Controlled mechanical ventilation (CMV) in residential buildings

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GENERAL ISSUES: WHY VENTILATION?

Yesterday:

- numerous leaks, infiltration through windows and doors
- high consumption for heating

Today:

- Airtight Buildings
- Low permeability to outside air

Natural air change is impossible.

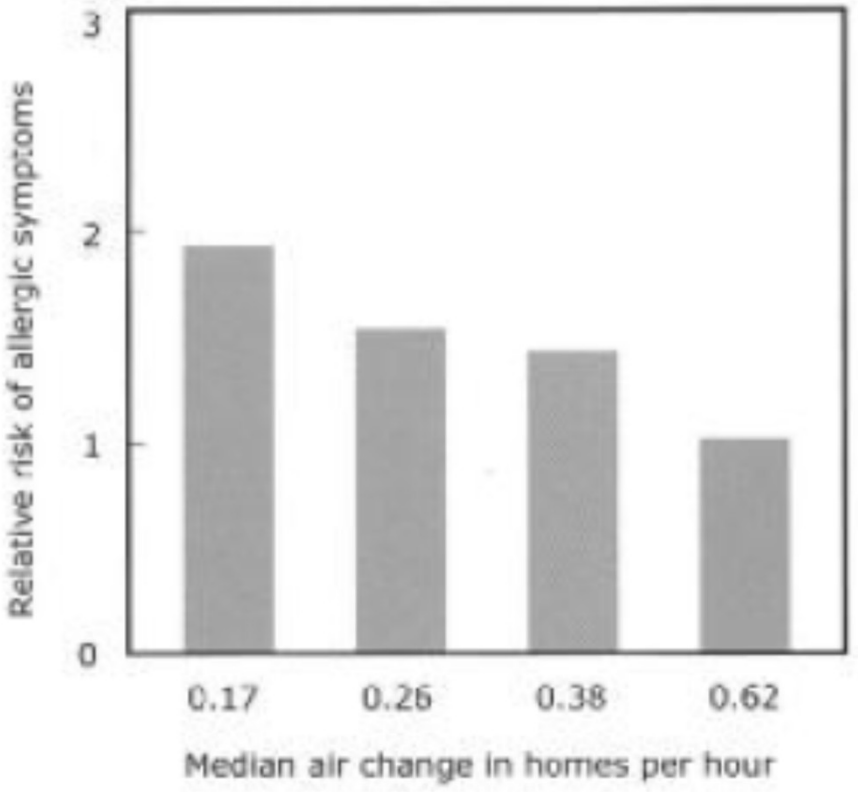
MOISTURE IN BUILDINGS

BUILDING: Unavoidable presence of moisture:

- normal air composition;
- consequence of vapor production for activities performed by users.

physiologic

pathologic



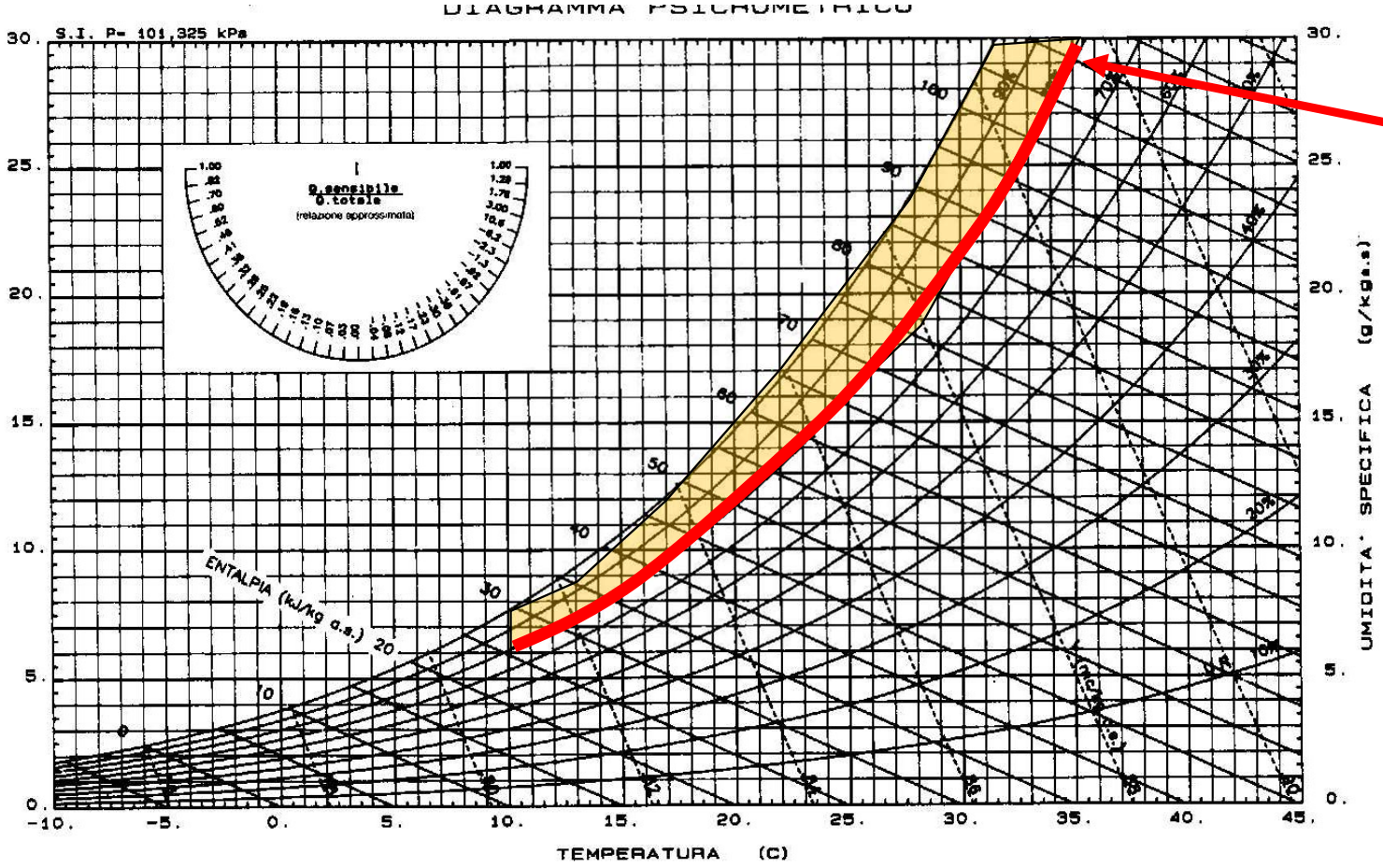
Bornehag et al. 2005

THE CONSEQUENCES OF INADEQUATE ACR

A) SURFACE CONDENSATION (possible appearance of mold)

B) INTERSTITITIAL CONDENSATION (possible deterioration of building materials and decrease in the thermal insulation)

C) LOW INTERNAL AIR QUALITY (onset of pathologies).



Local relative humidity range causing mold growth

THE IMPORTANCE OF VENTILATION

VENTILATION OF INDOOR ENVIRONMENTS:

It is a fundamental human need;

It is indispensable for the preservation of the building structure;

It must not be considered a "burden";

It involves an energy requirement that varies depending on the technology adopted;

THE IMPORTANCE OF VENTILATION

- Dilution and removal of indoor pollutants
- Dilution of specific pollutants (odors from toilets - cooking vapors)
- Ensure air for metabolic activity of occupants
- Ensure control of indoor humidity and avoid the formation of condensation and subsequently mold
- Providing the right amount of combustion air in the presence of gas appliances for domestic use

POSSIBILITIES FOR AIR CHANGE

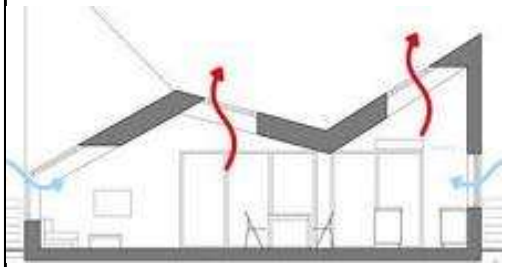
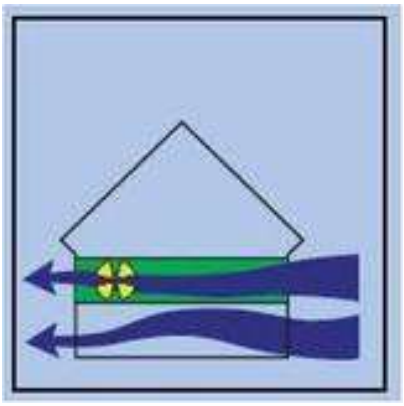
1: Opening of window frames (AERATION) and infiltration

2: Natural ventilation

3. Mechanical ventilation

4. Hybrid ventilation

} **System design**

			
1	2	3	4

AERATION AND VENTILATION

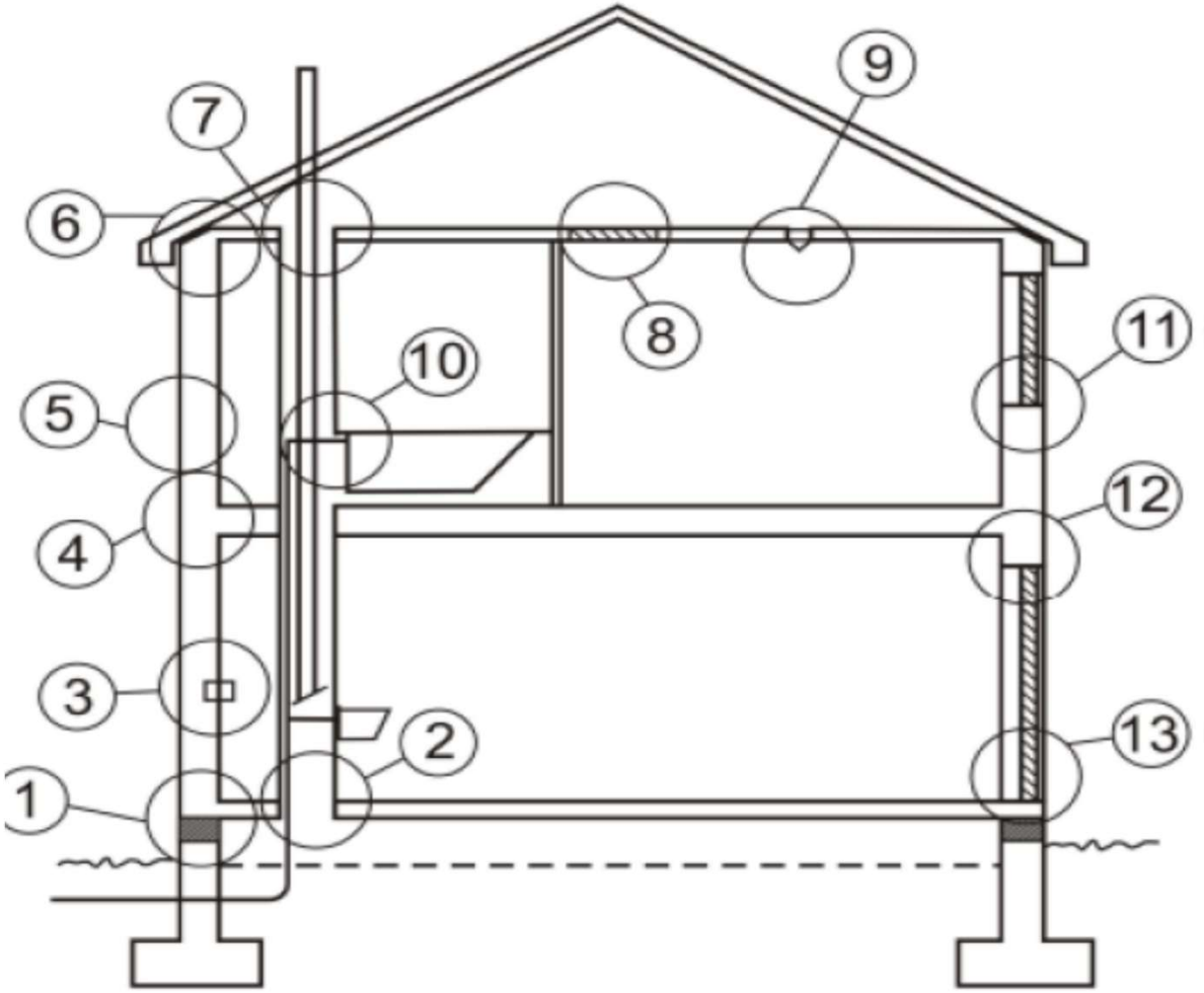
There is a frequent misunderstanding about the concept of ventilation in residential construction.

