BUILDINGENERGY BOSTON

Passive House Ventilation:

Humidity Considerations in Multi-Family Residential

August 13, 2020 · 3:00 pm

Presenter:

Mike Woolsey, Certified Passive House Designer
(Swegon)

Course Description

Passive House buildings and their occupants benefit from airtight construction. Infiltration and exfiltration are minimized, directly reducing energy used to ventilate, heat, and cool the building. Occupants benefit from the elimination of drafts and warmer indoor surface temperatures. Airtight construction also hinders airborne indoor moisture from escaping the building through the building skin, or from dry outdoor air infiltrating the building. Multifamily residential projects are at greater risk of moisture buildup due to the way spaces are used. This course examines causes of and solutions to humidity buildup in Passive House buildings.

Learning Objectives

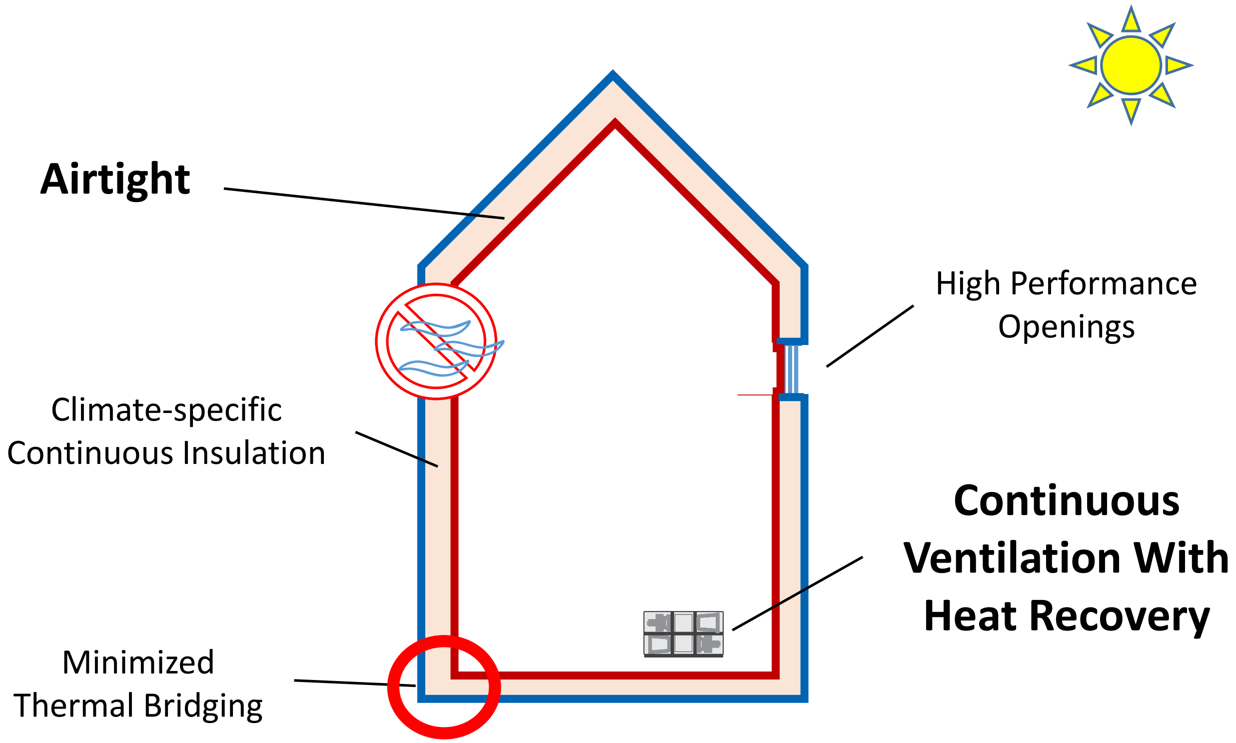
At the end of this program, participants will be able to understand:

1. the impact of airtight construction on moisture control
2. indoor humidity sources and interactions
3. ventilation system influence on indoor humidity
4. tradeoffs between humidity control and energy savings

PART 1

Air-tight Construction and Indoor Moisture

PASSIVE HOUSE CHARACTERISTICS



AIRTIGHT CONSTRUCTION
Saves Energy - Requires Continuous Ventilation

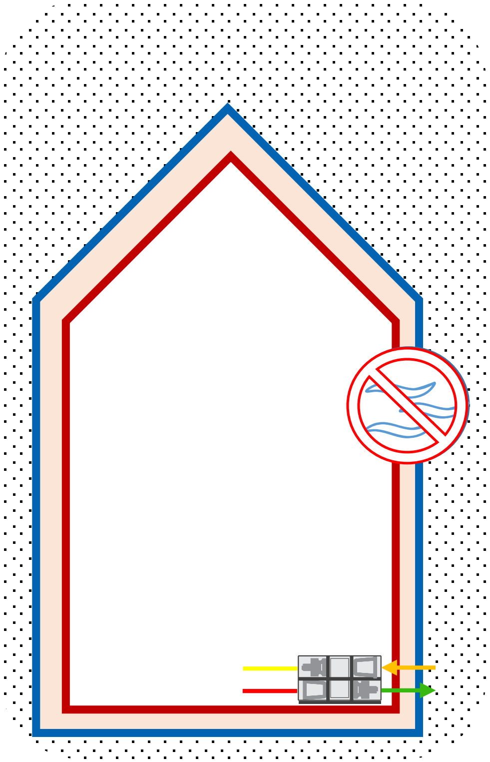


Photo courtesy of Rockwool

Airtight layer

- **saves energy** by minimizing infiltration of unconditioned air, and exfiltration of conditioned air
- **improves comfort** by reducing draftiness, enhancing insulation performance and keeping fine airborne particles outside
- ***traps moisture*** and contaminants

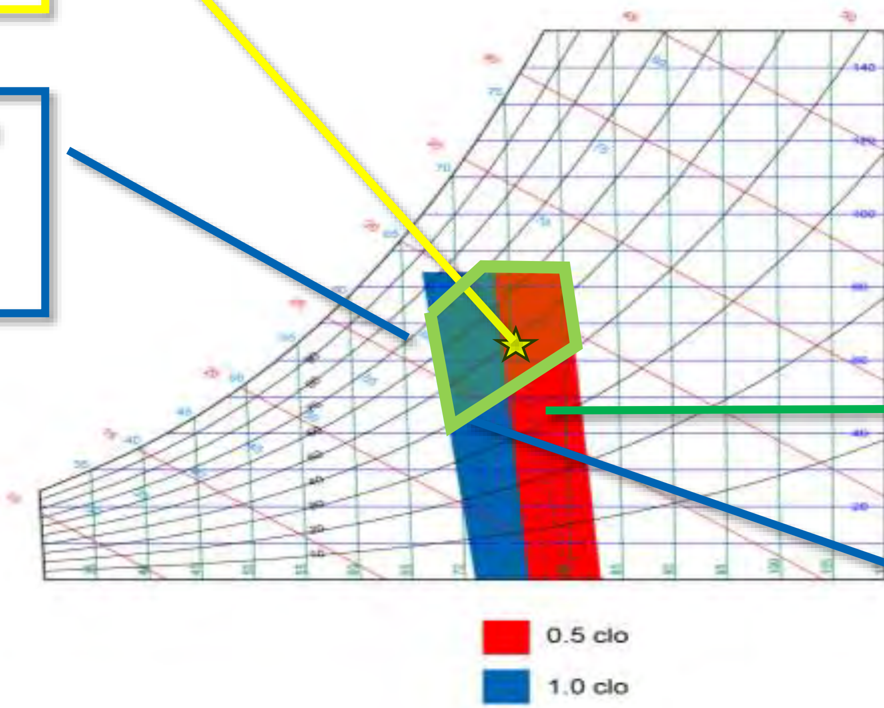
Continuous ventilation

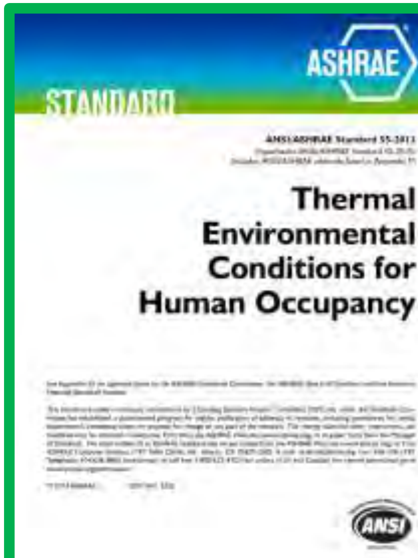
- Replaces moist and contaminated air with **conditioned fresh air**

INDOOR HUMIDITY
for comfort, health, resilience

Traditional indoor comfort design target "Setpoint"

60% Maximum RH Goal for building resilience

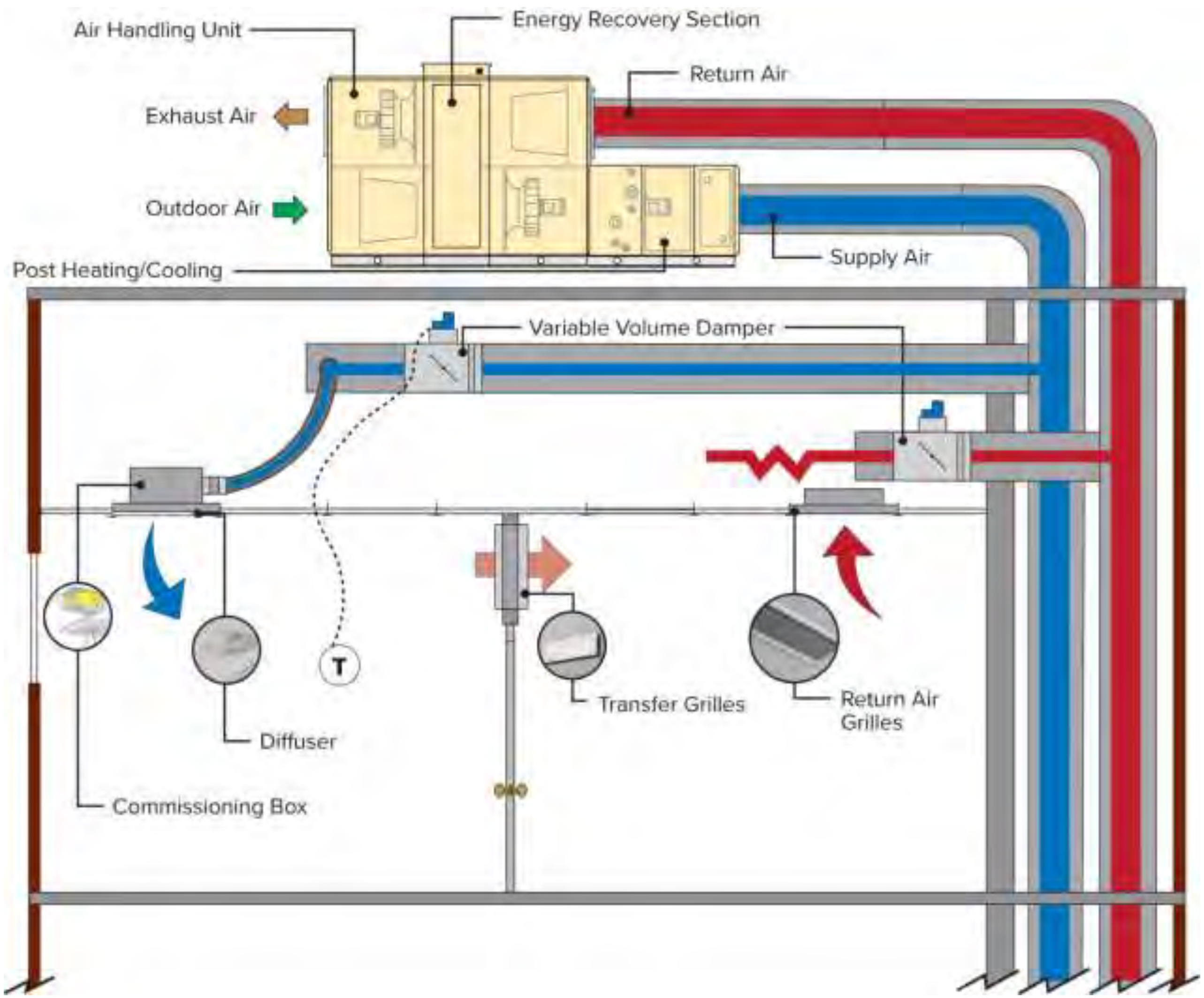




ASHRAE 55 Comfort target range

40% Minimum RH Goal of for human health

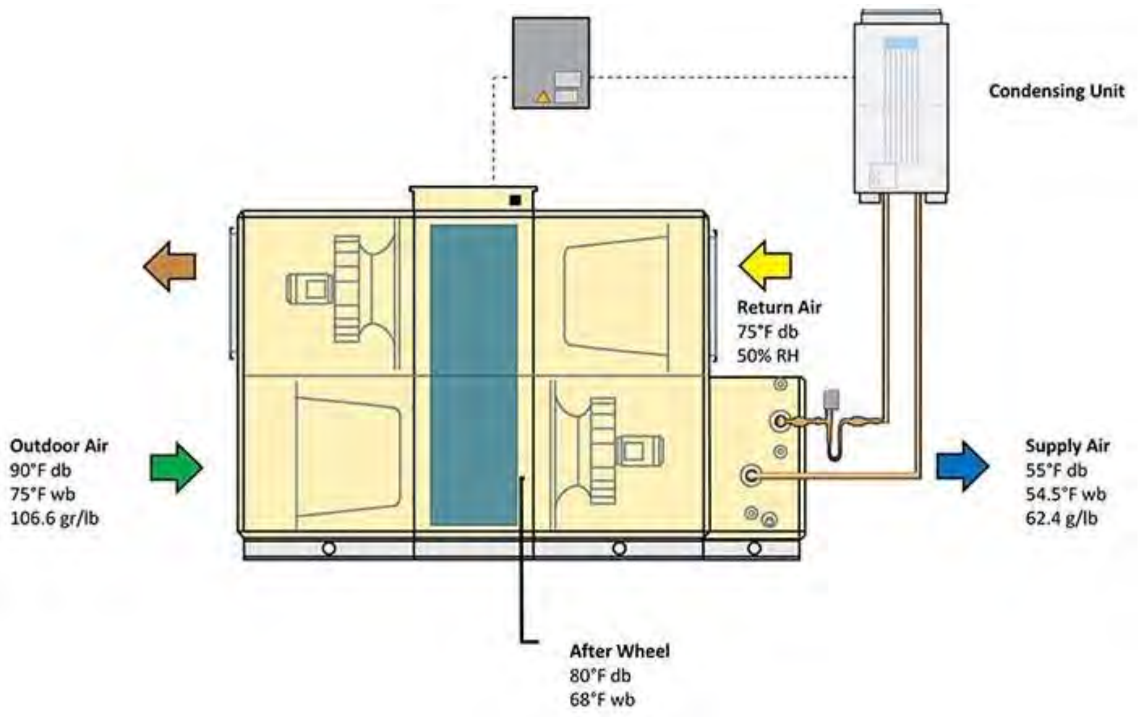
PASSIVE HOUSE VENTILATION SOLUTION
Typical Multifamily Residence - Centralized



