGY SAVINGS

Energy Performance Results									
Project	Climate Zone	Project Floor Area (sq ft)	Base Load EUI (Btu / sq ft)	Pre-conversion EUI (Btu / sq ft)		Code Minimum Replacement EUI (Btu / sq ft)		Post-Conversion EUI (Btu / sq ft)	
				Bldg.	HVAC	Bldg.	HVAC	Bldg.	HVAC
Law Office	4	11,615	6.8	52.8	46.0	51.4	44.6	**19.1**	**12.3**
Pizza Restaurant	4	1,730	1,193	1,515	322	1,470	277	**1,352**	**159**
Government District Office	4	13,200	23.7	57.9	33.1	51.7	26.9	**31.4**	**7.7**
Utility District Office	5	5,681	31.3	91.7	60.4	86.4	55.1	**68.3**	**37.0**
Airport Terminal Building	6	26,200	34.1	152.5	117.7	122.0	87.3	**48.1**	**13.3**
Government Dormitories (4)	5	~11,000, each building	36.2	102.9	66.7	67.9	31.7	**51.5**	**15.3**
Seattle Office	6	6,100	20.1	51.5	31.4	51.3	31.2	**29.7**	**9.6**
Restaurant	4	1,147	636	924	289	875	239	**701**	**65**

1. SIGNIFICANT ENERGY SAVINGS

Project	Pre-conversion HVAC EUI (Btu / sq ft)	Code Minimum HVAC EUI (Btu / sq ft)	Post-Conversion HVAC EUI (Btu / sq ft)	Pre- conversion to Code HVAC Savings	Code to Post-Conversion HVAC Savings	Pre-conversion to Post-conversion HVAC Savings
Law Office	46.0	44.6	12.3	10%	73%	**75%**
Pizza Restaurant	322	277	159	14%	43%	51%
Government District Office	33.1	26.9	7.7	18%	73%	**77%**
Utility District Office	60.4	55.1	37.0	9%	33%	39%
Airport Terminal Building	117.7	87.3	13.3	26%	85%	**89%**
Government Dormitories (4)	66.7	31.7	15.3	52%	52%	**77%**
Seattle Office	31.4	31.2	9.6	1%	69%	**69%**
Restaurant	289	239	65	17%	73%	**77%**

1. COSTS PER SQUARE FOOT CAN VARY

Project	Floor Area (sq ft)	Installed System Capacity (tons)	Conditioned Floor Area / Ton (sq ft / ton)	Number of System Zones	Conditioned Floor Area per Zone (sq ft / zone)	Project Cost	Project Cost per Square Foot
Law Office	11,615	16	726	8	1,452	$181,256	$15.61
Pizza Restaurant	1,730	9	192	4	433	$37,400	$21.62
Government District Office	3,770	8	471	2	1,885	$43,238	$11.47
Utility District Office	5,681	8	710	8	710	$125,528	$22.10
Airport Terminal Building	26,200	24	1,092	37	708	$928,500	$35.44
Government Dormitories (4)	~11,000, (each building)	16	688	5	2,200	$106,000	$9.64
Seattle Office	6,100	14	422	12	508	$99,500	$16.83
Restaurant	1,147	3	382	3	382	$35,550	$30.99

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CASE STUDY

TRAPPER CREEK DORM SNARES ENERGY SAVINGS FOR GOOD

HIGH-PERFORMANCE HVAC ALLEVIATES OVERHEATING AND VENTILATION ISSUES

The Trapper Creek Dormitory is a federal government work campus in rural Montana. When restricted airflow caused summertime overheating, ventilation issues, and unsafe $C0_2$ levels in their dormitories, the facility managers decided to partner with Ravalli Electric Co-op and Bonneville Power Administration to implement a high-performance HVAC conversion.

Fortunately, Ravalli Electric Co-op and Bonneville Power Administration had an innovative and cost-effective solution that would not only solve Trapper Creek's airflow issues, but also significantly reduce their energy costs. To make the project even more cost-effective, Ravalli Electric Co-op provided $80,591 in incentives that dramatically cut the project's upfront costs.

"First and foremost, we were focused on alleviating the unsafe CO2 levels," said Dan Gager, Project Manager at Trapper Creek Dorms. "It was particularly a problem in the winter when windows had to be closed. We were very happy to learn that this new system could take care of our ventilation issues and provide fresh air to the sleeping areas throughout the winter."

In partnership with: Ravalli Electric Co-op

PROJECT OVERVIEW

BUILDING TYPE
DORMITORY

PROJECT FLOOR AREA
~11,000 sq. ft. per dorm

ENERGY UTILITY/PROGRAM
Ravalli Electric Co-op in partnership with the Bonneville Power Administration

TOTAL PROJECT COST
$9.64 per sq. ft.

REDUCTION IN HVAC ENERGY USE
52%

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CASE STUDY

INNOVATIVE HVAC APPROACH HELPS AIRPORT'S ENERGY SAVINGS TAKE OFF

HISTORIC AIRPORT TERMINAL GETS STATE-OF-THE-ART HVAC UPGRADES

Although a two-story, 1930s airport terminal building in Seattle underwent a major renovation in 2002, the HVAC was largely untouched. The duo of large, multizone rooftop units (RTUs) were left in place, with a third unit of the same type added during the renovations. This inefficient HVAC system wasted energy and money, led to inconsistent temperatures, and caused severe occupant discomfort. Additionally, the system didn't address the building's unique air quality challenges. Nestled between airport runways and very densely trafficked rail lines, jet fumes would infiltrate the airport terminal building and linger for hours.

"The system wasn't doing its job," said David Broustis, Energy Manager at King County Dep. of Natural Resources and Parks. "And when it did decide to work, the cost associated with it was astronomical." After years of increased maintenance and poor performance, the building management team faced a decision to continue to repair their current system or replace it. That's when they learned of an innovative approach to upgrading their HVAC system. This new approach could significantly reduce energy use, ensure 100-percent fresh air at all times, and provide year-round comfort in the variable Seattle climate.

Seattle City Light

BETTERBRICKS

Powerful Energy. More. Delivered by NEEA

PROJECT OVERVIEW

BUILDING TYPE
AIRPORT TERMINAL BUILDING

YEAR BUILT
1930

PROJECT FLOOR AREA
25,200 sq. ft.

ENERGY UTILITY/PROGRAM
Seattle City Light

TOTAL PROJECT COST
$36.85 per sq. ft.

REDUCTION IN HVAC ENERGY USE
85%

UTILITY HVAC INCENTIVE
$53,052

TOTAL SAVINGS
196,488 kWh/year

KING COUNTY BOEING FIELD AIRPORT

BEFORE

Removing large rooftop air handlers

AFTER

Using original ductwork, but 1/5 the size

82% EUI Reduction!

EUI BEFORE: 168

EUI AFTER*: ~~30~~ 11

26,500 Ft^2

19 main + 21 upper zones

HVAC BEFORE:

- 3 “Enormous” Rooftop Air Handlers: Gas Heat, Electric Cool & Constant Fan

HVAC AFTER:

- 3 VS1000 RTs
- 4 Mitsubishi PURY VRF Heat Pumps (=34T)

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Home › Solutions › Showcase Projects › King County Airport Terminal Deep Retrofit

Share

New air-source heat recovery and energy recovery ventilation (ERV) units

Showcase Project: King County Airport Terminal Deep Retrofit

SECTOR TYPE
Local Government

LOCATION
Seattle, Washington

PROJECT SIZE
25,000 Square Feet

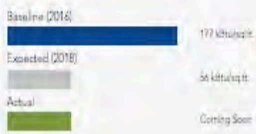
FINANCIAL OVERVIEW
$350,000*

King County

*Incremental energy efficiency investment

Annual Energy Use

(Source EUI)



Energy Savings:

68%

Annual Energy Cost

Cost Savings:

$40,000

BACKGROUND

The King County Airport Terminal project is a deep energy retrofit focused on replacing the mechanical and lighting systems throughout the facility with state-of-the-art efficient technologies. This project highlights how a modern design approach to mechanical and lighting systems can dramatically reduce energy use, and how older and historic buildings can achieve deep energy reductions and exceed advanced energy code requirements.

More

SOLUTIONS

The following energy conservation measures were implemented as part of the airport terminal's deep energy retrofit:

- Variable Refrigerant Flow (VRF) heat pumps and a Dedicated Outdoor Air System (DOAS) have replaced existing multi-zone air handler roof top units (RTUs)
- New, high-efficiency heat recovery ventilator installed with up to 90 percent heat recovery
- Interior 32-watt fluorescent tubes have been replaced with 15-watt light emitting diode (LED) lamps. The facility is partially fitted with advanced lighting controls to fully optimize energy savings, including daylight and occupancy sensors
- Outdoor airport ramp and parking lot lighting have been upgraded to LED technology with night setbacks to 30 percent of full lighting levels.

More

OTHER BENEFITS

These upgrades will improve traveler comfort and reduce staff time spent on building maintenance. It is expected that the building will earn ENERGY STAR® certification. Additionally, staff education has improved energy reductions. Prior to the retrofit, workers often used personal electrical devices in their workspaces, such as fans, task lights, space heaters, and hot plates. Following this deep energy retrofit, staff have discontinued the use of these

- **ACTUAL ENERGY BILLS**
- **MODELED < MEASURED**
- **EVEN WITH IMPERFECT APPLICATION**

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Making Buildings Healthy · Efficient · Smarter

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

LARGEST PROJECT TO DATE

- 71,000 sq ft Office
- Four Floors
- Retrofit Done While Occupied
- 50% Complete on April 1, 2019
- Owners Very Happy

1. Quiet
2. Improved IAQ
3. Energy Cost Reduction $10k in April 2019

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

ELECTRIFICATION DONE RIGHT!

