HIGH PERFORMANCE VENTILATION for Commercial Buildings

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

Presented by
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Portland, OR
5 November 2018

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 Institute

LEED
LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

LIVING BUILDING CHALLENGE

INTERNATIONAL WELL BUILDING INSTITUTE™

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

Side Benefits of High Performance Buildings

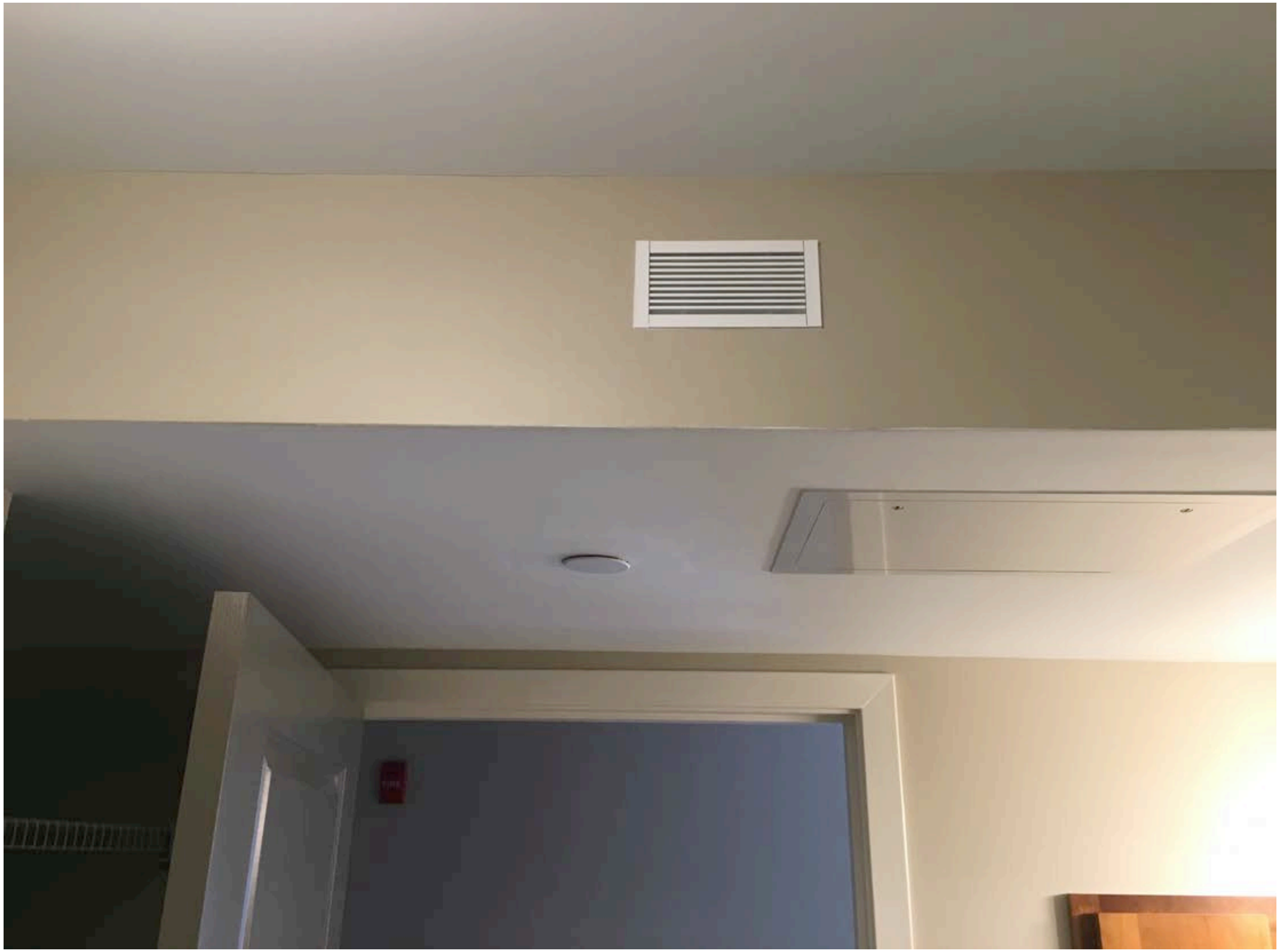
- Happy occupants
- Higher productivity
- Higher rent and/or lower vacancy rate
- Increased building value
- Hedged energy costs

A Very Busy Roof

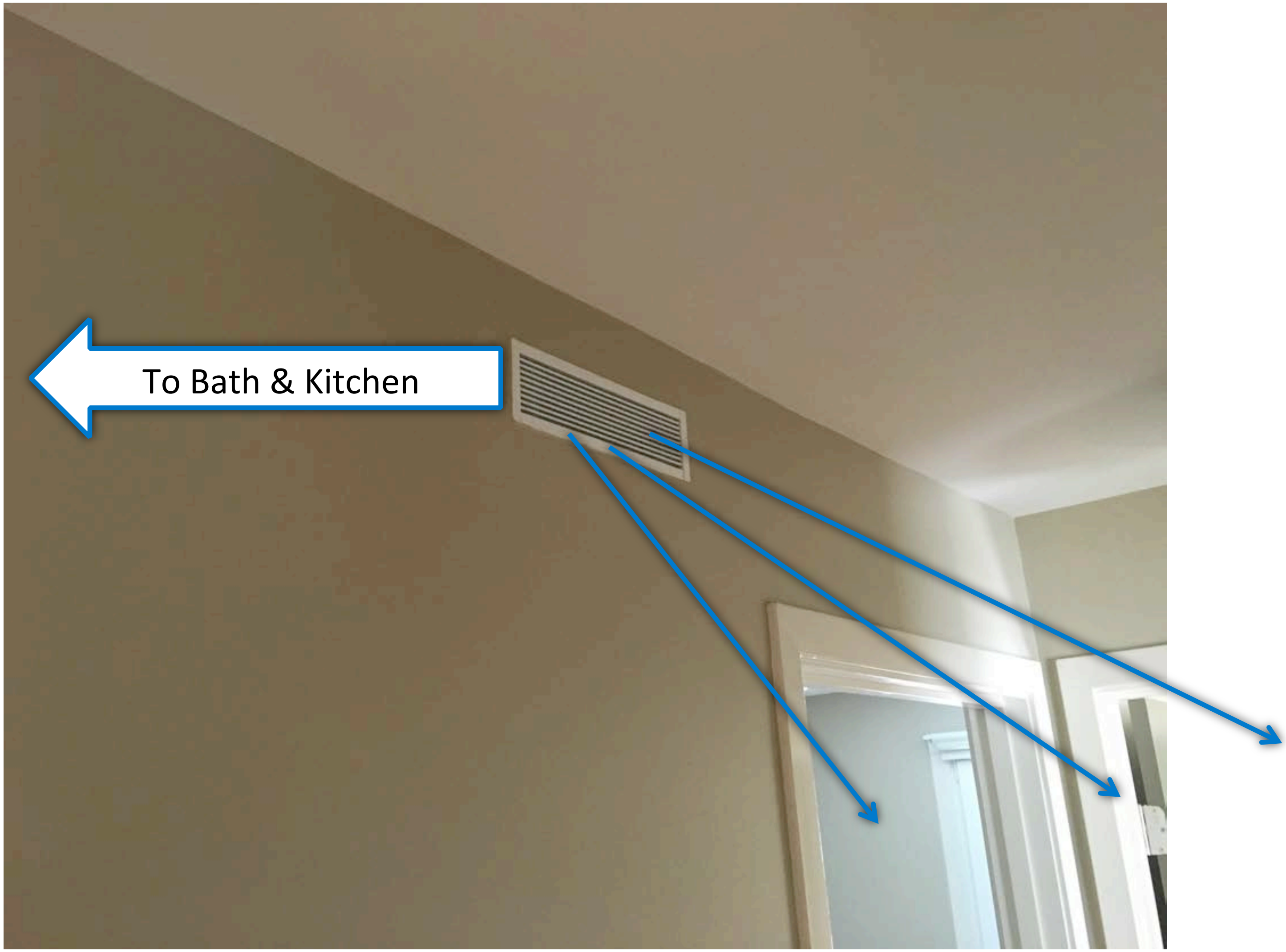
Plenty of Hot Air!

Exhaust the Kitchen (and suck up some grease)

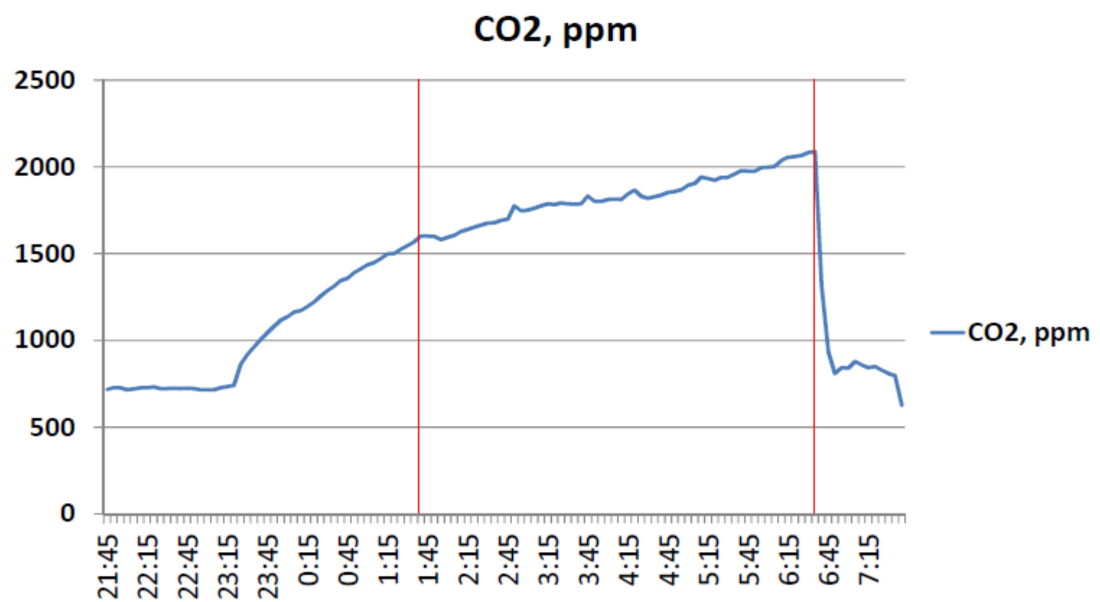
Exhaust the Bathroom



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

Why Ventilate? Air is Life

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

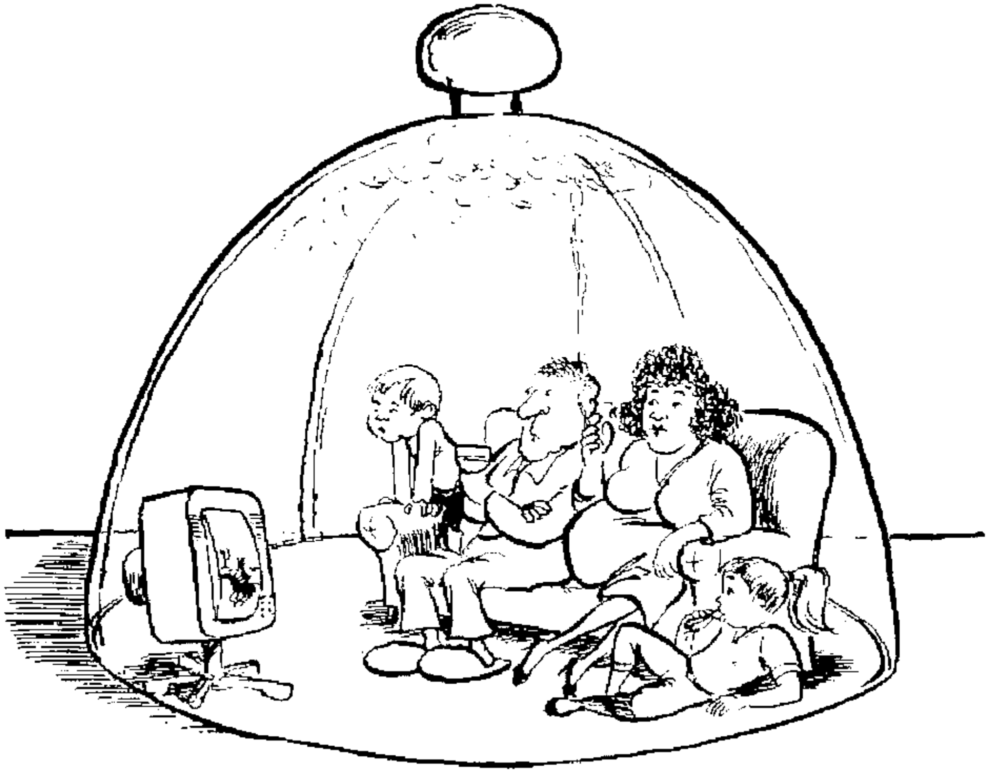
Why Ventilate? Air is Important

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

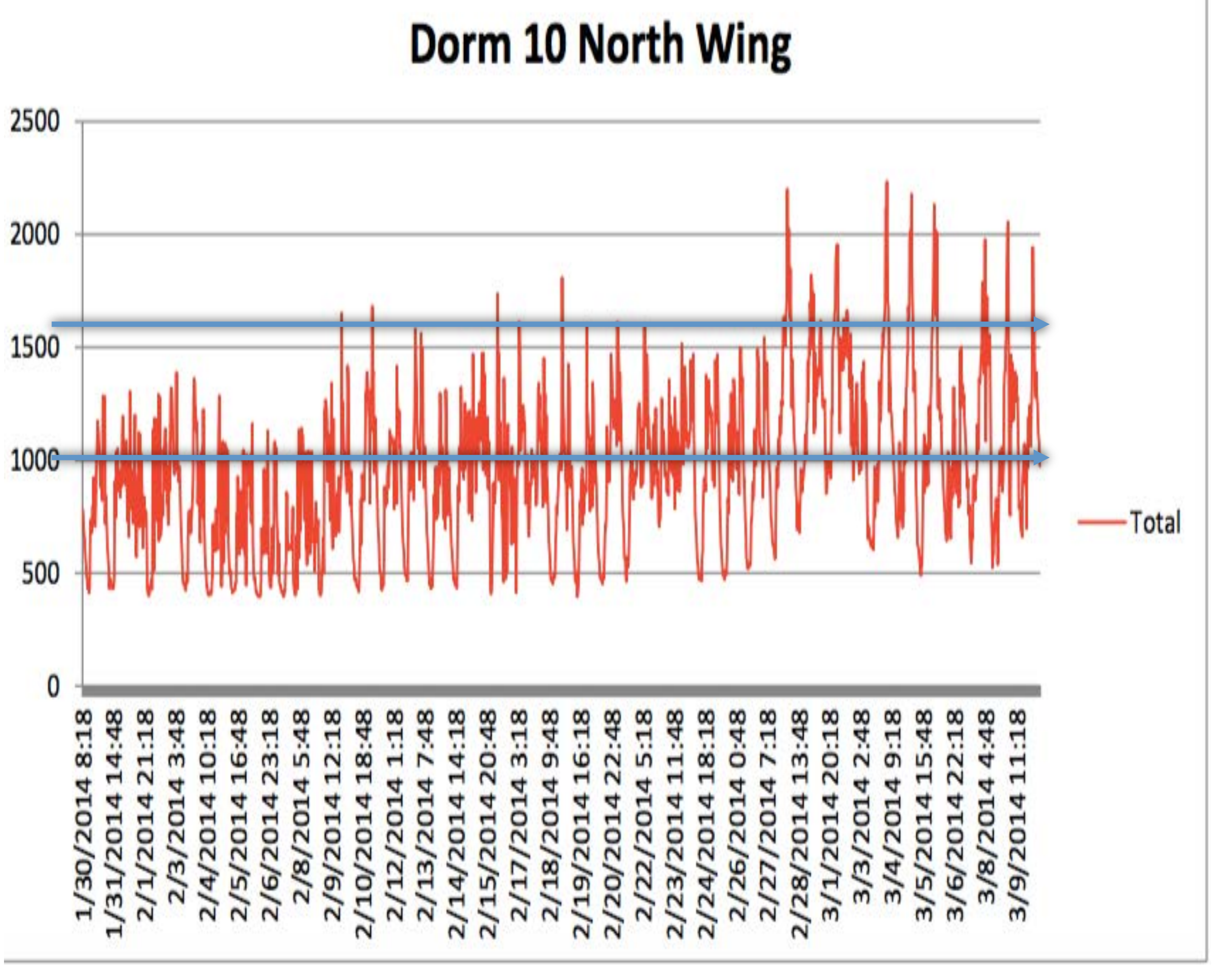
- Lawrence Berkeley National Laboratory study of California classrooms
- Increasing ventilation from 8 CFM/student to 15 CFM/student
- Reduced sickness related absenteeism by almost 4%

Why Ventilate? 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.

VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

Adopted Washington State Commercial Mechanical Code 1 July 2017

Section C403.6—Dedicated outdoor air systems (DOAS).

C403.6 Dedicated outdoor air systems (DOAS) (This section is optional until June 30, 2017; and becomes prescriptive as of July 1, 2017). For office, retail, education, libraries and fire stations. Outdoor air shall be provided to each occupied space by a dedicated outdoor air system (DOAS) which delivers 100 percent outdoor air without requiring operation of the heating and cooling system fans for ventilation air delivery.

EXCEPTIONS: 1. Occupied spaces that are not ventilated by a mechanical ventilation system and are only ventilated by a natural ventilation system per Section 402 of the *International Mechanical Code*.

2. High efficiency variable air volume (VAV) systems complying with Section C403.7. This exception shall not be used as a substitution for a DOAS per Section C406.6 or as a modification to the requirements for the Standard Reference Design per Section C407.

C403.6.1 Energy recovery ventilation with DOAS. The DOAS shall include *energy recovery ventilation* that complies with the minimum energy recovery efficiency and energy recovery bypass requirements, where applicable, of Section C403.5.1.

EXCEPTIONS: 1. Occupied spaces under the threshold of Section C403.5 with an average occupant load greater than 25 people per 1000 square feet (93 m2) 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.

C403.6.2 Heating/cooling system fan controls. Heating and cooling equipment fans, heating and cooling circulation pumps, and terminal unit fans shall cycle off and terminal unit primary cooling air shall be shut off when there is no call for heating or cooling in the zone.

EXCEPTION: Fans used for heating and cooling using less than 0.12 watts per cfm may operate when space temperatures are within the setpoint deadband (Section C403.2.4.1.2) to provide destratification and air mixing in the space.

C403.6.3 Impracticality. Where the code official determines that full compliance with all the requirements of Sections C403.6.1 and C403.6.2 would be impractical, it is permissible to provide an approved alternate means of compliance that achieves a comparable level of energy efficiency. For the purposes of this section, impractical means that an HVAC system complying with Section C403.6 cannot effectively be utilized due to an unusual use or configuration of the building.

Proposed Change to the Washington State Commercial Mechanical Code 1 July 2017

Table C403.5.1(1)
Energy Recovery Requirement
(Ventilation systems operating less than 8,000 hours per year)

Percent (%) Outdoor Air at Full Design Airflow Rate								
Climate zone	≥ 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 (cfm)								
4C, 5B	NR	NR	NR	NR	NR	NR	≥ 5000	≥ 5000

NR = Not required.

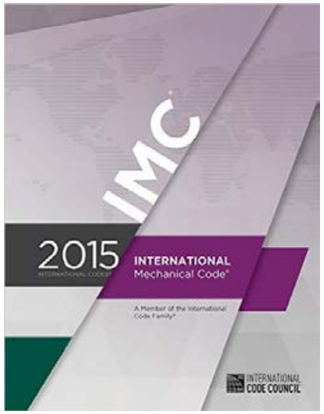
Table C403.5.1(2)
Energy Recovery Requirement
(Ventilation systems operating not less than 8,000 hours per year)

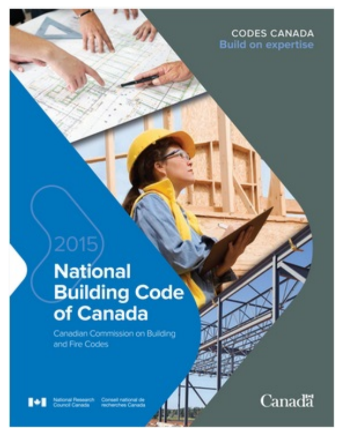
Percent (%) Outdoor Air at Full Design Airflow Rate								
Climate zone	≥ 10% and < 20%	≥ 20% and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
Design Supply Fan Airflow Rate (cfm)								
4C	NR	≥ 19500	≥ 9000	≥ 5000	≥ 4000	≥ 3000	≥ 1500	≥ 0
5B	≥ 2500	≥ 2000	≥ 1000	≥ 500	≥ 0	≥ 0	≥ 0	≥ 0

NR = Not required.

Chapter 4: Ventilation Requirements

How Much Ventilation is Needed?

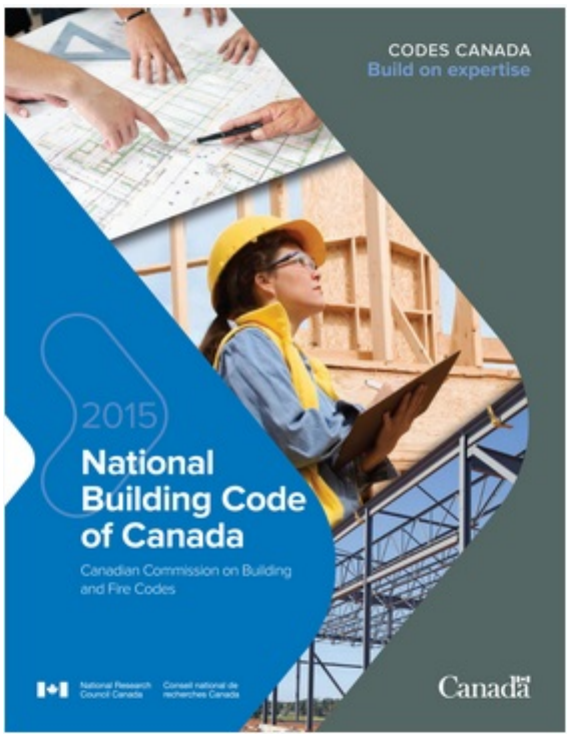




- International Mechanical Code (IMC)
- ASHRAE 62.1
- Passive House
- National Building Code of Canada

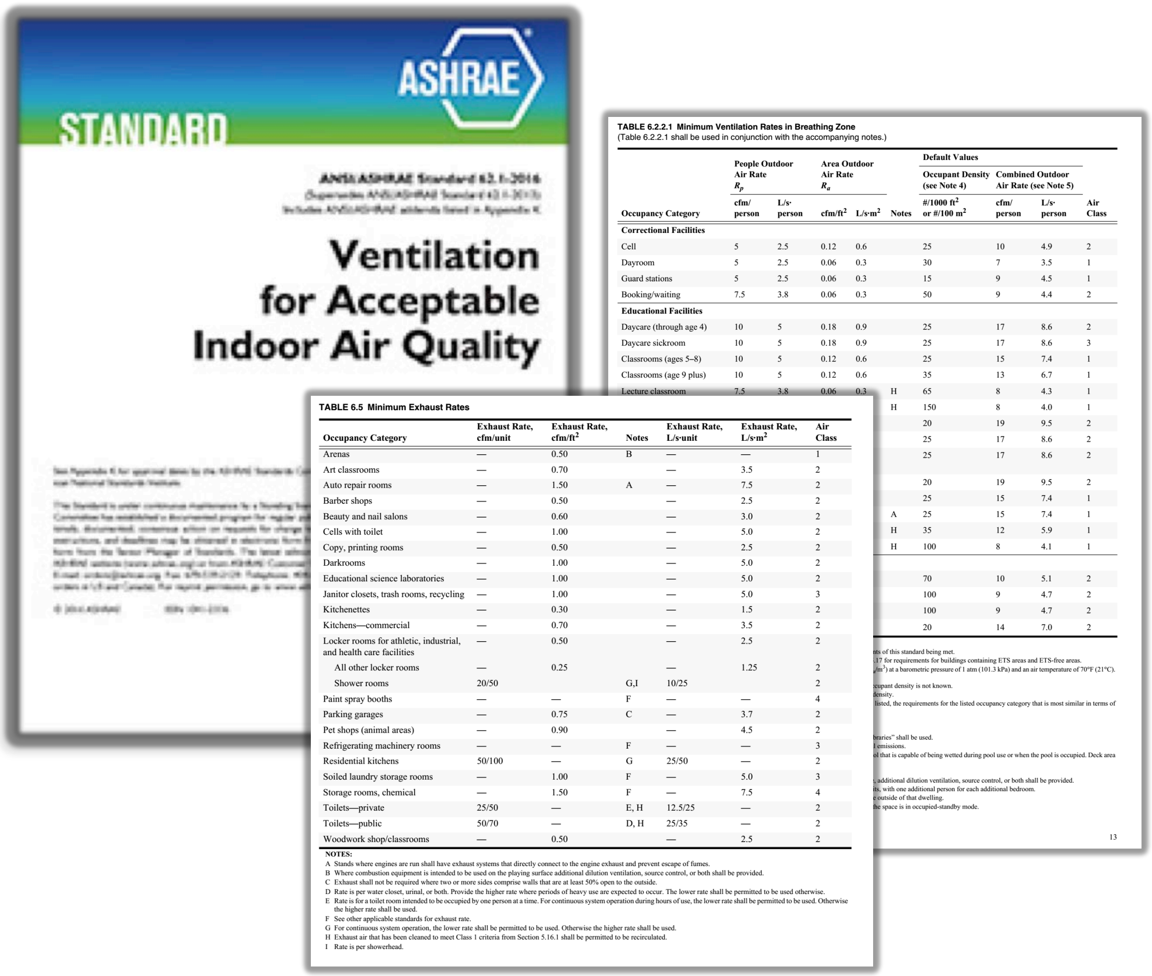
How much Ventilation is needed?
2015 National Building Code of Canada

[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

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

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.)

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
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·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 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
LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

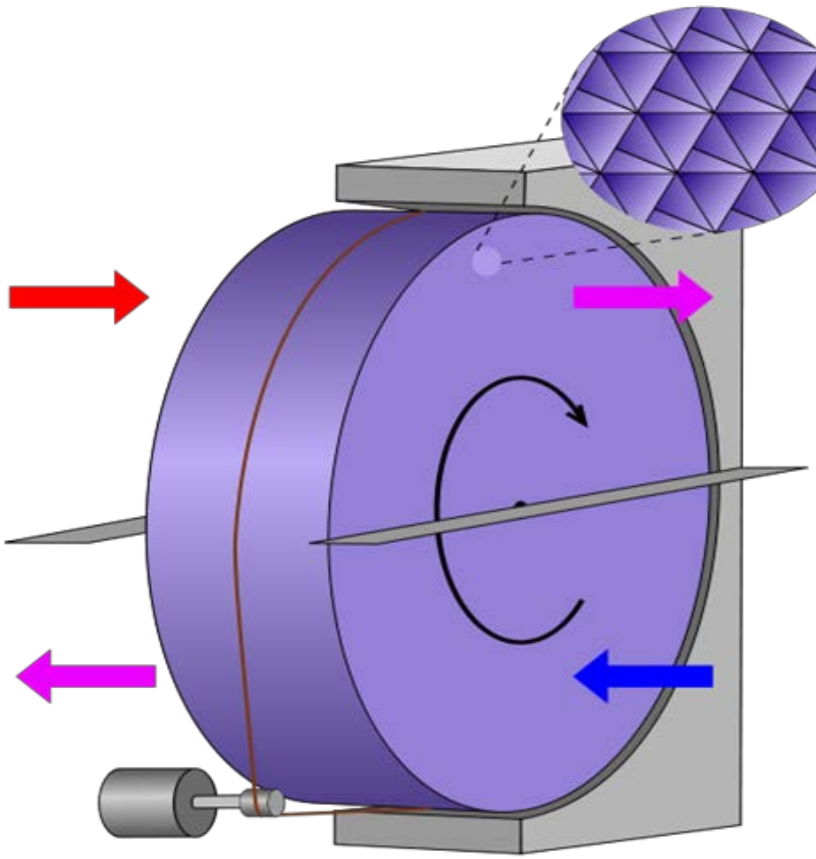
LIVING BUILDING CHALLENGE

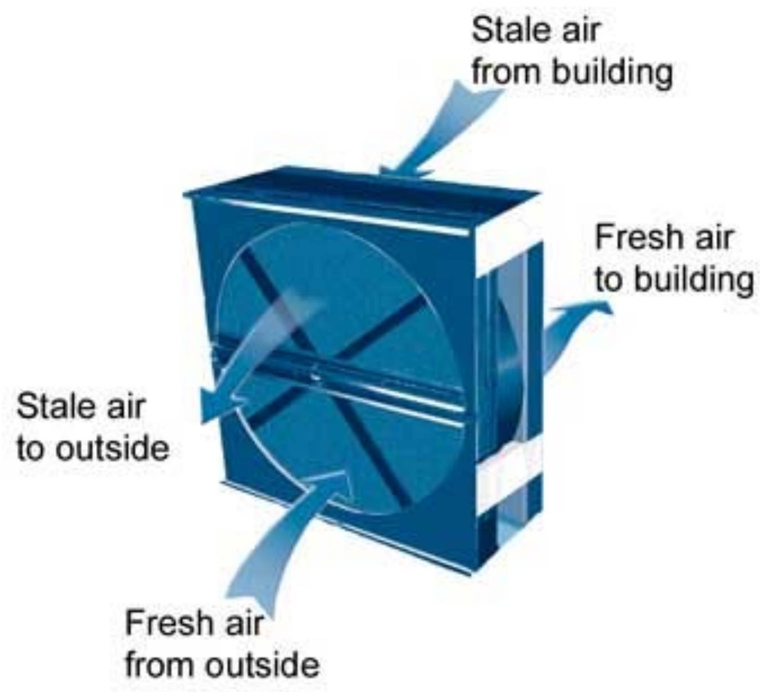
INTERNATIONAL WELL BUILDING INSTITUTE™

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

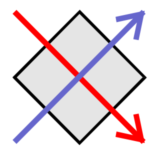
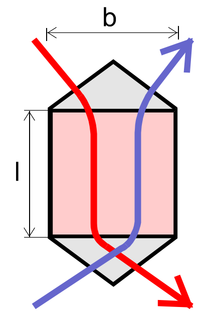
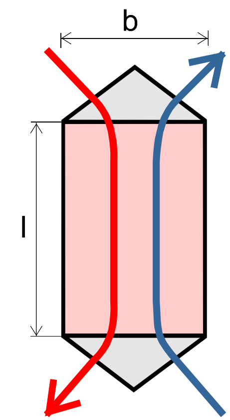
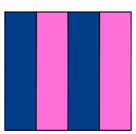
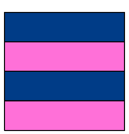
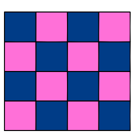
Chapter 5: What’s In The Box?