PASSIVE HOUSE VENTILATION SOLUTION
Typical Multifamily Residence – as installed


Photo: ICF Builder Magazine

AIRTIGHT BUILDING
Summer – cooling



<u>Summer - High Outside Air Humidity</u>

- ✓ Energy Recovery system rejects outside air moisture
- ✓ Post-cooling system further removes moisture from Supply Air
- ✓ Moist Indoor Air continuously replaced by cool, dry air
- ✓ Indoor surfaces are warm, posing low condensation risk

AIRTIGHT BUILDING
Winter – heating

If the outside temperature is:	Then condensation will occur on the inner glass surface if the interior relative humidity rises above:	
° C (°F)	**Double Glazed Windows % of Humidity**	**Triple Glazed Windows % of Humidity**
-40 (- 40)	25	36
-34 (- 35)	28	39
-28 (- 20)	33	44
-23 (- 12)	38	48
-18 (0)	44	53
-12 (10)	50	63
-7 (20)	57	67
-1 (30)	63	72

Winter - Low Outside Air Humidity

- ✓ Outside Air contains little moisture
- ☒ RISK: Energy Recovery system may return building moisture to the building
- ☒ PASSIVE HOUSE RISK: Airtightness reduces moisture egress through building leaks and permeance
- ☒ PASSIVE HOUSE RISK: Airtightness prevent infiltration of dry air
- ☒ Surfaces are cool, more likely to condense than summer

PART 2

Indoor Humidity

Sources and Interactions

INDOOR HUMIDITY
Sources*

Liquid moisture	Gaseous moisture	(Solid)
Precipitation	Outdoor Air (summer)	Ice
Construction materials (concrete, mortar, plaster, etc)	Occupant Respiration and Perspiration	
Condensation	Occupant activities (cooking, showering, laundering, etc.)	
Deferred maintenance (pipe leaks, groundwater, envelope leaks)	Occupant possessions (houseplants, pets, firewood)	
*Source: 2017 ASHRAE Fundamentals, Chapter 36 Moisture Management in Buildings ASHRAE, Atlanta GA		

INDOOR HUMIDITY
Load Estimating Methods


STANDARD

ASHRAE

ANSI/ASHRAE Standard 160-2016
(Supersedes ANSI/ASHRAE Standard 160-2009)
Includes ANSI/ASHRAE addenda listed in Annex D

Criteria for Moisture-Control Design Analysis in Buildings

See Annex D for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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ANSI

4.3 Indoor Design Humidity. If the HVAC equipment and controls are included in the design, the intended design indoor humidity shall be used.

Required ERV Design Input Values

- ❑ Outside Air Temperature
- ❑ Outside Air Humidity
- ❑ Supply Air Temperature
- ❑ Supply Air Humidity
- ❑ Return Air Temperature*
- ❑ Return Air Humidity*

*Return Air conditions represent occupied zone conditions, are often assumed based on tradition and commercial buildings, and therefore deserve close review for Passive House projects

INDOOR HUMIDITY
Load Estimating Methods

Table 15.1 *Moisture production due to occupant breathing and sweating*

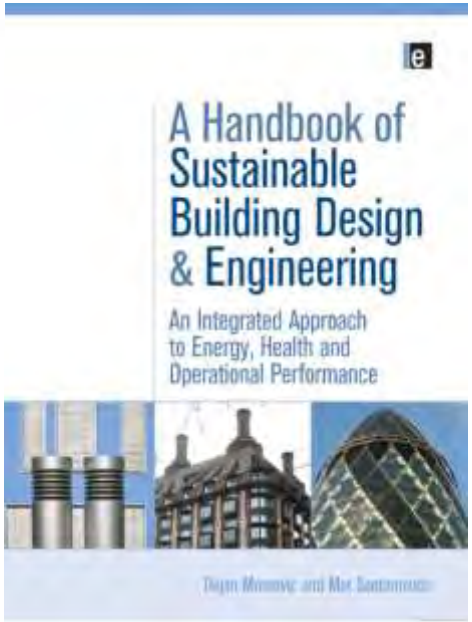
Author	Moisture production rate per person
BS5250	Asleep (40g/h) Awake (55g/h)
Annex 27	Adult asleep (30g/h) Adult awake (55g/h) Child asleep (12.5g/h) Child awake (40g/h)
HMSO (1970)	0.625kg/day
Finbow (1982)	0.752kg/day
BRE (1985)	Person asleep (0.25–0.5kg/day) Person active (0.75–1.5kg/day)
CIBSE (1986)	0.96–2.4kg/day
CIBSE (1999)	40–100g/h
Boyd et al (1988)	0.7475kg/day
Angell and Olson (1988)	1.26kg/day
Strum (1992)	1.44kg/day
Latiburek (1993)	65g/h
Hanson (2002)	180g/h
Tresch[illegible]	[illegible]
Rousse[illegible]	
Yik et [illegible]	
Pretlov[illegible]	

Table 15.2 *Moisture due to cooking*

Author	Moisture production rate per person
BS5250	Gas (3 kg/day) Electricity (2 kg/day)
Annex 27 (includes dishwashing)	Breakfast (50g/h) Lunch (150g/h) Dinner (300g/h)
HMSO (1970)	0.525kg/day
Finbow (1982)	0.6kg/day
BRE (1985)	0.5–1kg/day
CIBSE (1986, 1999)	0.9–3 kg/day
Boyd et al (1988)	Gas (3kg/day) Electricity (2kg/day)
Angell and Olson (1988)	Gas (1.35kg/day) Electricity (1.0kg/day)
Latiburek (1993)	Breakfast gas/electricity (520/200g/day) Lunch gas/electricity (300/680g/day)
Hanson (2002)	
Treschel (2001)	
Rousseau (1984)	
Pretlove (2000)	

Table 15.3 *Moisture due to washing clothes*

Author	Moisture production rate per dwelling
BS5250	0.5kg/day
Annex 27	0.2kg/day
HMSO (1970)	2.0kg/day
Finbow (1982)	1.0kg/day
BRE (1985)	0.5–1.0kg/day
CIBSE (1986, 1999)	0.5–1.8kg/day
Meyringer (1985)	0.15kg/day
Boyd et al (1988)	0.5kg/day
Strum (1992)	0.63kg/day
Hanson (2002)	1.96kg/day
Pretlove (2000)	0.5kg/day



HUMIDITY CONTROL EXAMPLE
Apartment Humidity Loads

Source	Pints	Grains
5 Minute Shower	0.5	3650
Indoor drying of cloths	4-6 per load	29225-43840 per load
5-7 house plants	1/day	7300/day
Washing Dishes (Dinner, family of 4)	0.7	5100
Cooking (Dinner, Family of 4)	1.2 (1.5 with gas cooktop)	8770 (10950 with gas cooktop)
Respiration/Perspiration	0.4/hr	3040/hr
Evaporation, New Construction Materials	10+/day	73000+/day
1 Cord Green Firewood, stored indoors for 6 mo	400-800	2.9M-5.8M

*Source: Minnesota Extension Service, University of Minnesota

INDOOR HUMIDITY interactions*

Outside conditions	Inside conditions	Envelope	HVAC
Temperature	**INTERIOR SOURCES**	Heat flow	Heating/cooling
RELATIVE HUMIDITY	Temperature	**AIR FLOW**	**DE- /HUMIDIFICATION**
Solar Radiation	Relative Humidity	**LIQUID/VAPOR FLOW**	(De)Pressurization
WIND	Air pressure		**VENTILATION**
Vapor Pressure	Vapor pressure		
Precipitation			

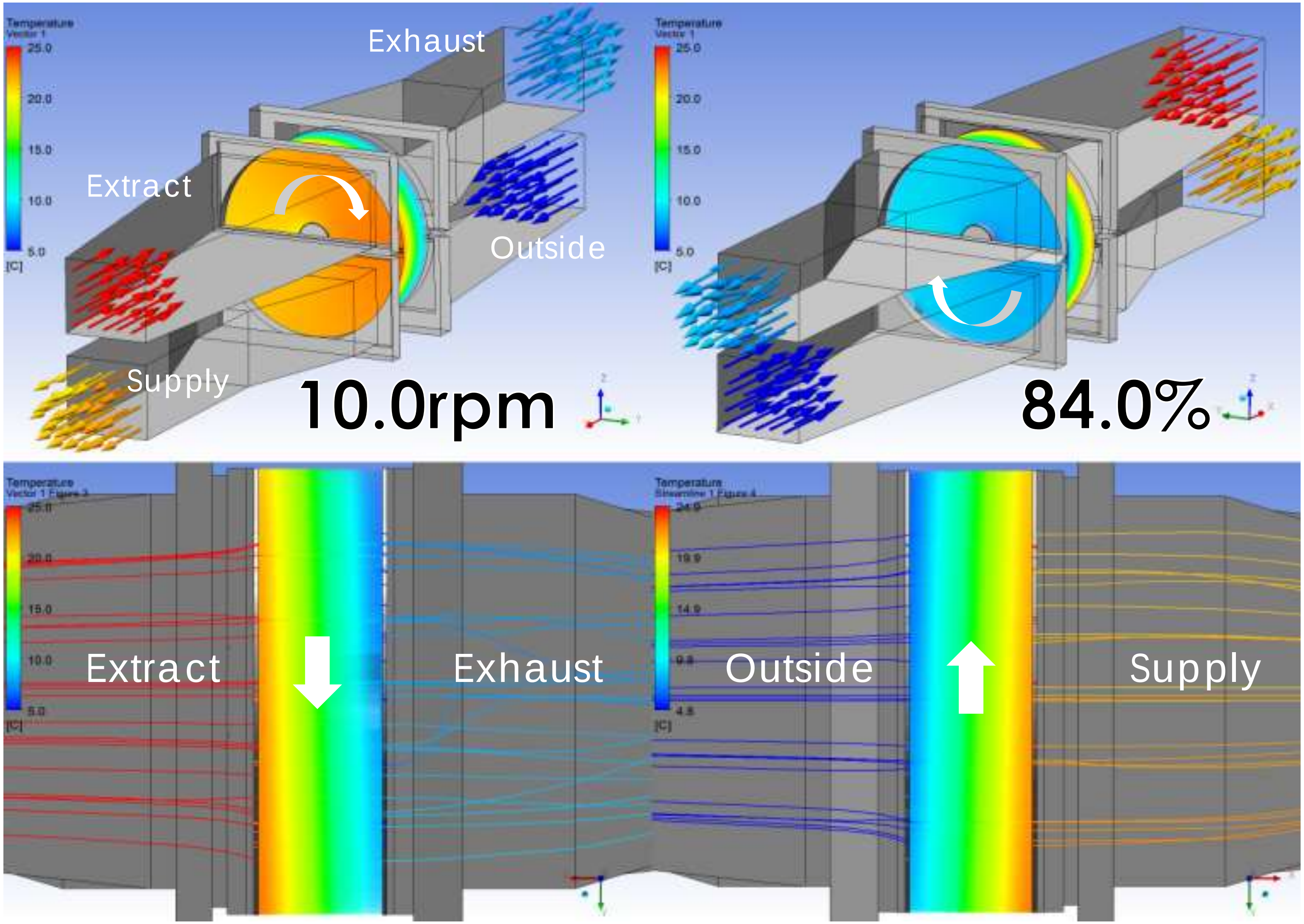
*2017 ASHRAE Fundamentals, Chapter 36 Moisture Management in Buildings ASHRAE, Atlanta GA

PART 3

Ventilation System

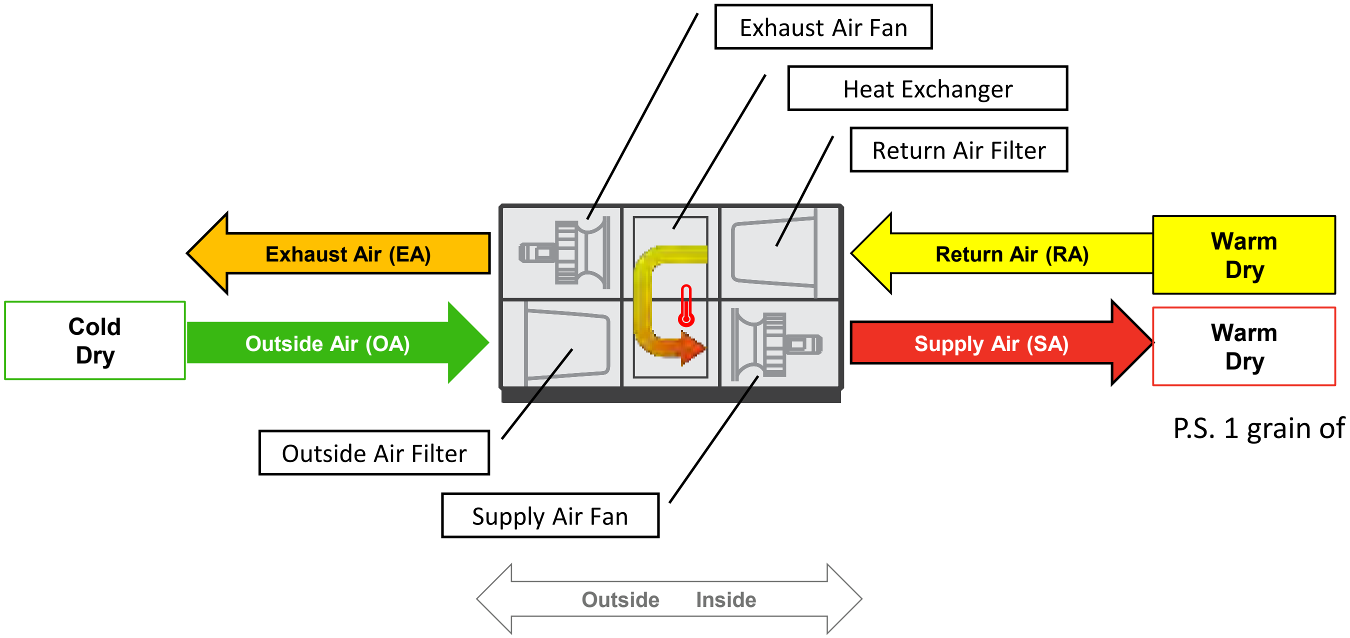
Design for Humidity Control

SYSTEM DESIGN
Heat or Energy Recovery?



