Dehumidification in residential buildings

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Introduction (1/2)

Developments in the field of air conditioning with radiant systems are also stimulating interest in issues related to air treatment.

In particular, with radiant systems, humidity control in summer operation is of fundamental importance.

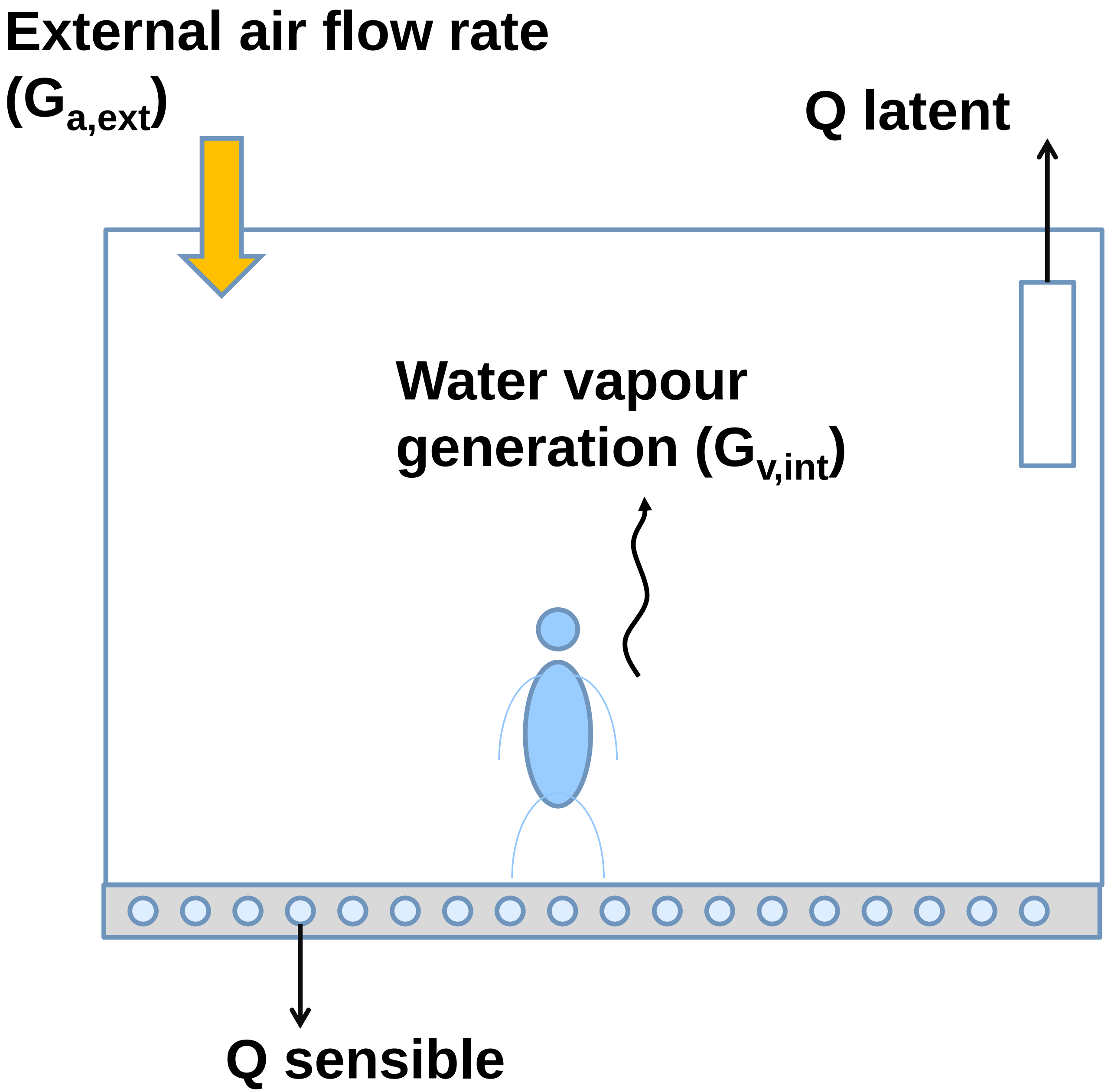
The problem of high specific humidity occurs only in the summer season because in winter, even in conditions of high external relative humidity, the specific humidity is low.

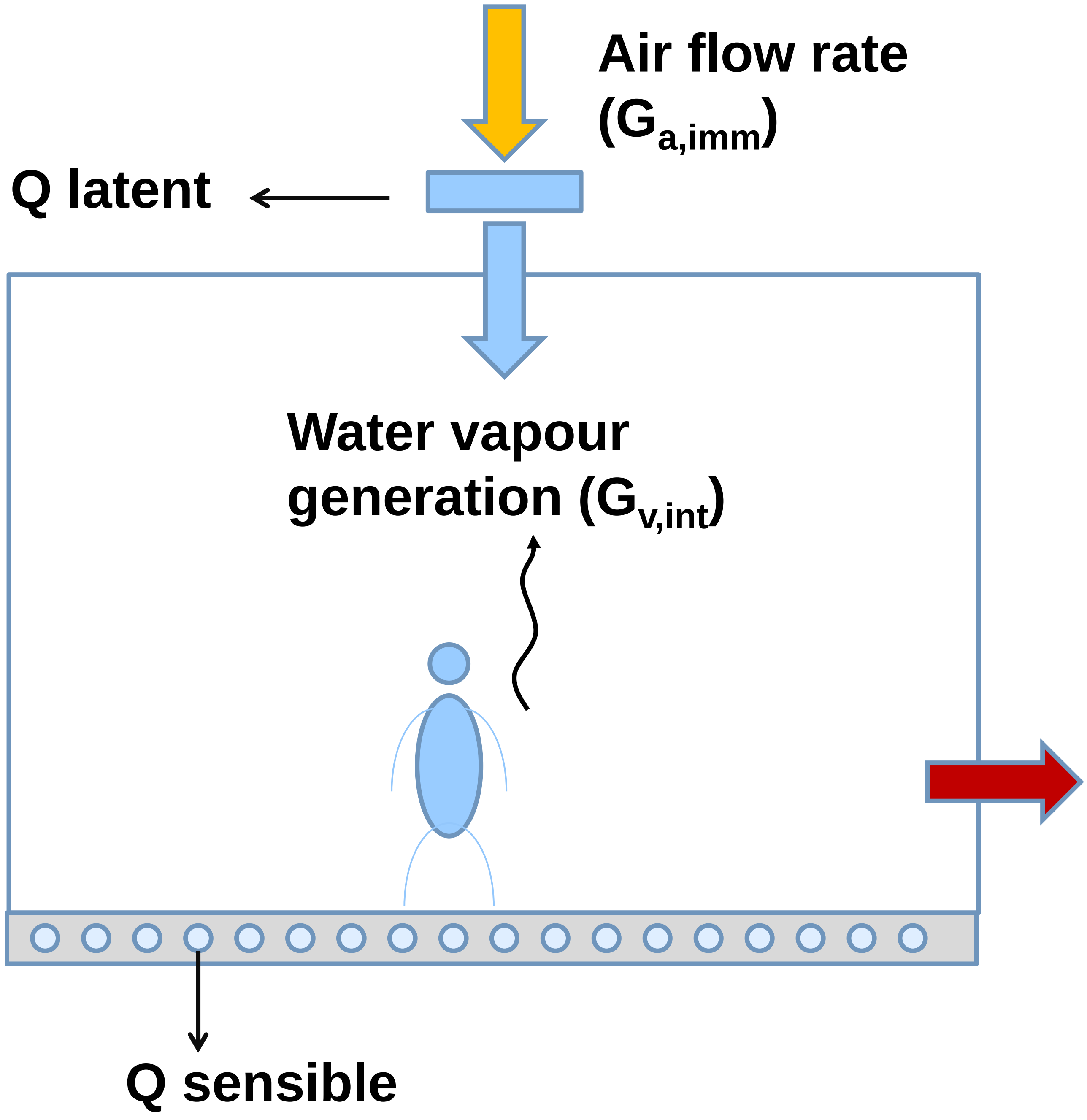
Introduction (2/2)

In summer it often happens that:
external specific humidity > 12 g_v /kg_{as} = limit value according to UNI EN 16798.

In addition, internal vapour generation further contributes to increasing the specific humidity level in the indoor environment.

A radiant system <u>cannot</u> provide latent power. In this case all of the latent power required by the environment must be provided by air handling.

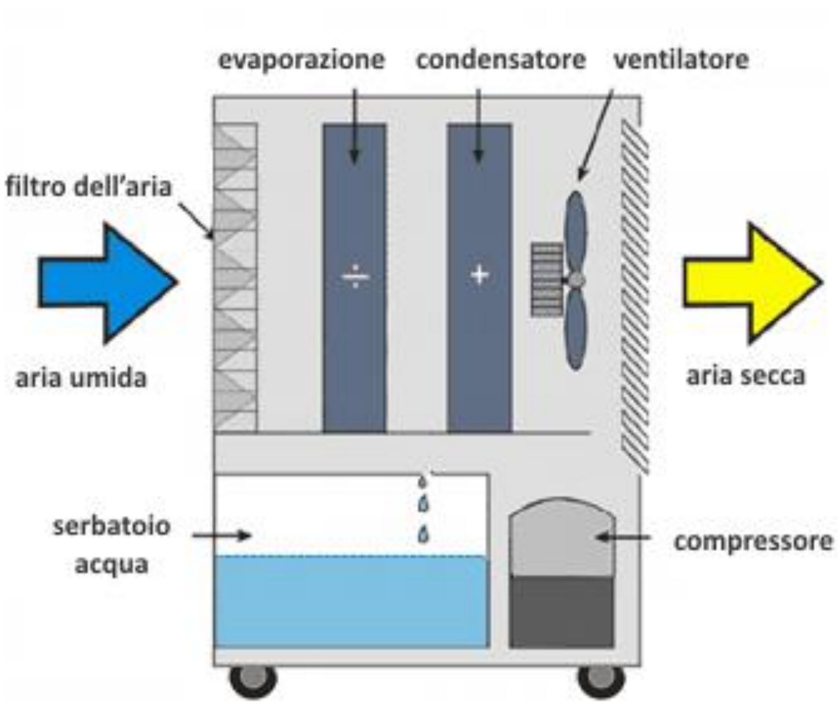

External air flow rate ($G_{a,ext}$)
Q latent
Water vapour generation ($G_{v,int}$)
Q sensible



Air flow rate
($G_{a,imm}$)
Q latent
Water vapour
generation ($G_{v,int}$)
Q sensible

Dehumidification systems

portable dehumidifiers



Fonte: MASTER

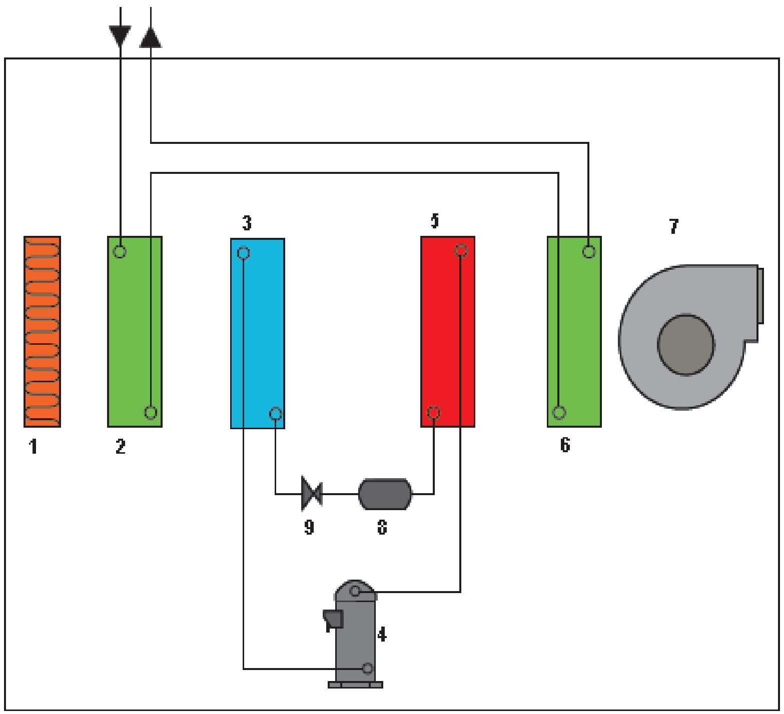
dehumidifiers specifically designed to be combined with radiant systems:

Isothermal dehumidifiers

Deu-air conditioners

Dehumidification systems for radiant systems

- Isothermal Dehumidifier



1 - Air filter
2 - Pre-cooling coil
3 - Evaporator
4 - Compressor
5 - Condenser
6 – Post-cooling coil
7 - Fan
8 – Filter
9 – Lamination valve

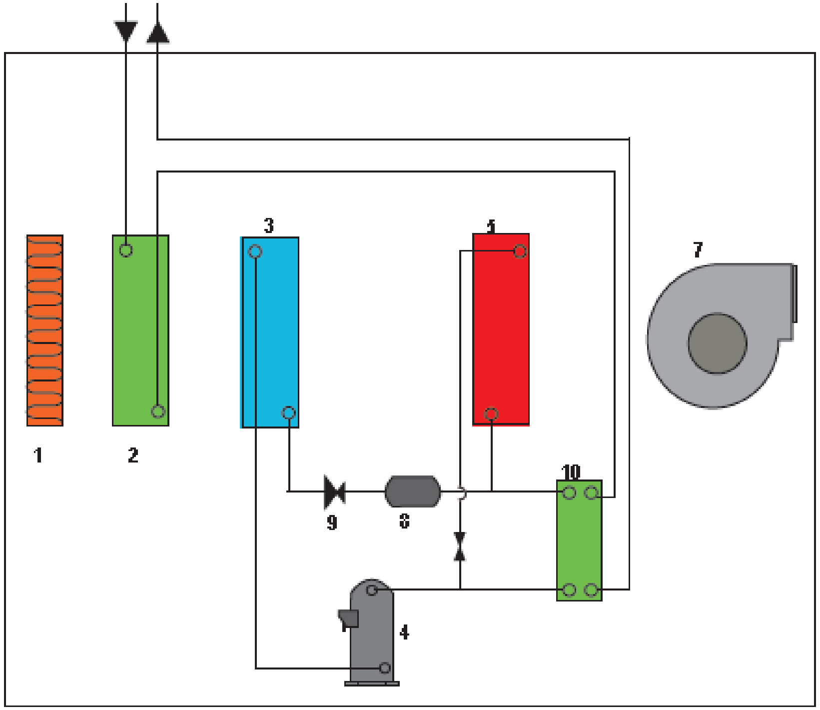
$t_{supply} = t_{ambient}$

Isothermal dehumidifier: characteristics

- Refrigeration fluid: R134a or R407C
- Condenser and evaporator: made of copper tubes and aluminum fins.
- The hermetic reciprocating type compressor with motor cooled by the suction gas.
- Centrifugal type, double inlet forward-bladed, multi-speed (the most common solution is three-speed) directly coupled supply fan.

Dehumidification systems for radiant systems

- Deu-air conditioner



$t_{supply} < t_{ambient}$

1 - Air filter
2 - Pre-cooling coil
3 - Evaporator
4 - Compressor
5 - Air Condenser
7 - Fan
8 - Filter
9 - Lamination valve
10 - Water Condenser

Isothermal dehumidifiers: control and protection devices

All isothermal dehumidifiers have the following control and protection devices:

Defrost thermostat, which provides the need to perform the defrost cycle and determines its duration.

Limit probe, which occurs when the temperature limits of the water entering the pre- and post-cooling coils are exceeded.

In deu-air conditioner, there is also a high-pressure switch, which blocks the operation of the unit if the preset limits are exceeded.

Other systems for radiant systems

Fan – coil

and

Controlled Mechanical Ventilation
(CMV)

Fan-coil

An alternative to the use of dehumidifiers in rooms with radiant systems are fan-coils.

These are given the task of taking charge of the latent power in summer operation, possibly providing sensitive power.

Fan-coils are usually sized with an inlet water temperature of 7°C, necessary to ensure a good dehumidification capacity. In this case, the water feeding the fan-coils is not the same as the water circulating in the radiant system.

The fan-coils can eventually work also in winter as a support to the radiant system.

Fan-coil

For summer cooling supply water temperature 7°C

Cooling coil

condensate collection tank

fan

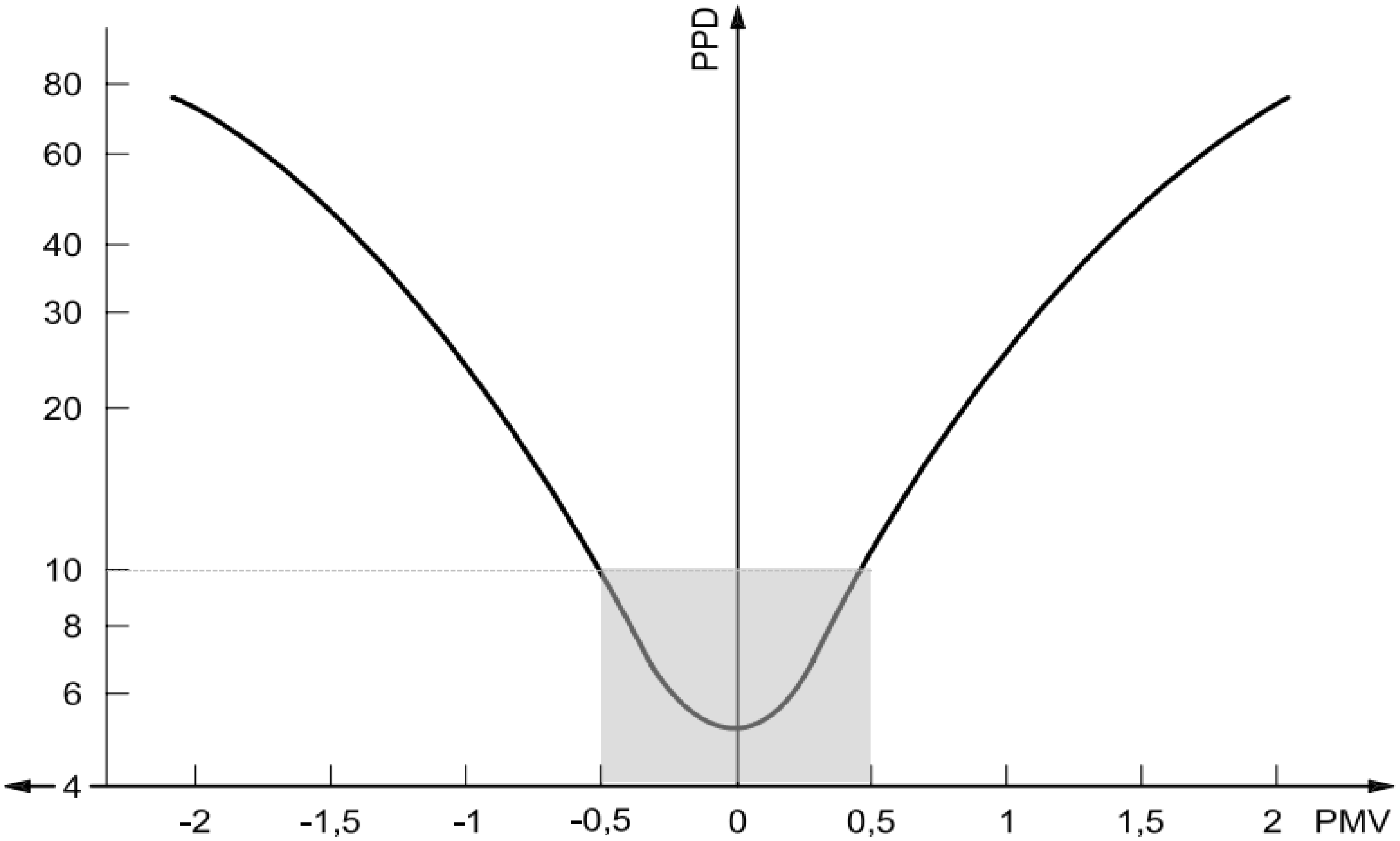
Controlled mechanical ventilation

CMV with double flow

Extraction → bathrooms and kitchen

Supply → other rooms

Thermal comfort



PMV predicted mean vote

PPD predicted percentage dissatisfied, %

Thermal comfort

Table B.1 — Default categories for design of mechanical heated and cooled buildings

Category	Thermal state of the body as a whole	
	Predicted Percentage of Dissatisfied PPD %	Predicted Mean Vote PMV
I	< 6	−0,2 < PMV < + 0,2
II	< 10	−0,5 < PMV < + 0,5
III	< 15	−0,7 < PMV < + 0,7
IV	< 25	−1,0 < PMV < + 1,0

UNI EN 16798

Thermal comfort

Table B.2 — Default design values of the indoor operative temperature in winter and summer for buildings with mechanical cooling systems (for more examples see FprCEN/TR 16798-2 [7])

Type of building/ space	Category	Operative temperature °C	
		Minimum for heating (winter season), approximately 1,0 clo	Maximum for cooling (summer season), approximately 0,5 clo
Residential buildings, living spaces (bed room's, living rooms, kitchens, etc.) Sedentary activity ~1,2 met	I	21,0	25,5
	II	20,0	26,0
	III	18,0	27,0
	IV	16,0	28,0
Residential buildings, other spaces (utility rooms, storages, etc.) Standing-walking activity ~1,5 met	I	18,0	
	II	16,0	
	III	14,0	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met	I	21,0	25,5
	II	20,0	26,0
	III	19,0	27,0
	IV	18,0	28,0
NOTE A 50% relative humidity level and low air velocity level (<0,1 m/s) is assumed.			

