Dehumidification in residential buildings

Michele De Carli
Angelo Zarrella

Department of Industrial Engineering

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.

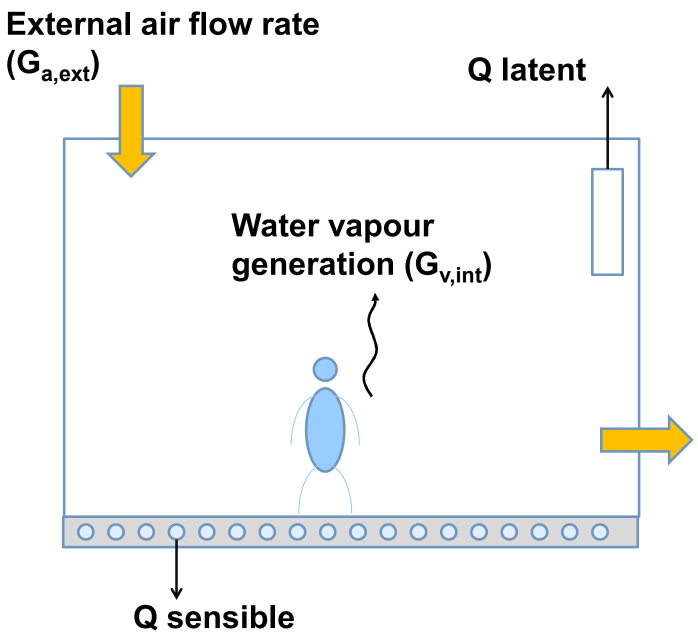
The problem of high specific humidity occurs only in the summer season because in winter, even in conditions of high external relative humidity, the specific humidity is low.

Introduction (2/2)

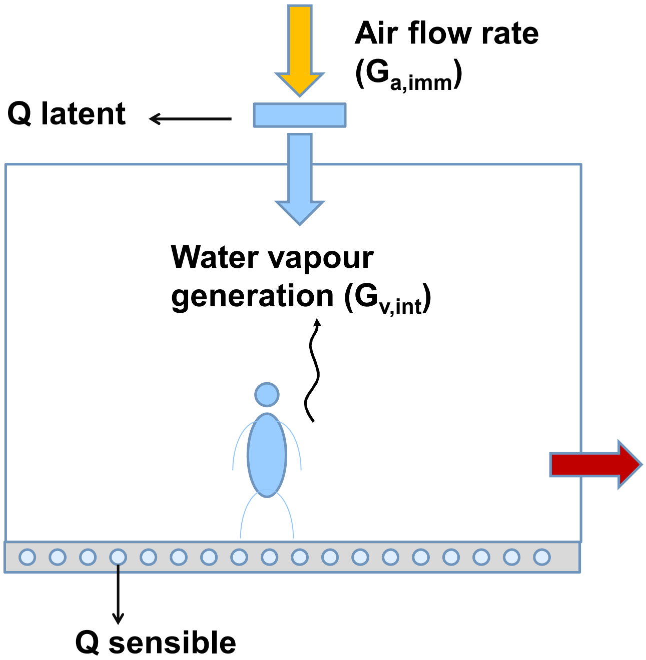
In summer it often happens that:
external specific humidity > 12 g_v/kg_{as} = limit value according to UNI EN 16798.

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

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



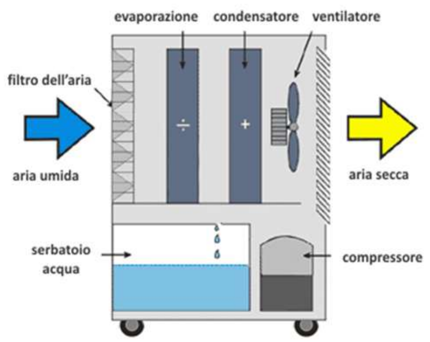
4



5

Dehumidification systems

portable dehumidifiers



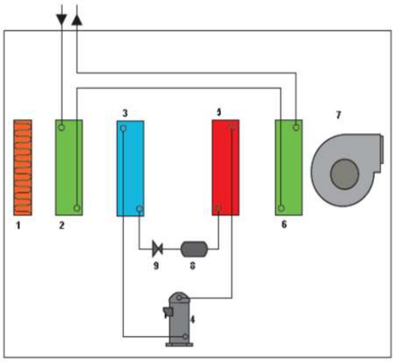
Source: MASTER

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 – Throttling valve

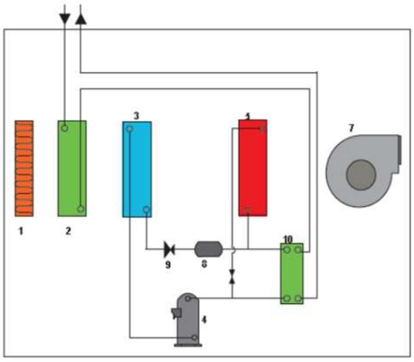
$t_{supply} = t_{ambient}$

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



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

$t_{supply} < t_{ambient}$

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 sensible power.

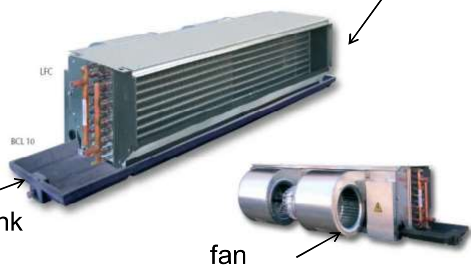
Fan-coils are usually sized with an inlet water temperature of 7°C, necessary to ensure a good dehumidification capacity. In this case, the water feeding the fan-coils is not the same as the water circulating in the radiant system.

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

<u>Potential undercooling in case of humid days with low solar radiation</u>

Fan-coil

For summer cooling supply water temperature 7°C



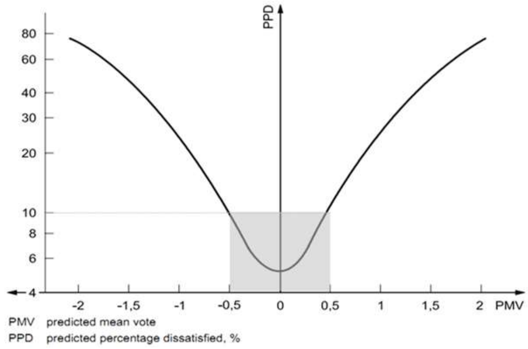
Controlled mechanical ventilation

CMV with double flow

Extraction → bathrooms and kitchen

Supply → other rooms

Thermal comfort



UNI EN 16798

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

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.