The UNI EN 12792:2005 Standard highlights the difference between "ventilation" and "aeration":

The term ventilation indicates a method of air exchange by opening windows. Ventilation, on the other hand, means the intake and corresponding extraction of air, both calculated, into and from a given space.

The Standard UNI EN 16798:2019, also clearly specifies that ventilation must be continuous in buildings when occupied, and can be decreased, but not canceled, when they are not. The same Standard indicates ventilation rates, at times of occupancy of housing, significantly higher than those tended to be suggested by energy assessment procedures and the same UNI TS 11300-1.

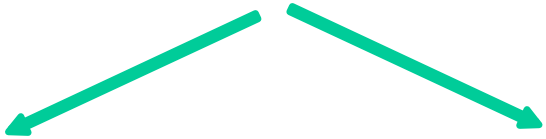
INFILTRATION



NATURAL VENTILATION

When openings are placed in the building envelope, the pressure differential between the various facades (or between different areas of the same facade) generated by the wind and/or the difference in temperature (and therefore density between the exterior and interior) gives rise to an internal airflow, which can be used for ventilation.

NATURAL VENTILATION



Pressure uses the principle of the chimney effect: warm air, which is lighter than cold air, tends to rise, drawing in more cold air. The temperature differences in the various rooms of the house determine a ventilation that allows the air to be exchanged.

The depression exploits the effect of the wind: when a building is hit by the wind, the wall directly exposed is subject to a strong pressure, while the wall located on the opposite side (downwind) is affected by a depression. The difference in pressure between the two facades is sufficient to create a natural ventilation of the rooms.

Ventilation according to EN 12792

Balanced ventilation (dual flow):

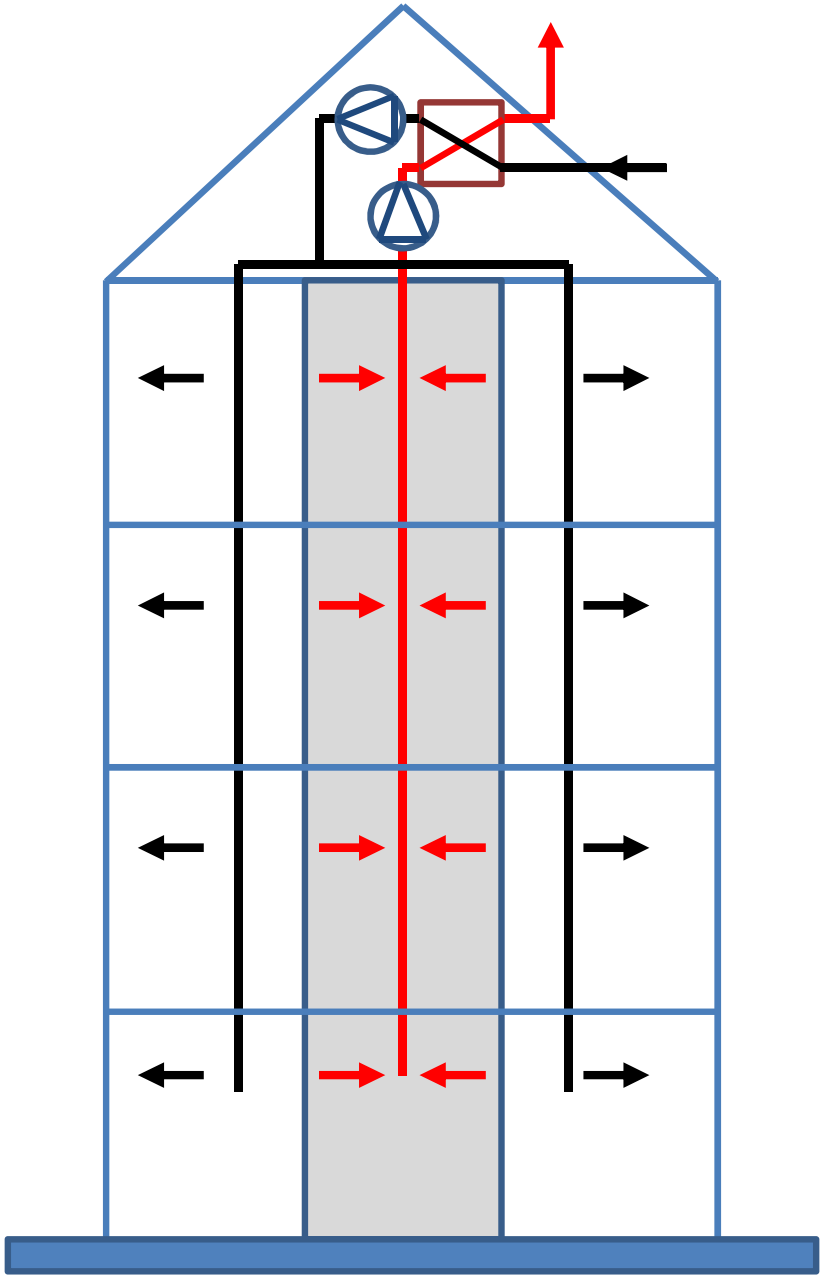
Air is supplied and taken back into the rooms.
There is a supply fan with fresh air
There is an expulsion fan with exhausted air

Pros:

- **Possibility of thermal recovery**
- **Possibility of air treatment with cooling and dehumidification coils**
- **Possible integration with GAHE (air-ground exchangers)**
- **Good air flow control**
- **Centralized maintenance**

Cons:

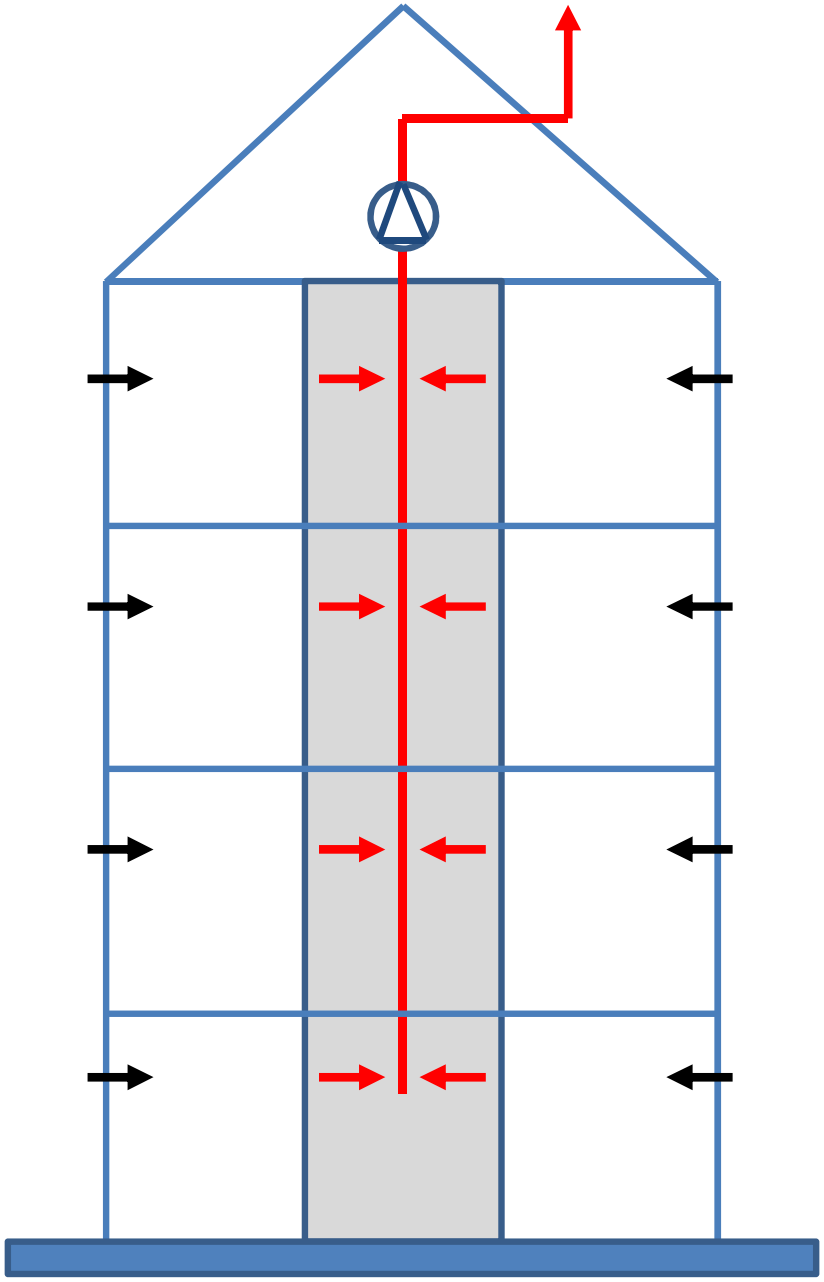
- **High costs;**
- **In case of more users, impossibility of autonomous management of the plant**



Ventilation according to EN 12792

Exhaust ventilation (single flow):

The air is returned to the rooms.
There is an exhaust fan for the exhausted air
The air enters through openings in the casing or in the window frames



Pros:

- **Inexpensive;**
- **Adjusts the opening of the vents according to the relative humidity (and therefore the actual presence of people)**

Cons:

- **Maintenance delegated to the user**
- **In case of more users, impossibility of autonomous management of the plant**
- **It does not allow heat recovery (unless you put a Heat Pump on the expulsion)**
- **There is no control on the flow rate actually entering the single environment**
- **Inlet air cannot be pre-handled**

Ventilation according to EN 12792

Supply ventilation (single flow):