Table B.2 presents design values for the indoor operative temperature in buildings that have active heating systems in operation during winter season and active cooling systems during summer season.

Assumed clothing thermal insulation level for winter and summer (clo-value) and activity level (met-value) are listed in Table B.2. Note that the operative temperature limits shall be adjusted when clothing levels and/or activity levels are different from the values mentioned in the table.

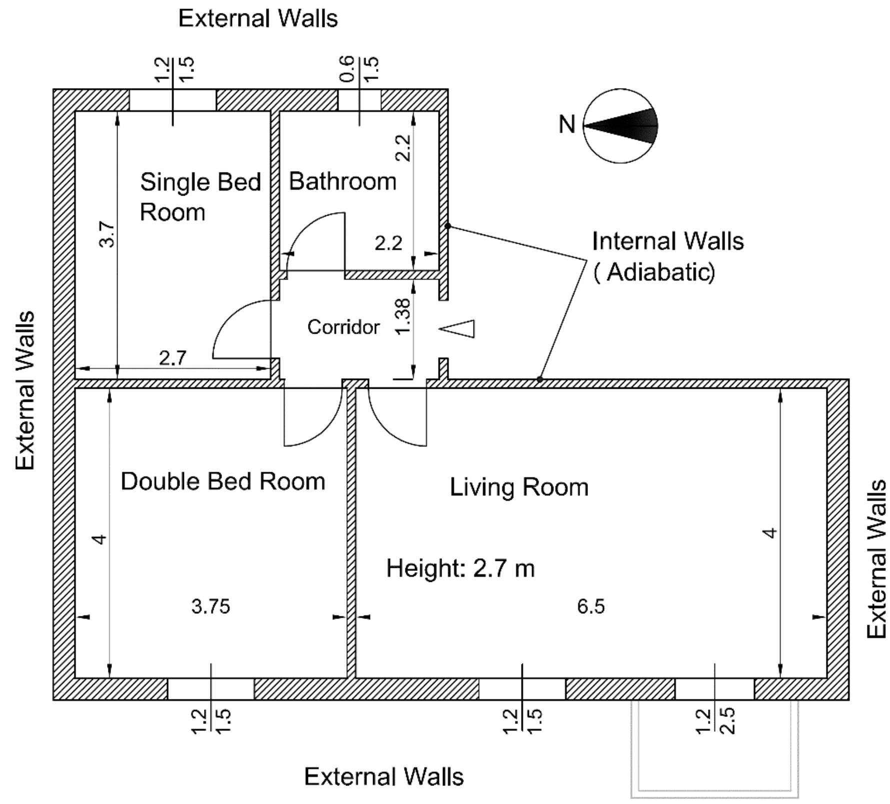
UNI EN 16798

Case Study

Apartment of 60 m^2

Opaque external wall:
U_T= 0.25 W/(m^{2}K)

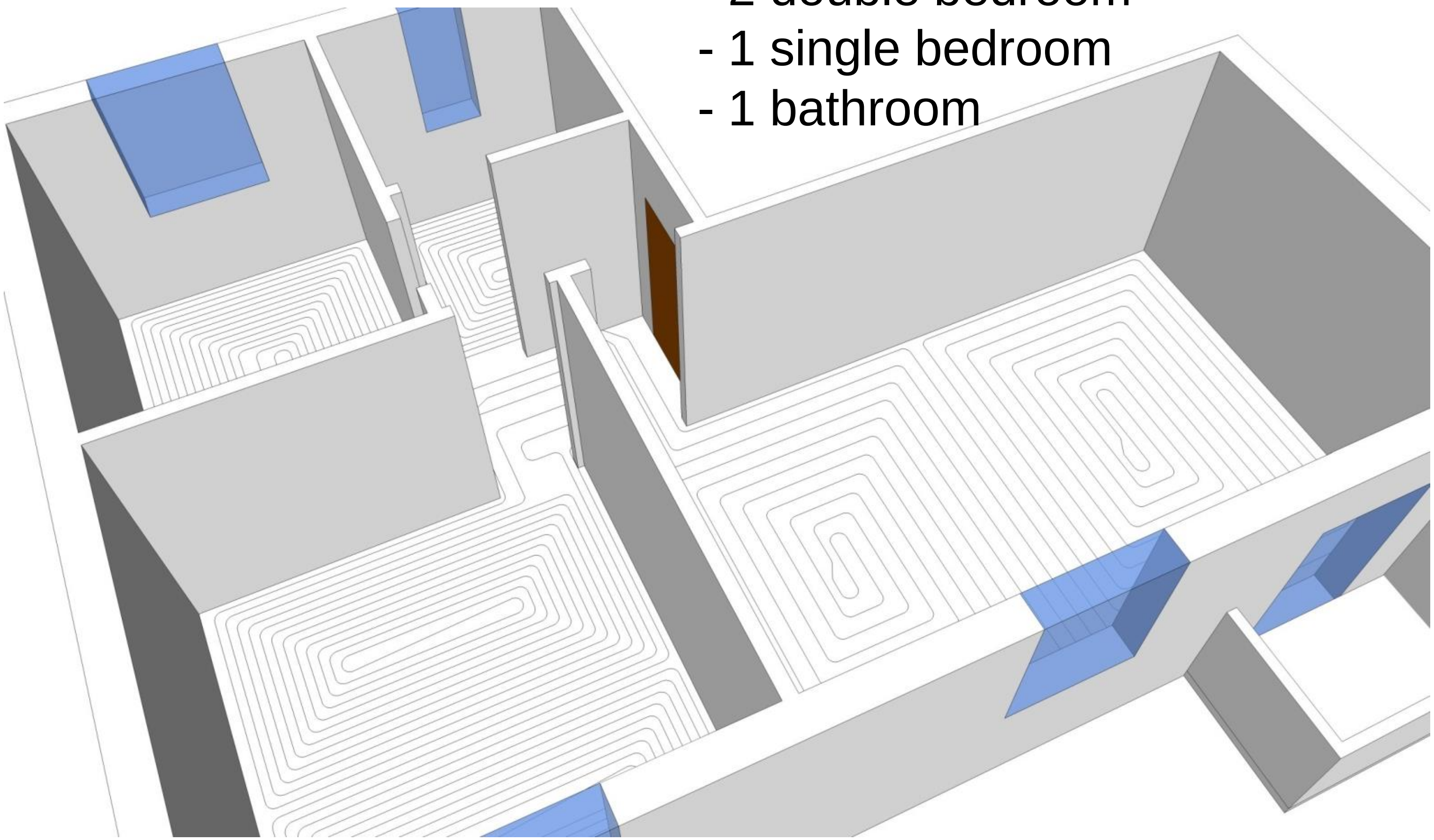
Windows:
U_w= 1.5 W/(m^{2}K)



Case Study

Radiant systems: 6 floor circuits

- 2 living-room
- 2 double bedroom
- 1 single bedroom
- 1 bathroom



Floor radiant systems

Floor covering:

- ➢ livingroom, bathroom, corridor → TILE (ceramic)
- ➢ bedrooms → PARQUET (wood)

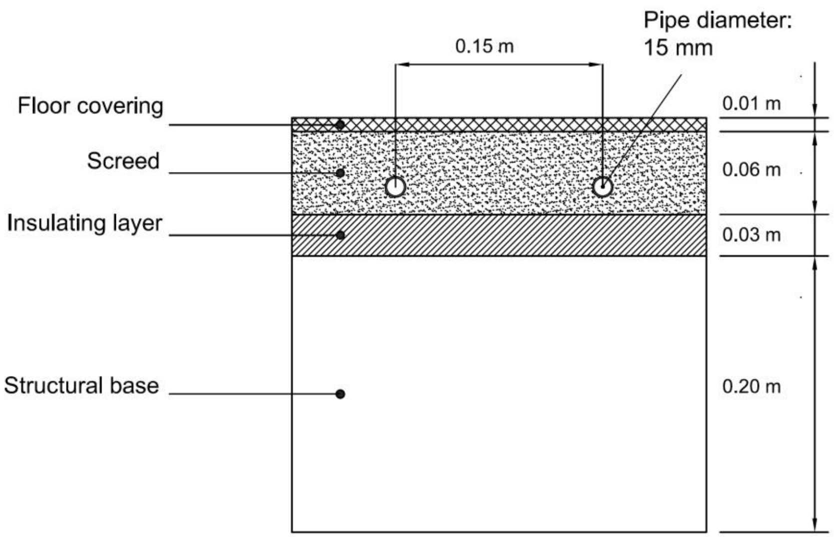


Table 1 – Thermal properties of the floor radiant system.			
	Thermal conductivity	Specific heat	Density
	[W/(m K)]	[J/(kg K)]	[kg/m^3]
Floor covering (tile)	1.00	800	2000
Floor covering (wood)	0.16	1255	720
Screed	0.93	970	2000
Insulation layer	0.04	1400	30
Structural base	0.50	920	1100

Computer simulation

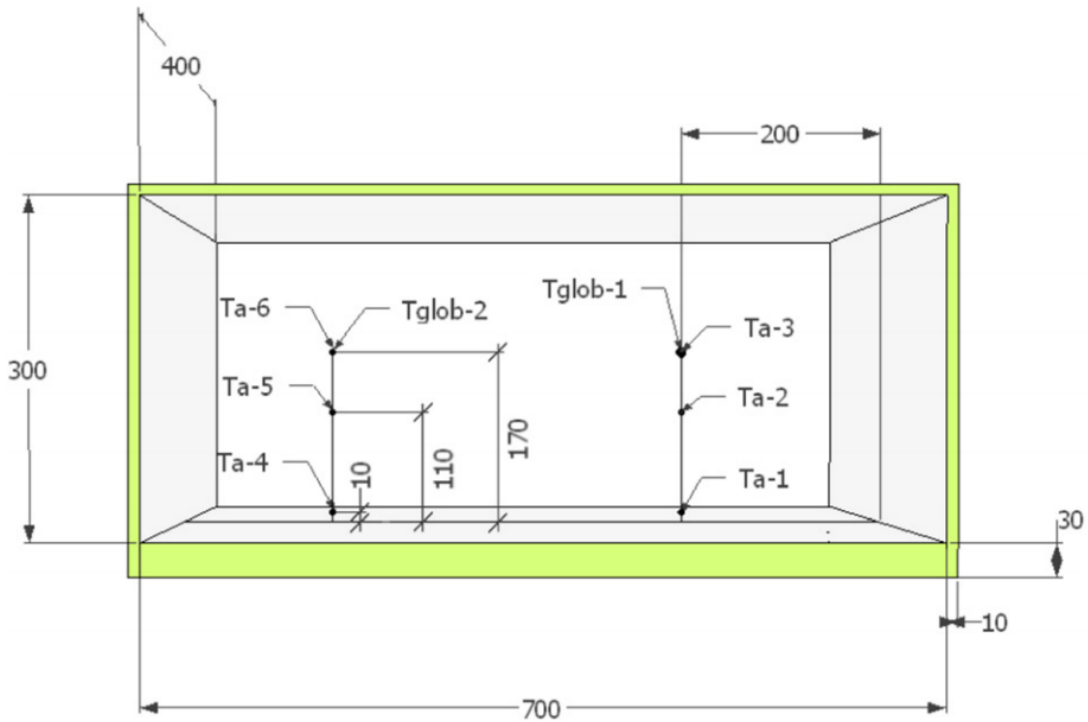
Software: DigiThon

- for simulations of the thermal behavior in transient regime of the building

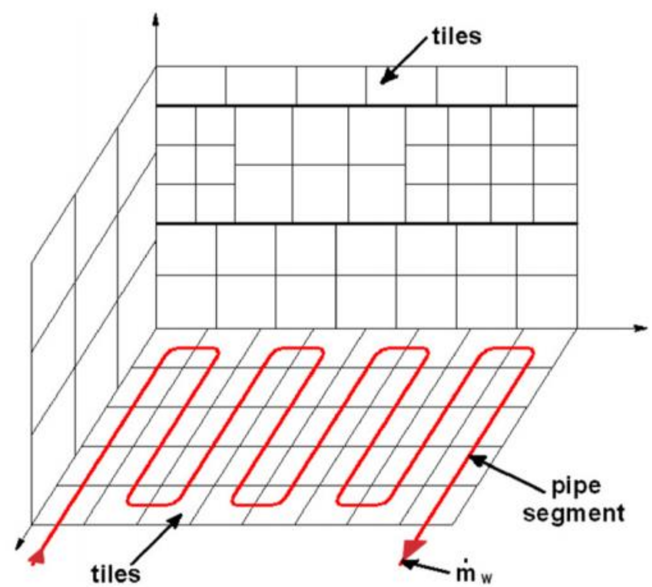
Climates

- Venice
- Rome
- Bari

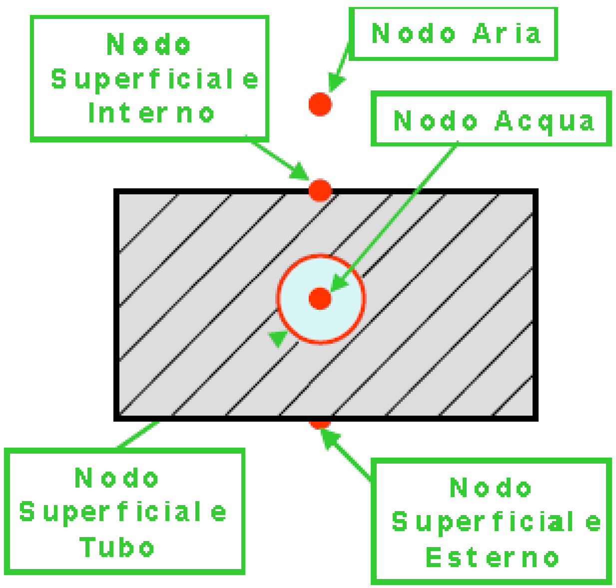
DigiThon (1/3)



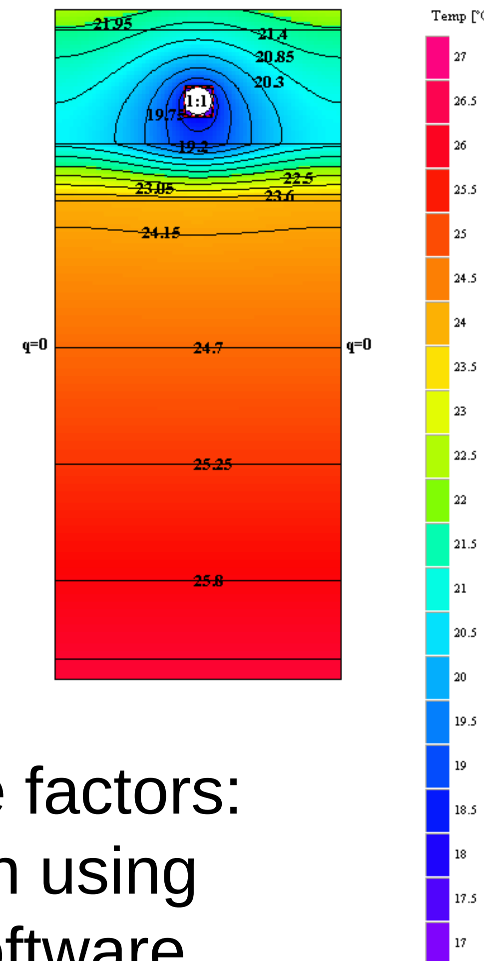
BETA_Lab Group



DigiThon (2/3)

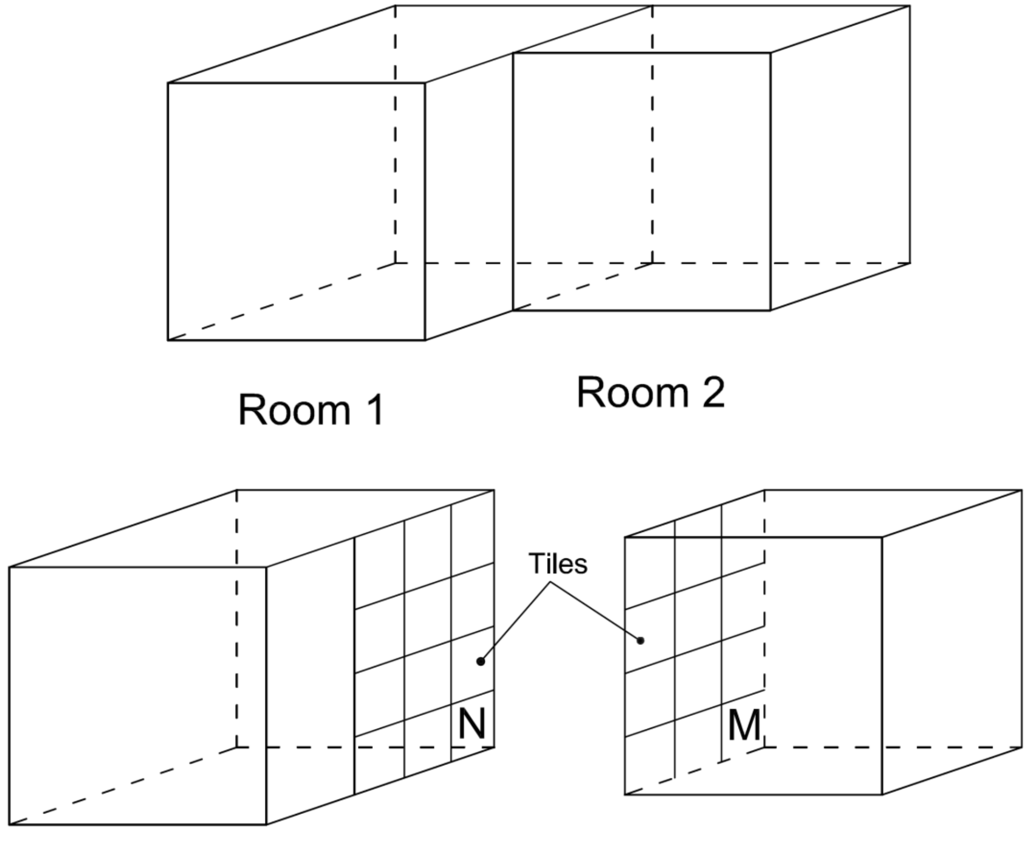


Nodal modeling scheme for a radiant panel tile



Response factors: calculation using HEAT2 software

DigiThon (3/3)

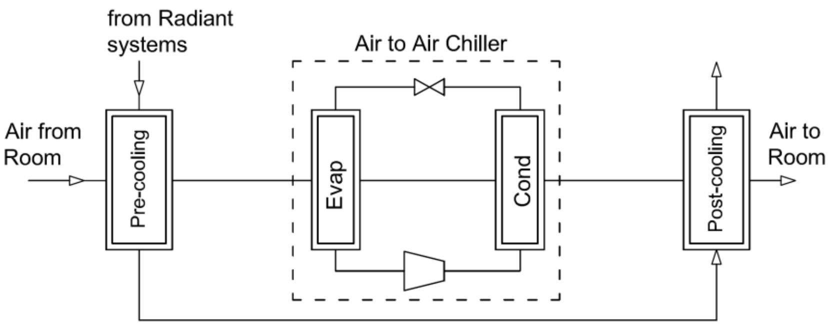


Analysis

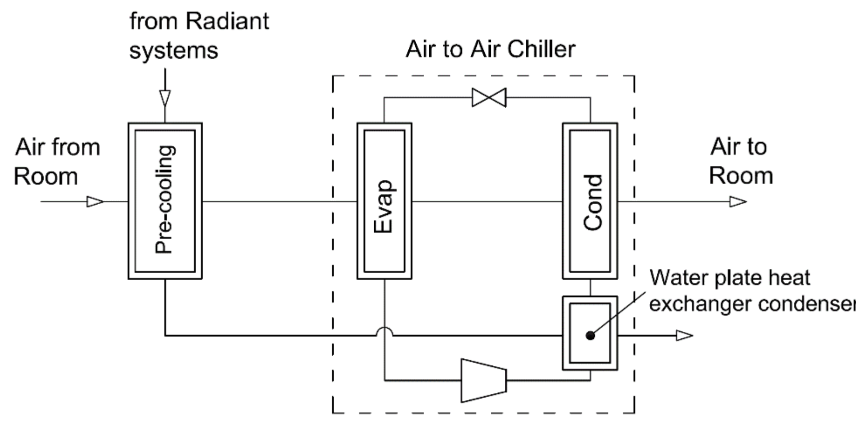
Table 3 – List of the case studies analyzed.		
		External fresh air flow rate vol/h
Case 1 (RF)	Radiant floor AND Natural ventilation	0.6
		1
Case 2 (RF – ID)	Radiant floor AND Isothermal dehumidifier	0.6
Case 3 (RF – DC)	Radiant floor AND Dehu-conditioner	0.6
Case 4 (RF – FC)	Radiant floor AND Fan coil	0.6
Case 5 (RF – MV)	Radiant floor AND Mechanical ventilation	0.6
		1