IMPROVED COMFORT

IMPROVED HEALTH

ASK US HOW

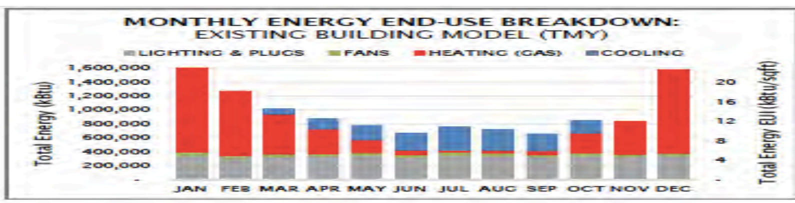


Figure 2.1
Monthly energy end-use breakdown for the Existing Building Model (TMY).

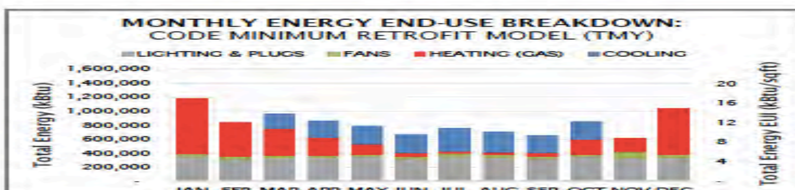


Figure 2.2
Monthly energy end-use breakdown for the Code Minimum Model (TMY).

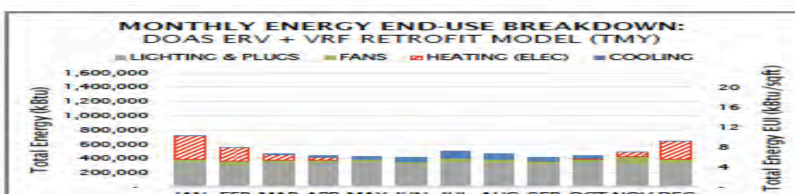


Figure 2.3
Monthly energy end-use breakdown for the DOAS ERV + VRF Model (TMY).

LARGEST PROJECT TO DATE

- **71,000 sq ft Office**
- **Four Floors**
- **Retrofit Done While Occupied**
- **50% Complete on April 1, 2019**

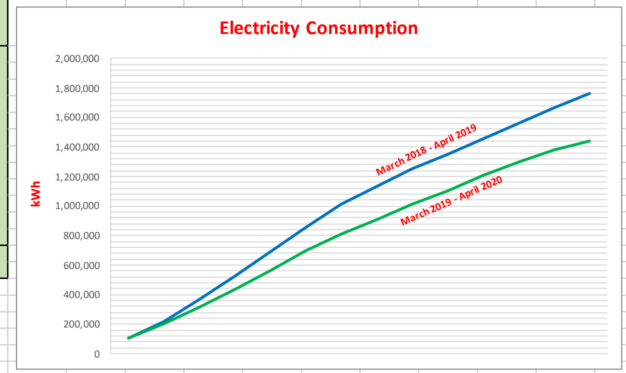
Savings 4 Months

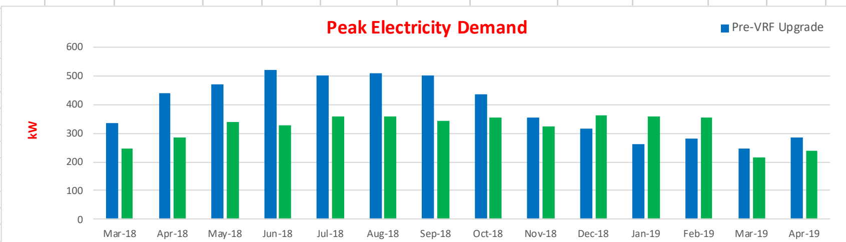
1. **$ 49,854**
2. **126,200 kWh**
3. **622.32 kW Demand Reduction**
4. **38,800 Therms Gas Reduction (modeled)**

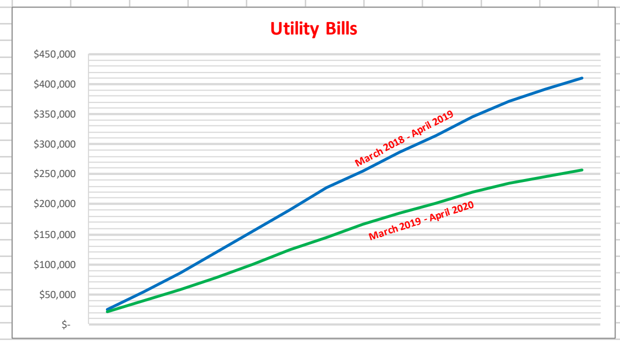
VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

1. SIGNIFICANT SAVINGS EXCEED THE MODEL

	Pre VRF Consumption							Post VRF Consumption						
Time Period	Electricity (kWh)	Electricity Total YTD (kWh)	Peak Demand (kW)	Natural Gas (therms)	Utility Bill	Utility Bill Total YTD	Time Period	Electricity (kWh)	Electricity Total YTD (kWh)	Peak Demand (kW)	Natural Gas (therms)	Utility Bill	Utility Bill Total YTD	
Mar-18	103,600	103,600	336	8,116	$ 25,533	$ 25,533	Mar-19	103,600	103,600	246.72	5,586	$ 21,137	$ 21,137	With 1/2 building upgraded to VRF
Apr-18	116,000	219,600	440.64	5,560	$ 28,006	$ 53,539	Apr-19	98,400	202,000	283.68	2,730	$ 17,851	$ 38,988	
May-18	152,200	371,800	470.4	1,397	$ 32,313	$ 85,852	May-19	115,200	317,200	340.56	1,452	$ 19,488	$ 58,476	
Jun-18	153,600	525,400	519.84	198	$ 34,067	$ 119,919	Jun-19	115,600	432,800	328.08	264	$ 19,891	$ 78,367	
Jul-18	164,000	689,400	502.08		$ 35,348	$ 155,267	Jul-19	130,400	563,200	358.32		$ 22,650	$ 101,017	
Aug-18	163,200	852,600	507.36		$ 34,513	$ 189,780	Aug-19	134,000	697,200	356.4		$ 23,740	$ 124,757	
Sep-18	160,400	1,013,000	501.84		$ 37,036	$ 226,815	Sep-19	115,200	812,400	341.52		$ 20,225	$ 144,982	
Oct-18	121,600	1,134,600	436.56		$ 28,952	$ 255,767	Oct-19	95,600	908,000	354.48		$ 21,404	$ 166,386	
Nov-18	120,000	1,254,600	353.76		$ 30,146	$ 285,913	Nov-19	103,600	1,011,600	322.32		$ 18,491	$ 184,877	
Dec-18	95,600	1,350,200	316.32		$ 28,461	$ 314,374	Dec-19	90,400	1,102,000	360.24		$ 17,009	$ 201,886	
Jan-19	105,600	1,455,800	261.6		$ 31,292	$ 345,666	Jan-20	102,800	1,204,800	359.52		$ 17,422	$ 219,307	
Feb-19	106,400	1,562,200	281.28		$ 25,107	$ 370,772	Feb-20	96,400	1,301,200	352.56		$ 16,279	$ 235,586	
Mar-19	103,600	1,665,800	246.72		$ 21,137	$ 391,910	Mar-20	77,200	1,378,400	216.24		$ 10,701	$ 246,287	With full building upgraded to VRF
Apr-19	98,400	1,764,200	283.68		$ 17,851	$ 409,761	Apr-20	61,600	1,440,000	240		$ 10,216	$ 256,503	
								Savings	18%				37%	
									324,200 kWh				$ 153,258	

