

# INTENSE

## Systems engineering – cooling and ventilation

6. - 8. December 2010  
Sigulda, Latvia

# Ventilation

## Need for ventilation

### Reasons for ventilation / air quality:

#### CO<sub>2</sub>

- Dr. Max Pettenkofer: The limit is 1000ppm
- EN 13779: classifications of air quality (e.g. good air quality IDA 2, max. 600 ppm over natural fresh air concentration)

#### H<sub>2</sub>O

- risk of mould → minimum design air change rate
- not too high air change rates to get comfortable humidity in winter

Other pollutants are formaldehyde, VOC, ozon, radon, NO<sub>x</sub>, CO etc. These pollutants have to be flush as well!



Source: Slide from EnergyAgency.NRW, D

## Need for ventilation

### Reasons for ventilation / air quality:

– **Comfort / odour**

- Unit “olf”: odour by one reposing person in one hour

$$? \quad \dot{V} = \frac{\sum \text{olf} \cdot 3600}{100 \cdot dP} \left[ \frac{\text{m}^3}{\text{h}} \right]$$

- dP = decipol is a unit how a human senses the air quality!  
It is based on one olf and measured in [l/s]



Person	Products
normal = 1 olf	linoleum = 0,2 olf/m <sup>2</sup>
smoker = 6 olf (non smoking)	stone floor = 0,02 olf/m <sup>2</sup>
smoker = 25 olf (smoking)	housing normal = 0,3 olf/m <sup>2</sup>
active person = 5 – 11 olf	housing little = 0,2 olf/m <sup>2</sup>

On off should be flushed by 10 l/s; dp means “decipol”.

Fresh air supply and human disagreement, Percentage of not satisfied people (PNS).

PNS caused by CO<sub>2</sub> [%] =  $395 \times \exp(-1.83 \times (\text{Frischlufft [cbm/h]} / 3,6)^{0,25})$

Odours and CO<sub>2</sub> according to Fanger:

PNS caused by odour [%] =  $395 \times \exp(-3,25 \times \text{dezipol}^{(-0,25)})$

Typical values:

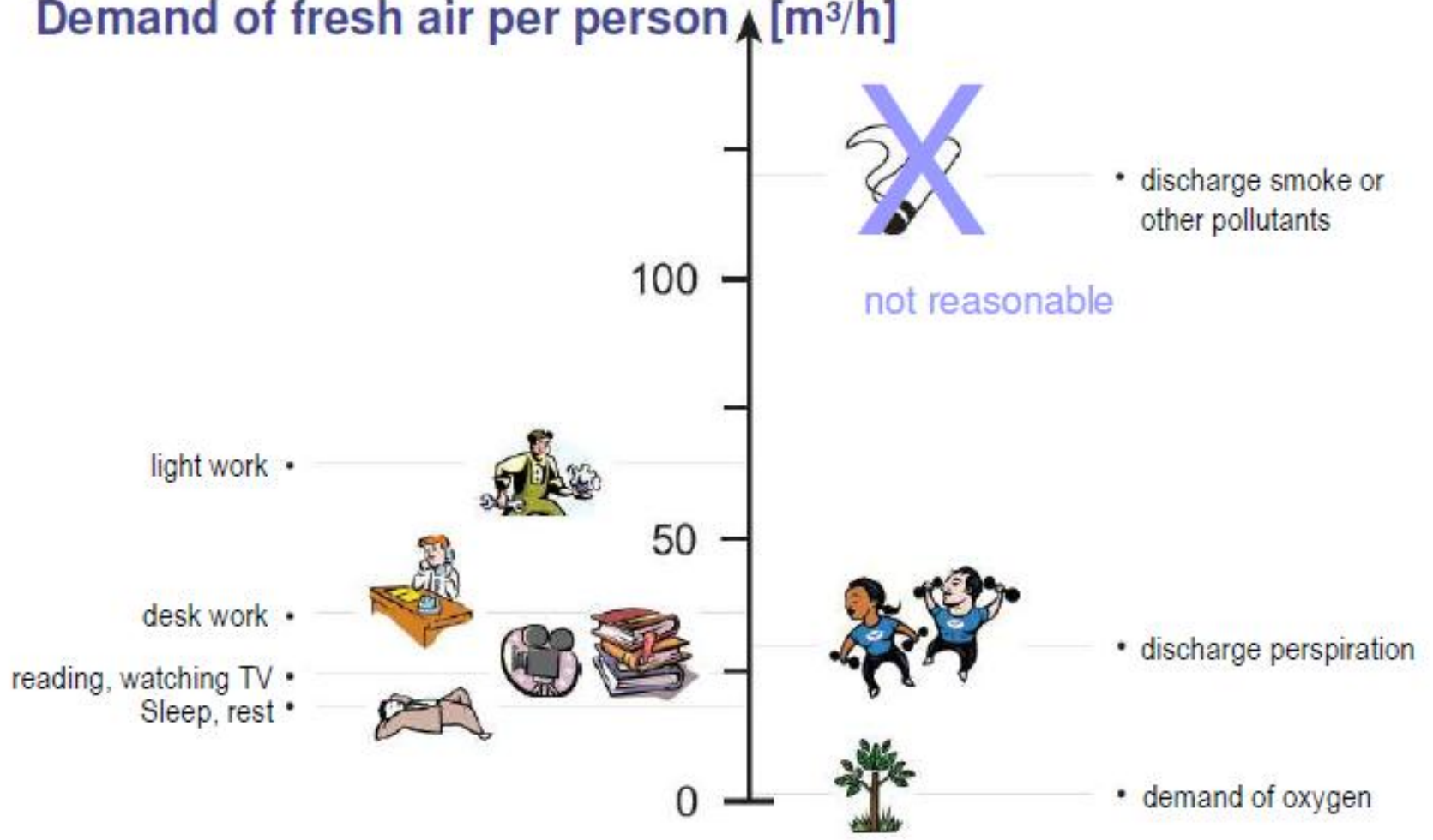
"A" : 0,7 dP or 10 % PNS (excellent)

"B" : 1,4 dP or 20 % PNS (good)

"C" : 2,5 dP or 30 % PNS (medium)

### Human demand of fresh air

## Demand of fresh air per person [m<sup>3</sup>/h]



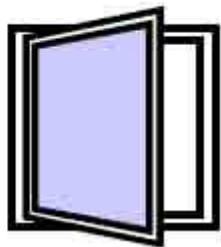
Ok, we need fresh air. Which systems are suitable for that?

- **Window ventilation:**
  - not sufficient in most types of modern tight buildings
  - not efficient at all
- **Peripheral systems:**
  - good for retrofitting
- **Semi central systems:**
  - easy to maintain (filter change)
  - individual heating / cooling
- **Central ventilations systems:**
  - residential buildings
  - for one or many housing units
  - in most cases highest HR efficiency
- **Central air conditioning unit:**
  - for big (commercial) buildings
  - humidification possible

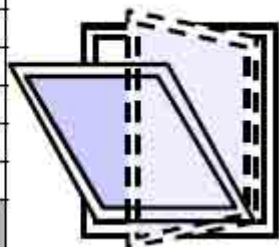
Possible system combinations	Exhaust air sys.	Heat recovery	Heating, cooling	Humidify
Peripheral	x	x		
Semi central	x	x	x	
Central vent.	x	x	x	
Central AC	x	x	x	x

# NATURAL VENTILATION – THE USE OF WINDOWS

Side-hung casement				
Air flow	☺	☺	☺	
Ventilation control	☺	☺		
Weather protection	☺	☺		
Night ventilation	☺			
Relative cost	medium			
BMS controllable	yes			
<b>Comments:</b> Poor security when open. Rain can enter.				