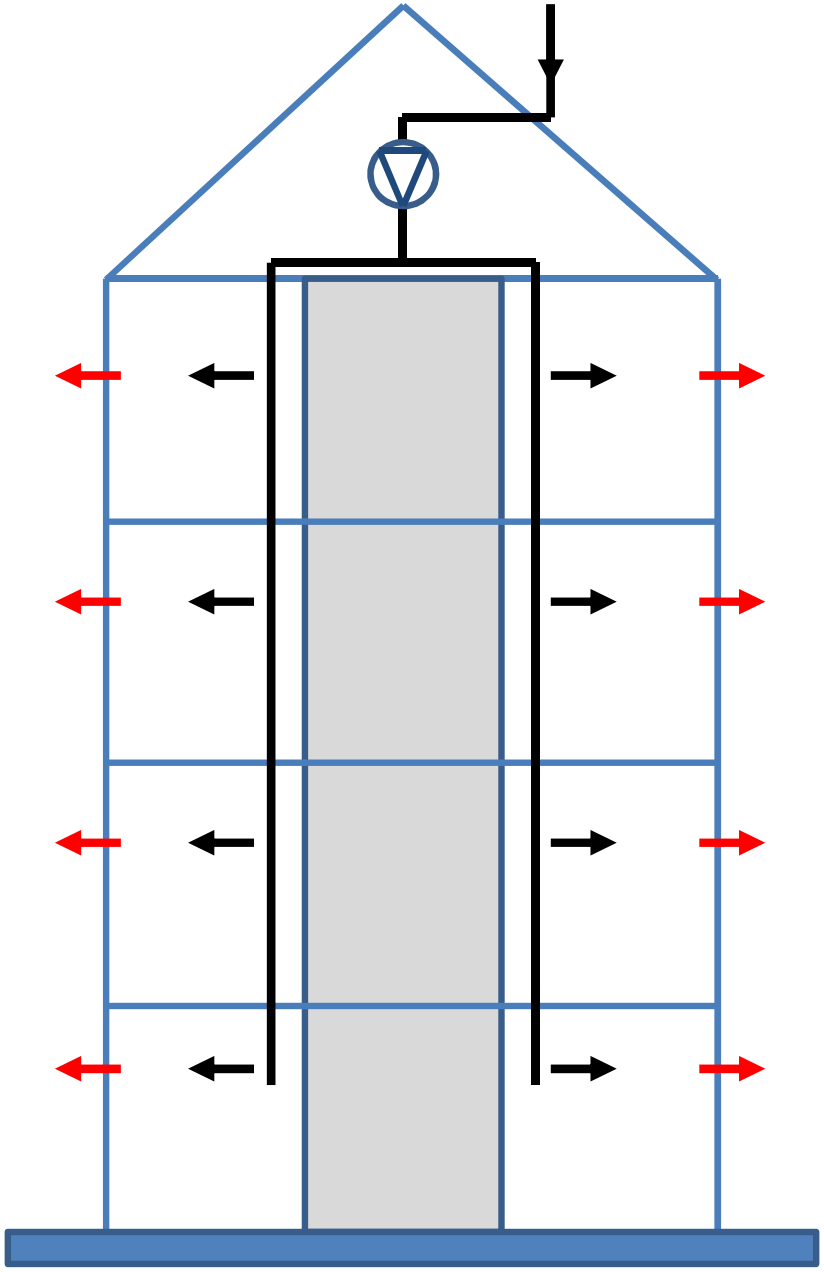
Air is returned to the rooms.
There is a supply fan with fresh air
The air exits through openings in the casing or in the window frames

Pros:

- **Possibility of air handling with cooling and dehumidification coils**
- **Possible integration with GAHE (air-ground exchangers)**
- **Good control of air flows**

Cons:

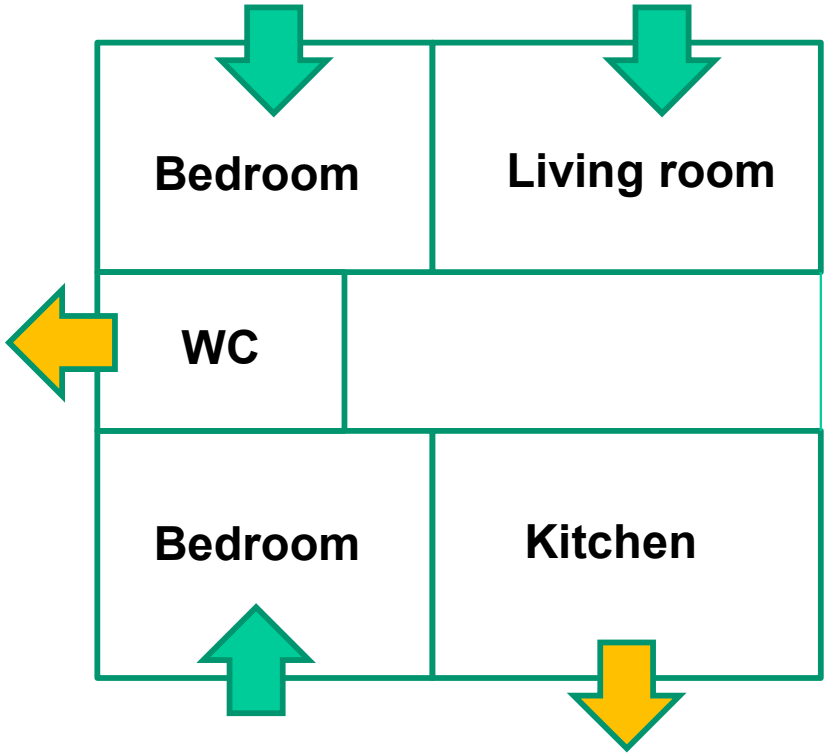
- **Maintenance delegated to the user**
- **In case of more users, impossibility of autonomous management of the plant**
- **Does not allow heat recovery**
- **Difficulty in balancing flows in operating conditions**



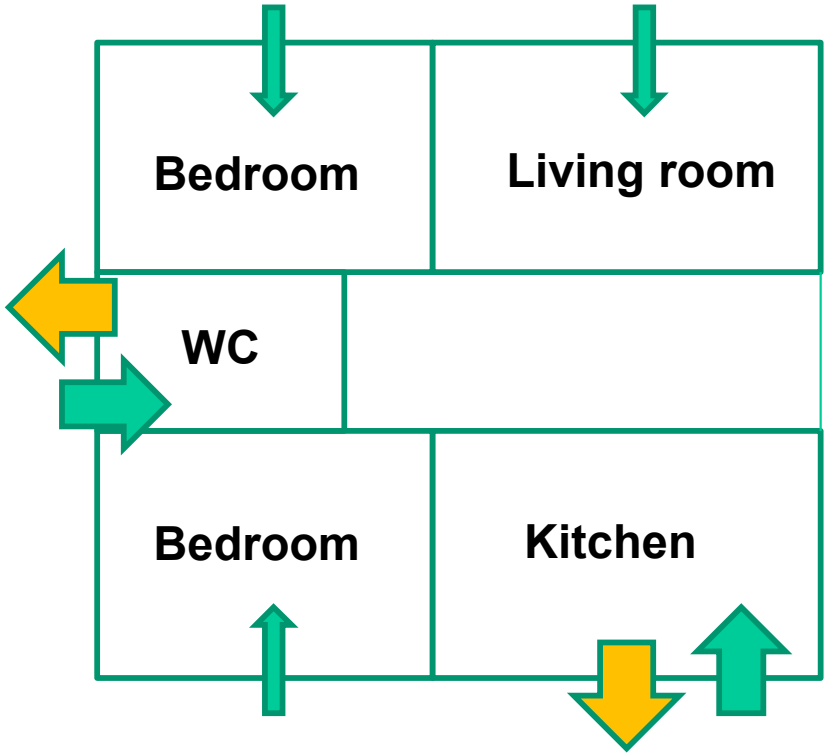
Criticality of single-flow (exhaust) vs. dual-flow ventilation

- Enclosure losses are greater than air flowing from vents
- Air enters predominantly negative pressure environments
- Result: lower effective air flow rate into the room

ideal



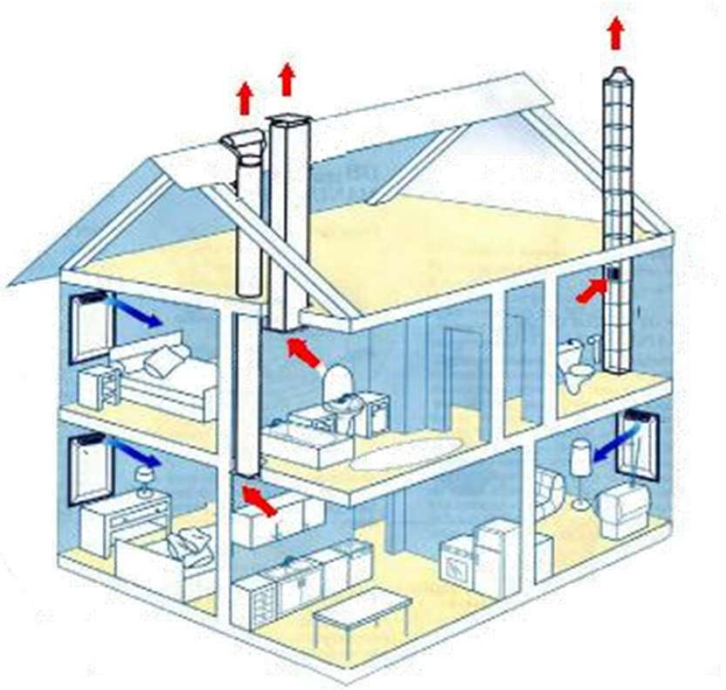
real



Mechanical ventilation

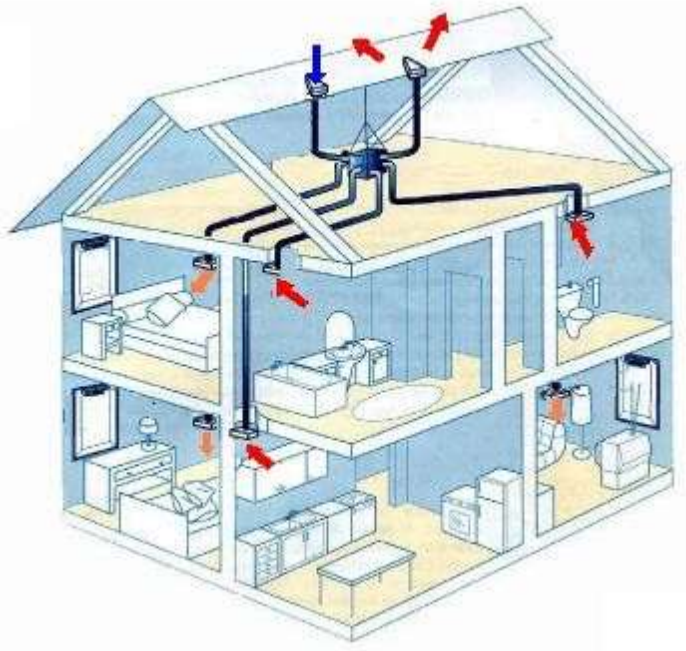
Single flow

The system provides the mechanical extraction of the stale air while the inflow of external air takes place through outlets equipped with devices for the flow rate self-regulation.