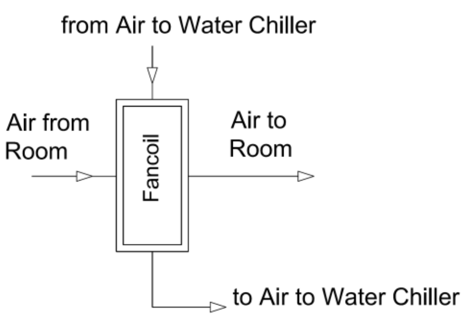
Analysis

isothermal dehumidifier

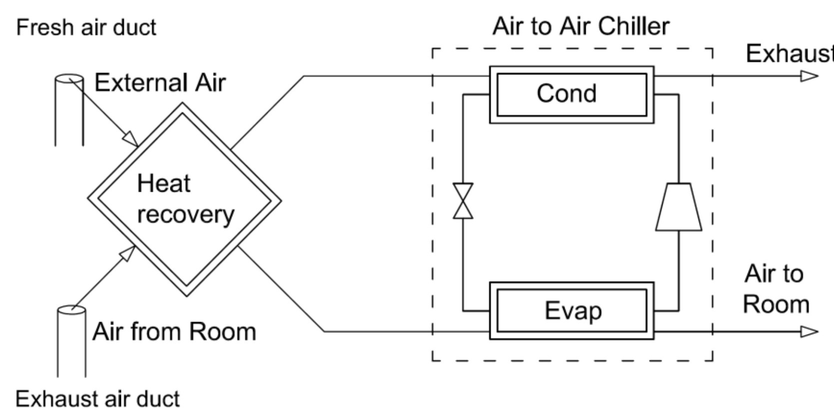


dehu-conditioner





fan coil



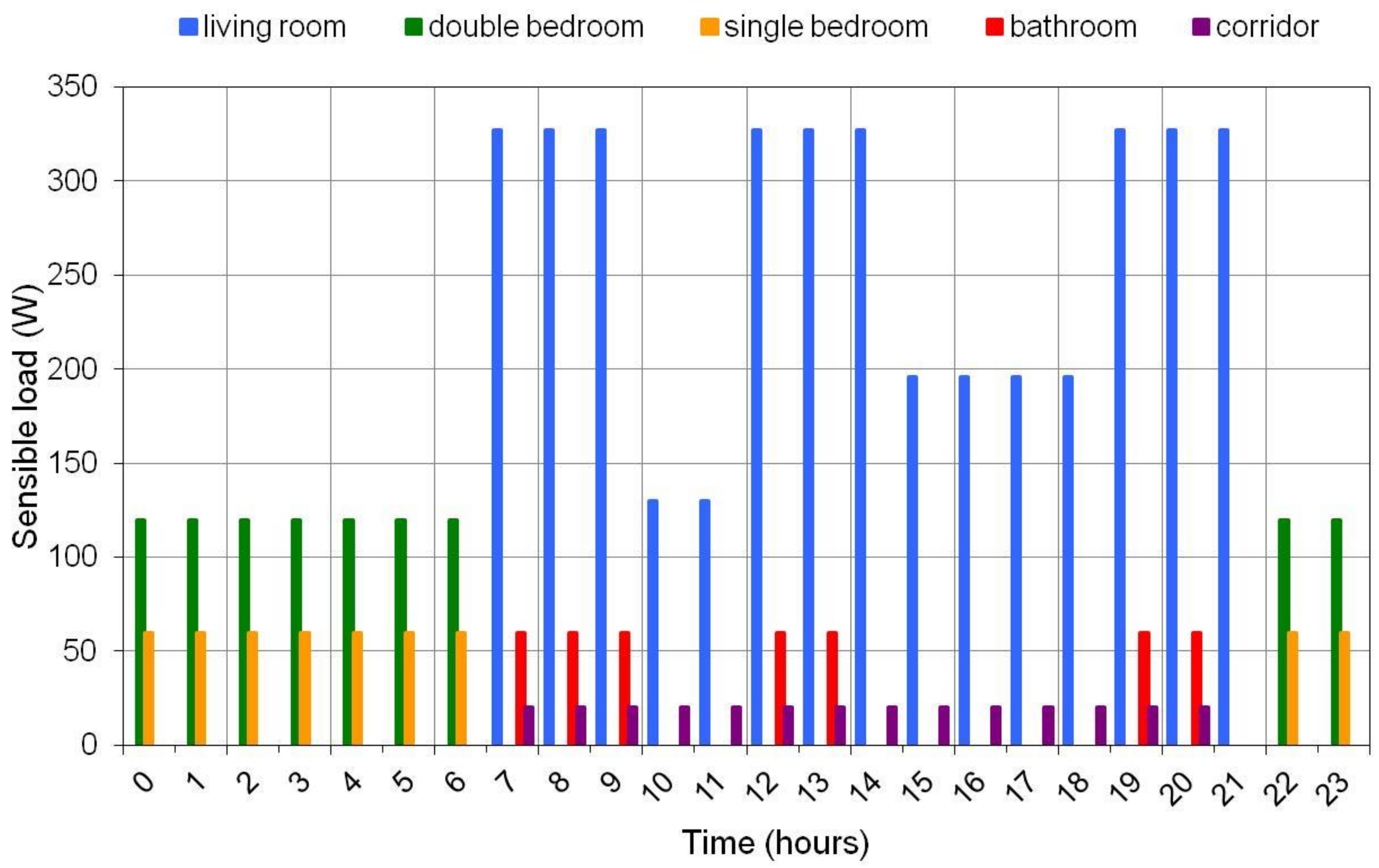
mechanical ventilation system

Boundary conditions

- Given the type of building, some walls have been considered adiabatic since they divide rooms with the same internal conditions (floor and ceiling, because it is an inter-floor apartment, and the two walls of internal type that are along the perimeter of the apartment).

- The internal loads were considered variable during the hours of the day according to the different activities that can be carried out in each room. It is assumed that the apartment is occupied by three persons, who contribute to both sensible and latent internal loads.

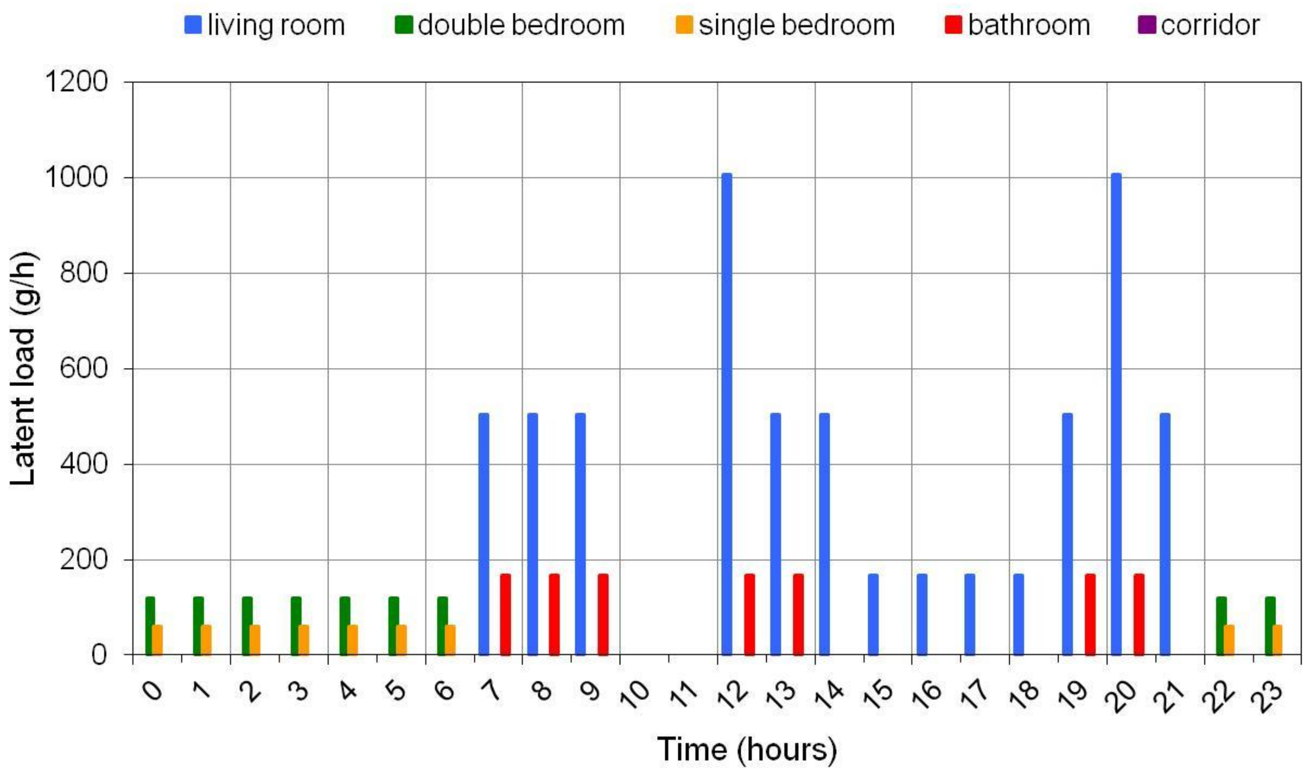
Heat gain profiles



Possible latent loads

DAILY HUMIDITY FOR DOMESTIC ACTIVITIES			
Number of people	Humidity expressed in kg/day		
	Low moisture emission	Average moisture emission	High moisture production
1	3,5	6	9
2	4	8	11
3	4	9	12
4	5	10	14
5	6	11	15
6	7	12	16

Latent load profiles



Loads

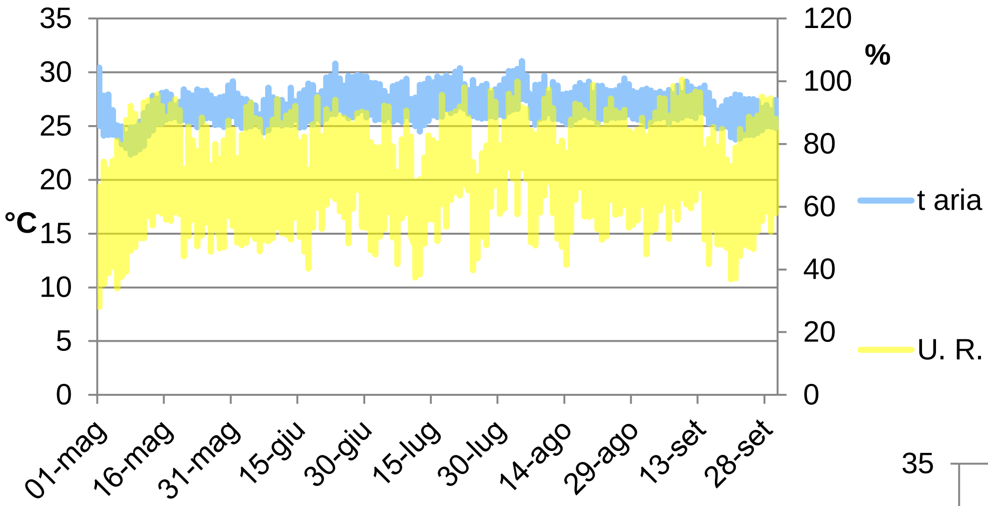
	WINTER	SUMMER
	Energy need	**Cooling load**
VENICE DD = 2345 (climate zone E)	2275 kWh (39 kWh/m^2)	1925 W (33 W/m^2)
ROME DD = 1415 (climate zone D)	937 kWh (17 kWh/m^2)	2183 W (37 W/m^2)
BARI DD = 1185 (climate zone C)	658 kWh (11 kWh/m^2)	2059 W (35 W/m^2)

Results

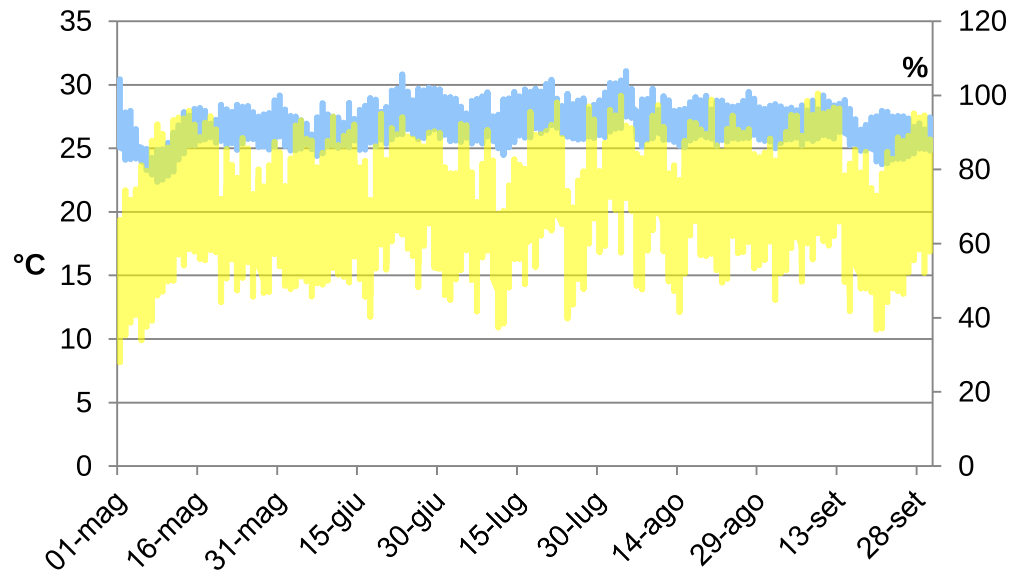
Without dehumidification
Reference climate: Venice

Temperature (°C) e HR (%)

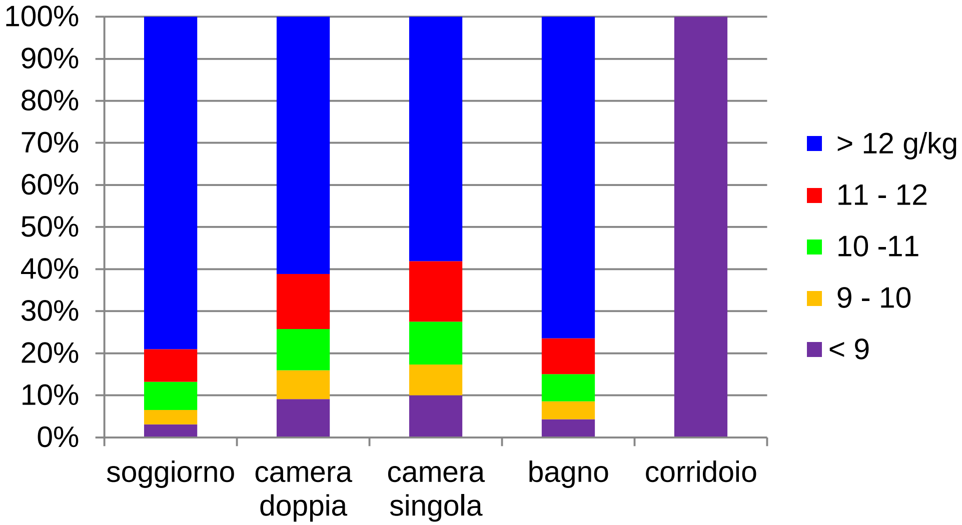
ACH
1 vol/h



ACH
0.6 vol/h



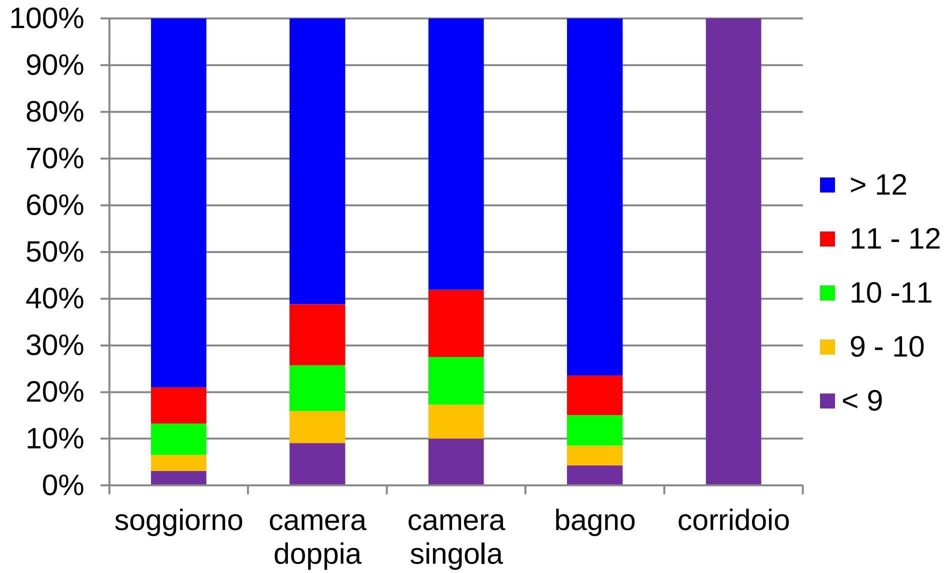
Without dehumidification
Reference climate: Venice



ACH
0.6 vol/h

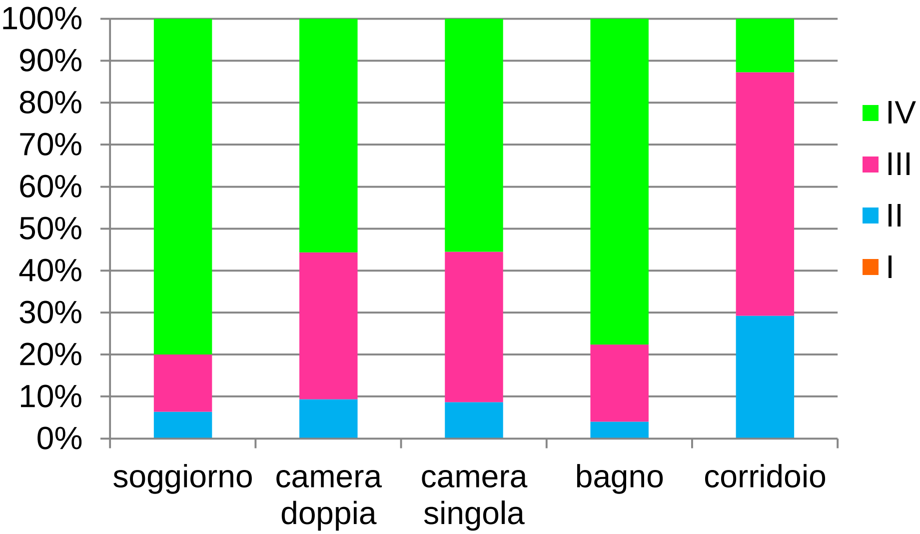
Relative humidity range (%)