Enthalpy Wheel ERV

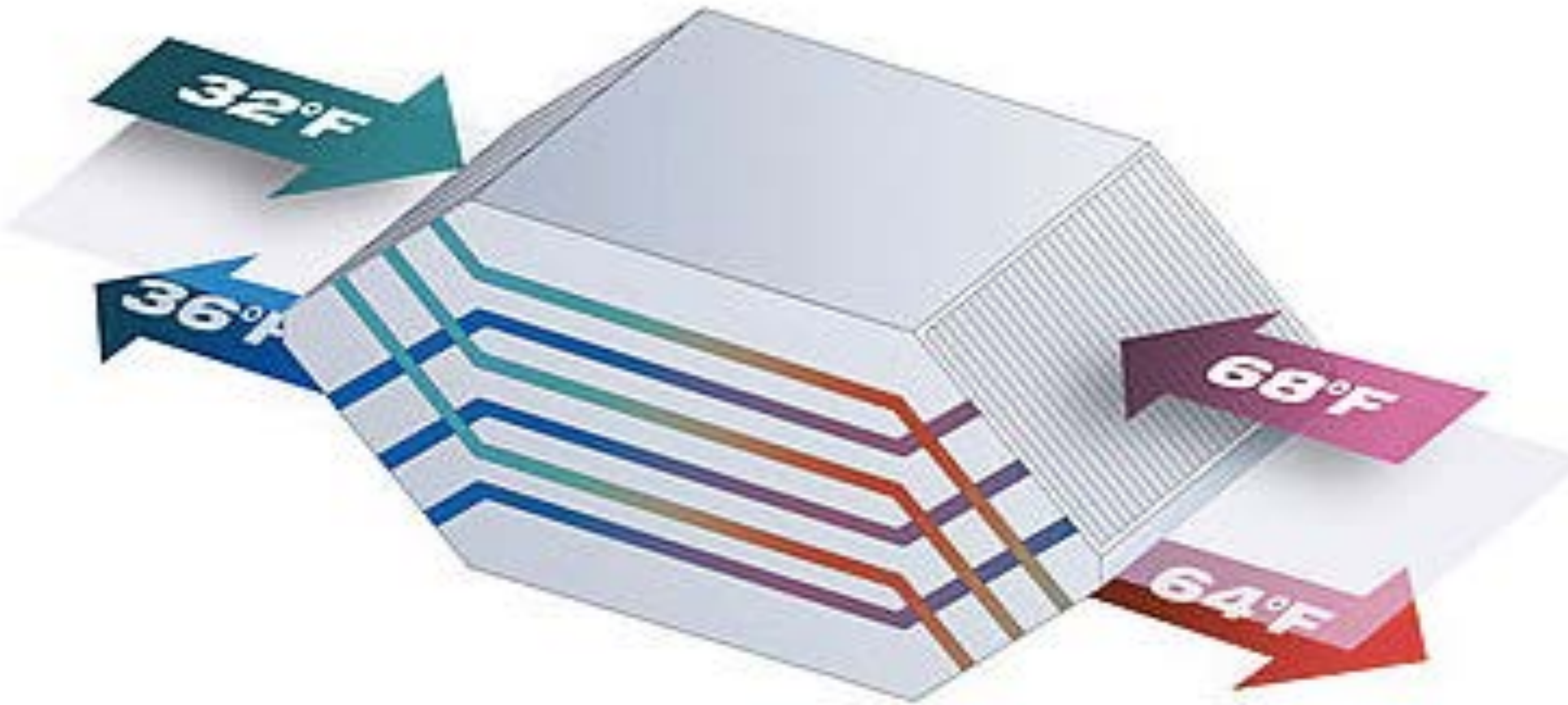




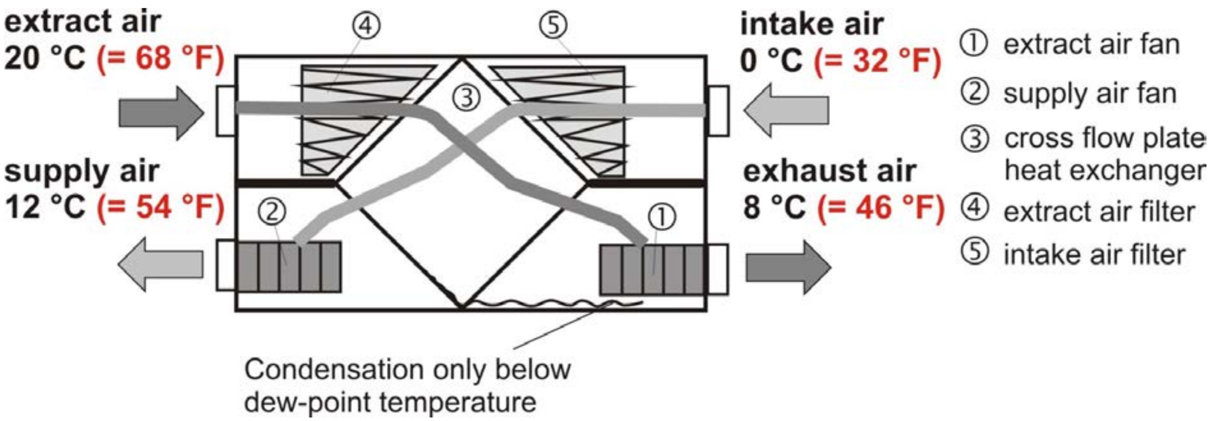
Options for H/ERV Cores

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

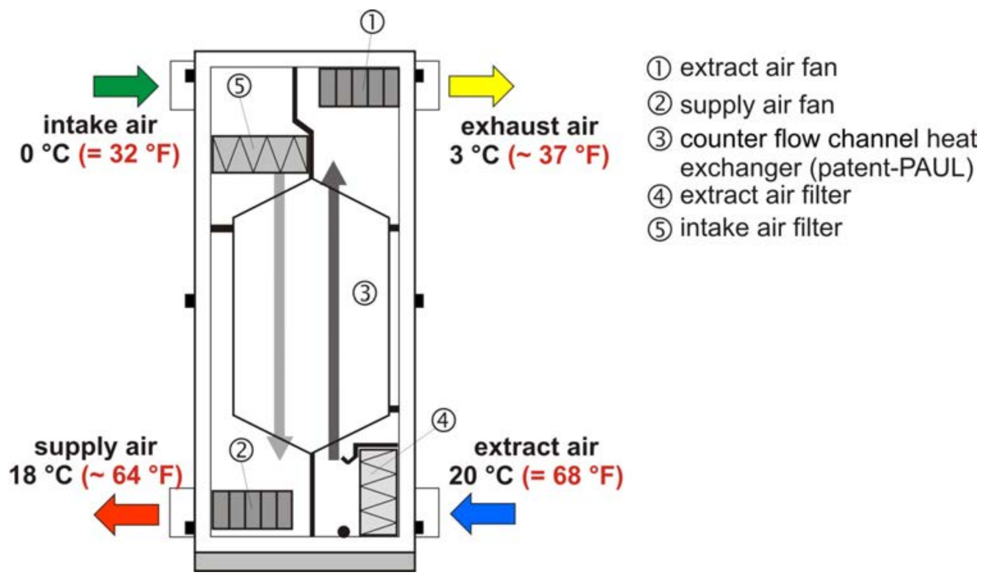
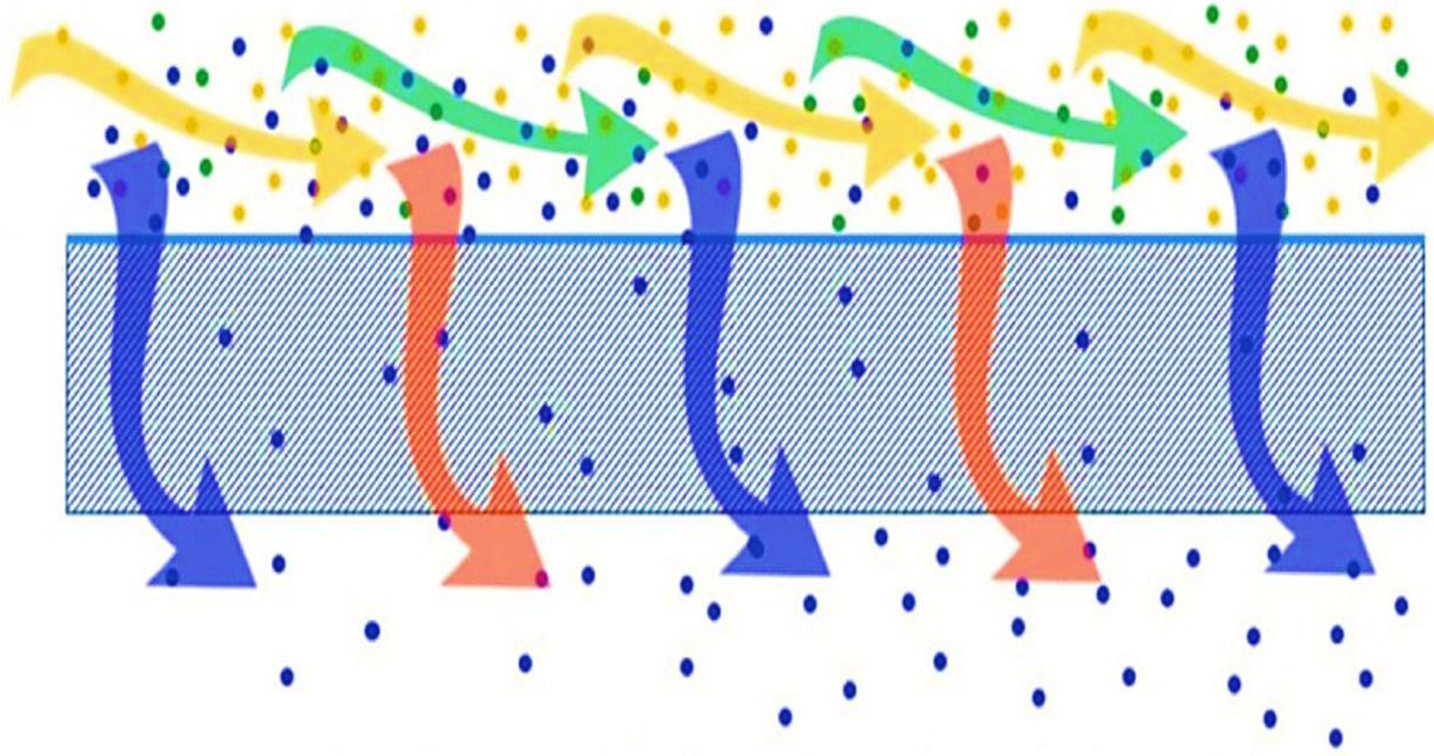
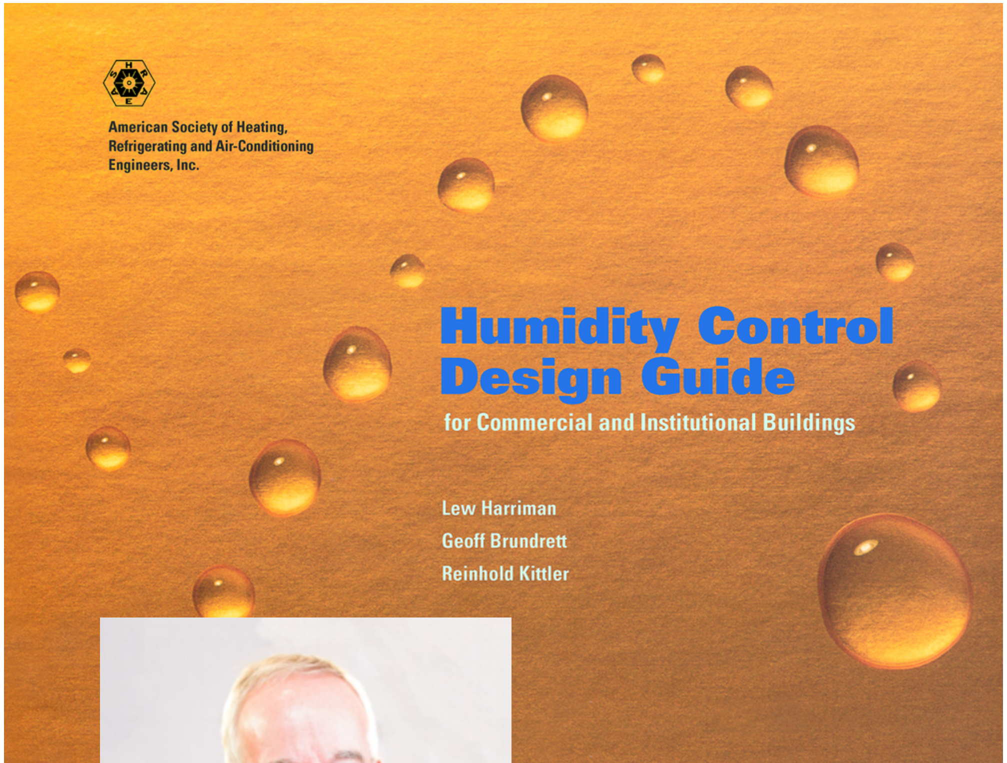


Plate Exchanger with Enthalpy Recovery



- water vapor
- heat
- odors
- gases, contaminants

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

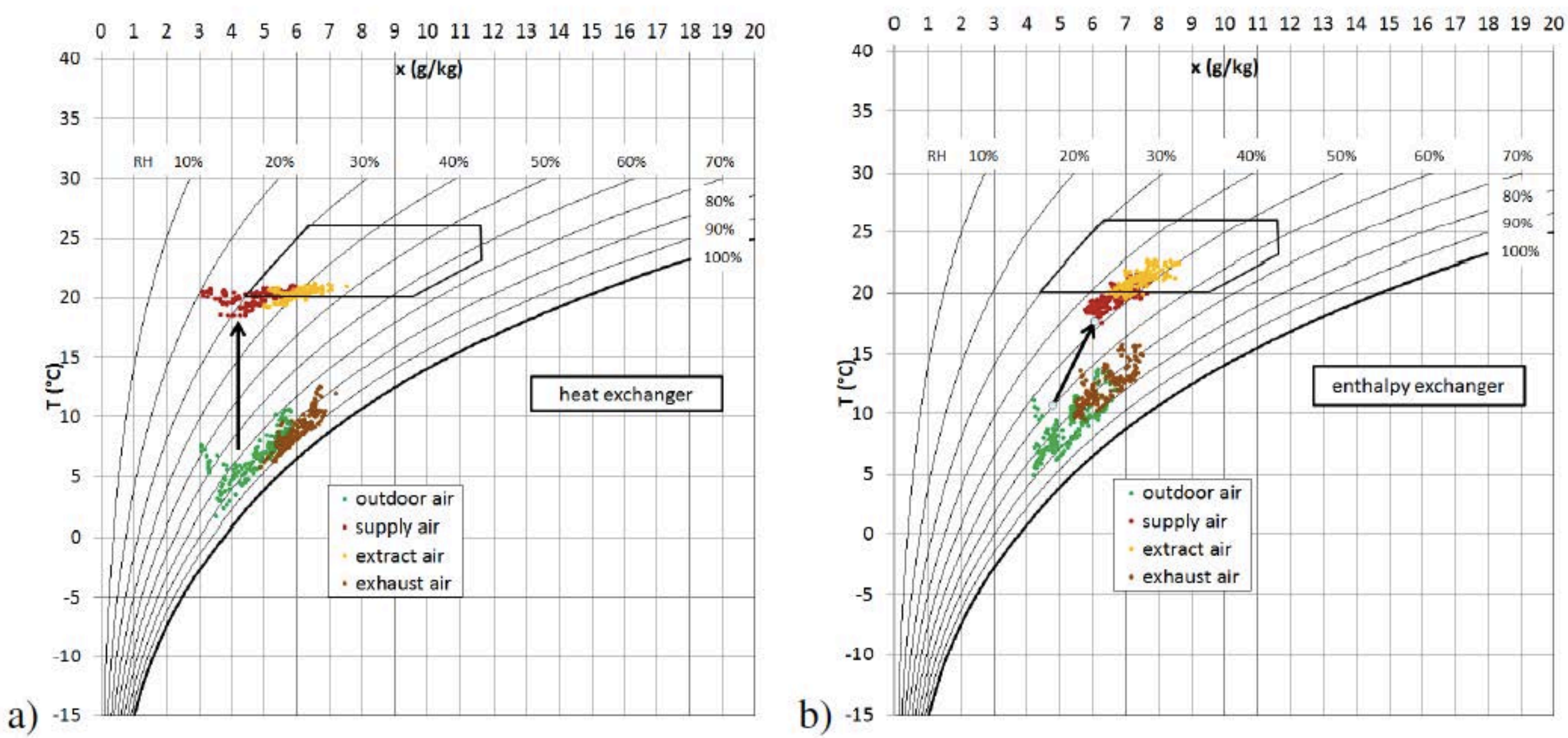
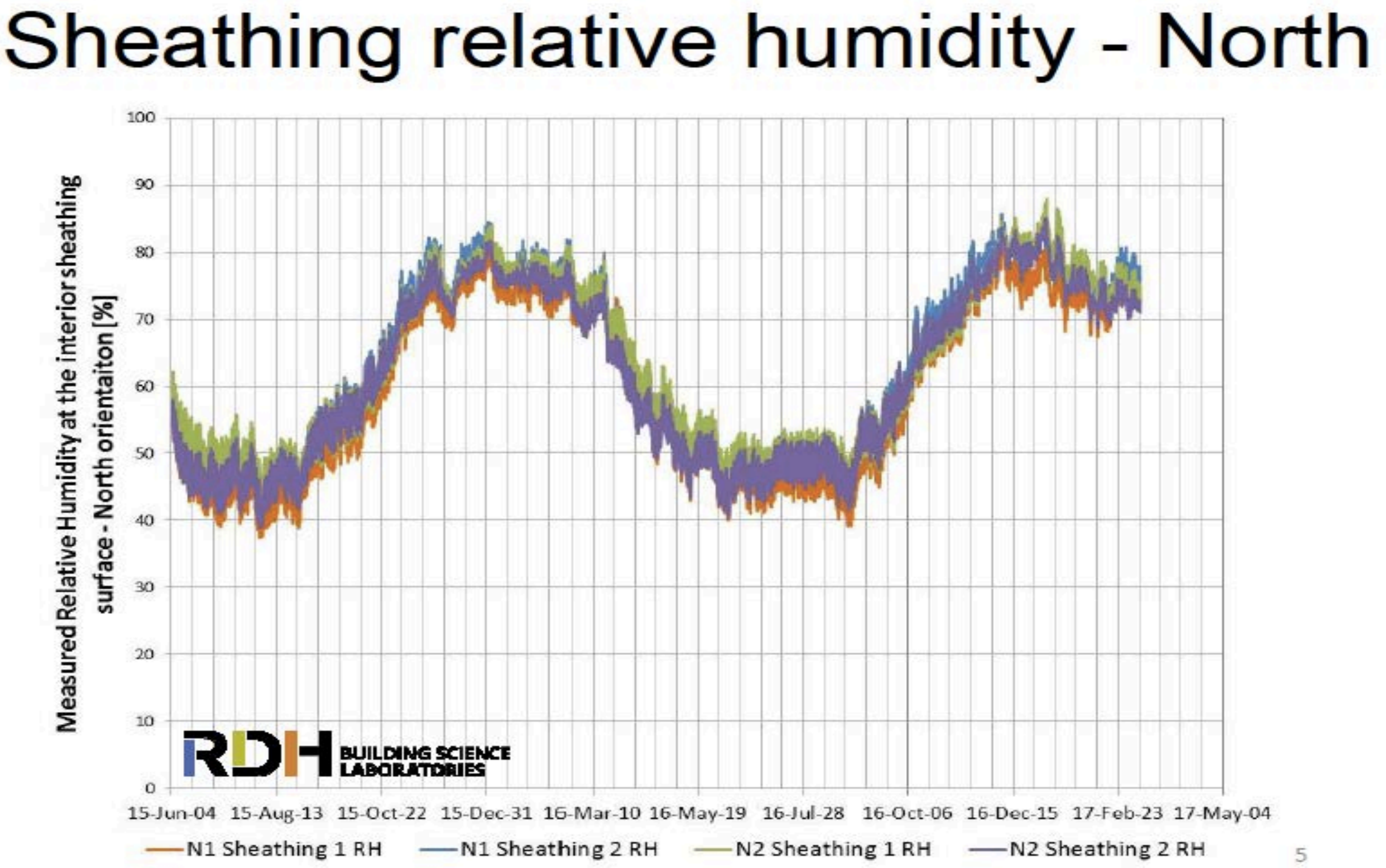
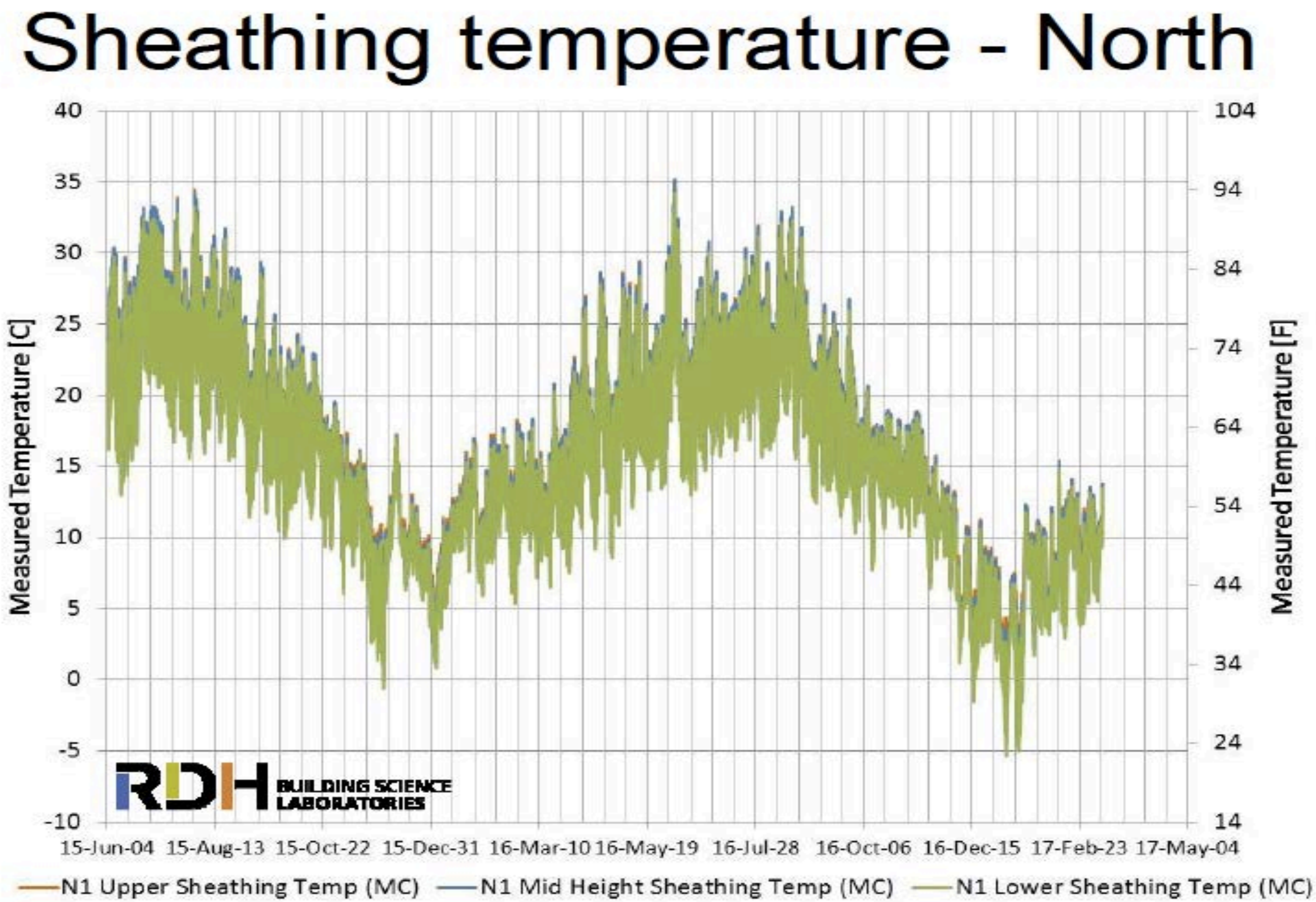


Figure 3: The effect of a heat exchanger (a) and an enthalpy exchanger (b) on the supply air and the indoor air.

Should you use an HRV or an ERV?



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

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

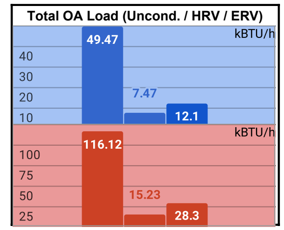
Winter Conditions Heating

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

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

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

Unconditioned OA Heating Load

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

HRV OA Heating Load

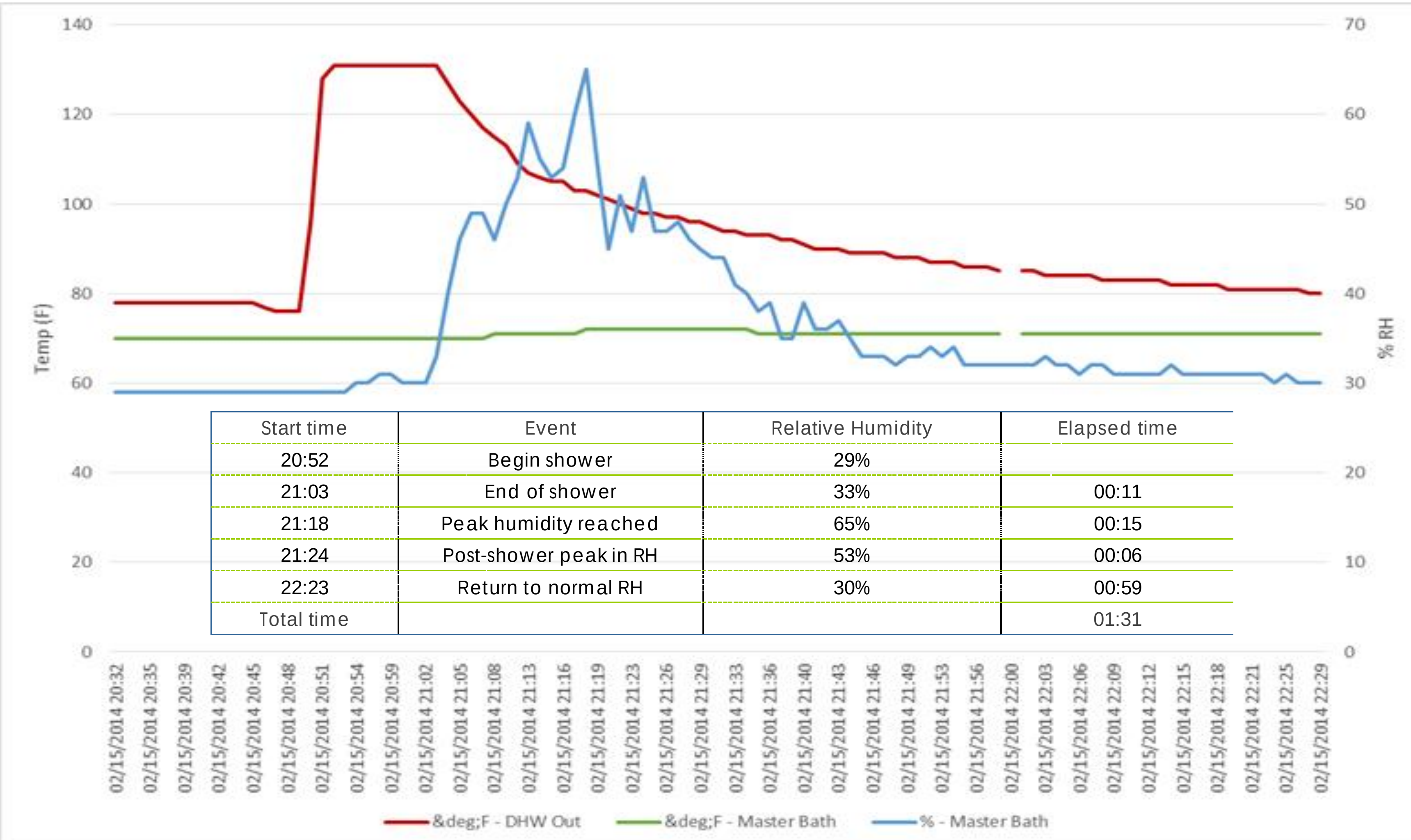
Supply DBT	64.1	°F
Supply WBT	45.1	°F
Supply RH	16.3	%
Efficiency (S)	86.9	%
Total Load	**15.23**	**kBTU/h**
(Sensible)		

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	**28.3**	**kBTU/h**
(Sensible)		

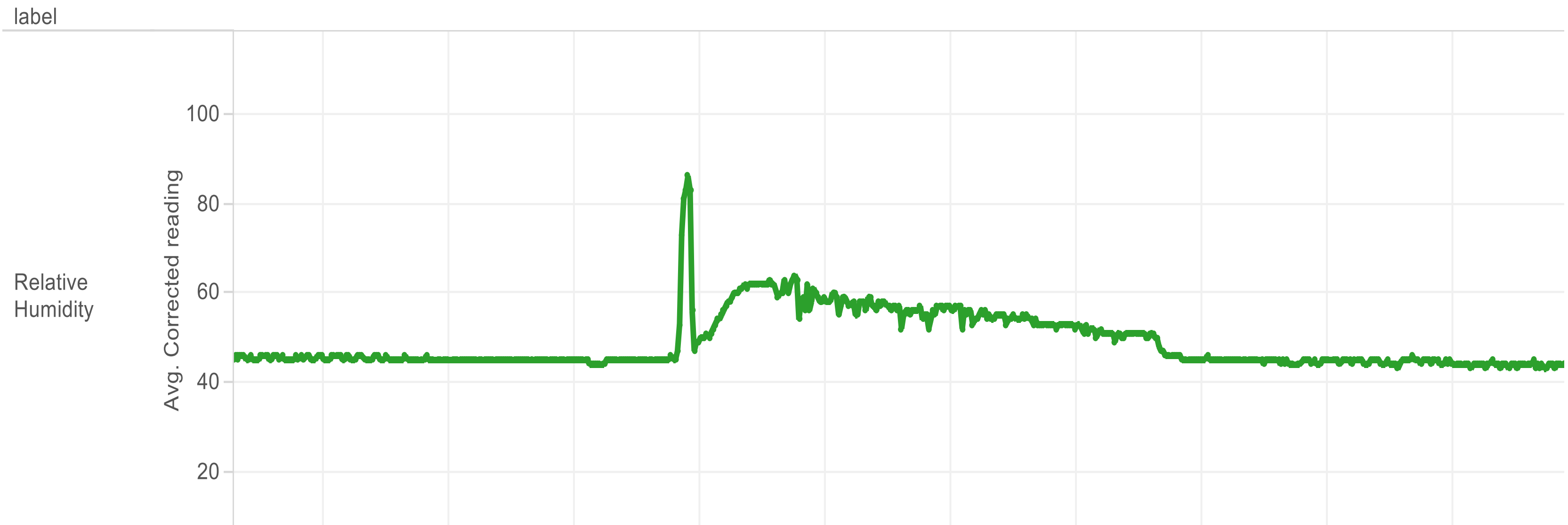
Continuous Exhaust Ventilation With Balanced HRV System