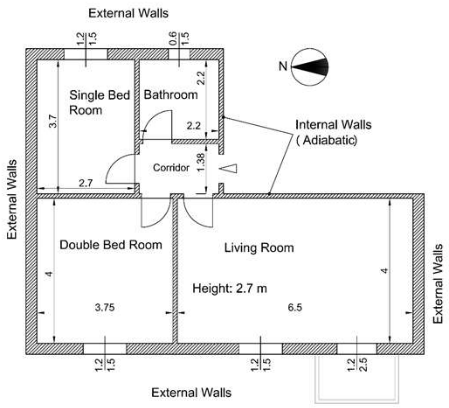
Assumed clothing thermal insulation level for winter and summer (clo-value) and activity level (met-value) are listed in Table B.2. Note that the operative temperature limits shall be adjusted when clothing levels and/or activity levels are different from the values mentioned in the table.

Case Study

Apartment of 60 m^2

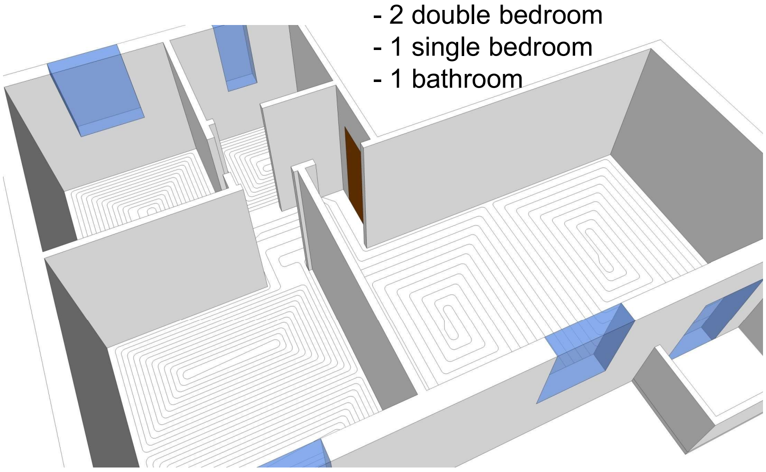
Opaque external wall:
U_T= 0.25 W/(m^{2}K)

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)

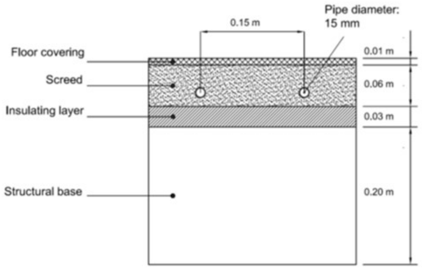


Table 1 – Thermal properties of the floor radiant system.

	Thermal conductivity [W/(m K)]	Specific heat [J/(kg K)]	Density [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

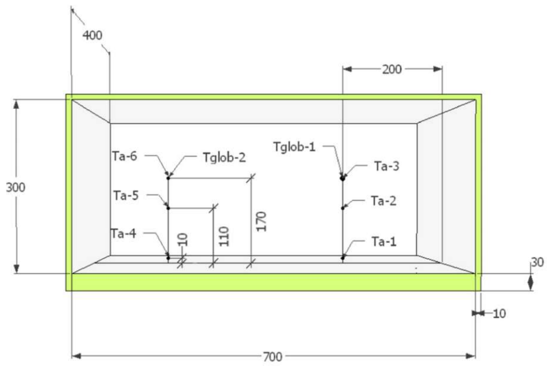
Software: DigiThon

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

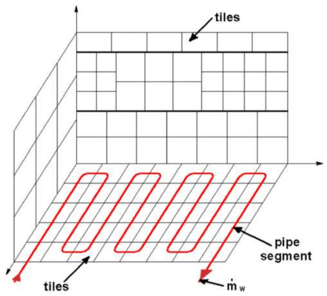
Climates

- Venice
- Rome
- Bari

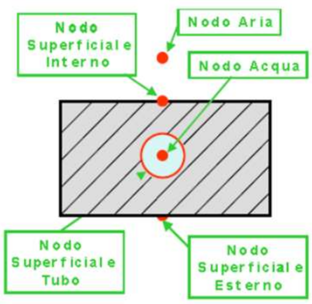
DigiThon (1/3)



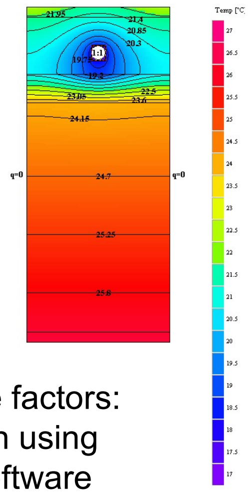
BETA_Lab Group



DigiThon (2/3)

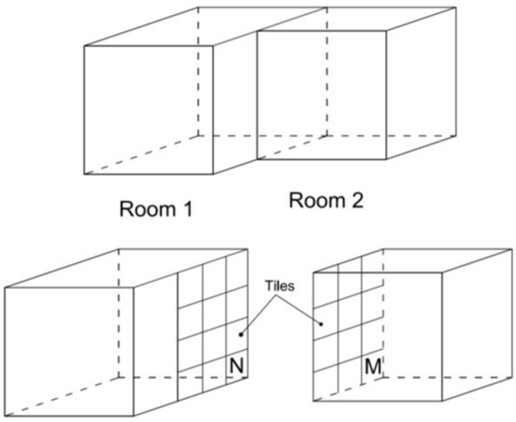


Nodal modeling scheme for a radiant panel tile



Response factors: calculation using HEAT2 software

DigiThon (3/3)



23

Analysis

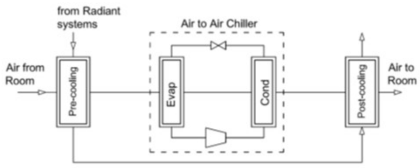
Table 3 – List of the case studies analyzed.