ACH
1 vol/h



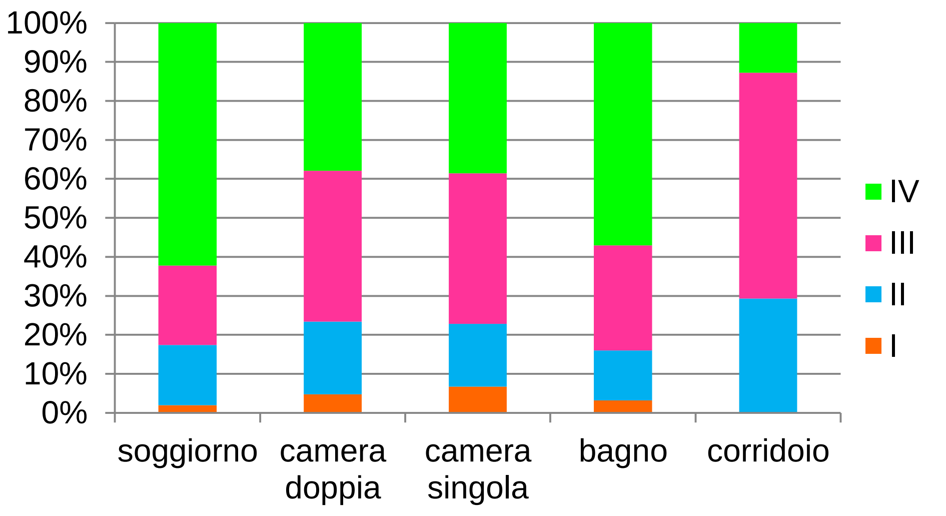
Without dehumidification
Reference climate: Venice

PMV



ACH
0.6 vol/h

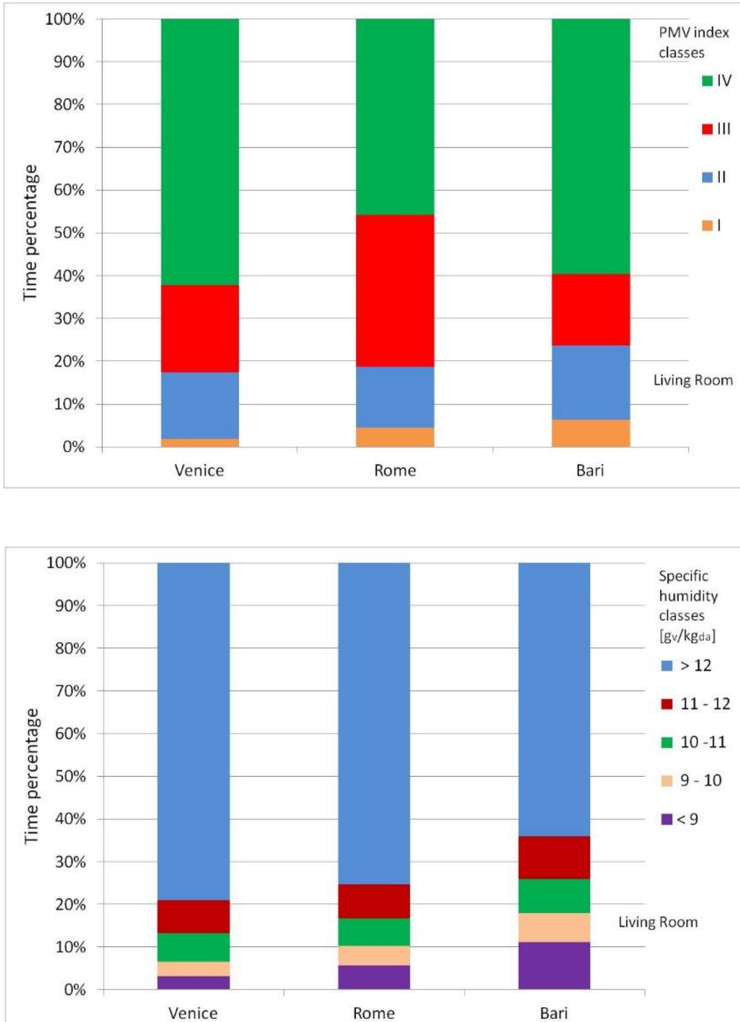
ACH
1 vol/h



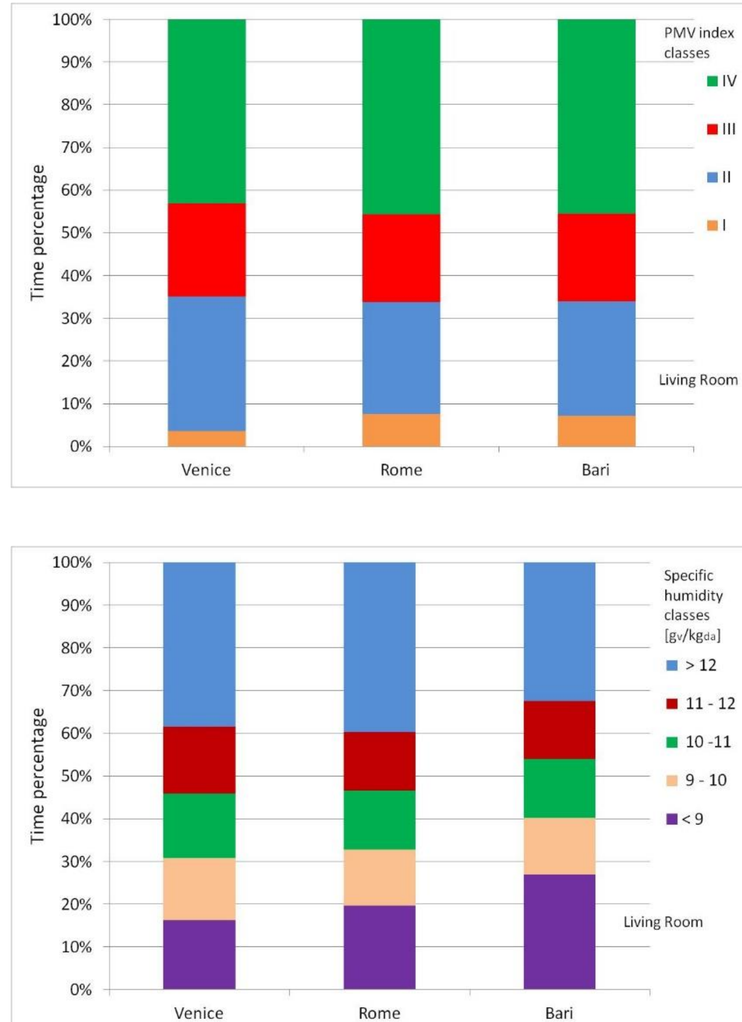
Without dehumidification
Reference climate: Venice

- High specific humidity > 12 $g_v/kg_{a.s.}$
- High relative humidity
- Air temperature not constant at set-point value

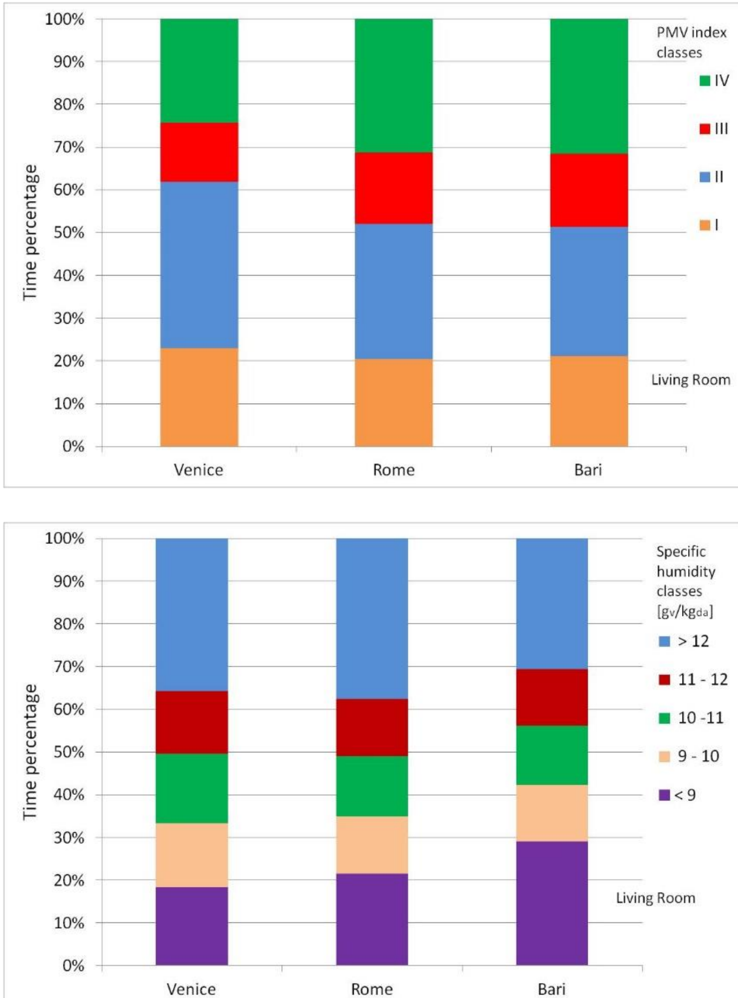
→ Dehumidification is required!



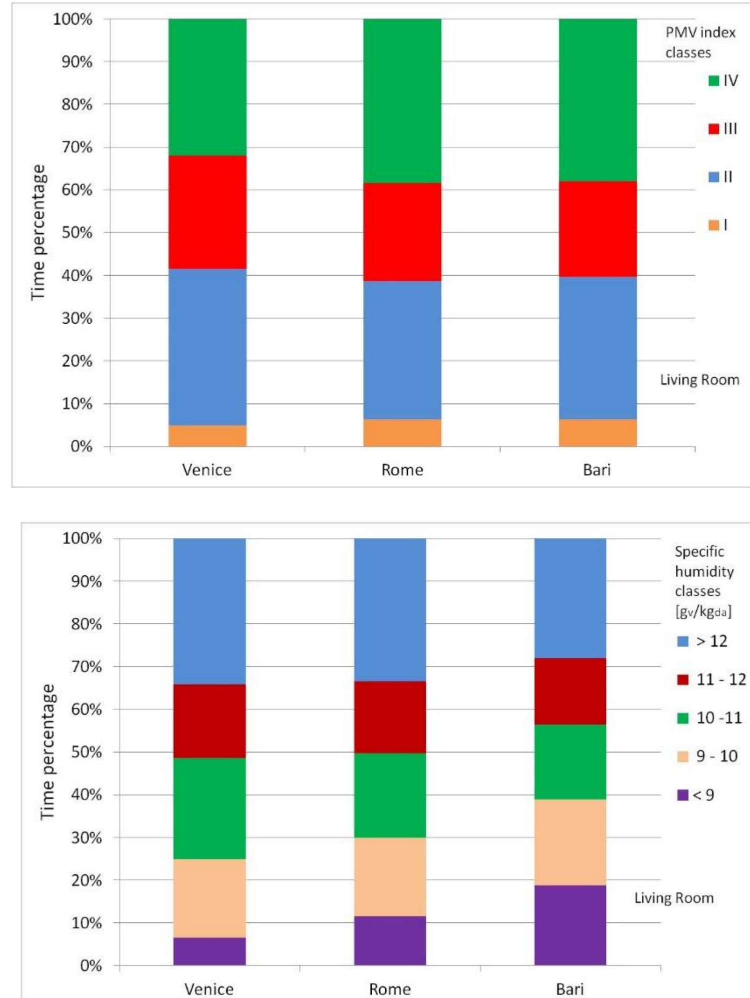
Radiant floor only with air infiltration rate equal to 1 vol/h: time percentage of PMV index and specific humidity ranges in living room.



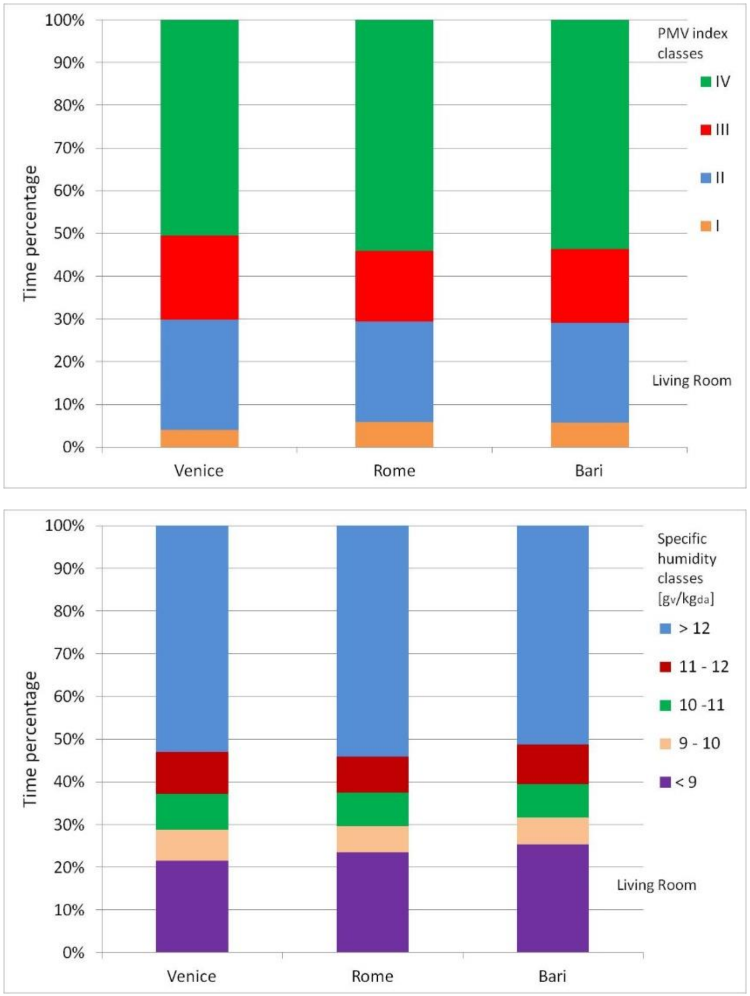
Radiant floor with isothermal dehumidifier: time percentage of PMV index and specific humidity ranges in living room.



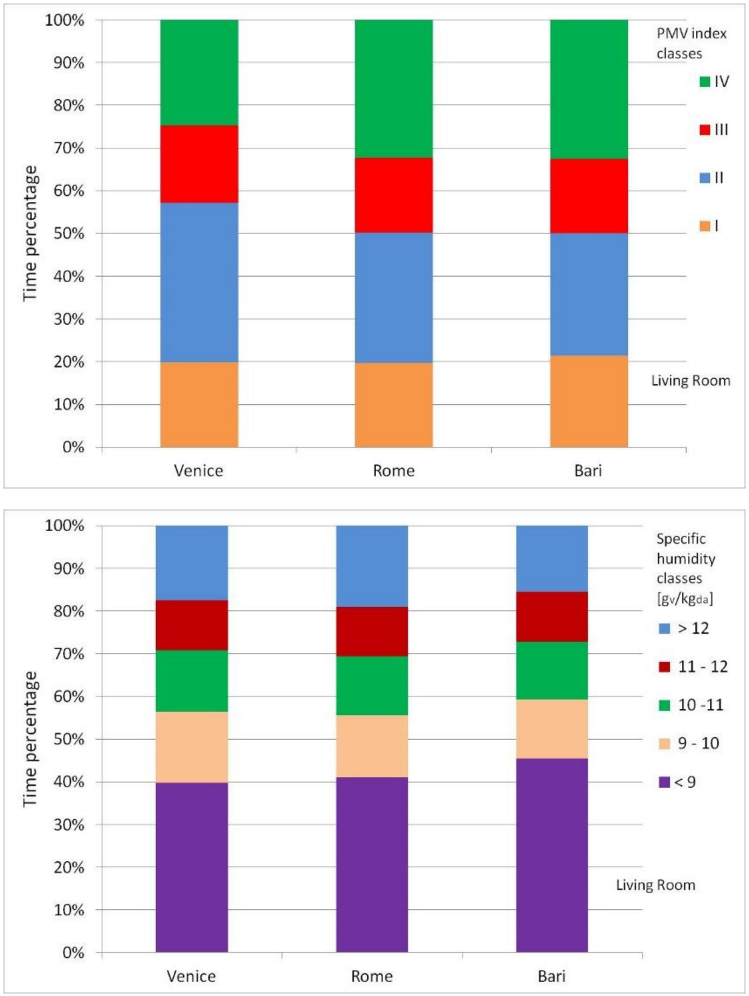
Radiant floor with dehu-conditioner: time percentage of PMV index and specific humidity ranges in living room.



Radiant floor with fan coil: time percentage of PMV index and specific humidity ranges in living room.

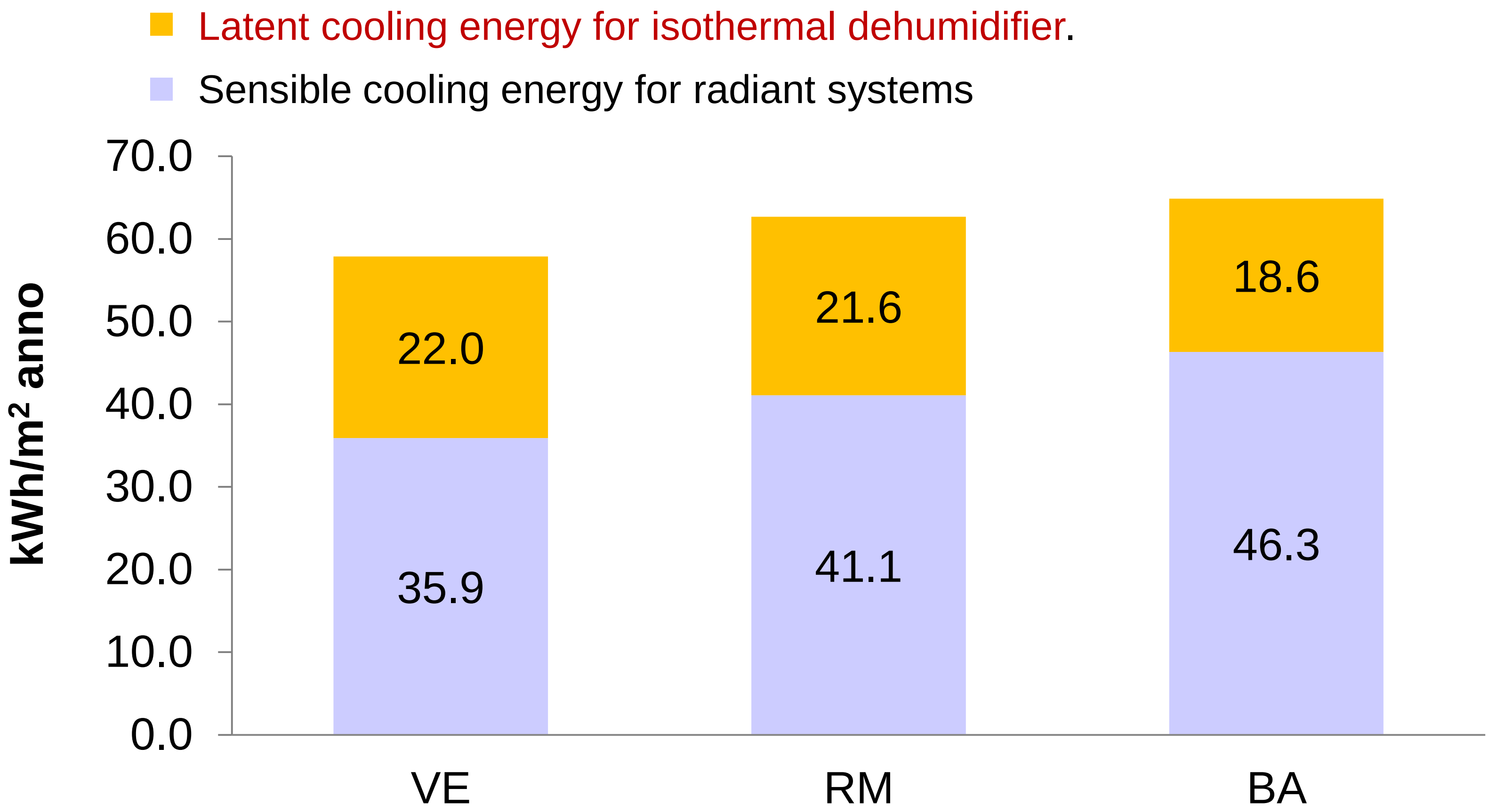


Radiant floor with mechanical ventilation system (0.6 vol/h): time percentage of PMV index and specific humidity ranges in living room.