Tilt and turn				
Air flow	☺	☺	☺	
Ventilation control	☺	☺	☺	
Weather protection	☺	☺	☺	
Night ventilation	☺	☺		
Relative cost	high			
BMS controllable	yes*			
<b>Comments:</b> *BMS controllable in one plane only. Complex.				



Upper fanlight & outward opening casement				
Air flow	☺	☺	☺	
Ventilation control	☺	☺	☺	☺
Weather protection	☺	☺	☺	☺
Night ventilation	☺	☺	☺	☺
Relative cost	high			
BMS controllable	yes			
<b>Comments:</b> Upper fanlight can be motorised. Good all round performance.				



## Key points

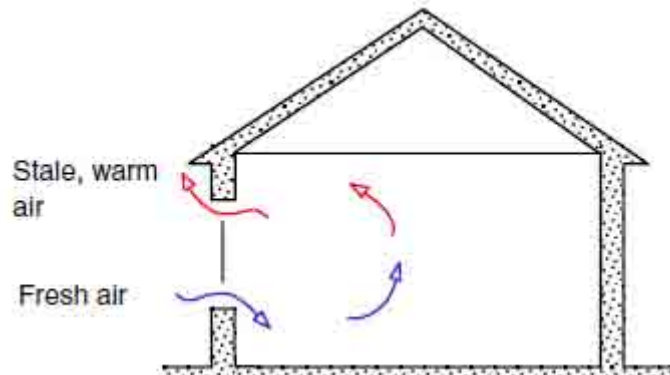
- Simplicity.
- Low cost.
- Good occupant control.
- Occupants may accept higher internal temperatures.

## Limitations

- Potential for draughts.
- Limited cooling potential.
- Potential for excessive heat loss in winter.
- External air-borne contaminants and noise can enter building.
- Poorly positioned furniture can restrict access.

# NATURAL VENTILATION – SINGLE SIDED AND CROSS VENTILATION

## SINGLE SIDED VENTILATION



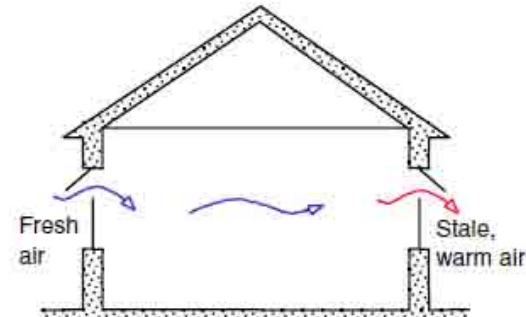
### Key points

- Simplest form of natural ventilation.
- Good occupant control.
- Windows should be tall, ideally with top and bottom openings.
- A space which can be daylit by perimeter windows on one side is generally suitable for single-sided ventilation up to a depth of around six to seven metres.
- Minimal cost.

### Limitation

- Dependent on the presence of wind for good ventilation.
- Inappropriate window design/positioning may result in disruptive draughts, and papers being blown off desks.
- Opening windows during cold weather can waste a significant amount of energy.
- Not suitable for deep-plan spaces.
- May not be appropriate for noisy, polluted environments such as town centres.

## CROSS VENTILATION



### Key points

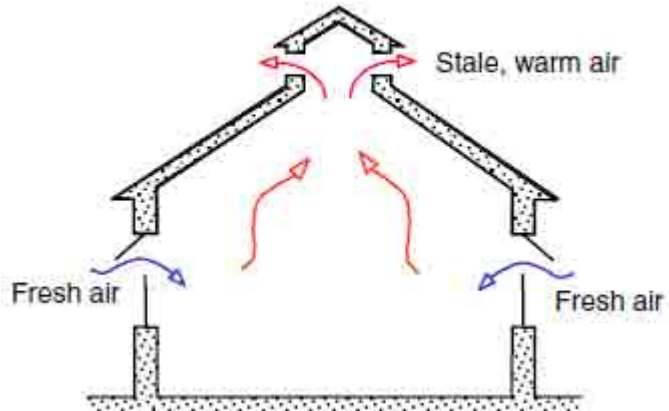
- A high rate of ventilation is possible under favourable weather conditions.
- Can be used in relatively deep-plan spaces with two or more perimeter walls containing windows that can be opened.
- Good occupant control.
- Minimal cost.