		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

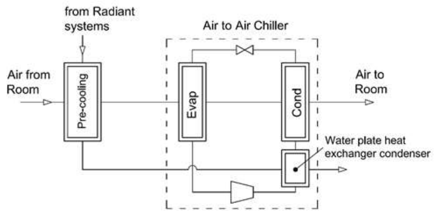
24

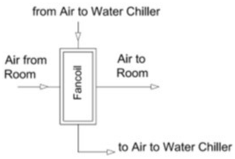
Analysis

isothermal dehumidifier

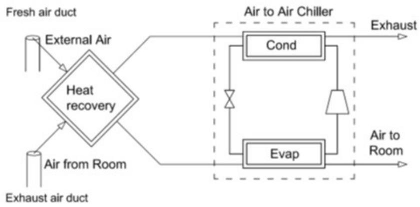


dehu-conditioner





fan coil



mechanical ventilation system

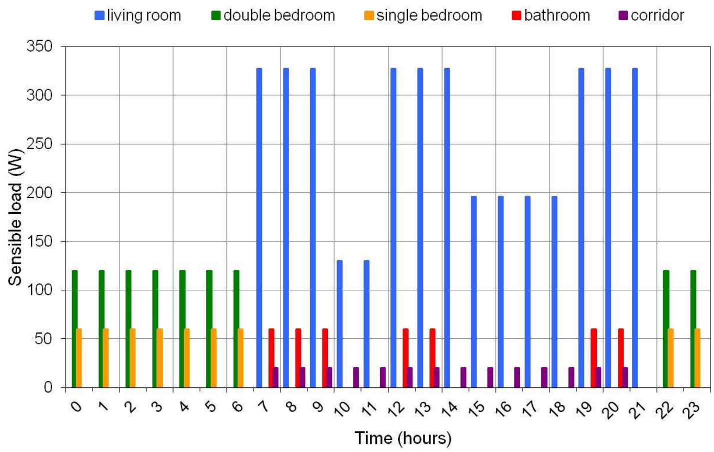
25

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



27

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

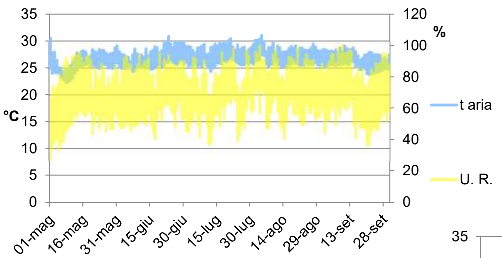
29

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

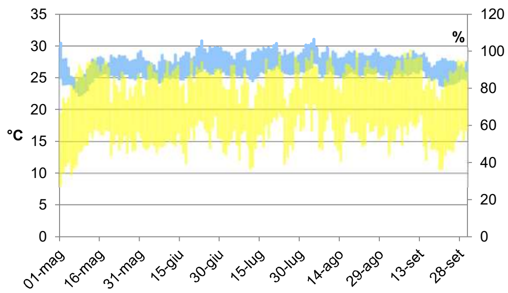
Without dehumidification
Reference climate: Venice



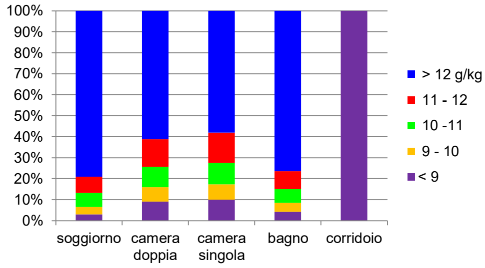
Temperature (°C) e HR (%)

ACH 1 vol/h

ACH 0.6 vol/h

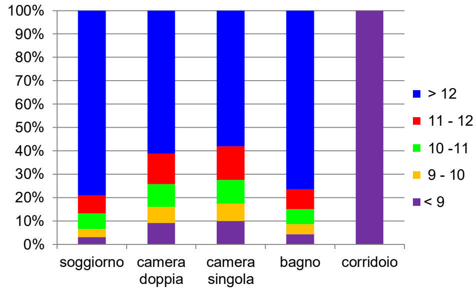


Without dehumidification
Reference climate: Venice



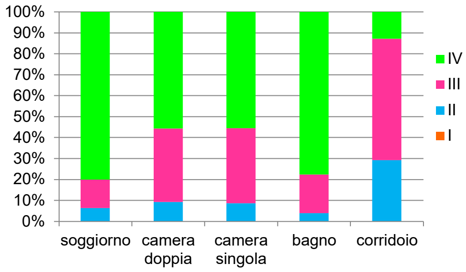
Relative humidity range (%)

**ACH
1 vol/h**



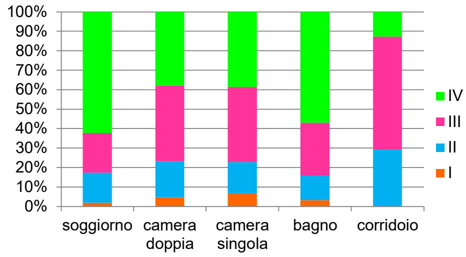
**ACH
0.6 vol/h**

Without dehumidification
Reference climate: Venice



PMV

**ACH
1 vol/h**

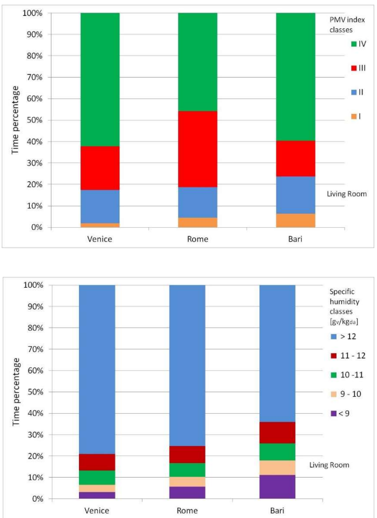


**ACH
0.6 vol/h**

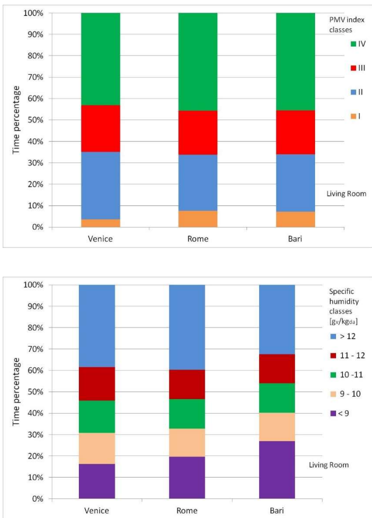
Without dehumidification
Reference climate: Venice

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

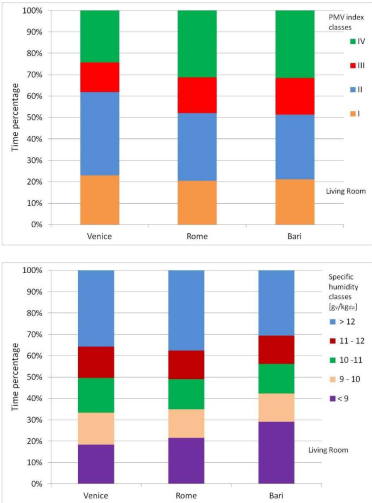
→ Dehumidification is required!



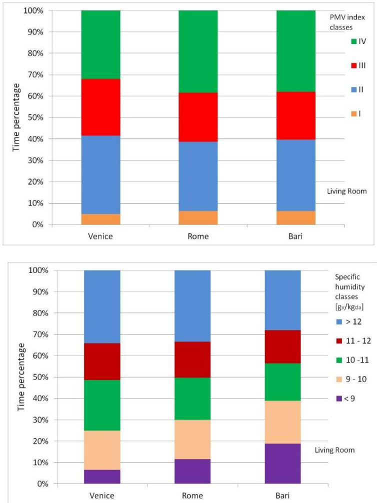
Radiant floor only with air infiltration rate equal to 1 vol/h: time percentage of PMV index and specific humidity ranges in living room.