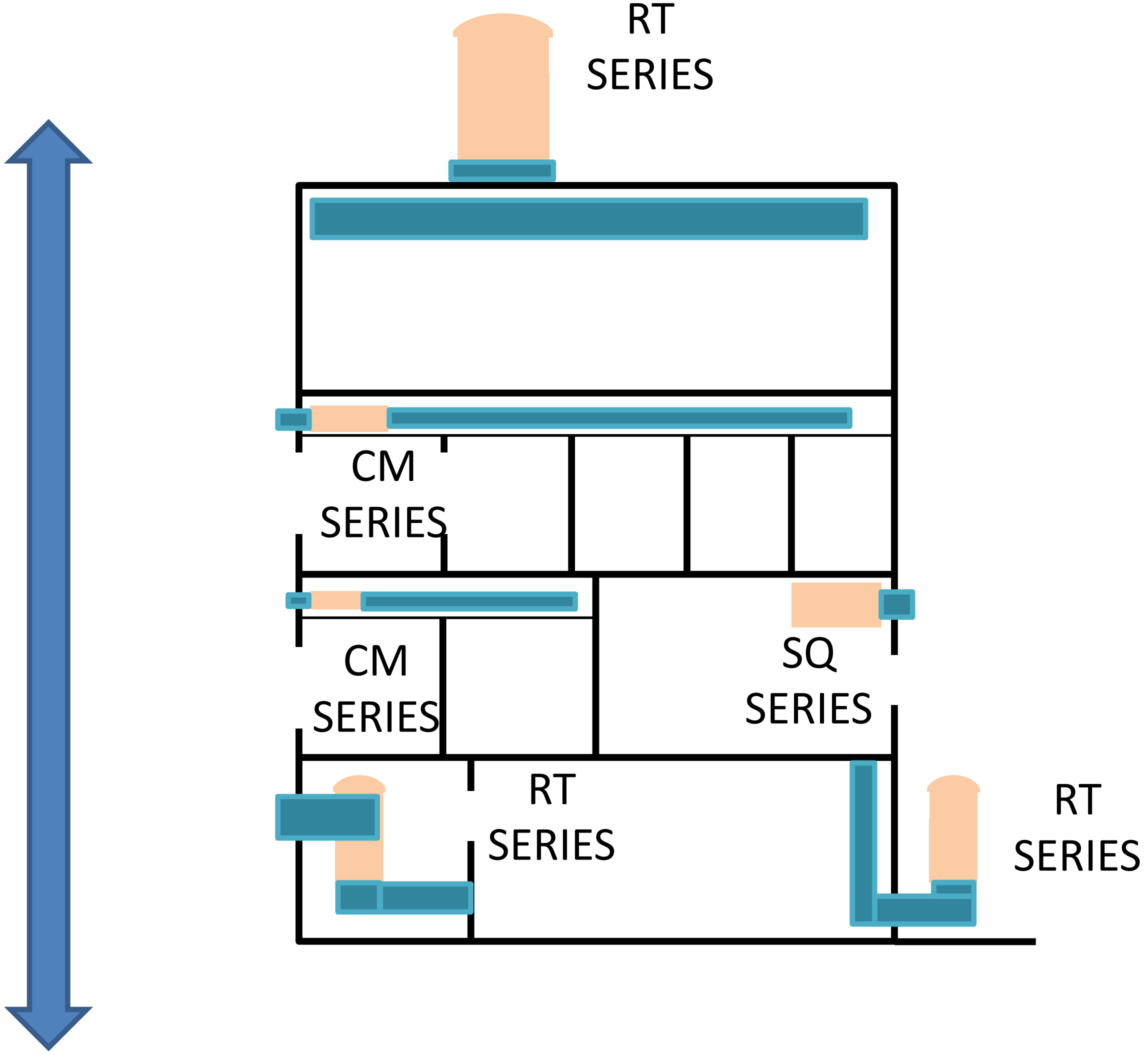




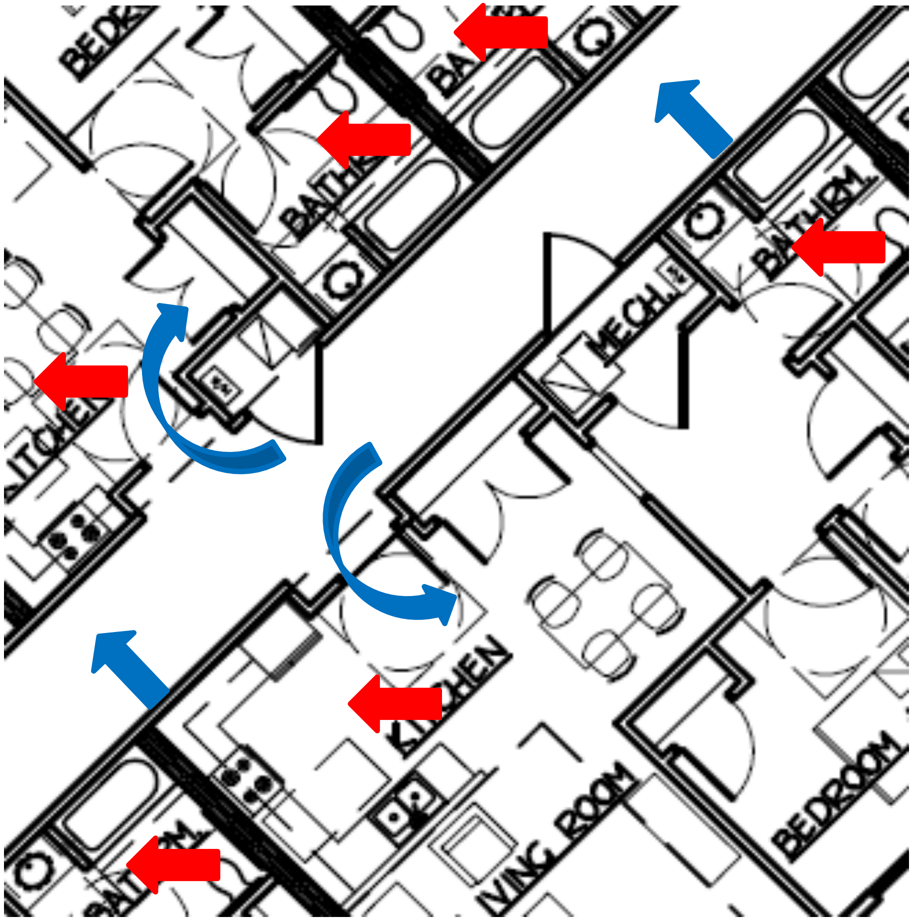


Chapter 10: Applications

Mounting for most commercial installs



Application: Multifamily Residential
Traditional Design



Exhaust Air Locations

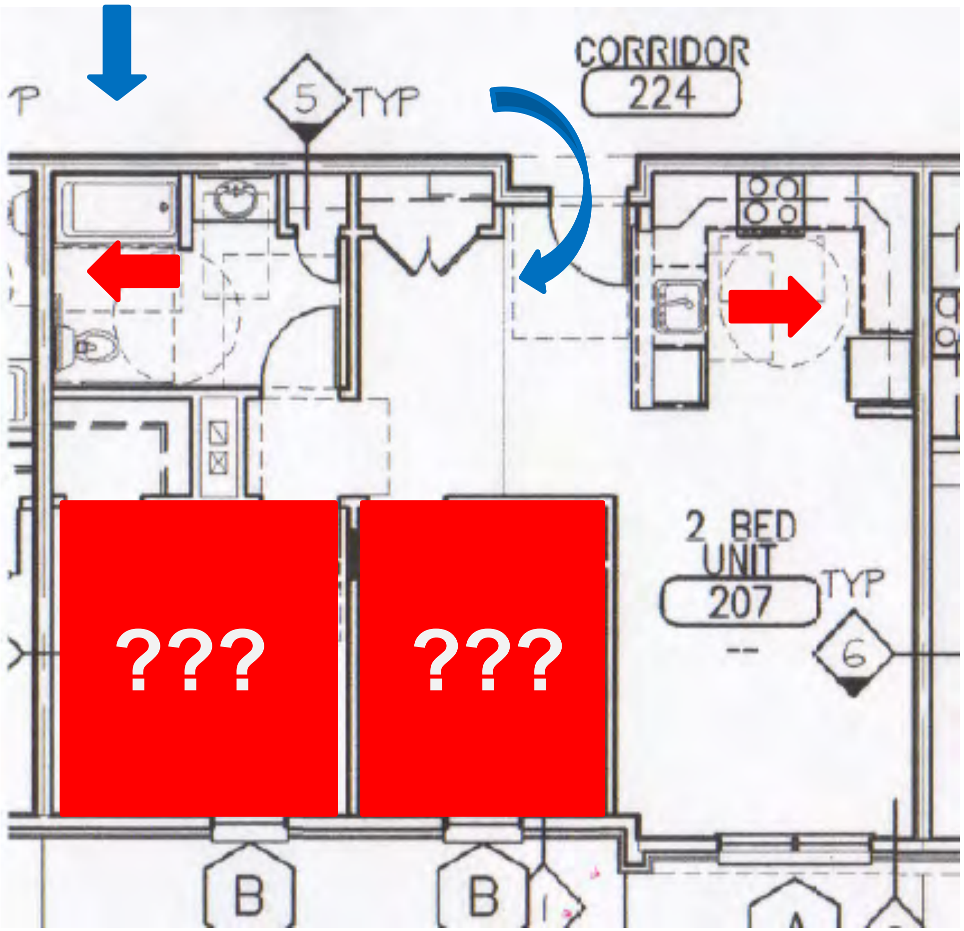
- Bathrooms
- Kitchen

Supply Air Locations

- Corridors

In theory, pressurized corridor forces make-up air into apartments around entry door

Application: Multifamily Residential
Traditional Design



Exhaust Air Locations

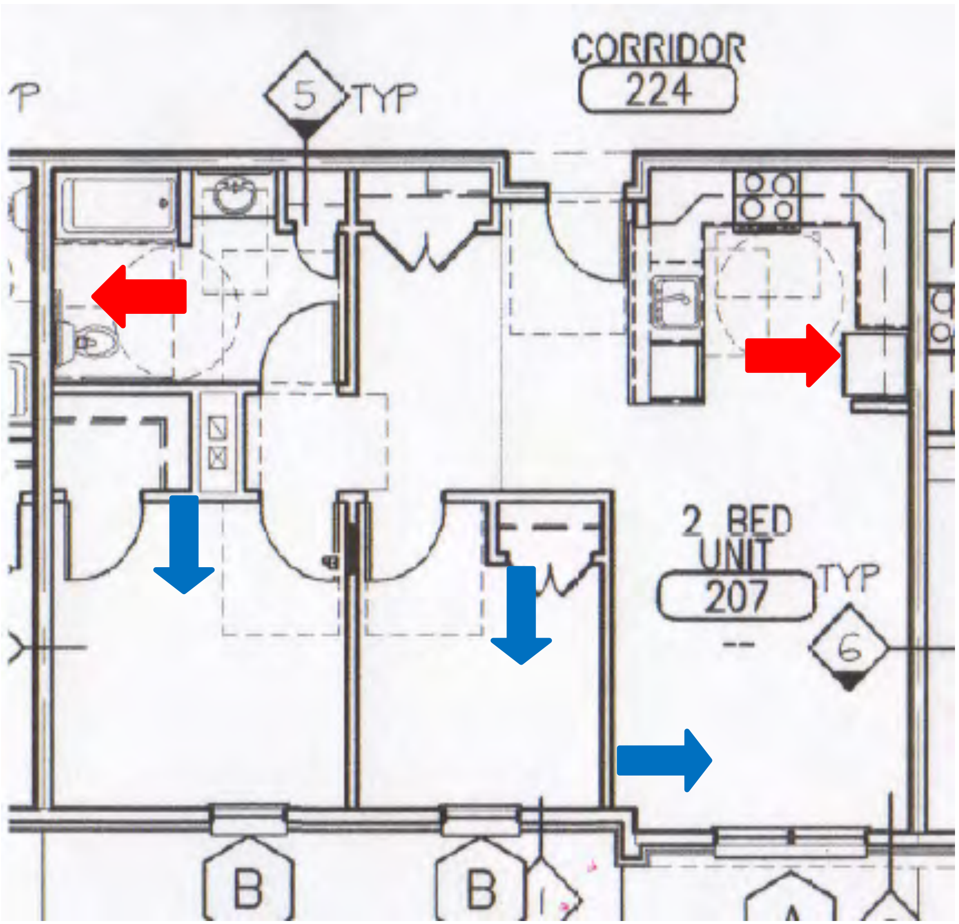
- Bathrooms
- Kitchen

Supply Air Locations

- Corridors

What is the ACH in the Bedrooms?