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

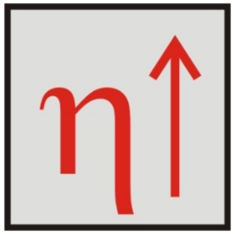
VENTACITY SYSTEMS
ALWAYS HEALTHY • ALWAYS EFFICIENT

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

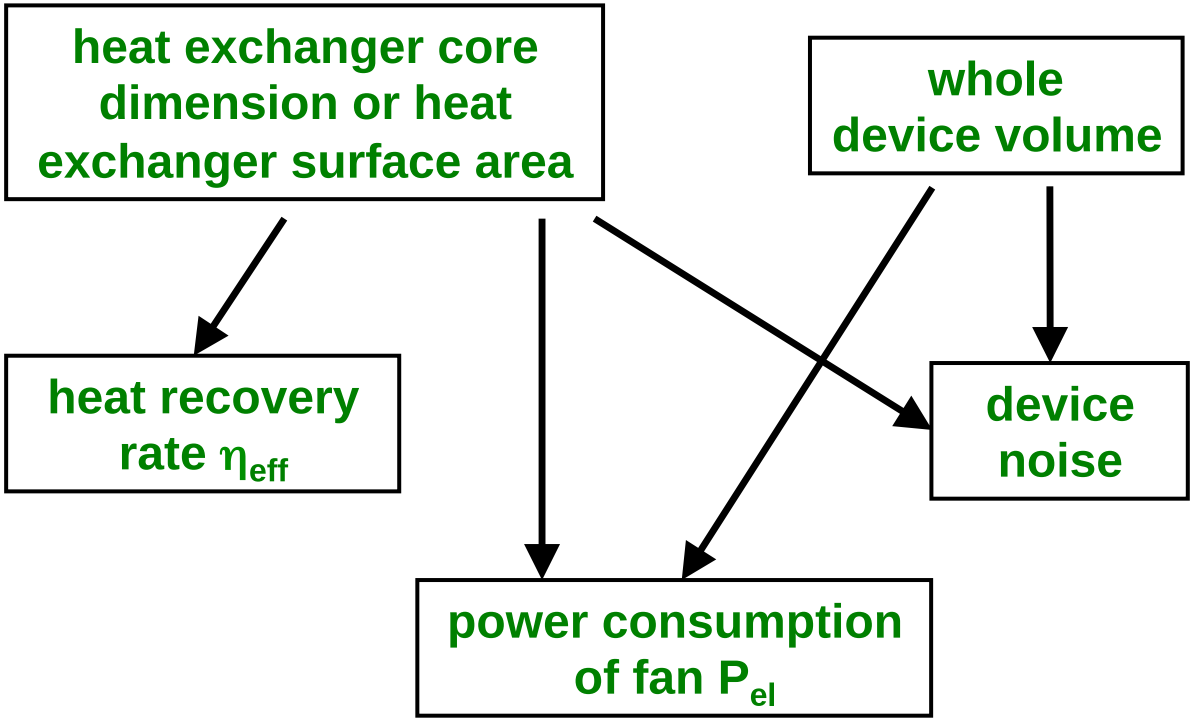


heat recovery rate

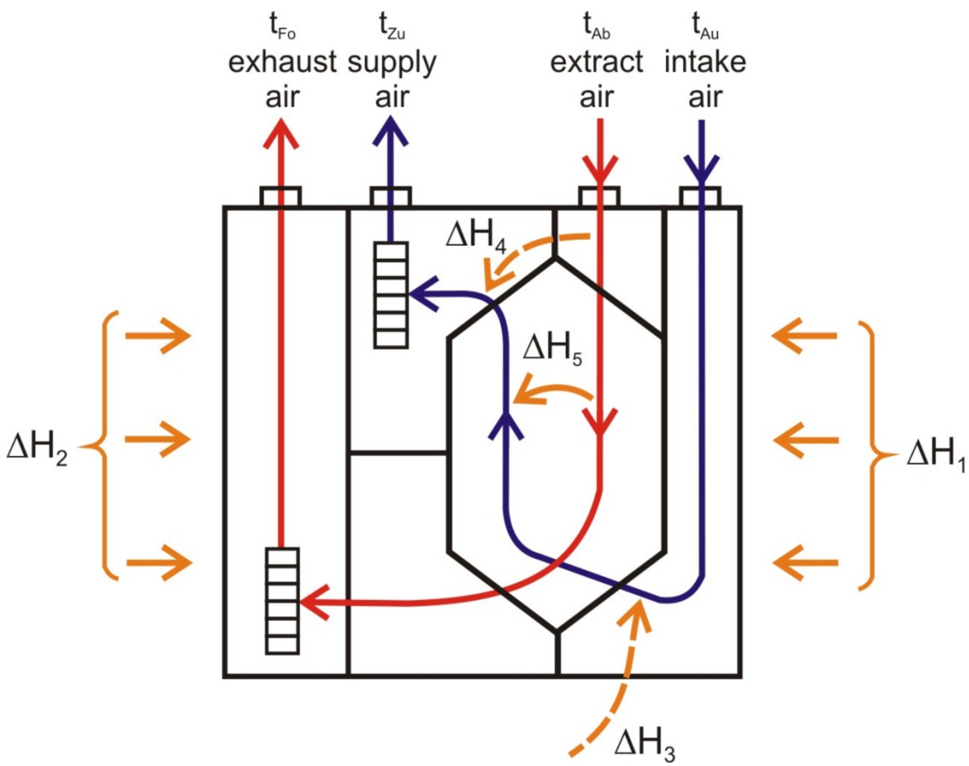
power consumption

noise

Performance Metrics Are Inter-Related

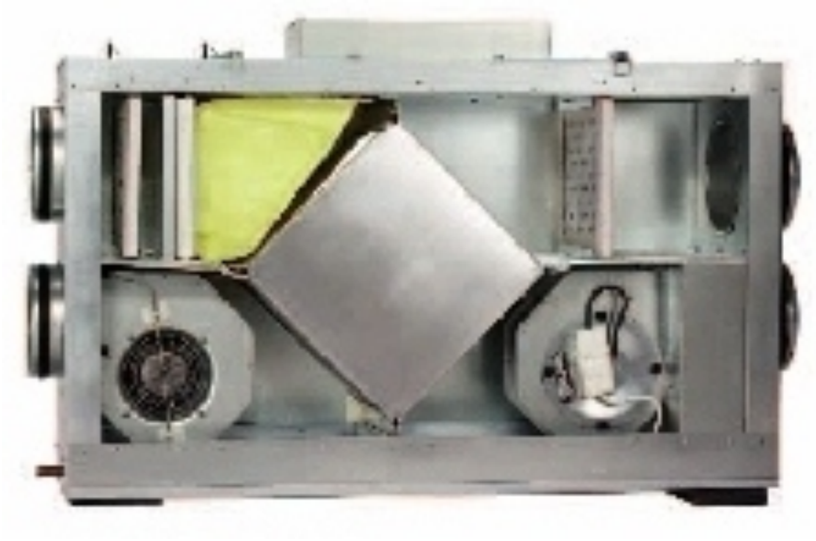


Conventional Measurement Of Efficiency Has A Lot Of Issues



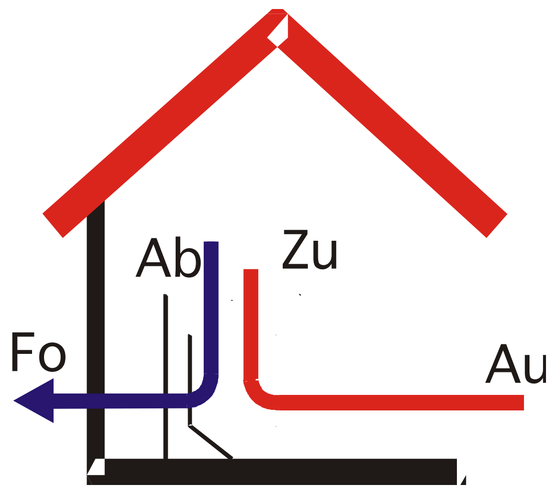
additional heat flow
from installation roomum into intake air (ΔH_1)
or into exhaust air (ΔH_2)
+
leakage hot air flows into intake/supply air:
external (from installation room ~ 20 °C (= 68 °F)) → ΔH_3
internal (from extract air ~ 21 °C (~70 °F)) → ΔH_4

Unit With Thermal Bridging – Casing Leakage



PHI vs North American Protocols For Measurement Of Efficiency

low heat losses in the exhaust air

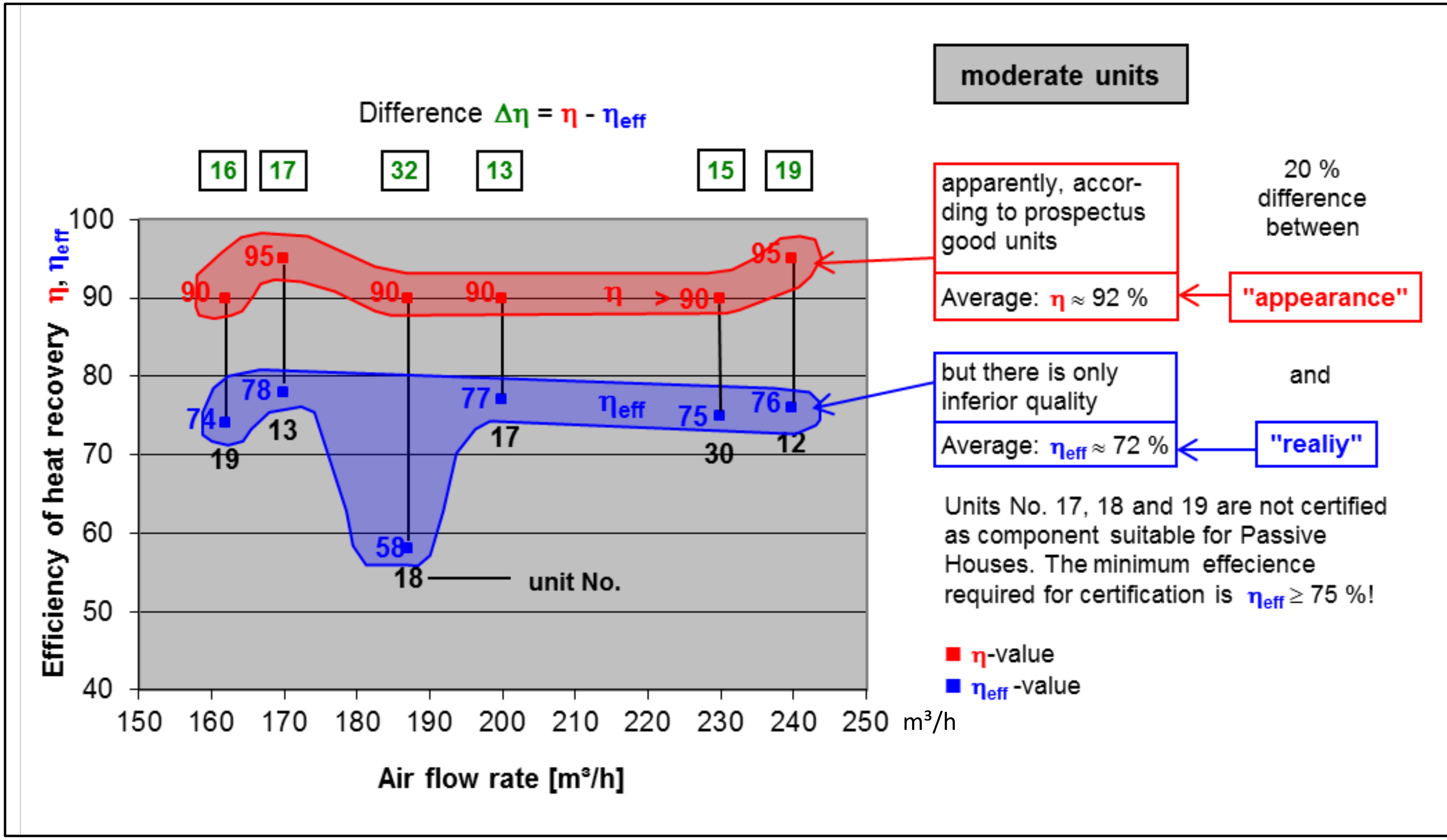


Manufacturer	η_{eff}	η
	$\eta_{Ext} = \dfrac{t_{Ext} - t_{Exh} + \dfrac{P_{el}}{\dot{m} \cdot c_P}}{t_{Ext} - t_{In}}$	$\eta_{Su} = \dfrac{t_{Su} - t_{In}}{t_{Ext} - t_{In}}$
1	69.9 %	90 %
2	59.2 %	95 %
3	93.0 %	94 %

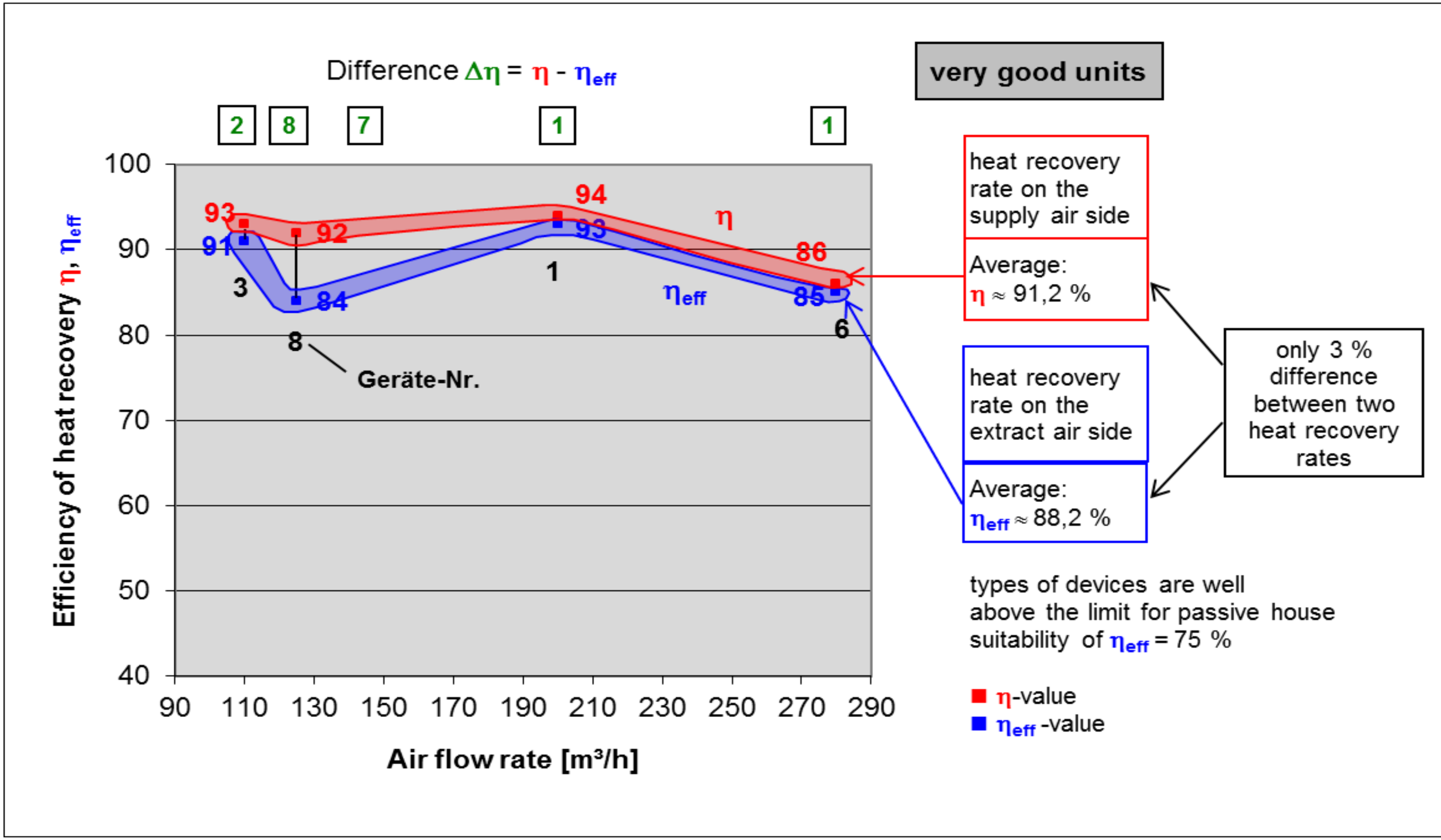
GE	Test method according to Passive House Institute Dr. Wolfgang, Feist Darmstadt PH certified device see www.passiv.de
GE	DIN V 18599-6:2007-02 and DIN EN 13141-7:2004(D) the included test report requires, among others:
CH	HTA Luzern Prüfreglement für Energie-Etikette (ohne $P_{el}/\dot{m} \cdot c_P$)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

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

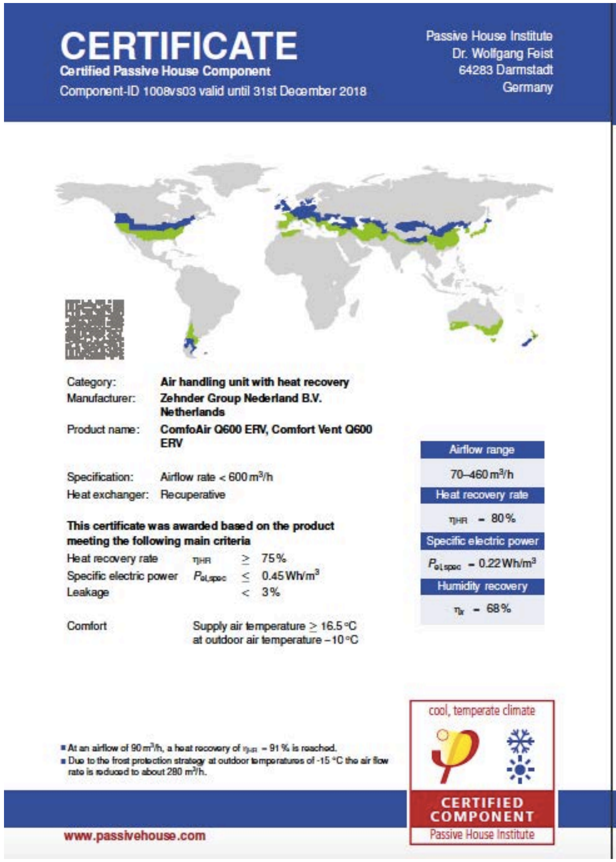
Significant Discrepancies Between Measured Efficiencies



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%

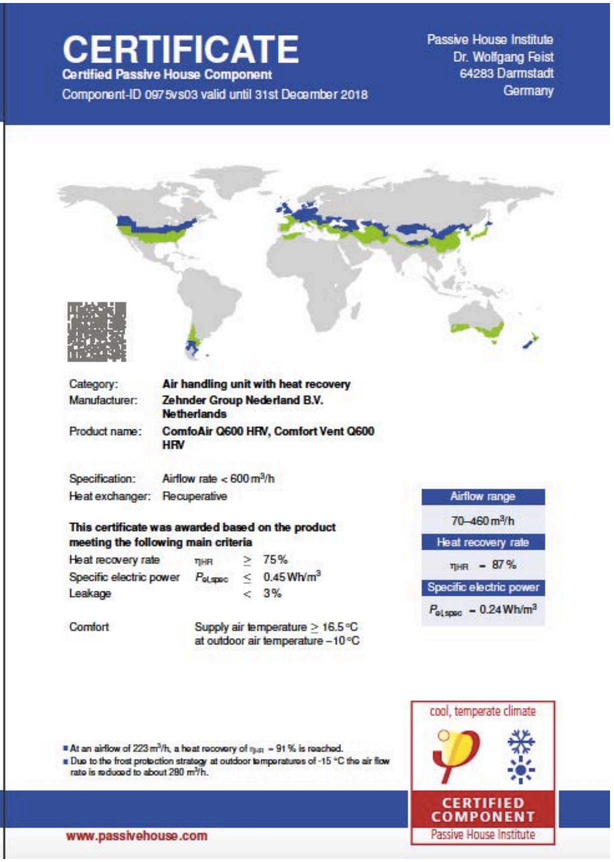
Comfort: Supply air temperature ≥ 16.5 °C at outdoor air temperature −10 °C

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**
Manufacturer: **Zehnder Group Nederland B.V. Netherlands**
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

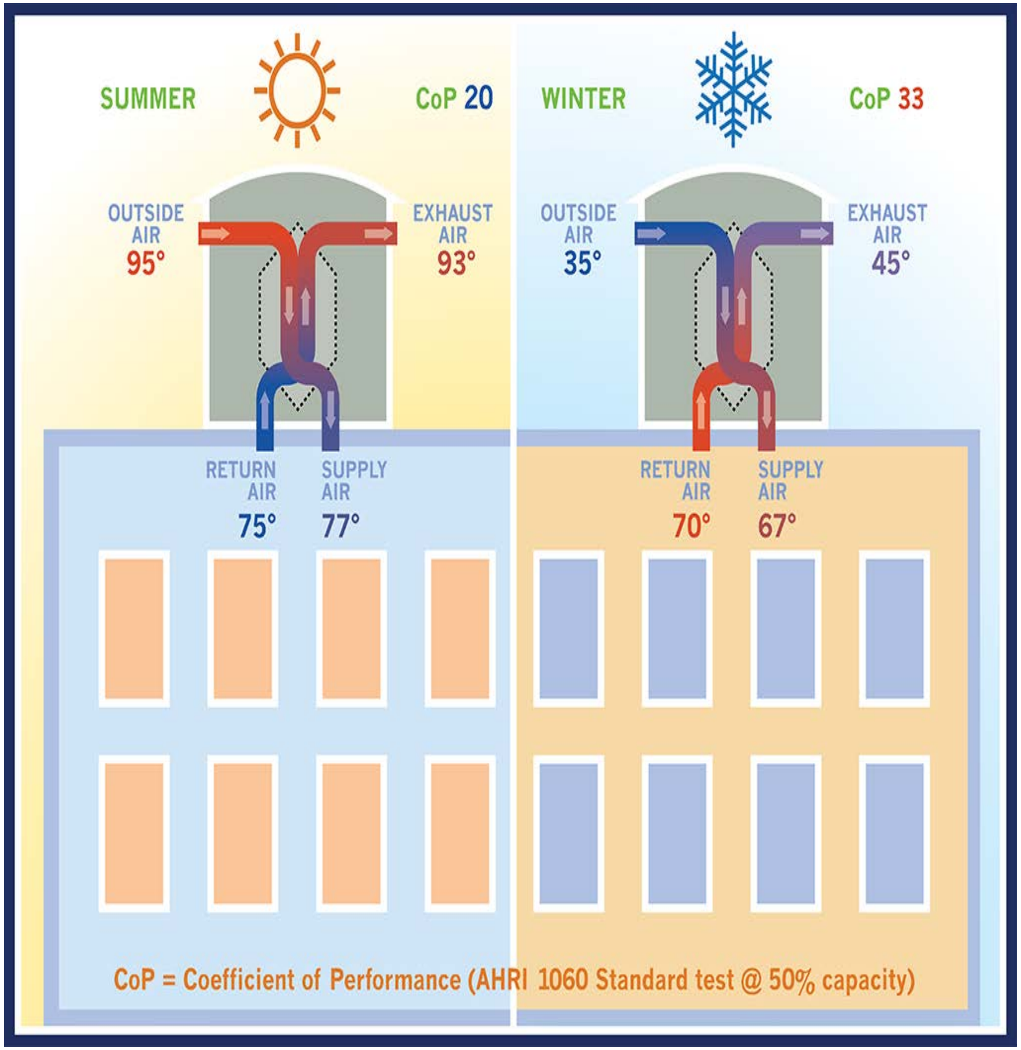
BETTER METRIC, BUT LOWER EFFICIENCY NUMBER

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

COP Of HVAC Options Tells The Story

	HVAC OPTION		COP	Savings of primary energy Δq_p [1)] [kWh/m²a] (use-expense)	Costs K [€]	Costs K [$]	spezifische Kosten $k = \frac{K}{\Delta q_p} \left[\frac{€}{kWh/m^2a}\right]$
(1)	Exhaust 0 % DC fan		0	(10[2)] – 1.5) 8.5	4200	~5600	494
(2)	HEX 60 % DC fan		7 (5 – 10)	(30 – 5)[3)] 25	7400	~9900	296
(3)	HEX 90 % DC fan		20 (10 – 27)[11)] best alternative	(38[4)] – 3[5)]) 35	8400	~11200	240 best alternative
(4)	HP exhaust air-supply air AC fan		heating: 3.0 (2 – 3.8)	(63 – 44) 19[6)]	9700	~12900	510 uneconomical!
(5)	HEX 60 % + HP AC fan		heating: 2.8 (2 – 3.4)	(65 – 44) 21[7)]	10700	~14300	510 uneconomical!
(6)	HP air-water AC fan	JAZ[14] = 2.6	2.0 – 3.8[12)] (2.0 – 2.6)[13)]	(31 – 24) 7	6000	~8000	857 uneconomical!
		JAZ[14)] = 3.8		(31 – 18) 13			461 theoretical

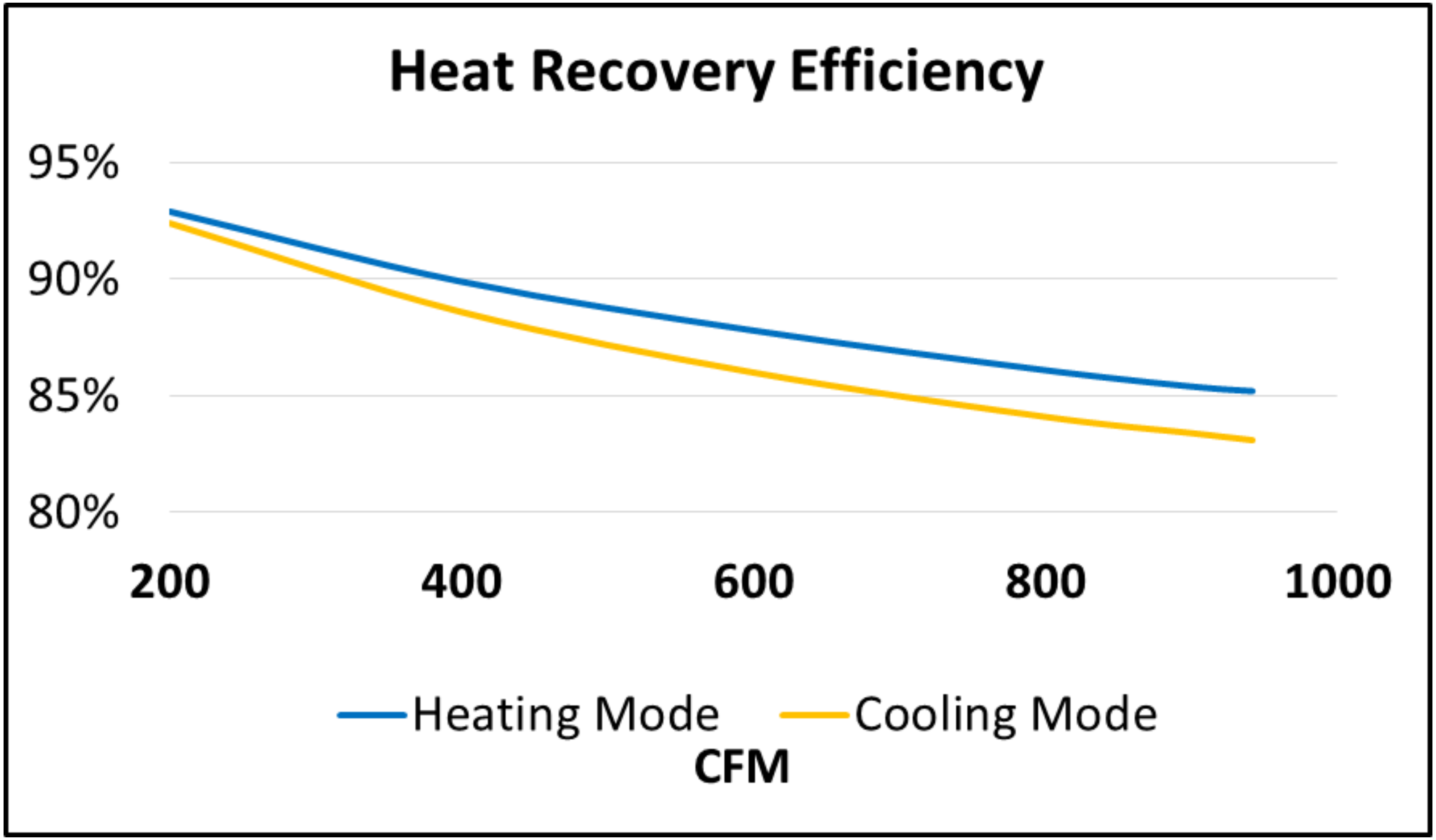
Efficiency, Efficiency, Efficiency!



