How your ventilation system can help with your air conditioning load

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Swegon

AGENDA

1. Cooling loads primer
2. Ventilation unit primer
3. Cooling with the ventilation unit
4. Energy Impact
5. Summary
6. Questions

PART 1

COOLING LOADS PRIMER

Passive House Cooling

- **Cooling load** – lower load, different use profile
- **Tight envelope** – lower portion of total coling load, humidity loads more important
- **Ventilation air** - higher portion of total cooling load
- **Comfort** - air temperature and mean radiant temperature are closer than typical buildings – an opportunity!
- **Comfort** – load, temperature, humidity, room air velocity

Passive House Sensible Cooling

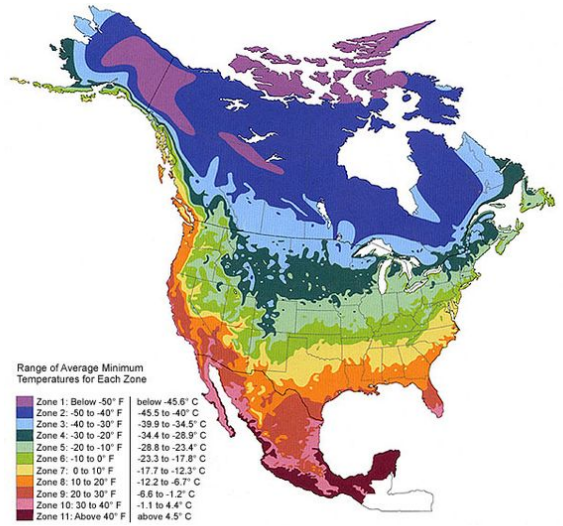
- **Sensible heat sources**
  - Envelope – much lower
  - Fenestration / Solar - lower
  - Plug loads - similar
  - Lighting - lower
  - People - similar
- **Building type becomes important**
  - Use: Office vs. multifamily
  - Compactness
  - Possible thermal zones

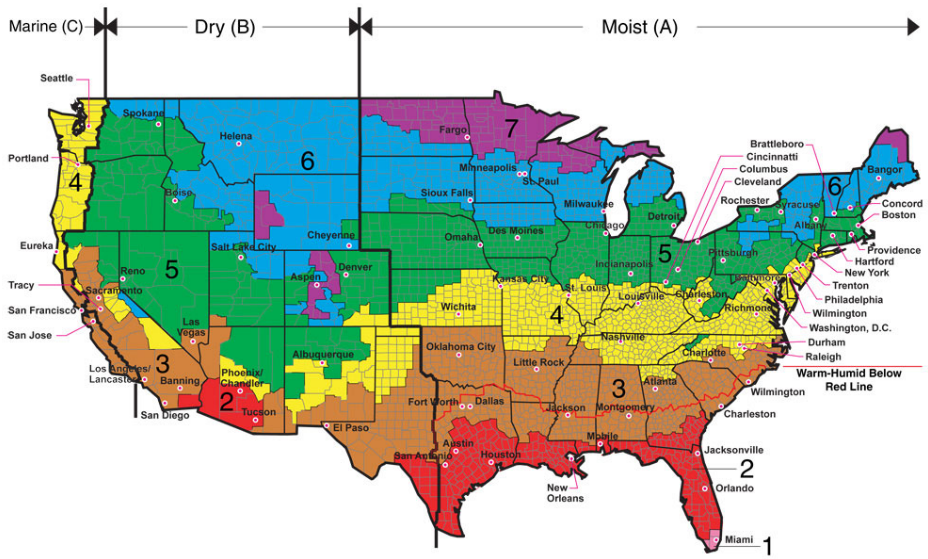
Sensible Cooling

- **Low area loads challenge existing HVAC equipment**
    - terminal units with good air distribution at low loads
    - Right-sizing
    - Risk of cycling

Cooling Loads & Compactness

- **Commercial buildings are inherently bigger than single family dwellings**
- **As buildings get bigger, the surface to volume ratio drops**
    - Envelope becomes less dominant
    - Surface-to-volume ratios
        - 2000 ft^2 home = 0.19
        - 20,000 ft^2 bldg= 0.078
        - 100,000 ft^2 bldg = 0.048
- **20,000 ft^2 building likely has a *zone* in cooling during winter**



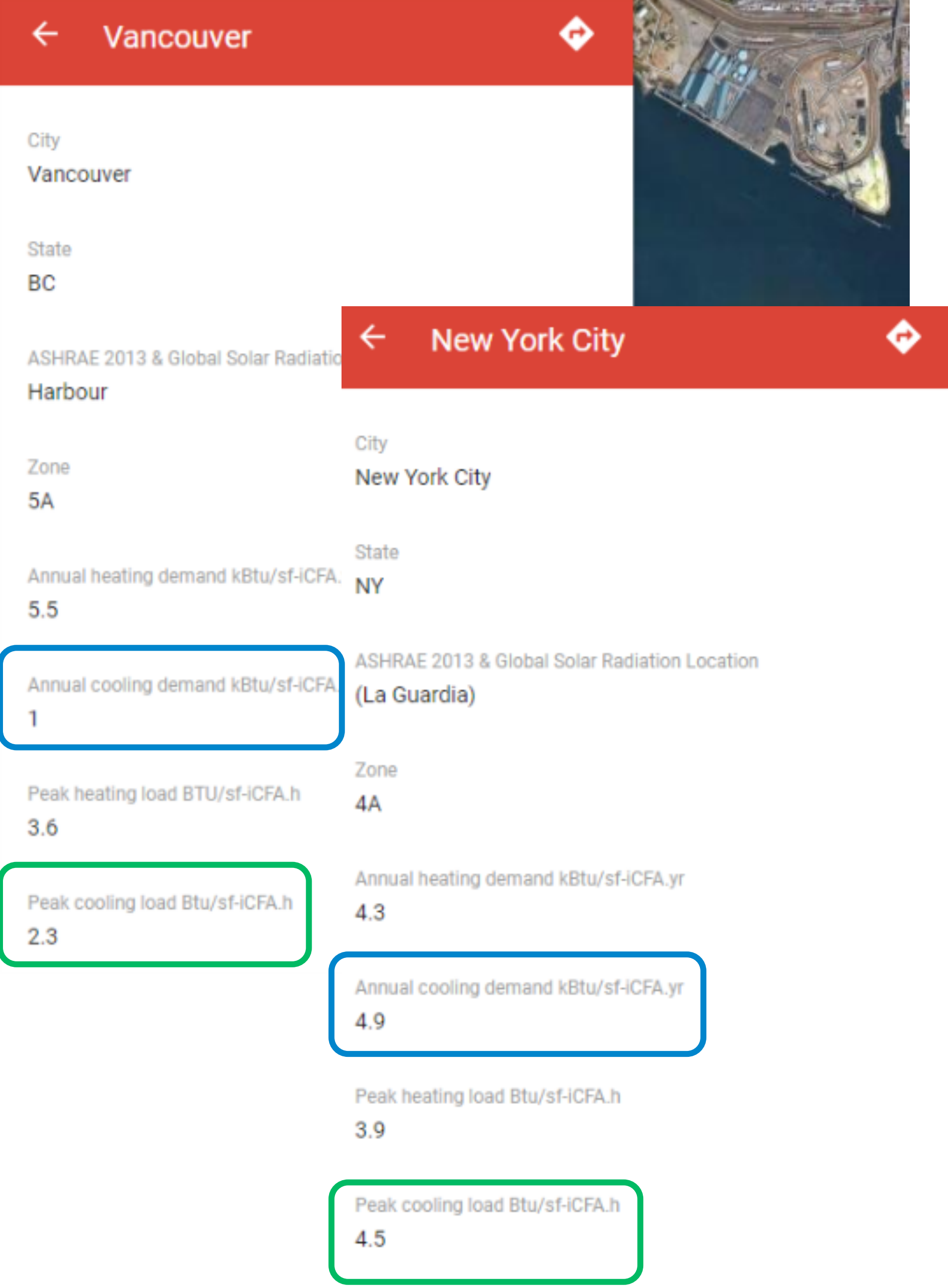


All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

Cooling Loads & Climate

- Hot
- Cold
- Moist
- Dry
- Marine

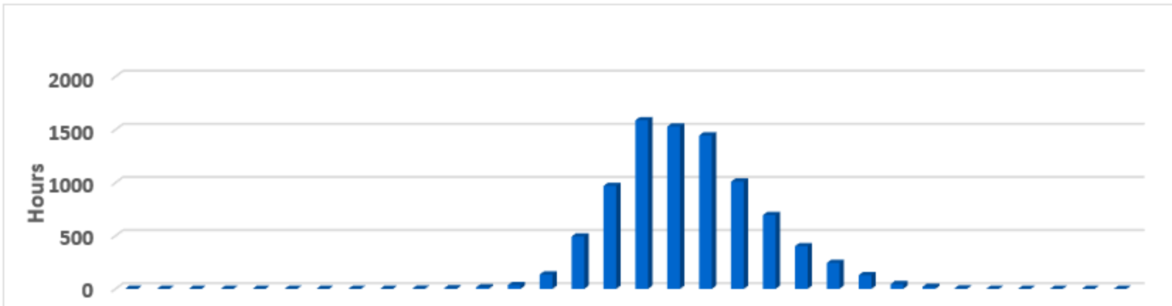


Passive House Cooling Demand & Load limits

- ≤1.8-8.9 kBtu/ft^2 -hr Peak Cooling Load
- ≤1.0-21.4 kBtu/ft^2-yr Cooling Demand
- Climate specific
- Maintain thermal comfort

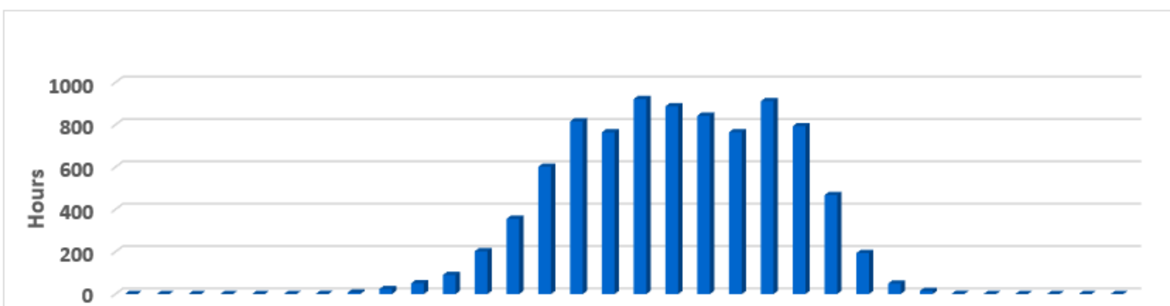
Annual Ventilation Loads

Vancouver



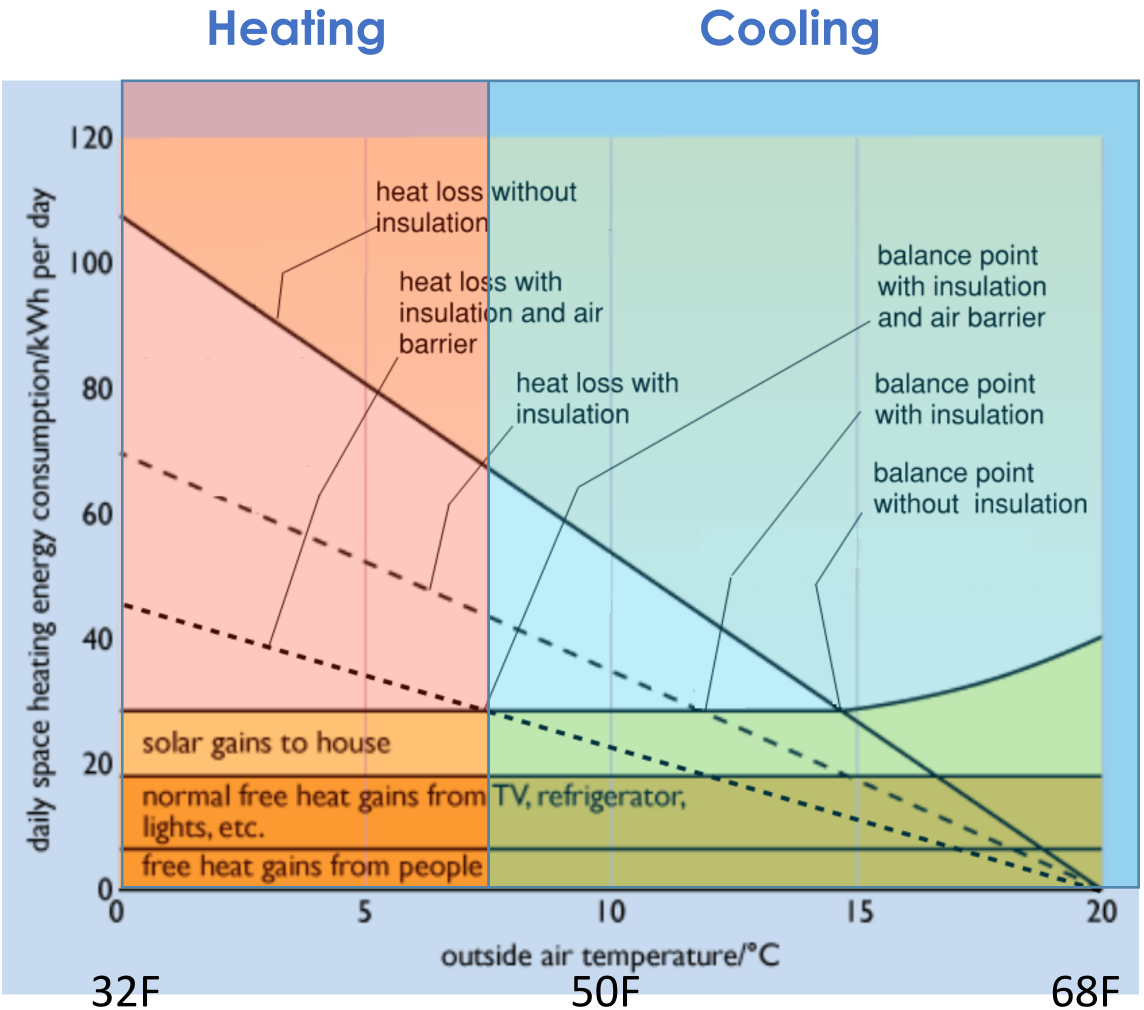
Ambient DB Temp. Range	Occurrences
-17.5-(-12.5) oF	0
-12.5-(-7.5) oF	0
-7.5-(-2.5) oF	0
-2.5-2.5 oF	0
2.5-7.5 oF	0.04
7.5-12.5 oF	0.88
12.5-17.5 oF	4.84
17.5-22.5 oF	13.5
22.5-27.5 oF	35.1
27.5-32.5 oF	135
32.5-37.5 oF	493
37.5-42.5 oF	969
42.5-47.5 oF	1588
47.5-52.5 oF	1529
52.5-57.5 oF	1445
57.5-62.5 oF	1010
62.5-67.5 oF	695
67.5-72.5 oF	401
72.5-77.5 oF	245
77.5-82.5 oF	129
82.5-87.5 oF	44.8
87.5-92.5 oF	17.6
92.5-97.5 oF	3.84
97.5-102.5 oF	0.48
102.5-107.5 oF	0.04
107.5-112.5 oF	0
112.5-117.5 oF	0
117.5-122.5 °F	0

New York City



Ambient DB Temp. Range	Occurrences
-17.5-(-12.5) oF	0
-12.5-(-7.5) oF	0.28
-7.5-(-2.5) oF	0.8
-2.5-2.5 oF	7.07
2.5-7.5 oF	23.6
7.5-12.5 oF	51.1
12.5-17.5 oF	90.3
17.5-22.5 oF	202
22.5-27.5 oF	356
27.5-32.5 oF	602
32.5-37.5 oF	816
37.5-42.5 oF	764
42.5-47.5 oF	921
47.5-52.5 oF	887
52.5-57.5 oF	843
57.5-62.5 oF	765
62.5-67.5 oF	912
67.5-72.5 oF	793
72.5-77.5 oF	467
77.5-82.5 oF	194
82.5-87.5 oF	49.5
87.5-92.5 oF	14.6
92.5-97.5 oF	1.16
97.5-102.5 oF	0
102.5-107.5 oF	0
107.5-112.5 oF	0
112.5-117.5 oF	0
117.5-122.5 °F	0

Internal Loads & Balance Point



Credit: Dan Nall, Syska Hennessy

Internal Loads & Balance Point

- Lower balance point leads to cooling at lower ambient temperature
- More free cooling hours
  - Air side economizer (ventilation unit)
  - Water side economizer (cooling tower)
  - Operable windows
- Fewer mechanical cooling hours – savings!