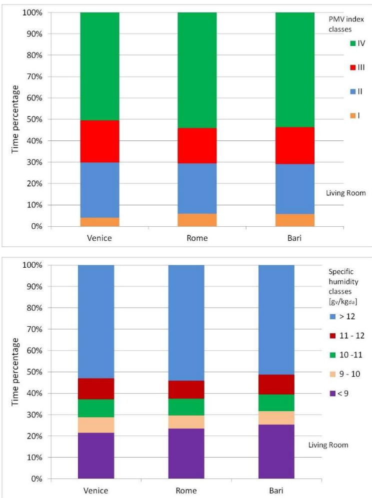
Radiant floor with isothermal dehumidifier: time percentage of PMV index and specific humidity ranges in living room.



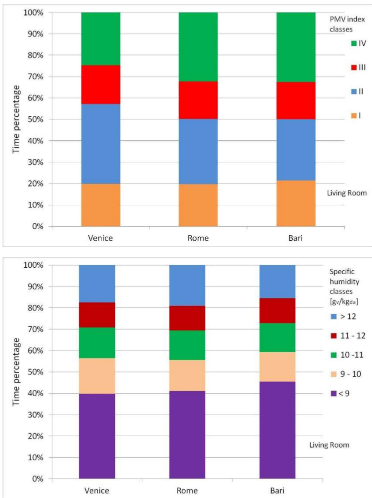
Radiant floor with dehu-conditioner: time percentage of PMV index and specific humidity ranges in living room.



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

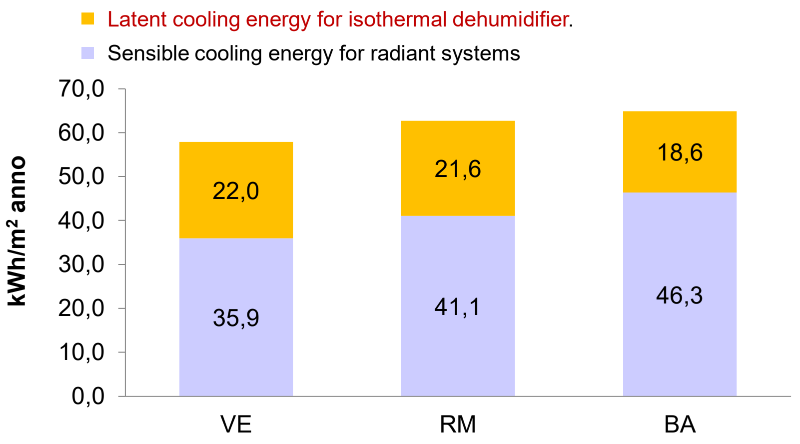


Radiant floor with mechanical ventilation system (0.6 vol/h): time percentage of PMV index and specific humidity ranges in living room.

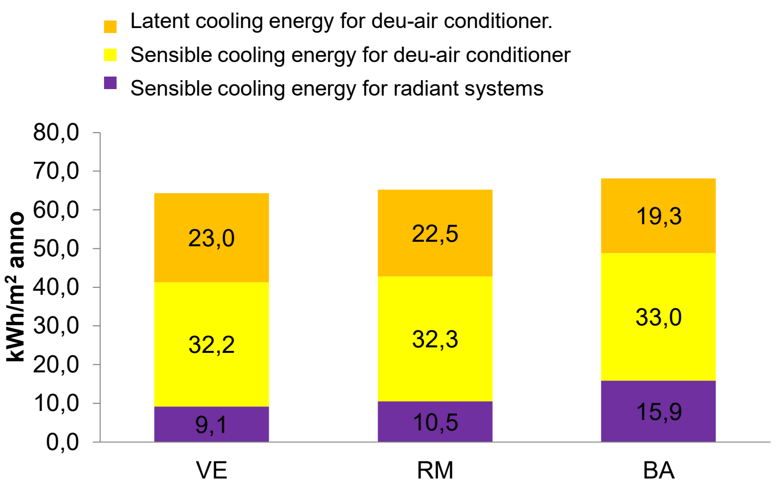


Radiant floor with mechanical ventilation system (1 vol/h): time percentage of PMV index and specific humidity ranges in living room.

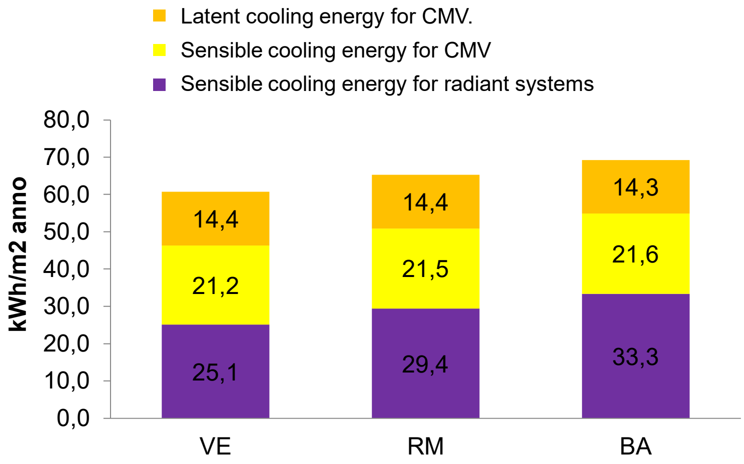
Radiant system and isothermal dehumidifier



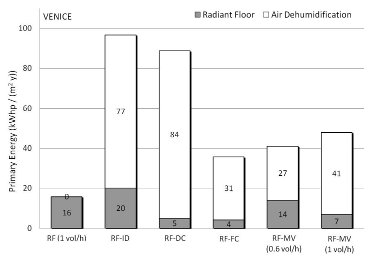
Radiant system and deu-air conditioner

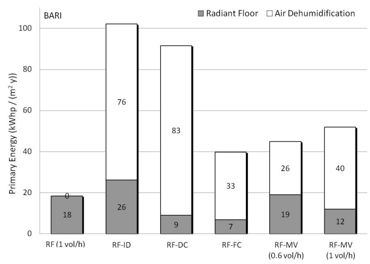


Radiant systems and controlled mechanical ventilation



Specific yearly primary energy use per unit floor area





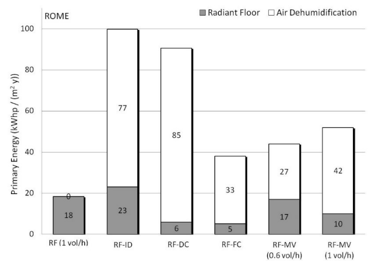


Table 4 – Mean seasonal COP during the cooling period.