SYSTEM DESIGN - HEAT RECOVERY VENTILATOR (HRV)
Winter Operation – dry indoor air

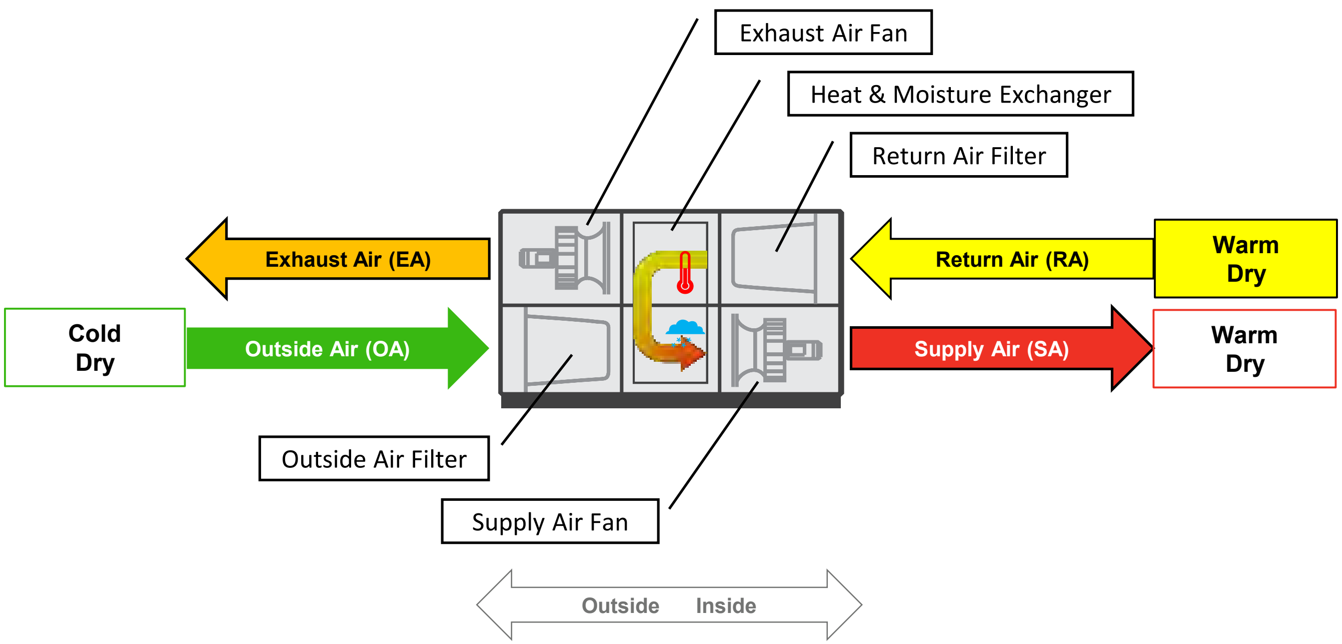
Function	Result
Continuous Ventilation	☑Safe and comfortable indoor air
Heat recovered from Return Air	☑Heating costs reduced ☑new energy use reduced
Moisture in Return Air is exhausted	☑Drying effect when Outside Air is drier than Return Air ☒**Possibility of over-drying** ☒**Summer heat-rejection benefit is lost**



P.S. 1 grain of moisture = 1/7000th pound

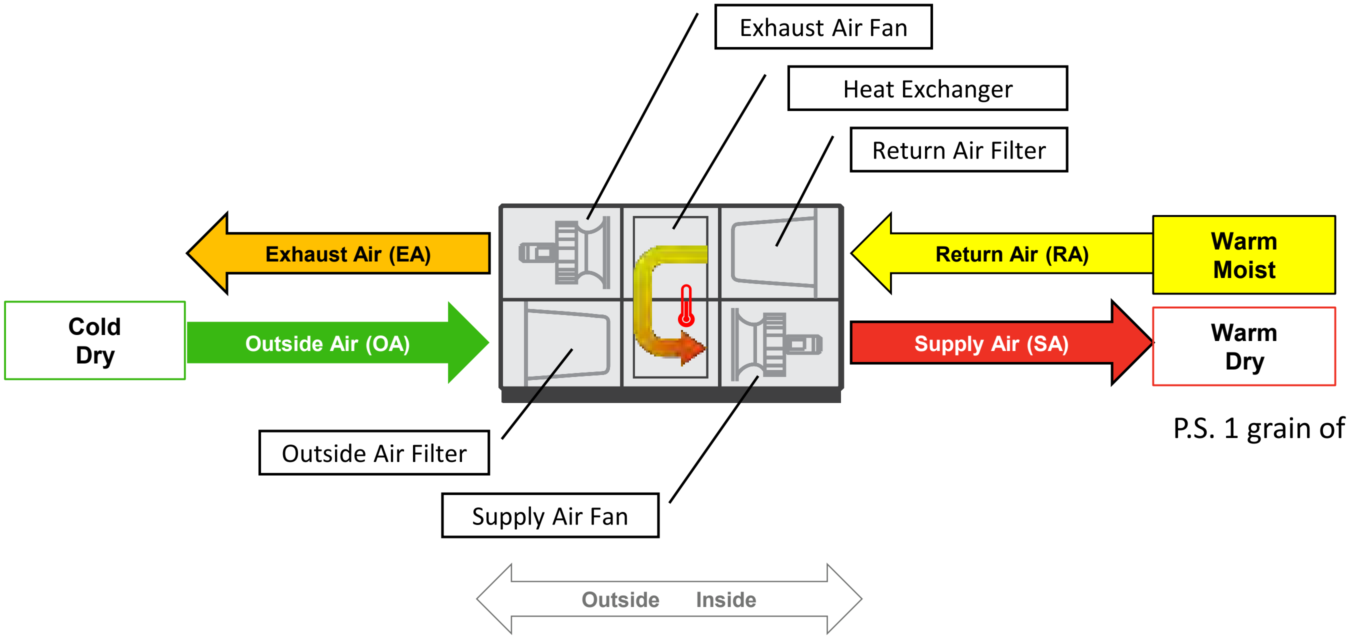
SYSTEM DESIGN - ENERGY RECOVERY VENTILATOR (ERV)
Winter Operation – dry indoor air

Function	Result
Continuous Ventilation	☑Safe and comfortable indoor air
Heat recovered from Return Air	☑Heating costs reduced ☑new energy use reduced
Moisture recovered from Return Air	**☑Increased comfort**



SYSTEM DESIGN - HEAT RECOVERY VENTILATOR (HRV)
Winter Operation – moist indoor air

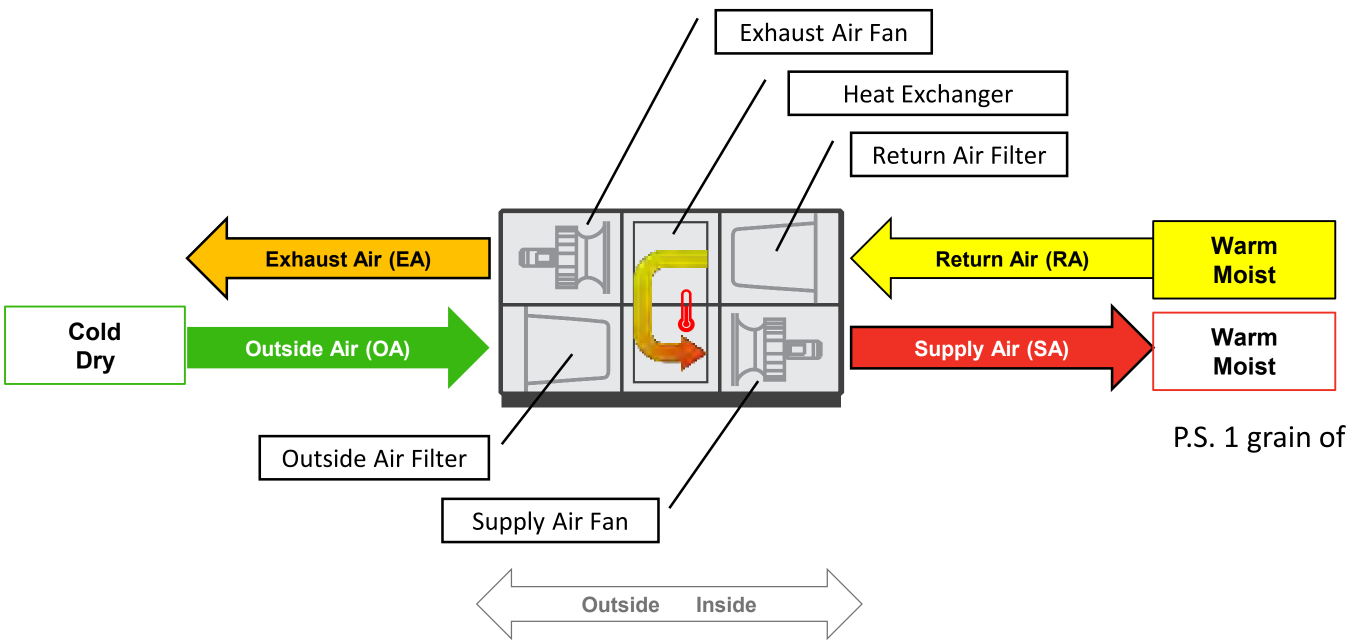
Function	Result
Continuous Ventilation	☑Safe and comfortable indoor air
Heat recovered from Return Air	☑Heating costs reduced ☑new energy use reduced
Moisture in Return Air is exhausted	☑Drying effect when Outside Air is drier than Return Air ☒Possibility of over-drying ☒ Summer heat-rejection benefit is lost



P.S. 1 grain of moisture = 1/7000th pound

SYSTEM DESIGN - ENERGY RECOVERY VENTILATOR (ERV) Winter Operation – moist indoor air

Function	Result
Continuous Ventilation	☑Safe and comfortable indoor air
Heat recovered from Return Air	☑Heating costs reduced ☑new energy use reduced
Moisture in Return Air is returned to building	☒ **Risk of contributing to moisture buildup**



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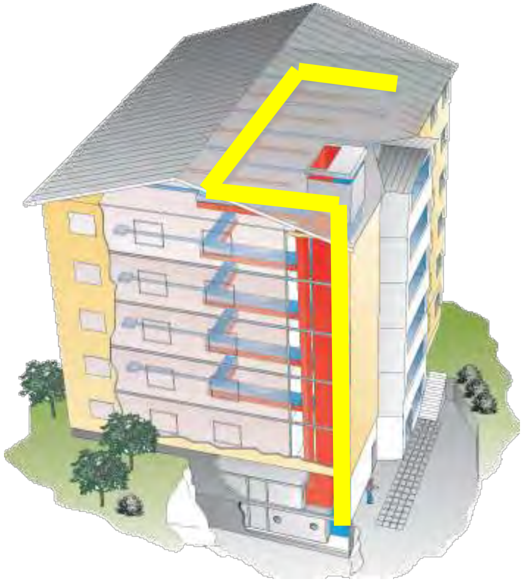
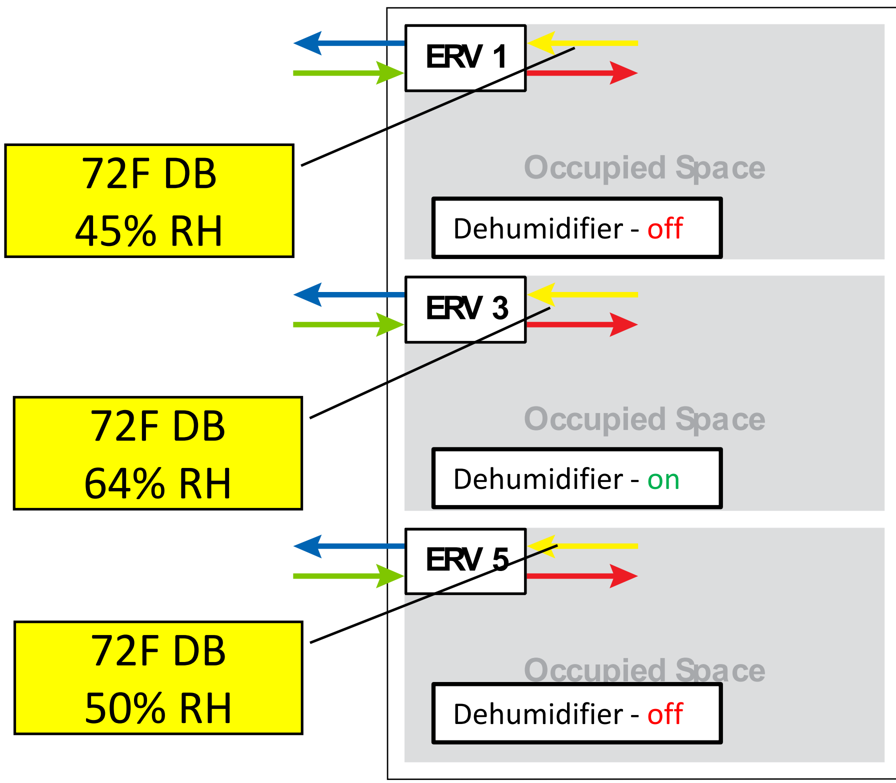
SYSTEM DESIGN
Centralized or Decentralized?



SYSTEM DESIGN
Decentralized Ventilation + Decentralized dehumidifier

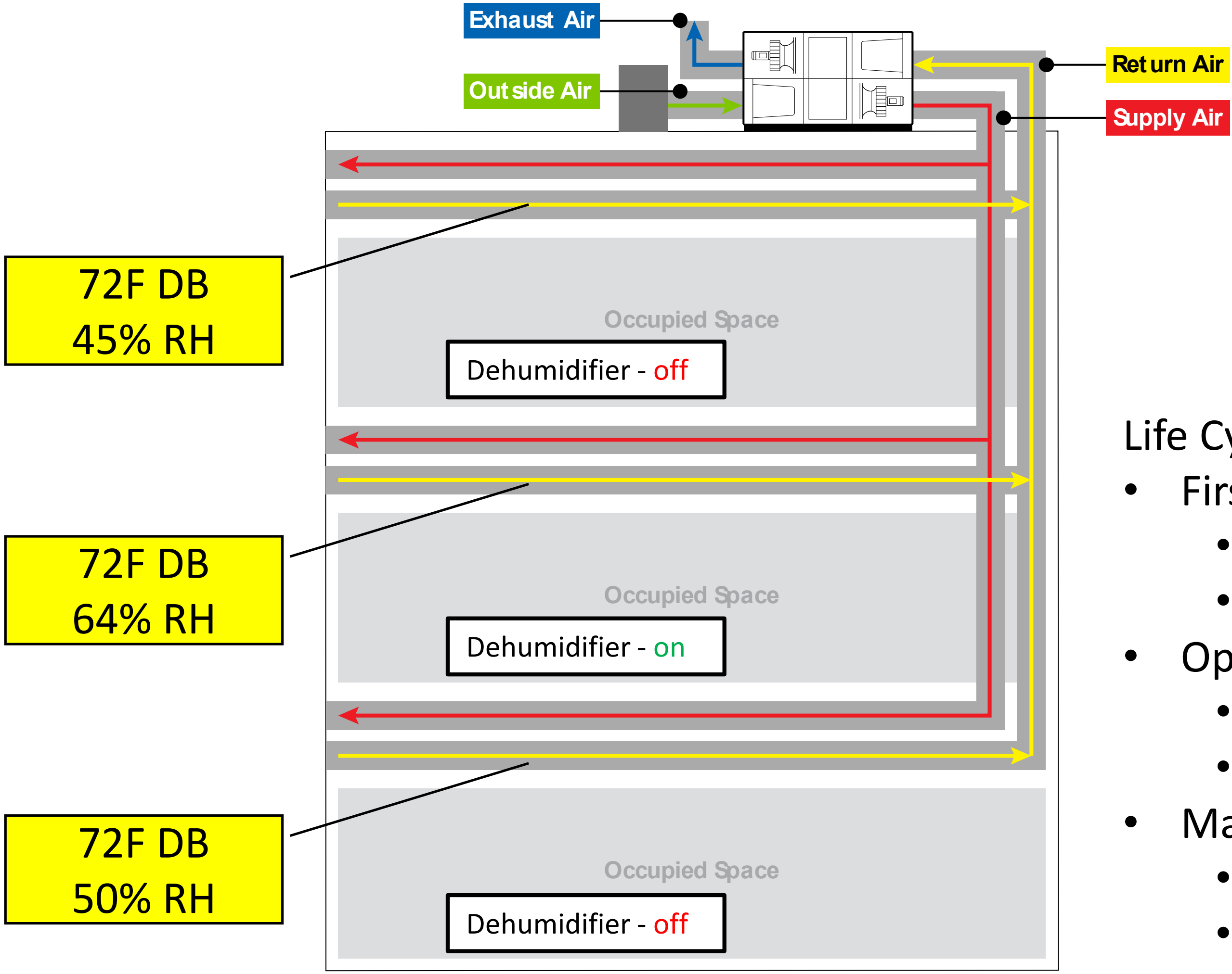


Decentralized Dehumidification required

Life Cycle Cost

- First cost
  - Dehumidifer
  - Drainage
- Operating cost
  - Hours of operation
  - Occupant manual control
- Maintenance
  - Life span
  - Ease of access