Application: Multifamily Residential
Optimized Design



Exhaust Air Locations

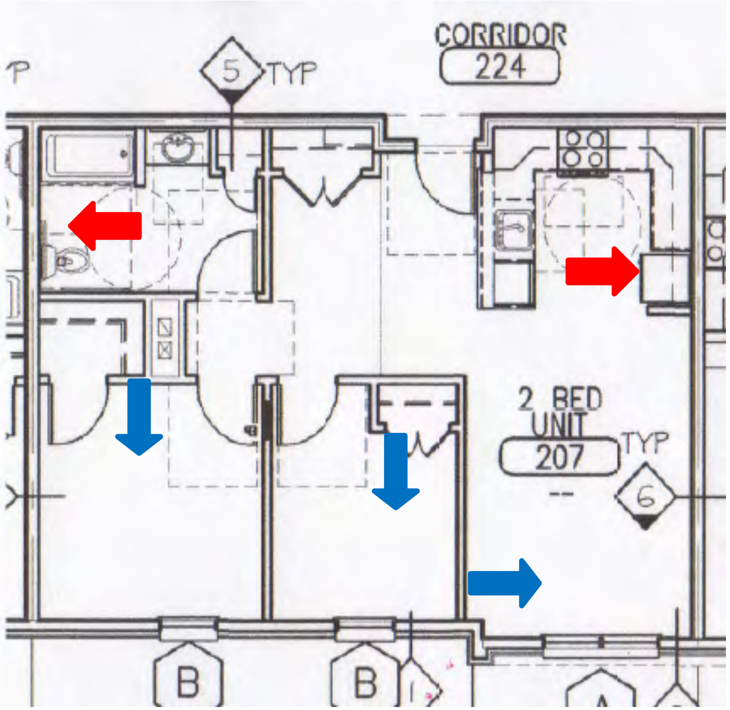
- Bathrooms
- Kitchen
- Laundry
- Moisture/Odor Laden Areas

Supply Air Locations

- Bedrooms
- Offices
- Living/Family Rooms*
- Remote Rooms

* Depending upon layout

Application: Multifamily Residential
System Options: Example Apartment

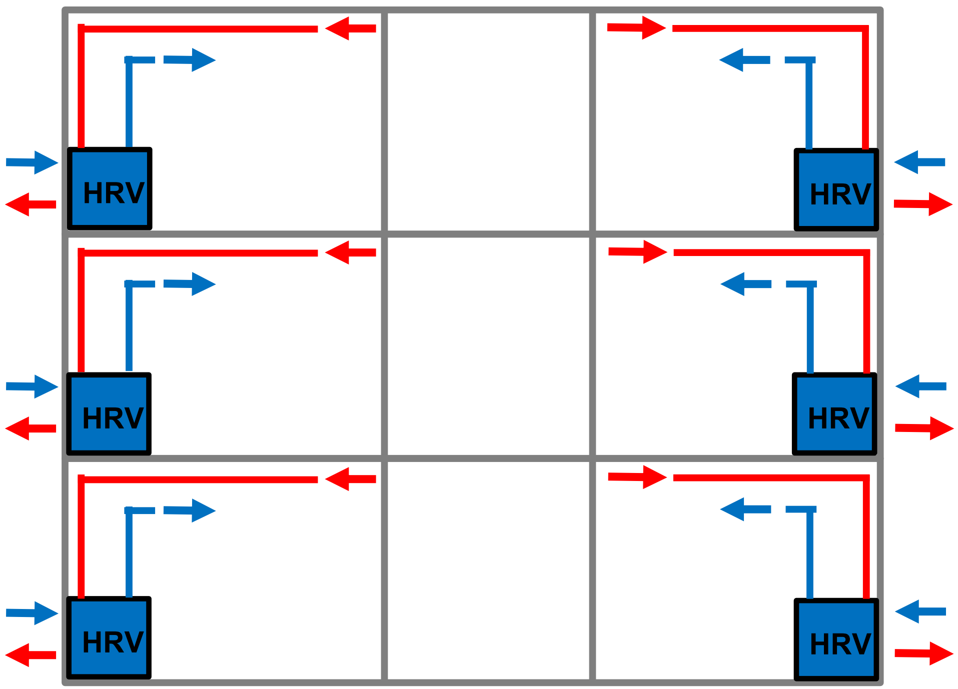


Standard	Supply	Exhaust
PHI	32 CFM	59 CFM
62.2-2013	47 CFM	57 CFM

Given Conditions:

- 800 SF TFA (~80 SM)
- 2 Bedrooms
- Living Room
- 1 Bathroom
- 7'x8' Kitchen (56 SF)

Multi-Family Options



Individual Apartment Units

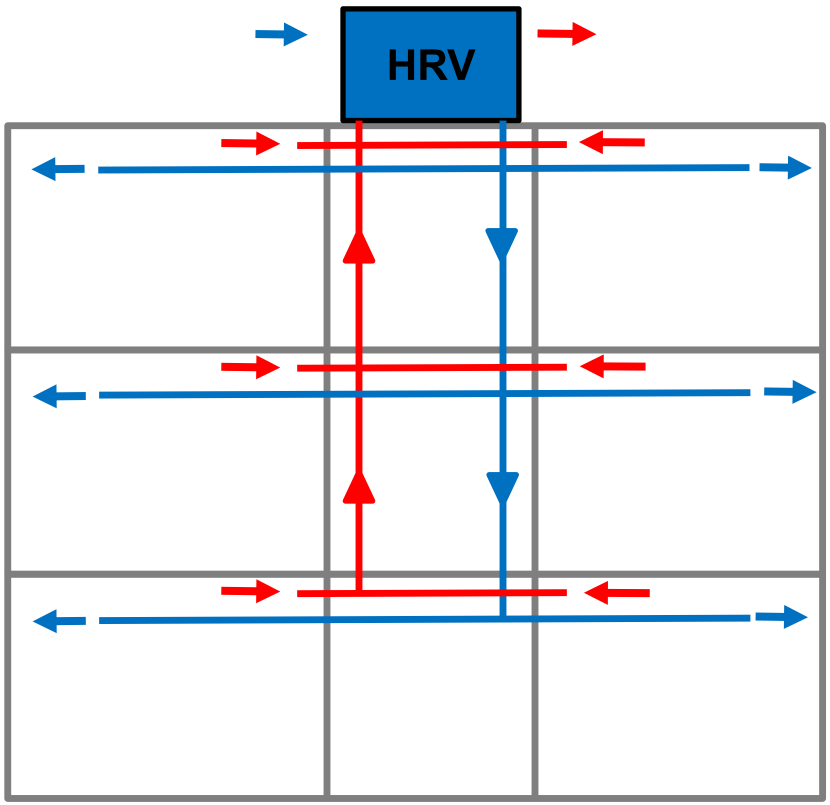
Pros

- Better Compartmentalization
- Minimize Stack Effect
- Individual Control
- Easy Boost Capacity
- Good for Condominiums
- Minimize Duct Runs
- Minimize energy usage
- Energy paid by occupant

Cons

- Multiple Wall Penetrations
- Dispersed Maintenance
- May be more expensive

Multi-Family Options



Central Ventilation Units

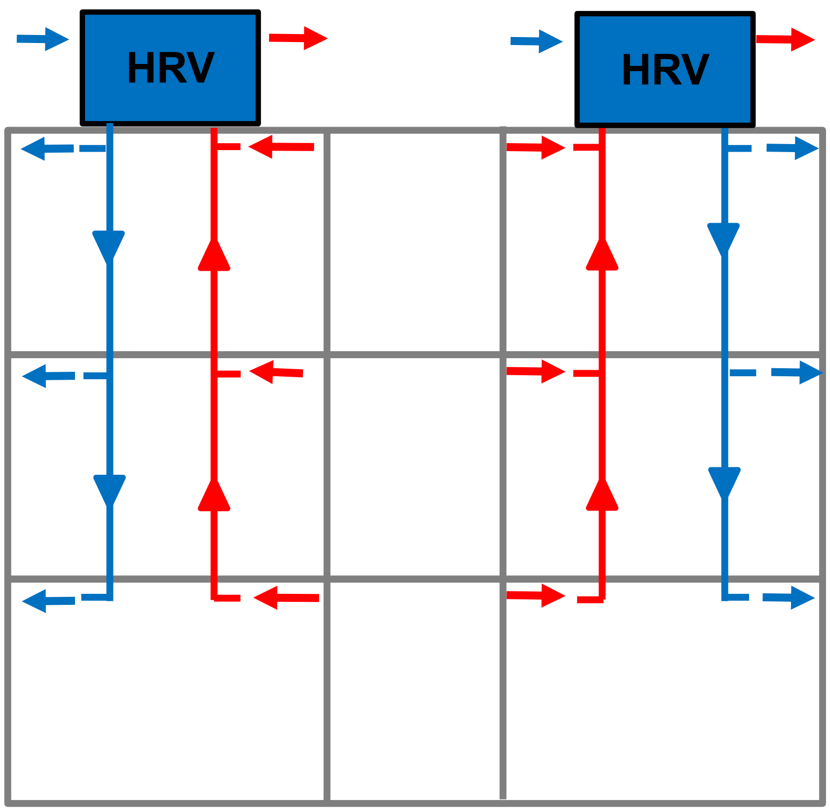
Pros

- Central Maintenance
- May be less expensive
- Minimize Penetrations

Cons

- Central Ductwork & Fire Dampers
- Fighting Stack Effect
- Loss of Floor Space for Shafts
- More Complex to Boost
- Harder to Balance
- Higher energy usage
- Energy paid by building owner