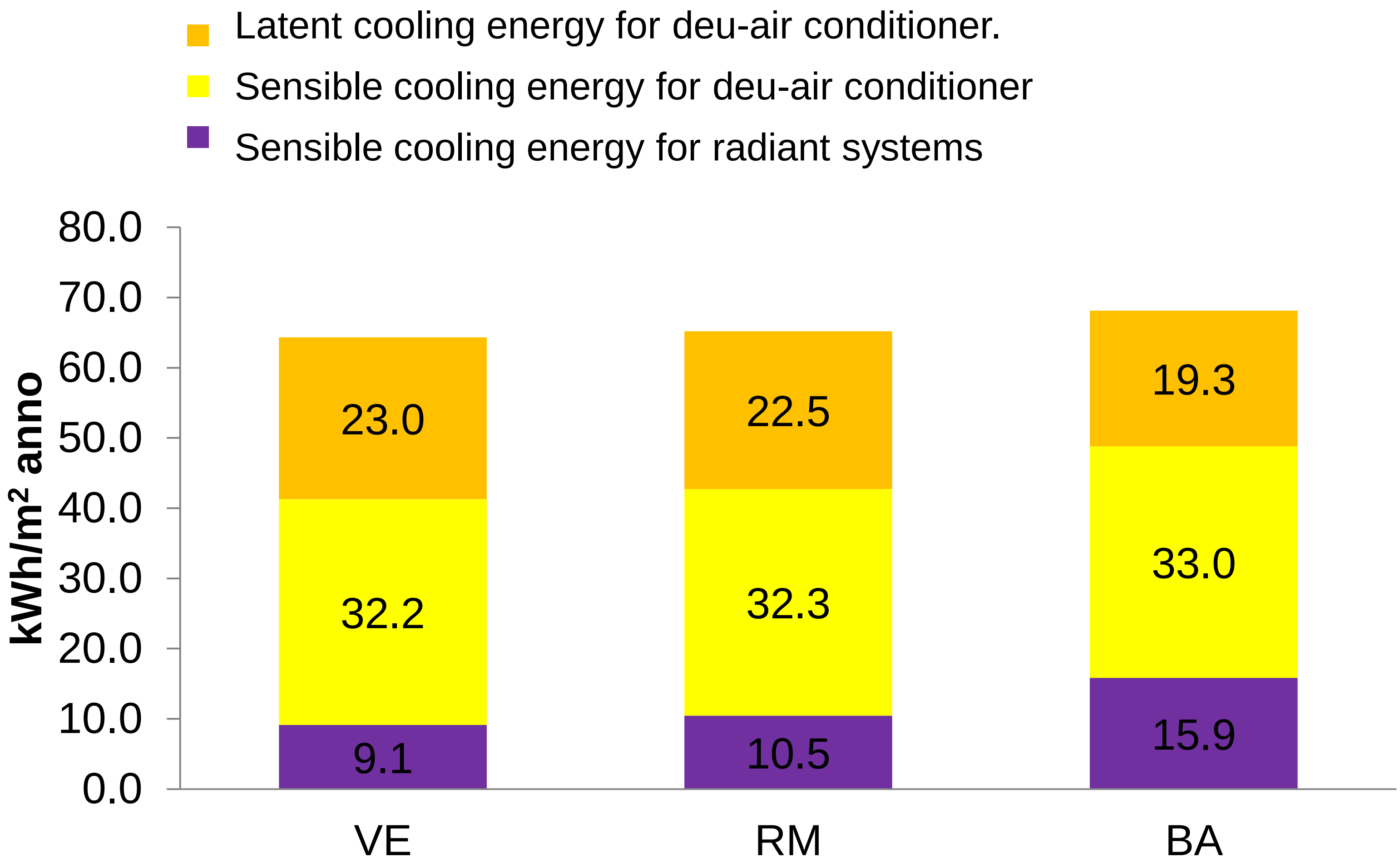


Radiant floor with mechanical ventilation system (1 vol/h): time percentage of PMV index and specific humidity ranges in living room.

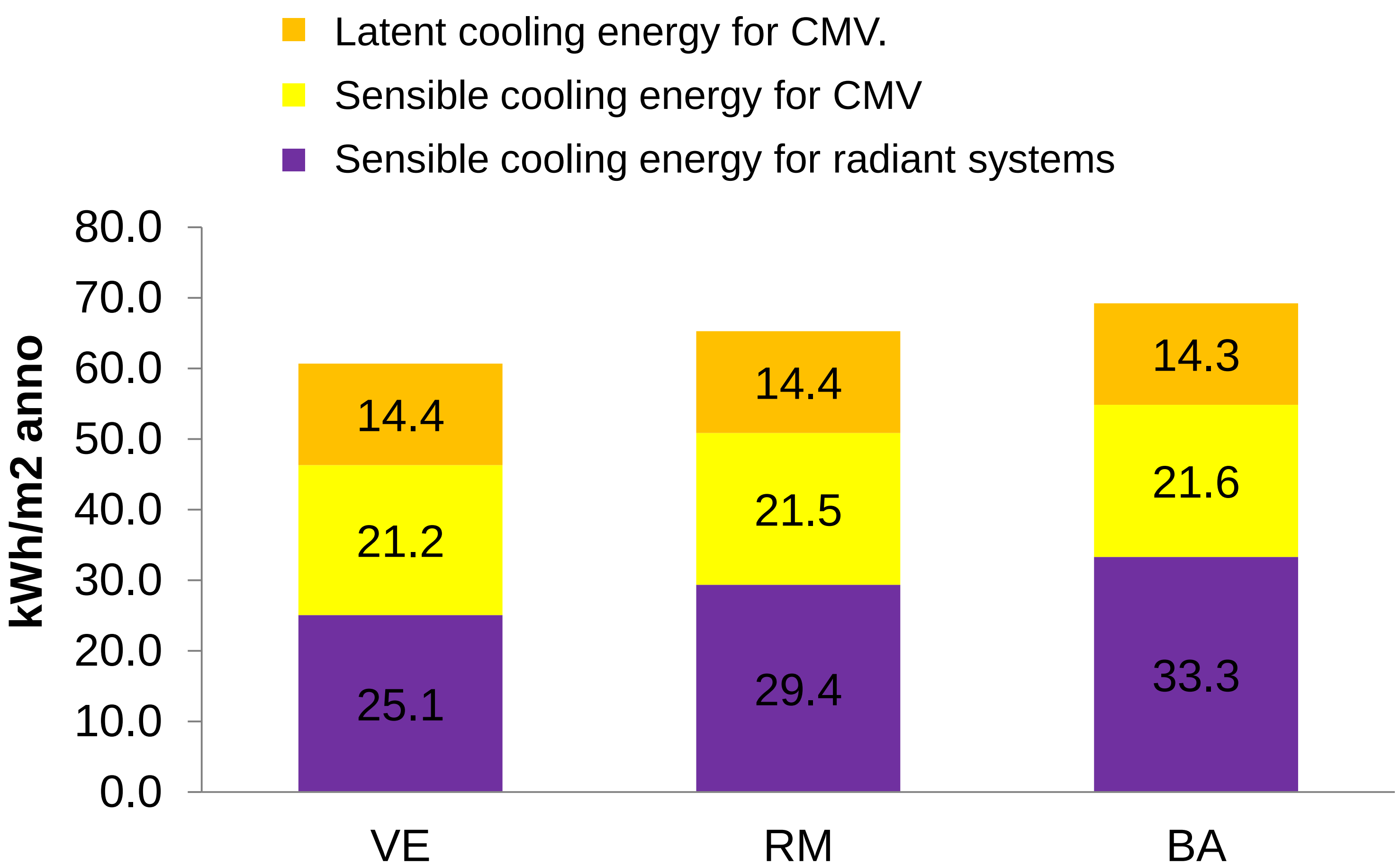
Radiant system and isothermal dehumidifier



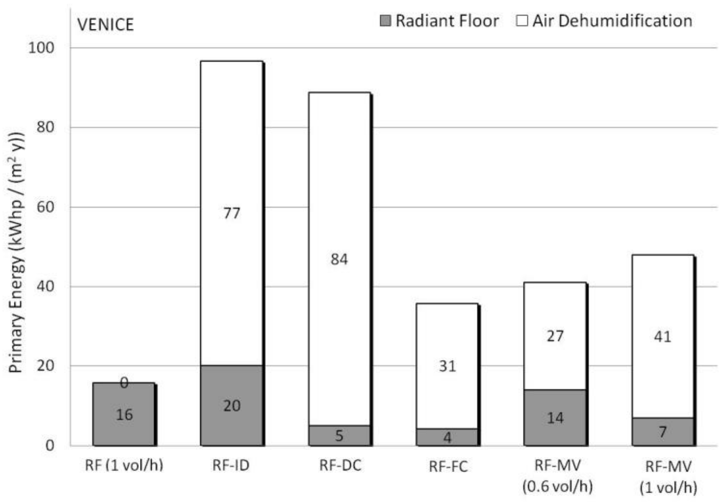
Radiant system and deu-air conditioner

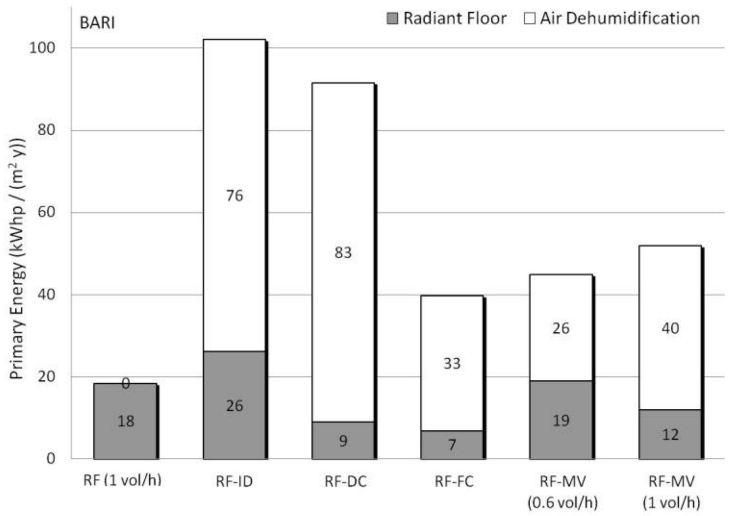


Radiant systems and controlled mechanical ventilation



Specific yearly primary energy use per unit floor area





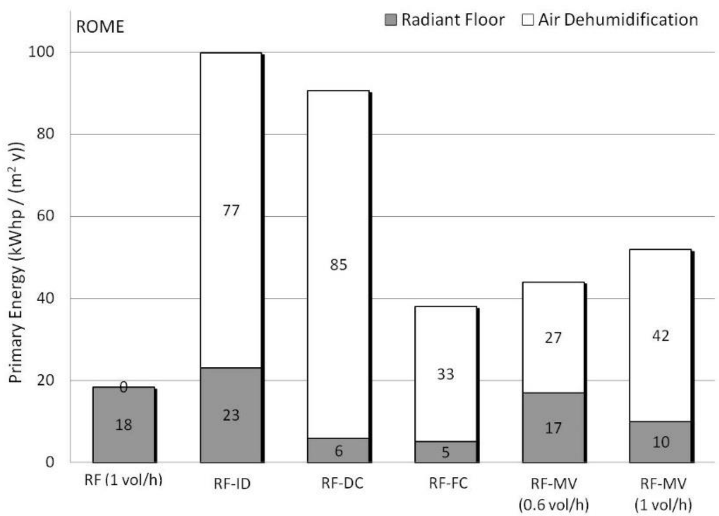


Table 4 – Mean seasonal COP during the cooling period.

	Venice	Rome	Bari
Reversible heat pump for radiant panels	3.86	3.85	3.84
Isothermal dehumidifier	3.31	3.31	3.27
Dehu-conditioner	3.38	3.36	3.32
Chiller for fan coil	4.07	4.05	3.93
Chiller for mechanical ventilation system (0.6 vol/h and 1 vol/h)	3.99	3.98	3.86

Conclusions

- In summer, with radiant cooling, air dehumidification system is needed.

- Dehumidifiers: good dehumidification but higher consumption.

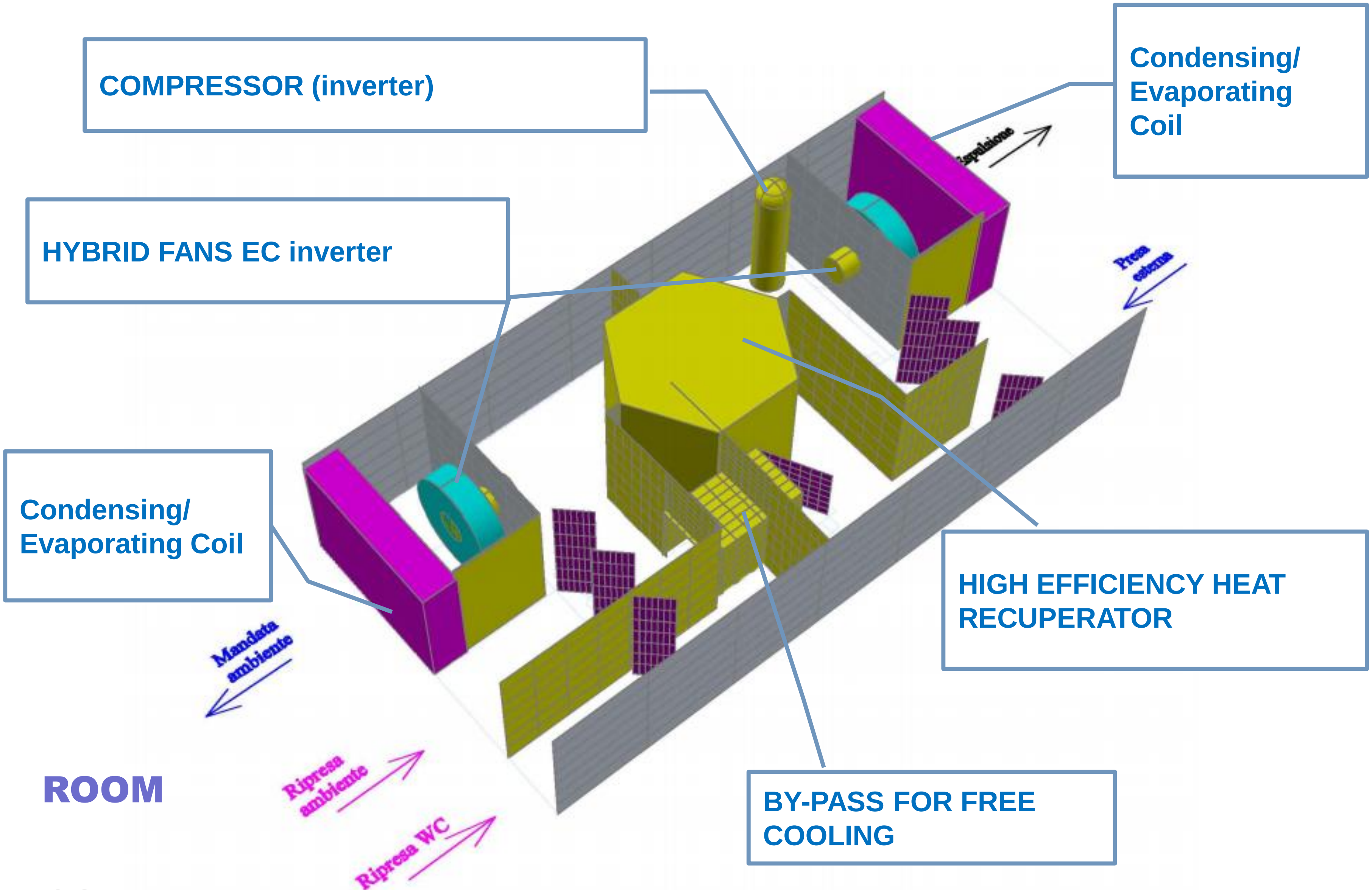
- Fan-coil: good dehumidification and low consumption.

- CMV: excellent dehumidification (with the same flow rate), low consumption and controlled air changes.

Typology of equipment

By Aertesi company

SOLUTION 2: Integrated System



EOS

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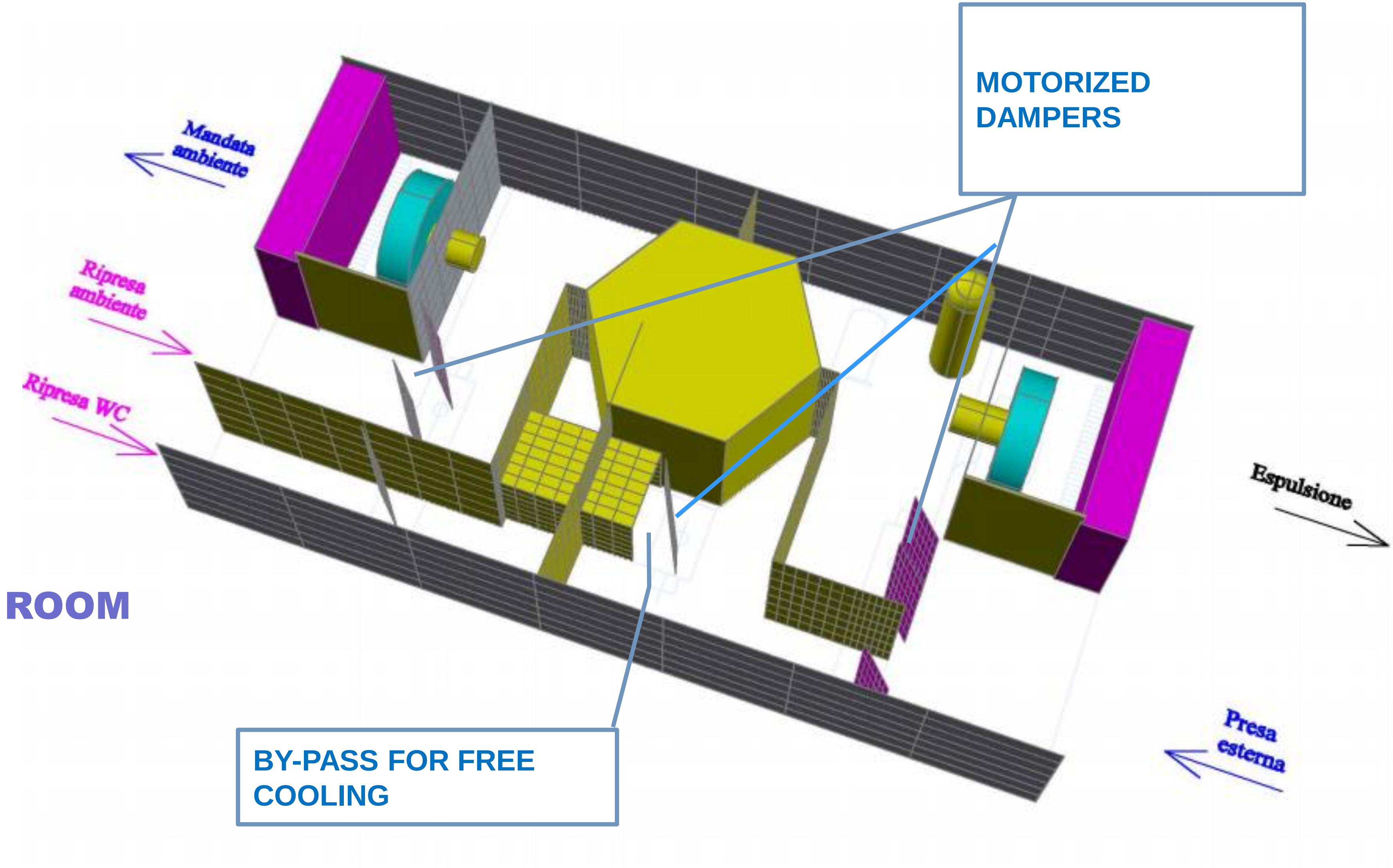
SOLUTION 2: Integrated System