Cooling Load Reduction Measures

- Active and Passive shading
- Maximum Daylighting and LEDs
    - Width and orientation of building allows light to reach across the entire floor

PASSIVE HOUSE BUILDING
COOLING LOADS SUMMARY

Low Balance Point

Low balance point means buildings need cooling at lower outside air temperatures

Cooling is required more frequently

Mechanical cooling may be required less frequently

More available hours of free cooling

Ventilation is Higher Portion of Load

Maximize rejection of heat from outdoor air by maximizing energy recovery effectiveness

Minimize energy consumed ventilating. Pick HRV/ERV with low electrical consumption (W/CFM)

Buildings are Very Tight

Humidity control must be considered – air tight enclosures don't permit moist air to flow out.

PART 2

VENTILATION UNIT PRIMER

ENERGY RECOVERY VENTILATION UNITS

Sensible Energy Recovery “HRV” – hot humid days

- Rejects heat but not humidity
- Lowers Supply Air temperature
- Free cooling mode
- Plate, wheel, heat pipe, run around loops

Total / Enthalpy Energy Recovery “ERV” – hot humid days

- Rejects heat and humidity
- Lowers Supply Air temperature *and humidity*
- Free cooling mode
- Enthalpy plate, enthalpy wheel

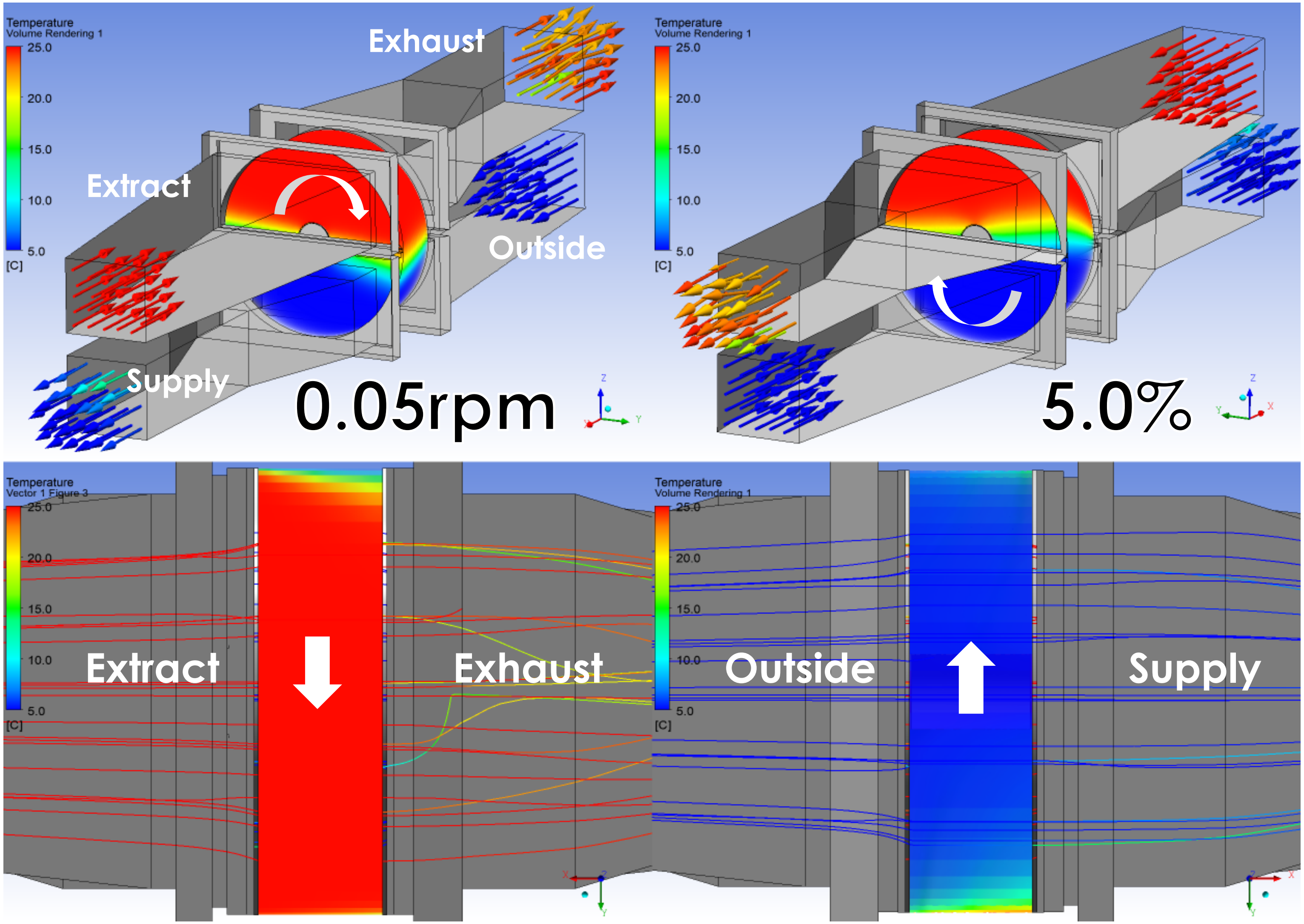
Centralized Ventilation Units

- Indoors or outdoors
- Whole Building or multiple zone

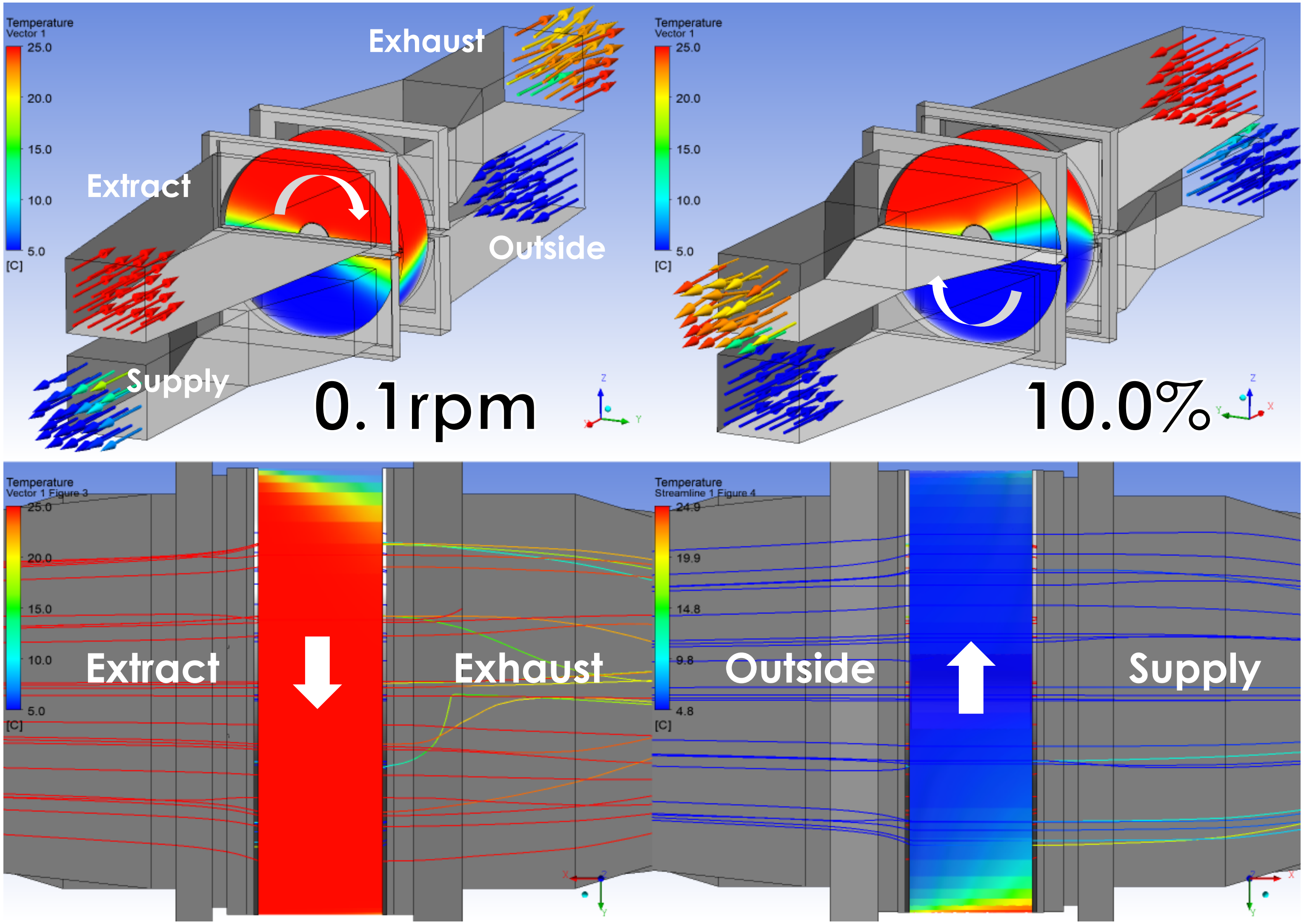
Decentralized Ventilation Units

- Mainly Indoors
- Through-wall
- One per residence or zone

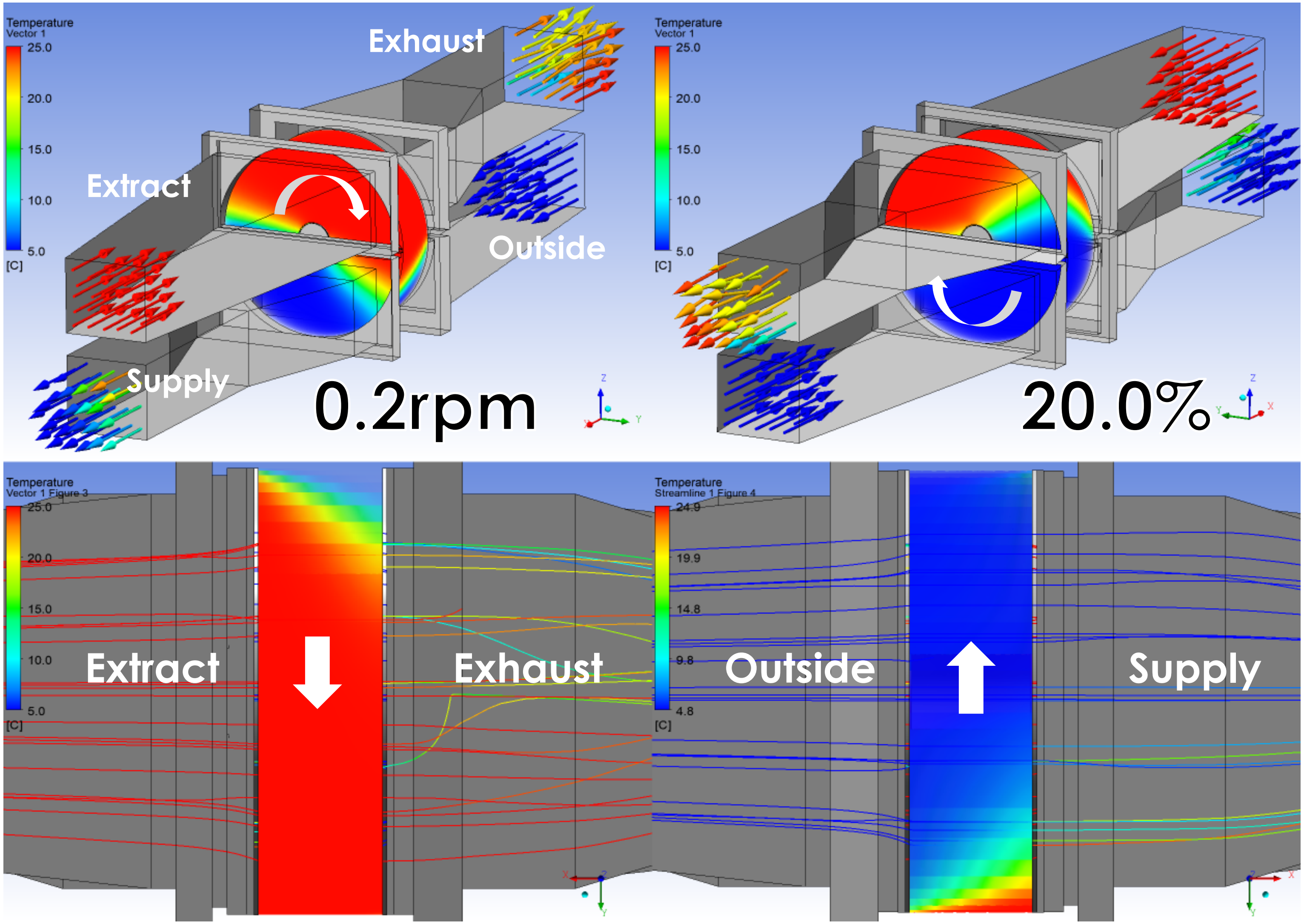
VENTILATION UNIT – WHEEL TYPE



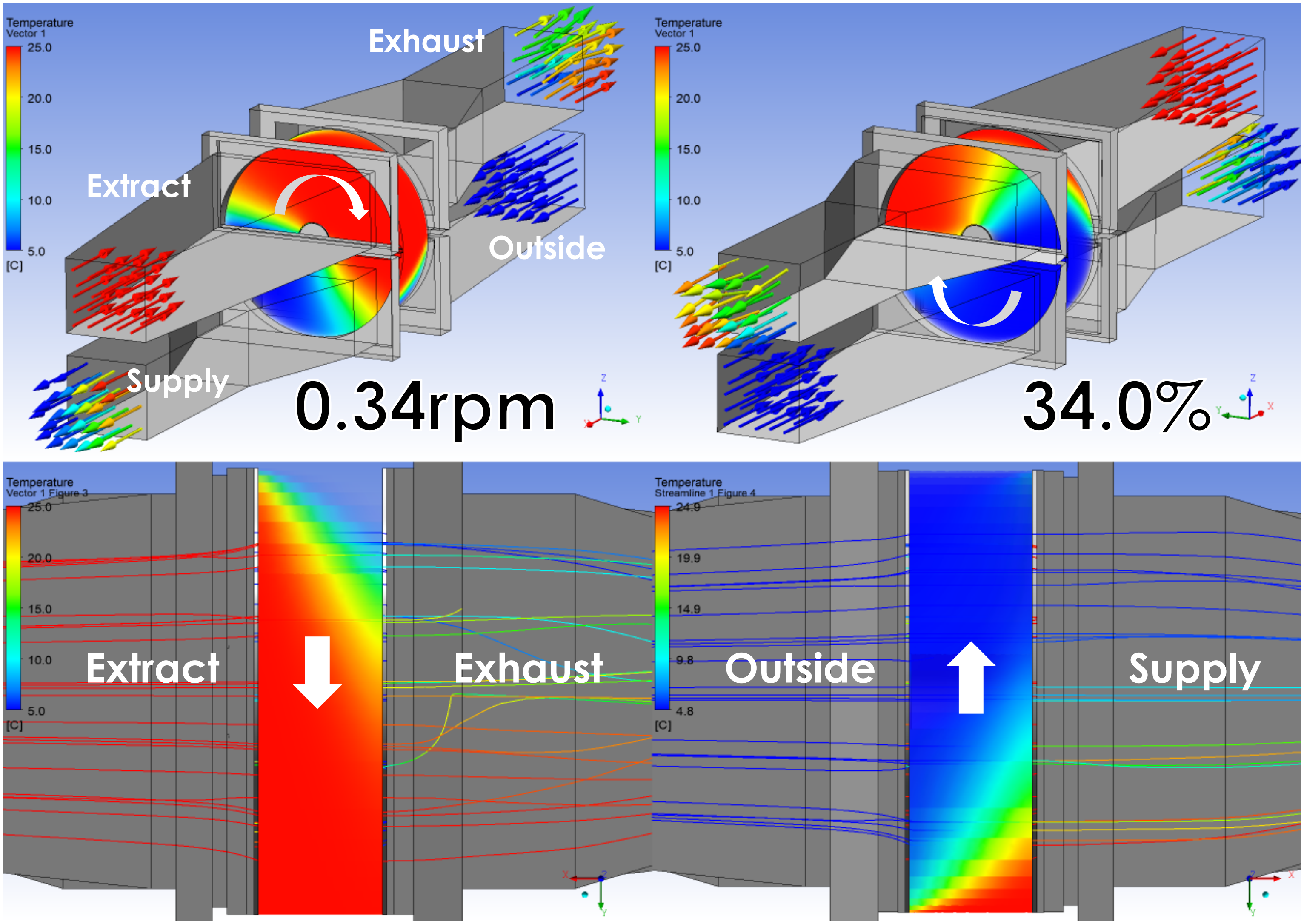
VENTILATION UNIT – WHEEL TYPE



VENTILATION UNIT – WHEEL TYPE



VENTILATION UNIT – WHEEL TYPE



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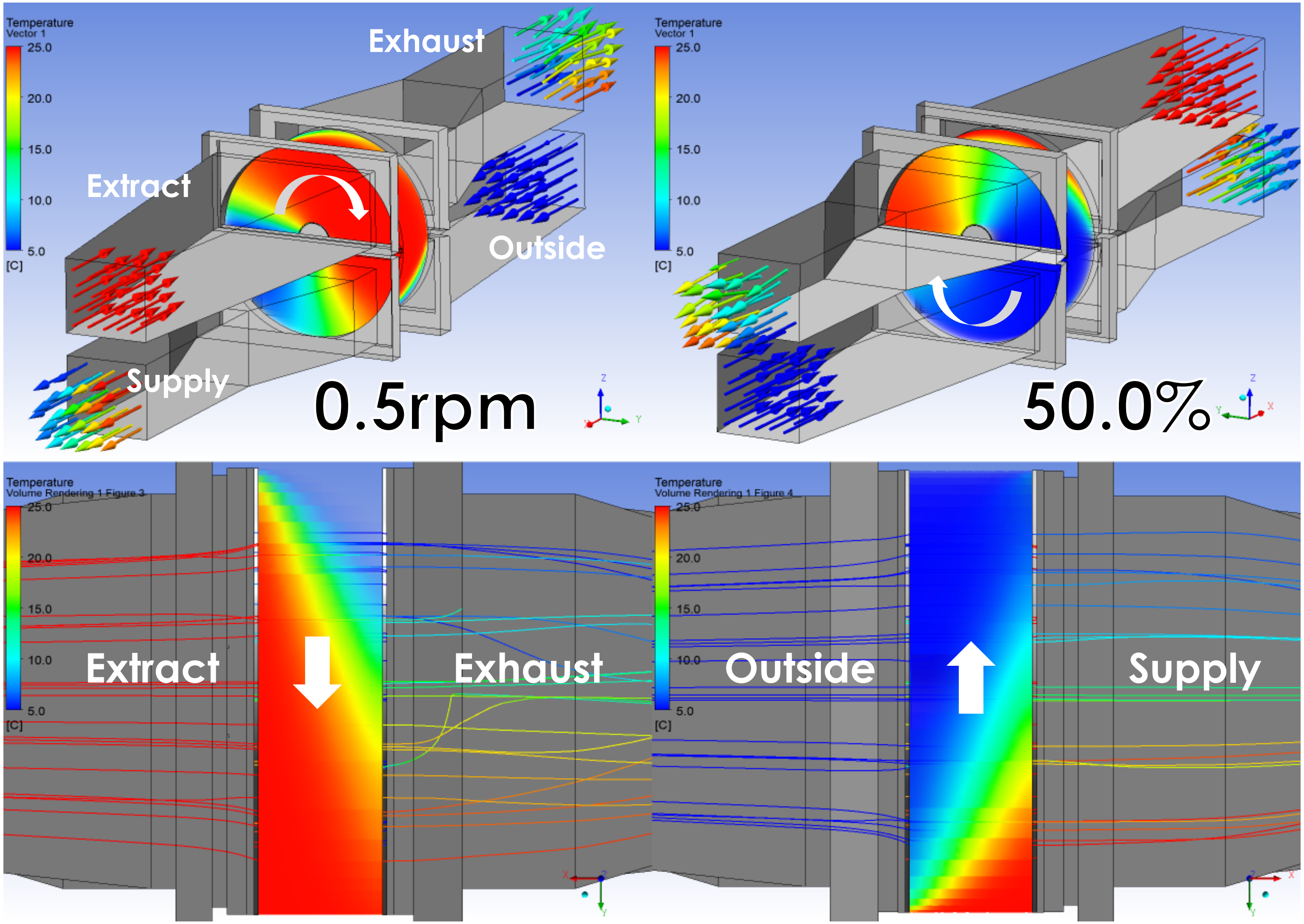

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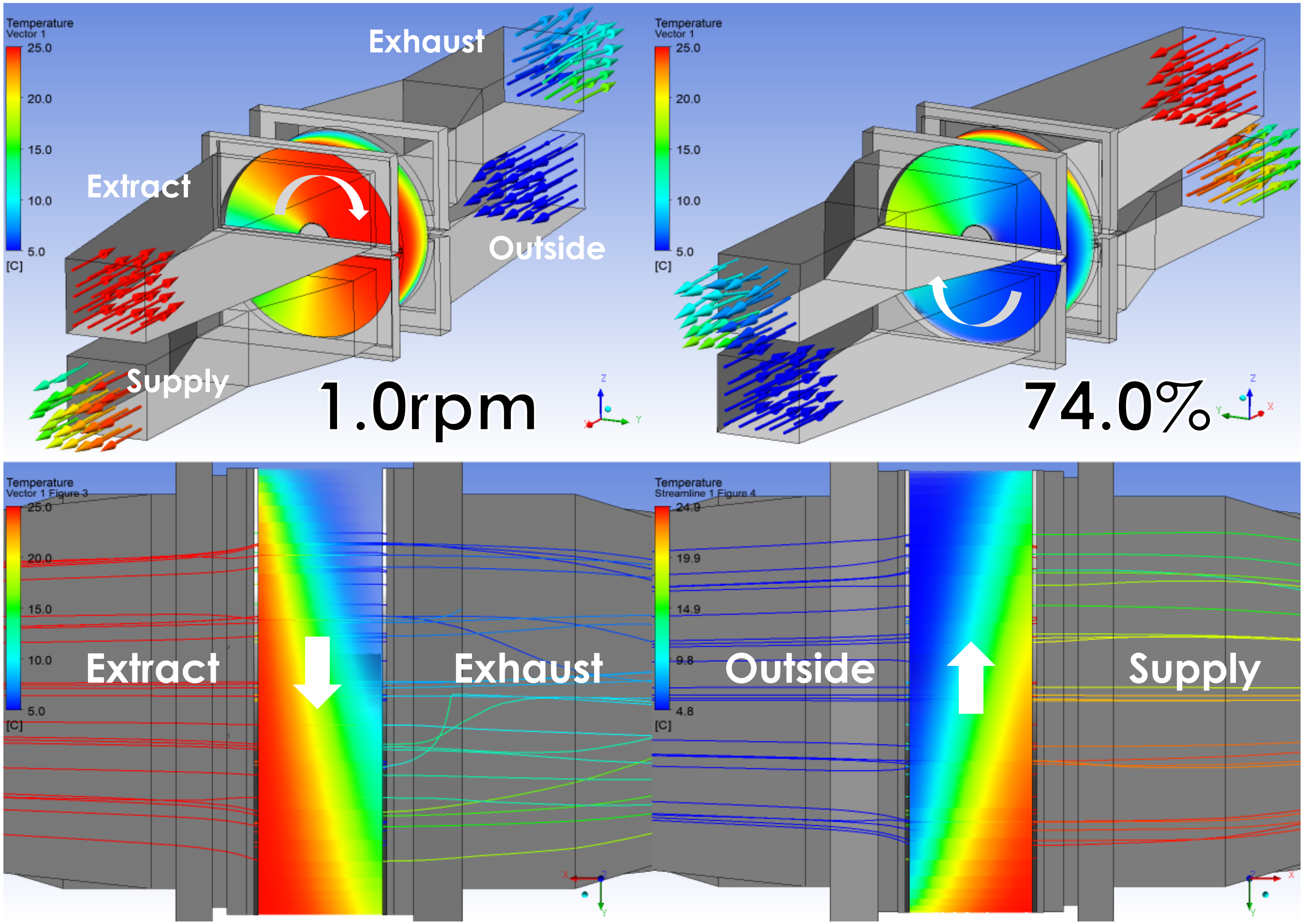

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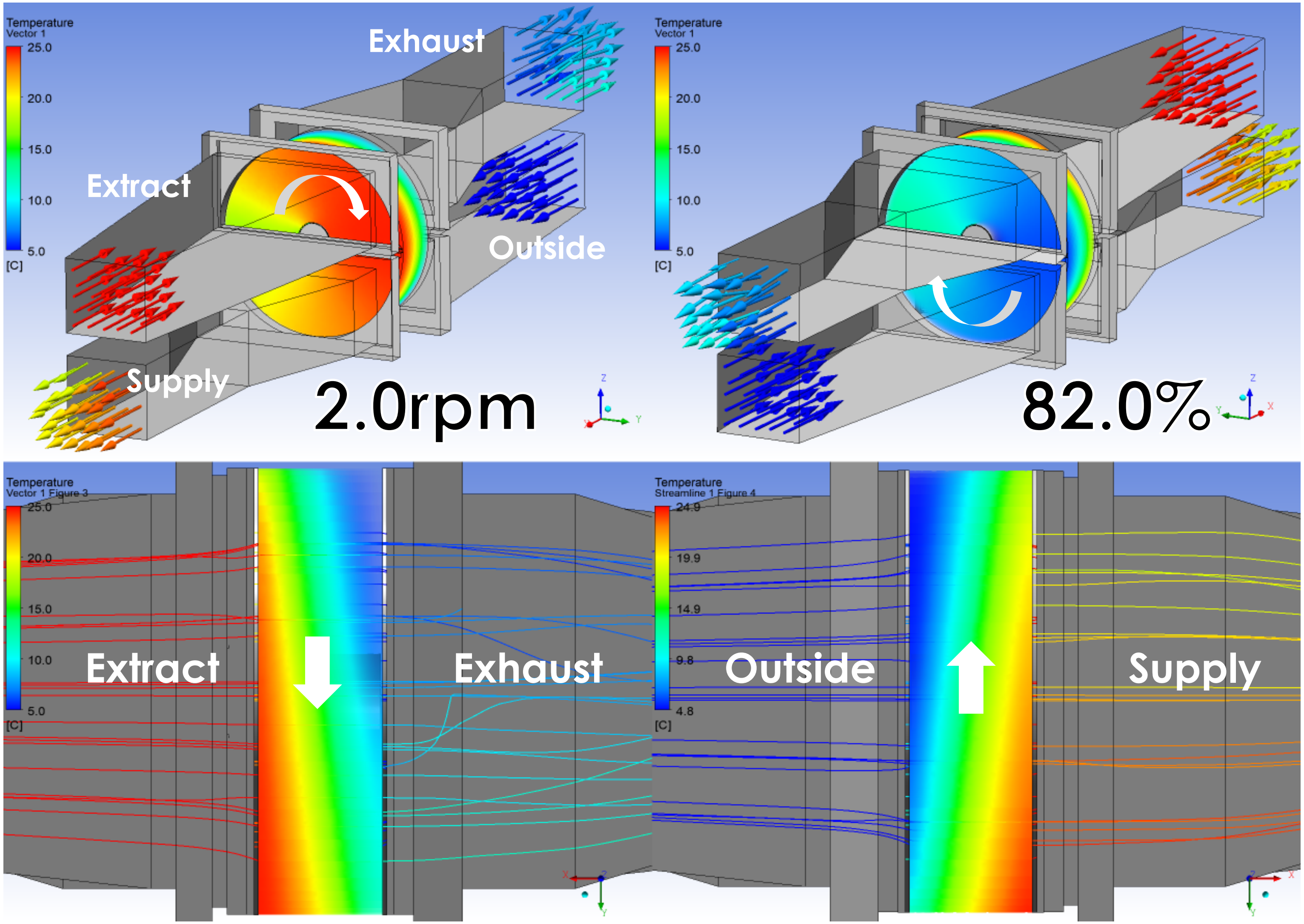