	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

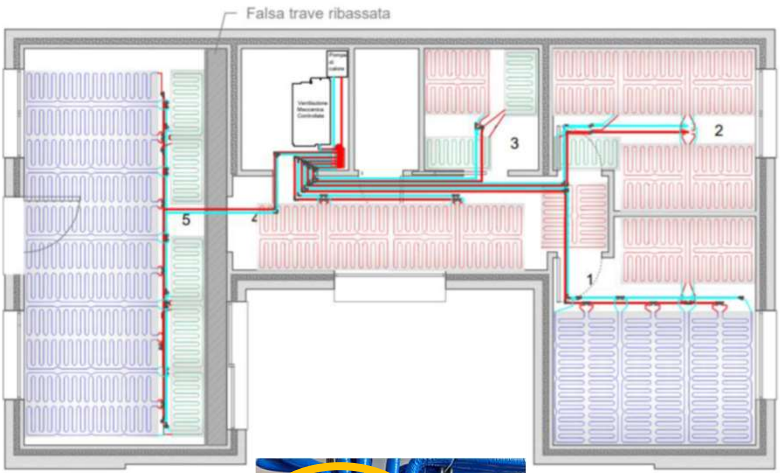
42

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.

UNIZEB

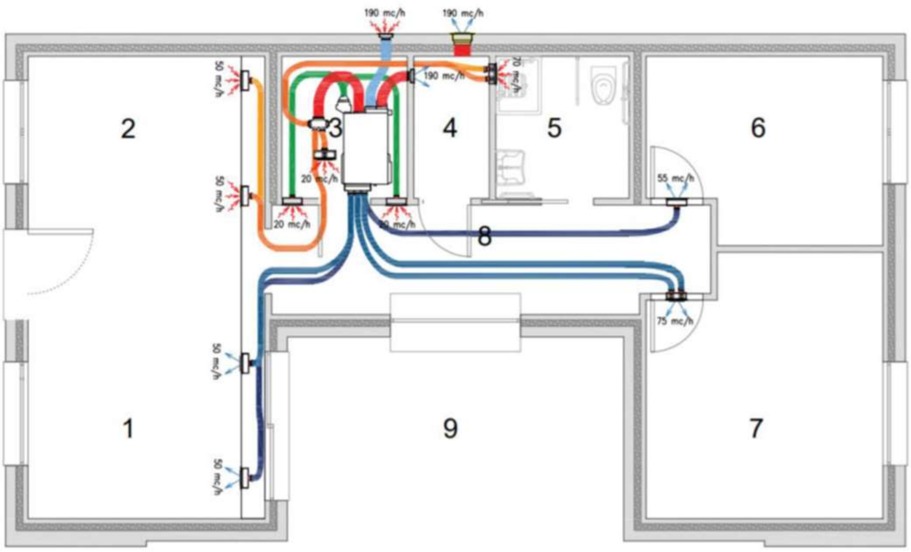
Radiant ceiling for heating & cooling



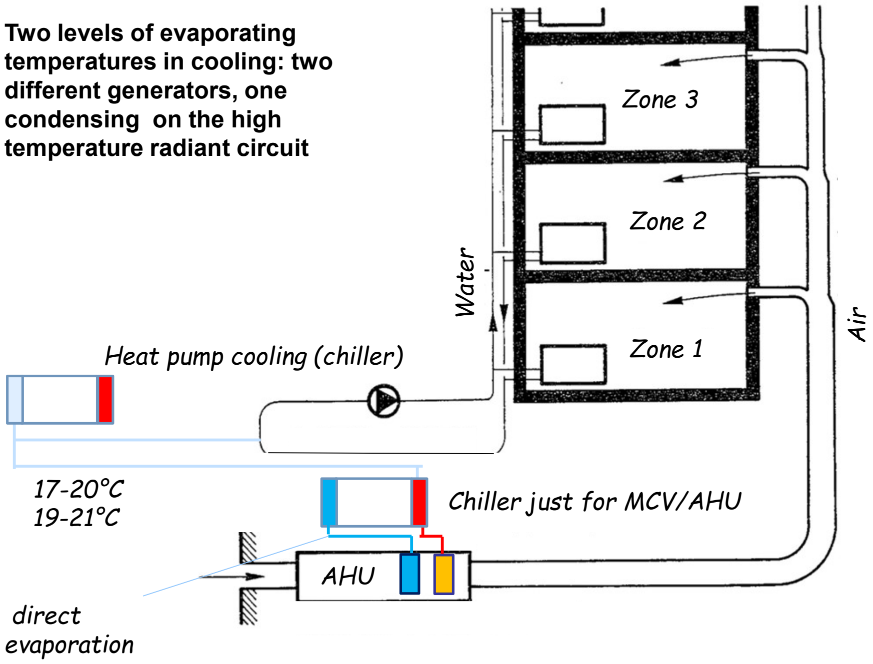
Radiant system

MVC dehumidification

MCV with chiller on board. The chiller condenses on a parallel circuit starting from the manifold



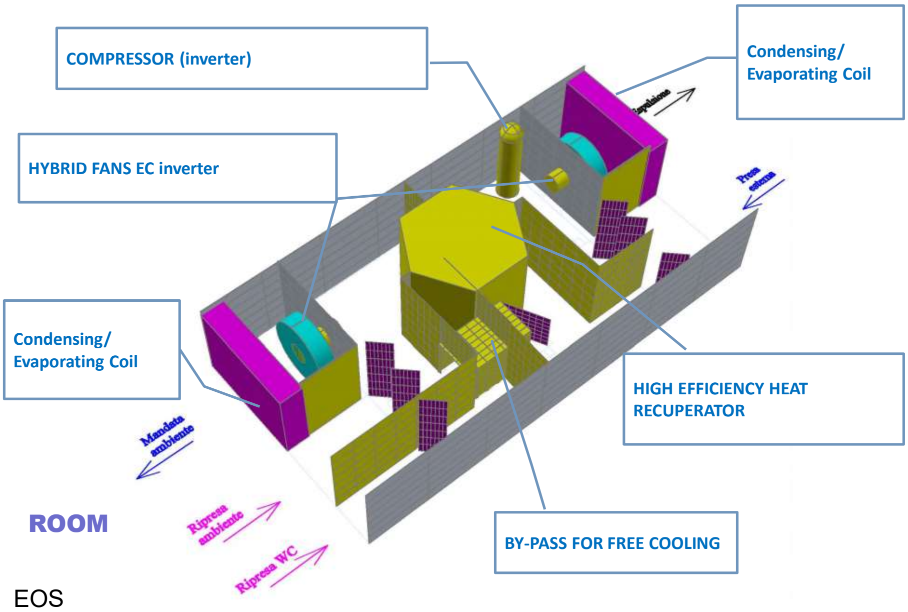
Two levels of evaporating temperatures in cooling: two different generators, one condensing on the high temperature radiant circuit