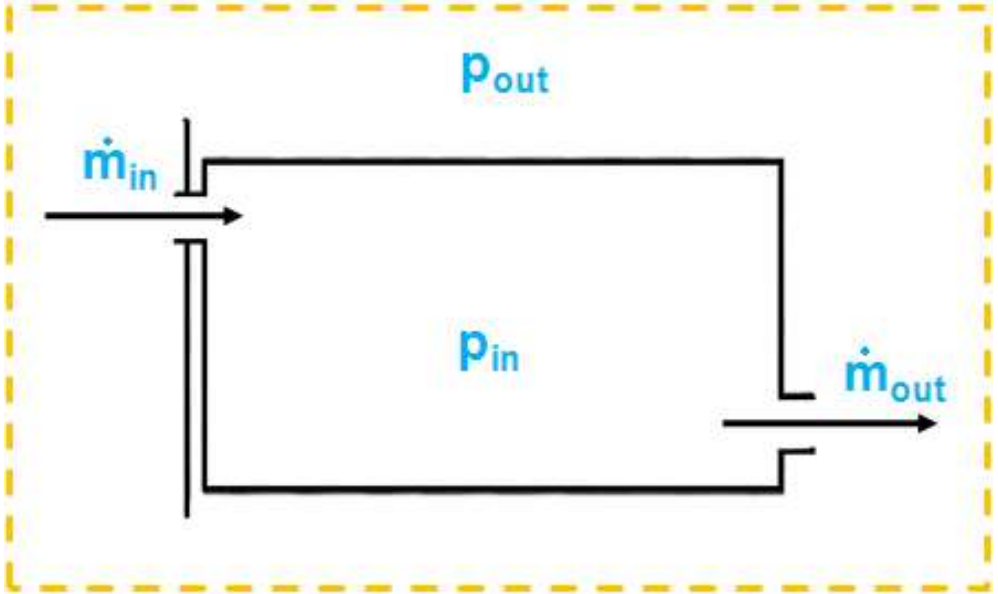
Dual-flow

The system provides the mechanical extraction of the stale air and the contemporary introduction of fresh air which can be previously filtered and/or pre-heated before being introduced into the system.

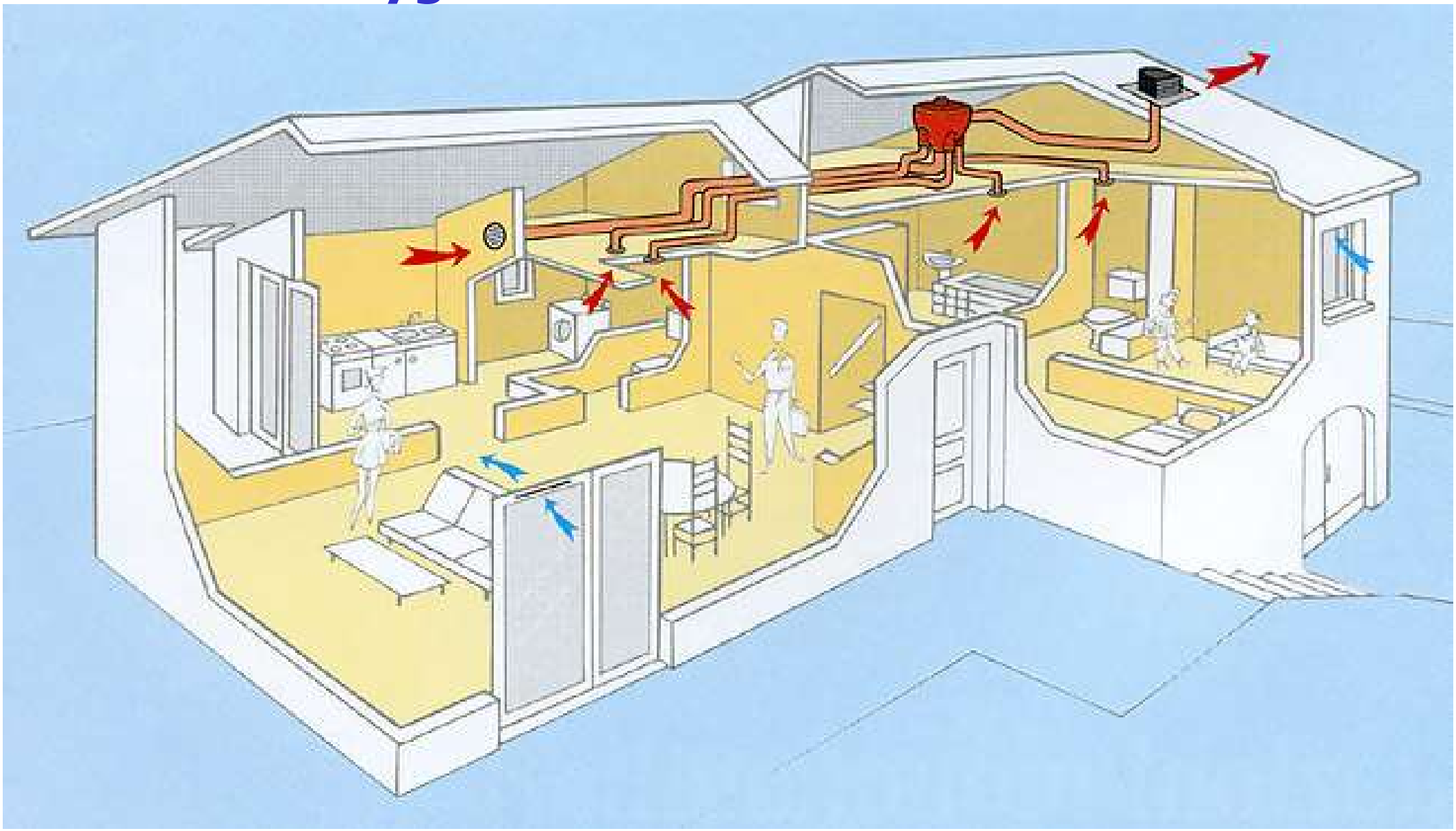


Mechanical ventilation - local conditions

Pressurized room	If you want to prevent air from entering you create an overpressure	$p_{in} > p_{out}$ $m_{in} > m_{out}$
De-pressurized room	If you want to prevent the air from escaping you create a depression	$p_{in} < p_{out}$ $m_{in} < m_{out}$



Single-family flow (self-regulating or) hygro-controlled ventilation

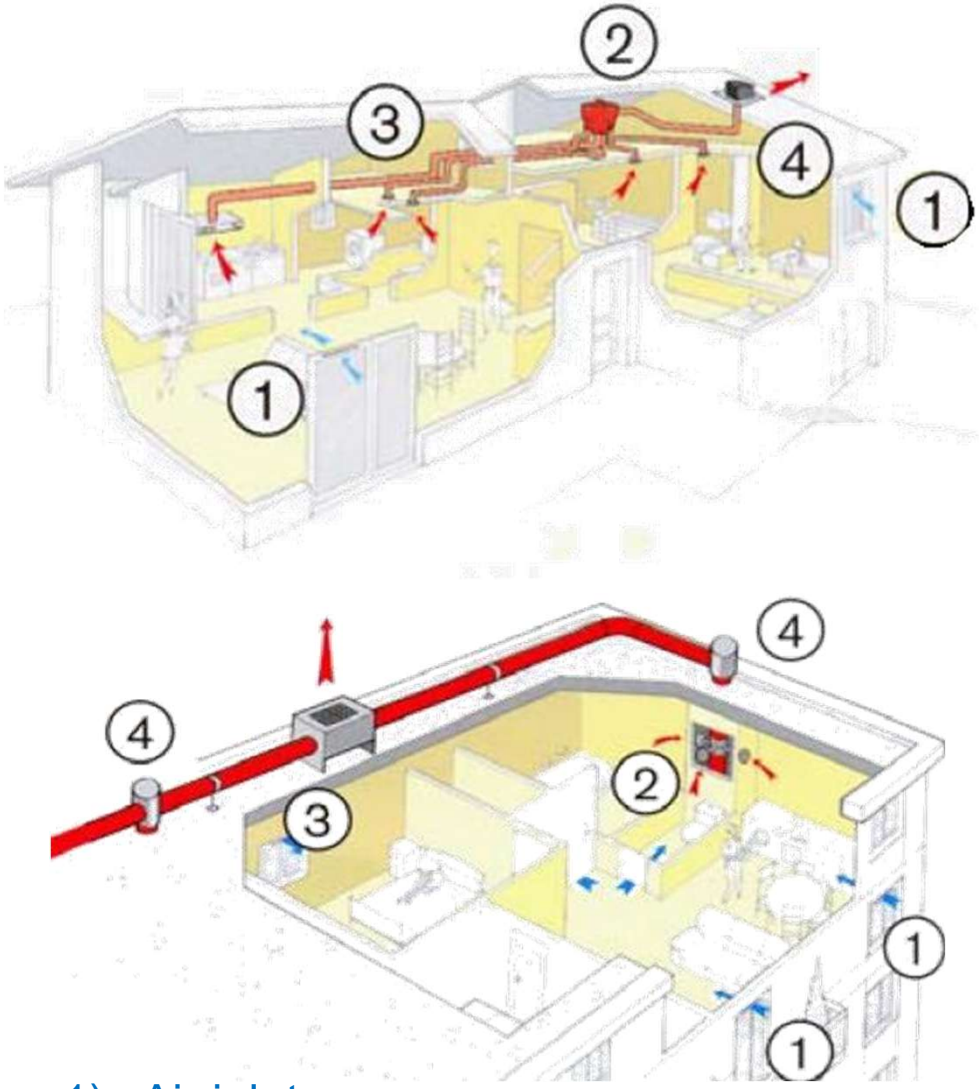


Mechanical ventilation – Single flow

- The system consists of a small electric fan for air extraction connected by rigid and/or flexible ducts to extraction grilles located in the service rooms (kitchen and bathrooms).