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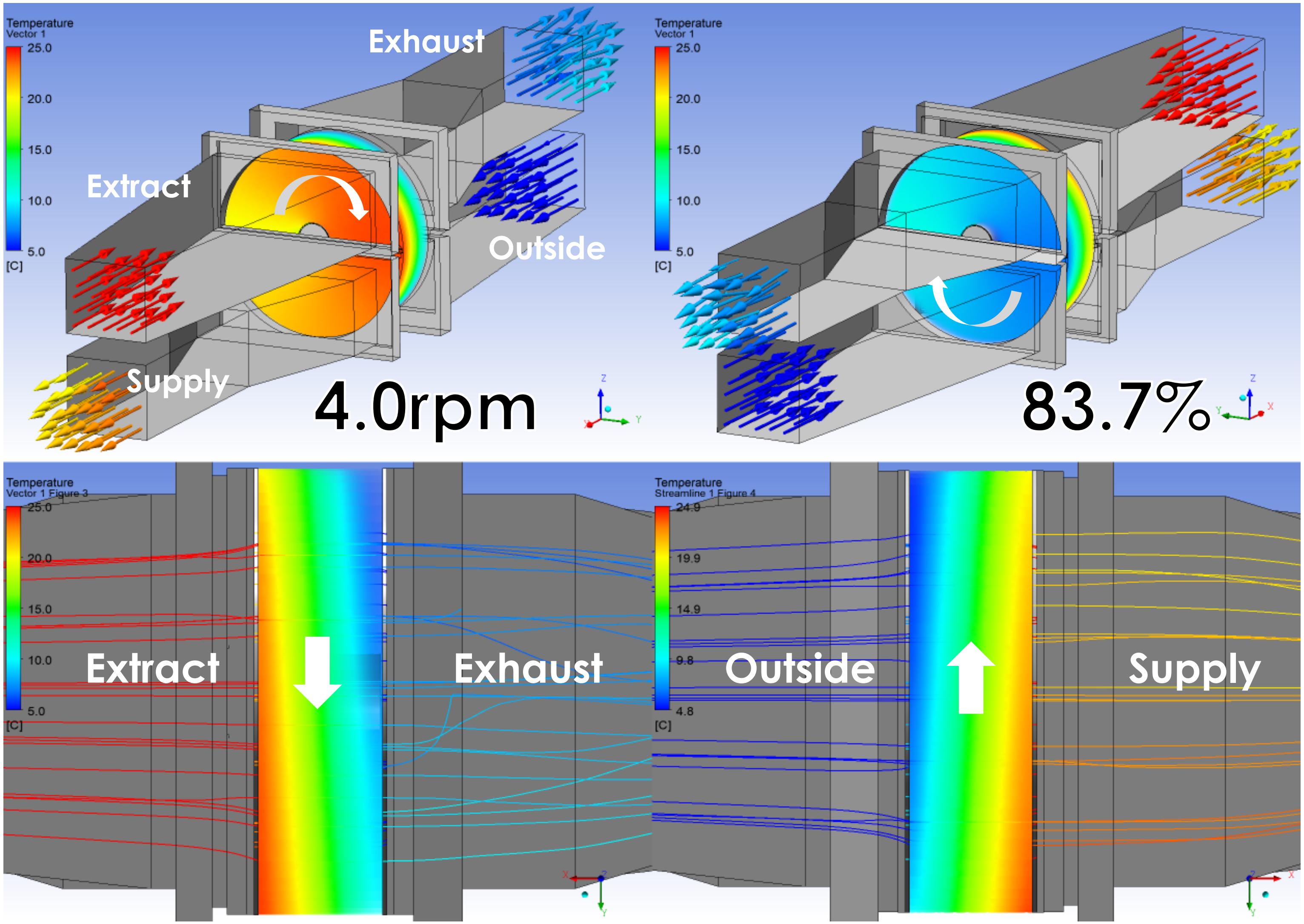

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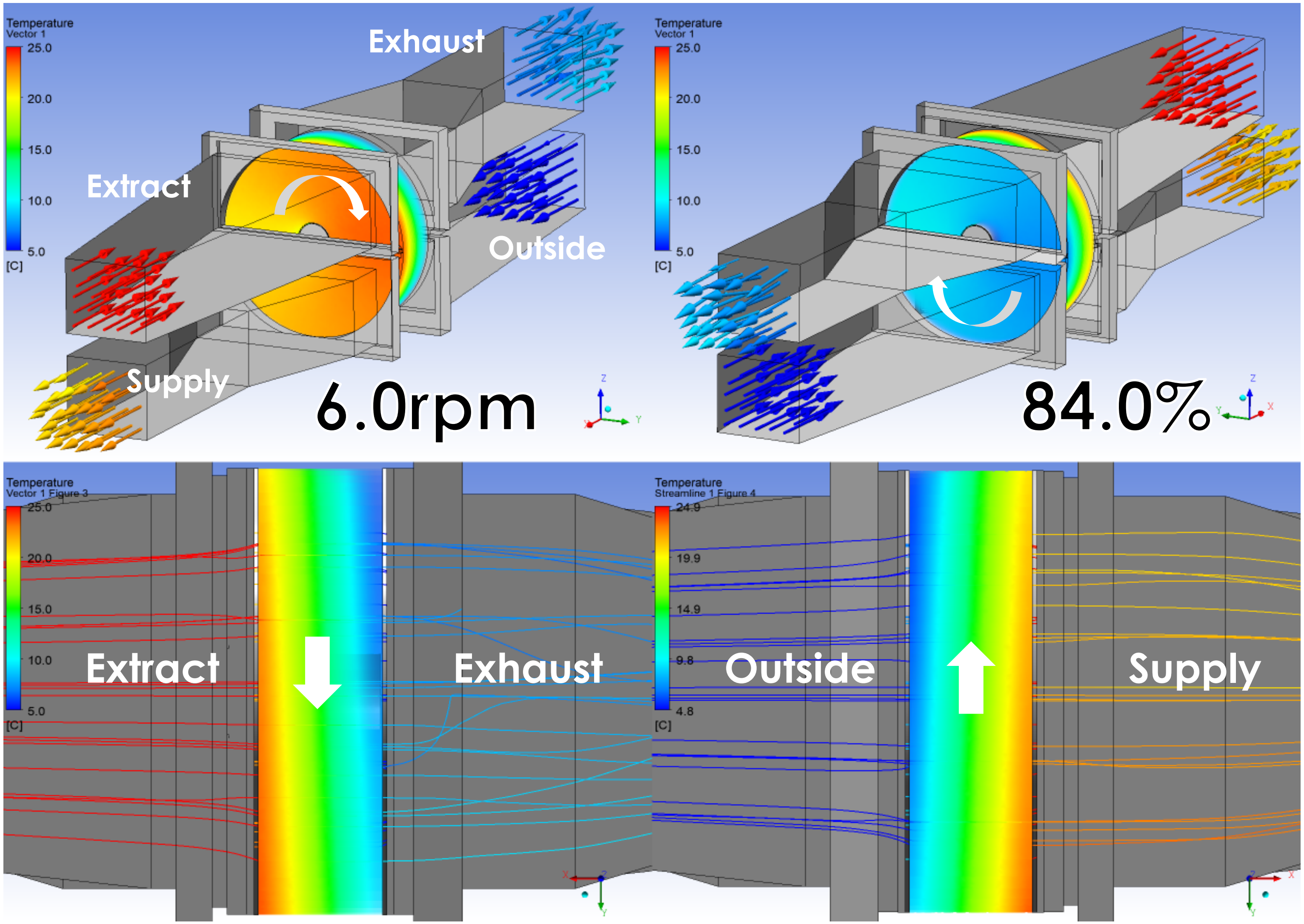
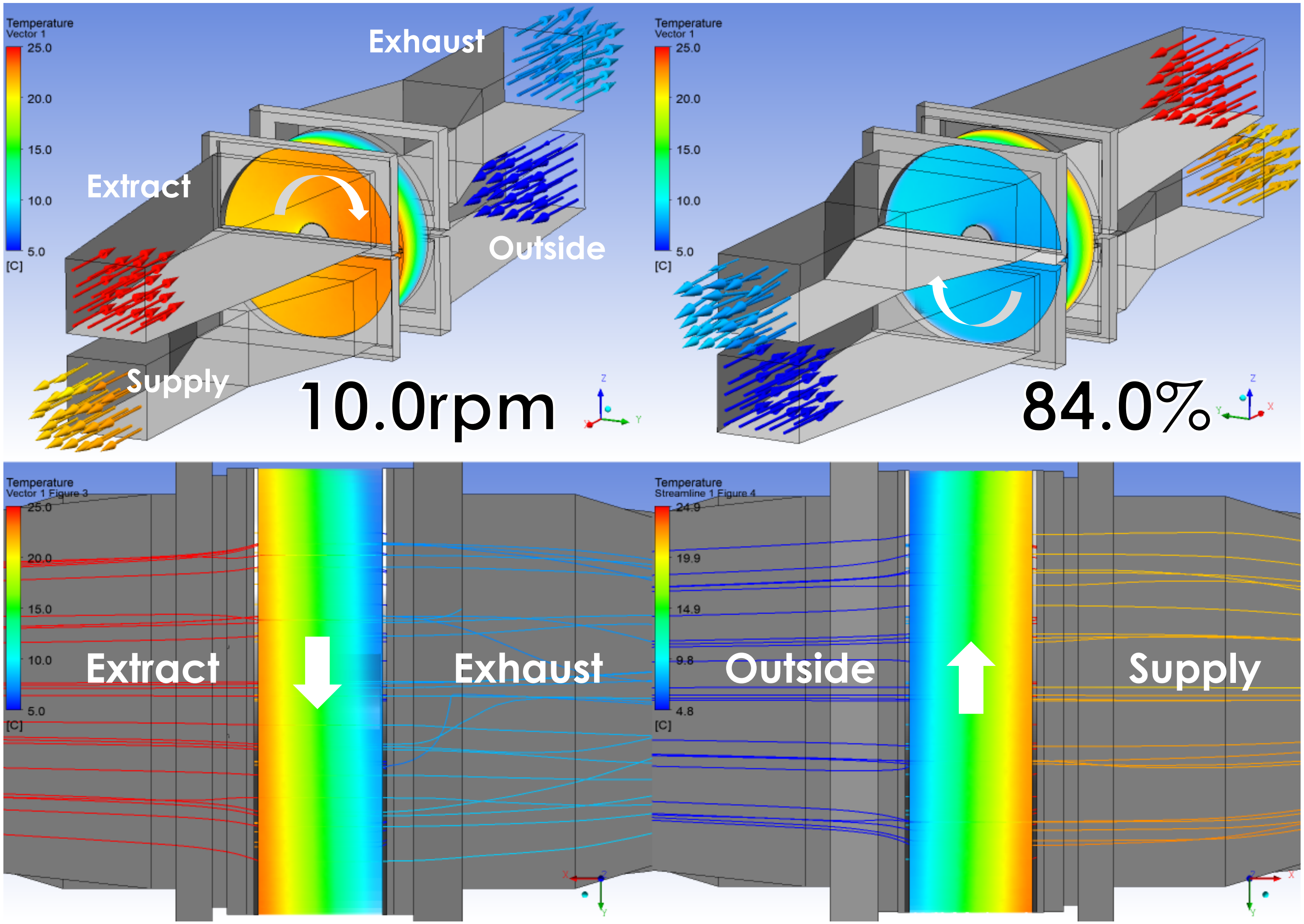
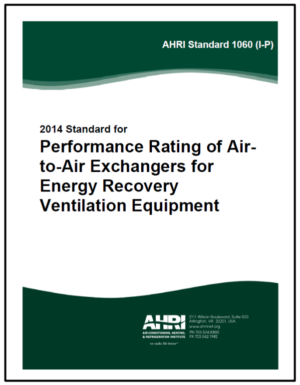
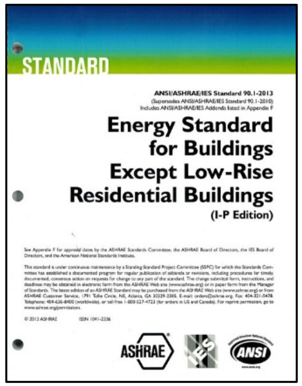
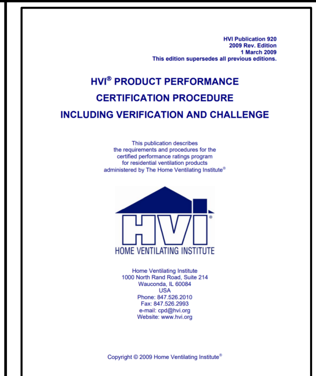


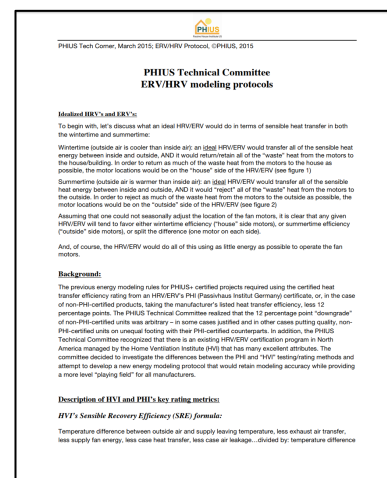
VENTILATION UNIT – WHEEL TYPE



RECOVERY EFFECTIVENESS
Different standards, different results

AHRI	ASHRAE	PHI	PHIUS	HVI
		CERTIFIED COMPONENT Passive House Institute	PHIUS Certified Ventilation Product	
$\varepsilon = cfmsa(Xoa - Xsa) / cfmmin(Xoa - Xra)$	$\varepsilon = (Xoa - Xsa) / (Xoa - Xra)$	$\varepsilon = (Xra - Xea) + (Pel / m \cdot cp) / (Xra - Xoa)$	$E_{SHR} = \frac{\left[\sum_{i=1}^{n} M_{si} \times C_p (t_{5i} - t_{1i}) \times \Delta\Theta\right] - Q_{SF} - Q_{SH} - Q_C - Q_D - Q_L}{\left[\sum_{i=1}^{n} M_{max,i} \times C_p (t_{3i} - t_{1i}) \times \Delta\Theta\right] + Q_{EF} + Q_{EH}}$	

- Specify the project HRV/ERV modeling protocol
- Specify the reference HRV/ERV test method / standard use
- Possible penalties for relying on wrong standard



PHIUS Tech Corner, March 2015; ERV/HRV Protocol, ©PHIUS, 2015

PHIUS Technical Committee
ERV/HRV modeling protocols

Idealized HRV's and ERV's:

To begin with, let's discuss what an ideal HRV/ERV would do in terms of sensible heat transfer in both the wintertime and summertime:

Wintertime (outside air is cooler than inside air): an ideal HRV/ERV would transfer all of the sensible heat energy between inside and outside, AND it would return/retain all of the "waste" heat from the motors to the house/building. In order to return as much of the waste heat from the motors to the house as possible, the motor locations would be on the "house" side of the HRV/ERV (see figure 1)

Summertime (outside air is warmer than inside air): an ideal HRV/ERV would transfer all of the sensible heat energy between inside and outside, AND it would "reject" all of the "waste" heat from the motors to the outside. In order to reject as much of the waste heat from the motors to the outside as possible, the motor locations would be on the "outside" side of the HRV/ERV (see figure 2)

Assuming that one could not seasonally adjust the location of the fan motors, it is clear that any given HRV/ERV will tend to favor either wintertime efficiency ("house" side motors), or summertime efficiency ("outside" side motors), or split the difference (one motor on each side).