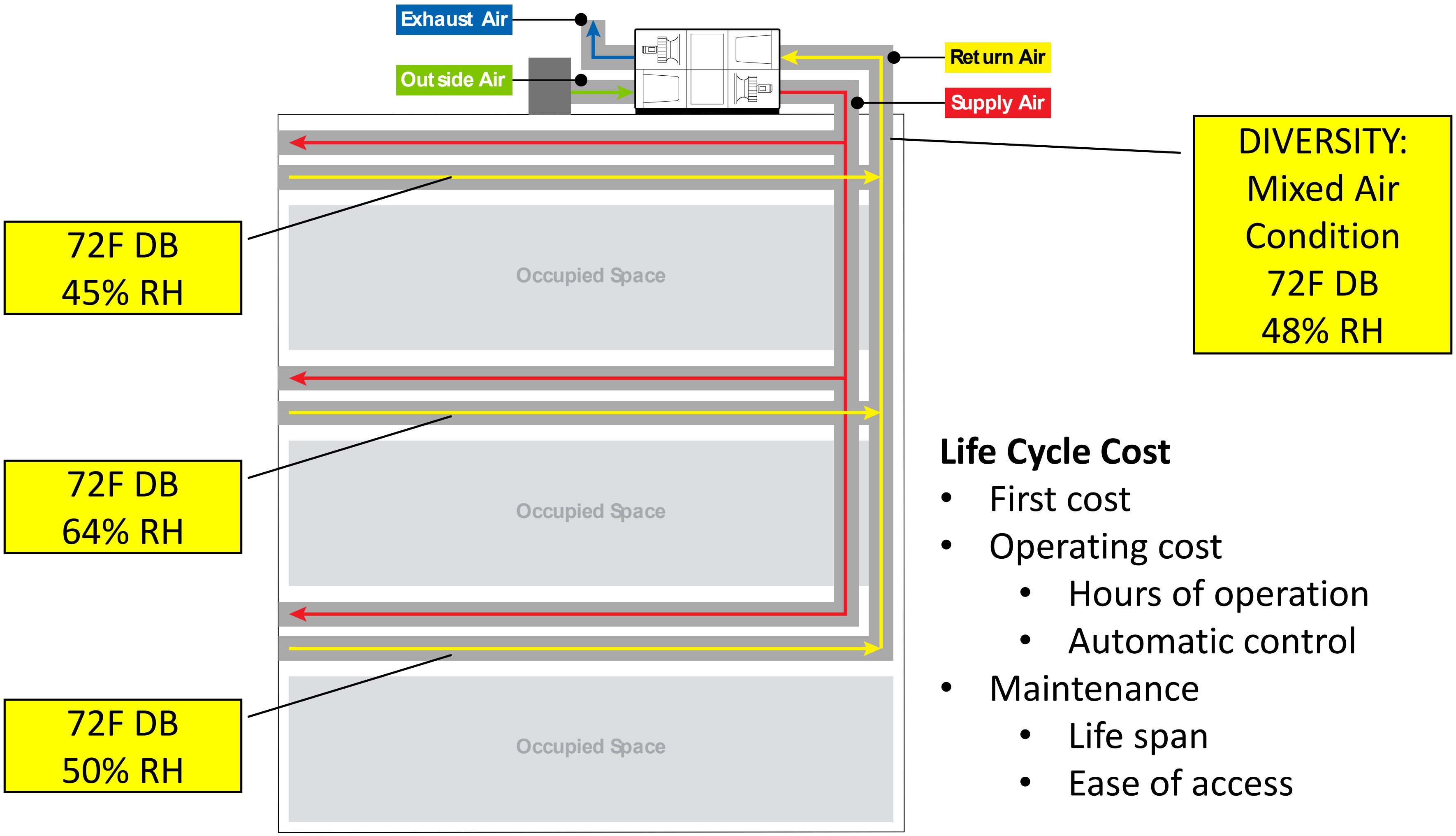
SYSTEM DESIGN
Centralized Ventilation – decentralized dehumidification



Life Cycle Cost

- First cost
  - Dehumidifier
  - Drainage
- Operating cost
  - Hours of operation
  - Occupant manual control
- Maintenance
  - Life span
  - Ease of access

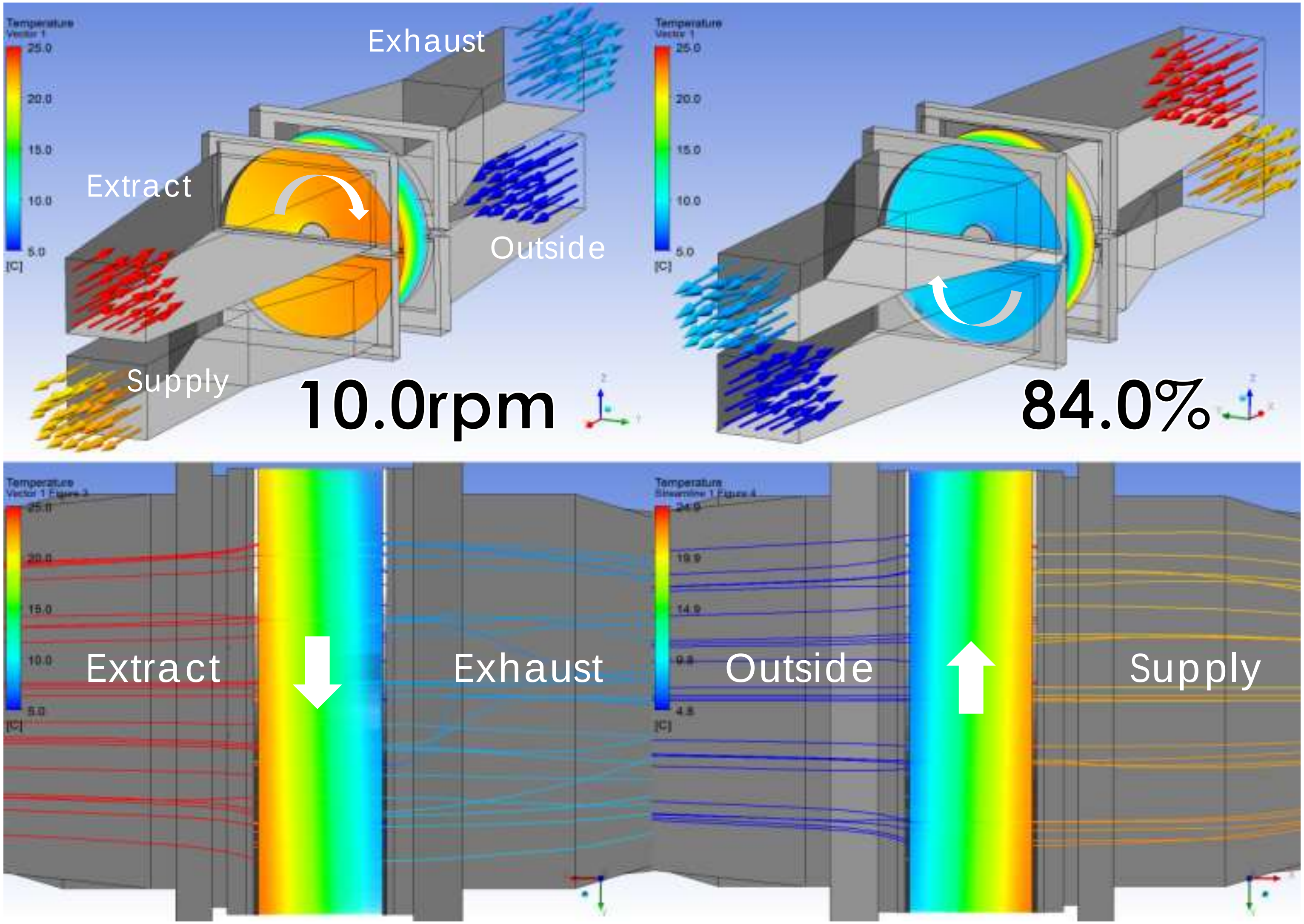
SYSTEM DESIGN
Centralized Ventilation – centralized dehumidification



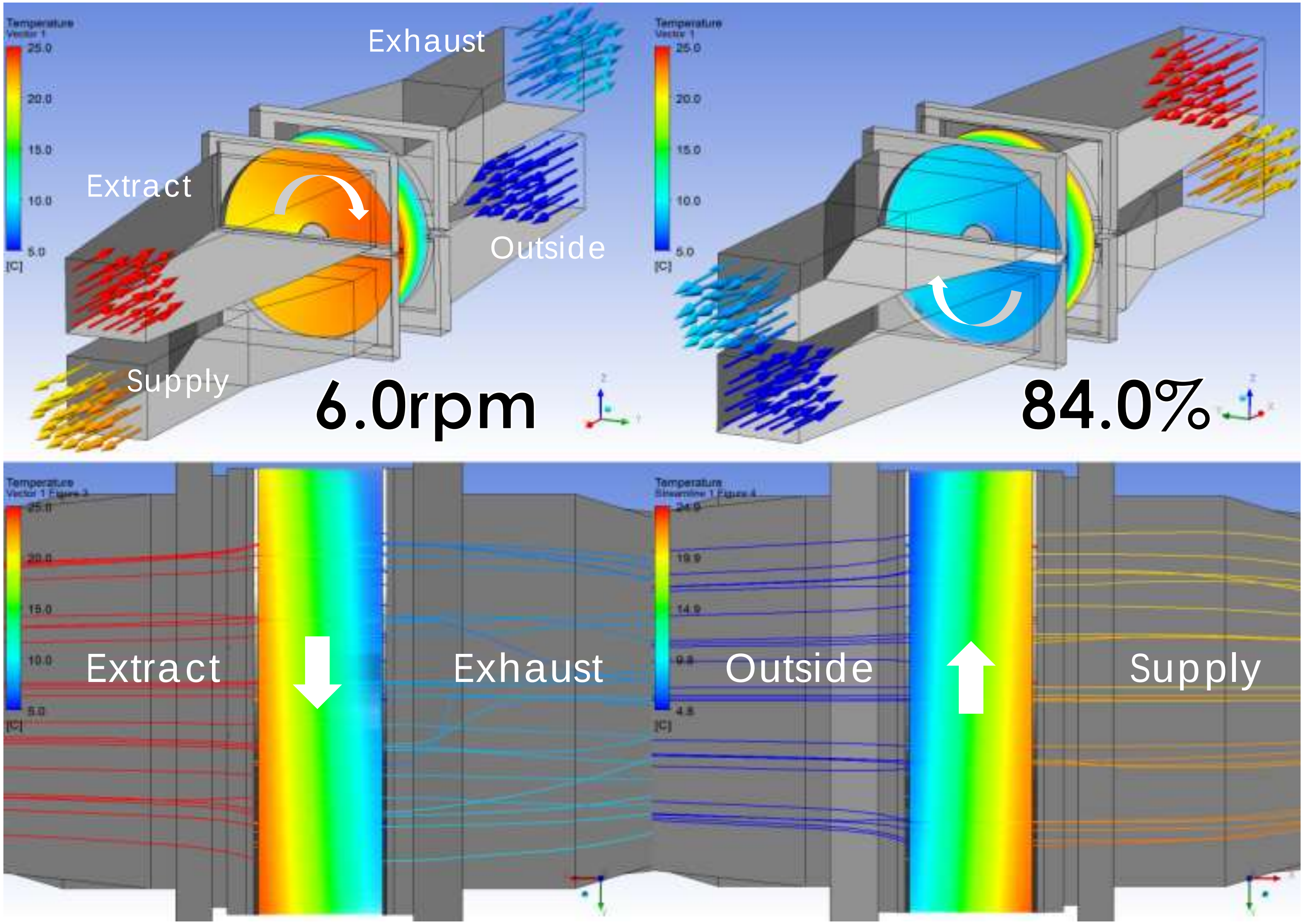
Life Cycle Cost

- First cost
- Operating cost
  - Hours of operation
  - Automatic control
- Maintenance
  - Life span
  - Ease of access

SYSTEM DESIGN
Controls - Reduce energy recovery rate



SYSTEM DESIGN
Controls - Reduce energy recovery rate



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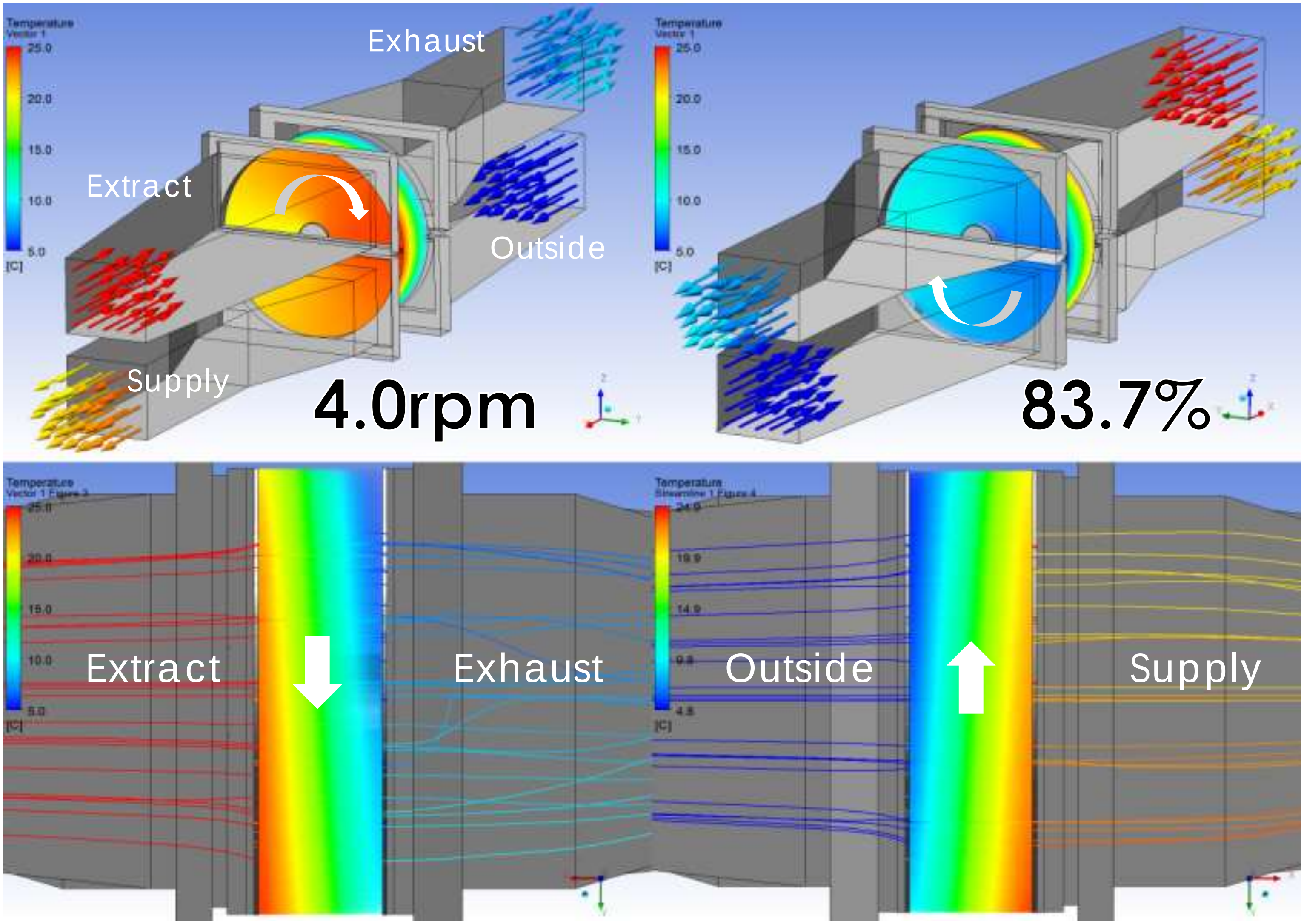
Controls - Reduce energy recovery rate