### Limitation

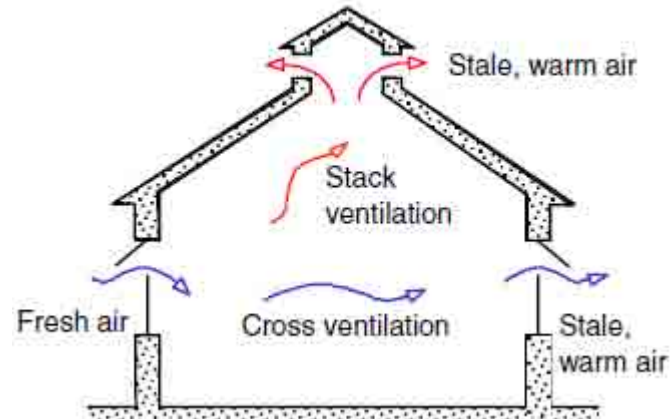
- Effective cross ventilation requires a relatively clear path for air to flow across the space.
- Partitions should be kept under 1.3 m and tall cupboards should be placed between windows on the perimeter wall.
- Dependent on the presence of wind for good ventilation.
- Inappropriate window design/positioning may result in disruptive draughts, and papers being blown off desks.
- Opening windows during cold weather can waste a significant amount of energy.
- May not be appropriate for noisy polluted environments such as town centres.

# NATURAL VENTILATION – STACK VENTILATION

Stack ventilation on a still day



Combined stack and cross ventilation



## Key points

- Temperature difference is the driving force, therefore stack ventilation is not reliant on wind to work effectively.
- Stack ventilation is particularly effective for night time cooling when there is the greatest differential between internal and external temperature.
- In practice, stack ventilation systems are often combined with wind-driven ventilation for improved daytime performance.

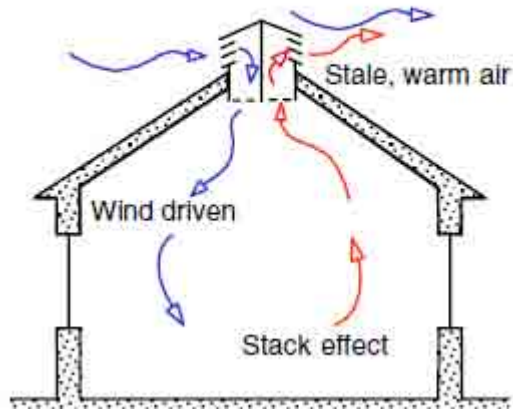
## Limitation

- The air outside must be cooler than the internal air for stack ventilation to work.
- A relatively clear path is required for air to travel easily from low level to the high-level ventilation opening.



# NATURAL VENTILATION – STACK/ WIND VENTILATORS

## Combined stack and wind ventilation



### Key points

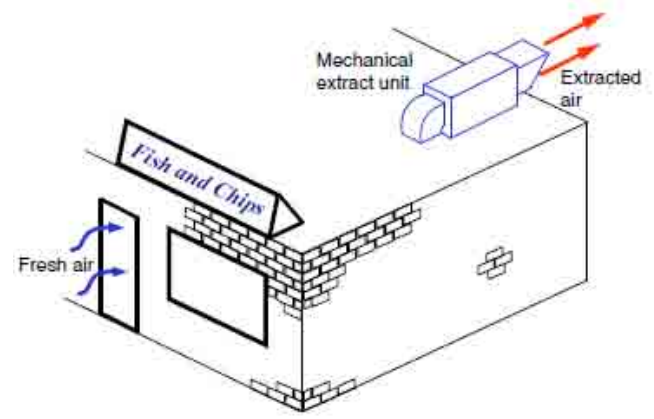
- Suitable for buildings where openable windows may not be practicable due to external noise and security risk.
- Fresh air is taken from high level which in some environments may be cleaner than air at ground level.
- Good night-time cooling performance.