And, of course, the HRV/ERV would do all of this using as little energy as possible to operate the fan motors.

Background:

The previous energy modeling rules for PHIUS+ certified projects required using the certified heat transfer efficiency rating from an HRV/ERV's PHI (Passivhaus Institut Germany) certificate, or, in the case of non-PHI-certified products, taking the manufacturer's listed heat transfer efficiency, less 12 percentage points. The PHIUS Technical Committee realized that the 12 percentage point "downgrade" of non-PHI-certified units was arbitrary – in some cases justified and in other cases putting quality, non-PHI-certified units on unequal footing with their PHI-certified counterparts. In addition, the PHIUS Technical Committee recognized that there is an existing HRV/ERV certification program in North America managed by the Home Ventilation Institute (HVI) that has many excellent attributes. The committee decided to investigate the differences between the PHI and "HVI" testing/rating methods and attempt to develop a new energy modeling protocol that would retain modeling accuracy while providing a more level "playing field" for all manufacturers.

Description of HVI and PHI's key rating metrics:

HVI's Sensible Recovery Efficiency (SRE) formula:

Temperature difference between outside air and supply leaving temperature, less exhaust air transfer, less supply fan energy, less case heat transfer, less case air leakage…divided by: temperature difference

PART 3

COOLING WITH THE VENTILATION UNIT

VENTILATION AIR AS A LOAD

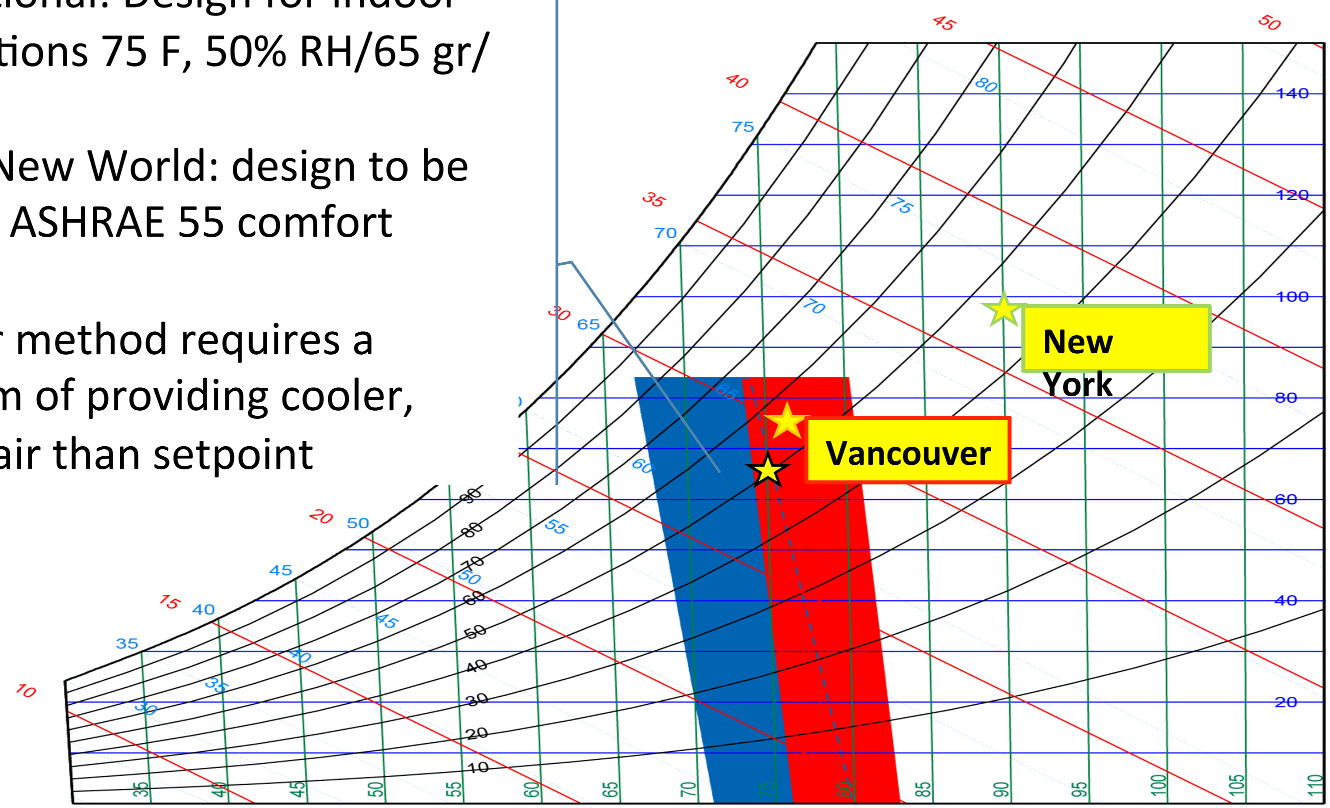
VENTILATION AIR AS LOAD Summer – ventilation air must be delivered free of excess humidity and heat

- 55°F (12.8 °C) is typical target to achieve mechanical dehumidification
- After mechanical dehumidification, Supply Air temperature *may* be too cold
- Dehumidification via ERV avoids overcooling, saves energy
- Use ERV heat rejection as first stage of cooling
- Integrate supplemental cooling (DX, chilled water, etc.) to avoid conflicting sequence of operations

ASHRAE Standard 55 Comfort Zone

COOLING GOALS

- ☆ Traditional: Design for indoor conditions 75 F, 50% RH/65 gr/lb
- Bold New World: design to be in the ASHRAE 55 comfort range
- Either method requires a system of providing cooler, drier air than setpoint



Outside Air	Temperature drybulb	Humidity Ratio
Vancouver ☆	77°F	75 gr/lb
New York ☆	90°F	95 gr/lb

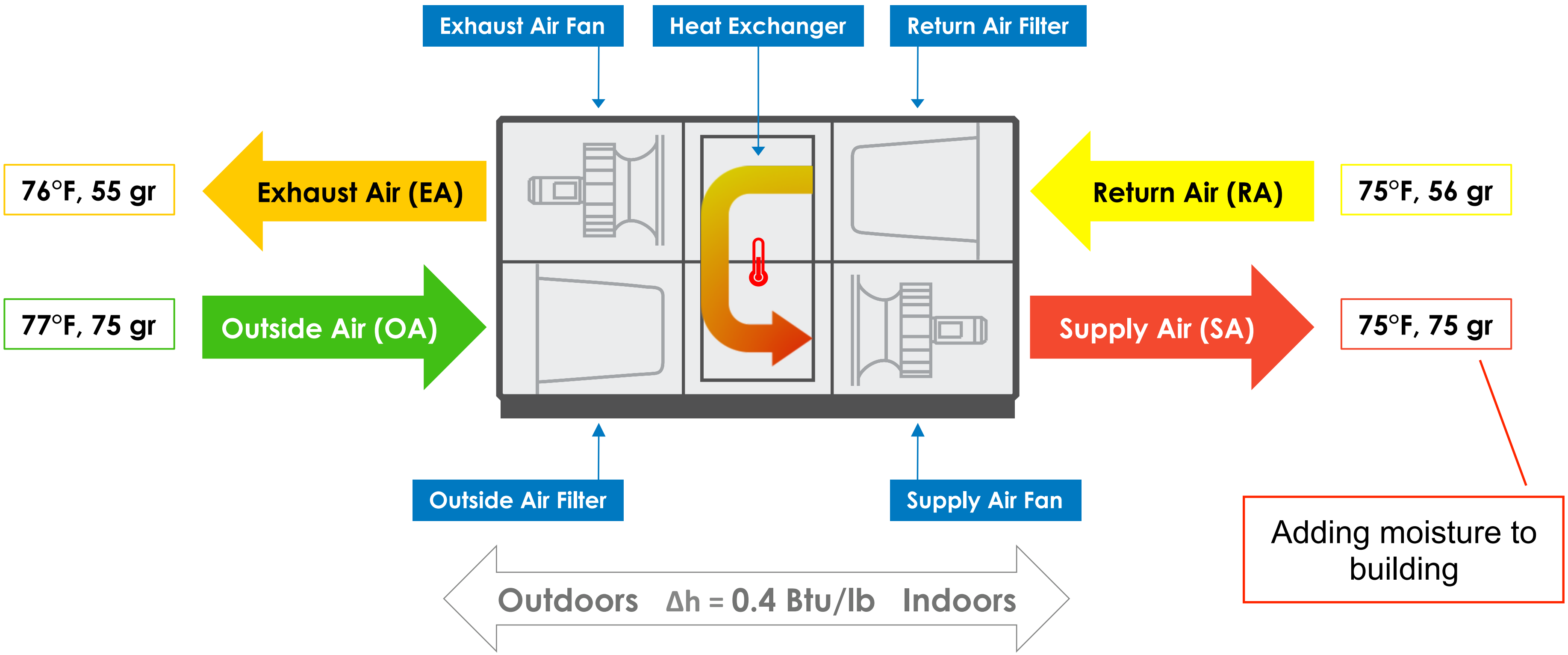
0.5 clo

1.0 clo

HEAT vs. TOTAL ENERGY RECOVERY

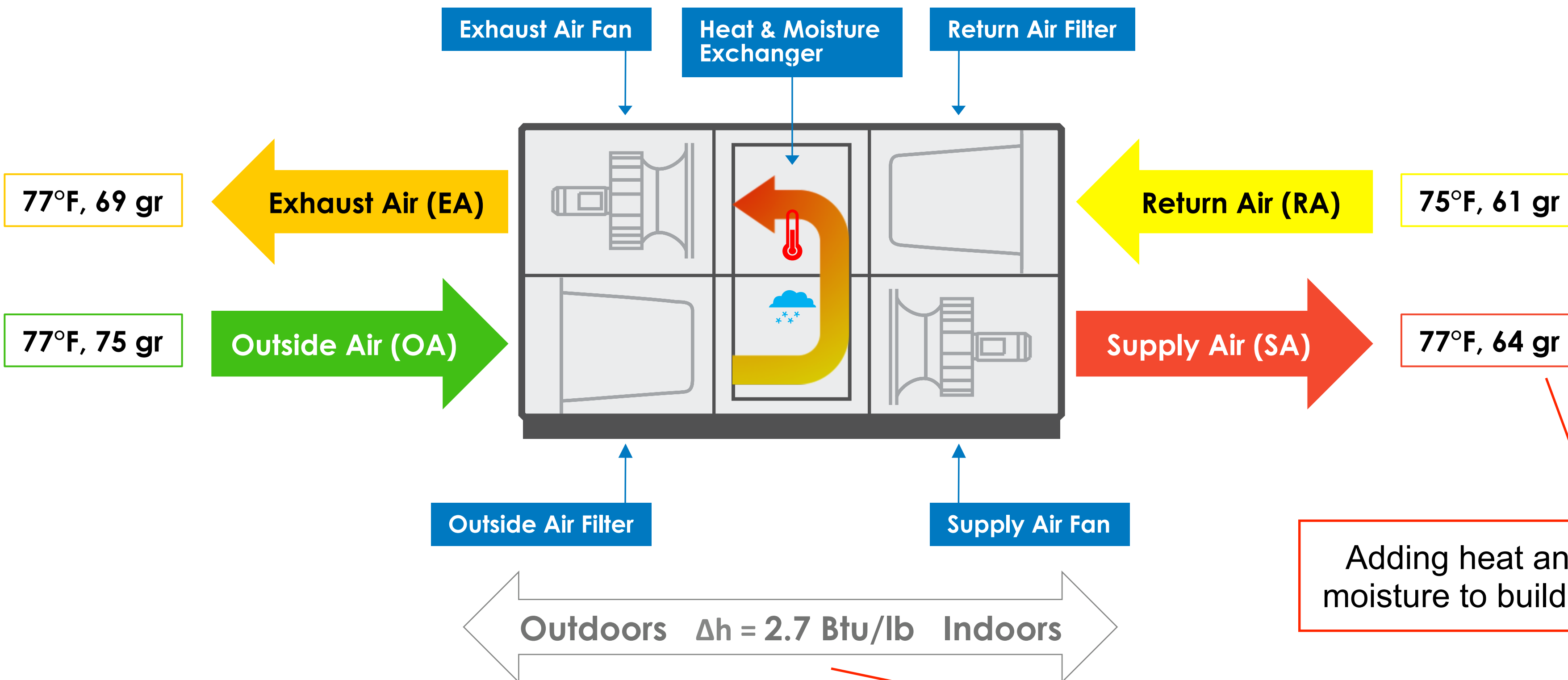
- Whether to use heat or total energy recovery for summer will depend on
  - the climate zone
  - The big picture summer vs winter vs shoulder
- Heat recovery devices (HRV) provide heat rejection only
- Total recovery devices (ERV) provide heat and moisture rejection
- Mechanical cooling will likely be required with either type

SENSIBLE ENERGY VENTILATION UNIT (HRV alone)
SUMMER OPERATION – Vancouver example



Certified values:
- > 86% heat recovery (rejection) effectiveness
- > 0.32 W/CFM electrical efficiency