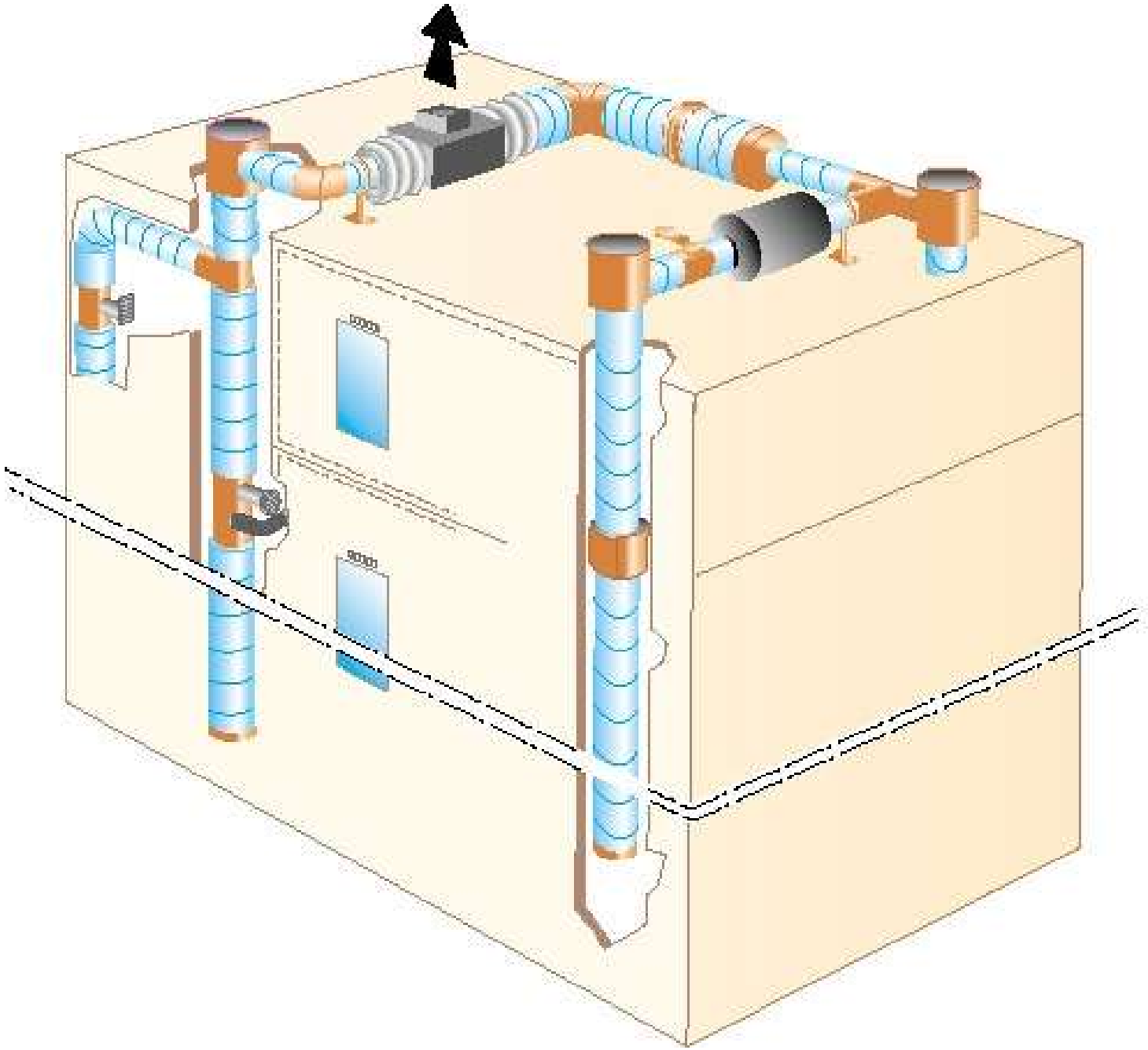
- The inflow of external air takes place by means of vents, placed on the external walls or on the window frames of the "main" rooms (living room and bedrooms), equipped with self-regulating flow rate devices or devices sensitive to the relative humidity of the environment.

- For centralized condominium installation, a single fan is installed (in the attic or outdoors) from which a series of ducts branch out connecting the risers.



1) Air inlet
2) Extraction
3) Ducts
4) Exit on the roof

Single Flow Ventilation in Apartment block



Mechanical ventilation – Single flow

Pros:

- Air flow control
- Possibility of integration with natural ventilation
- Independence from inconstant weather factors or random occupant behavior
- Adaptability to seasonal climatic conditions
- Limitation of ambient noise
- Control of air speed in the environment

Cons:

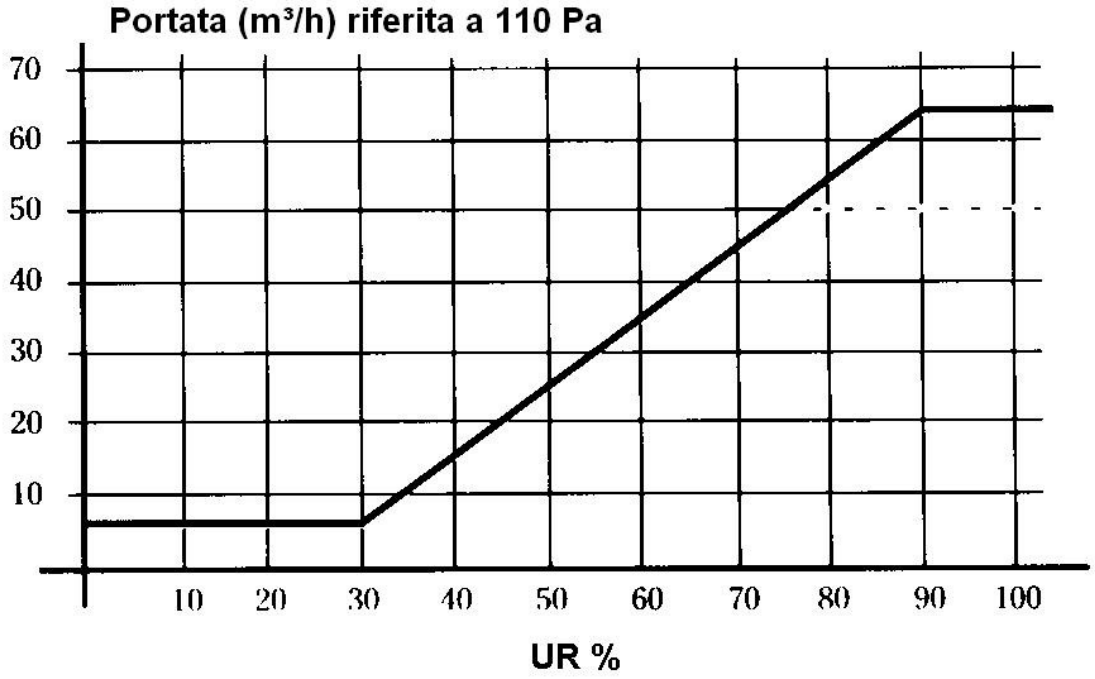
- Cost of the plant and its operation
- Impossibility to control the quality of fresh air
- Energy loss in the cold season
- Intake of too hot air in summer

Supply air vents

- Self-adjustable: they are equipped with deformable PVC membranes that modify the passage section; they are sized to introduce in the rooms the same quantity of air that is extracted from the services to make up for the internal depression.
- Adjustable: they are equipped with a humidity sensor directly connected to a calibration damper (if humidity tends to fall, the device limits the air flow, maintaining a minimum value); they must be installed in the main rooms of the house (bedrooms, living room) in order to create a wash in the direction of the technical compartments.

They can be installed on the upper part of the box or frame and on the window frame; they are of the linear type made of plastic and equipped with soundproofing.

Example



Hygro-controlled

Presence of a hygroscopic element that opens or closes the vent depending on the RH in the room.

It can be installed for inlet (more frequent or for expulsion)

It can provide variable flow rate (different ventilation needs in presence/absence of people in residential). A variable speed fan is needed.

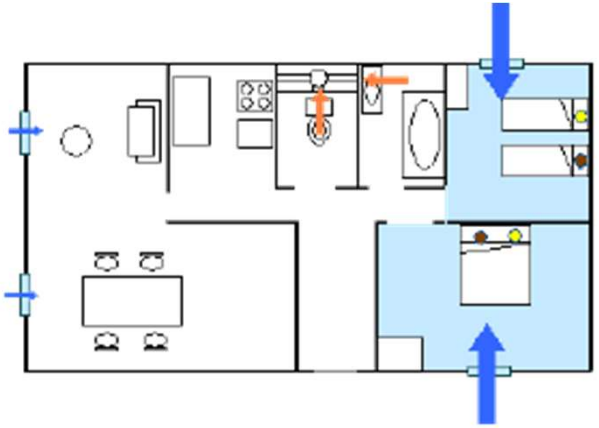
In case of high infiltration in cold periods the relative humidity drops and therefore the vents limit the air entering the room.

Outlet air vents

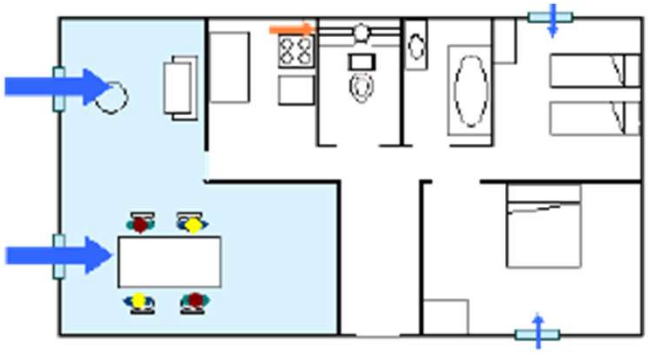
Self-adjustable: they are made of PVC and have, at the center, a self-adjustable regulating device consisting of a rubber membrane that modifies the air passage section according to the pressure it is subjected to.

Hygro-controlled: made of PVC, they have a humidity sensor in the center and a membrane capable of regulating the amount of extraction air according to humidity; it works for pressure differences between 70-130 Pa.

The total ventilation rate calculated for the sleeping area is extracted from the wall vents in the bathroom, while the ventilation rate for the living area is extracted from the wall vent in the kitchen.

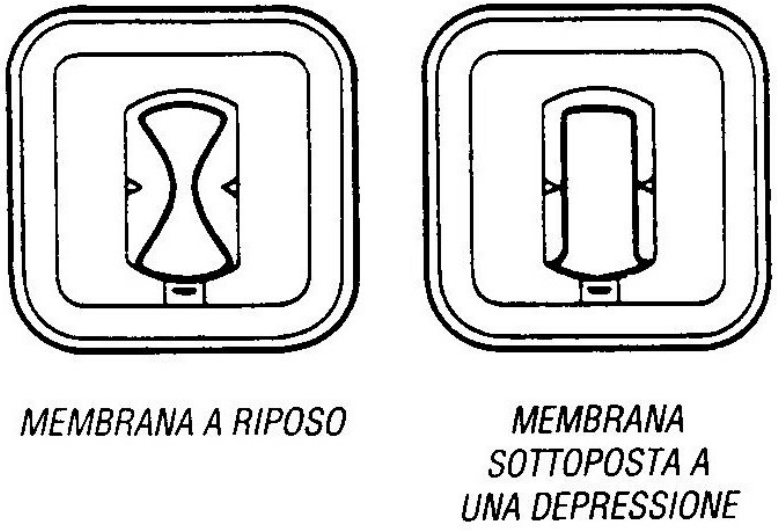


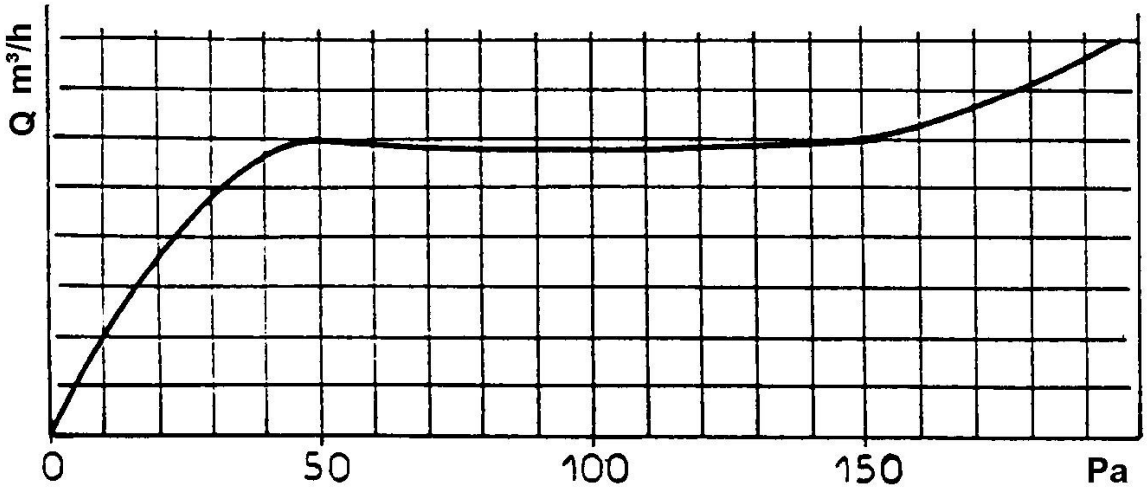
Night



Day

Example





Diagram

Self-adjustable air vents

In winter in the coldest periods there is still entrance from infiltration (not perfectly sealed envelope) because of the large internal-external Δt which causes large internal-external Δp.