### Limitation

- The air outside must be cooler than the internal air for stack ventilation to work.
- A relatively clear path is required for air to travel easily from low level to the high level ventilation opening.

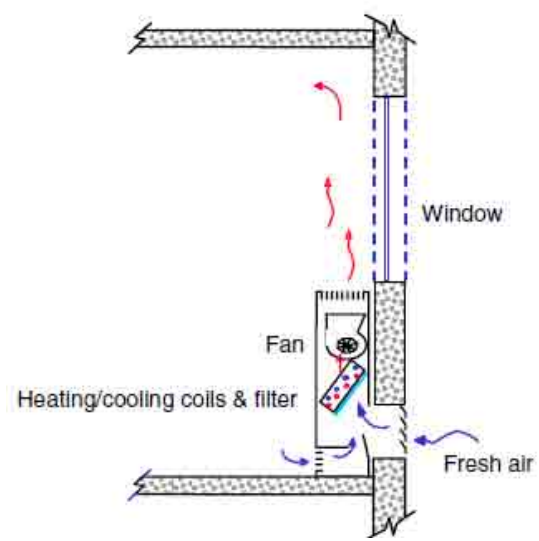
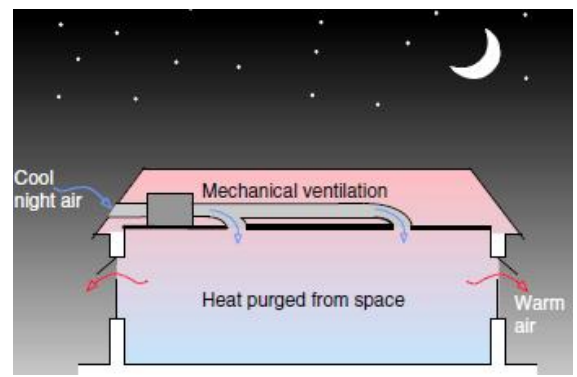


## MECHANICAL VENTILATION – EXTRACT ONLY



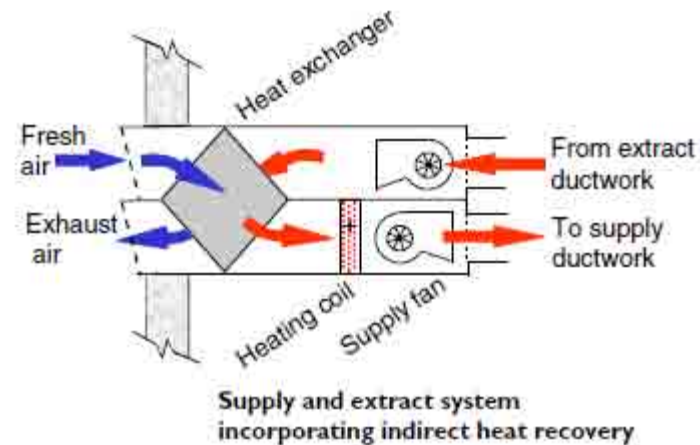
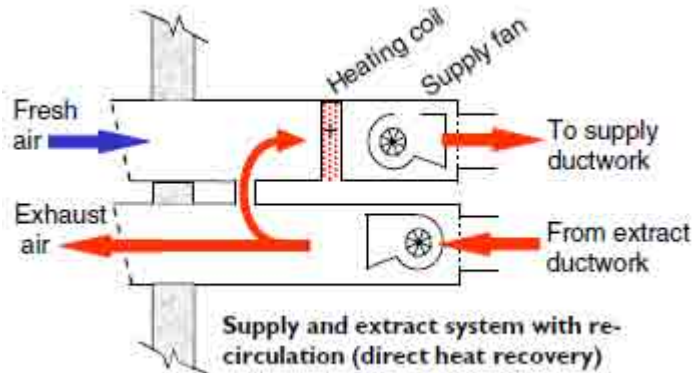
- Key points**
- Extraction of contaminated air is assured.
  - Localised extraction prevents contamination of adjacent areas.
- Limitation**
- Make-up air entering space cannot be heated or filtered.
  - Very limited control of air movement in space.