EOS

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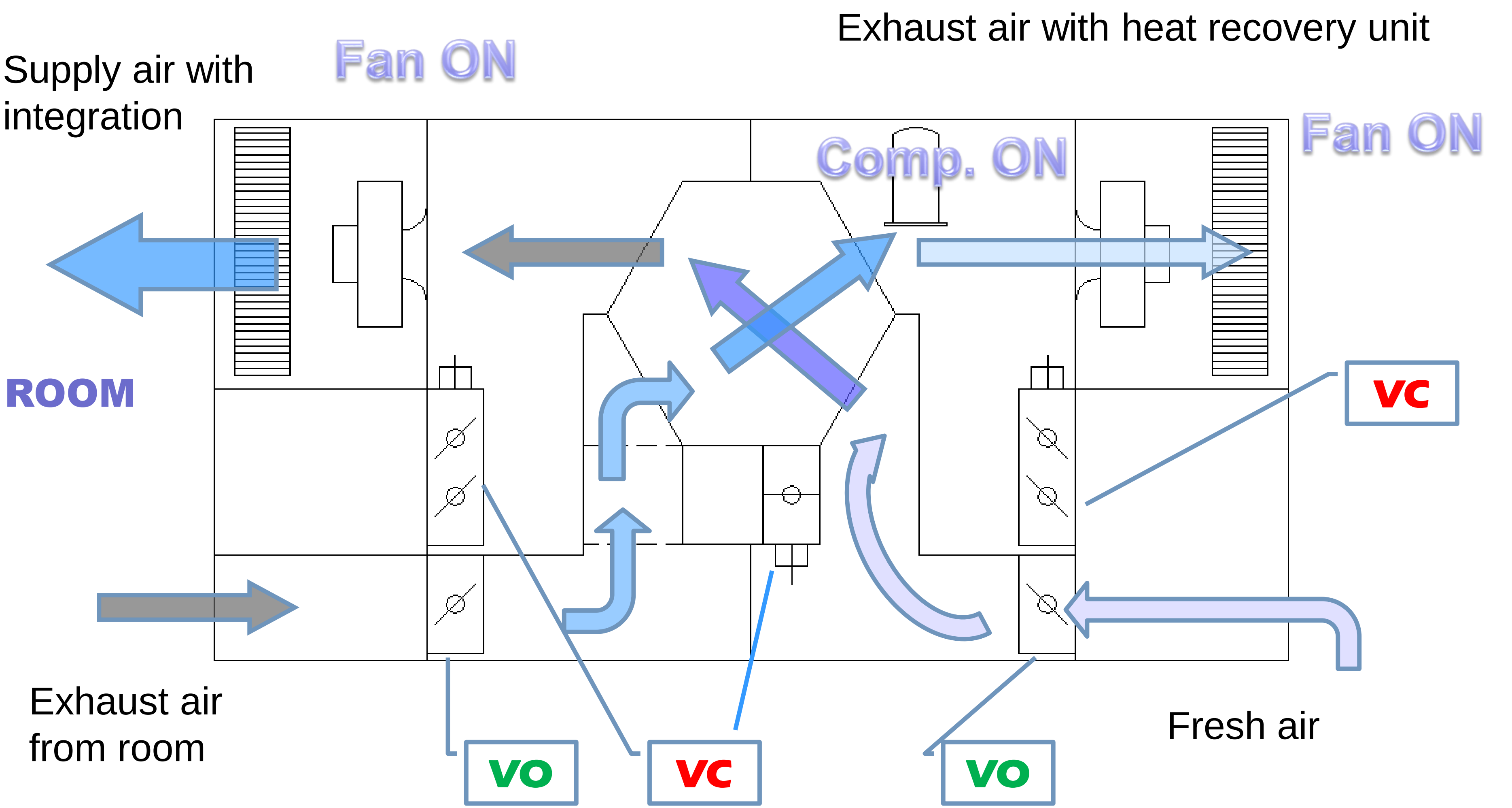
RENEWAL WITH RECOVERY AND INTEGRATION



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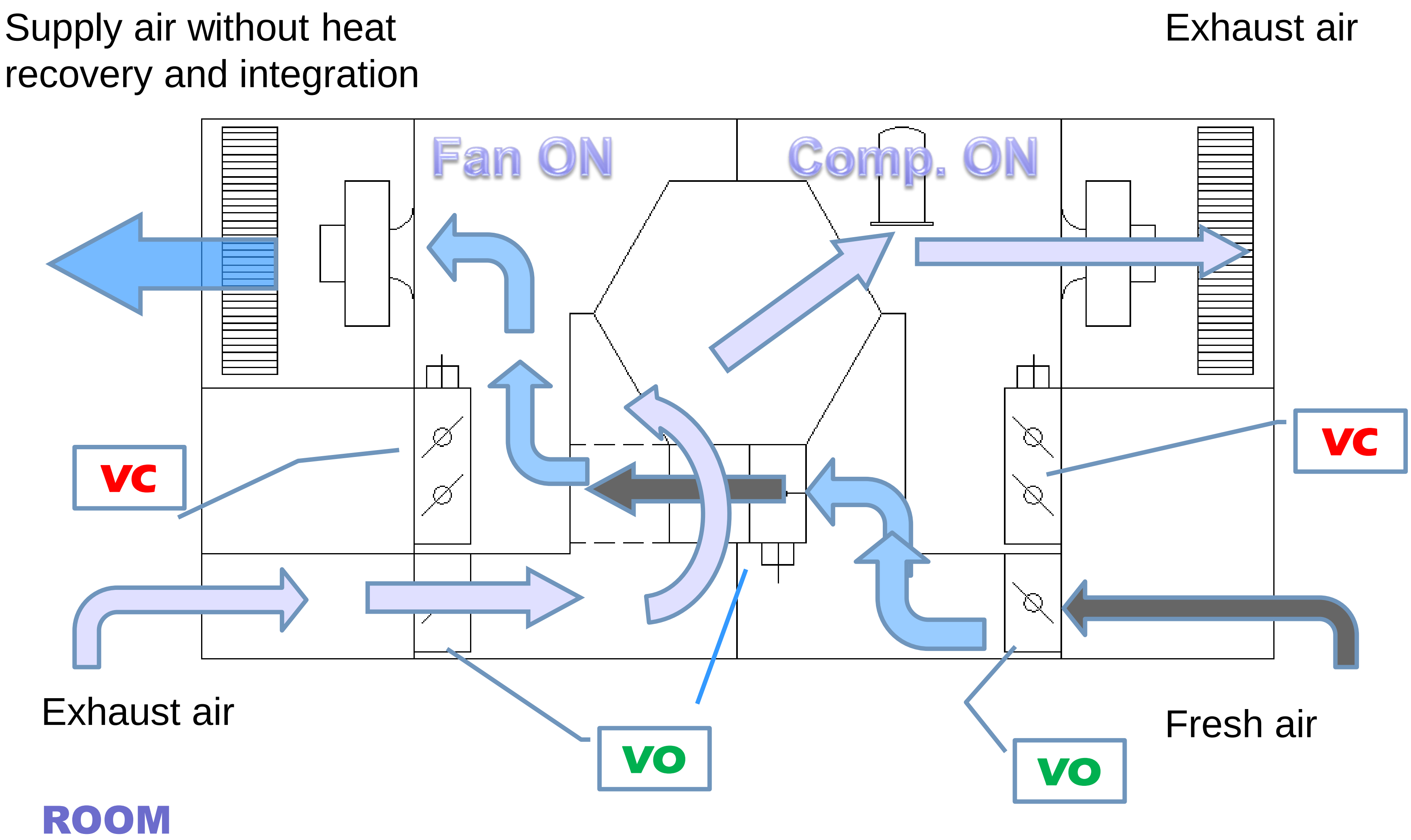
RENEWAL WITH FREE COOLING



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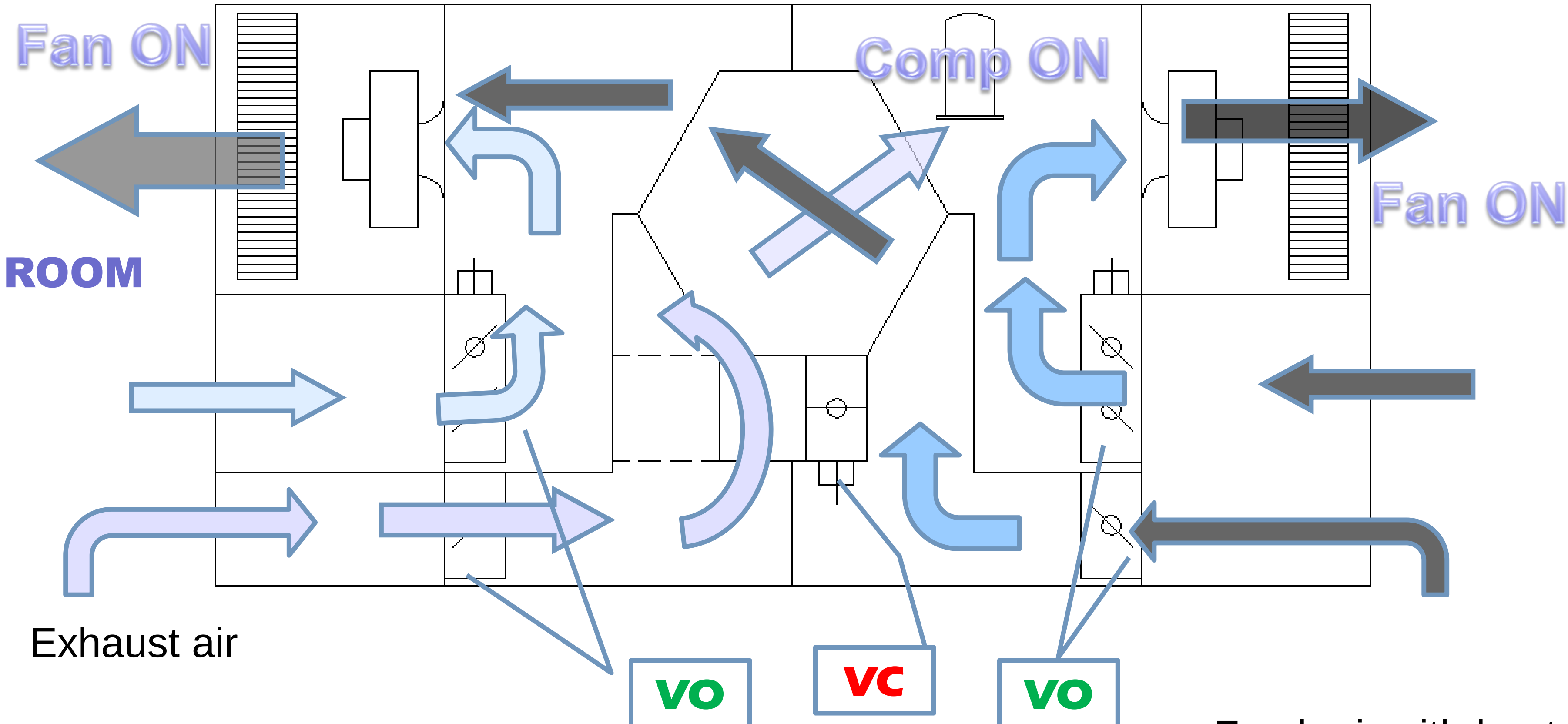
RENEWAL WITH RECOVERY AND INTEGRATION

External fresh air with recirculation mixing, heat recovery and integration

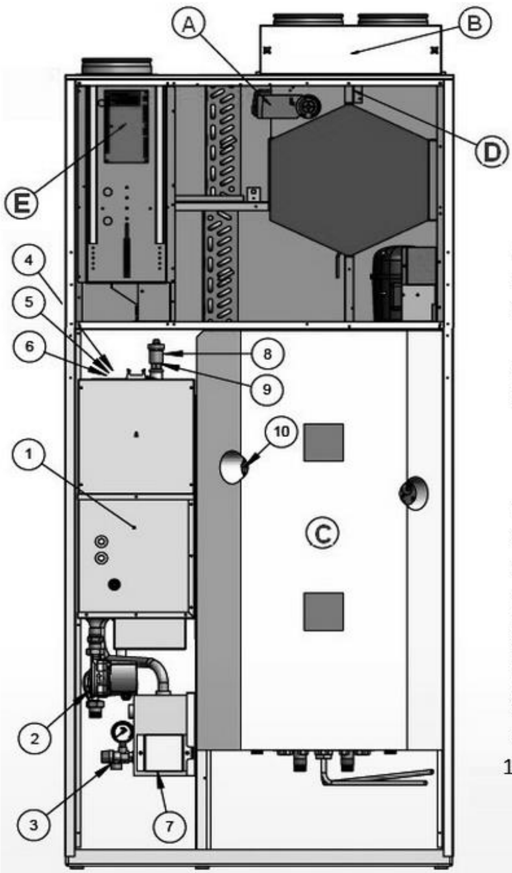
air exhaust and heat recovery



Exhaust air

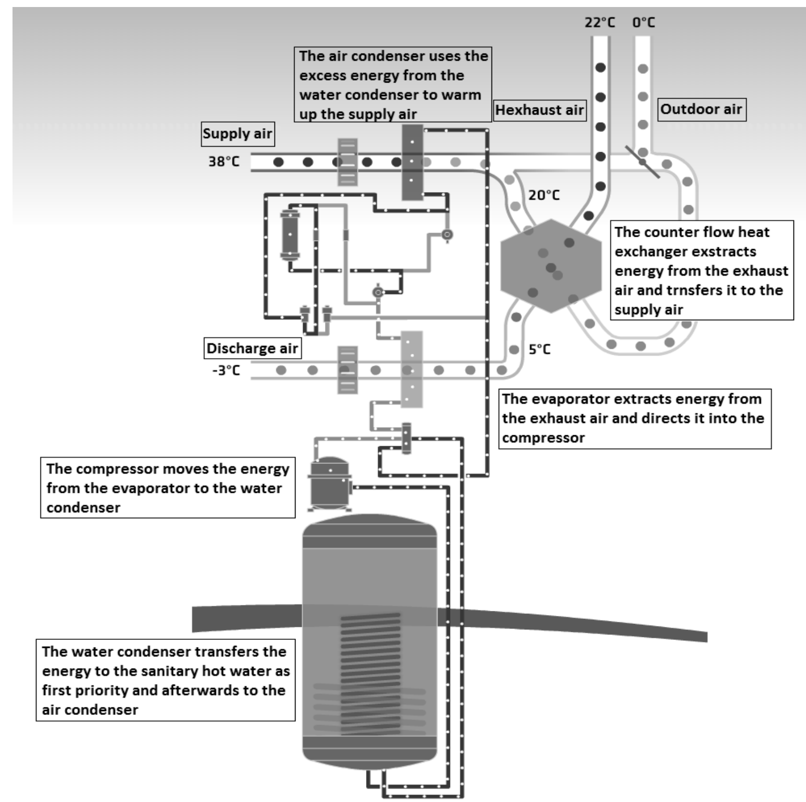
Fresh air with heat recovery unit

By Nilan company



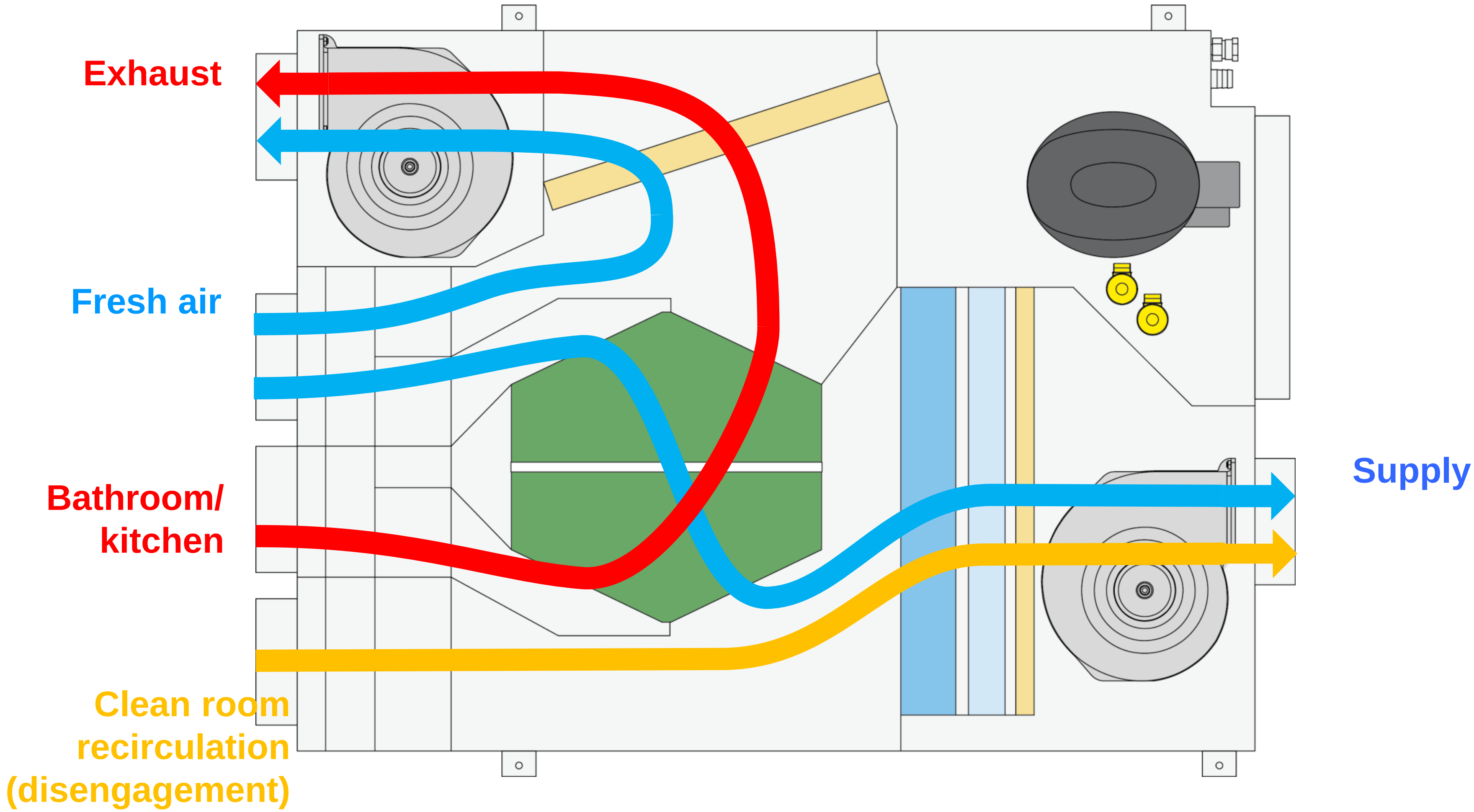
A Bypass
B Filters G4
C DHW tank, 180 liters, electrical heater 1200W
D humidity manifold
E Control system

1. Heat pump
2. Circulation pump
3. Security valve
4. Environmental pressure switch
5. Expansion vessel
6. Expansion vessel
7. Power supply
8. Automatic vent
9. Automatic vent
10. Anode