Multi-Family Options

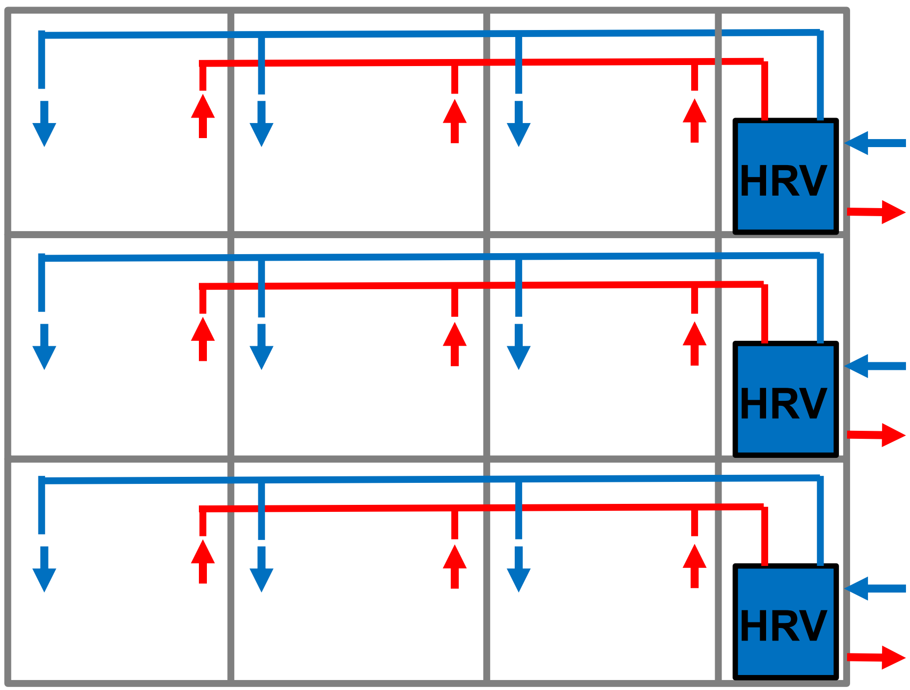


Semi-central Ventilation Units Vertical Configuration

Pros
- Consolidated Maintenance
- May be less expensive
- Minimize Penetrations
- Reduce Ductwork
- Reduce Energy Usage

Cons
- Central Ductwork & Fire Dampers
- Fighting Stack Effect
- Loss of Floor Space for Shafts
- More Complex to Boost
- Harder to Balance
- Energy paid by building owner

Multi-Family Options



Semi-central Ventilation Units Horizontal Configuration

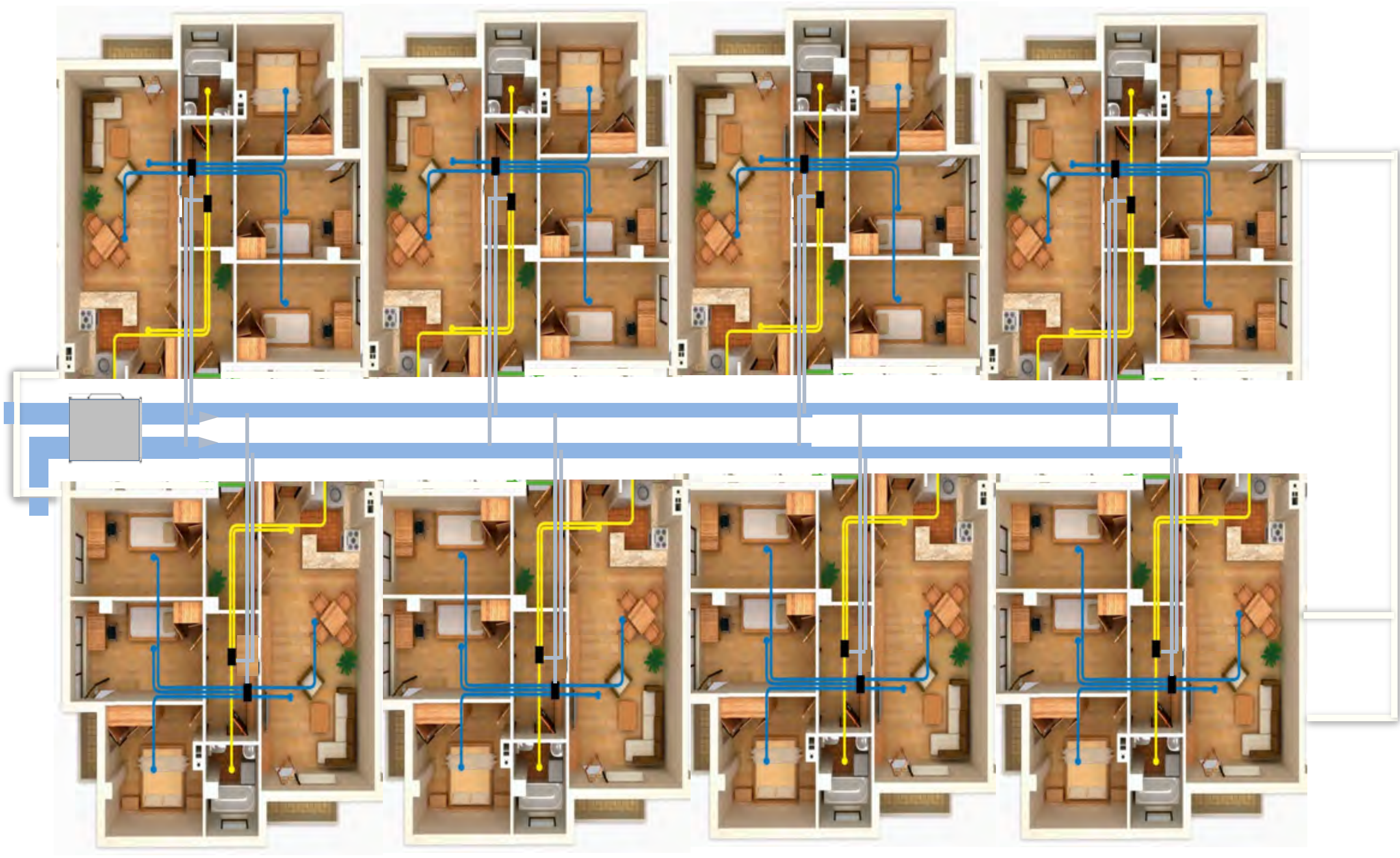
Pros

- Consolidated Maintenance
- Minimize Stack Effect
- Eliminate Shafts
- May be less expensive
- Minimize Penetrations
- Reduce Energy Usage
- Possibly Eliminate Fire Dampers

Cons

- Central Ductwork
- More Complex to Boost
- Harder to Balance
- Energy paid by building owner

Horizontal Units In Hallway



Application: Multifamily Residential System Options: Example Apartment

Standard	Supply	Exhaust
PHI	32 CFM	59 CFM
62.2-2013	47 CFM	57 CFM

Individual unit per apartment = Controllability

High speed (boost mode) operation:	59 CFM
Normal Speed operation (77% max):	45 CFM
Low speed operation (0.3 ACH):	32 CFM
Absent mode operation:	20 CFM

Simple Central System = One Speed

Full Time operation:	59 CFM

Advanced Central System = Normal and Boost Operation

Boost operation:	59 CFM
Normal Operation	45 CFM

More Air = More Energy

- Higher thermal load to heat it
- Higher electrical usage to deliver it
- Need to also consider occupancy demographic for best control strategy

Application: Multifamily Residential
Non-Dwelling Ancillary Spaces

Other Possible Occupancies

- Corridors
- Trash Rooms
- Janitor's Closets
- Gathering Rooms
- Bathrooms
- Storage Areas
- Laundry
- Gym
- Rental Office
- Follow ASHRAE 62.1 for these spaces

Application: Multifamily Residential Non-Dwelling Ancillary Spaces

Corridors:

- 0.06 CFM / SF

Trash Rooms:

- 1.00 CFM / SF Exhaust

Janitor's Closets:

- 1.00 CFM / SF Exhaust

- A good strategy to supply into the corridors and exhaust from the trash rooms & janitors closets.
- Dedicated HRV for this purpose at continuous rate.

Application: Multifamily Residential Non-Dwelling Ancillary Spaces

Gathering Rooms:

- 5 CFM/Person + 0.06 CFM/SF

Public Bathrooms:

- 25 CFM/unit Exhaust single occupant
- 50 CFM/unit Exhaust multi occupant

- A good strategy to supply into gathering room and exhaust from the adjoining bathrooms.
- Dedicated HRV(s) for this purpose
- Good occupancy for CO_2 control – low rate to meet bathroom requirements and ramp up with increased occupancy.

Application: Multifamily Residential Non-Dwelling Ancillary Spaces

Laundry Rooms:

- 7.5 CFM/Person + 0.06 CFM/SF

- Likely can be tied into an HRV system with other spaces.
- Per IMC, dryer exhaust over 200 CFM must have make-up air!
- Possible strategy to build dryer bank into a make-up air plenum behind the machines.
- Interconnect make-up air dampers to open with dryer operation

Application: Multifamily Residential
Non-Dwelling Ancillary Spaces

Gyms:

- 20 CFM/Person + 0.06 CFM/SF

Storage Rooms:

- 0.12 CFM/SF

Office Spaces:

- 5 CFM/Person + 0.06 CFM/SF

- Can likely be tied into HRV with other spaces
- Gym may utilize dedicated HRV with CO_2 control since high rates and intermittent usage likely.

Application: Office Building

Office Spaces:

- 5 CFM/Person + 0.06 CFM/SF

Conference Rooms:

- 5 CFM/Person + 0.06 CFM/SF

Corridors:

- 0.06 CFM / SF

Storage Rooms:

- 0.12 CFM/SF

Public Bathrooms:

- 25 CFM/unit Exhaust single occ.
- 50 CFM/unit Exhaust multi occ.