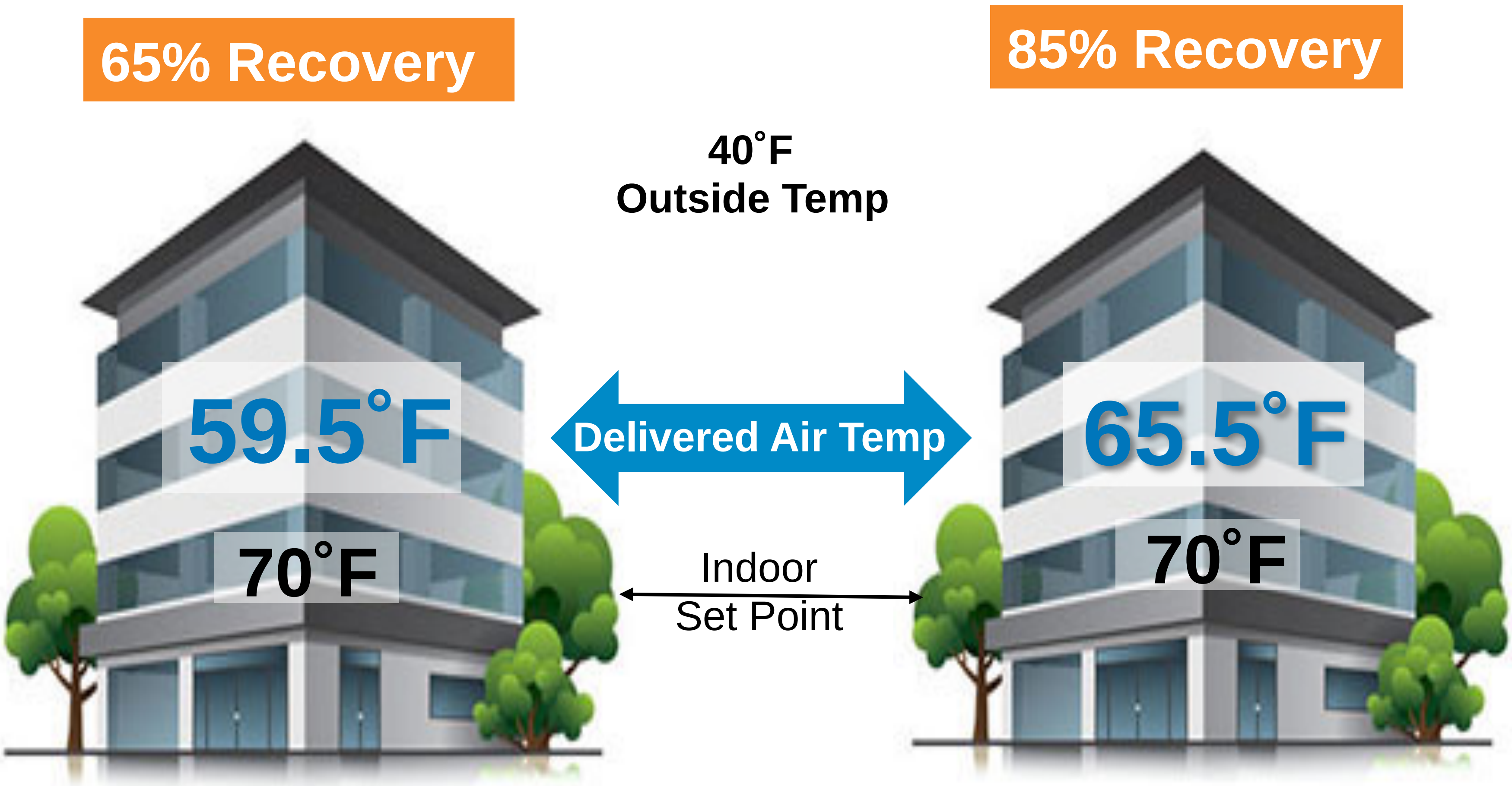
NET EFFICIENCY MATTERS!

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

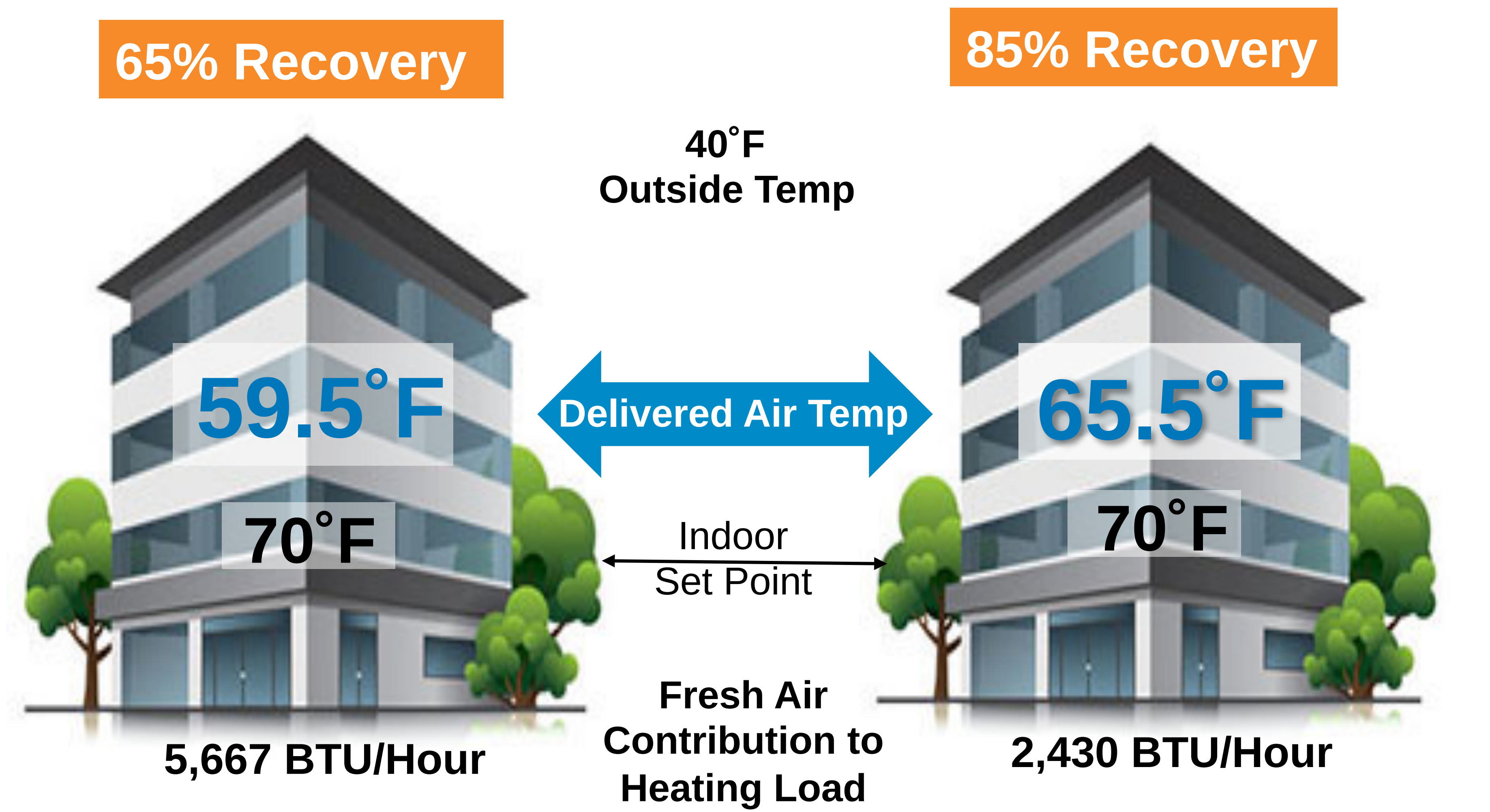
Heat Exchanger Core Efficiency – VS1000 RT



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℉
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

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 HVAC^2
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 2015 Platinum
Candidate

Specific building demands with reference to the treated floor area

		Value	Unit	Requirements	Fulfilled?*
	Treated floor area	2082.2	m^2		
Space heating	Heating demand	14	kWh/(m²a)	15 kWh/(m²a)	yes
	Heating load	11	W/m²	10 W/m²	-
Space cooling	Overall specif. space cooling demand	1	kWh/(m²a)	16 kWh/(m²a)	yes
	Cooling load	4	W/m²	-	-
	Frequency of overheating (> 25 °C)		%	-	-
Primary energy	Heating, cooling, auxiliary electricity, dehumidification, DHW, lighting, electrical appliances	114.40	kWh/(m²a)	120 kWh/(m²a)	yes
	DHW, space heating and auxiliary electricity	53	kWh/(m²a)	-	-
	Specific primary energy reduction through solar electricity		kWh/(m²a)	-	-
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!

			kWh/a	kWh/(m²a)
Using Canadian-made Ventilation unit (7	$Q_L - Q_G$	=	28305	**14**
Using PHI-Certified Ventilation unit (85	$Q_L - Q_G$	=	21625	**10**

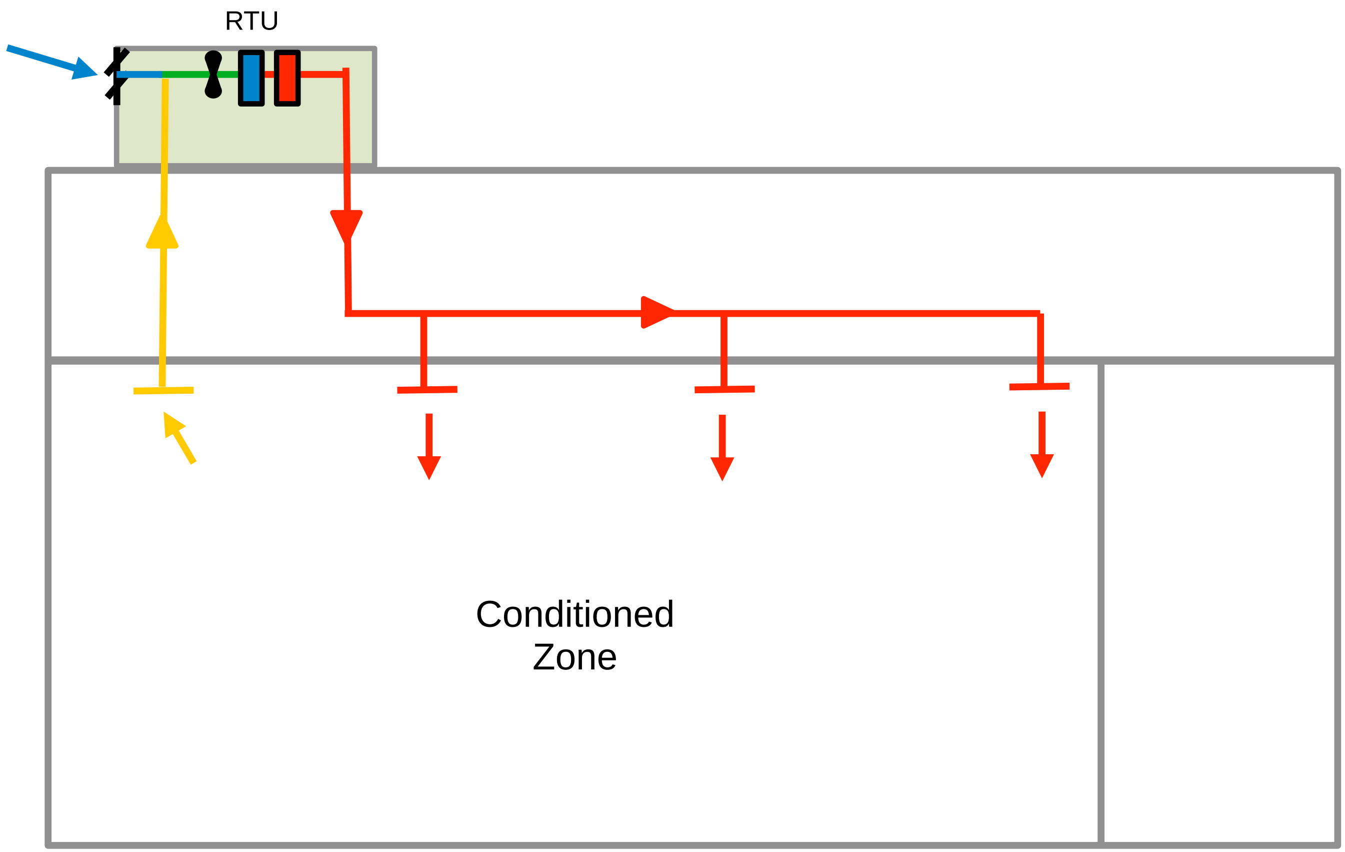
PENALTY = 6680 kWh/y

Transmission Losses, Exterior Walls = 12281 kWh/y

Chapter 6: Traditional Ventilation Methods

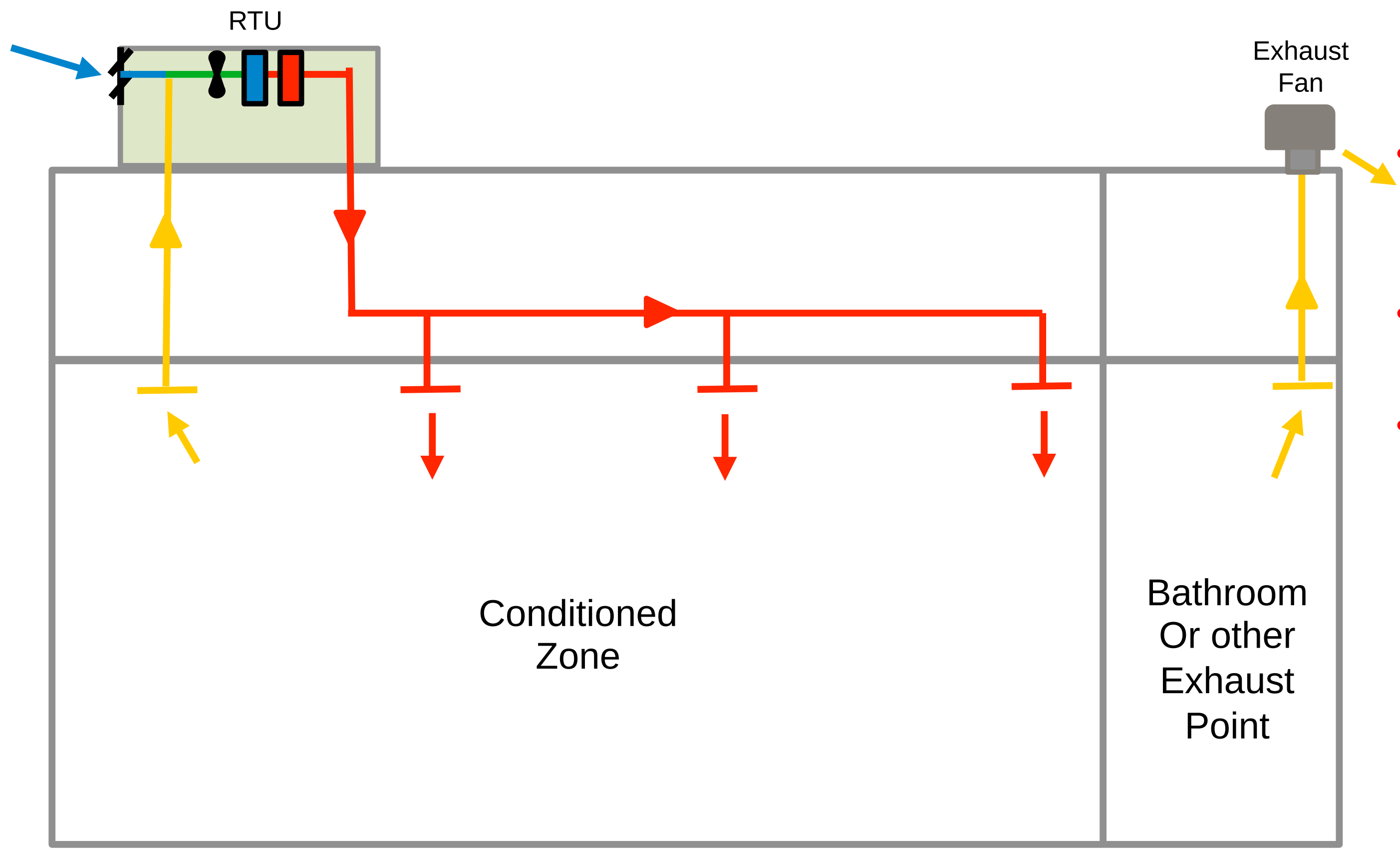
Mary 2017 | © Ventacity Systems, Inc.

Traditional Ventilation Methods: Outside Air Inlet to Roof Top Unit



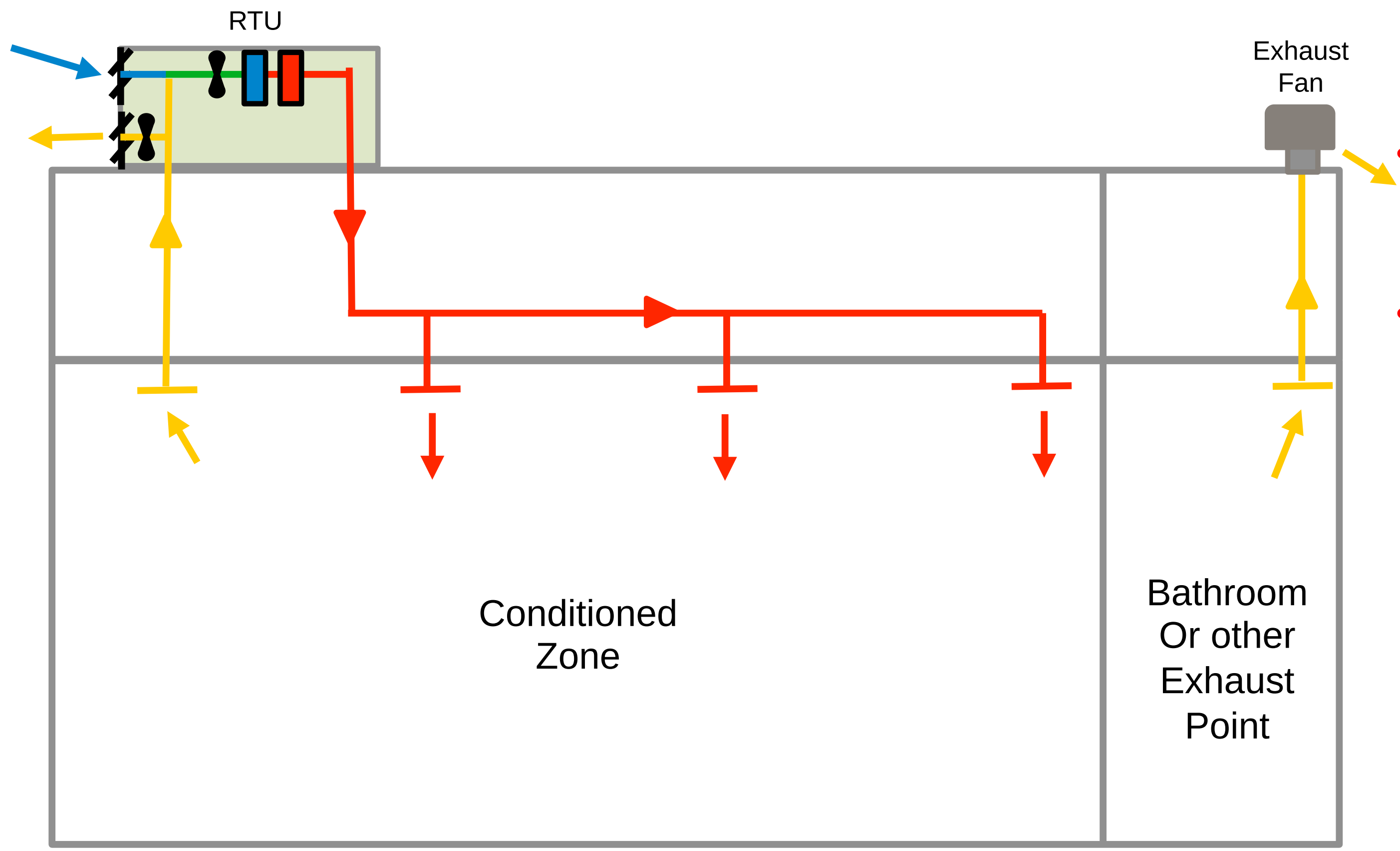
- RTU primarily for H&AC
- System designed around H&AC loads
- Need full fan operation for OA distribution
- Often pressurizes the building and leads to exfiltration
- OA dampers often closed to save energy

Traditional Ventilation Methods: Exhaust Fans



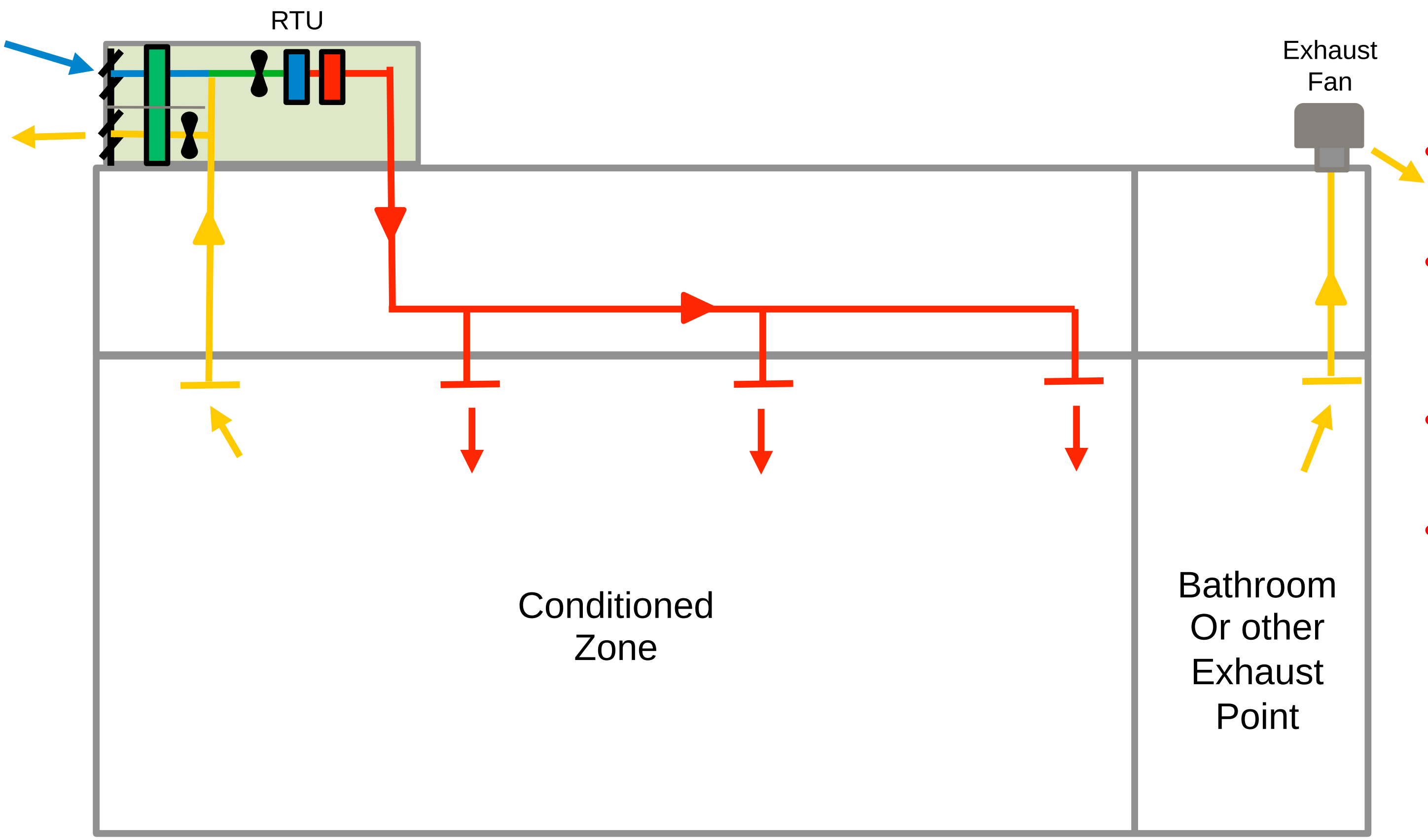
- Usually RTUs coupled with dedicated exhaust fans for bathrooms, etc
- Meets exhaust requirements but energy wasted
- Usually not balanced to OA airflows
- If OA damper closed to save energy, promotes infiltration

Traditional Ventilation Methods: Relief Fan for Balance



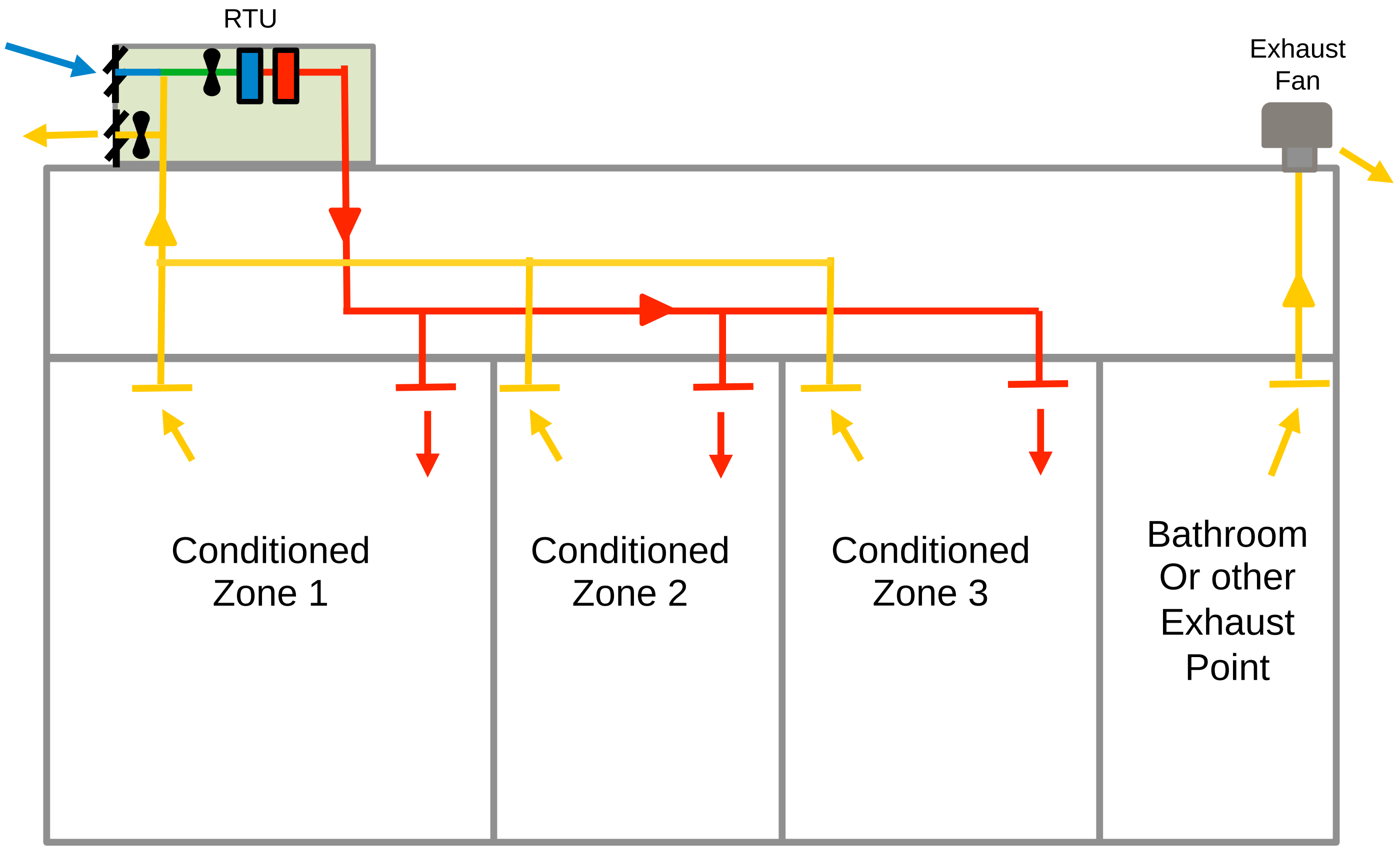
- Addition of relief air damper and fan can help properly balance the system
- Reduces amount of infiltration and exfiltration potential
- Energy still wasted in exhausting air

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)

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

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

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

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

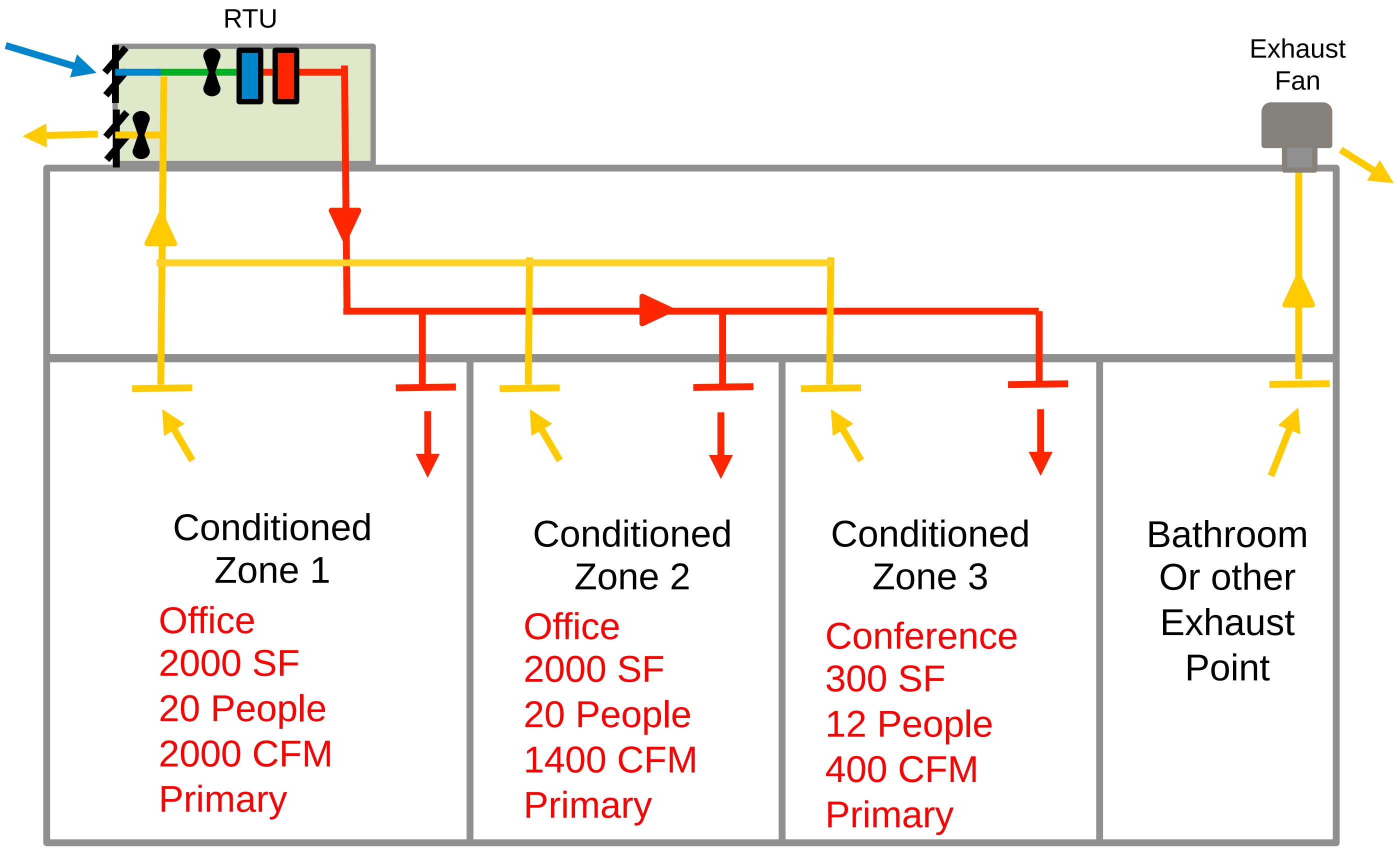
$V_{ot} = V_{ou} / E_v$

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)	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
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