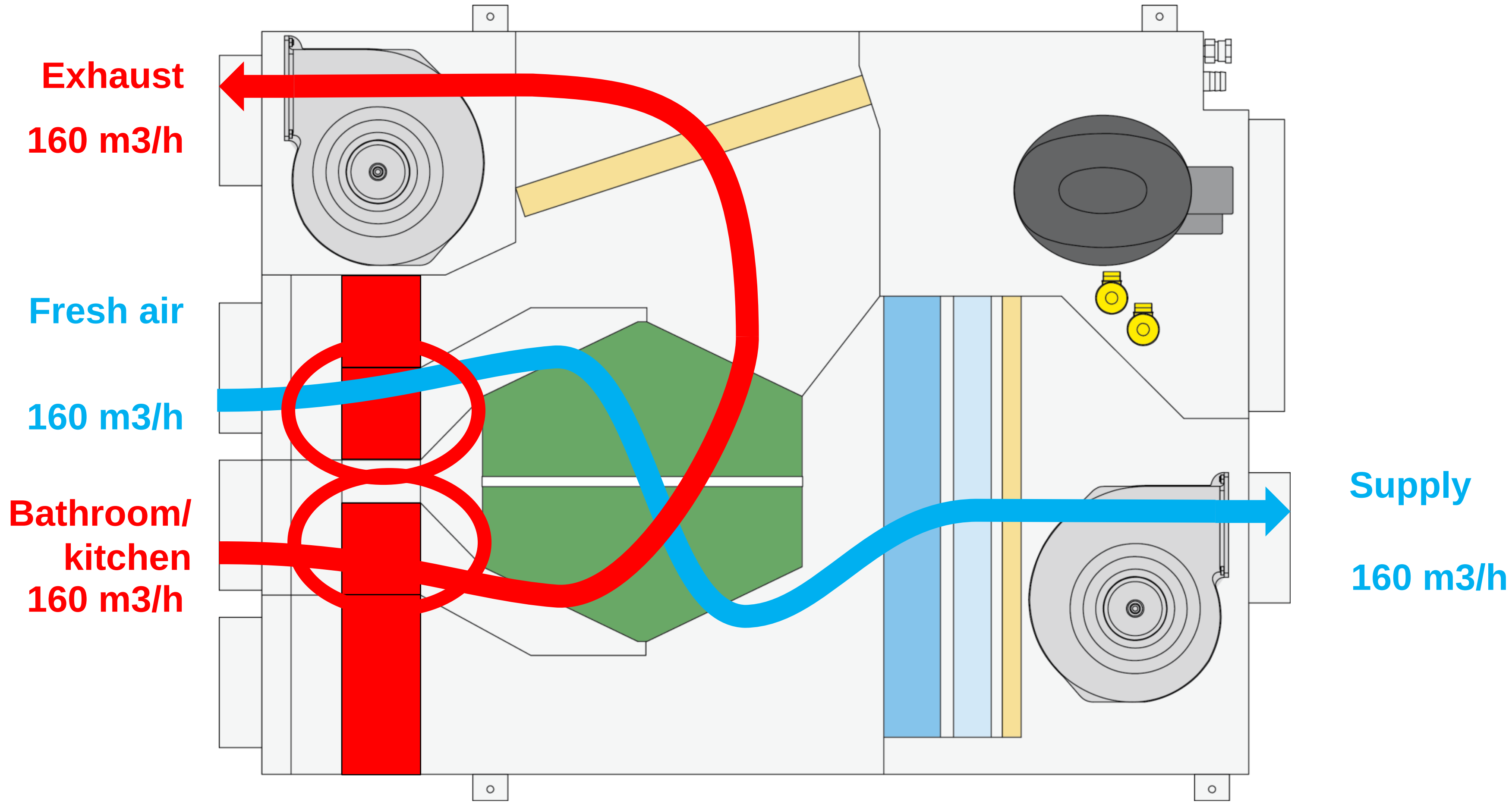
Air flows

By RDZ company



air renewal only

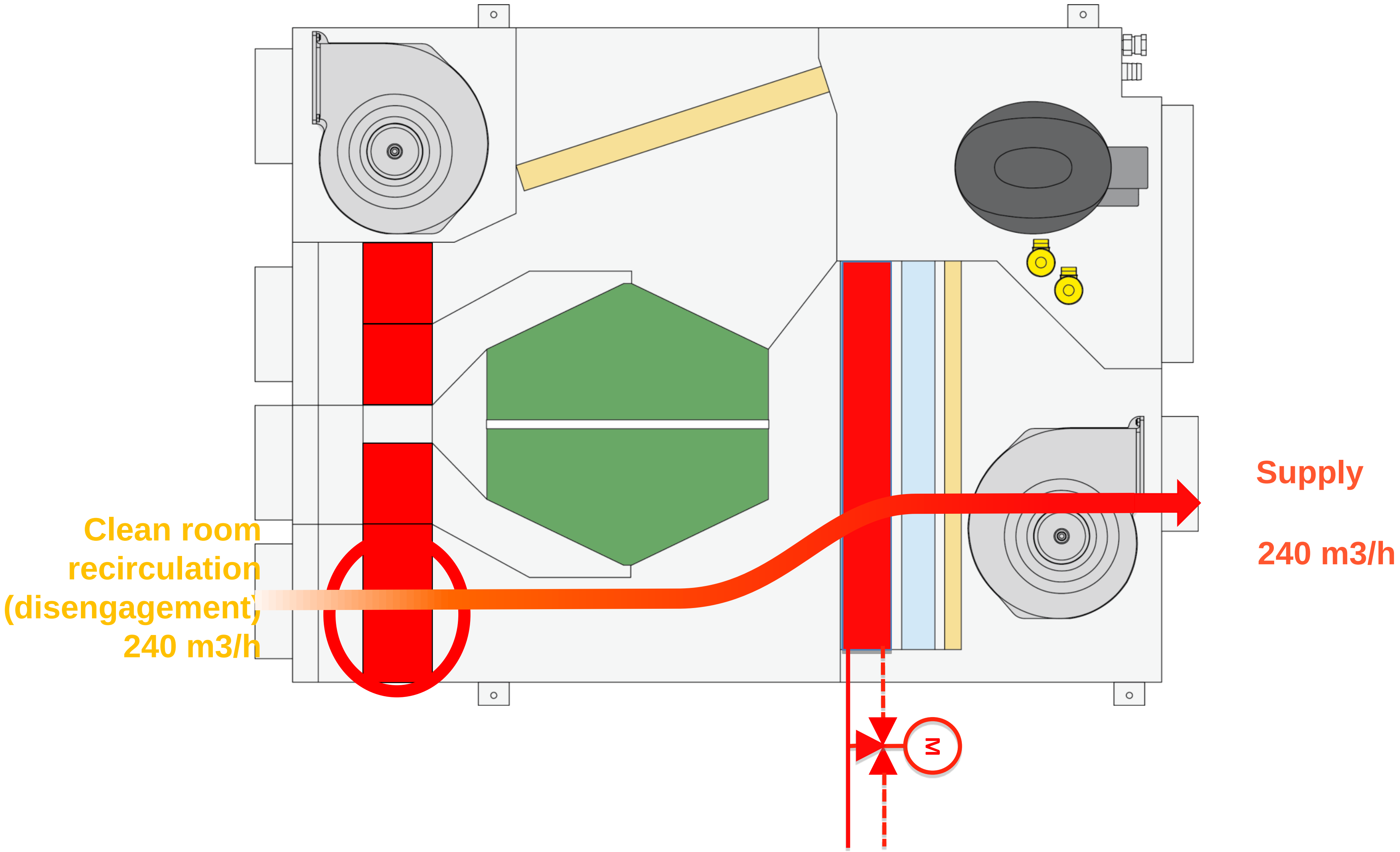
By RDZ company



By RDZ company

air recirculation

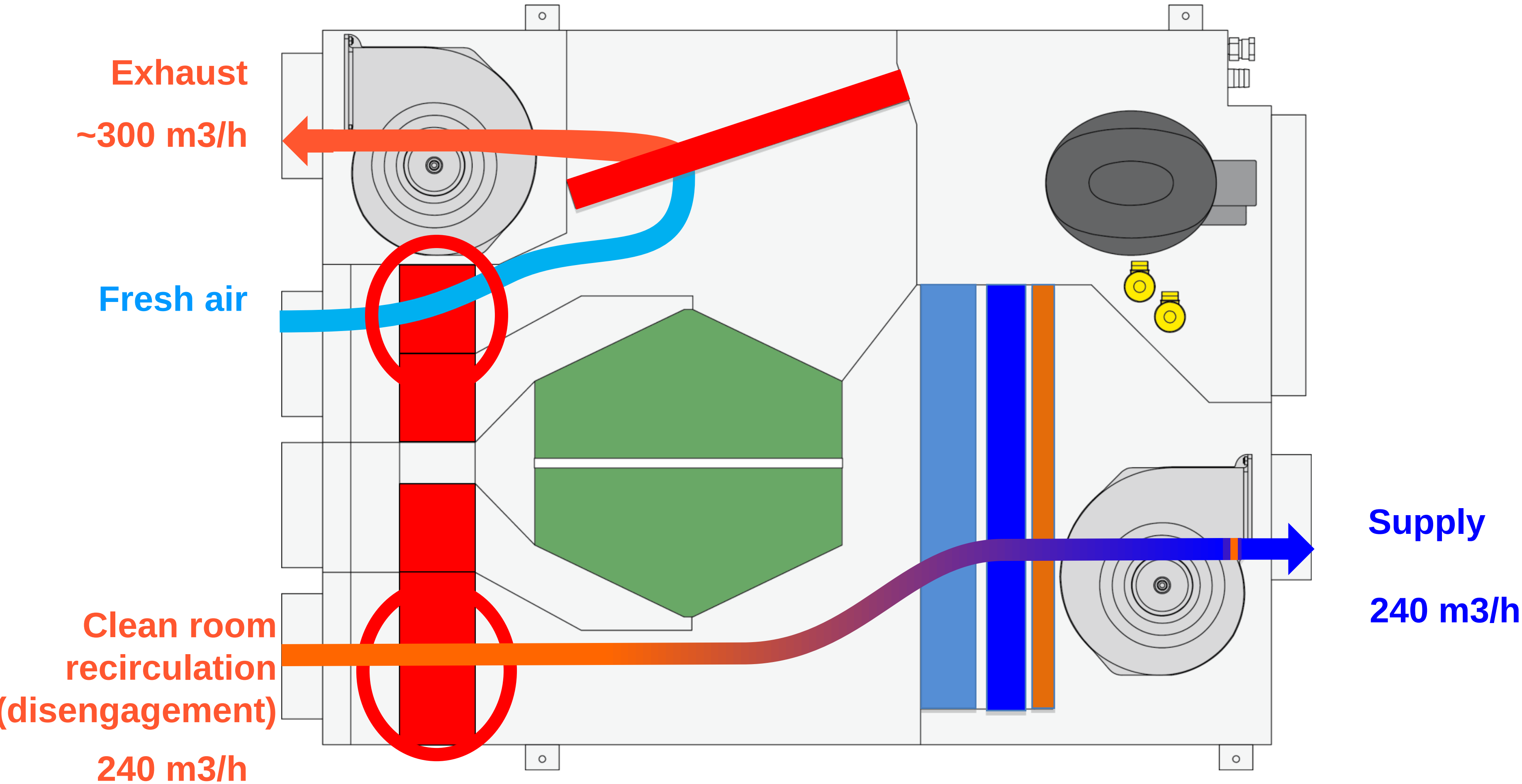
Flows for winter integration



By RDZ company

air recirculation

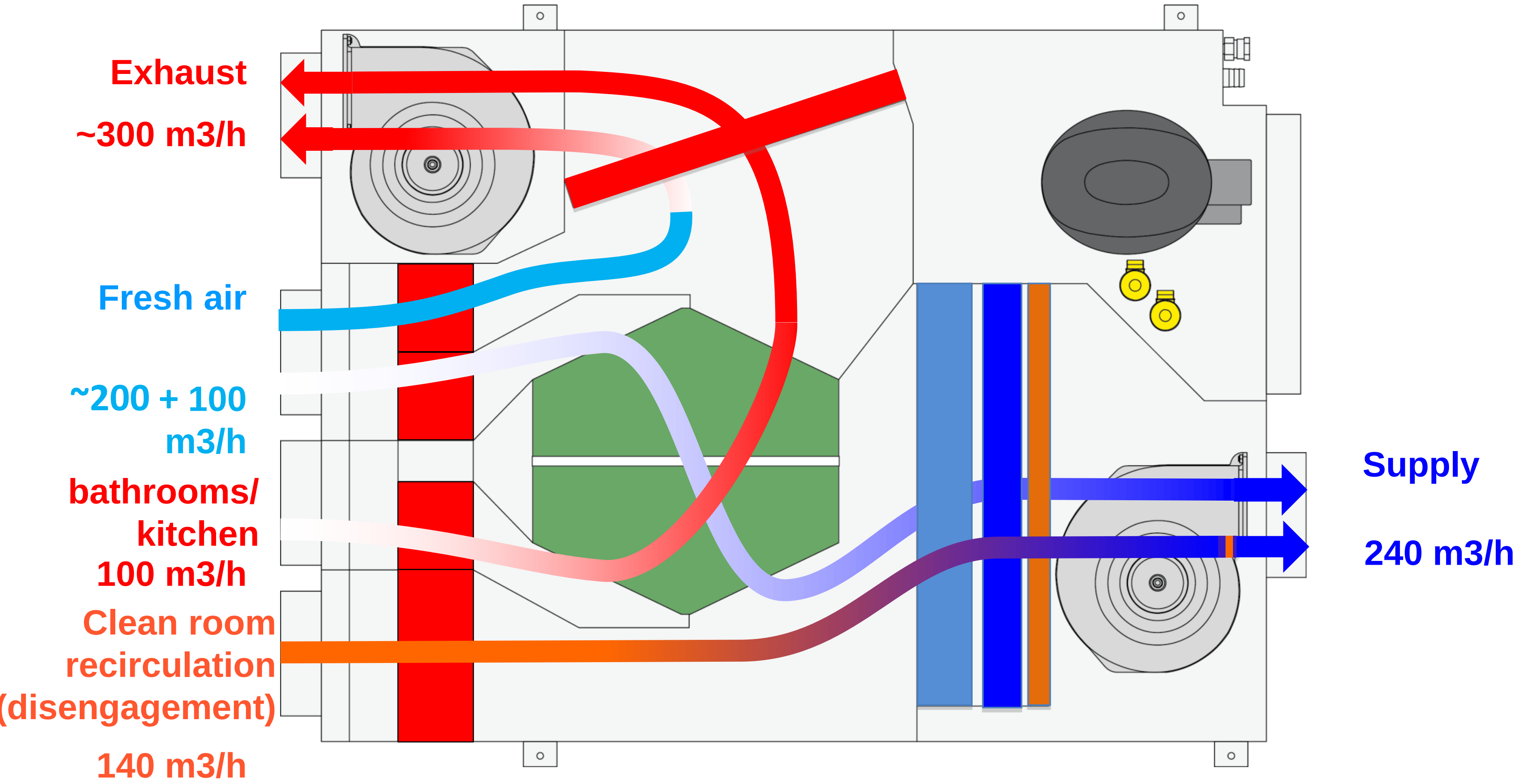
Flows for dehumidification/summer integration



air renewal

By RDZ company

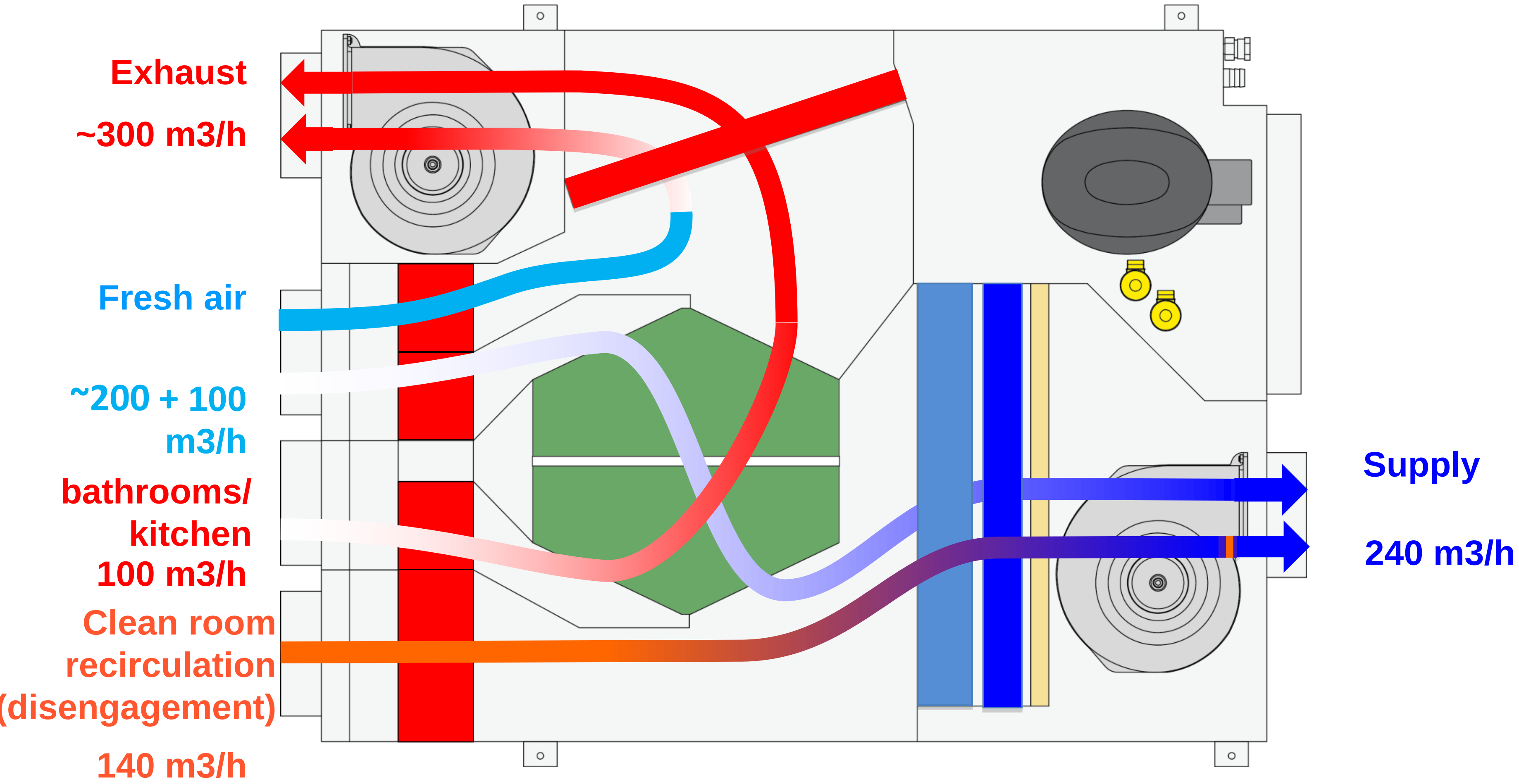
Flows for summer dehumidification



air renewal

By RDZ company

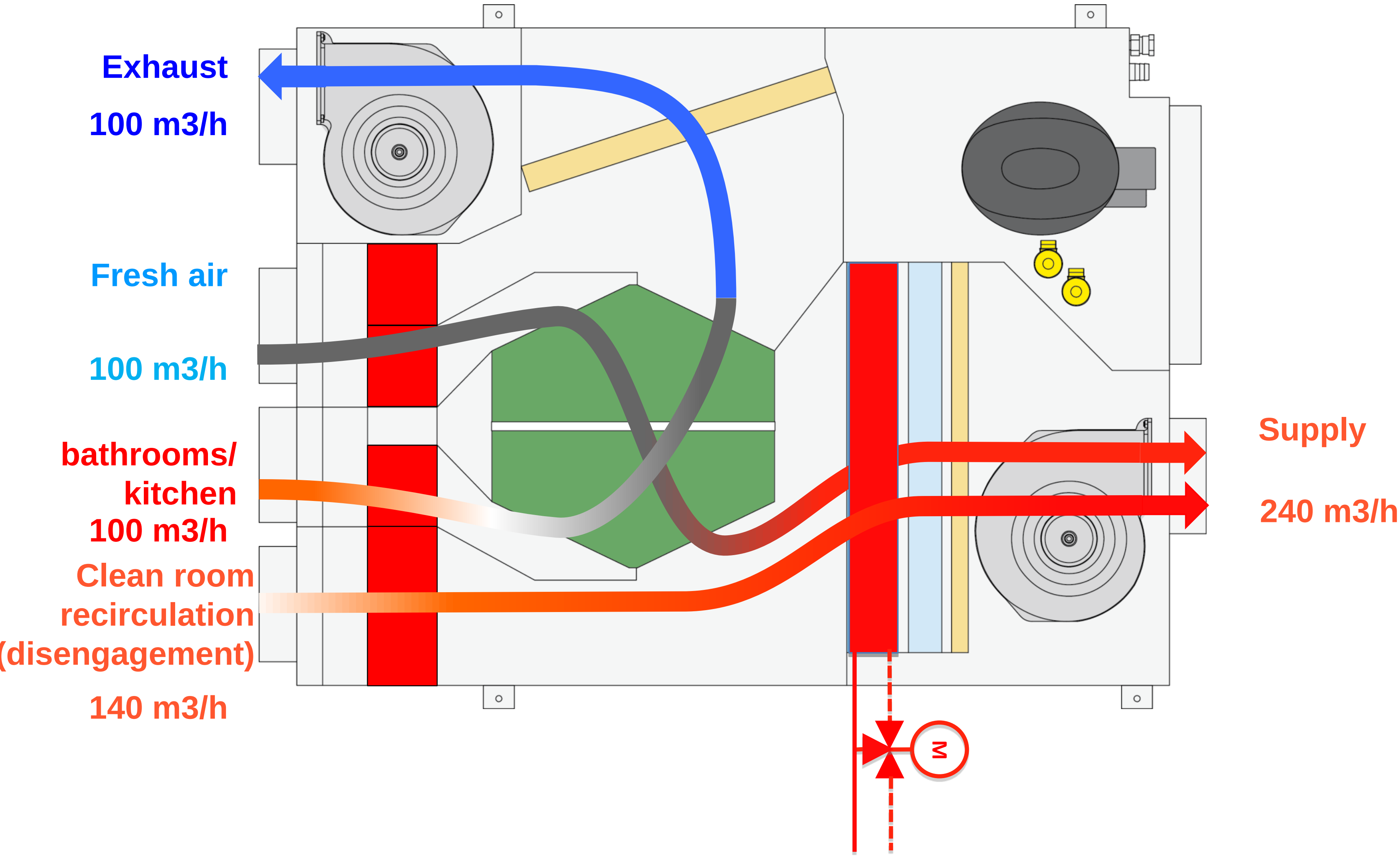
Flows for summer integration



By RDZ company

air renewal

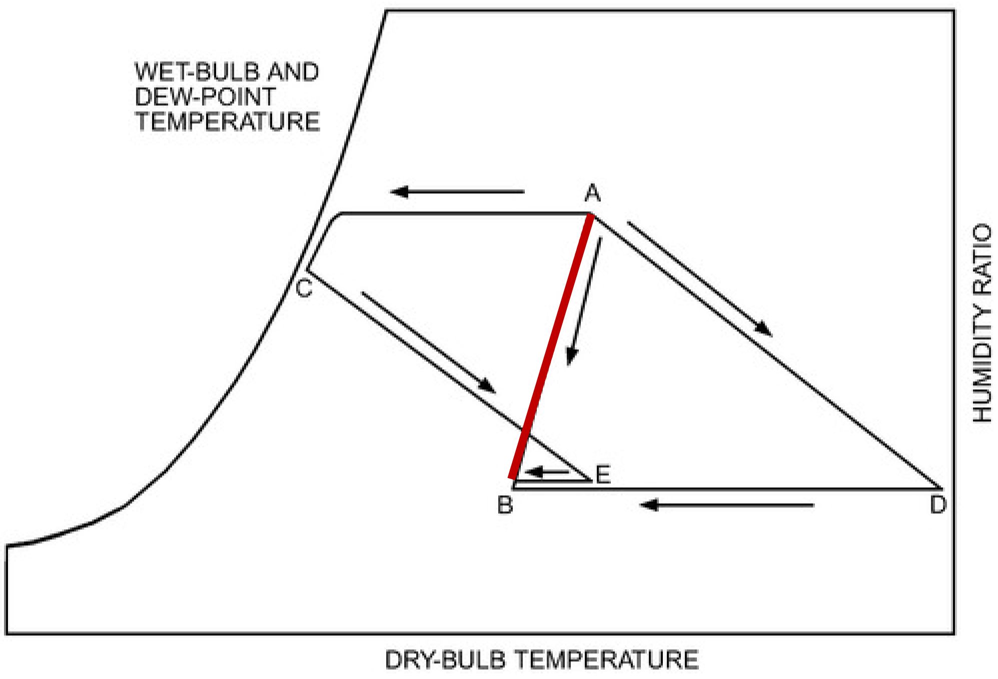
Flows for winter integration



Dessicant Dehumidification

Air may be dehumidified by (1) cooling it or increasing its pressure, reducing its capacity to hold moisture, or (2) removing moisture by attracting the water vapor with a liquid or solid desiccant.