Break Rooms:

- 5 CFM/Person + 0.12 CFM/SF

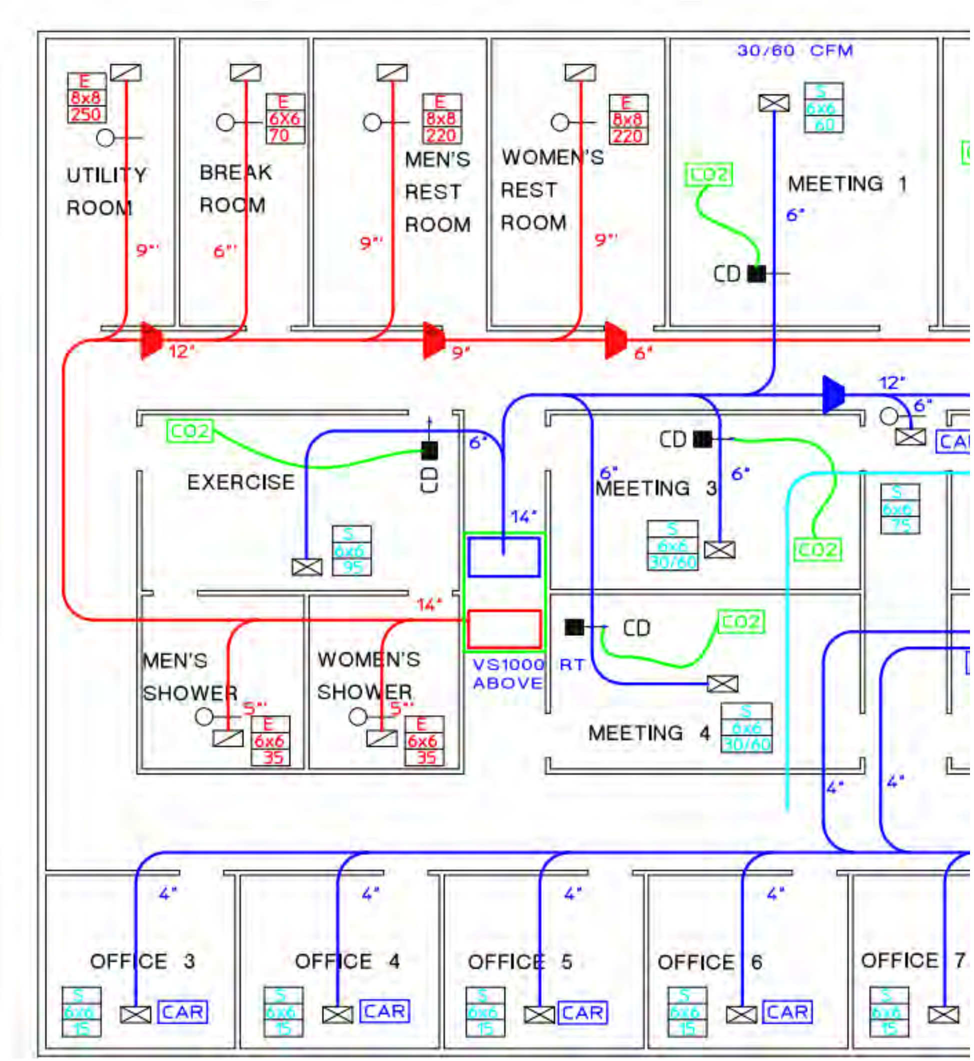
Kitchenette:

- 0.3 CFM / SF Exhaust

Janitor's Closets:

- 1.00 CFM / SF Exhaust

Application: Office Building



Supply to:

- Open office space
- Individual offices
- Conference/meeting rooms
- Corridors
- Storage rooms (possibly)

Exhaust from:

- Bathrooms
- Utility/Janitor's closets
- Kitchenette/break room

Strategies:

- CO_2 Demand control for conference rooms
- Oversize ductwork for ecomomizer mode

Application: Retail Building

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a			Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		
Occupancy Category	cfm/person	L/s·person	cfm/ft²	L/s·m²	Notes	#/1000 ft² or #/100 m²	cfm/person	L/s·person	Air Class
Residential									
Dwelling unit	5	2.5	0.06	0.3	F,G, H	F			1
Common corridors	—	—	0.06	0.3	H				1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3	H	40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3	H	25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3	H	8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.12	0.6		20	14	7.0	2

Typical Sales Retail Occupancy:

- 7.5 CFM/Person + 0.12 CFM/SF
- Other specialty categories - see ASHRAE 62.2

Strategies:

- Widely varying occupancy - CO_2 Demand control
- Supply sales floor
- Exhaust bathrooms and storage rooms
- Potentially exhaust locally if any product is odorous / off-gasses

Application: Schools

TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a			Default Values			
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
Occupancy Category	cfm/ person	L/s· person	cfm/ft^2	L/s·m^2	Notes	#/1000 ft^2 or #/100 m^2	cfm/ person	L/s· person	Air Class
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3	H	65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3	H	150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3	H	35	12	5.9	1
Multiuse assembly	7.5	3.8	0.06	0.3	H	100	8	4.1	1

14 different classroom types depending on age and utilization

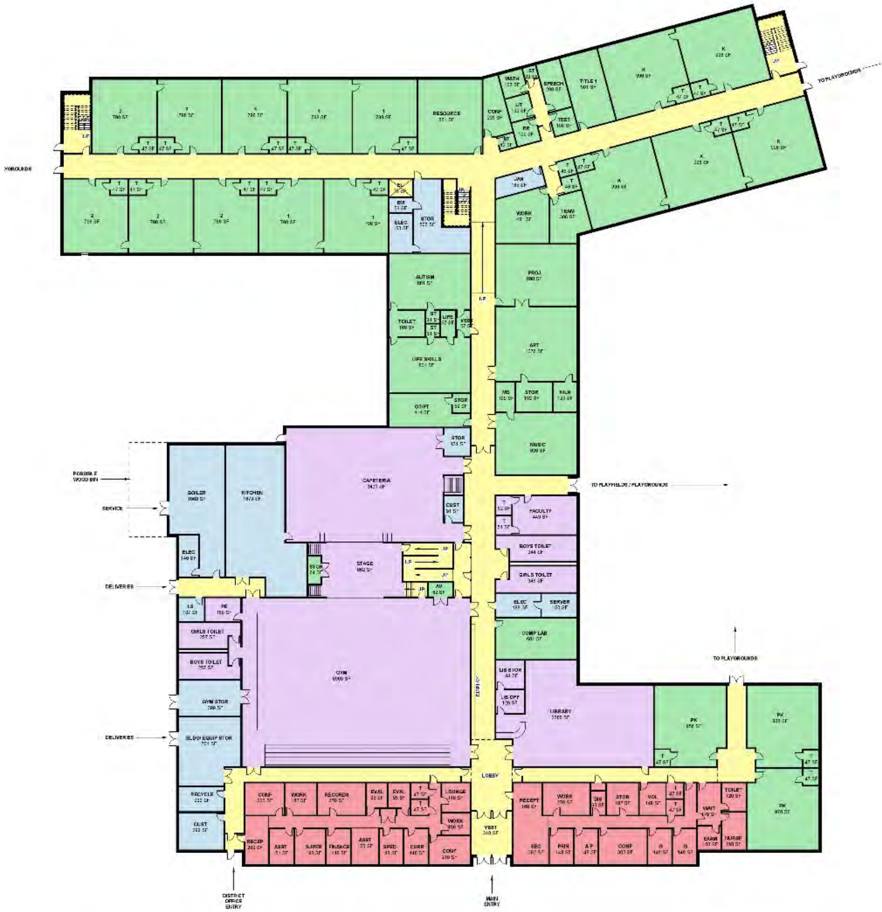
Ancillary spaces can include:

- Cafeterias
- Auditoriums
- Gymnasiums
- Office Space
- Libraries

Ancillary Spaces best served by dedicated systems

- Often fluctuating occupancy
- May only be utilized part-day
- CO2 Demand control potential

Application: Schools



Classroom Strategies:

Individual classroom HRVs

- CO_2 Demand control potential
- Minimize ductwork

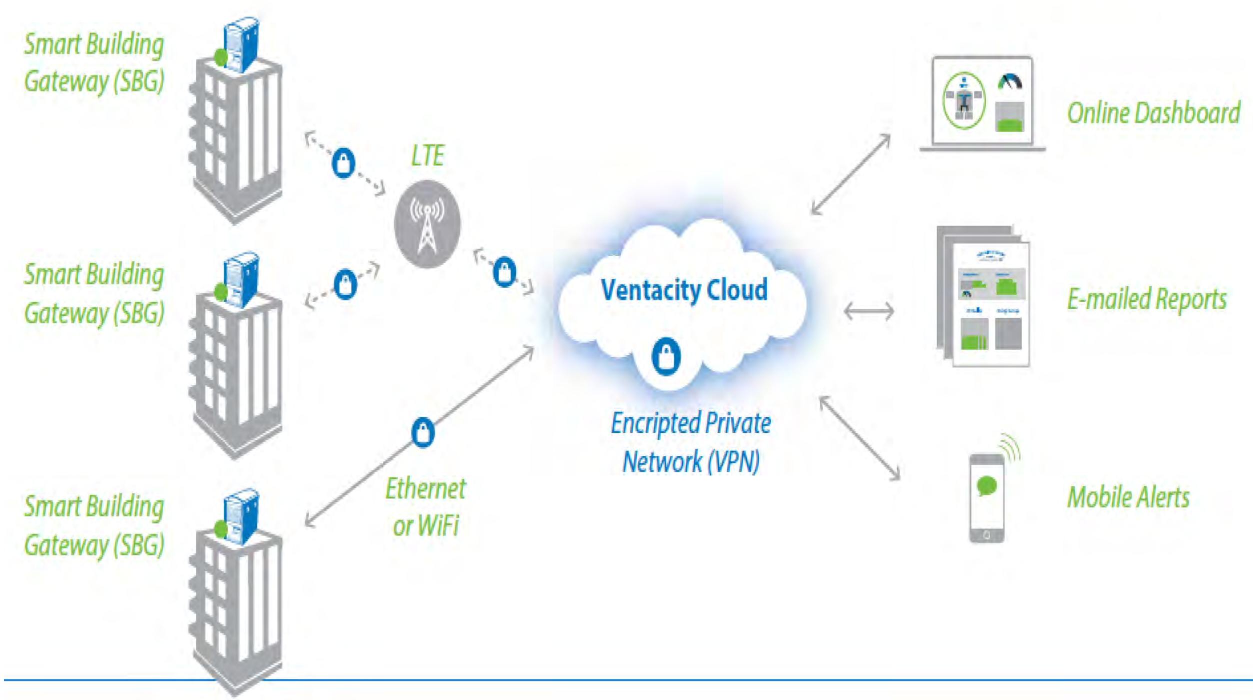
Central Systems

- Can use CO_2 demand control with zone dampers
- Possibility for reduced equipment sizing with diversity if not all spaces used simultaneously.