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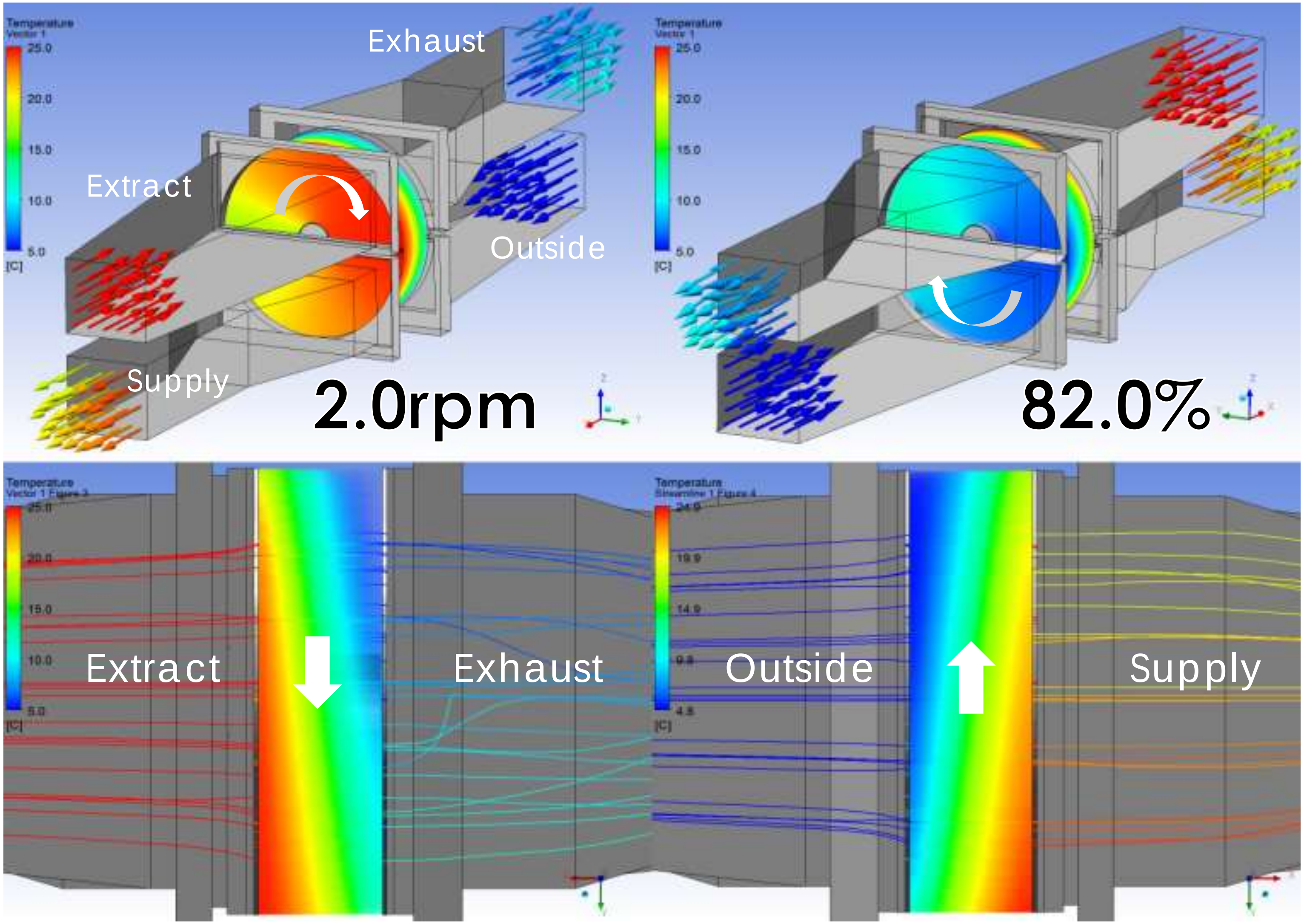
Controls - Reduce energy recovery rate



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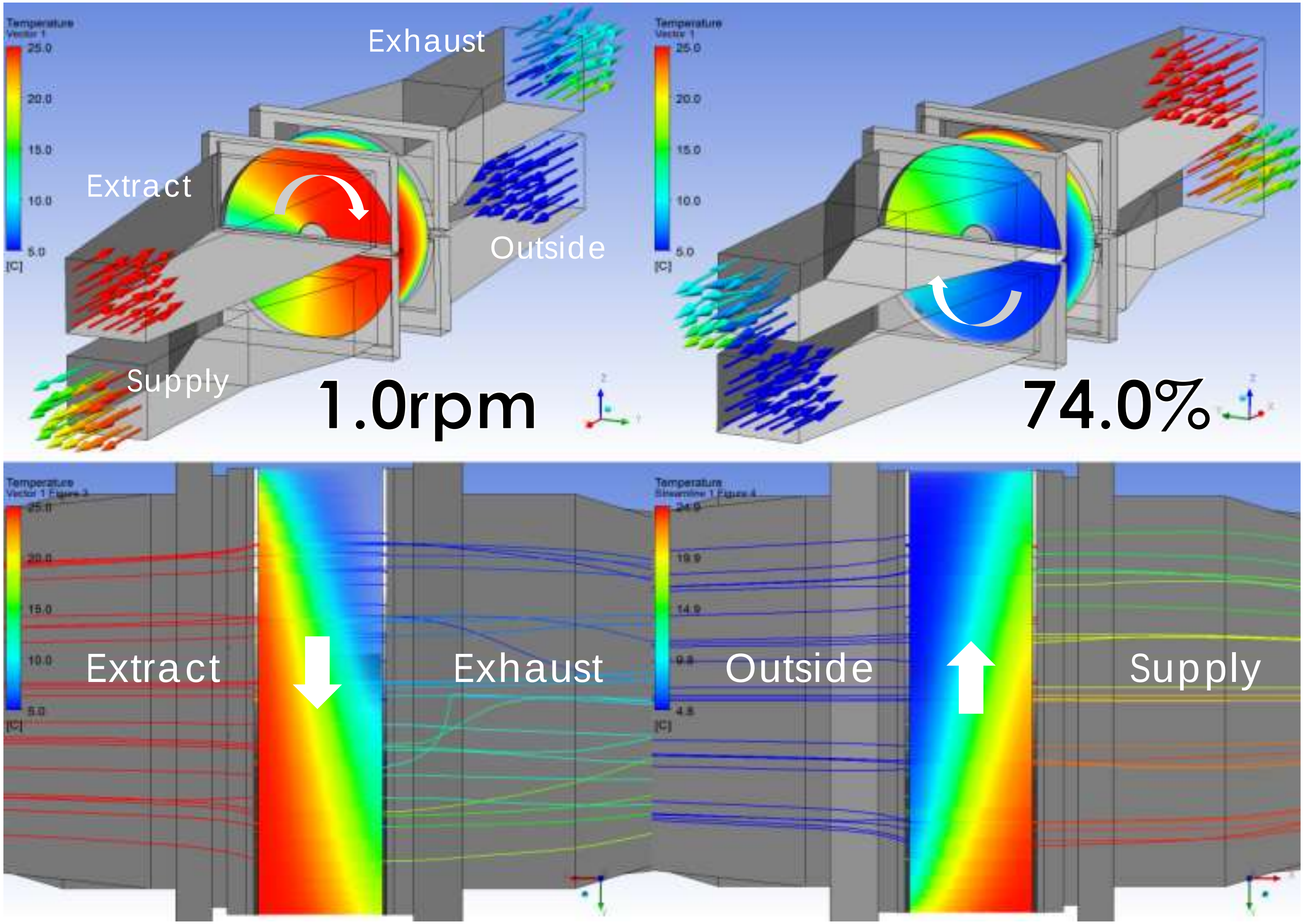
Controls - Reduce energy recovery rate



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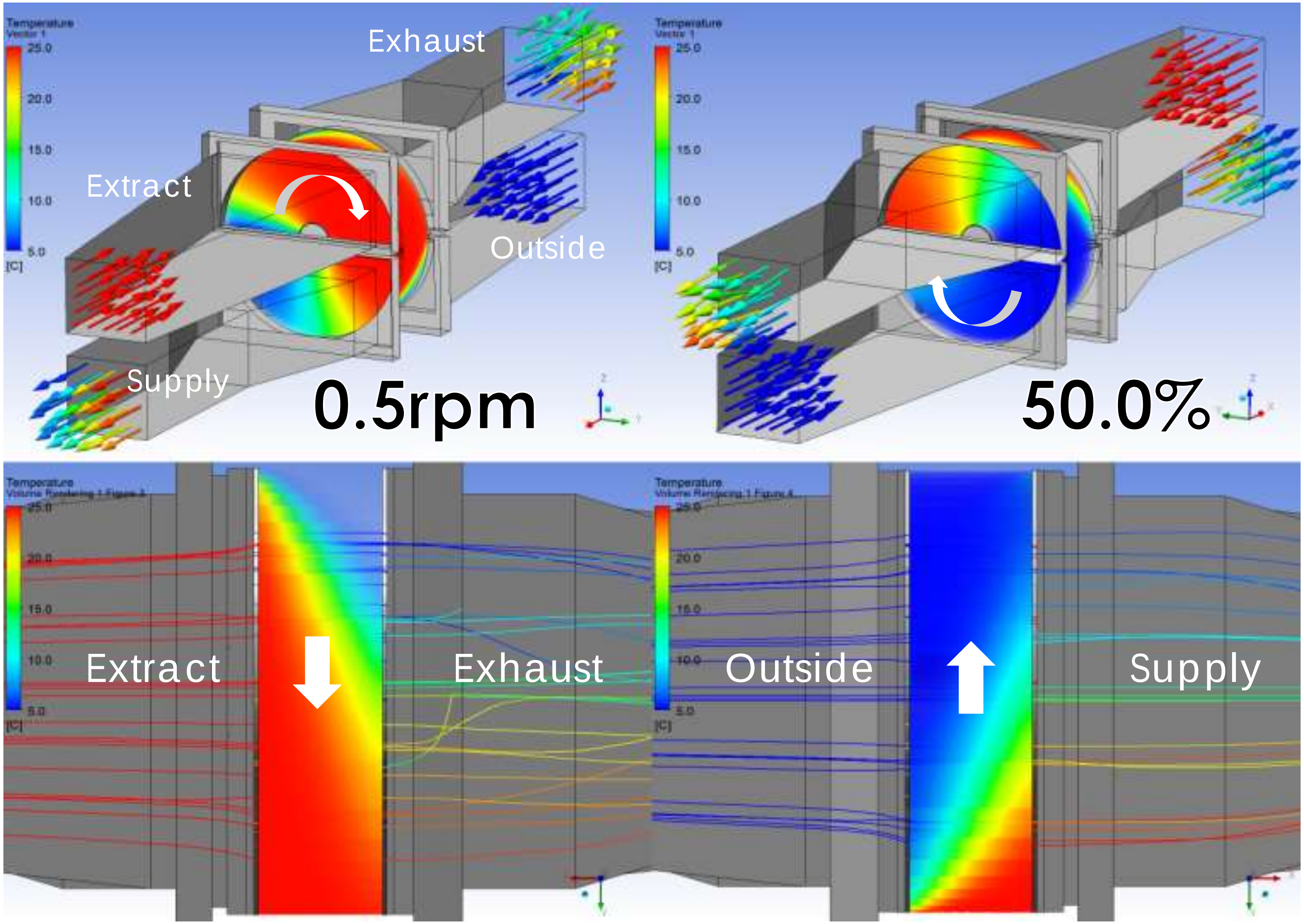
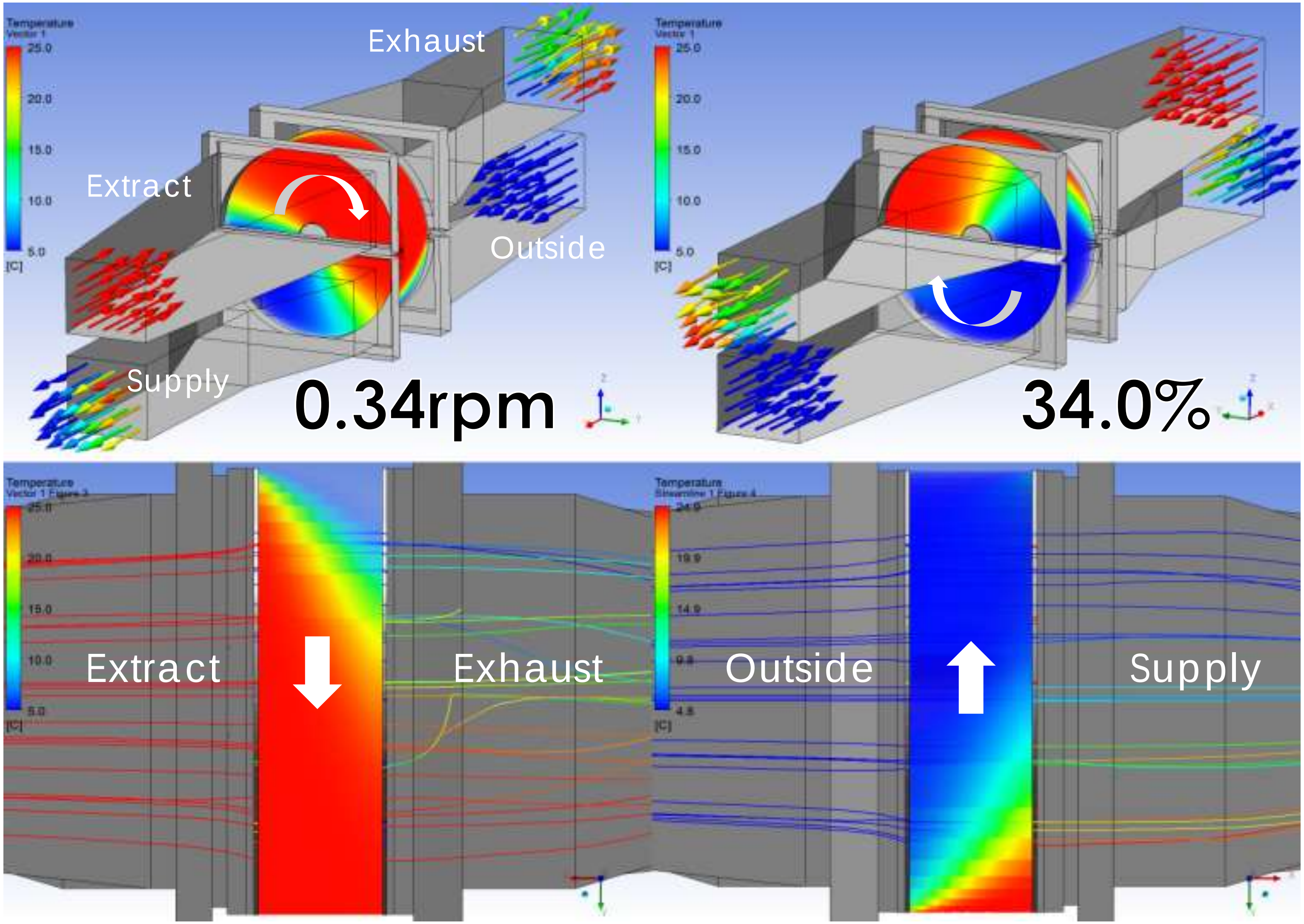
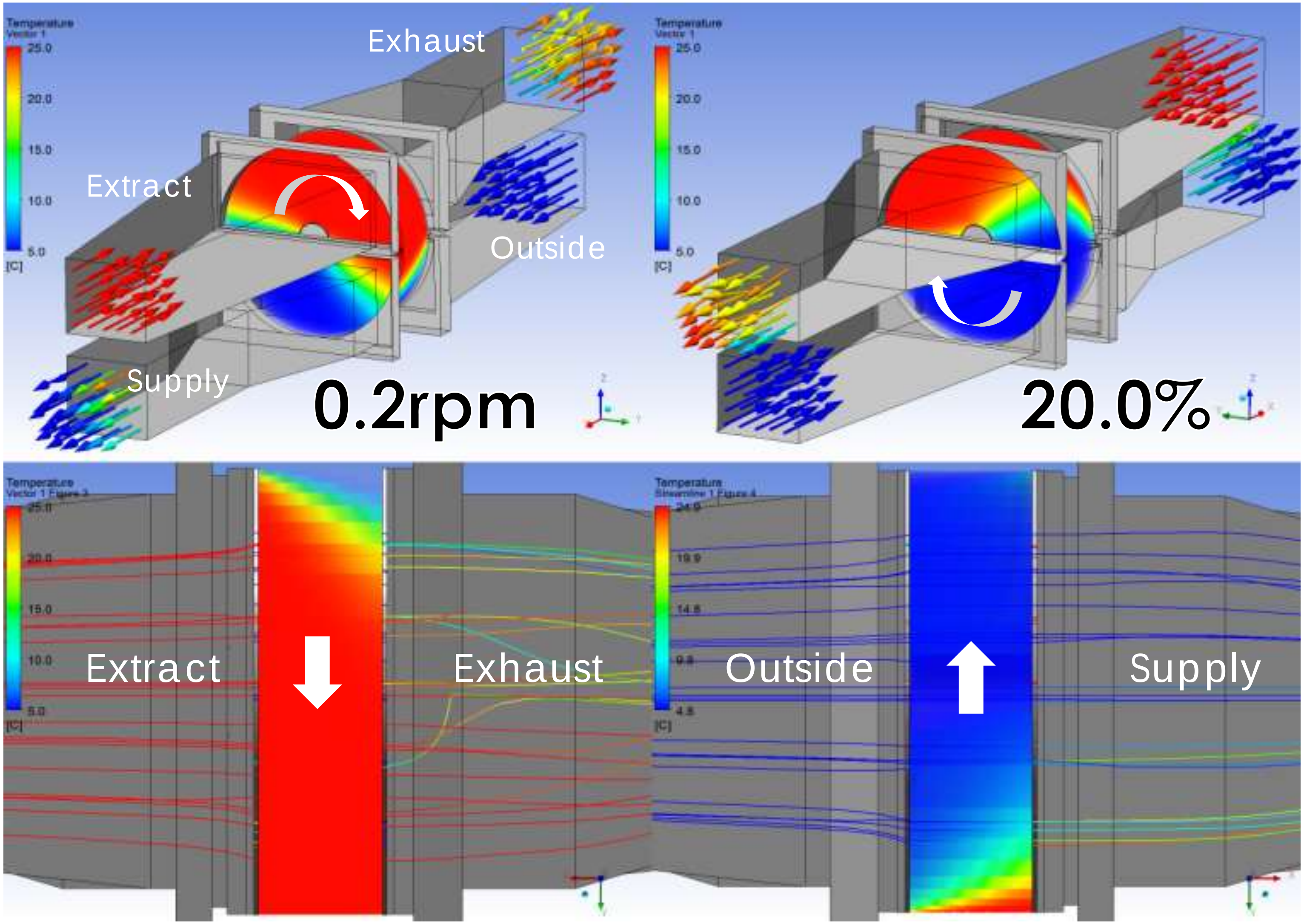
Controls - Reduce energy recovery rate