Frequently, systems use a combination of these methods to maximize operating efficiency and minimize installed cost.



Dessicant Dehumidification

Compression: Compressing air reduces its capacity to hold moisture. The resulting condensation reduces the air's moisture content in absolute terms, but produces a saturated condition: 100% relative humidity at elevated pressure. In atmospheric-pressure applications, this method is too expensive, but is worthwhile in pressure systems such as instrument air. Other dehumidification equipment, such as coolers or desiccant dehumidifiers, often follows the compressor to avoid problems associated with high relative humidity in compressed-air lines.

Cooling: Refrigerating air below its dew point is the most common method of dehumidification. This is advantageous when the gas is comparatively warm, has a high moisture content, and the desired outlet dew point is above 5°C. Frequently, refrigeration is combined with desiccant dehumidification to obtain an extremely low dew point at minimum cost.

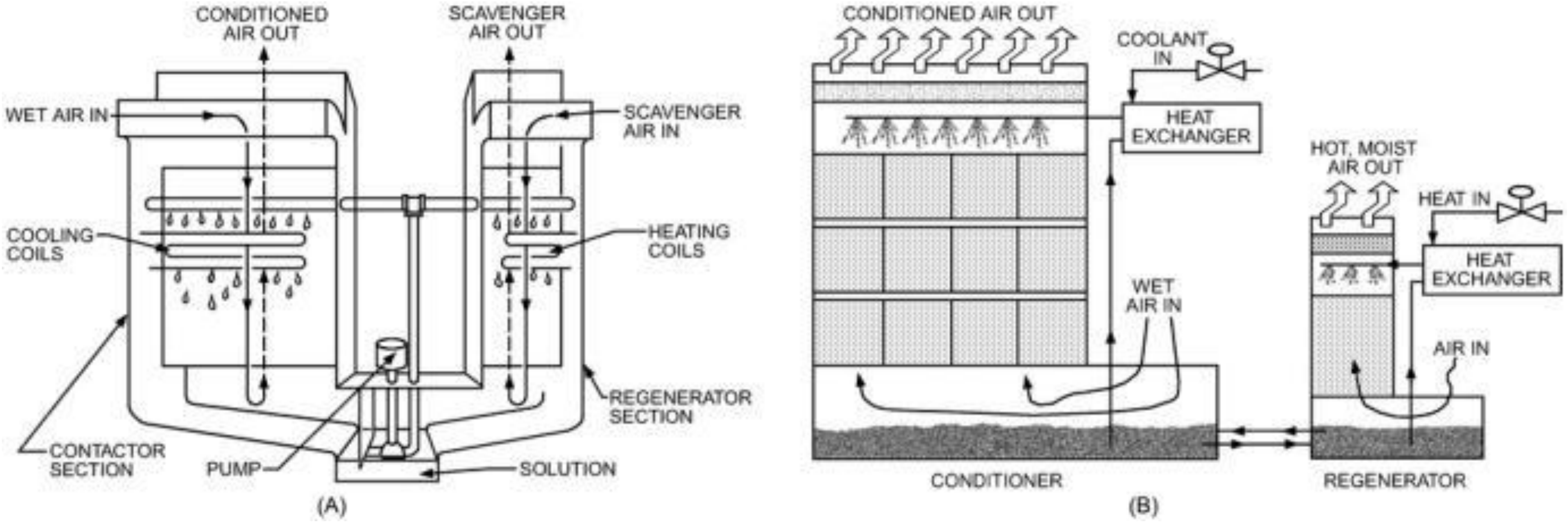
Dessicant Dehumidification

Liquid Desiccants: Liquid desiccant conditioners (absorbers) contact the air with a liquid desiccant, such as a solution of lithium chloride or glycol, to dehumidify and often cool that air.

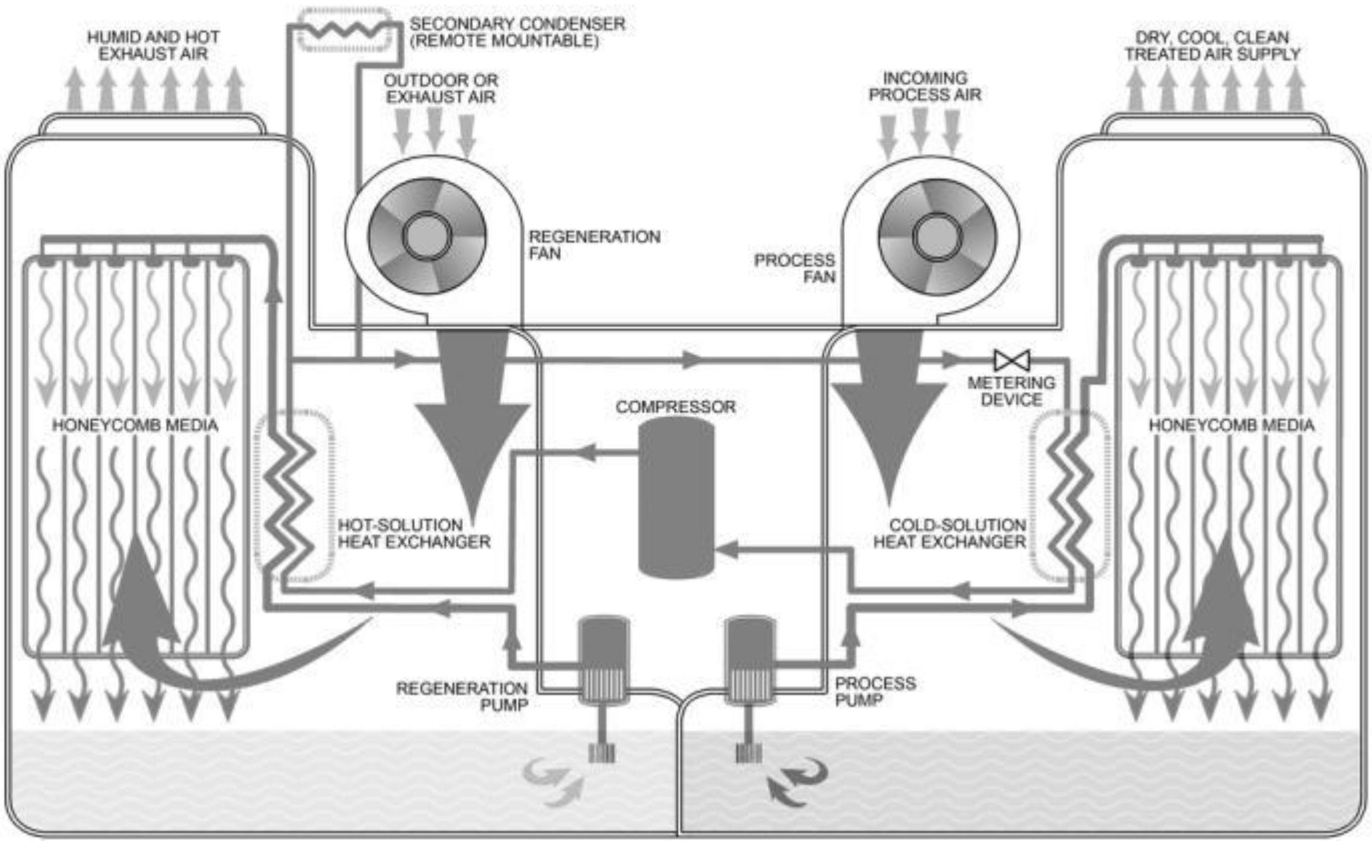
When the water vapor pressure of such a solution is lower than the partial pressure of water in the surrounding air, the solution will collect moisture, thereby decreasing its concentration and dehumidifying the air. The solution's water vapor pressure is a function of its temperature and concentration. Solutions of higher desiccant concentration and/or lower temperature result in lower water vapor pressures and have a stronger dehumidifying effect on the contacted air.

Conversely, liquid desiccant regenerators also contact the air with the same liquid desiccant. When the water vapor pressure of such a solution is higher than the partial pressure of water in the surrounding air, the solution will reject moisture, thereby increasing its concentration and humidifying the air. Solutions of lower desiccant concentration and/or higher temperature result in higher water vapor pressures and have a humidifying effect on the contacted air.

Dessicant Dehumidification

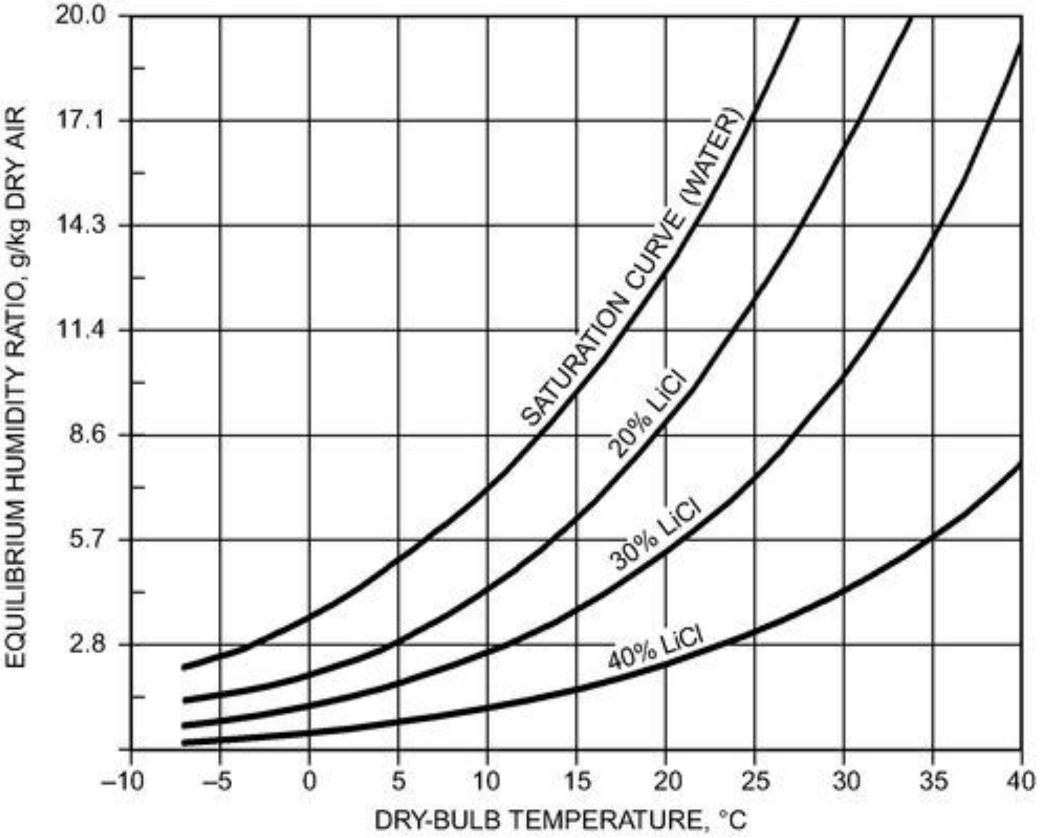


Dessicant Dehumidification



Dessicant Dehumidification

Figure presents the relationship for lithium chloride/water solutions in equilibrium with air at 101.325 kPa. The graph has the same general shape as a psychrometric chart, with the relative humidity lines replaced by desiccant concentration lines.



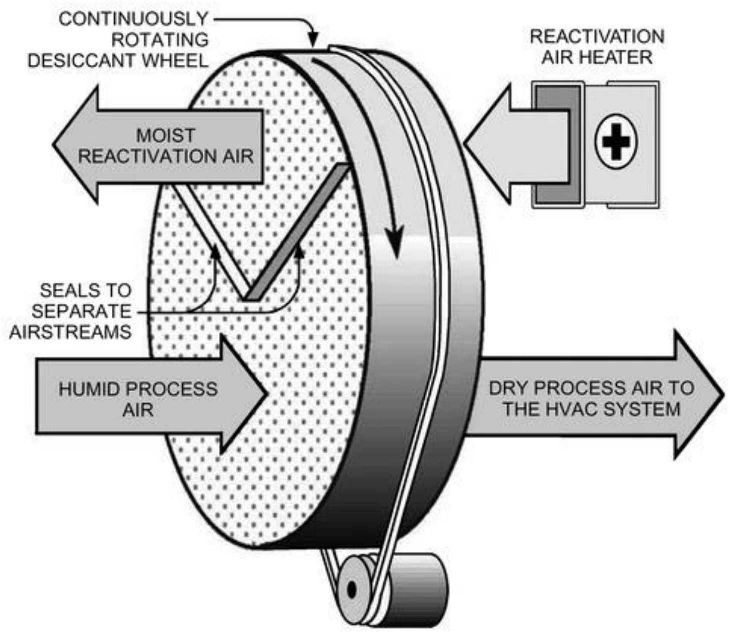
Dessicant Dehumidification

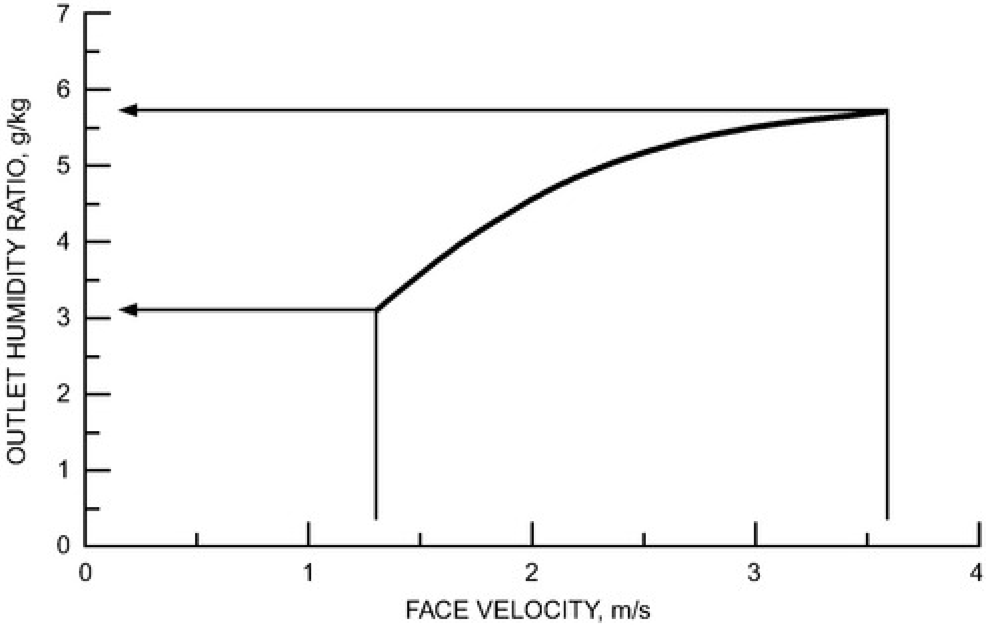
To dehumidify air, a first airstream (either outdoor, return, or mixed air) contacts a cooled solution in the conditioner; water condenses into the desiccant solution from the air, and the solution is diluted. The diluted solution is continuously reconcentrated in the regenerator, where it is heated to elevate its water vapor pressure and equilibrium humidity ratio. A second airstream, usually outdoor air, contacts the heated solution in the regenerator; water evaporates from the desiccant solution into the air, and the solution is reconcentrated. Desiccant solution is continuously circulated between the conditioner and regenerator to complete the cycle. Liquid desiccant conditioners typically have high contact efficiency, so air leaves the conditioner at a temperature and humidity ratio very close to the entering temperature and equilibrium humidity ratio of the desiccant.

Liquid desiccants are typically very effective antifreeze. As a result, liquid-desiccant conditioners can continuously deliver air at subfreezing temperatures without frosting or freezing problems. Lithium chloride/water solution, for example, has a eutectic point below –68°C; liquid desiccant conditioners using this solution can cool air to temperatures as low as –45°C.

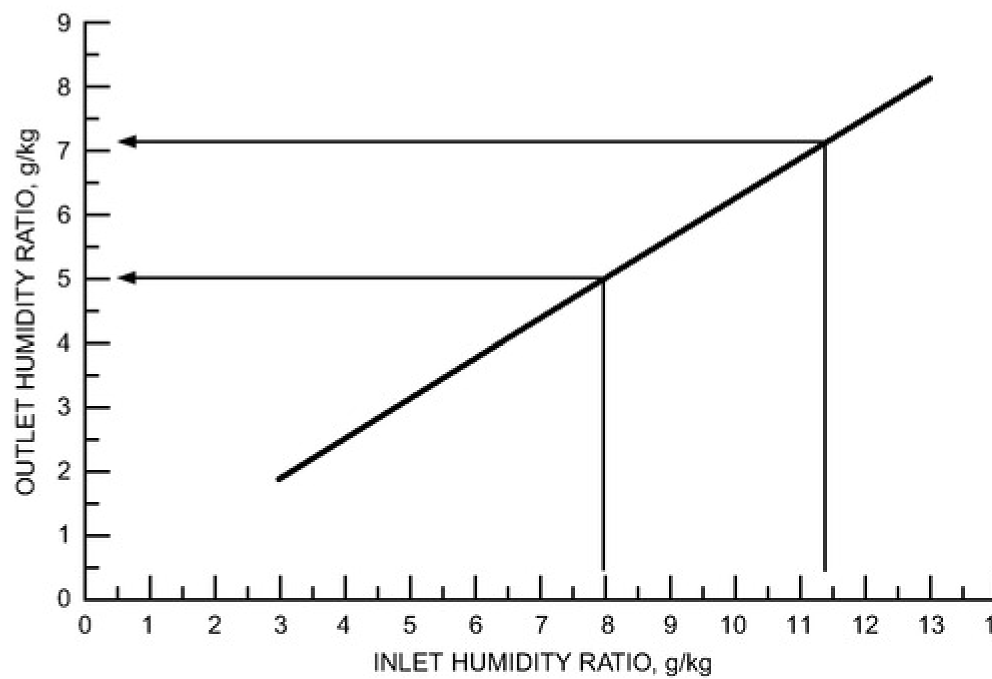
Dessicant Dehumidification

Solid Sorption: Solid sorption passes air through a bed of granular desiccant or through a structured packing impregnated with desiccant. Humid air passes through the desiccant, which when active has a vapor pressure below that of the humid air. This vapor pressure differential drives water vapor from the air onto the desiccant. After becoming loaded with moisture, the desiccant is reactivated (dried out) by heating, which raises the vapor pressure of the material above that of the surrounding air. With the vapor pressure differential reversed, water vapor moves from the desiccant to a second airstream called the reactivation air, which carries moisture away from the equipment.





OUTLET HUMIDITY RATIO, g/kg
0
1
2
3
4
5
6
7
0
1
2
3
4
FACE VELOCITY, m/s



OUTLET HUMIDITY RATIO, g/kg
0
1
2
3
4
5
6
7
8
9
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
INLET HUMIDITY RATIO, g/kg