VENTACITY SYSTEMS
ALWAYS HEALTHY · ALWAYS EFFICIENT

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}

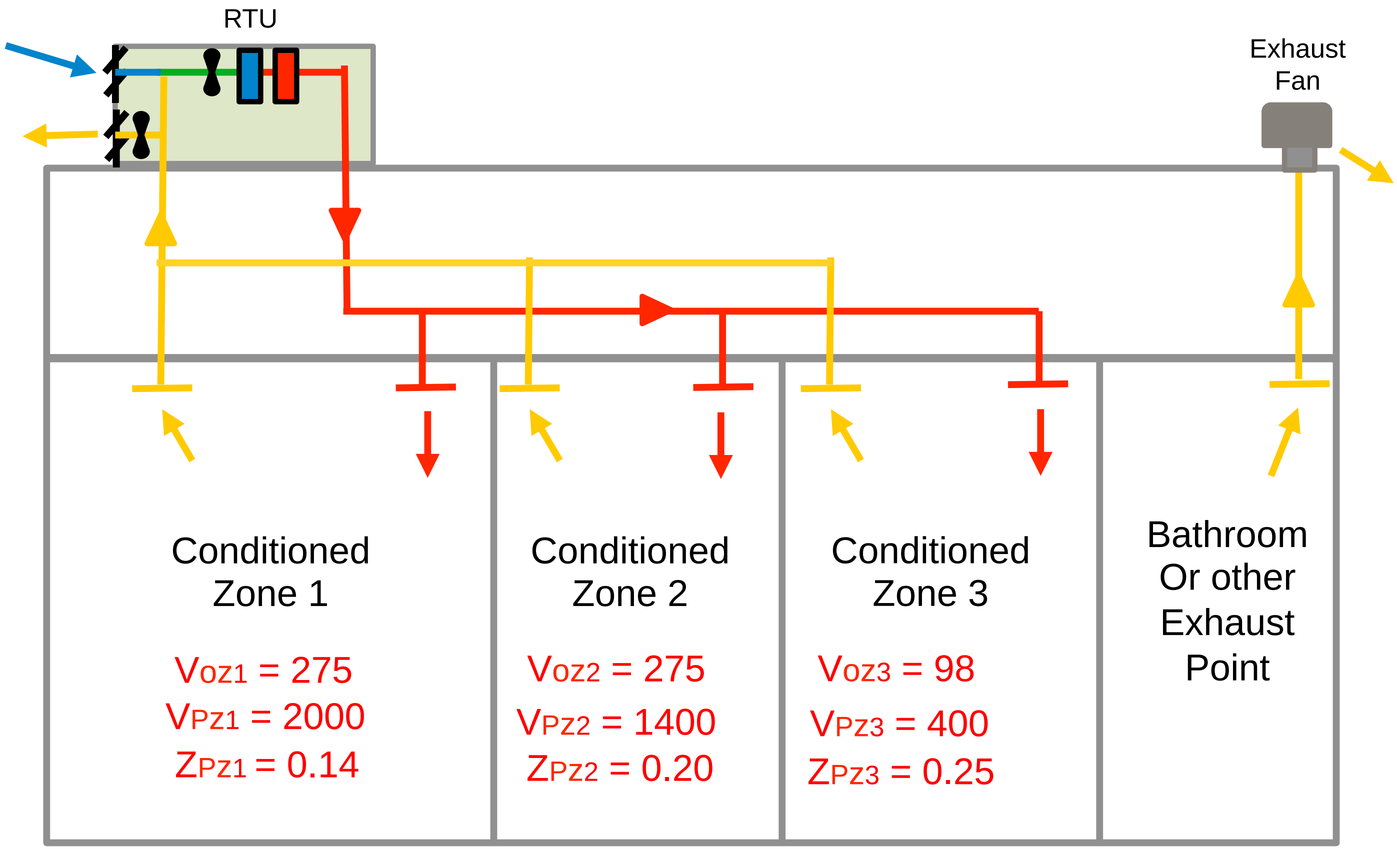
TABLE 6.2.5.2 System Ventilation Efficiency

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

Occupant Diversity (D)

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

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,

$P_s = 40$ 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})

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

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%

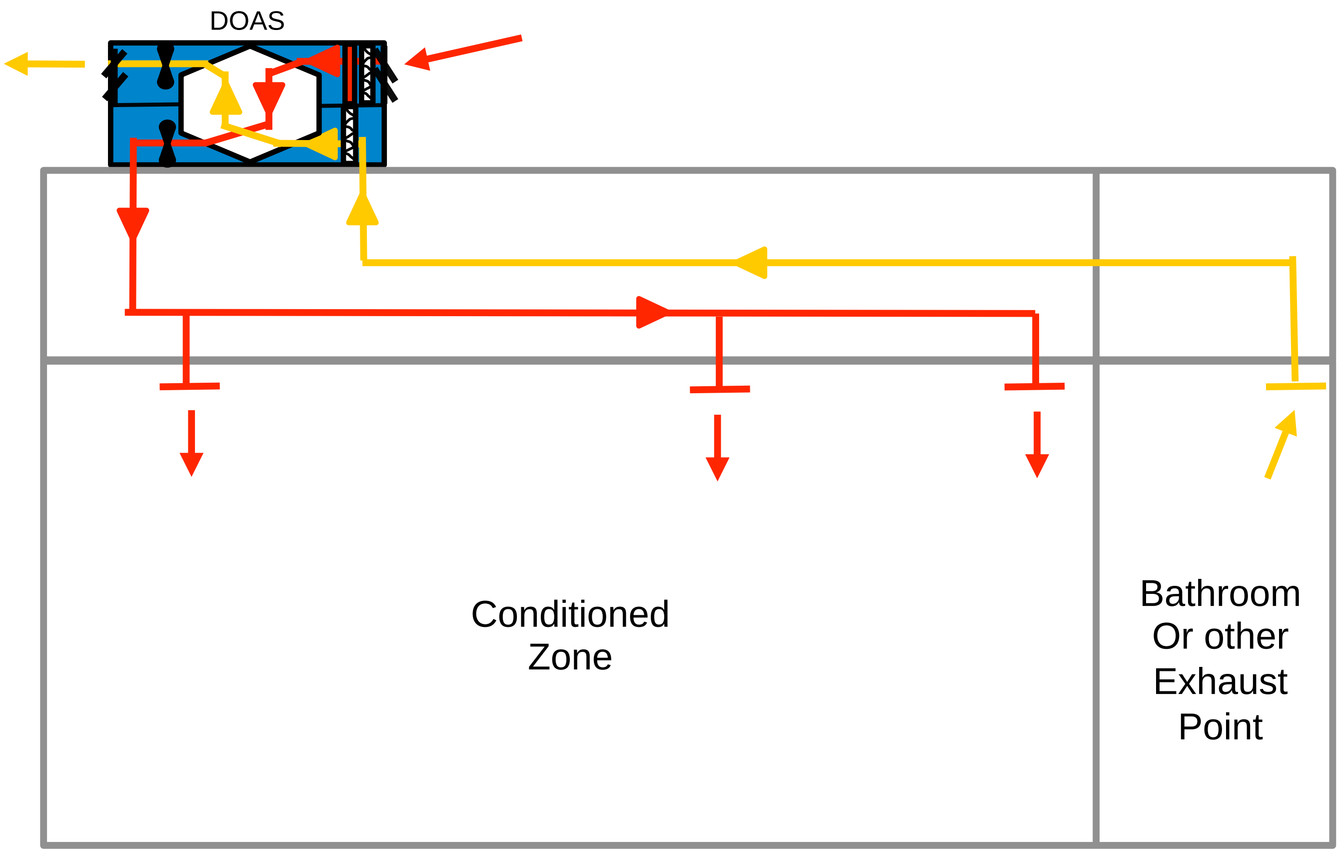
How good is the air in that conference room going to be
After a long meeting?

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

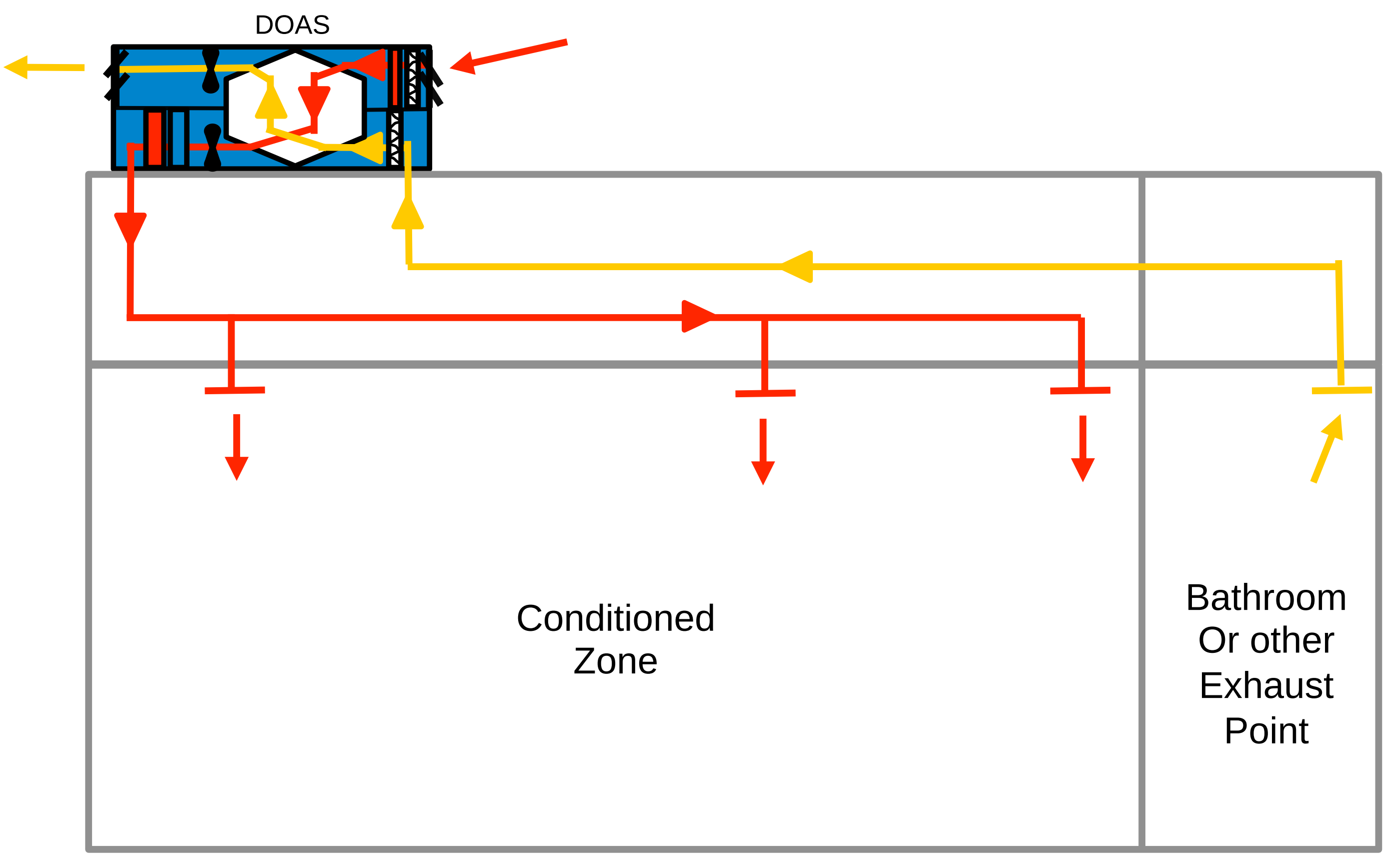
Chapter 7: DOAS
(Dedicated Outdoor Air Systems)

Dedicated Outdoor Air Systems (DOAS)
The High Performance Solution



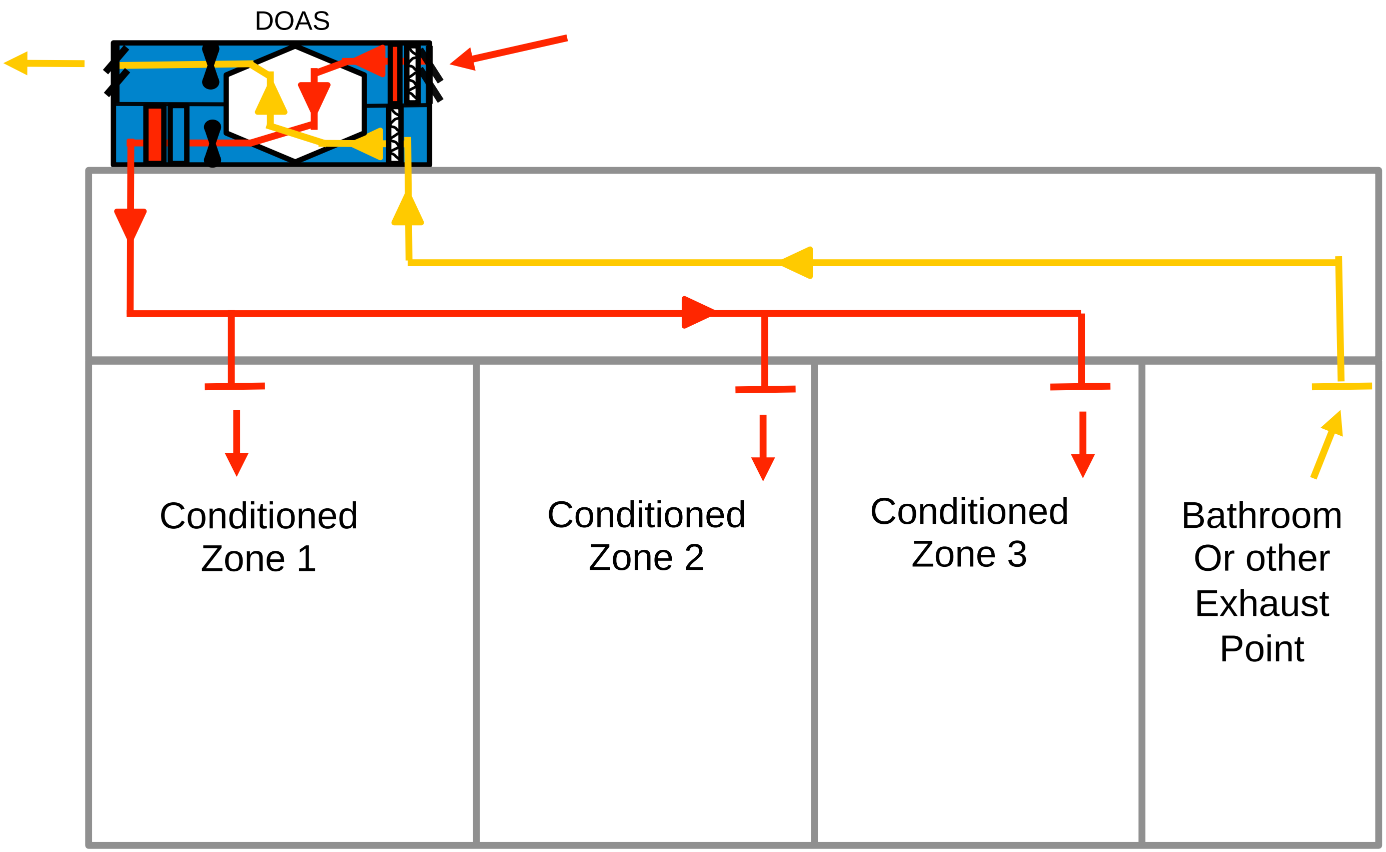
- DOAS ventilation is decoupled from the heating and cooling.
- Supply air is ducted independently to the conditioned zone(s).
- Exhaust air is ducted back to the DOAS H/ERV to recovery energy before exhausting.

Dedicated Outdoor Air Systems (DOAS) Post Conditioning Possibilities



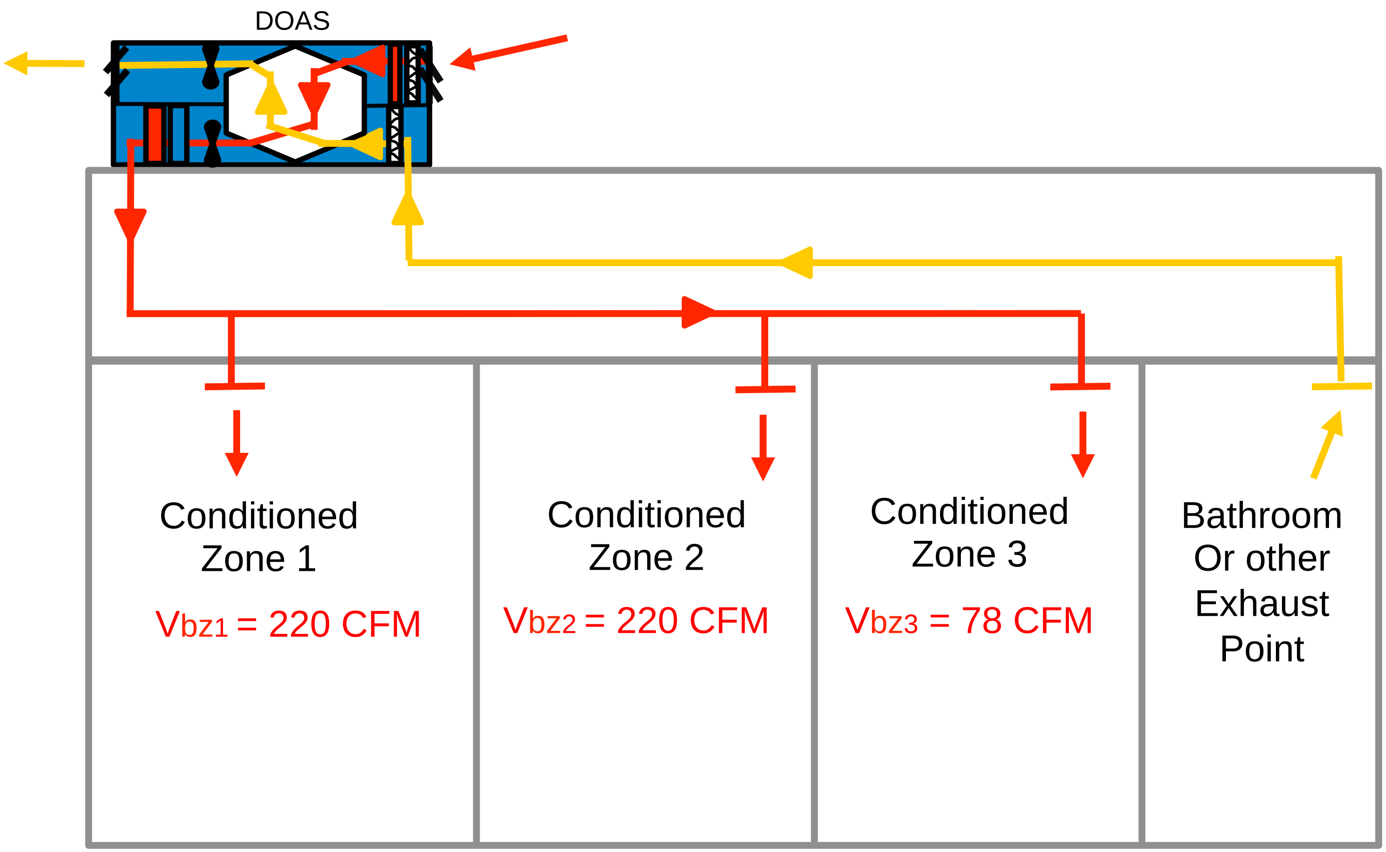
- Post heat exchanger conditioning coils possible for additional tempering to further heat, cool and/or dehumidify OA airstream.
- Sometimes internal to DOAS unit or installed downstream separately.

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
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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.
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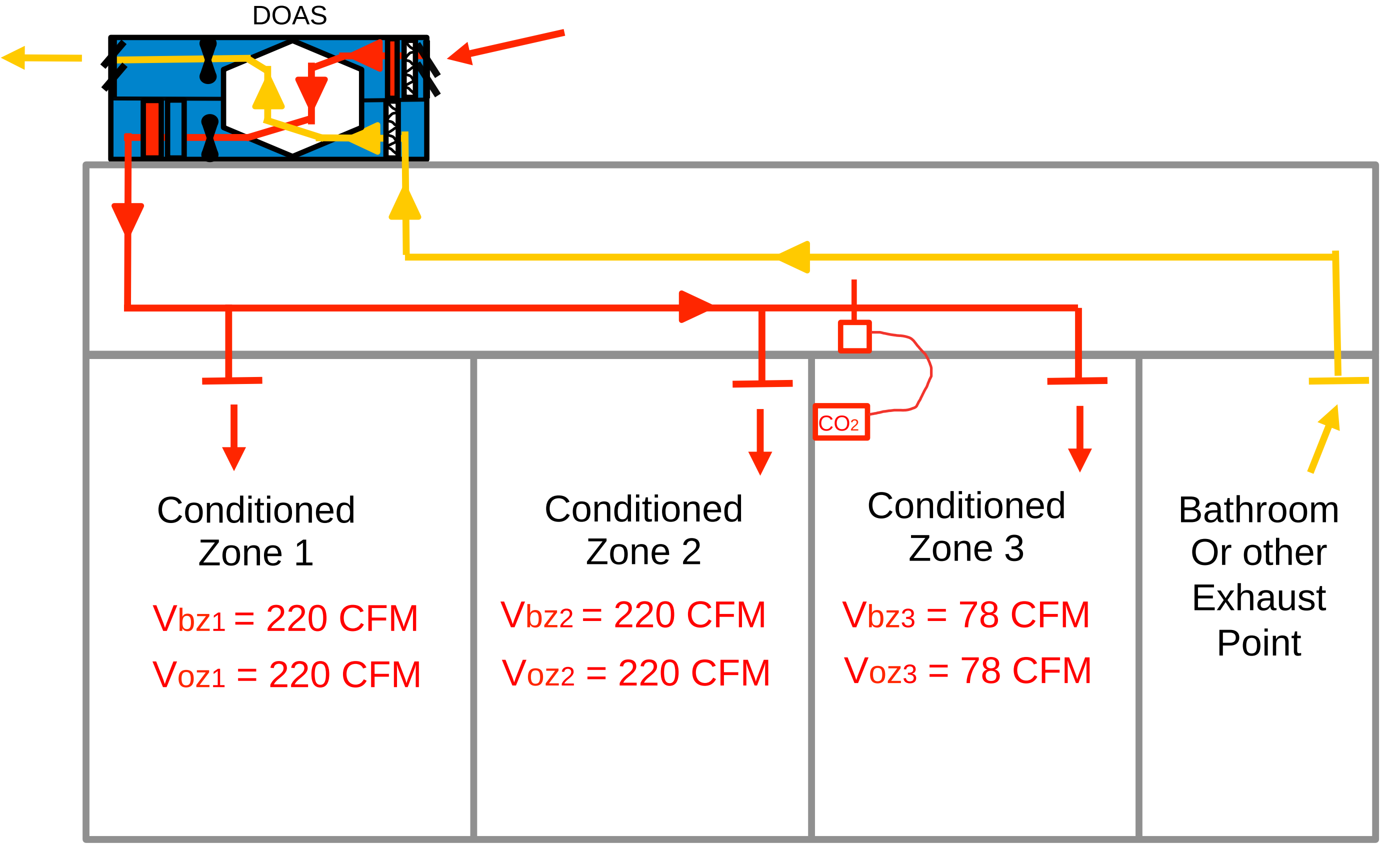
4. "Floor supply" includes any point below the breathing zone.
5. As an alternative to using the above values, E_z may be regarded as equal to air-change effectiveness determined in accordance with ASHRAE Standard 129 [16] for air distribution configurations except unidirectional flow.
6. For lower velocity 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



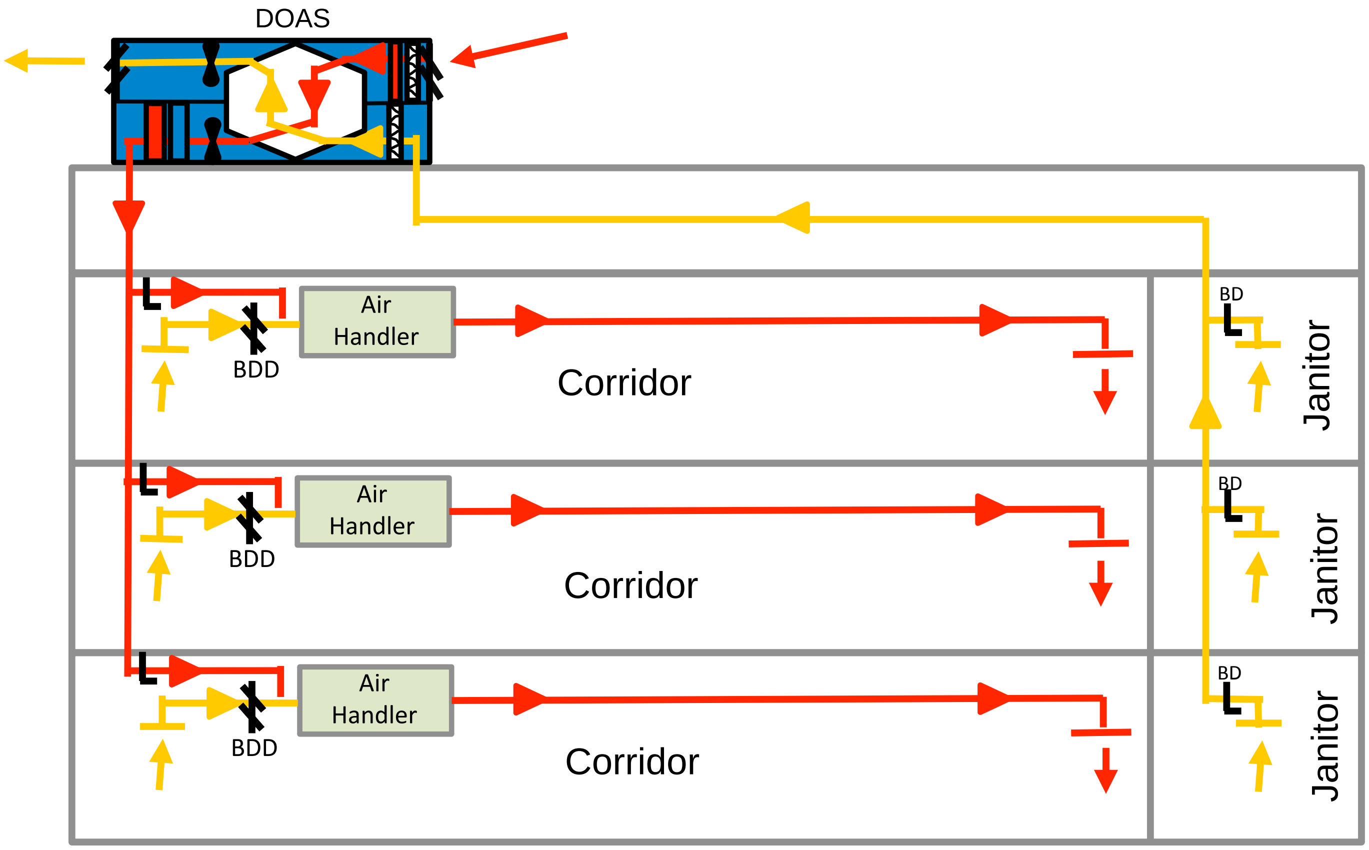
$V_{ot} = \Sigma_{\text{all zones}} V_{oz}$

V_{ot} = 220 CFM + 220 CFM + 78 CFM

V_{ot} = 518 CFM

- 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

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.