TOTAL ENERGY VENTILATION UNIT (ERV alone)
SUMMER OPERATION – Vancouver example



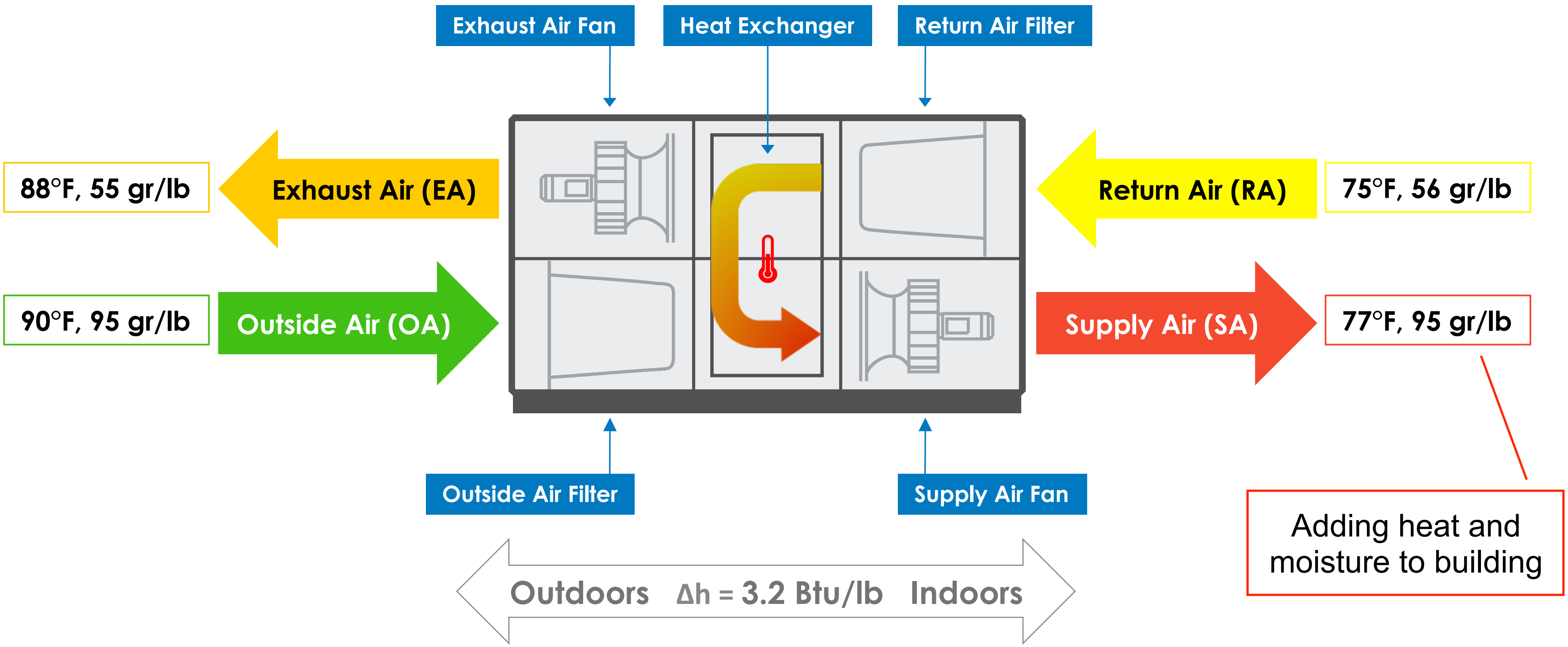
Adding heat and moisture to building

ERV provides 6x more cooling than HRV of same effectiveness

Certified values:

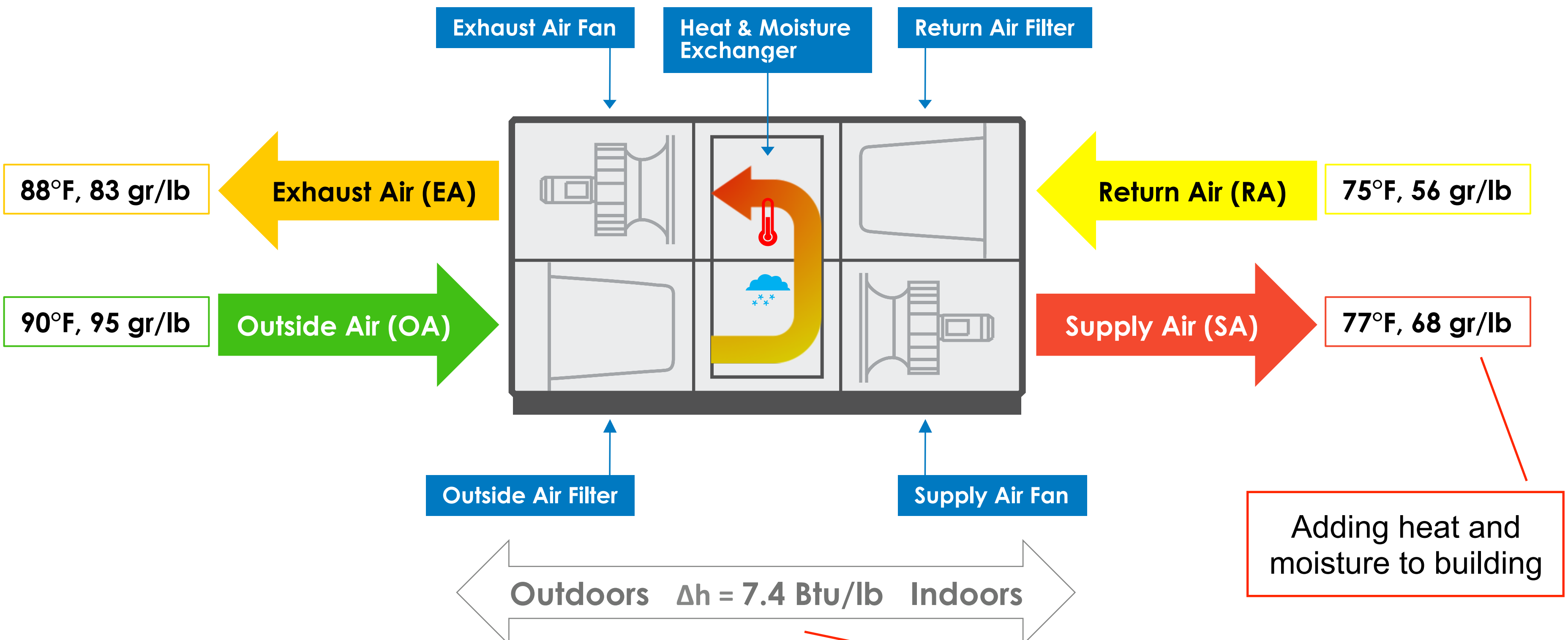
> 86% heat recovery (rejection) effectiveness
> 73% moisture recovery (rejection) effectiveness
> 0.32 W/CFM electrical efficiency

SENSIBLE ENERGY VENTILATION UNIT (HRV alone)
SUMMER OPERATION – New York City example



Certified values
> 86% heat recovery (rejection) effectiveness
> 0.32 W/CFM electrical efficiency

TOTAL ENERGY VENTILATION UNIT (ERV alone)
SUMMER OPERATION - New York City example



Certified values
- 86% heat recovery (rejection) effectiveness
- 68% moisture recovery (rejection) effectiveness
- 0.32 W/CFM electrical efficiency

ERV provides 2.3x more cooling than HRV of same effectiveness

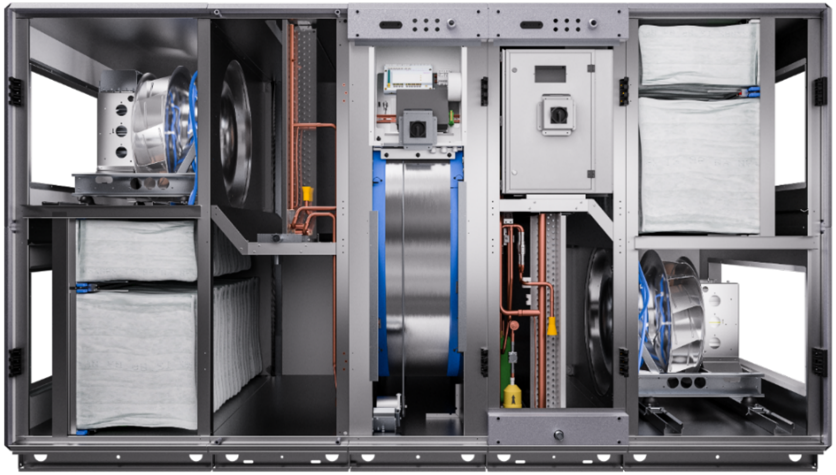
Cooling Sources

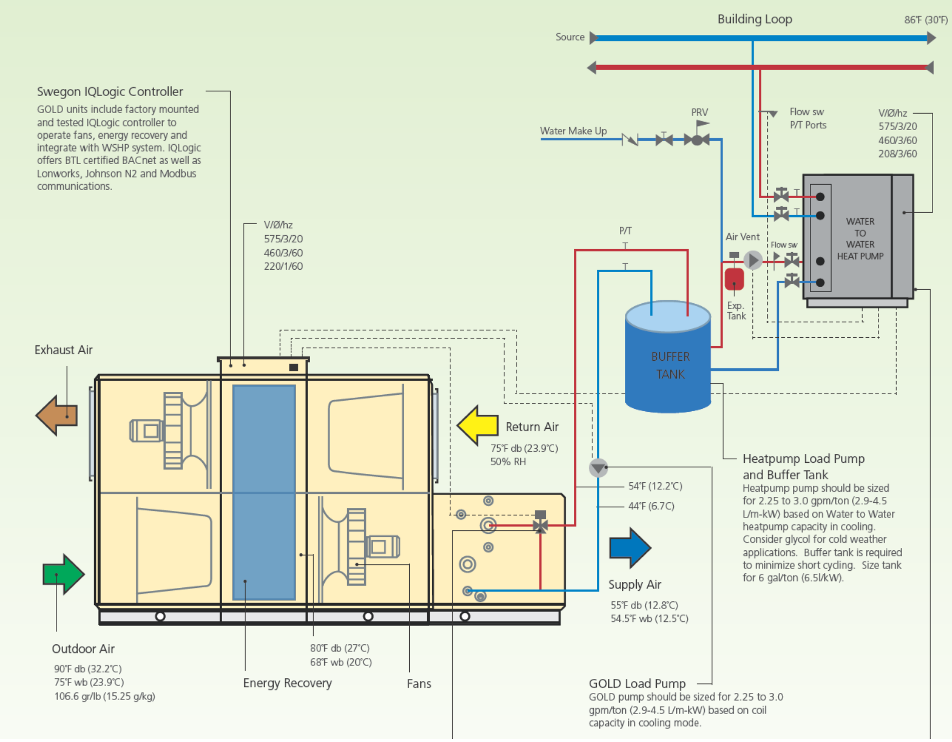
Chilled water (**CHW**)

- High efficiency chillers
- Geothermal
- Central Plant
- Water side free cooling
- Best control range due to modulating valve

Variable refrigerant flow (**VRF**)

- Heat pump
- Heat recovery
- Integration requires more engineering





Cooling Sources

Self contained DX

- Stand alone unit
- Heatpump

Heat Pump (WSHP or GSHP)

- Tied to building or ground loop
- Heating and cooling

Cooling Distribution

Active Chilled Beam

- Cools zone with ventilation air and chilled water
- Requires chiller plant
- Heat recovery and water side free cooling
- Common in NZB

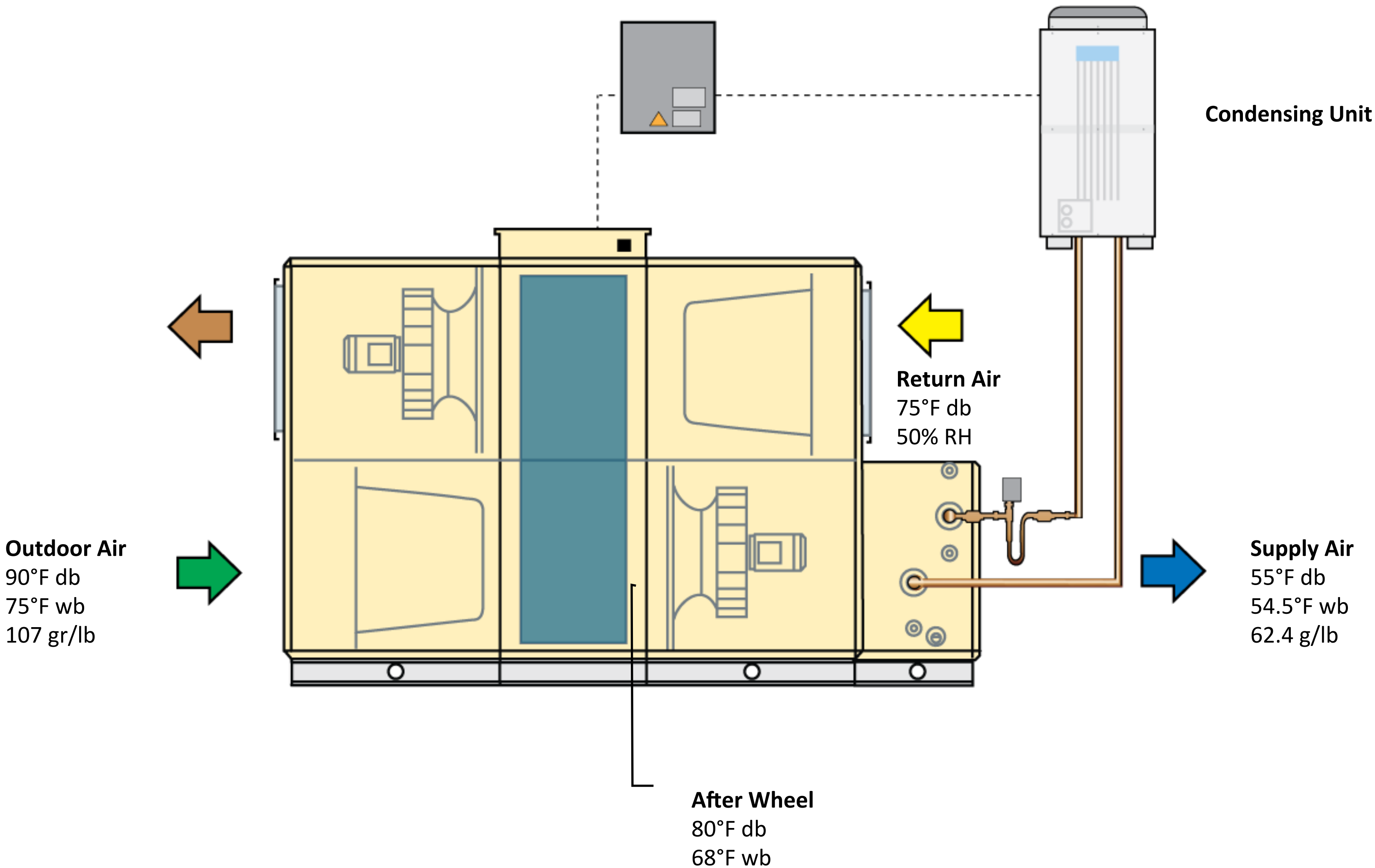
Fan Coil Unit

- Cools zone with ventilation air and chilled water
- Less efficient than chilled beams
- Rare in passive house buildings