The sealing aspect of the envelope is all the more important the colder the winter climate.

Examples

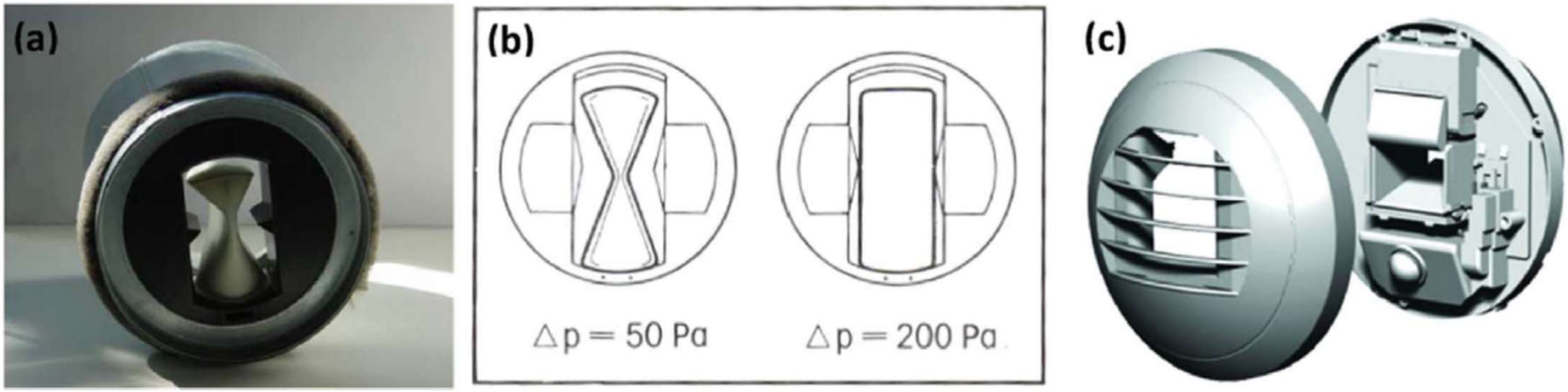
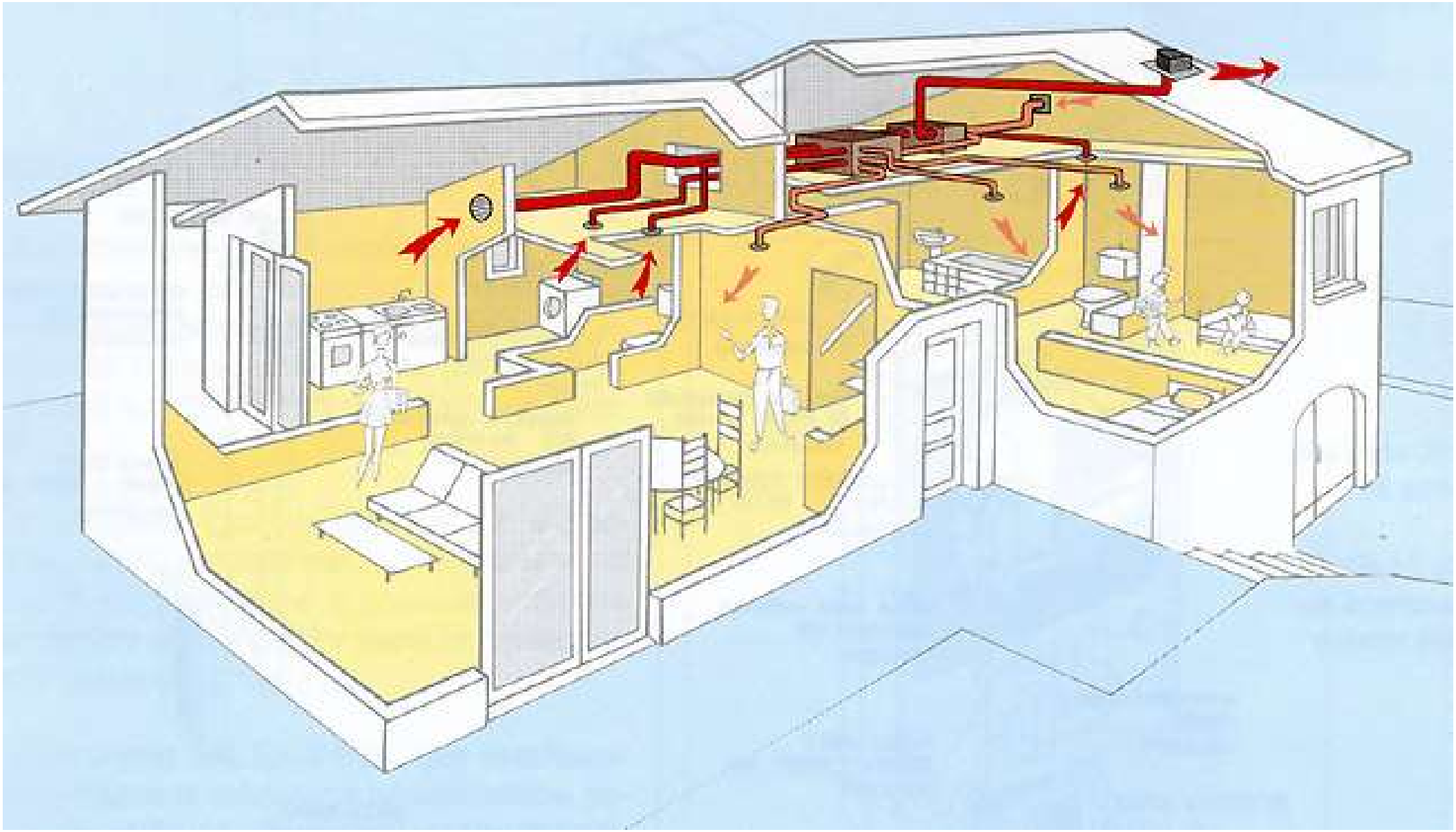


Fig. 1. (a, b): Constant flow extract unit with auto-adjustable silicon membrane [source: Aldes]; (c): Hygro-adjustable extract unit [source: Ecoclima].

Single-family dual-flow ventilation with heat recovery



Mechanical ventilation – Dual flow

In more complex systems, it is possible to handle the fresh air before it is introduced into the environment, i.e. filter it, cool it or heat it, humidify it or dehumidify it. Finally, with dual-flow systems, energy recovery is also possible of the exhaust air through heat recovery units.

Pros:

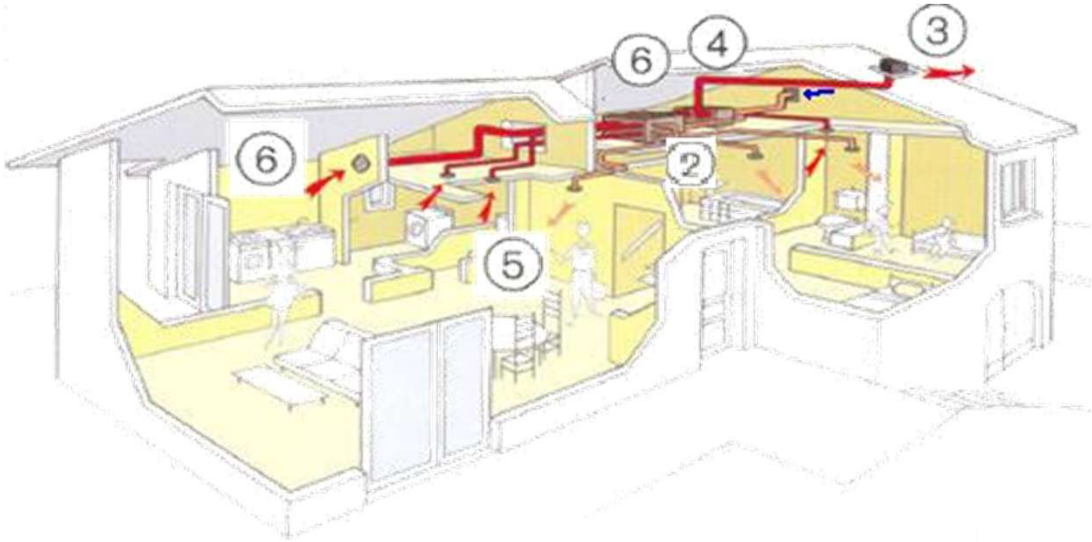
- Air flow control
- Possibility to combine a heat recovery unit
- Possibility of integration with natural ventilation
- Independence from inconstant meteorological factors or random behaviors of the occupants
- Adaptability to seasonal climatic conditions
- Limitation of noise in the environment
- Control of air speed in the room
- Control of fresh air quality

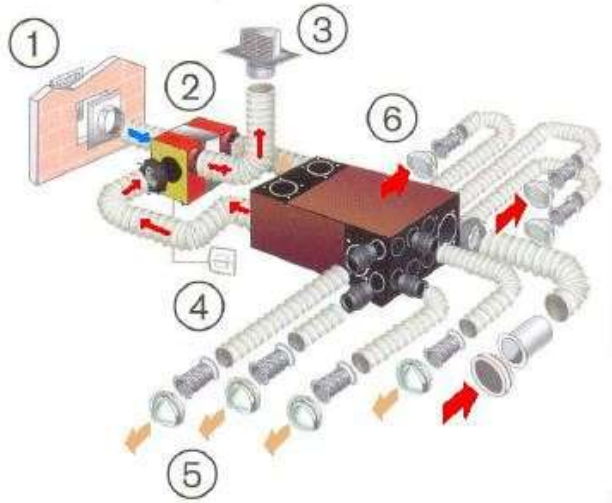
Cons:

- Costs

Mechanical ventilation – Dual flow

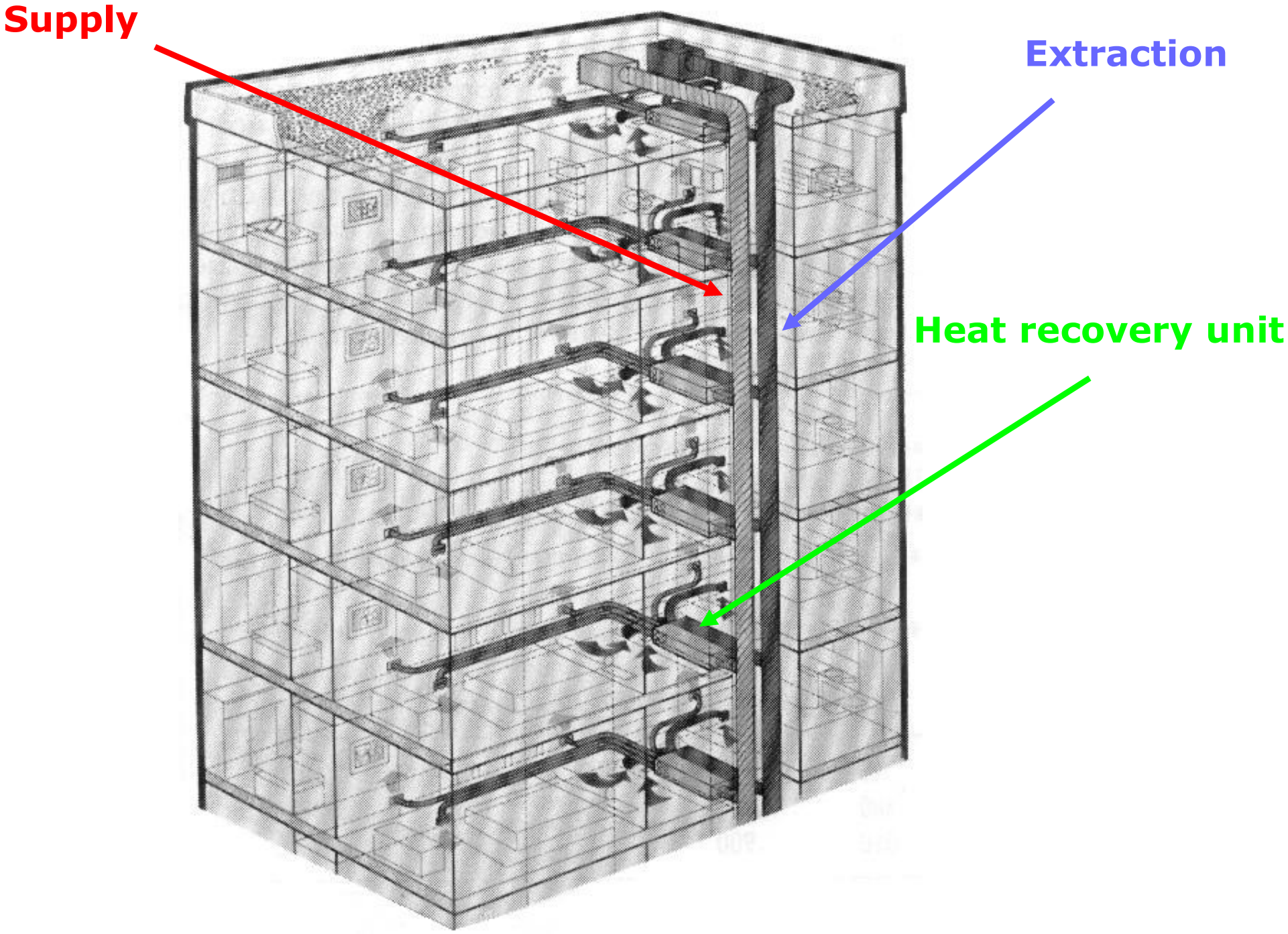
- *A dual-flow system mechanically provides both supply and return air to the room.*
- Extraction is the same as for single flow systems.
- The inlet is also made through ducts and vents in a separate circuit from the previous one.
- The inlet and outlet flows are coordinated by a control system



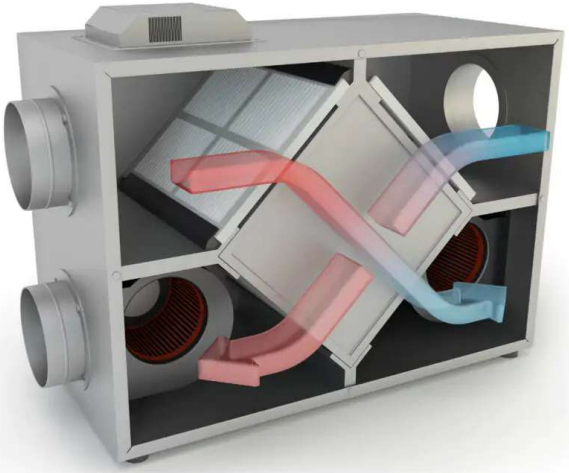


1) Inlet + filter
2) Fan
3) Roof extraction
4) Heat exchanger
5) Inlet points
6) Outlet points

Dual-Flow Ventilation in Apartment block with heat recovery



Example



The fans and the heat recovery unit is in the same prefabricated box

Usually 150, 250 m^3/h

Even 500, 800 m^3/h

Source: Helty

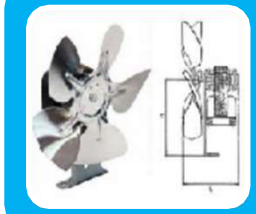
FANS

- Fans force air into (out of) the interior (exterior) of the building
- They can be placed in false ceilings, in the attic or outside the building.

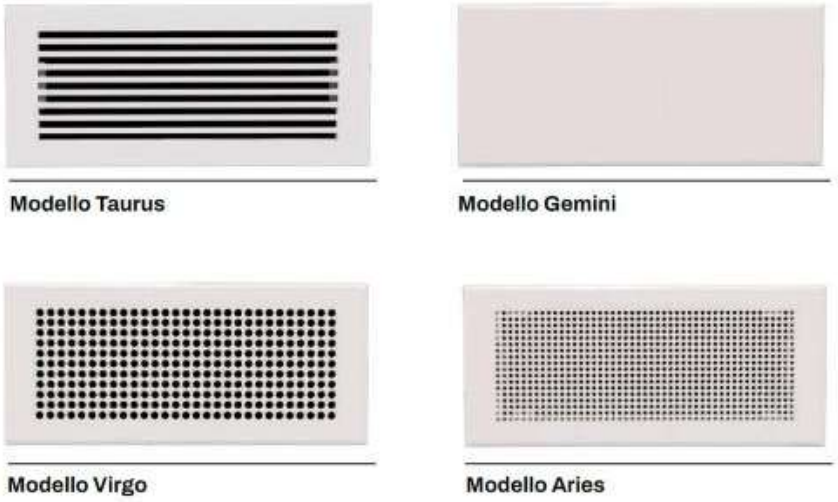

On the roof


Axial fan


Centrifugal fan


Low flow axial fan


Low flow compact axial fan



Source: iClima

Supply/outlet air vents

Source: Ecoclima

Plenums

Source: Emmeti

Source: Valsir

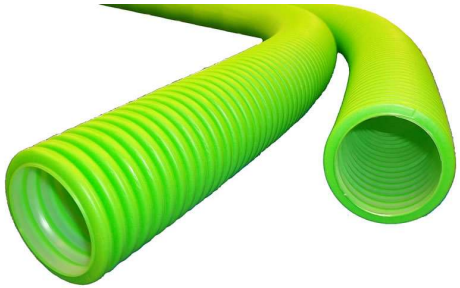
Air ducts

Secondary/terminal ducts

corrugated plastic pipe on the outside and smooth on the inside

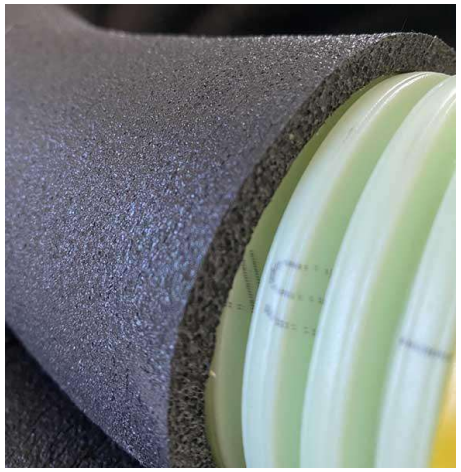
ϕ_{int}= 75 mm

ϕ_{ext}= 90 mm



Source: idealclima

Insulation foam for the supply ducts



Source: airplast

Main ducts

Source: Mistubishi

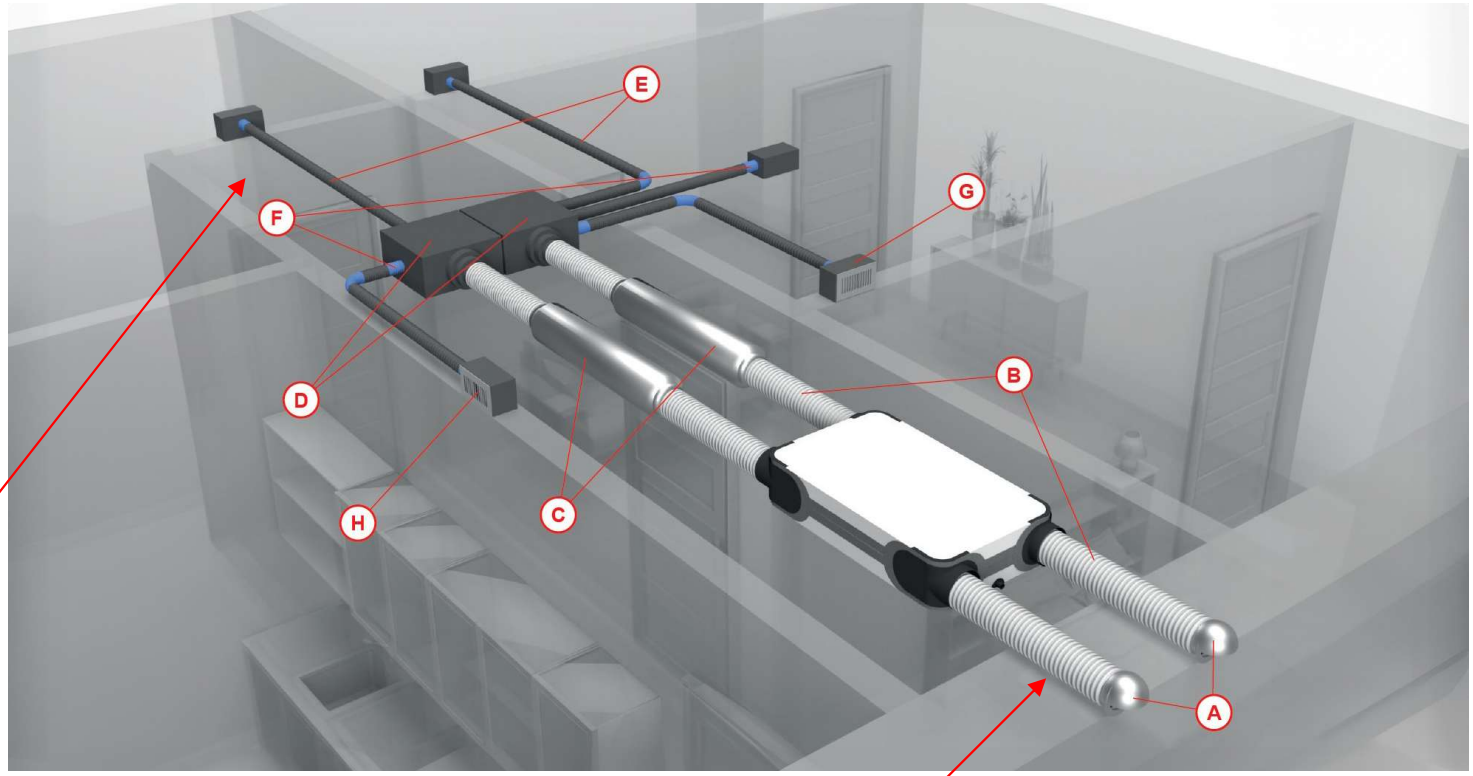
ϕ_{int} : 127 mm
160 mm
203 mm

The duct is flexible (harmonic steel wire spiral) with thermal insulation (fiber insulation)