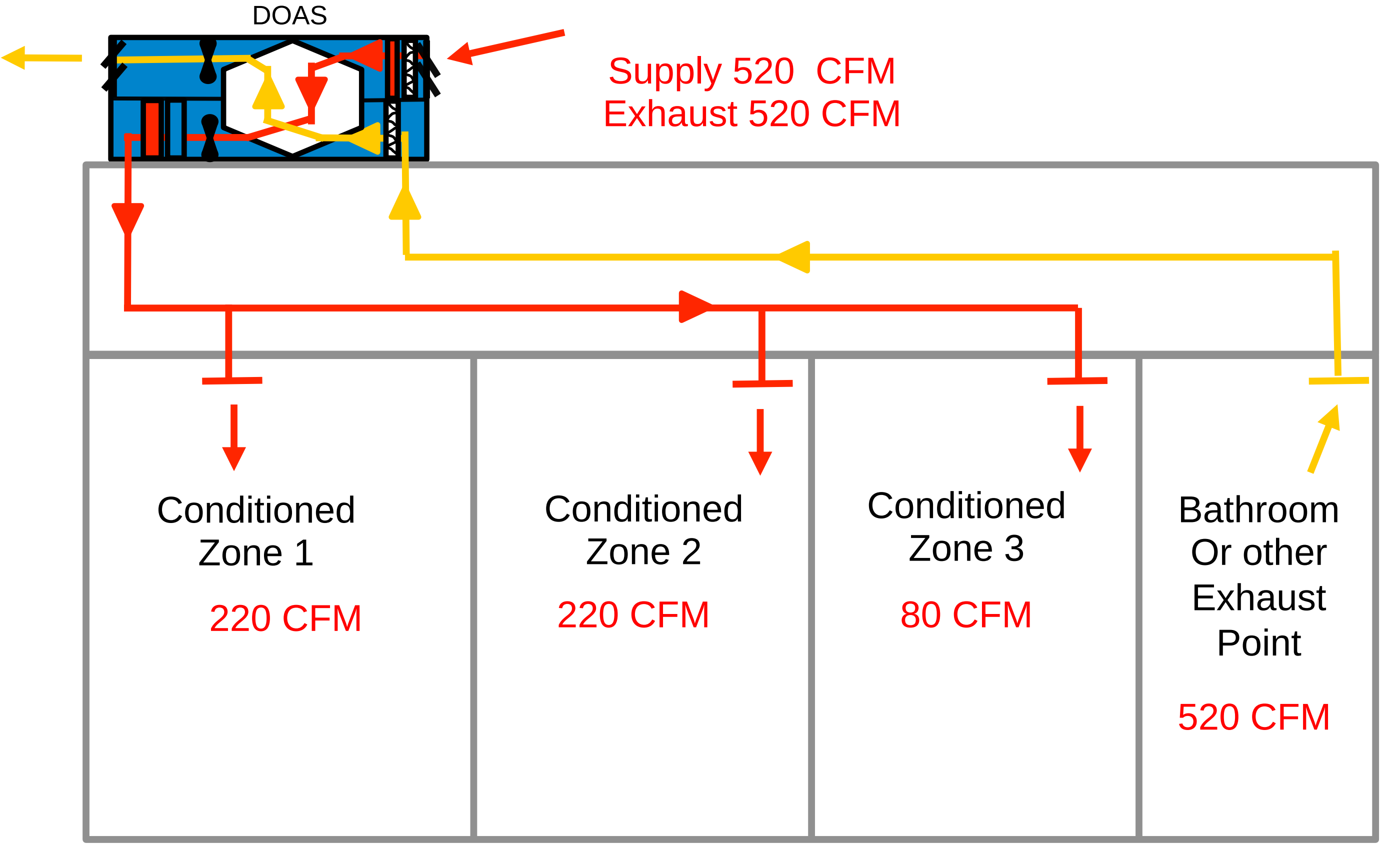
DOAS Control Strategies

Main Approaches:

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

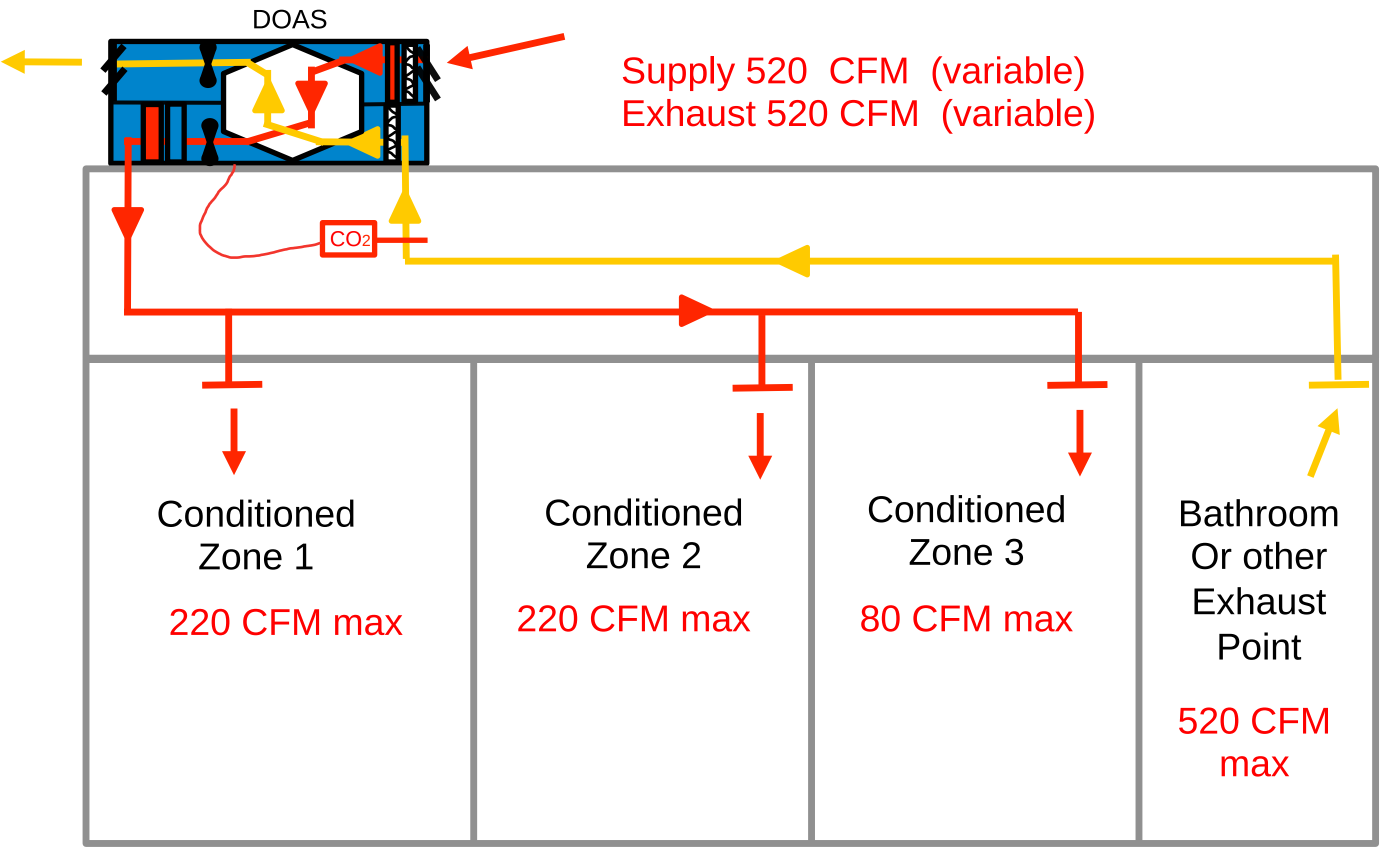
- Multiple strategies for controlling a DOAS from simple to sophisticated depending upon goals and budget.
- Some brands have flexible and elegent internal controls while others require a BMS system to do anything beyond basic control

DOAS Control Strategies:
CAV – Constant Air Volume



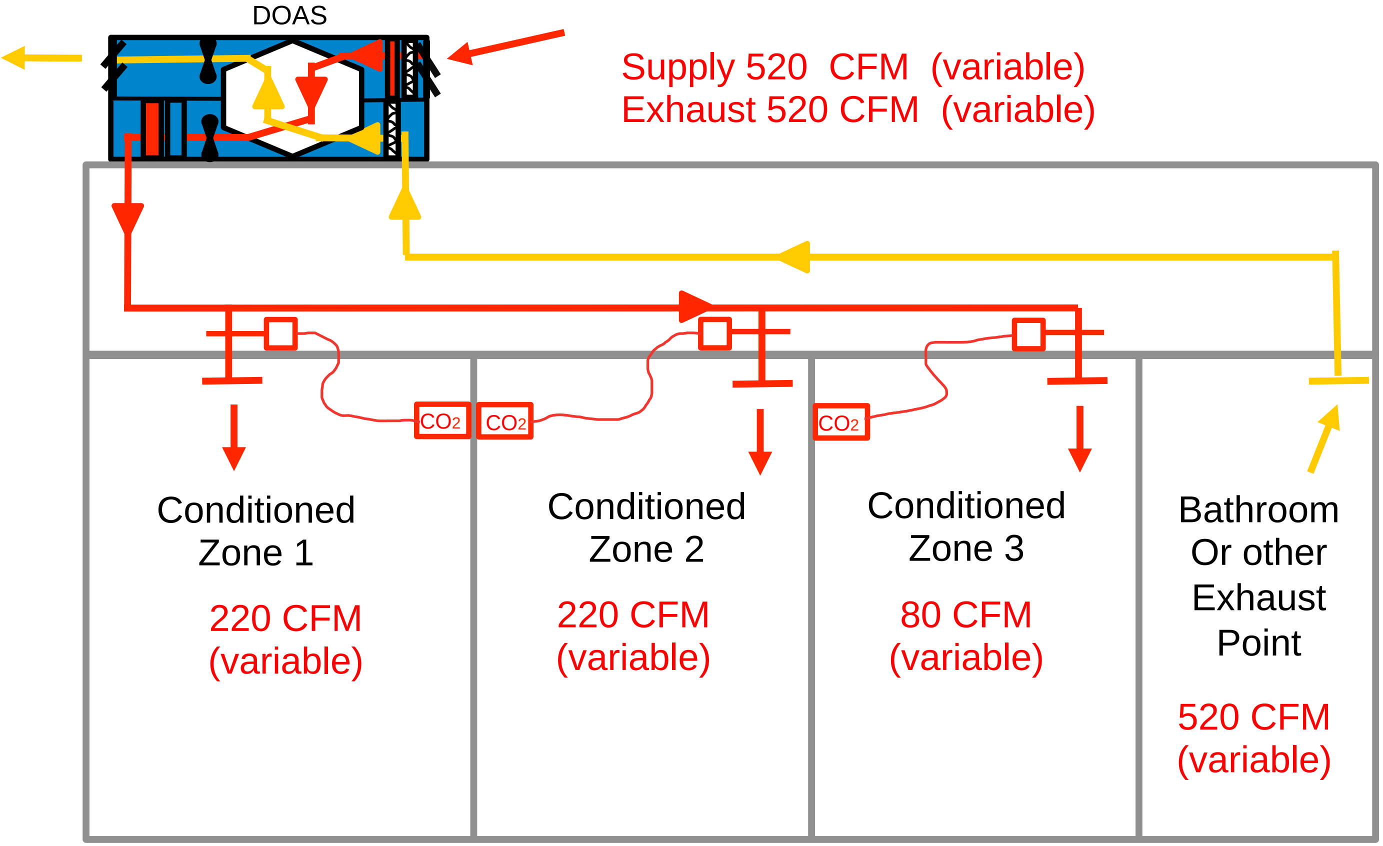
- During occupied hours DOAS runs at a constant single rate to meet the design airflows
- During unoccupied hours DOAS is in stand-by mode
- Schedule can be overridden for special events

DOAS Control Strategies:
DCV – Demand Control Ventilation



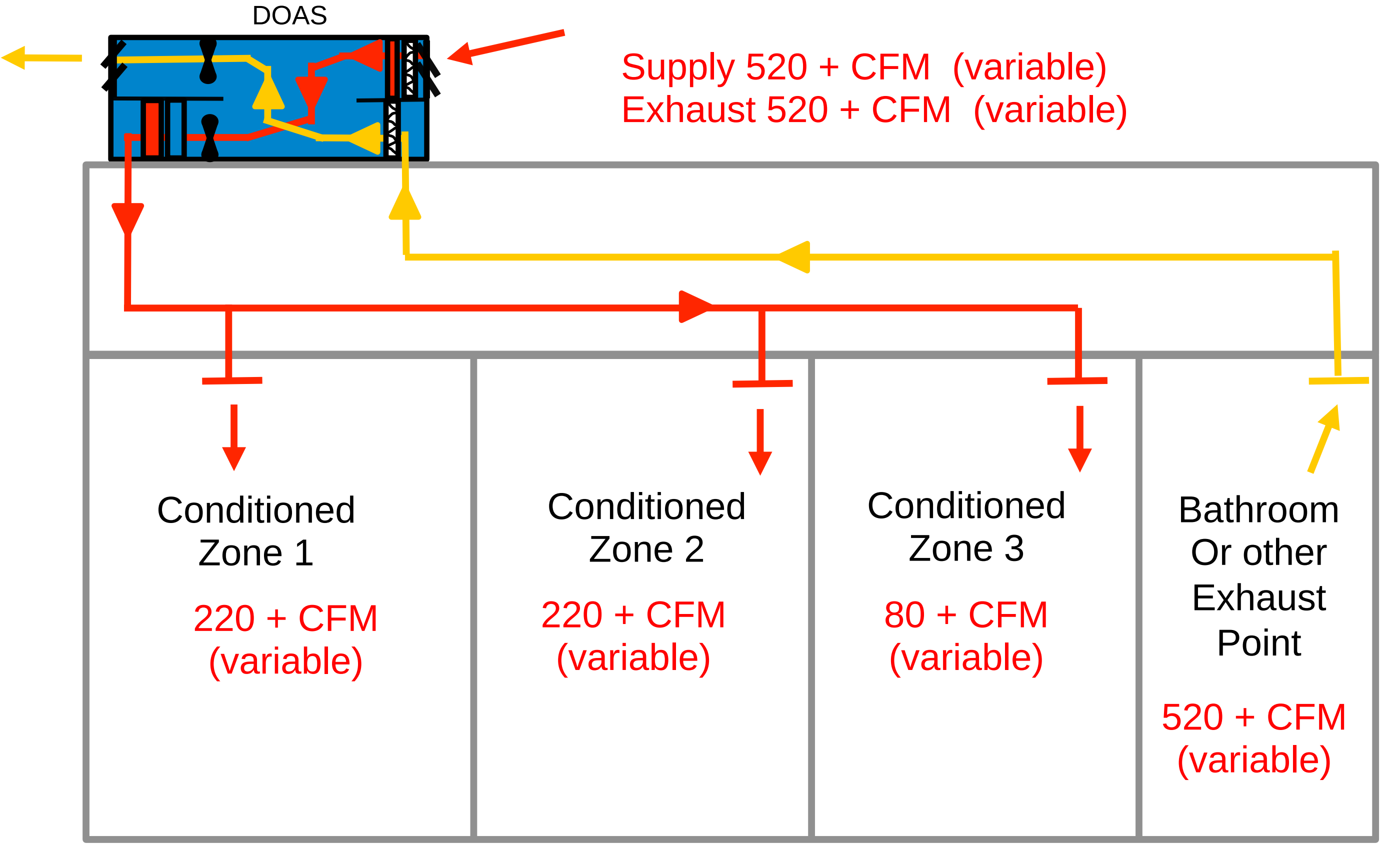
- Demand control ventilation allows system to ramp down during periods of lower occupancy
- Both supply and exhaust side fluctuate in parallel
- Lowest setting based on area rate or exhaust requirement.

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

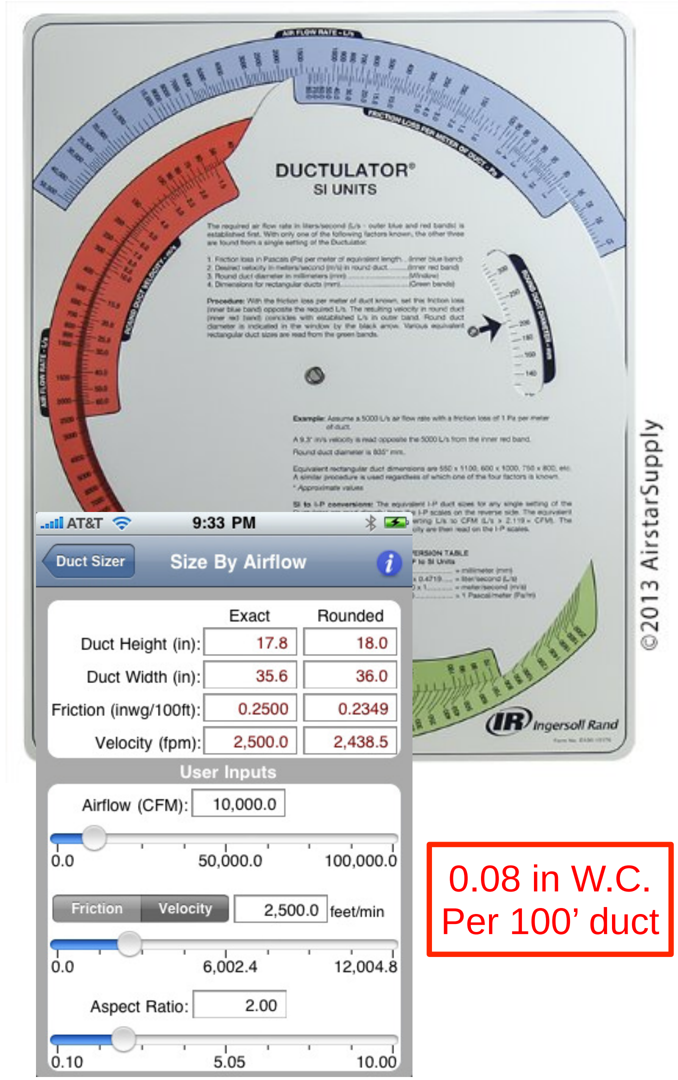
DOAS Control Strategies: Economizer



- 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

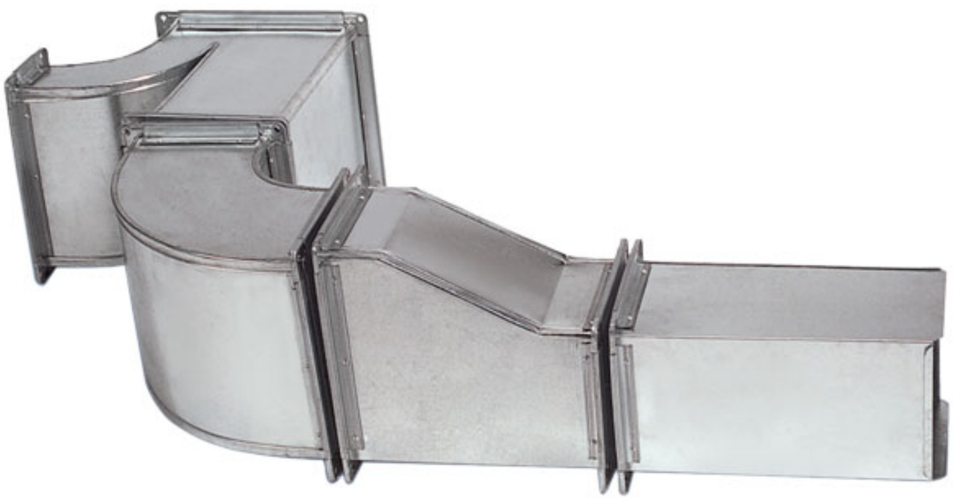
Ductwork Design: Duct sizing



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.

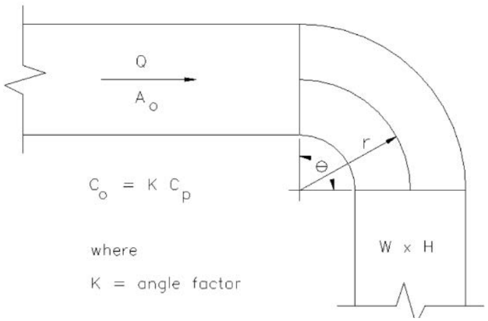
Ductwork Design: Duct sizing



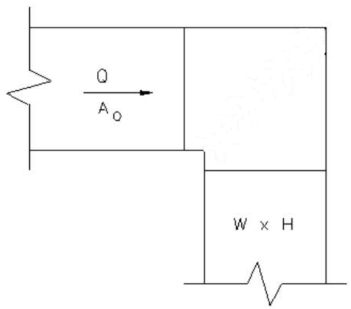
- Round ductwork is most efficient for airflow.
- Rectangular duct can sometimes fit in shallower height.
- Avoid aspect ratios of greater than 5:1 for most efficient flow.

Ductwork Design: Fittings

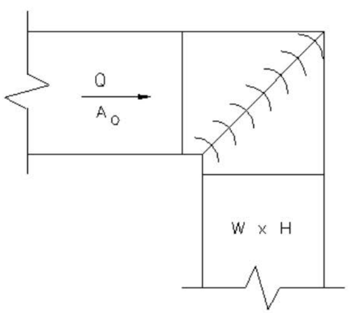
Example: 12”x12” duct with 800 CFM



Radius Elbow r = 1.5W
C_o = 0.17   ΔP = 0.01 in WG
Approx equal to 13’ of ductwork



Mitered Elbow
C_o = 1.18   ΔP = 0.05 in WG
Approx equal to 63’ of ductwork

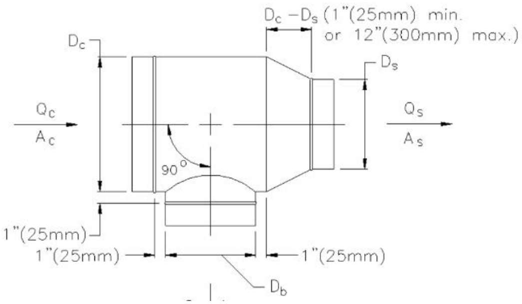


Mitered Elbow with vanes (1-1/2”)
C_o = 0.11   ΔP = 0.00 in WG
Approx equal to <6’ of ductwork
Note: wider spacing and/ double
Thickness vanes increase ΔP

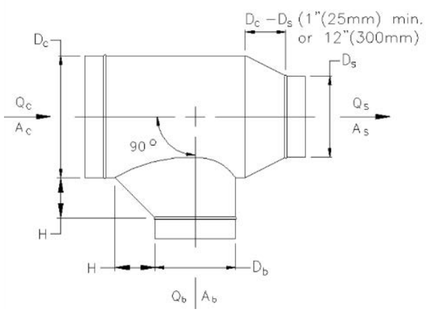
- Selection of fittings can make a big difference in system pressure drop.
- ASHRAE Ductwork Database and related App are good tools for selection and comparison

Ductwork Design: Fittings

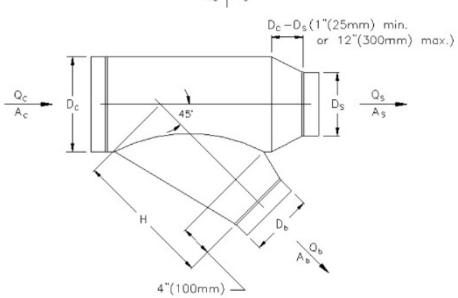
Example: 12” Φ duct with 600 CFM
and 200 CFM take-off
12” x 10” x 8” Fitting



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

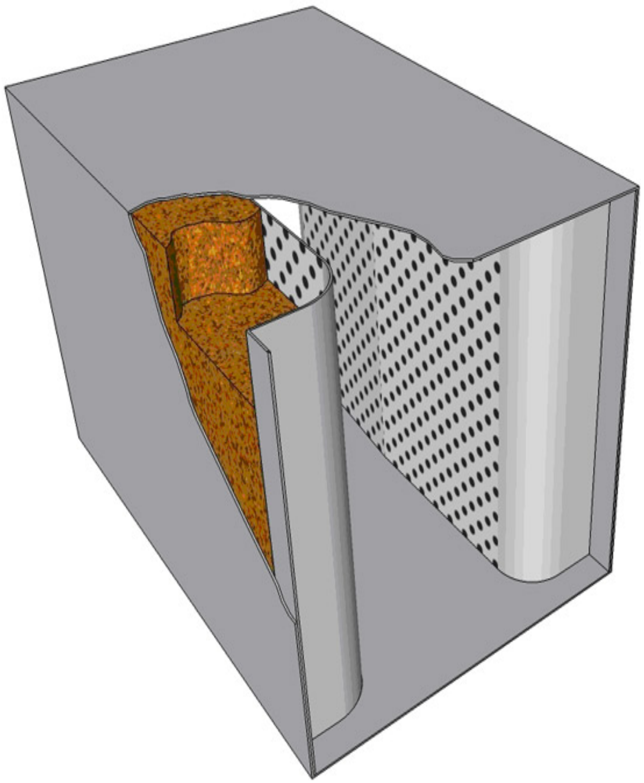
Ductwork Design: Air Sealing

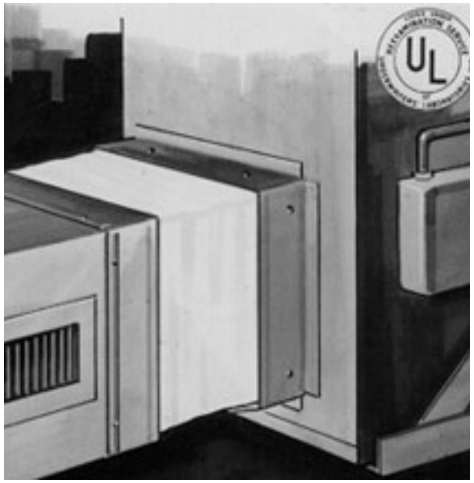
- Proper air sealing of ductwork is critical for efficient delivery of air to designed locations.
- Leakage causes fans to run harder to meet design airflows.
- Duct blaster testing important for confirmation.
- A duct is just a pipe for air. Plumbers can make their pipes 100% airtight!

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.
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Ductwork Design: Challenges

- Connect through roof with shortest duct/curb possible.
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CHANGE ORDER
DONZI
02/21/2005


Change Order
SAN FRANCISCO, CA


Change Order
ORANGE BEACH, AL

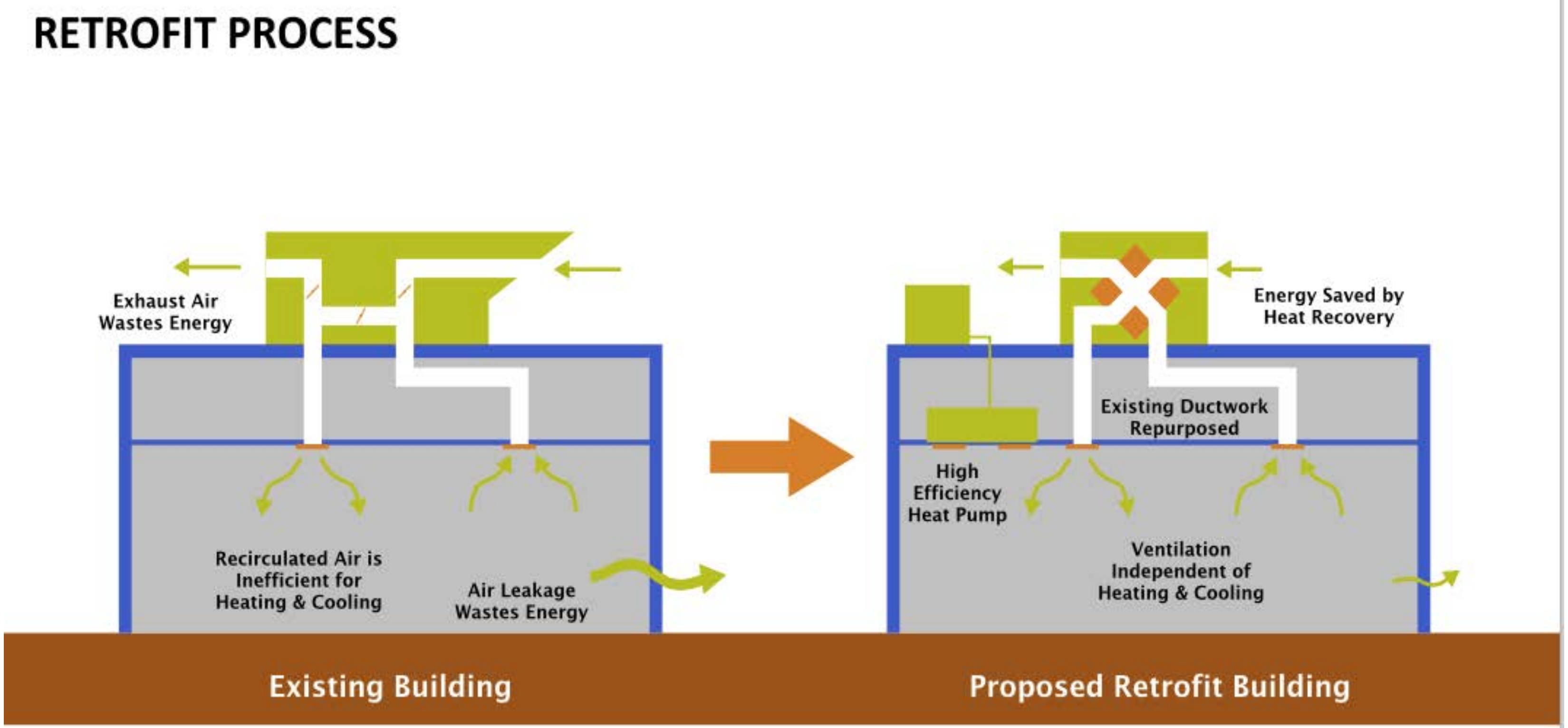

Change Order
Original Contract

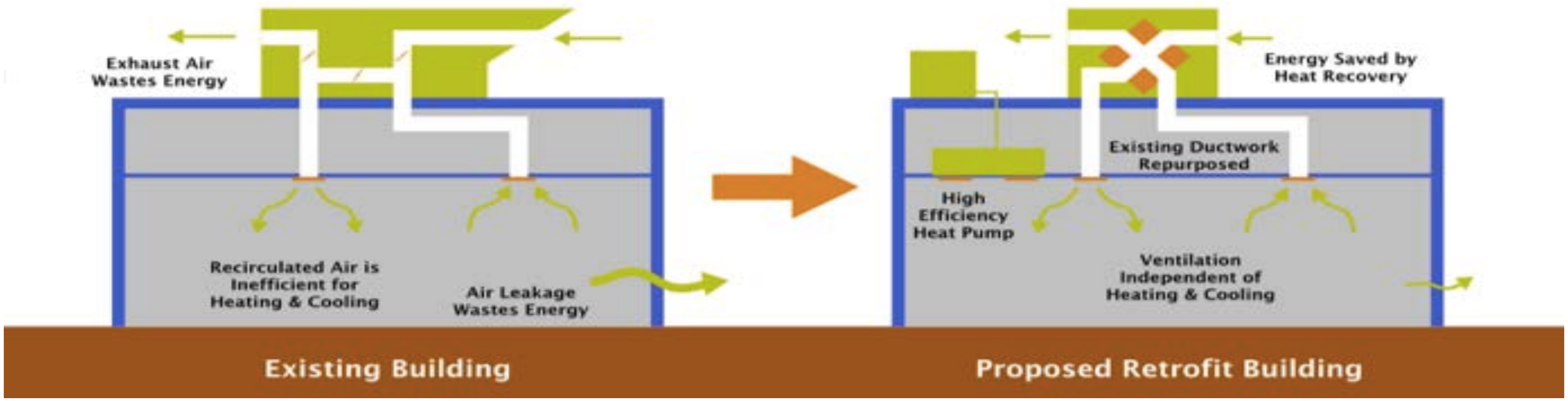

How to Avoid Change Orders
HCD GROUP
Change Order


CHANGE ORDER!

Chapter 9: RTU Replacement Program

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





- **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

OFFICES

Indoor Air Quality Affects Productivity & Cognition

The connection between indoor air quality and its impact on crisis response, strategy and information usage in office workers is indisputable. Improving office ventilation with units from Ventacity Systems:

- *Reduces CO_2 levels and high concentrations of VOCs, thereby improving IAQ and resulting in higher worker cognition and productivity*
- *Improves comfort*
- *Decreases energy usage, lowering operating costs*
- *Provides sentient, intelligent and secure ventilation management with the Smart Building Gateway*

Building Retrofit

Separate Ventilation from Heating and Cooling

Install New VRF or DMS System

Remove Aging RTUs

Install New VS1000 RT HRV

Building is now Healthy and Efficient

LAW FIRM REDUCES HVAC EUI BY 71%

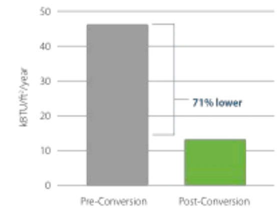
Building Facts

Building Construction Year	Circa 1909
Occupancy Type	Office
Number of Stories	2
Conditioned Area	12,000 sq.ft.
Ownership	Private

Practicing Financial and Environmental Stewardship While Practicing Law

Ventacity regards an early adopter as a flagship customer: a law practice working above retail spaces in a 1909 historic warehouse. In completing a gut remodel, the owners eagerly removed nine aging RTU's and replaced them with just four Ventacity VS1000 RT's and one VRF system. By upgrading lights, windows, and air-tightness, the office's overall EUI is expected to drop from 61.4 to 28 kBtu/ft²/year. HVAC EUI, in particular, is expected to drop 71%, a large impact compared with incremental HVAC improvements. Taking the holistic energy conservation approach also enabled the law firm to receive some ratepayer-funded rebates on non-Ventacity items. Ventacity staff was present on record 100°F summer days, yet the incoming, pre-cooled air from the recovery core was an ideal 78°F.