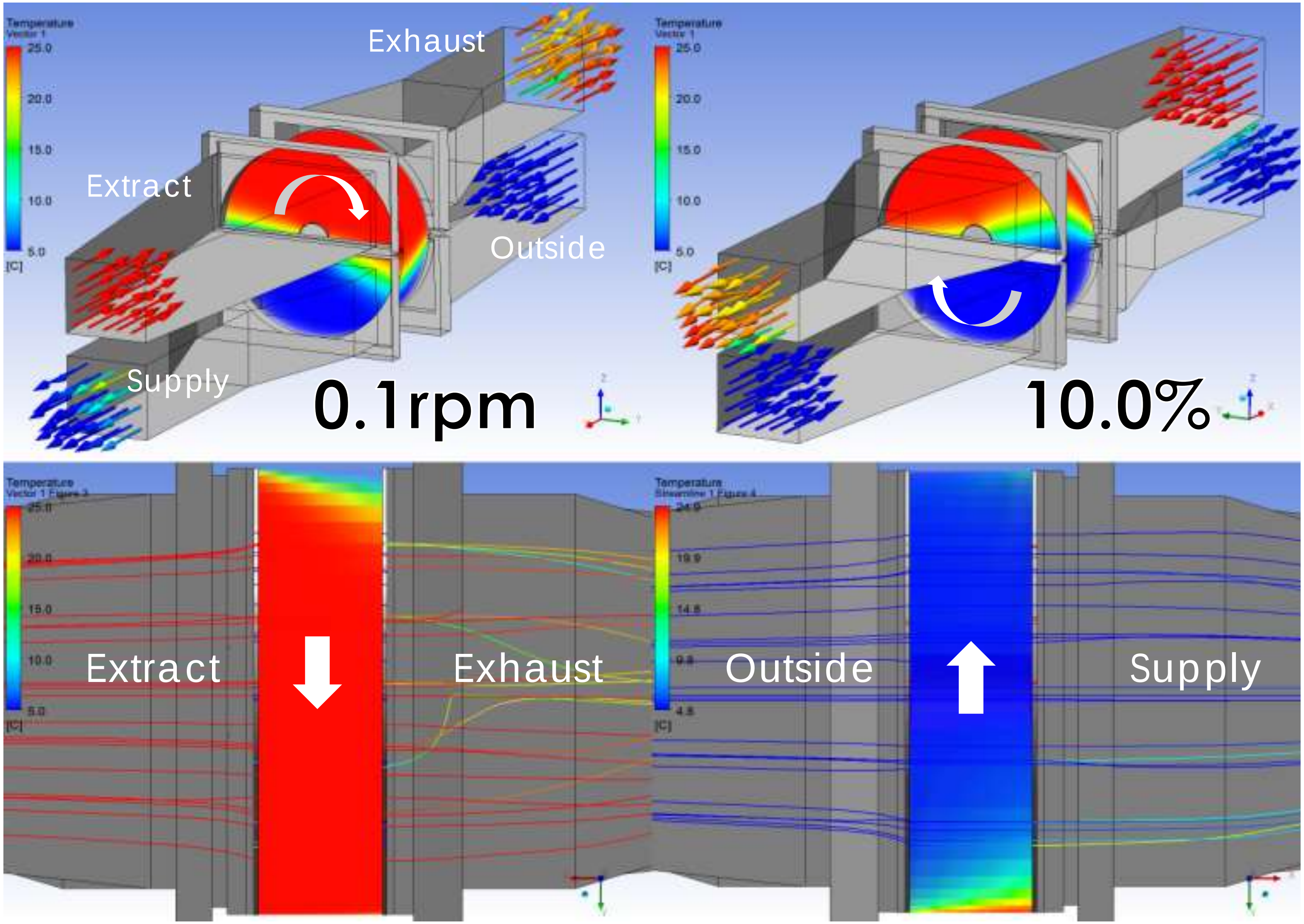
SYSTEM DESIGN
Controls - Reduce energy recovery rate



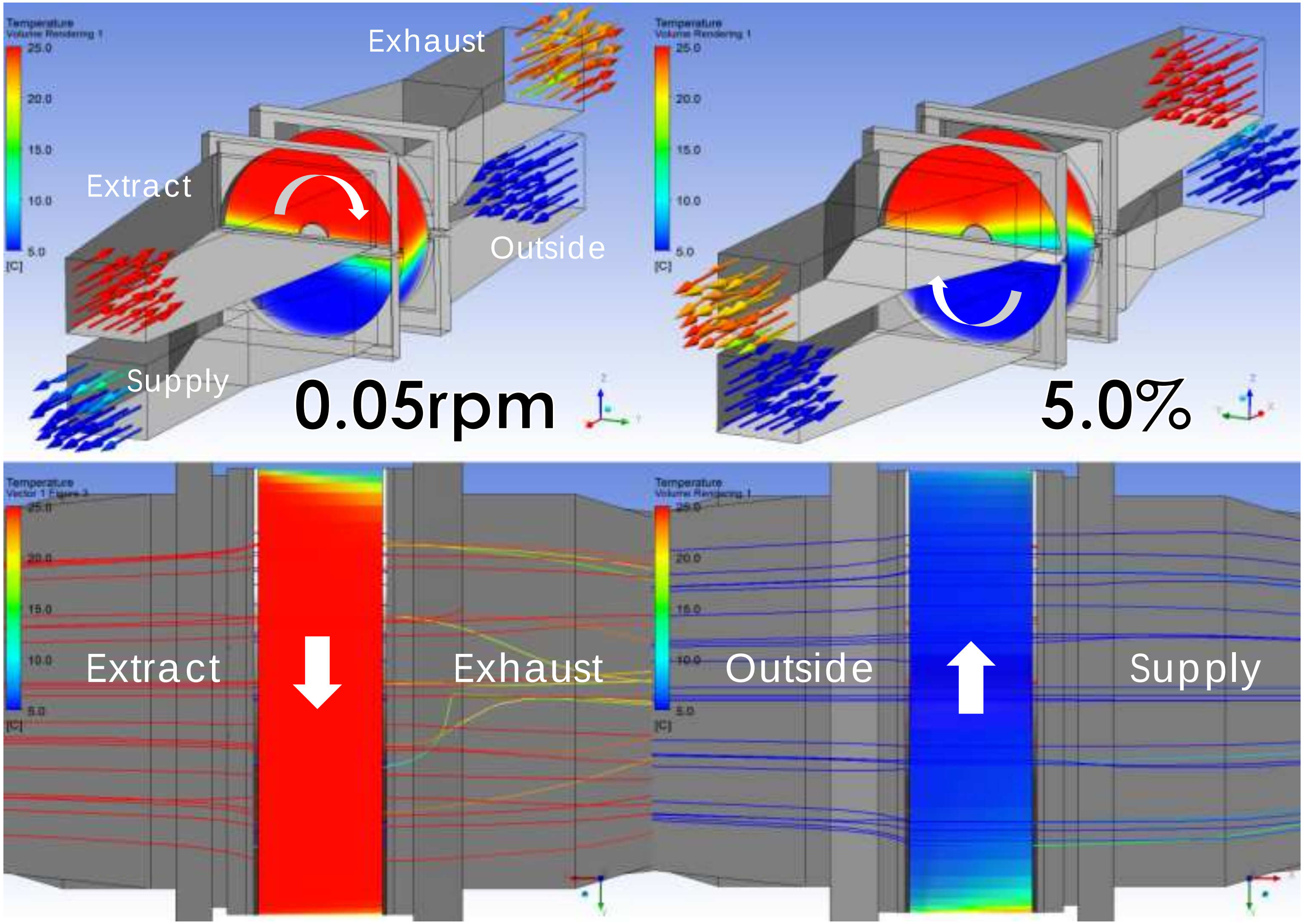
SYSTEM DESIGN
Controls - Reduce energy recovery rate



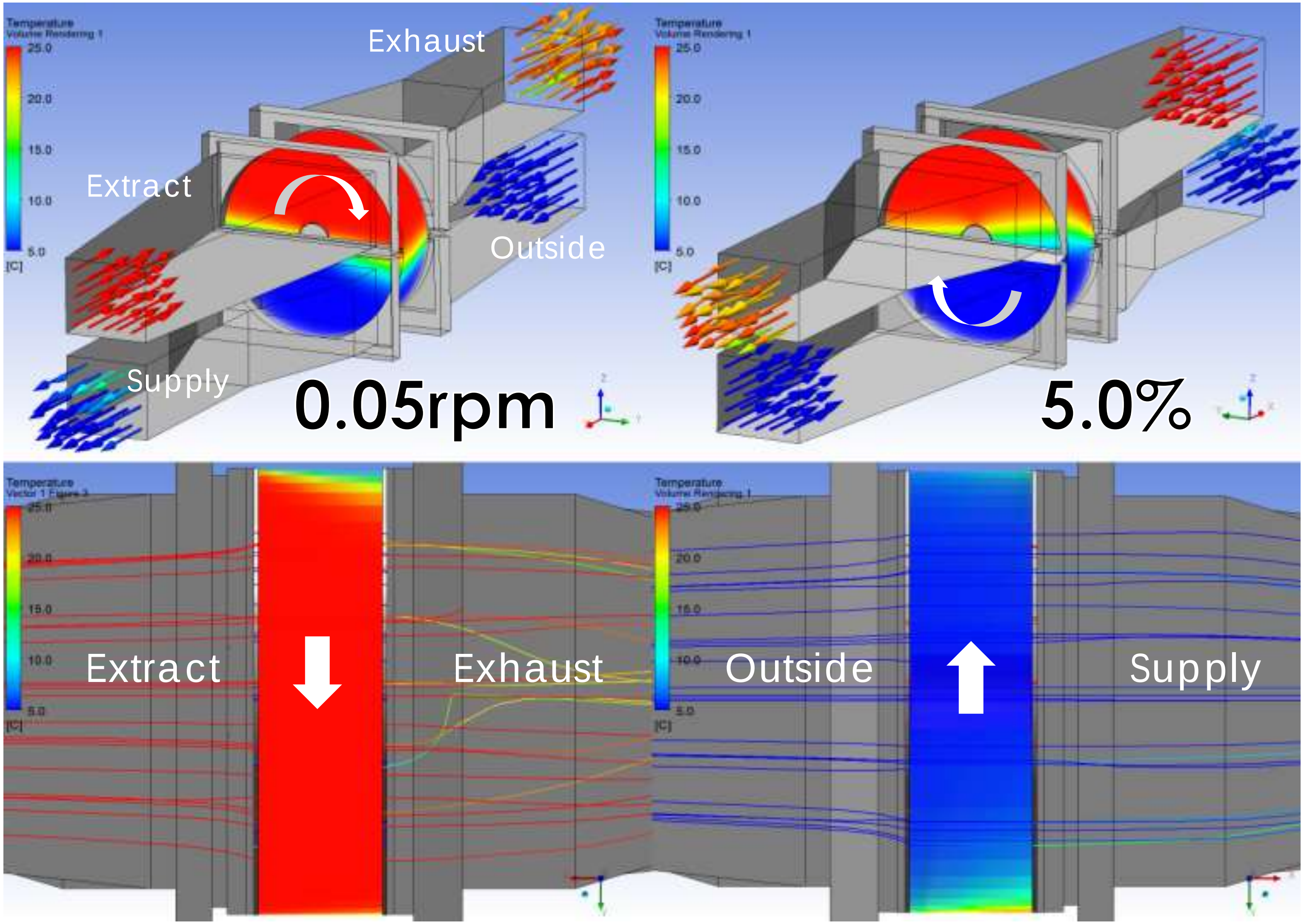
SYSTEM DESIGN
Controls - Reduce energy recovery rate