Diffusers

- Cooled air direct to zone
- Vary airflow to control cooling

Example: ENERGY RECOVERY WITH SUPPLEMENTAL DX COOLING

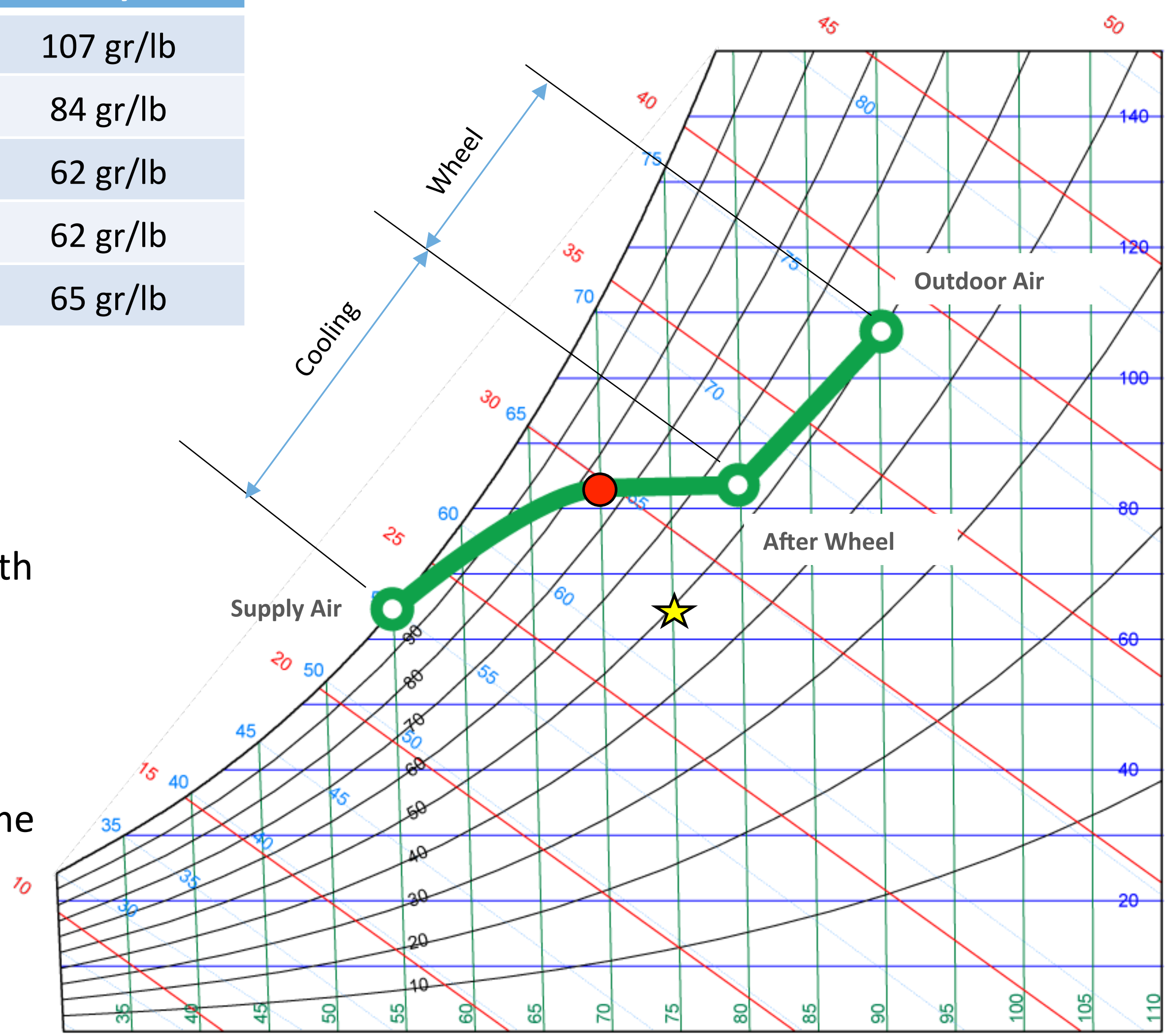


ENERGY RECOVERY WITH SUPPLEMENTAL COOLING

Air Path	Temperature $_{db}$	Humidity Ratio
Outside Air	90°F	107 gr/lb
After ER wheel	90°F	84 gr/lb
After DX coil	54°F	62 gr/lb
At supply diffuser	~54-55°F	62 gr/lb
Room setpoint	75°F	65 gr/lb

54°F supply air

- can overcool, or
- results in occupant comfort, if:
  - Air outlets are applied with precision
  - Air is ducted to terminal device
  - Zone control devices provide variable air volume

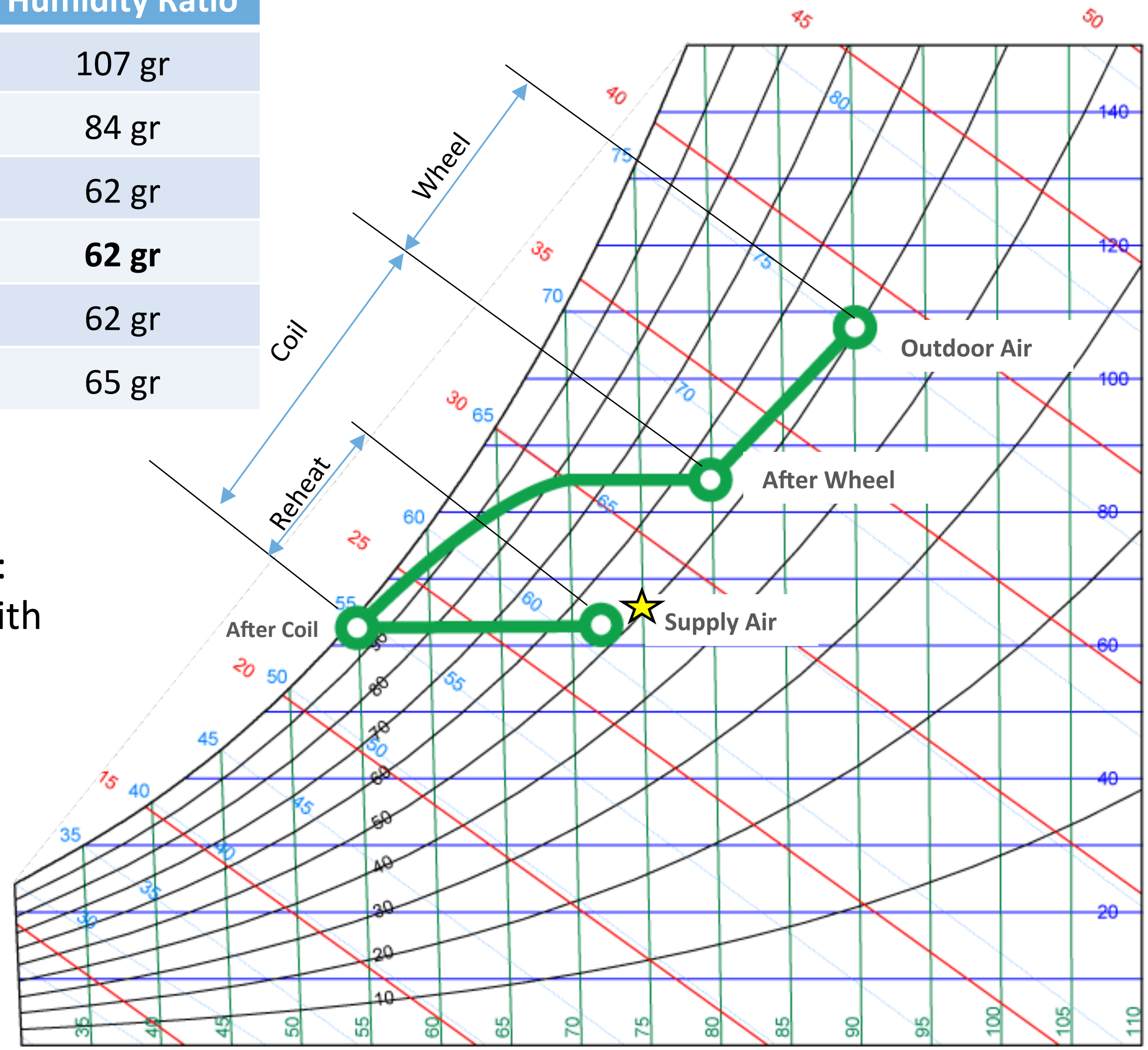


ENERGY RECOVERY WITH SUPPLEMENTAL COOLING AND REHEAT

Air Path	Temperature $_{db}$	Humidity Ratio
Outside Air	90°F	107 gr
After ER wheel	90°F	84 gr
After DX coil	54°F	62 gr
After reheat coil	**72°F**	**62 gr**
At supply diffuser	~72-73°F	62 gr
Room setpoint	75°F	65 gr

72°F supply air

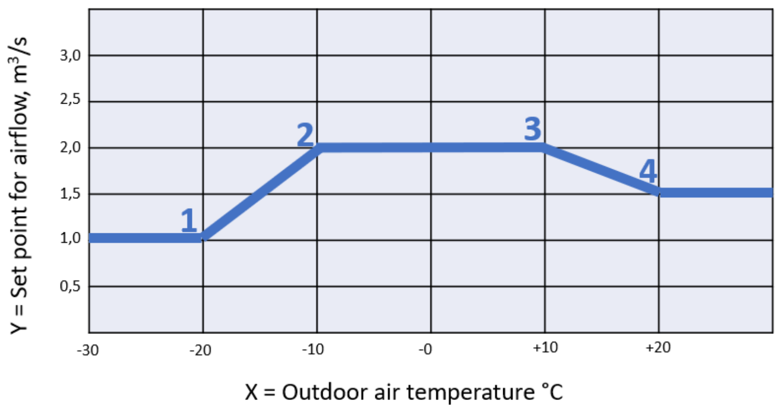
- neutral
- results in occupant comfort, if:
    - Air outlets are applied with precision
    - Air is ducted to terminal device
- Auxiliary terminal devices provide extra cooling.



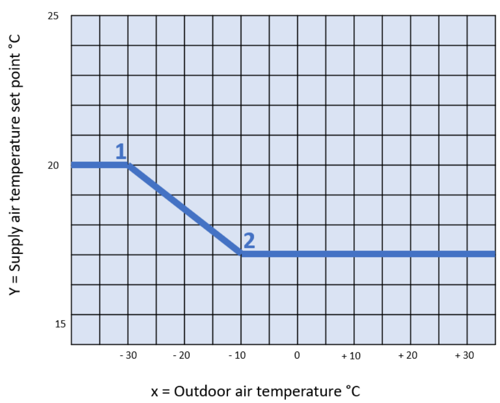
Use Controls to Get More Cooling

- BOOST flow to increase volume of cool air delivered
- LOWER air temperature is more efficient
  - When the indoor temperature is lower (Winter)

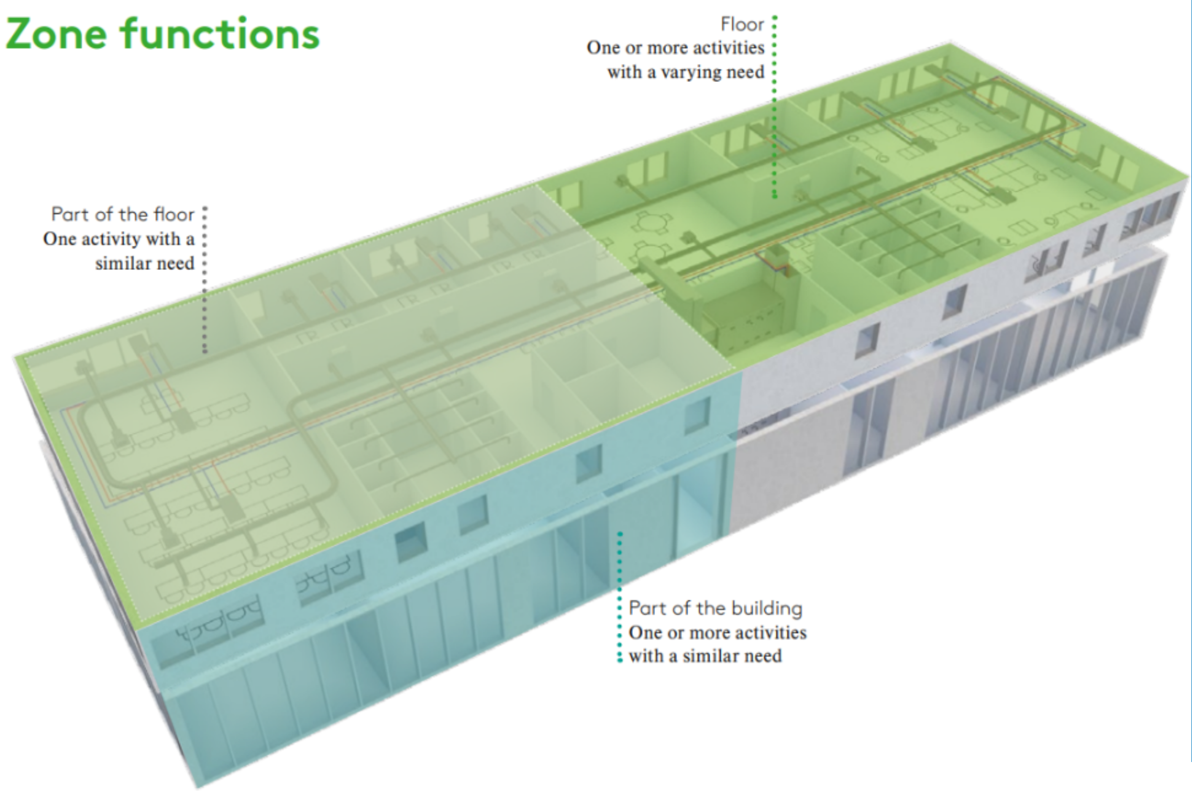
BOOST Air Flow



LOWER Supply Air Temperature

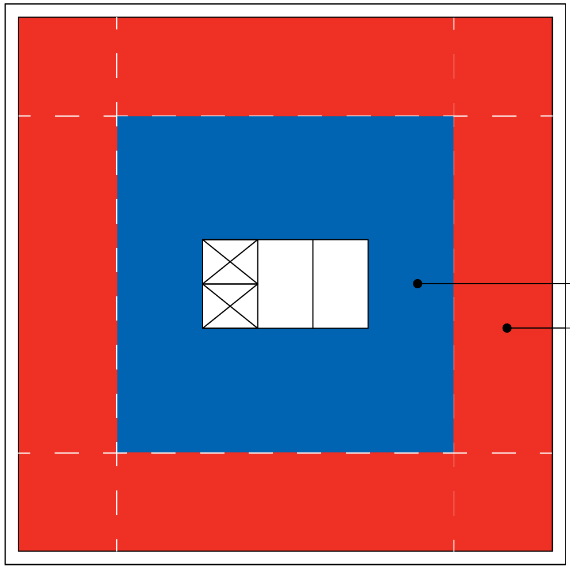


Space Temp. F	Supply Air Temp. F	Airflow Rate cfm/ft2	Sensible Cooling Btu/h-ft2
75	55	0.11	2.4
75	55	0.165	3.6
75	50	0.11	3.0
75	50	0.165	4.5
75	45	0.11	3.6
75	45	0.165	5.4
78	55	0.11	2.7
78	55	0.165	4.1
78	50	0.11	3.3
78	50	0.165	5.0
78	45	0.11	3.9
78	45	0.165	5.9