MCV + dehumidification technologies

By Aertesi company

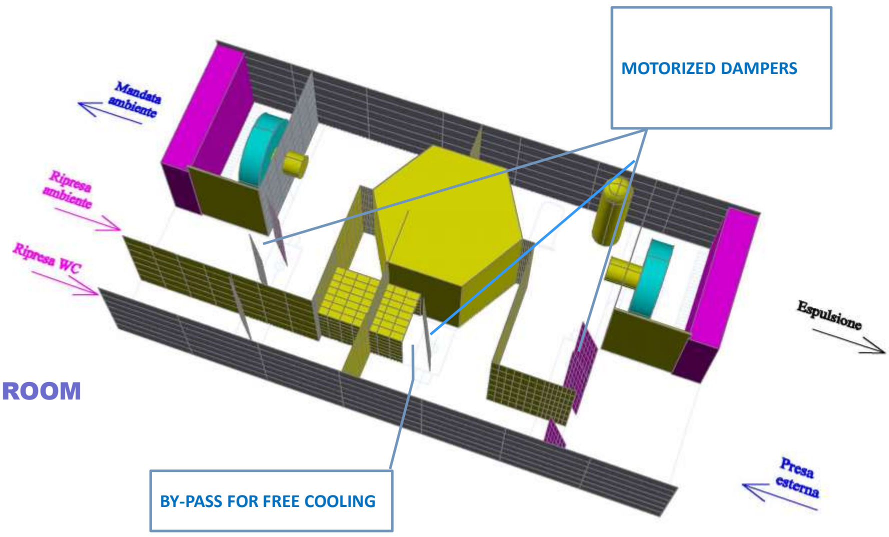
SOLUTION 2: Integrated System



EOS

By Aertesi company

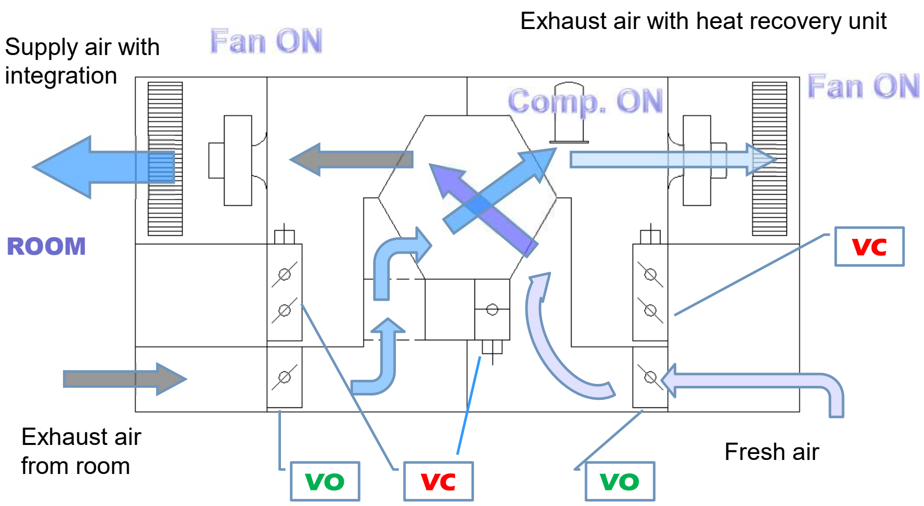
SOLUTION 2: Integrated System



EOS

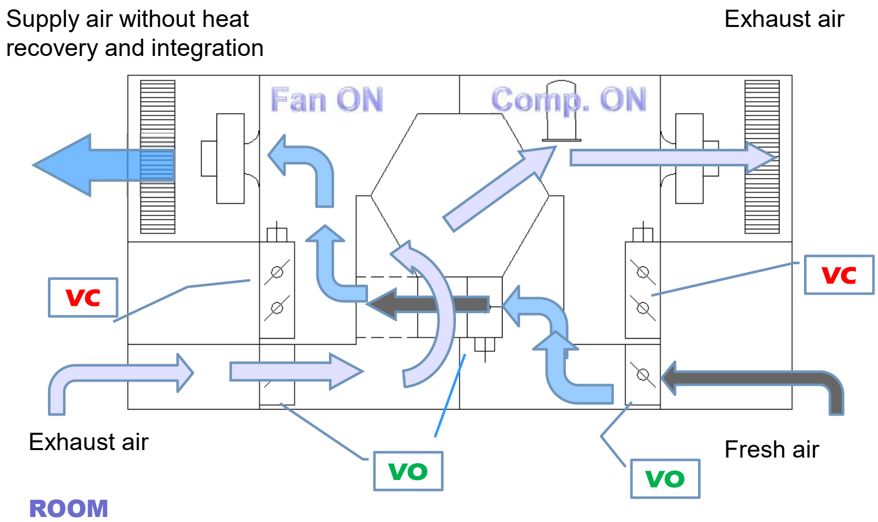
By Aertesi company

RENEWAL WITH RECOVERY AND INTEGRATION



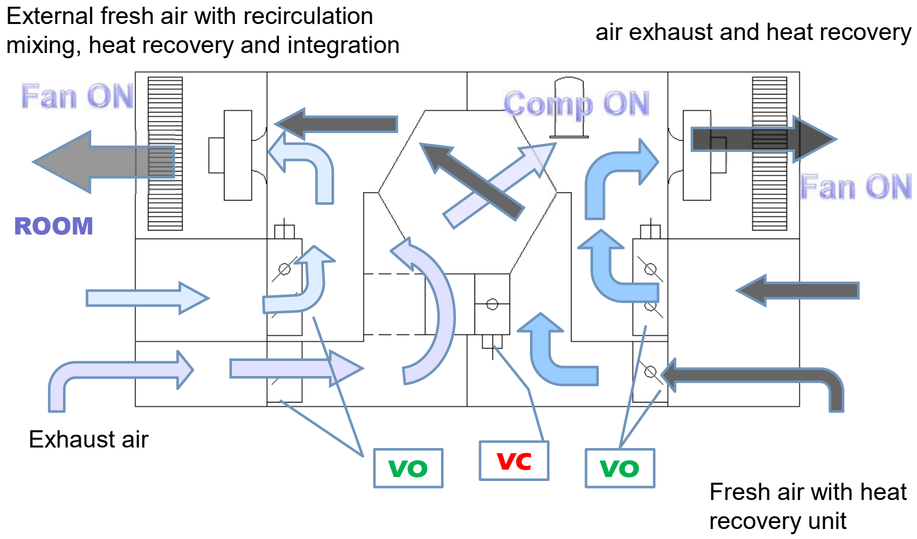
By Aertesi company

RENEWAL WITH FREE COOLING



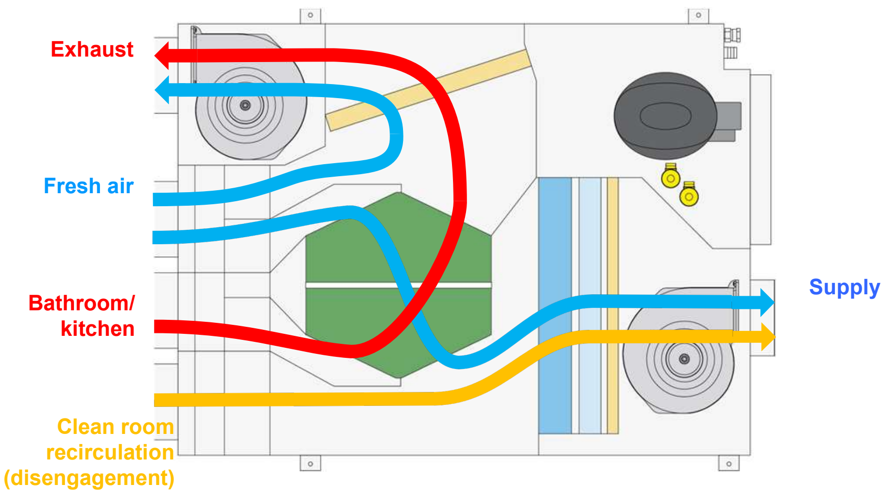