SYSTEM DESIGN
Controls - Reduce energy recovery rate



Controls - Reduce energy recovery rate



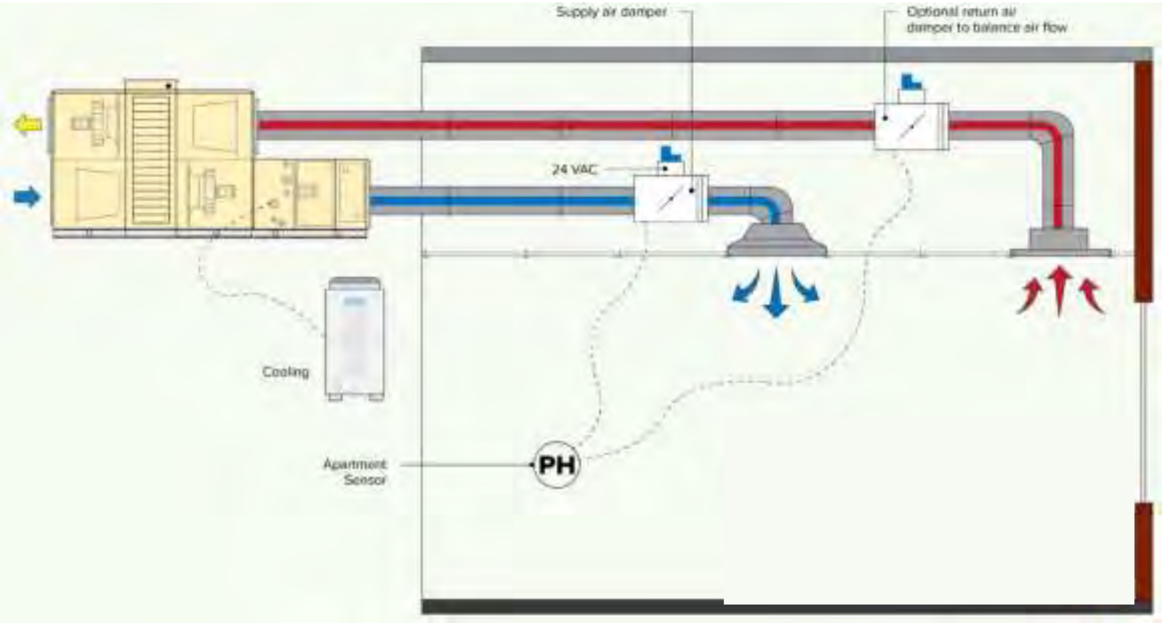
SYSTEM DESIGN
Controls - Reduce energy recovery rate

Wheel Speed	Recovery rate
10	84%
6	84%
4	83.7%
2	82%
1	74%
0.5	50%
0.34	34%
0.2	20%
0.1	10%
0.05	5%

Slowing the wheel rotation

- Reduces humidity transfer
- Reduces heat transfer
- Requires ability to precisely control wheel speed

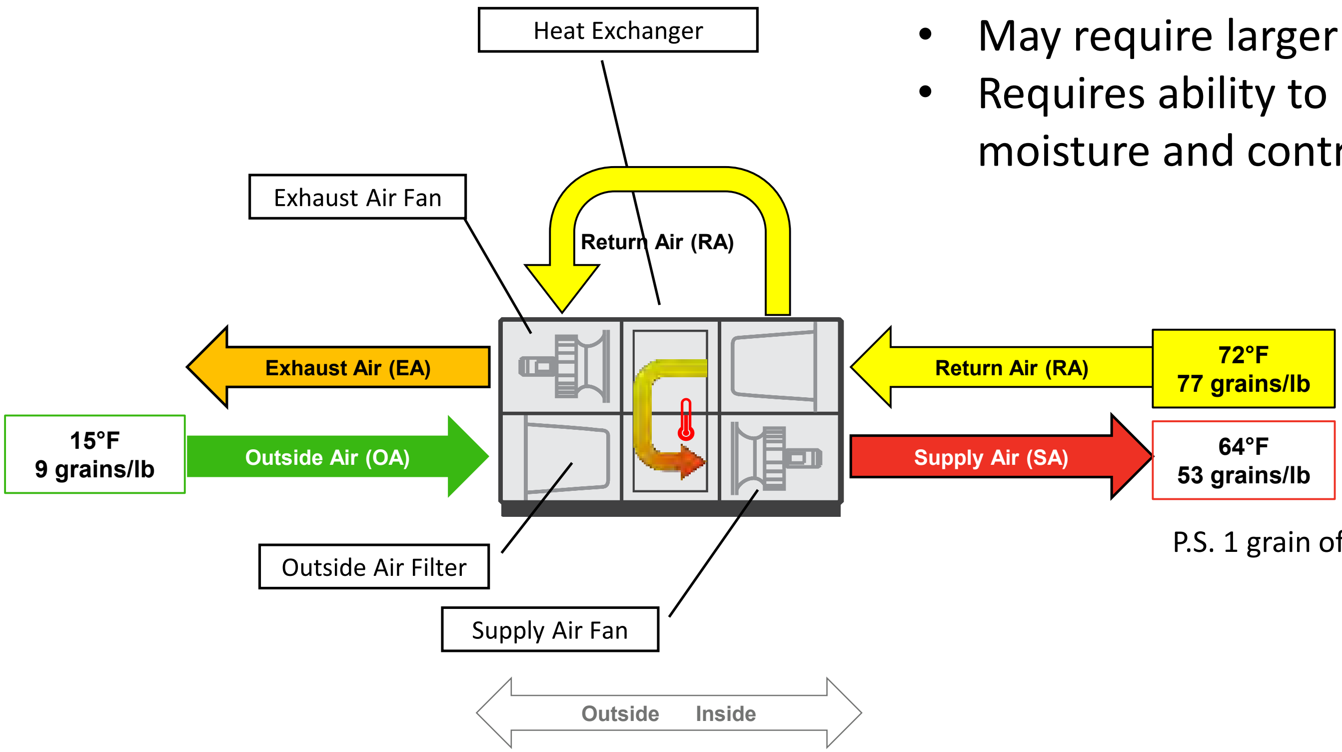
SYSTEM DESIGN
Controls – Incorporate Boost Mode



Boost (Increase) Supply and Return Air flowrate

- ERV Increases extraction rate of moist air
- ERV Increases rate of dry air flushing
- DAMPERS provide variable flow control
- Boost also useful for adding occupant comfort control

SYSTEM DESIGN
Reduce energy recovery rate – core bypass



Route humid Return Air around the wheel

- Reduces humidity transfer
- Reduces heat transfer
- May require larger ERU footprint
- Requires ability to measure Return Air moisture and control a damper

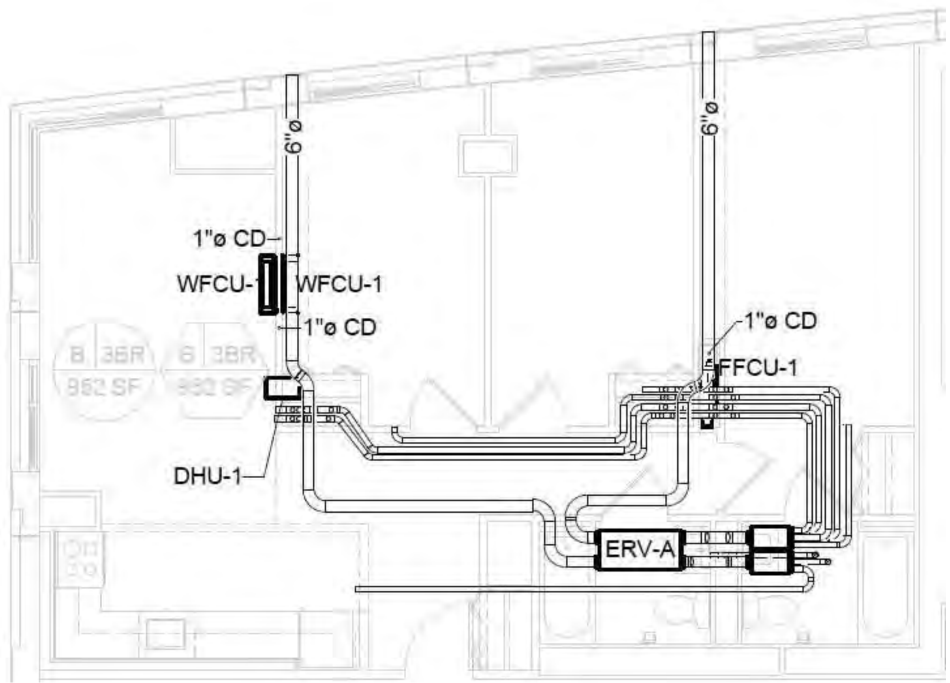
P.S. 1 grain of moisture = 1/7000th pound

PART 4

Humidity Control

Example - Winter

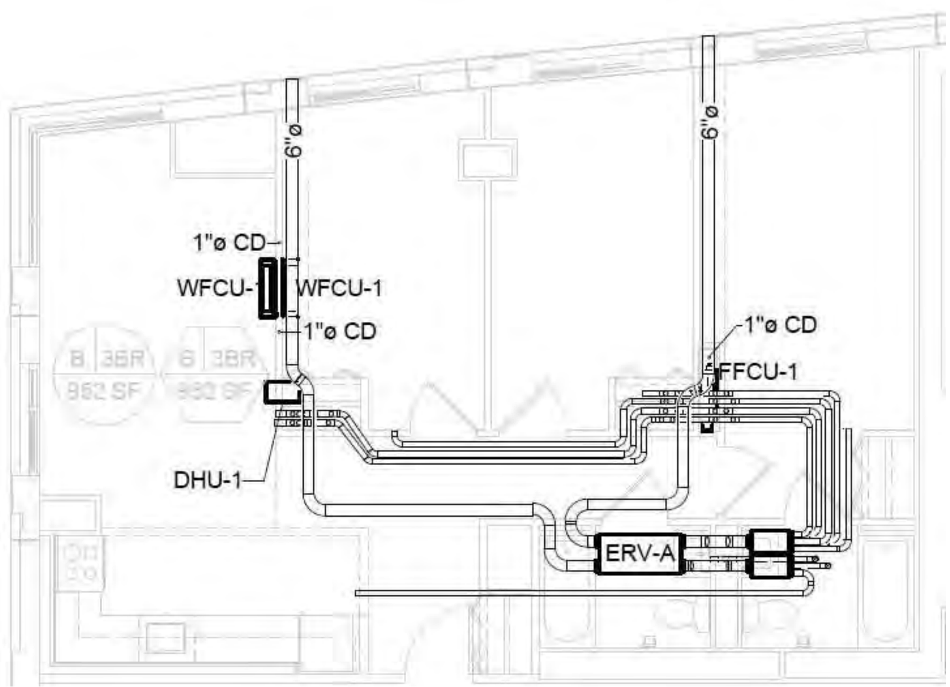
HUMIDITY CONTROL EXAMPLE
High Density Apartment



DESIGN

> Area: 952 ft²
> Ceiling: 8 ft
> 3 bedroom, 2 bathroom
> Design Occupancy: 4
> Laundry in common area
> Room setpoint: 72 degF
> Outside Air:
>> 15.4 degF Dry Bulb
>> 14.3 degF Wet Bulb
> Ventilation rate 85 cfm

HUMIDITY CONTROL EXAMPLE
High Density Apartment



EVALUATION
1-hour extreme moisture generation

Cooking
Dishwashing
2 showers
4 occupants

Centralized v. Decentralized
HRV v ERV

HUMIDITY CONTROL EXAMPLE
COMPARISON #1: *Decentralized Ventilation* – HRV vs ERV

HRV - Sensible Energy Recovery (heat)					
Airtightness	Humidity Gain (+)	Dehumidification		Result after 1 hour	
		Infiltration (-)	HRV Supply Air (-)	Humidity Ratio, at 72F	Relative Humidity, at 72F
	gr/hr	gr/hr	gr/hr	gr/lb	%
ASHRAE Std 90.1	33330	6240	7367	58	50.5
Passive House	33330	1733 (72% less)	7367	66	56.5

ERV - Total Energy Recovery (heat & moisture)					
Airtightness	Humidity Gain (+)	Dehumidification		Result after 1 hour	
		Infiltration (-)	ERV Supply Air (-)	Humidity Ratio, at 72F	Relative Humidity, at 72F
	gr/hr	gr/hr	gr/hr	gr/lb	%
ASHRAE Std 90.1	33330	6240	1473 (80% less)	69	59
Passive House	33330	1733	1473 (80% less)	77	65.7

HUMIDITY CONTROL EXAMPLE
COMPARISON #1: *Decentralized Ventilation* – HRV vs ERV

- Passive House: 72% less drying effect from infiltration than code building
- ERV: 80% less drying effect than HRV
- After one hour of extreme conditions assumed, ERV with inadequate humidity control capabilities returns too much moisture to the space
- Decentralized ERV system involves condensation risk

HUMIDITY CONTROL EXAMPLE
COMPARISON #2: *Centralized Ventilation* – HRV vs ERV

HRV - Sensible Energy Recovery (heat)					
Airtightness	Humidity Gain (+)	Dehumidification		Result after 1 hour	
		Infiltration (-)	HRV Supply Air (-)	Humidity Ratio, at 72F	Relative Humidity, at 72F
	gr/hr	gr/hr	gr/hr	gr/lb	%
ASHRAE Std 90.1	33330	6240	7367	58	50.5
Passive House	33330	1733 (72% less)	7367	66	56.5