Real World: Unequal Use

- Vacant zones
- Time of use difference
- Occupancy level
- Use Demand Control Ventilation and Zoning to svoid over-ventilating

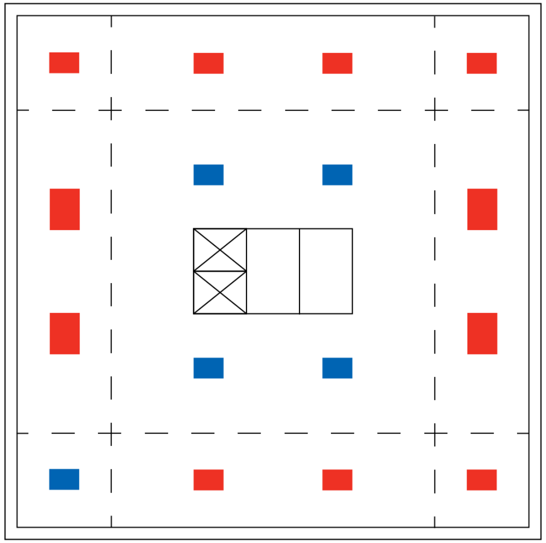


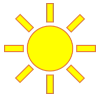
Example: Commercial

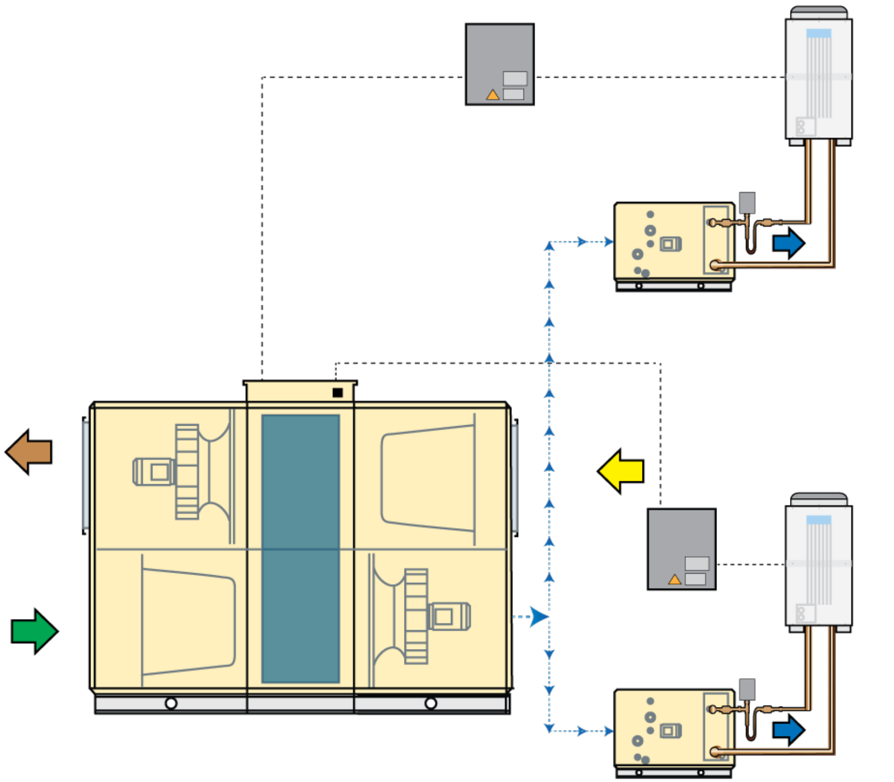
- Parameters
  - Sample floor: 20,000 ft^2
  - 145 ft by 145 ft
  - Passive House construction
  - Open floor plan
- Core and perimeter areas
- 45 °F outside air balance point
  - Above 45 °F, floor has net heat gain, cooling required
  - Perimeter zones may still need heat

Shoulder Season Strategy

- Supply Air: neutral or cooling)?
    - neutral (75°F) SA requires mechanical cooling in core year round
    - cooling (55°F) SA requires reheat at perimeter
- Strongly consider HVAC with heat recovery (VRF, WSHP, fan coil with HR chillers)







Zoning Ventilation Air

- Use a central ERV to recover as much energy as possible
- Use decentralized heating/ cooling sections to temper air as required
    - Core gets cooling air
    - Perimeter gets neutral air
    - Reset either zone based on time of year

COOLING with VENTILATION AIR SUMMARY

Ventilation air is a cooling load

Need to get ventilation air to a neutral condition. Enthalpy wheels become more important in cooling (dehumidification)

Ventilation Air can be used to provide some free cooling during shoulder weather

Low balance point means shoulder weather happens sooner. By adjusting room temperature, supply air temperature and supply airflow, you can double the cooling effect. In shoulder weather, the energy penalty is only the fan work

Control Zone load in shoulder weather makes ventilation cooling more complex

The core and perimeter zones will behave differently making the control sequence more complex. Consider decentralized supplemental heating and cooling based on control zone needs.

PART 4

ENERGY MODELLING

ENERGY MODEL SETUP
HRV vs. ERV, NYC

Energy Recovery

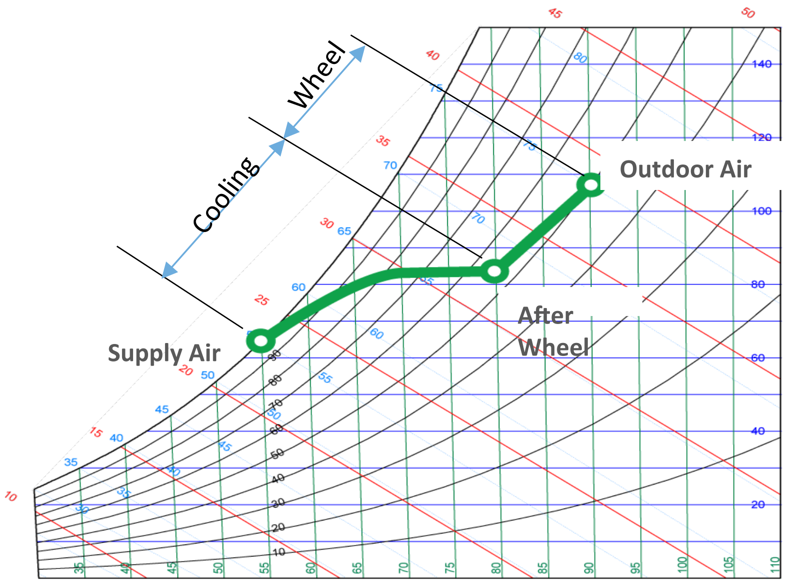
		System 1 Name	Total Recovery	System 2 Name	Sensible Recovery
Energy Recovery Type			Enthalpy Wheel		Sensible Wheel
Sensible Efficiency	%	82	86	82	86
Latent Efficiency	%	78	68	N/A	0
Purge	%	0.50	0	0.50	0
Frost Control Type			Exhaust Air DryBulb Control		Exhaust Air DryBulb Control

Fan Data

Supply Air Flow	cfm	500-16000	5000	500-16000	5000
Return Air Flow	cfm	500-16000	5000	500-16000	5000
Supply Fan Type		EC Fan	EC Fan	FC DWDI Fan	EC Fan
Supply Fan Efficiency	%	67	67	67	67
Supply Air TSP	"wc	4.0	4	4.0	4
Return Fan Type		EC Fan	EC Fan	FC DWDI Fan	EC Fan
Return Fan Efficiency	%	67	67	67	67
Return Air TSP	"wc	2.5	2.5	2.5	2.5
Airflow Control			Constant Volume		Constant Volume
Filter Type			MERV 13-15		MERV 13-15

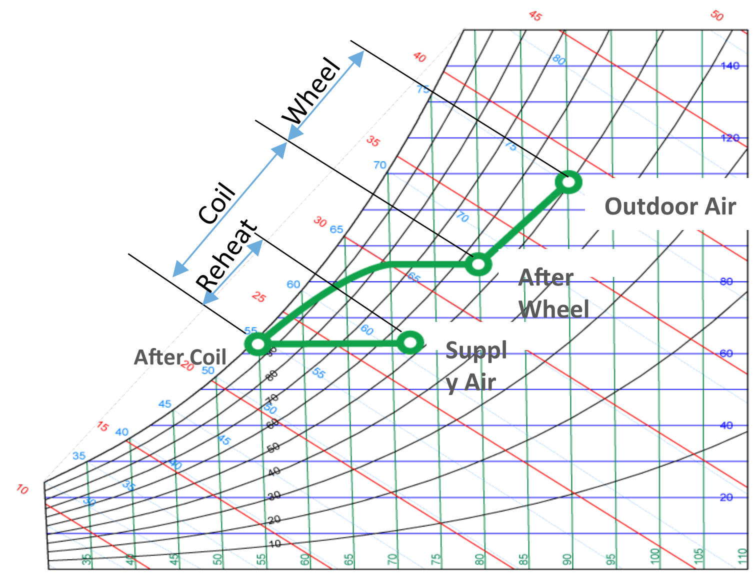
MODEL SETUP -

Scenario 1- No Reheat



55°F SAT

Scenario 2- Hot Gas Reheat



70°F SAT

ENERGY MODEL RESULTS
New York City - 55°F Cooling

Energy Recovery Savings

		System 1 Name	Total Recovery	System 2 Name	Sensible Recovery
Energy Recovery Type			Enthalpy Wheel		Sensible Wheel
Outdoor Air Energy Load	kBtu		907,940		908,327
Annual Recovered Energy	kBtu		575,327		455,906
Remaining System Load	kBtu		426,340		452,422
ASHRAE Std 90.1-2016 Compliant			Pass		Fail - Fan Power Limitationl
ASHRAE Std 189.1 Compliant			Pass		Fail - Fan Power Limitation

Unit Energy Consumption

		System 1 Name	Total Recovery	System 2 Name	Sensible Recovery
Fan Energy Usage	kWh		55,184		55,114
Rotor Motor Energy Usage	kWh		747		747
Cooling Energy Usage	kWh		27,479		30,456
Heating Energy Usage	kWh		311		311
Humidifier Energy Usage	kWh		0		0
Total Energy Usage	kWh		83,721		86,629

New York

Case 1: SAT = 55 F, 5000 CFM

- Sensible wheel unit (HRV) consumes 10.8% more electricity for cooling annually than total energy unit (ERV)
- HRV requires 30% more VRF cooling capacity than ERV
- All required heating is provided by recovered heat

	Total cooling required(tons)	Energy recovery cooling (tons)	Mechanical cooling remaining (tons)	Annual cooling energy (kWh)
HRV	**31.8**	7	24.8	30,456
ERV	**31.8**	12.6	19.2	27,479

New York City - SCENARIO 2- 55°F Cooling, Hot Gas Reheat

Energy Recovery Savings

		System 1 Name	Total Recovery	System 2 Name	Sensible Recovery
Energy Recovery Type			Enthalpy Wheel		Sensible Wheel
Outdoor Air Energy Load	kBtu		1,341,884		1,342,344
Annual Recovered Energy	kBtu		952,162		784,800
Remaining System Load	kBtu		532,116		557,544
ASHRAE Std 90.1-2016 Compliant			Pass		Fail - Fan Power Limitationl
ASHRAE Std 189.1 Compliant			Pass		Fail - Fan Power Limitation

Unit Energy Consumption

		System 1 Name	Total Recovery	System 2 Name	Sensible Recovery
Fan Energy Usage	kWh		54,446		54,377
Rotor Motor Energy Usage	kWh		747		747
Cooling Energy Usage	kWh		26,515		29,408
Heating Energy Usage	kWh		16,515		16,522
Humidifier Energy Usage	kWh		0		0
Total Energy Usage	kWh		98,224		101,054

New York

Case 2: SAT = 70 F, 5000 CFM +hot gas reheat

- Sensible unit (HRV) consumes 10.9% more electricity for cooling annually than total energy unit (ERV) (=case 1)
- HRV requires 30% more VRF cooling capacity than ERV (=case 1)
- Reheat coil adds 0.1" pressure drop but allows 70°F Supply air temperature for no additional energy cost

	Total cooling required(tons)	Energy recovery cooling (tons)	Mechanical cooling remaining (tons)	Annual cooling energy (kWh)
HRV	**31.8**	7	24.8	29, 408
ERV	**31.8**	12.6	19.2	26, 515

ENERGY MODELLING SUMMARY

Climate is Critical

ERV saves energy and requires less VRF cooling capacity in New York

ERV required to meet Std 90.1 in New York

ERV offers little benefit relative to HRV in Vancouver

Where Climate supports ERV use, savings may be substantial

In New York City, total energy recovery offers 4 times cooling savings over sensible cooling

Capital cost may be reduced due to smaller VRF condensing units

PART 5

SUMMARY

SUMMARY

Passive House Envelope Performance provides extra savings opportunities

Low balance point in Passive House results in greater free cooling availability.

Leverage close coupled room and mean radiant temperatures to maximize energy savings by widening room temperature set point range

Ventilation System Can help (or hurt) cooling design

Ventilation is a larger percentage load in PH projects. Make ventilation unit as efficient as possible.

Leverage ventilation system for free cooling. Optimize SAT to maximize energy savings summer and winter.

Always consider climate and the season

In New York City a total energy recovery system recovered 400% more cooling than a sensible system. In Vancouver, savings may be negligible.

Consider heating, cooling and shoulder season performance.

Thank you!