By Aertesi company

RENEWAL WITH RECOVERY AND INTEGRATION

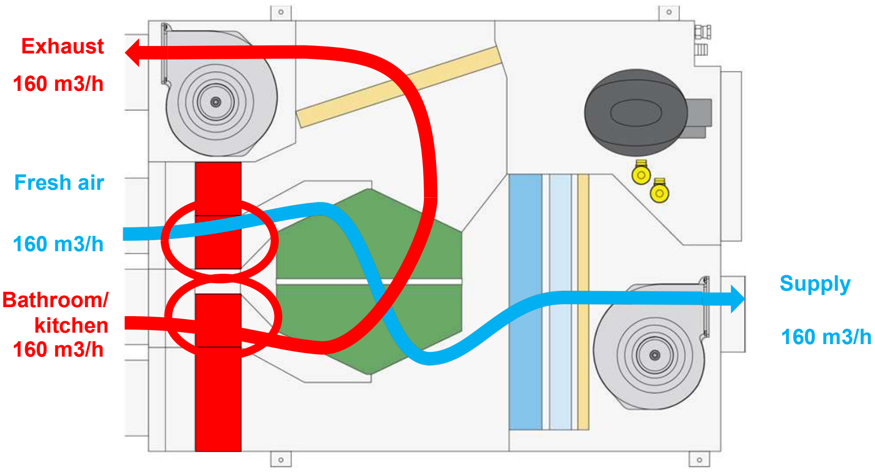


Air flows

By RDZ company

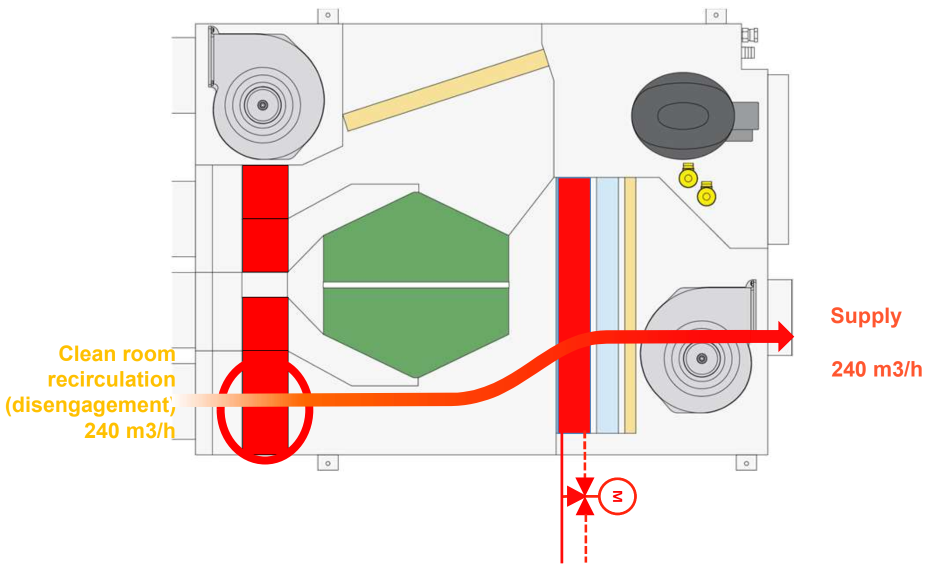


air renewal only By RDZ company



air recirculation By RDZ company

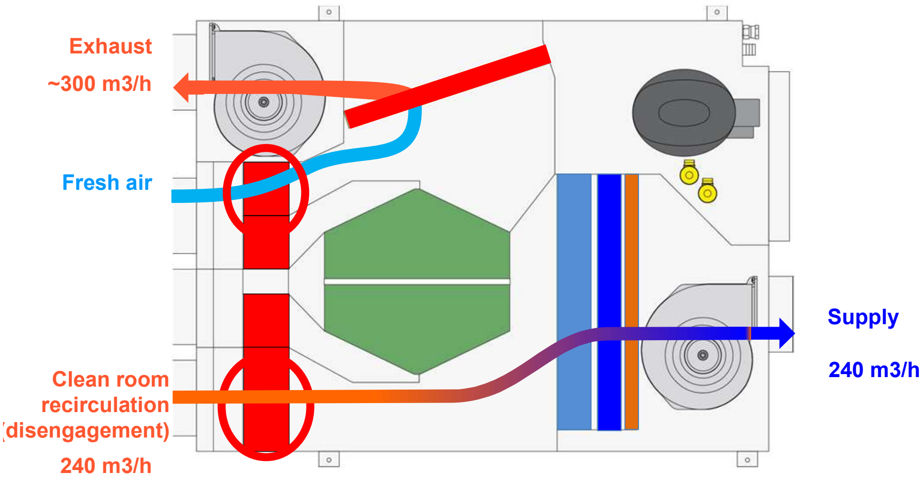
Flows for winter integration



air recirculation

By RDZ company

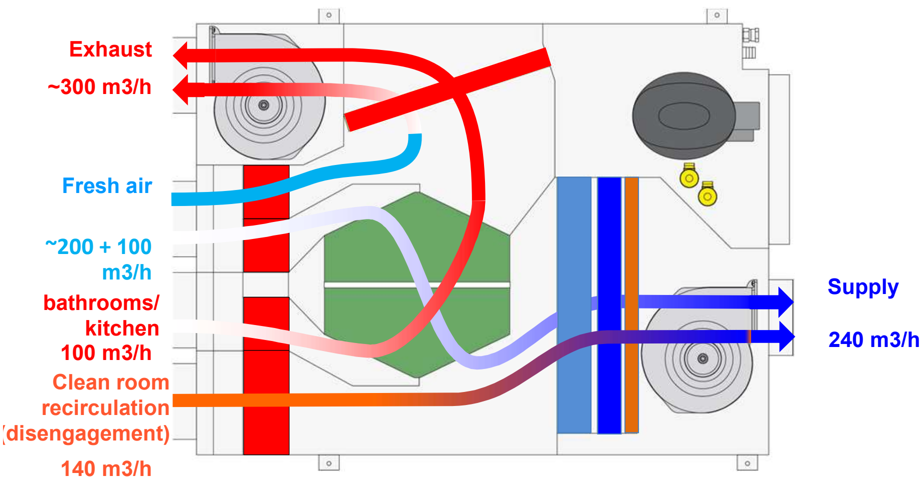
Flows for dehumidification/summer integration