Antibacterial and anti-mold treatment

Overall system

Source:
Mitsubishi



Secondary ducts

Main ducts: external air intake/exhaust to plenum

Secondary ducts

Source:
Idracol

Cloth filters

- They consist of a mesh of fibers whose dimensions are much smaller than the distances between them (so that the airflow is not greatly disturbed by the filter). The depth of the filter is much greater than the size of the particles, which are therefore forced to take a long and tortuous route through the filter.
- The air flow passes through the filter fibers and, solid particles with a diameter larger than the distance between the fibers constituting the filter, are stopped exactly as it happens through a sieve (sieve filtration mechanism). Smaller particles, on the other hand, are fixed along the filter fibers by elementary electrical forces.

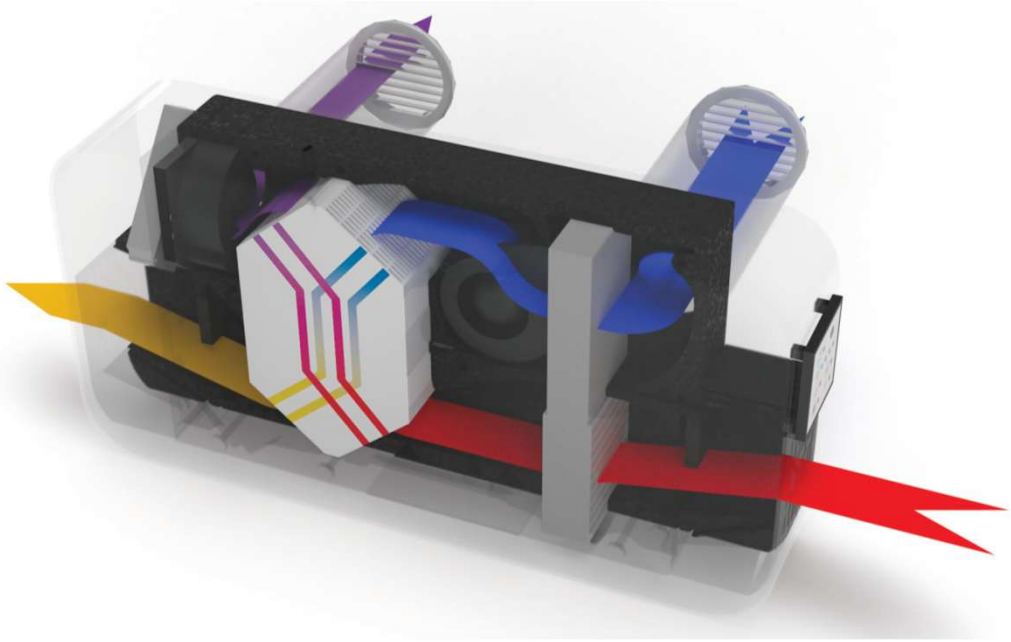
Flat Panel

With rigid pockets

With floppy pockets

Roller

Dual flow decentralized solutions



Pros

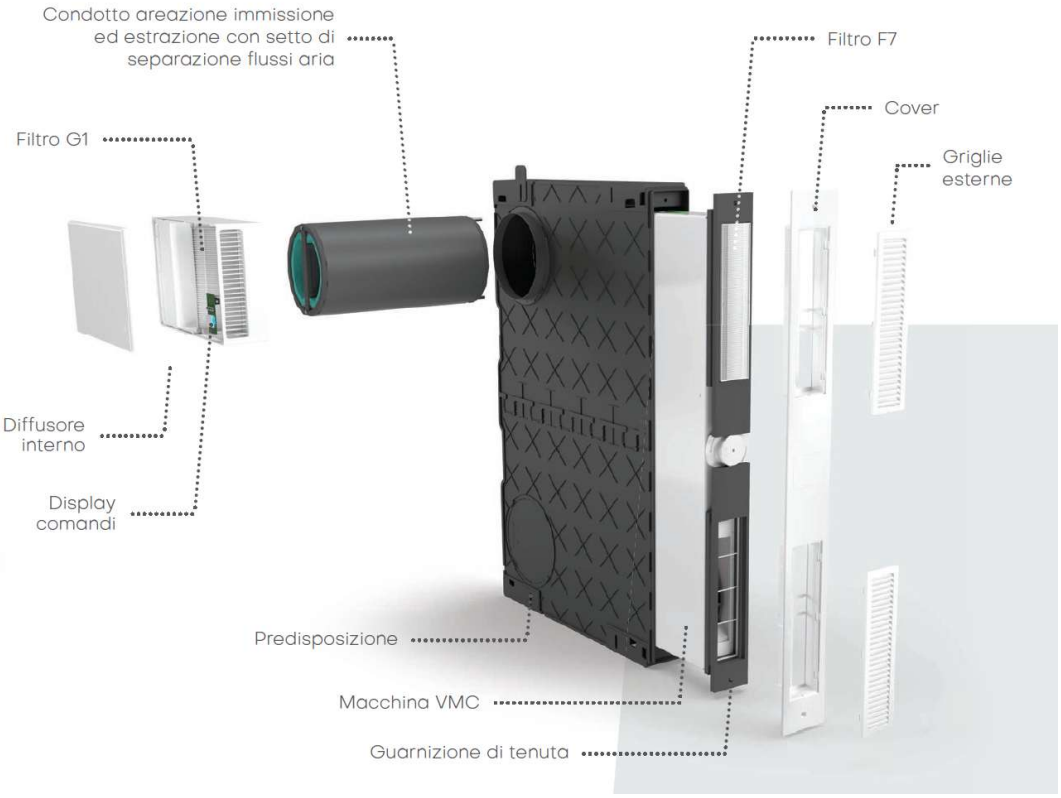
- No ducts
- Easy to install
- Easy to maintain

Cons

- Several holes on the outer walls
- No possibility to handle the air entering the room

Source: Helty

Dual flow decentralized solutions



Source: Helty

Alternate Flow Decentralized Solutions

This simplified system consists of machines that half the time extract and half the time introduce air from the same duct.

Heat recovery is limited, no special filtration is provided.

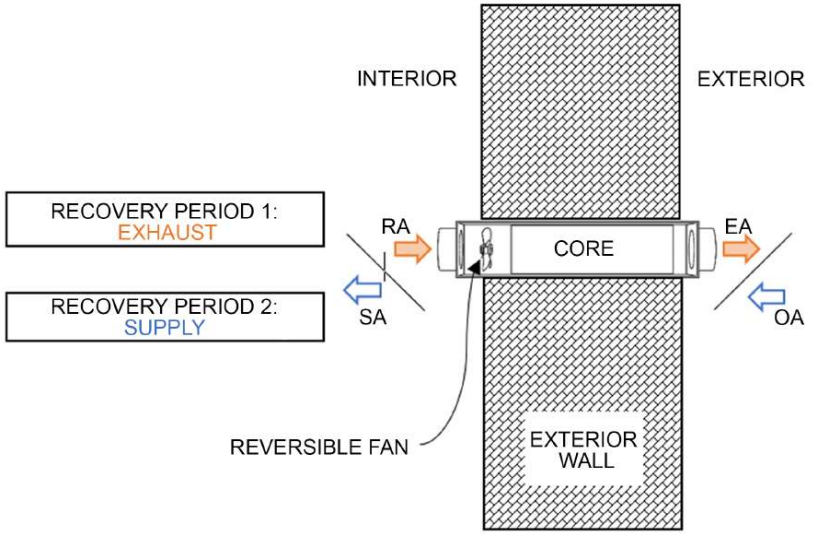
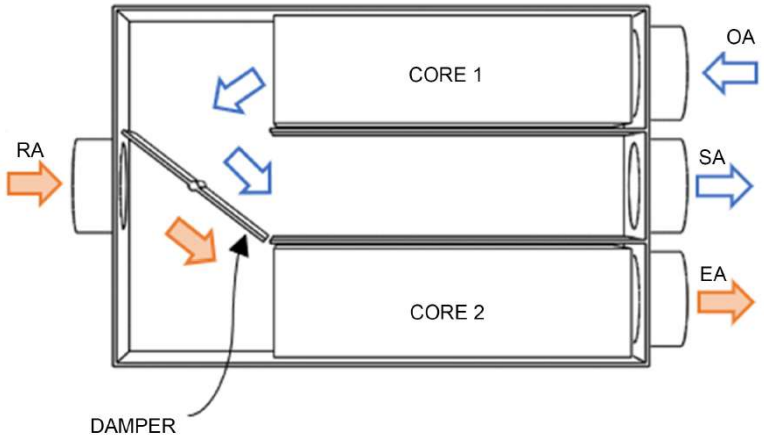
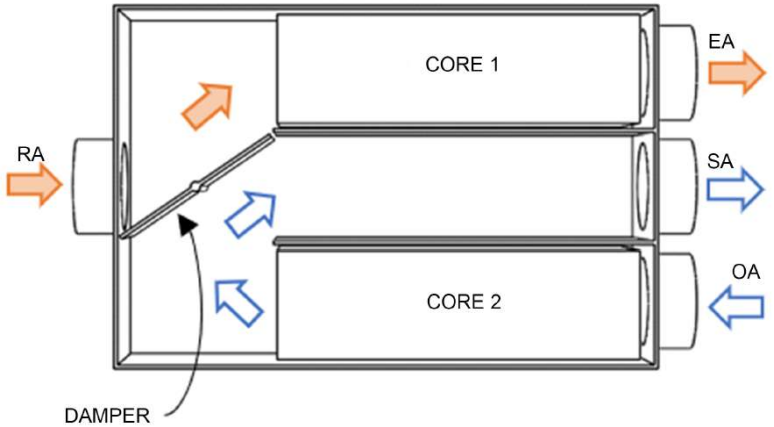


Fig. 23 Single-Core Fixed-Bed Regenerator



RECOVERY PERIOD 1



RECOVERY PERIOD 2