HVAC Energy Use Intensity



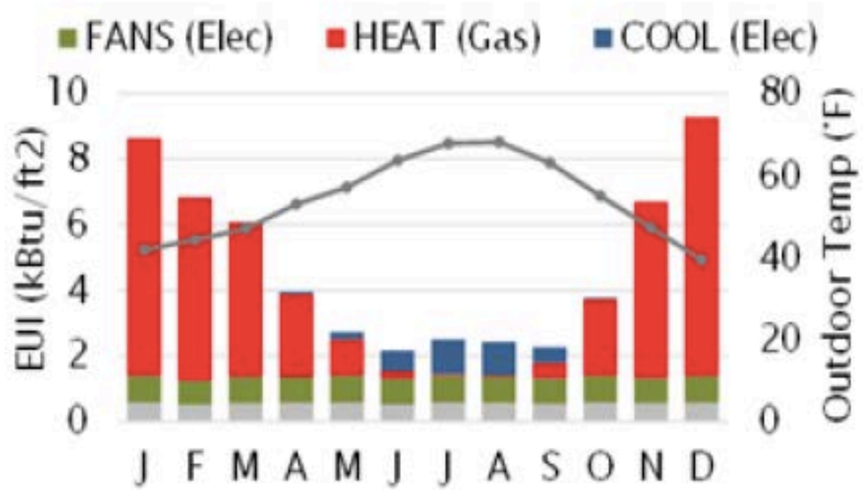
HVAC Facts

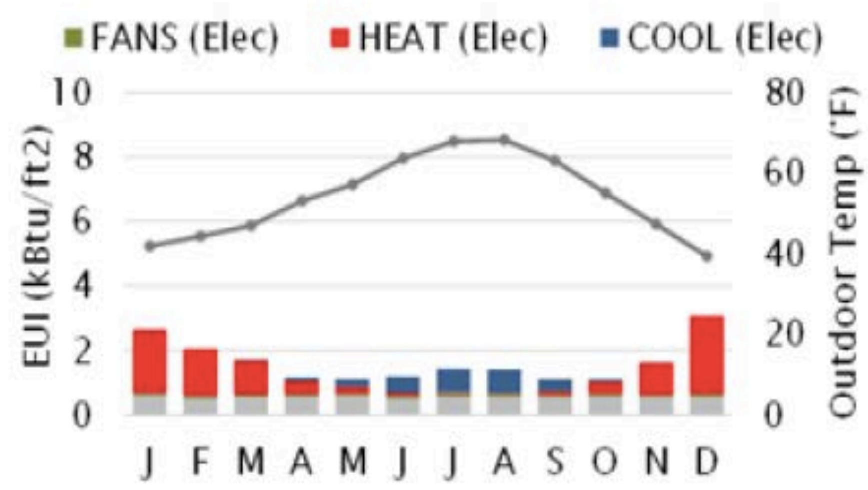
	PRE CONVERSION	POST CONVERSION
Fuel Source	H: Natural Gas; AC: Electricity	H: VRF Heat Pump; AC: VRF Heat Pump
HVAC System	(9) RTU's	(4) VS1000 RT; Mitsubishi PURY-P192TSLMU-A, (8) SEZ-KD18NA4 AH;
CFM	est. 14,000	est. 4,000 (H & AC) max 4,000 V
Tons	36	16

"I was surprised by how much our energy bill dropped"—Building Owner

Post-Conversion Temperature and Performance Data: Modeled vs. Actual

IMPRESSIVE RESULTS





	ANNUAL EUI	---
Total:	57.4 kBtu/ft²	---
Fans:	9.5 kBtu/ft²	---
Heating:	37.6 kBtu/ft²	---
Cooling:	3.6 kBtu/ft²	---
HVAC:	50.7 kBtu/ft²	---
Electricity:	19.8 kBtu/ft²	---
Gas:	37.6 kBtu/ft²	---

	ANNUAL EUI	ANNUAL SAVINGS
Total:	19.7 kBtu/ft²	37.8 kBtu/ft²
Fans:	1.0 kBtu/ft²	8.5 kBtu/ft²
Heating:	9.2 kBtu/ft²	28.4 kBtu/ft²
Cooling:	2.8 kBtu/ft²	0.8 kBtu/ft²
HVAC:	13.0 kBtu/ft²	37.8 kBtu/ft²
Electricity:	19.7 kBtu/ft²	0.1 kBtu/ft²
Gas:	0.0 kBtu/ft²	37.6 kBtu/ft²

Offices **Application Sheet**

OFFICES

Indoor Air Quality Affects Productivity & Cognition

The connection between indoor air quality and its impact on crisis response, strategy and information usage in office workers is indisputable. Improving office ventilation with units from Ventacity Systems:

- *Reduces CO_2 levels and high concentrations of VOCs, thereby improving IAQ and resulting in higher worker cognition and productivity*
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Building Retrofit

Separate Ventilation from Heating and Cooling

Install New VRF or DMS System

Remove Aging RTUs

Install New VS1000 RT HRV

Building is now Healthy and Effi-cient

AS-OFFICE:LAW-Jan2017

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Offices **Case Study**

GOVERNMENT OFFICE CLEANS AIR AND LOWERS BILL

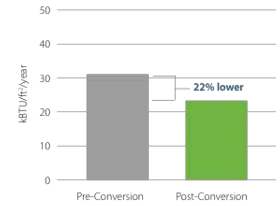
Building Facts

Building Construction Year	1940
Occupancy Type	Office
Number of Stories	1
Conditioned Area	13,200 sq.ft.
Ownership	Government Owned and Occupied

Partial Retrofit Still Reduces HVAC EUI By 22%

This Government Agency owns hundreds of buildings in the state of Oregon. With our help, they have modified 22% of one building as a test, working toward goals for a lessened energy footprint and carbon emissions. In short, 16 tons of heating/cooling capacity was replaced with 9 tons. This was done through a multi-zone ducted mini-split system, and the heat transferring powers of one VS1000 RT. Employees in the upgraded part of the offices report their workplace seems more comfortable and productive, while employees in the unaltered portion of the office report envy of their colleagues. Many visit the "fresh air" part of the building regularly. Three months of post-conversion summertime energy monitoring are following model projections closely, with the HVAC EUI at a 22% reduction

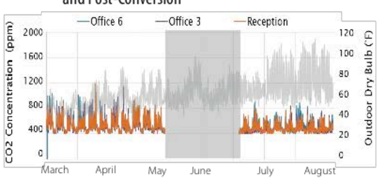
HVAC Energy Use Intensity



HVAC Facts

	PRE CONVERSION	POST CONVERSION
Fuel Source	H: Natural Gas; AC: Electricity	H: DMS, Ducted Fan Coils; AC: DMS, Ducted Fan Coils
HVAC System	(2) RTU's	(1) VS1000 RT; Mitsubishi MXZ-8C48NAHZ; (2) MVZ-A24AA4AH's
CFM	6,400	3,600
Tons	16	9

Interior CO2 Concentration, Temp Outdoor Pre and Post-Conversion



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Offices **Application Sheet**

OFFICES

Indoor Air Quality Affects Productivity & Cognition

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- *Improves comfort*
- *Decreases energy usage, lowering operating costs*
- *Provides sentient, intelligent and secure ventilation management with the Smart Building Gateway*

Building Retrofit

Separate Ventilation from Heating and Cooling

Install New VRF or DMS System

Remove Aging RTUs

Install New VS1000 RT HRV

Building is now Healthy and Efficient

AS-OFFICE:LAW-Jan2017

Offices **Case Study**

ELECTRIC COOPERATIVE REDUCES HIGH CO2

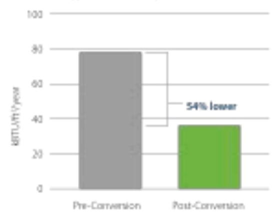
Building Facts

Building Construction Year	1938
Occupancy Type	Office
Number of Stories	1
Conditioned Area	5,681 sqft
Ownership	Cooperative

Rural Cooperative Invests in Comfort and Health

Many progressive energy efficiency initiatives in the United States are conducted by member-owned utilities, often called "demand-side management" programs. This rural cooperative was formed to bring electricity to 117 farmers in 1938. It is now the second-largest utility provider in the state, serving 48,000 customers. In September 2016, a district office removed 2 "swamp coolers" and a poor-performing 7.5 ton RTU to install the Ventacity HRV and upgrade to a 4-ton ductless heat pump with 7 wall units for both heating and cooling. Early monitoring results shown below show a noticeable "step down" in CO2 concentrations immediately. During the first two weeks, CO2 was almost always between 400ppm and 600ppm, with one peak of 810ppm. Pre-conversion, there were regular spikes in all areas well above 1000ppm. Another welcome change in a garage (not shown) is temperatures typically about 70F instead of between 80 to 85F, relative to the same outdoor highs.

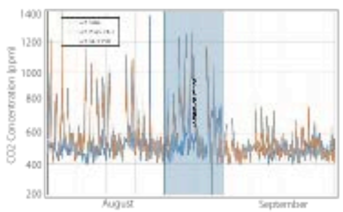
HVAC Energy Use Intensity



HVAC Facts

	PRE CONVERSION	POST CONVERSION
Fuel Source	H: Electricity; AC: Electricity	H: VRF Heat Pump +boiler; AC: VRF Heat Pump
HVAC System	2-stage electric boilers serving fan coils & radiators; packaged HP RTU for cooling offices; (2) swamp coolers for storage/garage area	(1) VS1000 RT HRV (2) MXZ-8C48NAHZ; (3) MSZ-GE06NA-9; (3) MSZ-GE09NA-9; (1) MSZ-GE12NA-9; (2) MVZ-A24AA4 AH; electric boiler back-up
CFM	est. 3,000	est. 1,600 (H & AC)
Tons	7.5	4

CO2 Concentration Pre and Post-Conversion



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Public Spaces **Application Sheet**

PUBLIC SPACES

Commercial Spaces Require Enhanced Ventilation

Airports and retail locations are close to various forms of exhaust and pollutants. In combination with large crowds that produce vast amounts of CO_2, improving ventilation in public spaces is essential. Enhancing ventilation with units from Ventacity Systems:

- *Reduces energy usage, lowering operating costs and the carbon footprint*
- *Provides sentient, intelligent and secure ventilation management with the Smart Building Gateway*
- *Improves indoor air quality and occupant comfort*

Building Retrofit

Separate Ventilation from Heating and Cooling

Install New VRF System

Remove Aging RTUs

Install New VS1000 RT HRV

Building is now Healthy and Effi-cient

AS-PUBLIC:AIRPORT-Jan2017

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Public Spaces **Case Study**

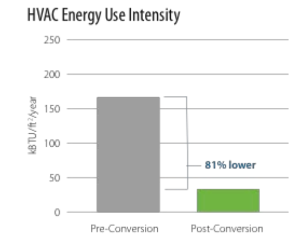
AIRPORT IMPROVES AIR QUALITY AND REDUCES ENERGY

Installation Facts

Building Construction Year	1930
Occupancy Type	Airport
Number of Stories	2
Conditioned Area	26,000 sq.ft.
Ownership	County Government

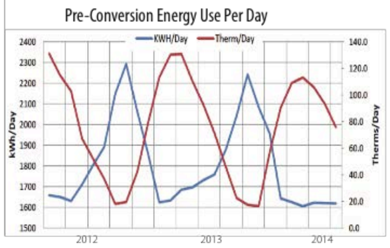
Airport Reduces HVAC EUI By 81%

This historic airport handles 200,000 flights per year for helicopters, small commercial airlines, private and chartered jets, flight tests, as well as celebrities and dignitaries needing immediate access to the city. With the help of a local energy consultant, the airport is acquiring three VS1000 RT units to reduce its EUI by 86% in the modified area to around 30 kBtu/ft²/year. One could say its current EUI is as large and unwieldy as early commercial aircraft, and is now being transformed by 21st century HRV technology. A number of the airport's 5,209 employees will soon benefit from improved ventilation, in addition to lowered utility bill costs for an urban county government.



HVAC Facts

	PRE CONVERSION	POST CONVERSION
Fuel Source	H: Natural Gas; AC: Electricity	H: VRF Heat Pump; AC: VRF Heat Pump
HVAC System	(3) Multi-Zone Air Handlers	(3) VS1000 RT; (3) Mitsubishi VRF Heat Pumps (model TBD)
CFM	est. 4,200	TBD
Tons	est. 10.5	TBD



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KING COUNTY BOEING FIELD AIRPORT

BEFORE

Removing large rooftop air handlers

AFTER

Using original ductwork, but 1/5 the size

93% 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 50 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

VERIFIED RESULTS

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

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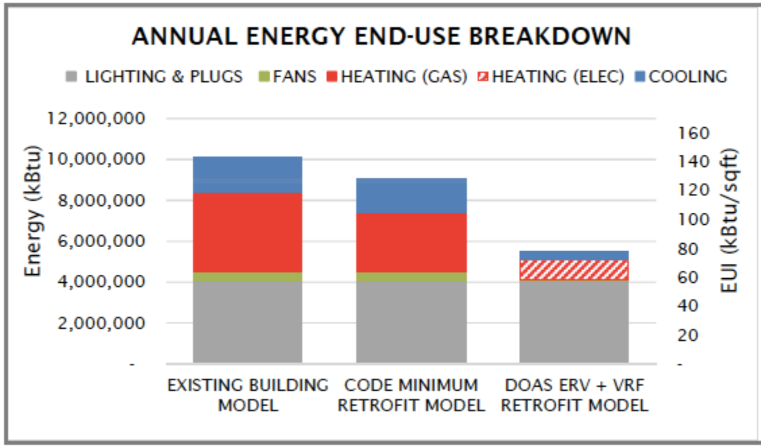

Figure 0.1

Comparison of annual energy consumption.

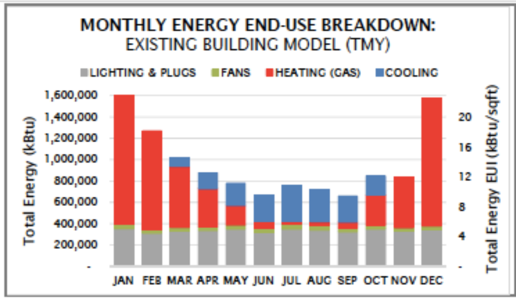

Figure 2.1

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

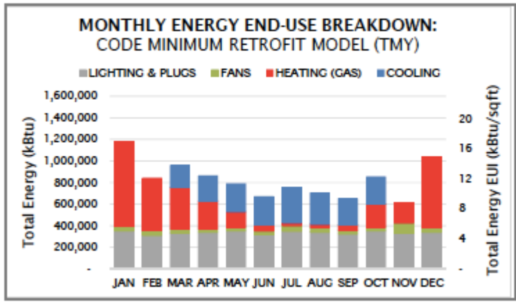

Figure 2.2

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

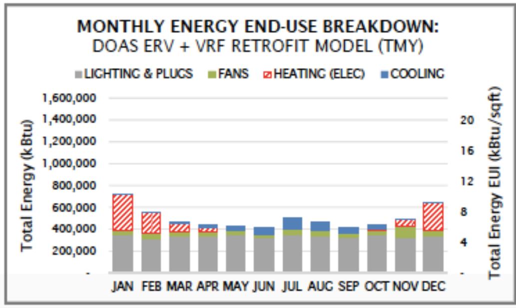

Figure 2.3

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

VERIFIED RESULTS

- **71,000 Sq Ft Office Building**
- **4 RTUs Existing**
- **4 x 3,000 CFM ERVs**
- **VRF System**

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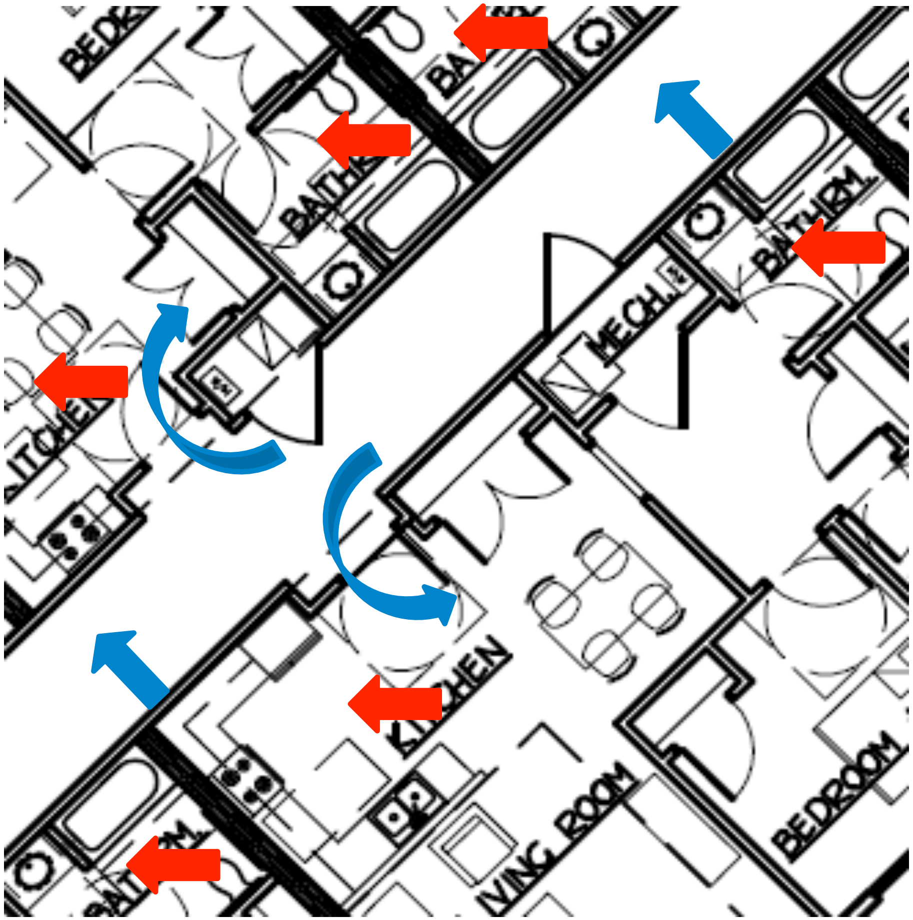
Chapter 10: Applications

Application: Multifamily Residential
Traditional Design



Exhaust Air Locations

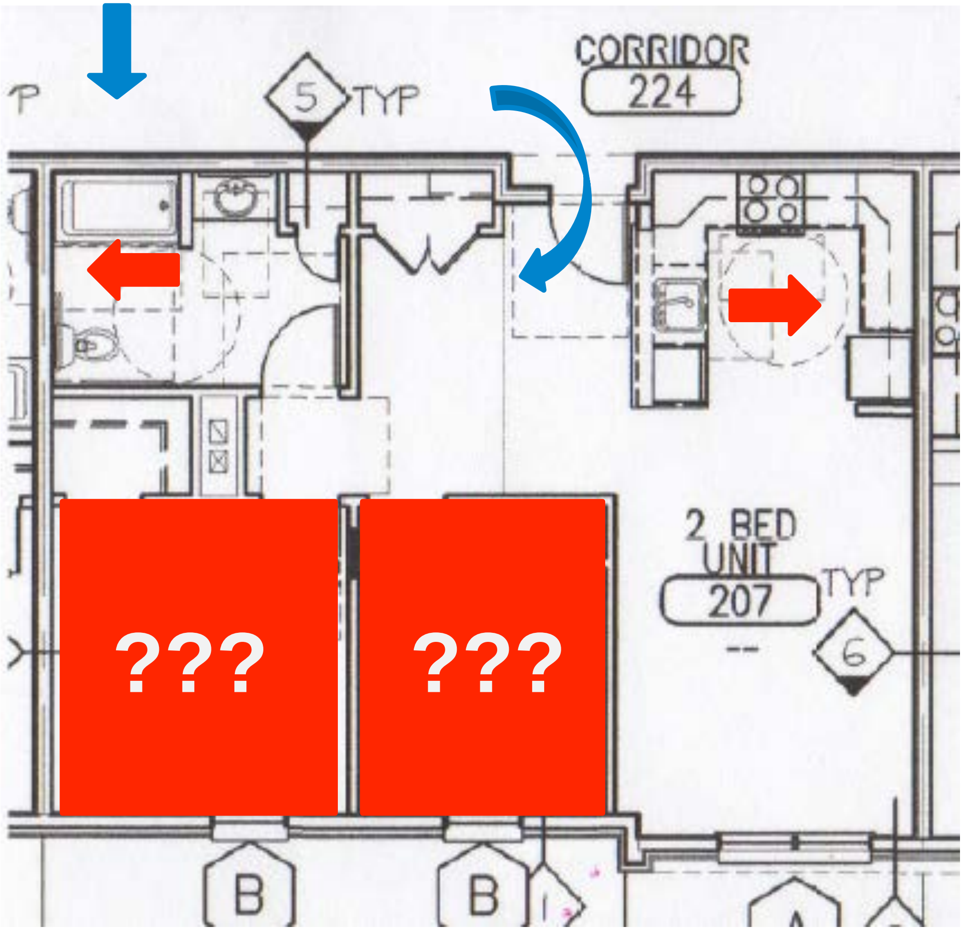
- Bathrooms
- Kitchen

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

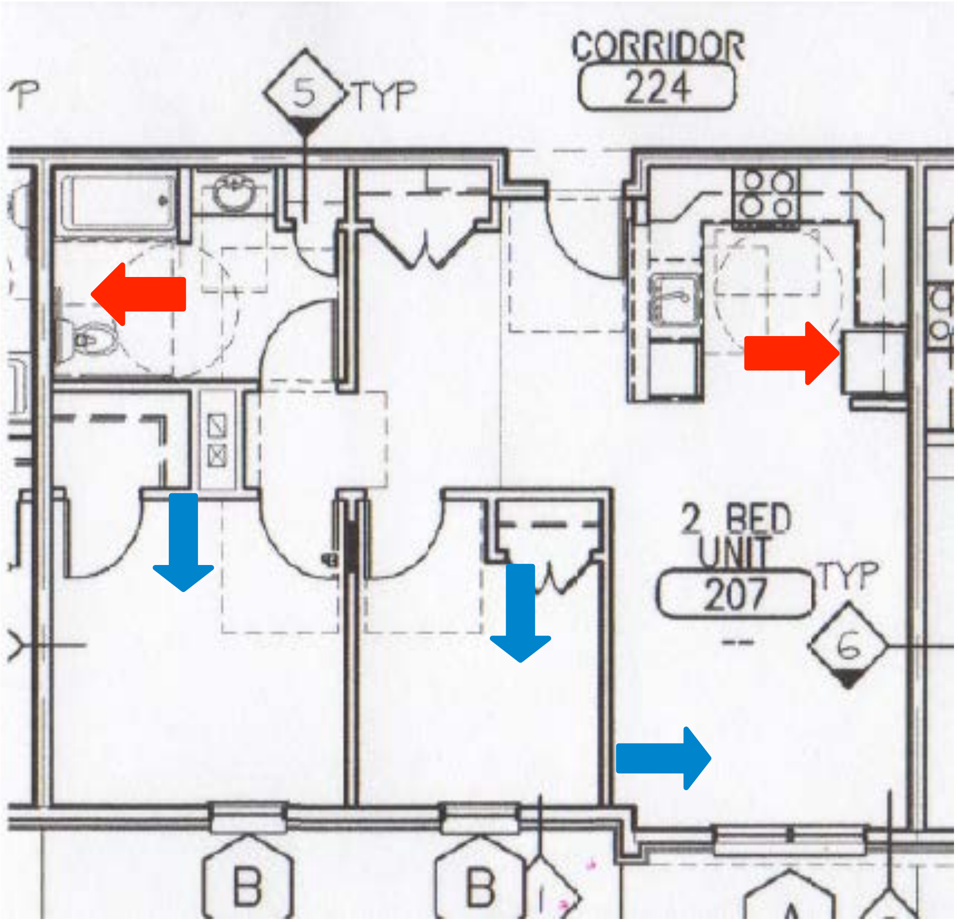
- Bathrooms
- Kitchen

Supply Air Locations

- Corridors

What is the ACH in the Bedrooms?

Application: Multifamily Residential Optimized Design



Exhaust Air Locations

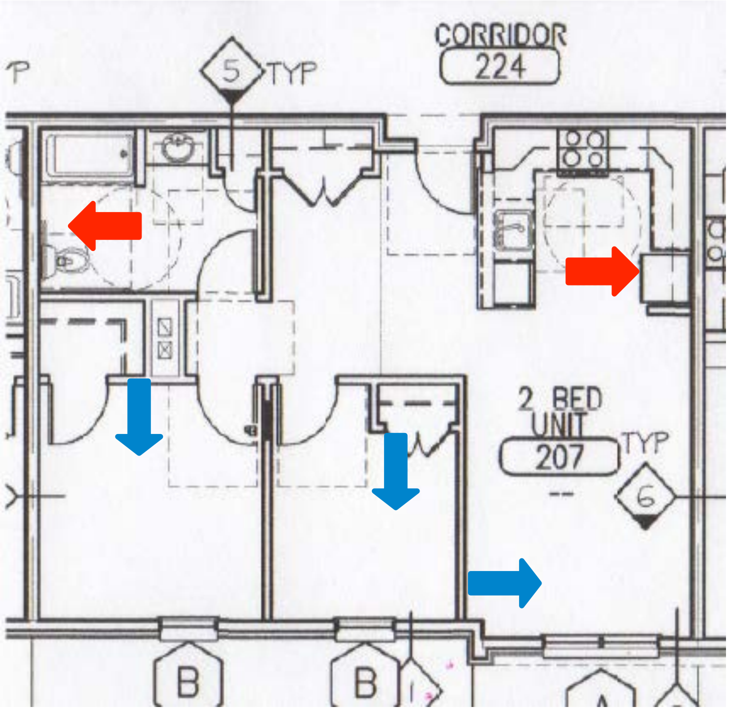
- Bathrooms
- Kitchen
- Laundry
- Moisture/Odor Laden Areas

Supply Air Locations

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

* Depending upon layout

Application: Multifamily Residential System Options: Example Apartment

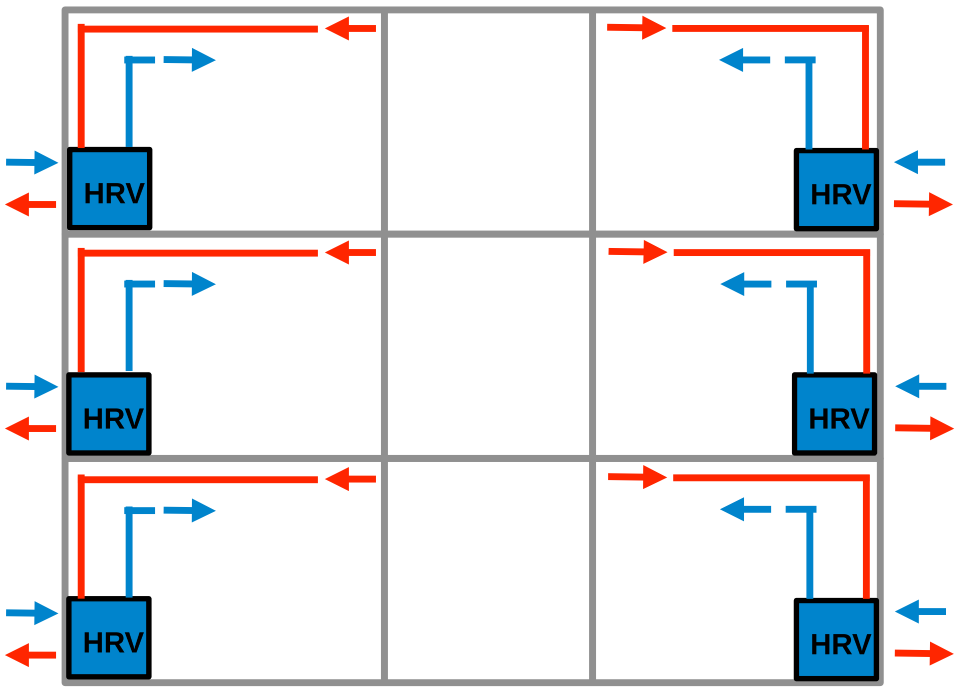


Standard	Supply	Exhaust
PHI	32 CFM	59 CFM
62.2-2013	47 CFM	57 CFM

Given Conditions:

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

Multi-Family Options



Individual Apartment Units

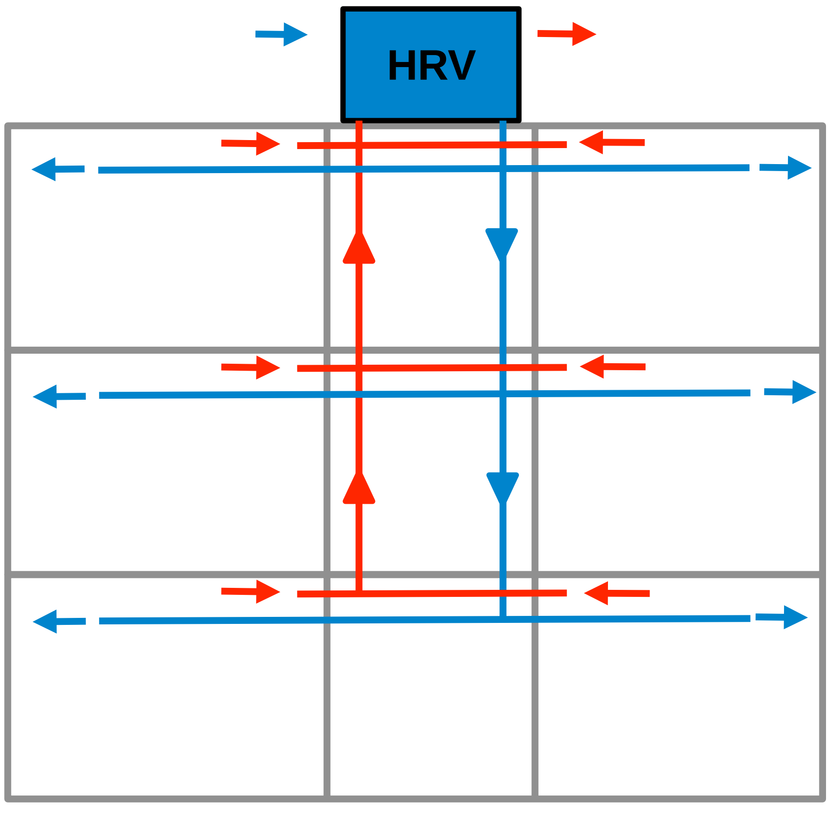
Pros

- 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

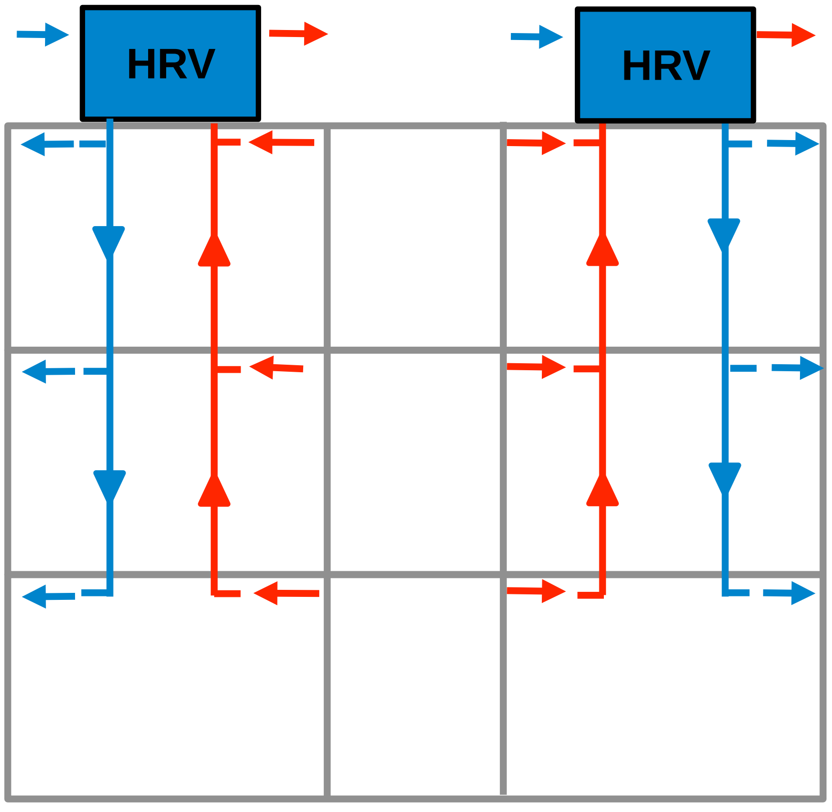
Pros

- 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

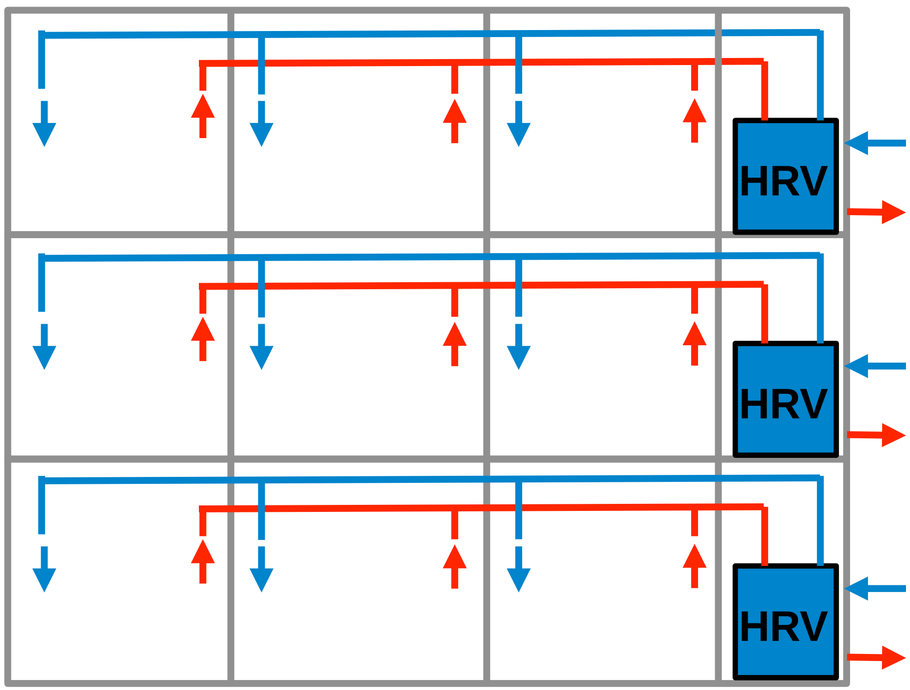
Pros

- 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

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

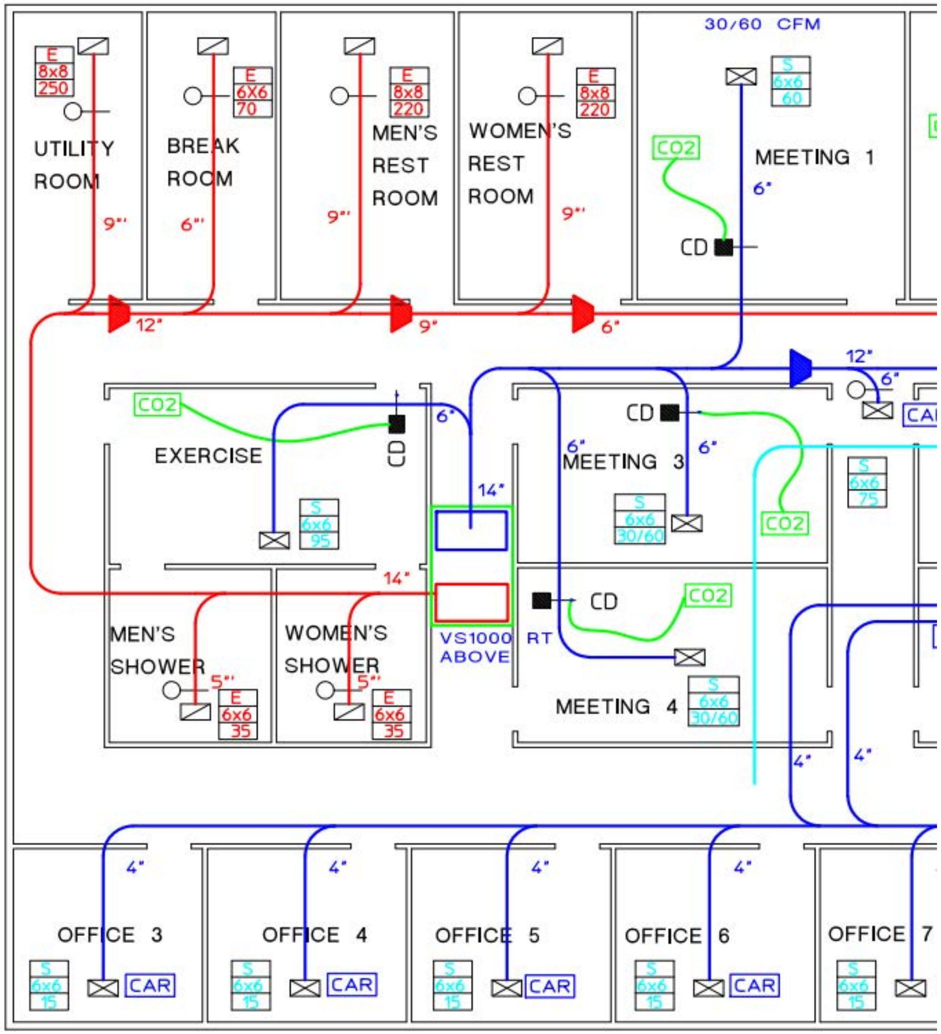
Public Bathrooms:
- 25 CFM/unit Exhaust single occ.
- 50 CFM/unit Exhaust multi occ.

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.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
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.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
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

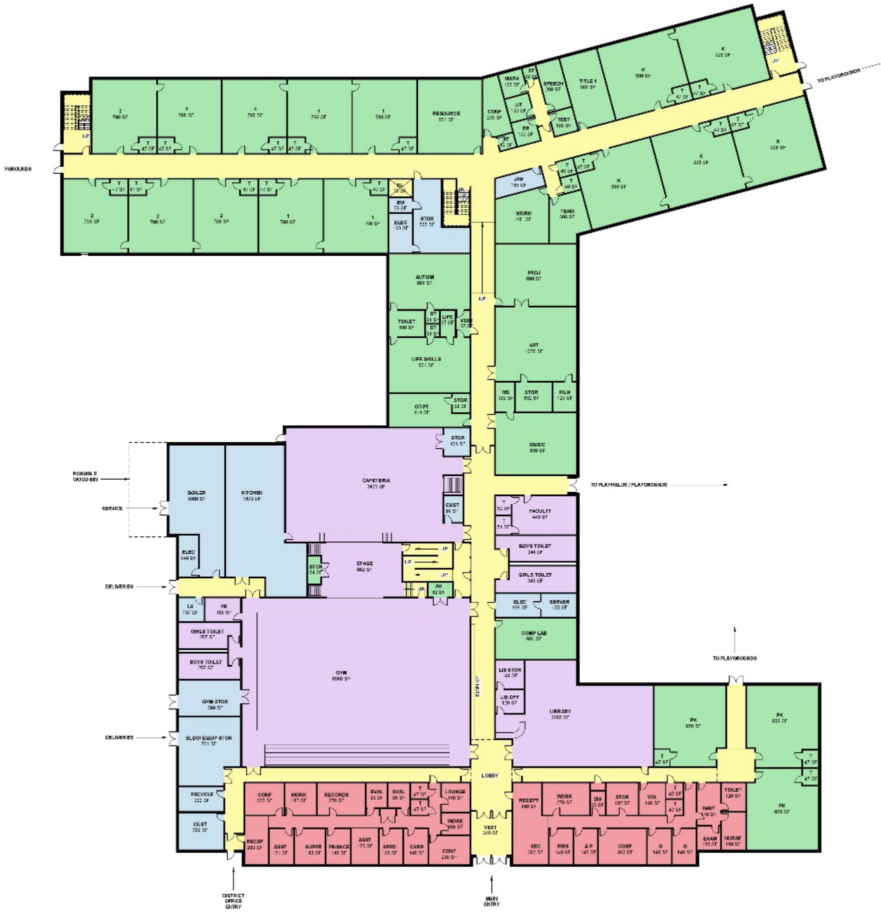
Ancillary spaces can include:

- 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

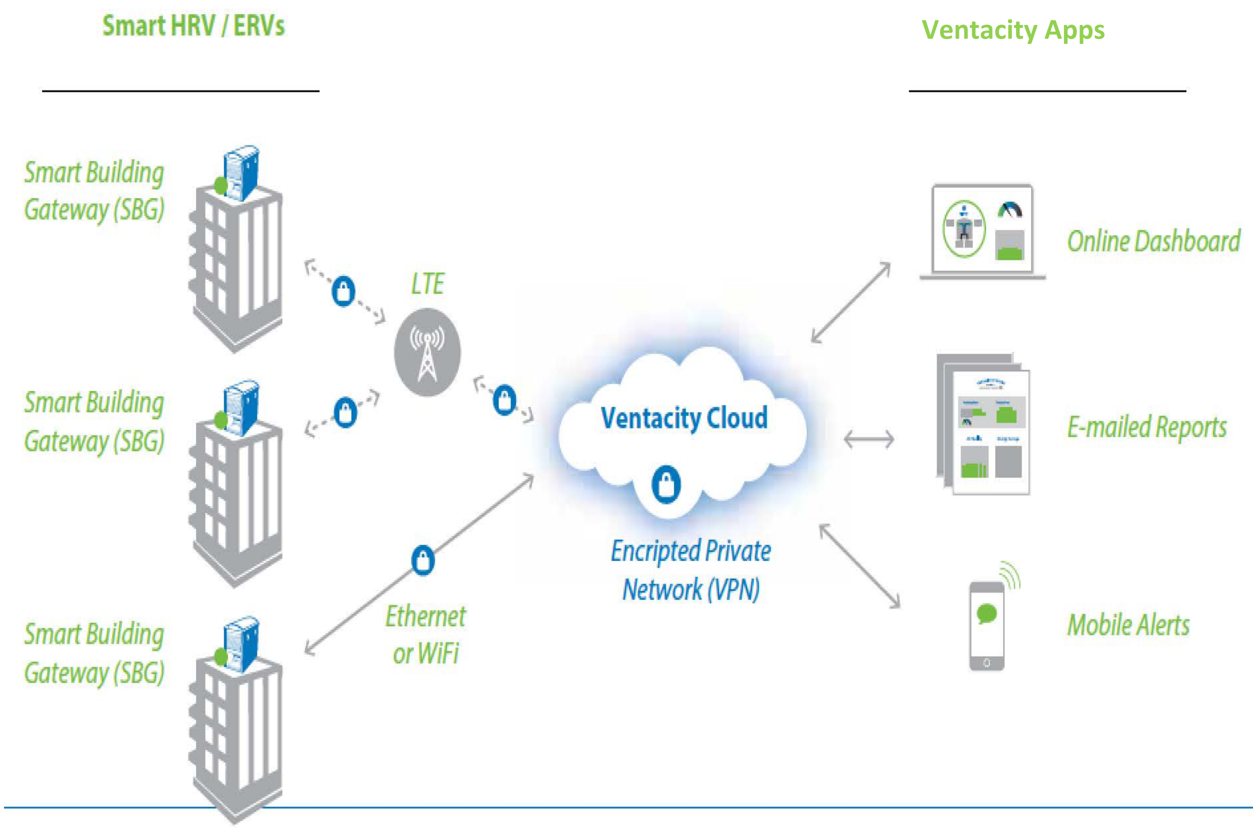
Central Systems

- 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

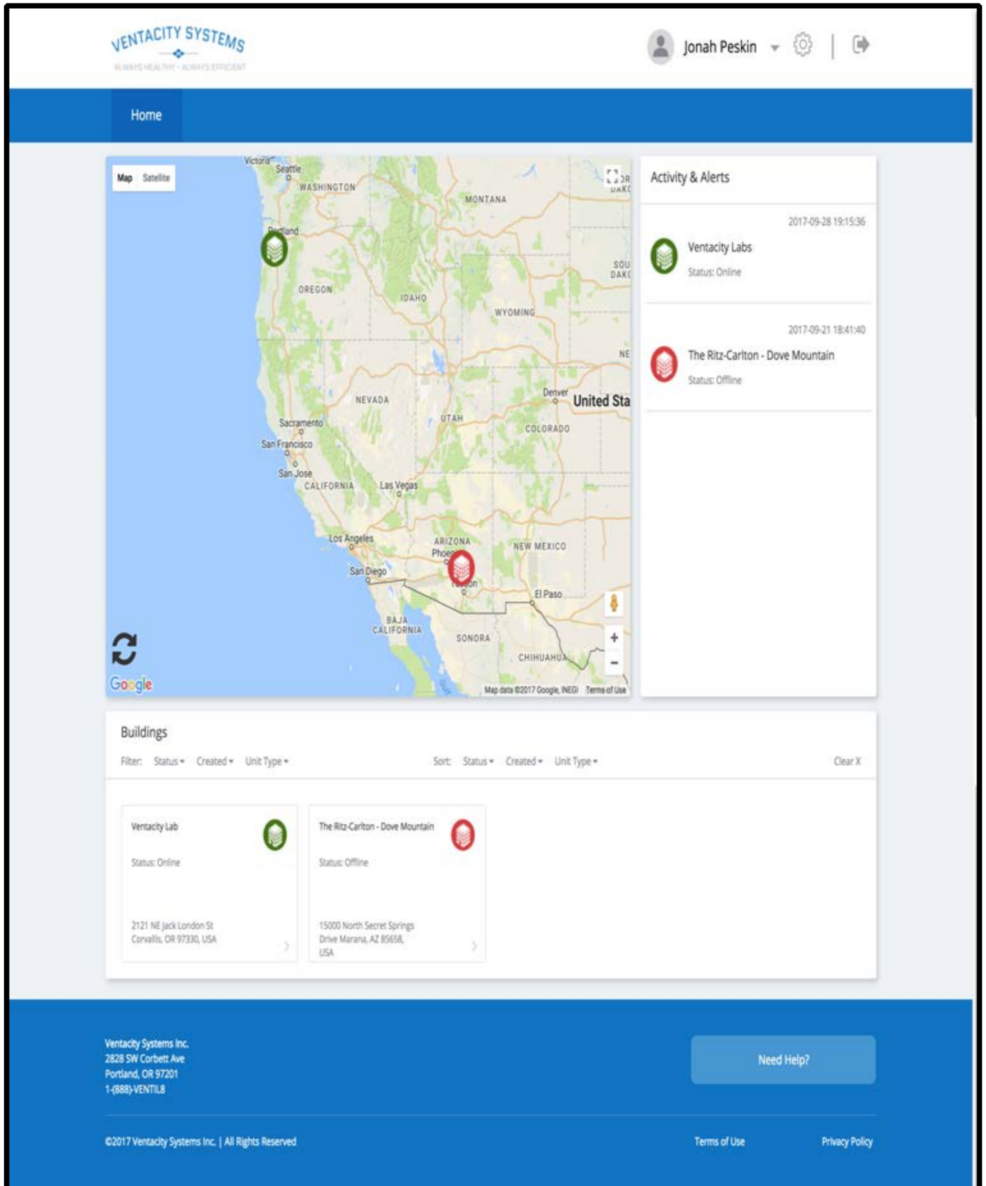
KEY FEATURES

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

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

PORTFOLIO MAP / HOME SCREEN



- OVERVIEW

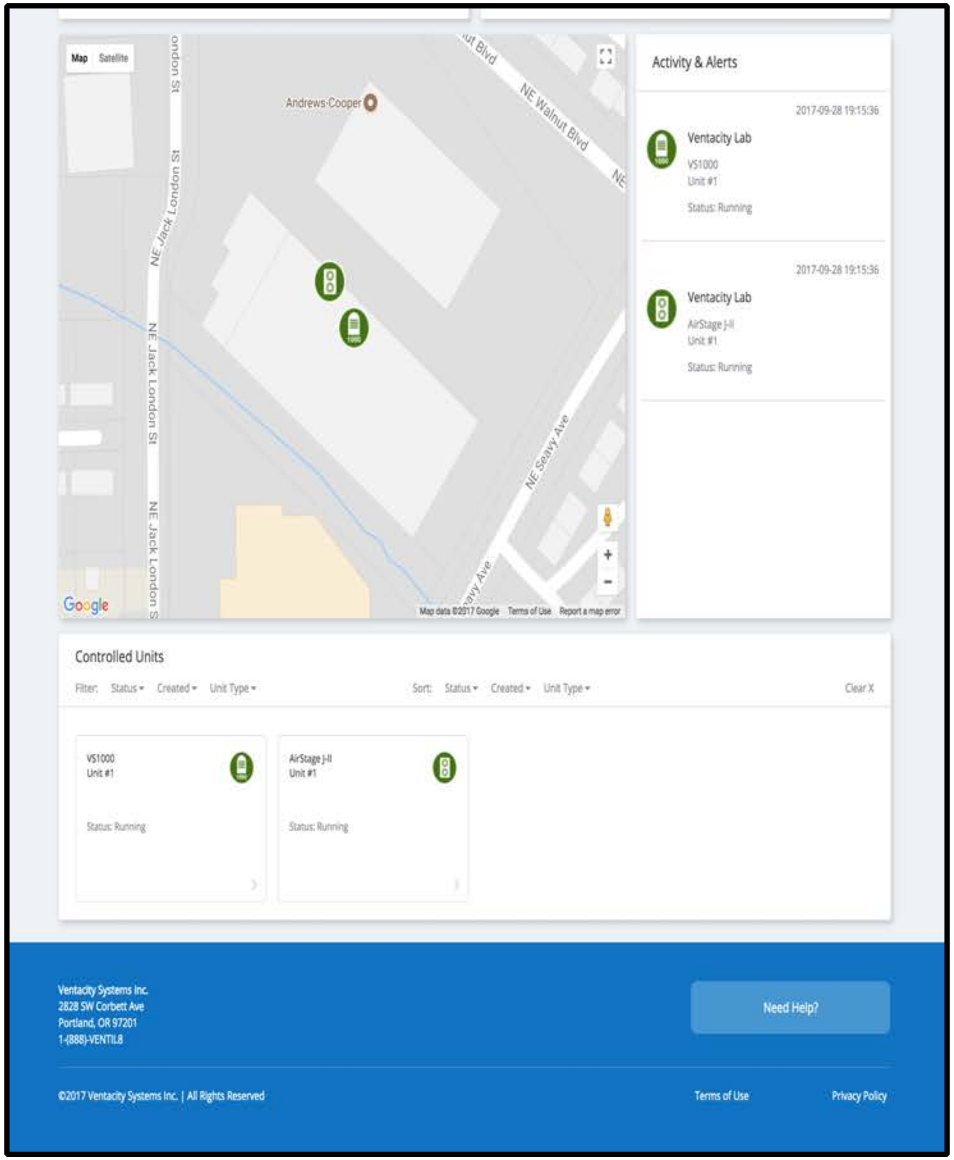
- "At a Glance" View of All Buildings Under Purview
- Color Coded Status:

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

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

BUILDING MAP



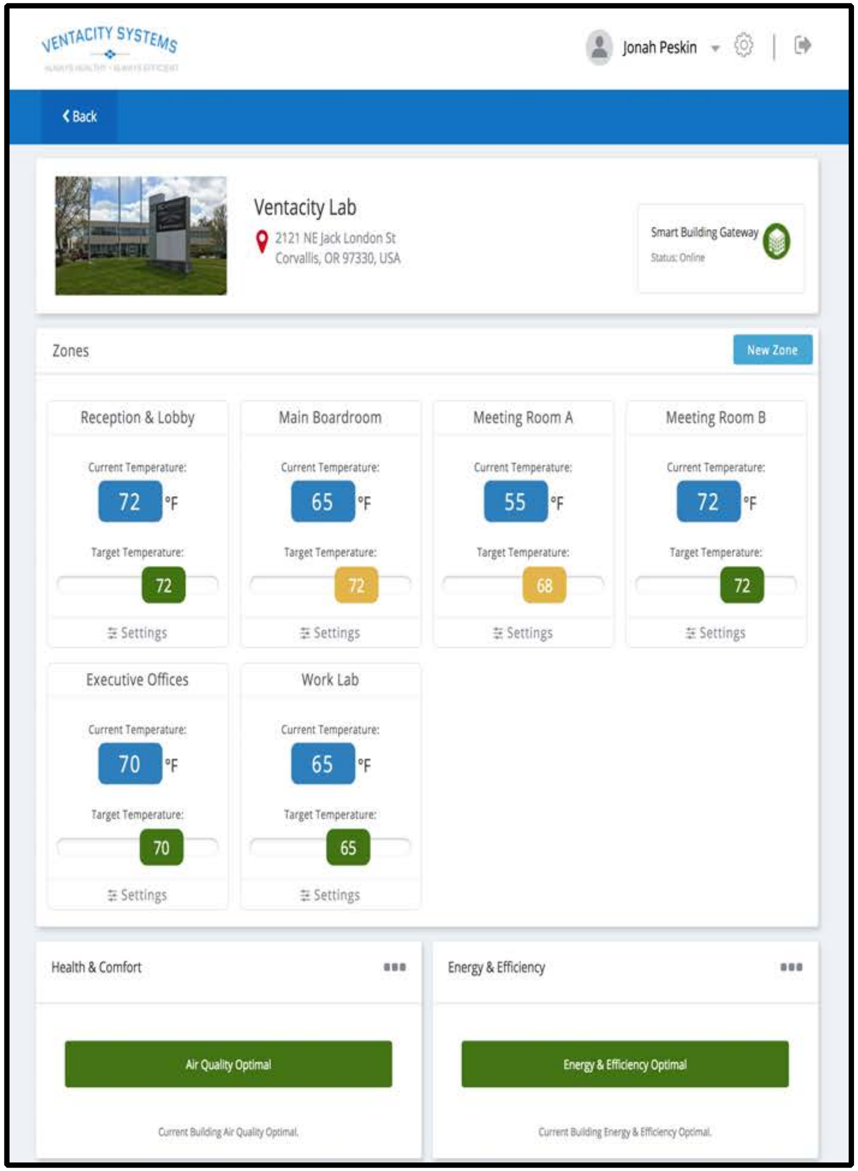
- OVERVIEW

- “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...

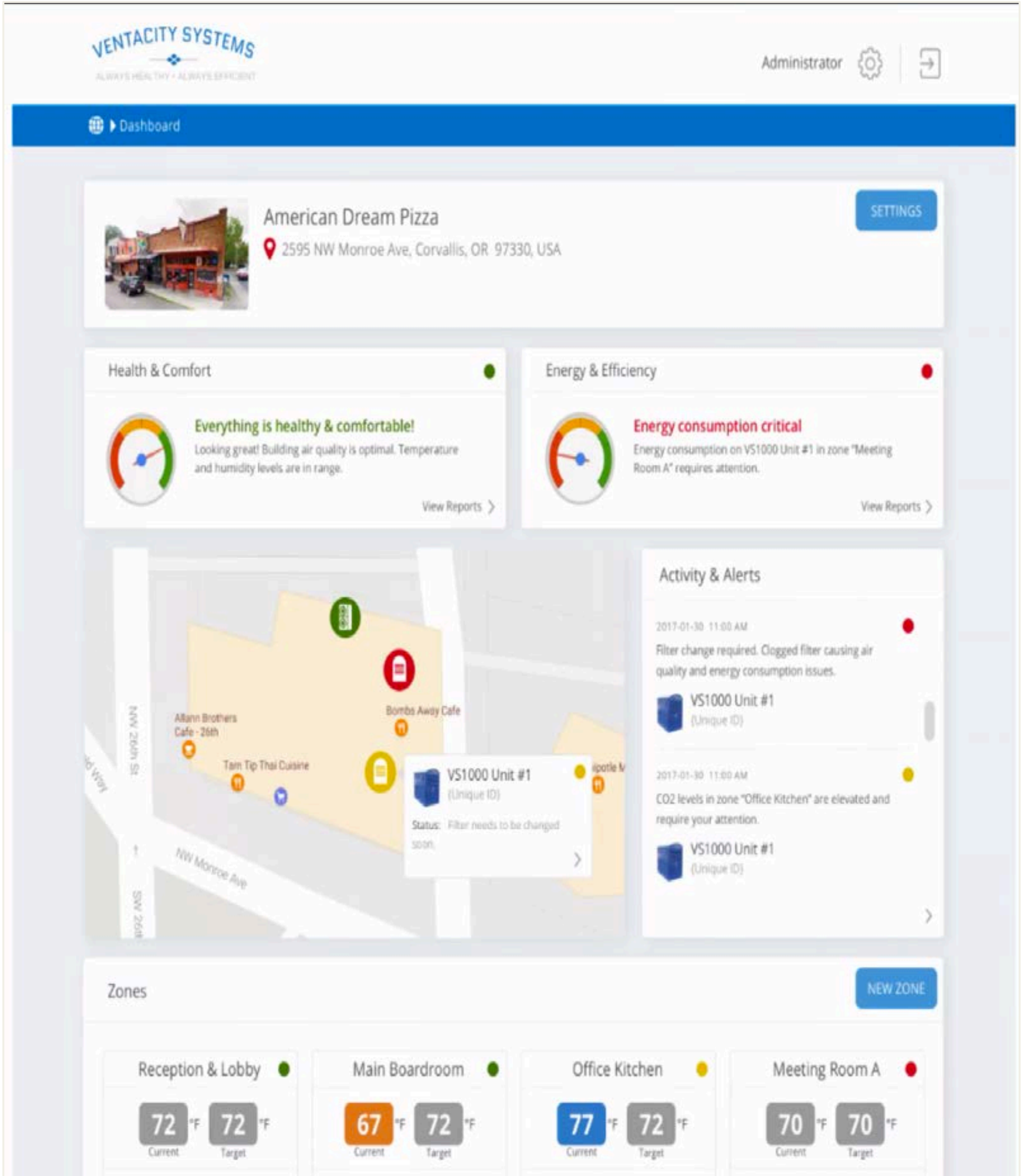
- OVERVIEW

- 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

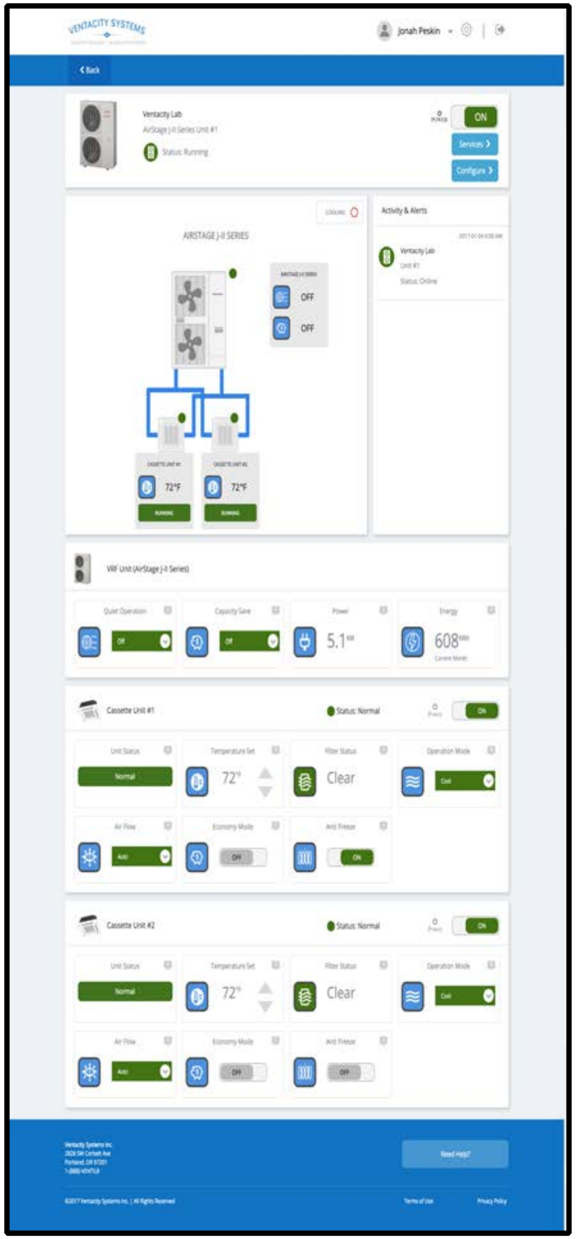
- OVERVIEW

- 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

VENTACITY SYSTEMS

ALWAYS HEALTHY • ALWAYS EFFICIENT

Thank you

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