Quiet equipment operation critical

Chapter 11: What's Next?

HVAC^2 = (HVAC x Control)
SMARTER BUILDING PLATFORM



VENTACITY ELEMENTS

- Smart Building Gateway (SBG)
- Ventacity Cloud

VENTACITY APPS

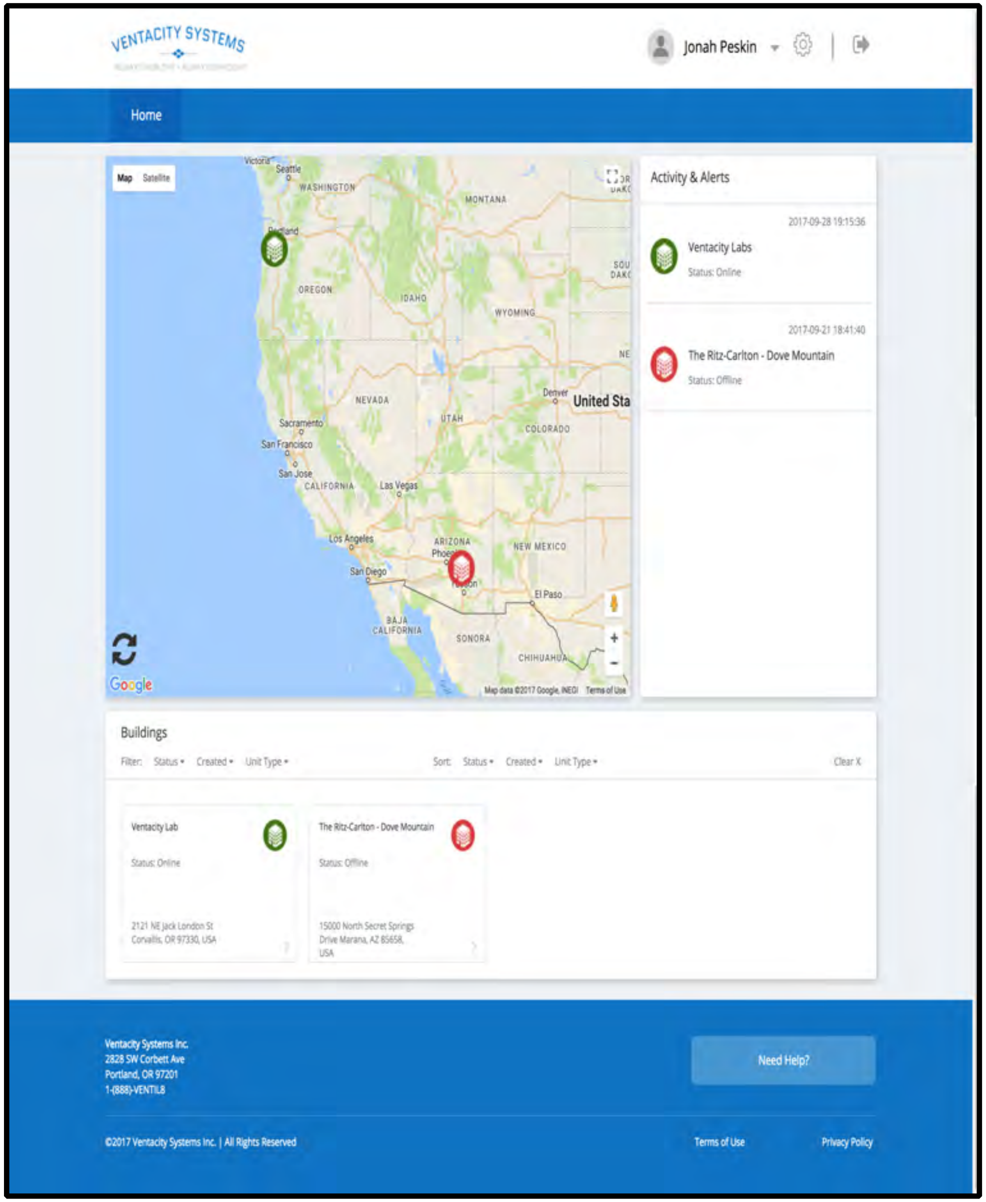
- Desktop Web Dashboards
- Contractor-Branded E-Mail Reports
- Mobile Web Apps & Alerts

KEY FEATURES

- One SBG per Building
- LTE = Secure & Simple
- VPN = Security

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

PORTFOLIO MAP / HOME SCREEN



- OVERVIEW

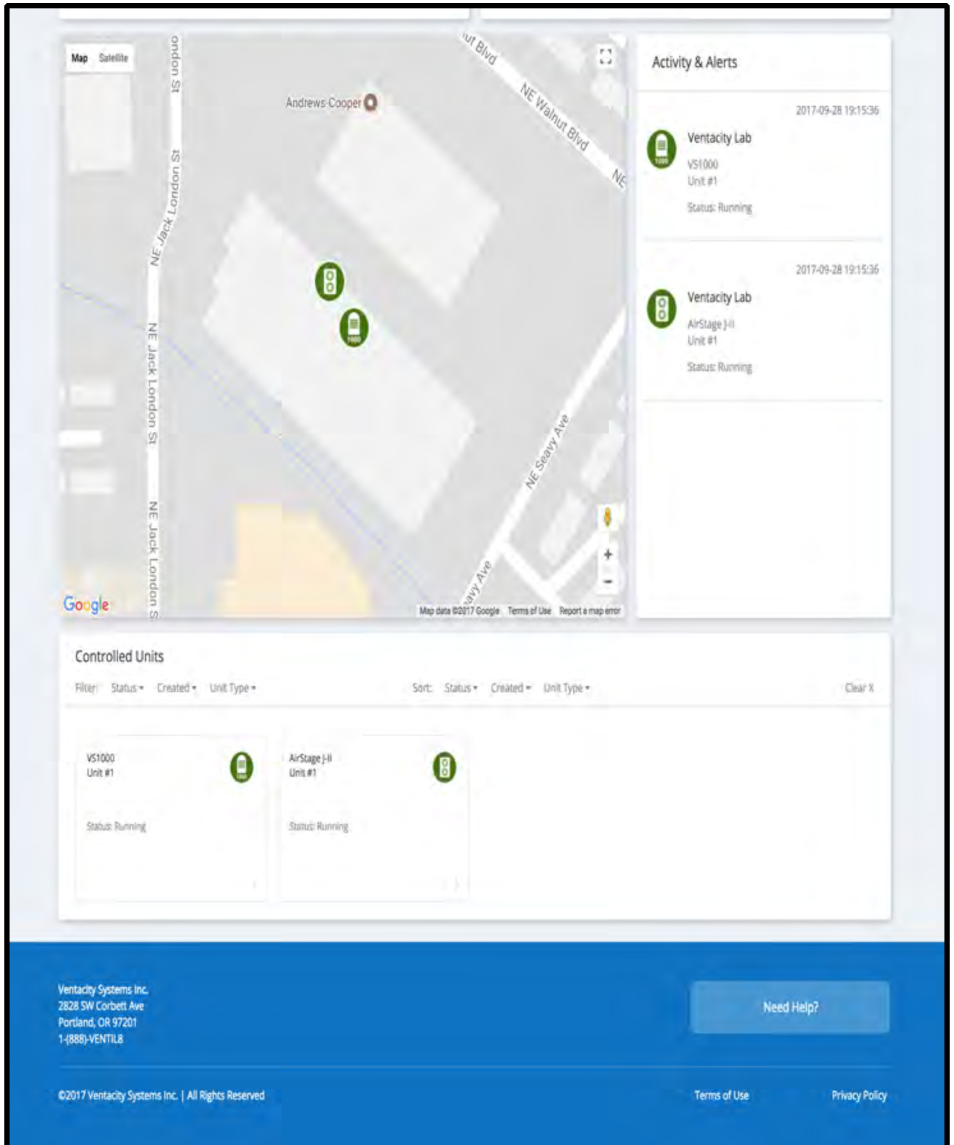
- "At a Glance" View of All Buildings Under Purview
- Color Coded Status:

- Green = OK
- Yellow =Warning
- Red = Error

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

VENTACITYSYSTEMS
Making Buildings Healthy - Efficient - Smarter

BUILDING MAP



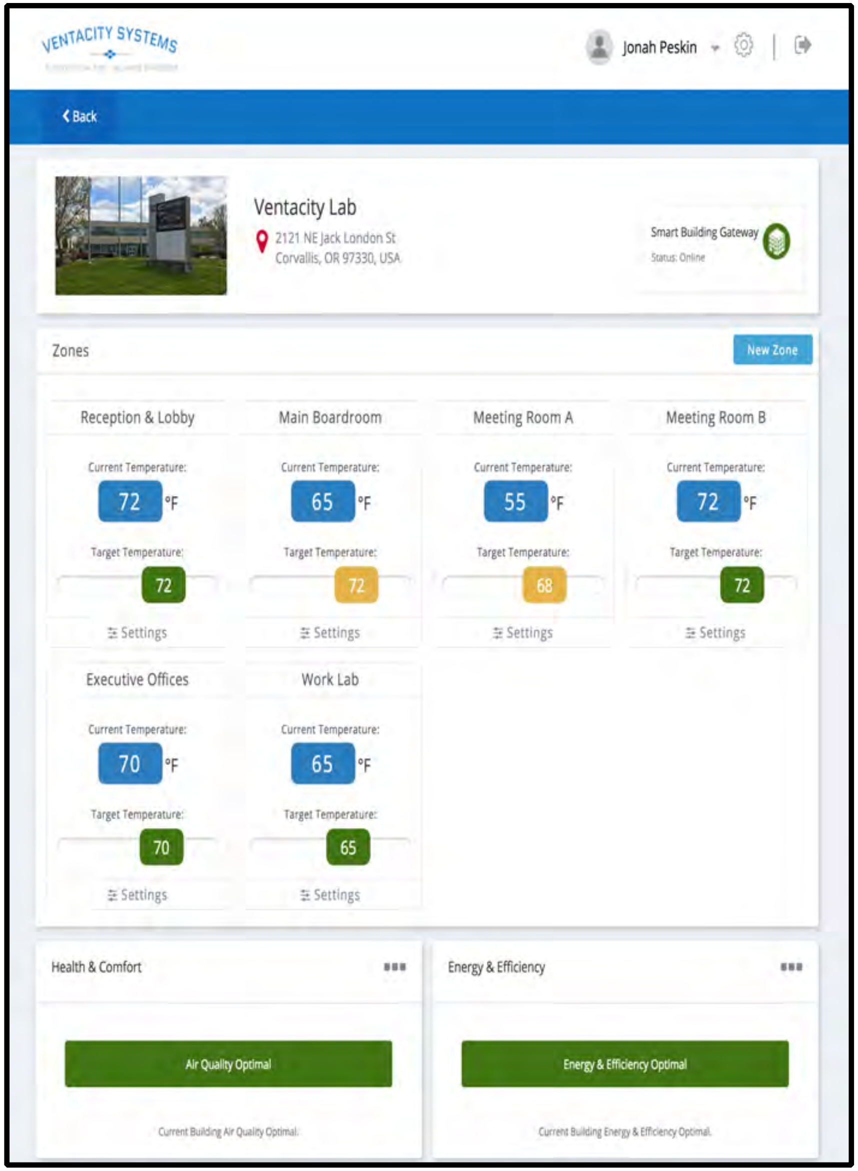
OVERVIEW

- "At a Glance" View of All Equipment On-Site
- Manage Zones
- See Air Quality & Energy Efficiency Status