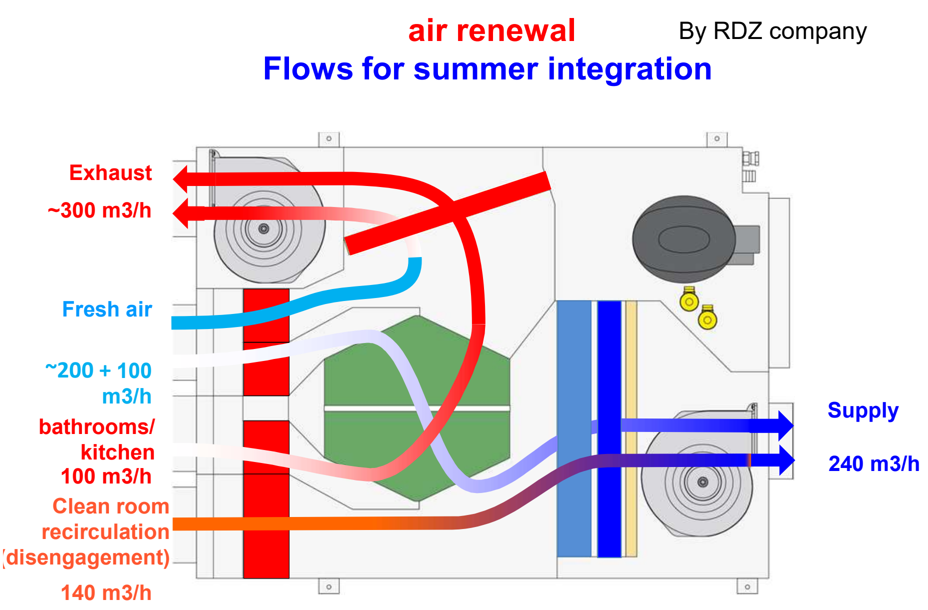


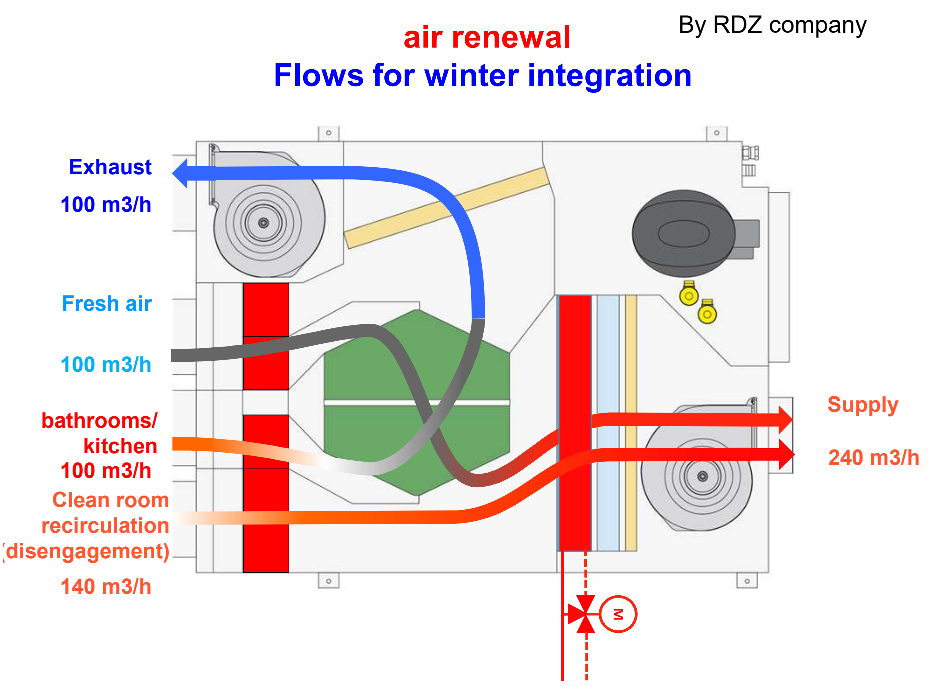
air renewal

By RDZ company

Flows for summer dehumidification



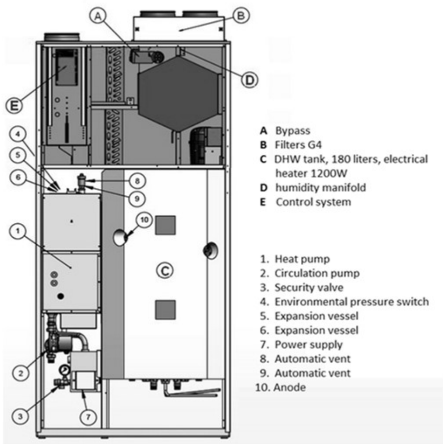

air renewal
By RDZ company
Flows for summer integration
Exhaust
~300 m3/h
Fresh air
~200 + 100 m3/h
bathrooms/ kitchen
100 m3/h
Clean room recirculation (disengagement)
140 m3/h
Supply
240 m3/h

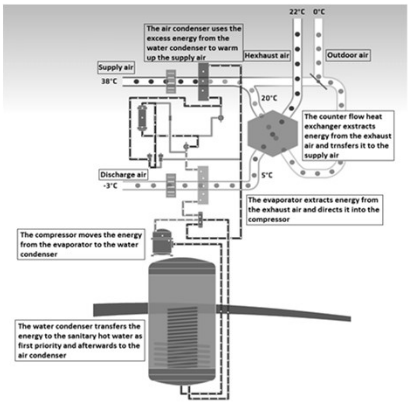

air renewal
By RDZ company
Flows for winter integration
Exhaust
100 m3/h
Fresh air
100 m3/h
bathrooms/ kitchen
100 m3/h
Clean room recirculation (disengagement)
140 m3/h
Supply
240 m3/h

Full air systems

61

By Nilan company





These solutions are named all-in-one