ERV - Total Energy Recovery (heat & moisture)					
Airtightness	Humidity Gain (+)	Dehumidification		Result after 1 hour	
		Infiltration (-)	ERV Supply Air (-)	Humidity Ratio, at 72F	Relative Humidity, at 72F
	gr/hr	gr/hr	gr/hr	gr/lb	%
ASHRAE Std 90.1	33330	6240	2947 (60% less)	66	56.5
Passive House	33330	1733	2947 (60% less)	74	63.6

HUMIDITY CONTROL EXAMPLE
COMPARISON #2: Centralized Ventilation – HRV vs ERV

- ERV: 60% less drying effect than HRV (20 percentage points better than decentralized system)
- After one hour of extreme conditions assumed, ERV with inadequate humidity control capabilities returns *marginally* too much moisture to the space
- Decentralized ERV system involves marginal condensation risk

HUMIDITY CONTROL EXAMPLE
Summary

Ventilation	Std.	Type	New Rel. Hum. At 72F (%)
DECENTRALIZED	90.1	Heat Recovery	50.5
		Energy Recovery	59
	PH	Heat Recovery	56.5
		Energy Recovery	65.7
CENTRALIZED	90.1	Heat Recovery	50.5
		Energy Recovery	59.0
	PH	Heat Recovery	56.5
		Energy Recovery	63.6

HUMIDITY CONTROL EXAMPLE
Summary

Tight Passive House construction impacts indoor humidity

Ultra low leakage rates can cause humidity to build up in apartments especially high density apartments

Decentralized Total Energy Recovery Ventilation has greater risk

Humidity recovery causes humidity to build up to unacceptable levels.
It may not be an issue in low density apartments

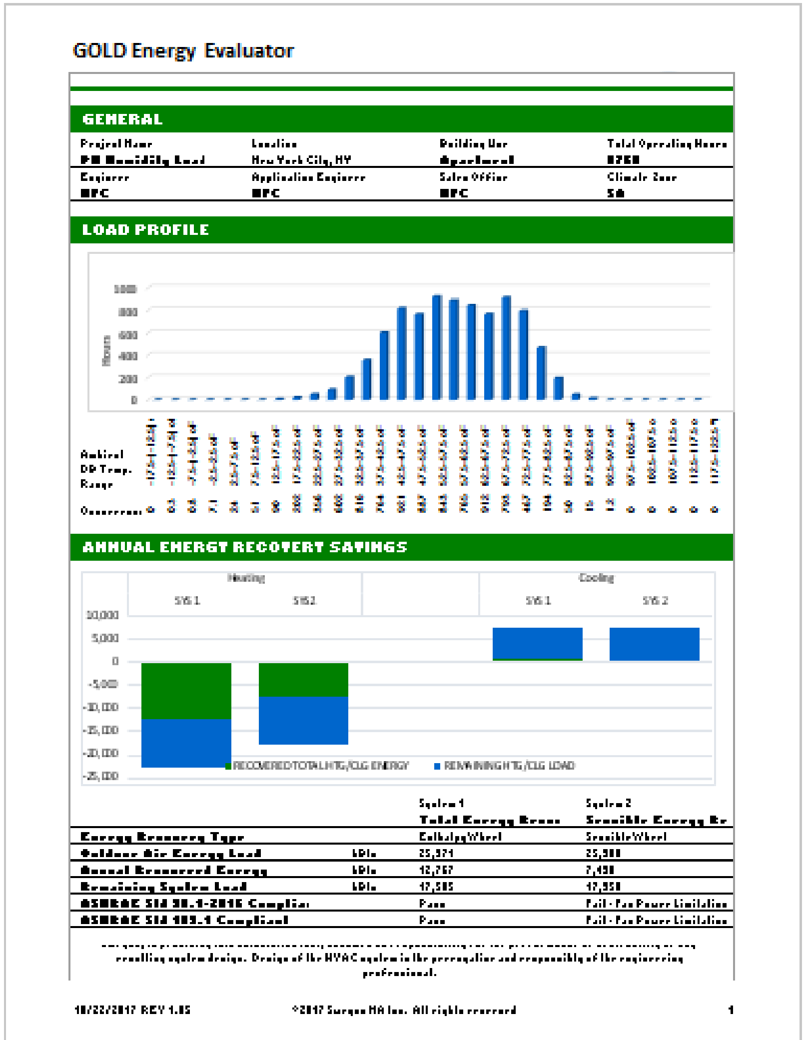
Centralized Ventilation units can help

The diversity from connecting to multiple apartments can reduce humidity build up and allow additional savings from total energy recovery

PART 4

ENERGY TRADEOFF

HUMIDITY CONTROL EXAMPLE
HRV / ERV energy tradeoff



ENERGY MODELLING

Example systems above compared

- Enthalpy Wheel vs. sensible wheel
- Scenario 1 – No cooling, hot water post-heating
- Scenario 2 - VRF DX cooling w/ reheat and heat pump heating
- Defrost cycle included in analysis

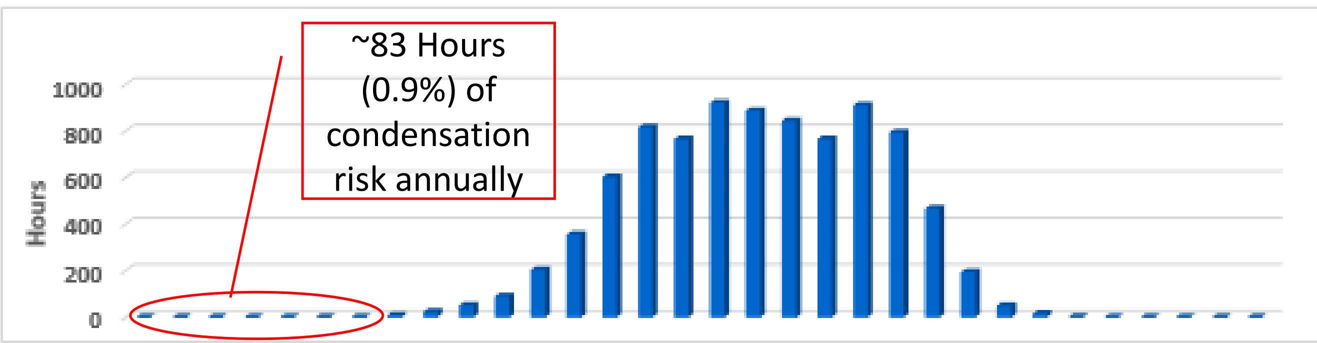
HUMIDITY CONTROL EXAMPLE
HRV / ERV energy tradeoff

GOLD Energy Evaluator

GENERAL

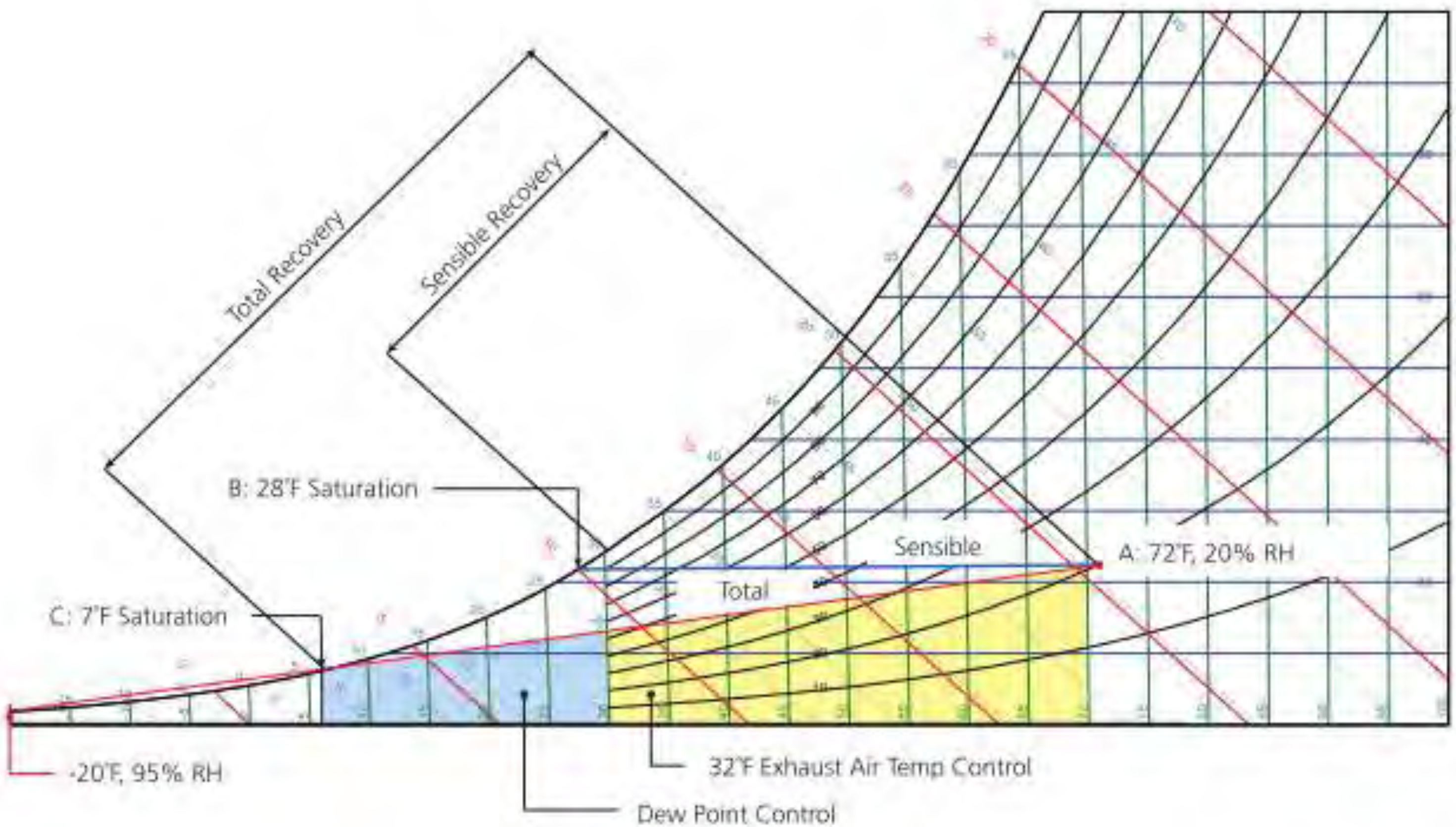
Project Name	Location	Building Use	Total Operating Hours
PH Humidity Load Proj	New York City, NY	Apartment	8760
Engineer	**Application Engineer**	**Sales Office**	**Climate Zone**
HFC	HFC	HFC	5A

LOAD PROFILE



Ambient DB Temp. Range	Occurrences
-17.5-(-12.5) o	0
-12.5-(-7.5) oF	0.3
-7.5-(-2.5) oF	0.8
-2.5-2.5 oF	7.1
2.5-7.5 oF	24
7.5-12.5 oF	51
12.5-17.5 oF	90
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	50
87.5-92.5 oF	15
92.5-97.5 oF	1.2
97.5-102.5 oF	0
102.5-107.5 o	0
107.5-112.5 o	0
112.5-117.5 o	0
117.5-122.5 °]	0

HUMIDITY CONTROL EXAMPLE
HRV / ERV energy tradeoff – wheel frost control



Total recovery much greater than sensible due to lower frost point

Almost twice winter energy recovery

Wheel speed vs. energy transfer not linear

Must slow wheel down to a few rpm to get capacity reduction

HUMIDITY CONTROL EXAMPLE
Scenario #1: post-heating only

Energy Recovery Savings

		System 1 Name	Total Energy Recovery	System 2 Name	Sensible Energy Recovery
Energy Recovery Type			Enthalpy Wheel		Sensible Wheel
Outdoor Air Energy Load	kBtu		21,238		21,238
Annual Recovered Energy	kBtu		18,977		15,662
Remaining System Load	kBtu		2,261		5,576
ASHRAE Std 90.1-2016 Compliant			Pass		Fail- ER Effectiveness
ASHRAE Std 189.1 Compliant			Pass		Fail - Fan Power Limitation

ERV: 17.5% more recovery due to defrost control

ERV: 59.5% less load remaining

Financial

		System 1 Name	Total Energy Recovery	System 2 Name	Sensible Energy Recovery
Design Cooling Load	Tons		0.5		0.5
Required Cooling Capacity	Tons		0.0		0.0
Design Heating Load	kBtu/h		7.7		7.7
Required Heater Capacity	kBtu/h		2.0		4
Design Humidifier Load	lb/h		N/A		N/A
Req'd Humidifier Capacity	lb/h		N/A		N/A
Capital Investment	$		2,000		1,980
Simple Payback	yrs		1.6		
Internal Rate of Return	%		66%		

HUMIDITY CONTROL EXAMPLE
Scenario #2: VRF post-cooling & post-heating

Energy Recovery Savings

		System 1 Name	Total Energy Recovery	System 2 Name	Sensible Energy Recovery
Energy Recovery Type			Enthalpy Wheel		Sensible Wheel
Outdoor Air Energy Load	kBtu		27,774		27,774
Annual Recovered Energy	kBtu		16,179		12,664
Remaining System Load	kBtu		11,595		15,110
ASHRAE Std 90.1-2016 Compliant			Pass		Fail- ER Effectiveness
ASHRAE Std 189.1 Compliant			Pass		Fail - Fan Power Limitation

ERV: 27.8% more recovery due to defrost control

ERV: 23.5% less load remaining

Financial

		System 1 Name	Total Energy Recovery	System 2 Name	Sensible Energy Recovery
Design Cooling Load	Tons		0.5		0.5
Required Cooling Capacity	Tons		0.3		0.4
Design Heating Load	kBtu/h		7.7		7.7
Required Heater Capacity	kBtu/h		2.0		4
Design Humidifier Load	lb/h		N/A		N/A
Req'd Humidifier Capacity	lb/h		N/A		N/A
Capital Investment	$		2,000		1,980
Simple Payback	yrs		0.5		
Internal Rate of Return	%		189%		

ERV: 25% less cooling capacity required

HUMIDITY CONTROL EXAMPLE
HRV / ERV energy trade-off summary

Evaluate airtight high-density apartments for winter humidity risks

Be especially careful with high density apartments and decentralized total energy recovery. Centralized total energy recovery should be okay. Always check humidity loads expected. Evaluate necessary humidity control measures.

Consider frequency of condensation risk

The hours of winter condensation risk are low. If the hours occur consecutively, mold growth risk increases. Humidity control measures can be specified to prevent condensation.

Total Energy Recovery saves energy and reduces operating cost

ERV
- recover more sensible energy in winter
- maintain indoor humidity for comfort and health
- Also dehumidifies in summer
- Reduces size of cooling equipment

Continue Learning

Martello, Dylan. “Establishing Moisture Control in Multifamily Buildings - Party Walls Blog.” *Party Walls - Steven Winter Associates*, Steven Winter Associates, 23 July 2019, www.swinter.com/party-walls/establishing-moisture-control-in-multifamily-buildings/.

Bednarova, Petra Vladykova. “What Is Airtightness? Or Is It Air Tightness...?” *Swegon Air Academy*, Swegon Air Academy, 16 Nov. 2018, www.swegonairacademy.com/2018/11/16/what-is-airtightness-or-is-it-air-tightness/.

Abdul Hamid, A, et al. “Moisture supply Set Point for avoidance of moisture damage in Swedish multifamily houses”, 6th International Building Physics Conference, IBPC Turin, Italy, 2015 .

This concludes the presentation.

Please contact me for more information.

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