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

BUILDING ZONES

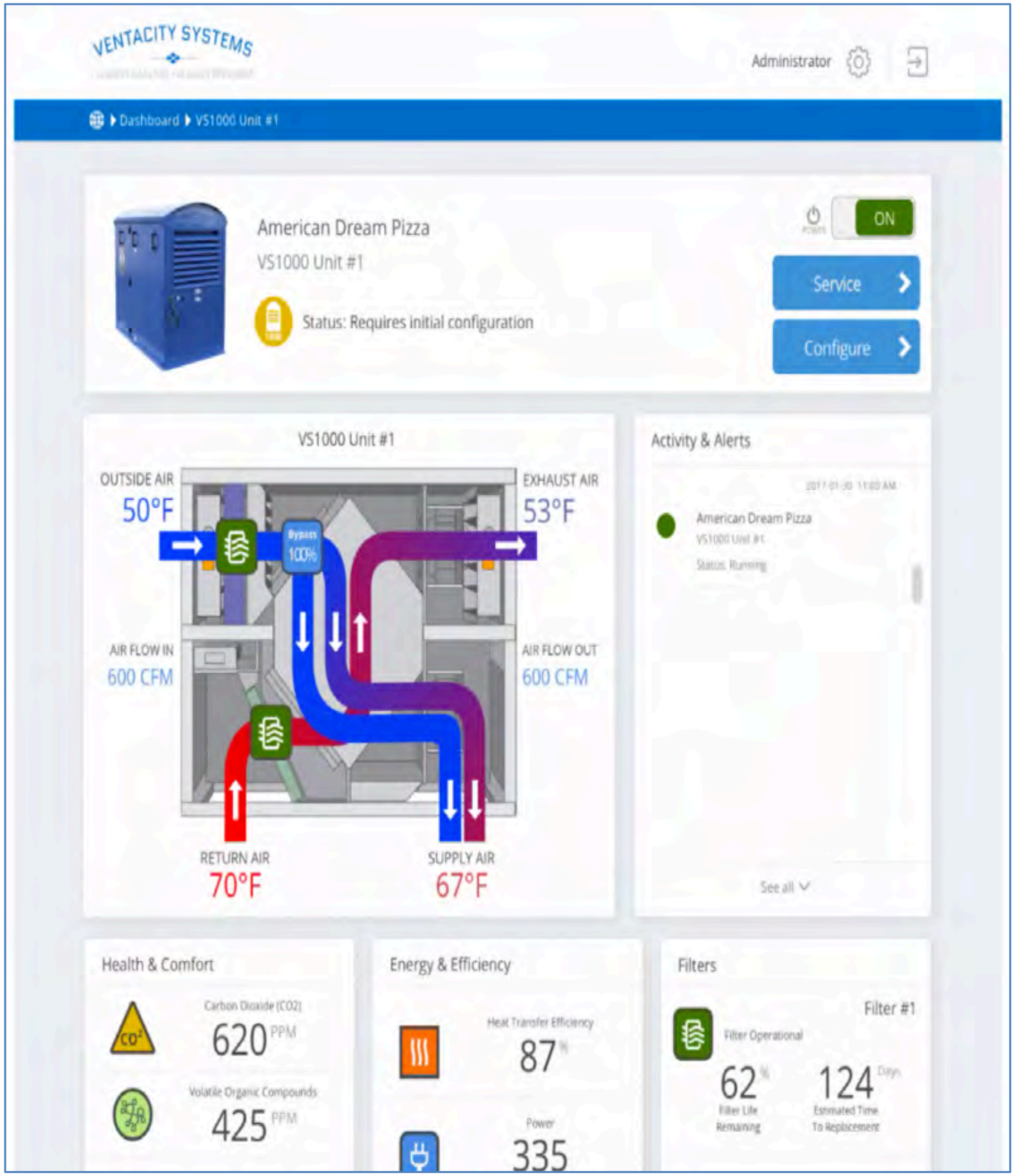


- OVERVIEW

- "At a Glance" View of All Equipment On-Site
- Manage Zones
- See Air Quality & Energy Efficiency Status

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

SNEAK PREVIEWS...



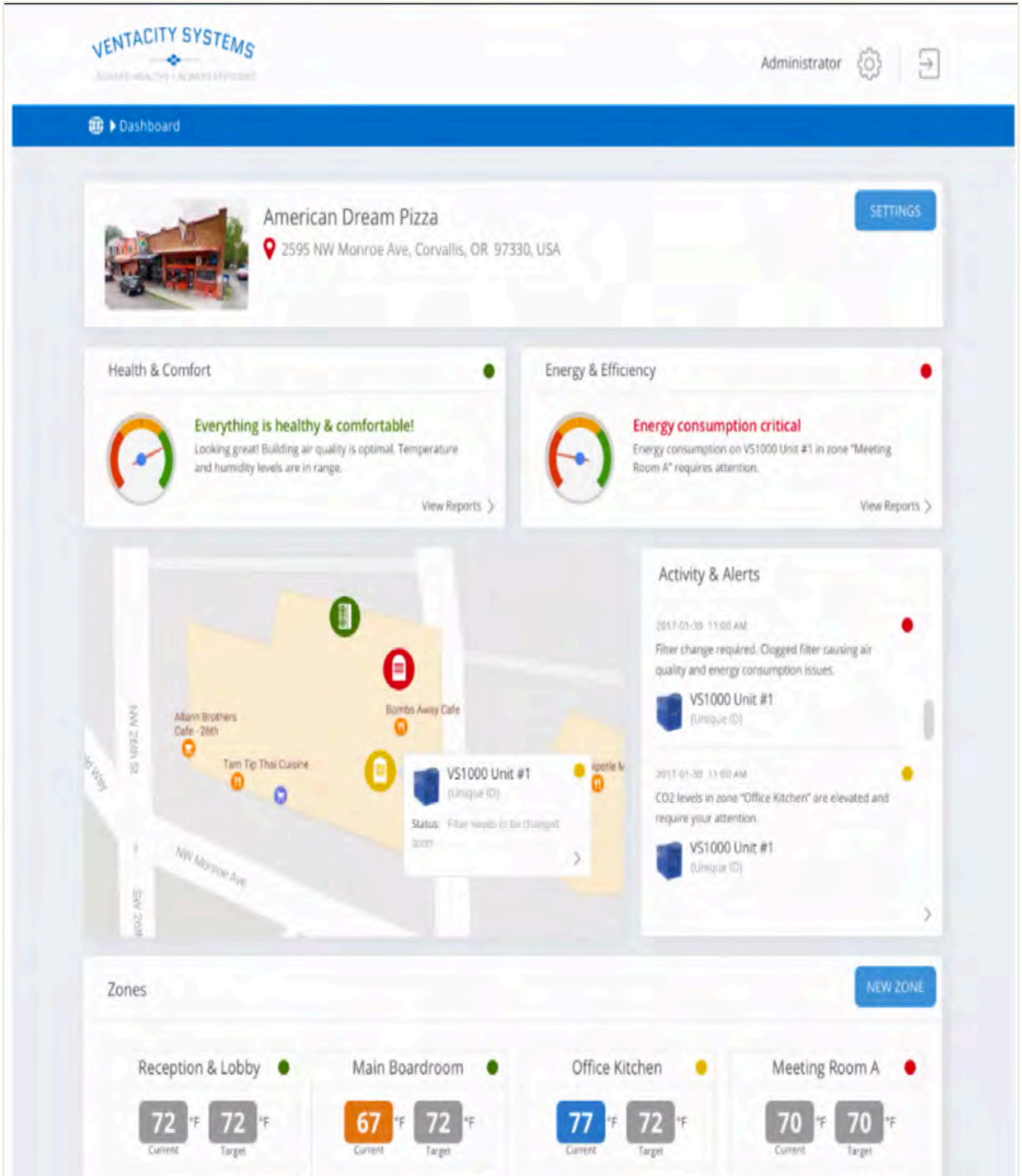
- OVERVIEW

- New & Improved Air Flow Diagram
- Bypass / Economizer Details

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

SNEAK PREVIEWS...



- OVERVIEW

- Real-Time Gauge Indicators
- Hover-Over Unit Details
- Zone UI Improvements

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

Air Quality

Energy Efficiency

- OVERVIEW

- Trends Over Time 1d, 1mo, 1yr, etc.
- Summary Warning / Error Indicators
- Contractor Branded Reports E-Mailed to Customer (Relationship Building for Service Contracts)

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

FUJITSU VRF UNIT STATUS

- OVERVIEW

- “At a Glance” VRF Unit Status
- Key Performance Indicators
- Basic Controls

Thank you

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