## MECHANICAL VENTILATION – SUPPLY ONLY



- Key points**
- Enables fresh air to be filtered and heated.
  - Ensures adequate supply of fresh air.
  - The pattern of air movement can be controlled.
- Limitation**
- No control over the extraction of air from space.
  - No opportunity for heat recovery from exhausted air to improve energy efficiency.
  - Any points where air leaves the building may also be a source of drafts and external noise.

# MECHANICAL VENTILATION – SUPPLY AND EXTRACT SYSTEMS



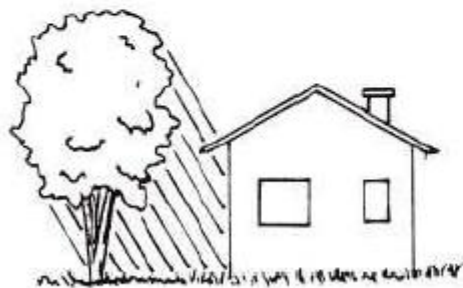
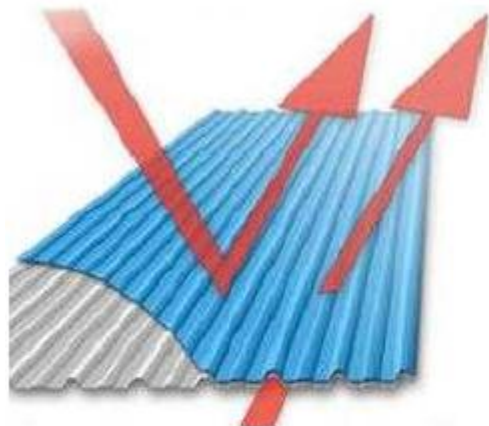
## Key points

- Constant, reliable rate of ventilation is assured.
- The volume of air entering/leaving a building can be controlled and the ability to recover heat ensures good energy efficiency in cold weather.
- Security and noise problems associated with openable windows are avoided.
- The pattern of air movement in a space can be controlled ensuring even distribution.
- Can be used for night-time cooling.
- Can be combined with natural ventilation to provide a mixed-mode ventilation system.

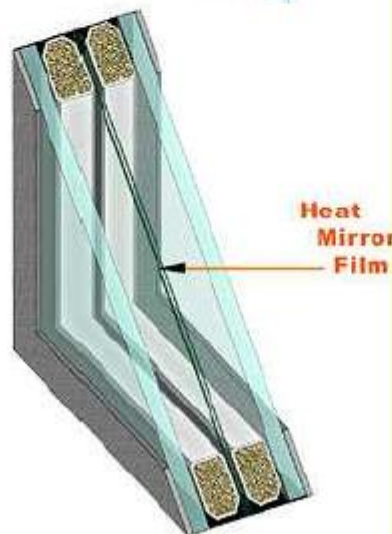
## Limitation

- Fans can consume a significant amount of energy and warm the air stream by up to 2°C. This may limit the effectiveness of night ventilation.
- Occupants have less control over their environment in comparison to a natural ventilation system and consequently may be less tolerant of high internal temperatures.
- The AHU and ductwork occupy potentially valuable space and require maintenance.
- As with natural ventilation, the cooling potential of the system is limited by external conditions and the risk of mechanical/electronic failure. All openable windows and actuators must be accessible.

# Cooling



Shade east and west windows from late morning and afternoon summer sun



### Information:

What kind of „high efficiency“ cooling strategies exist in your country or at your own option?

### PASSIVE COOLING

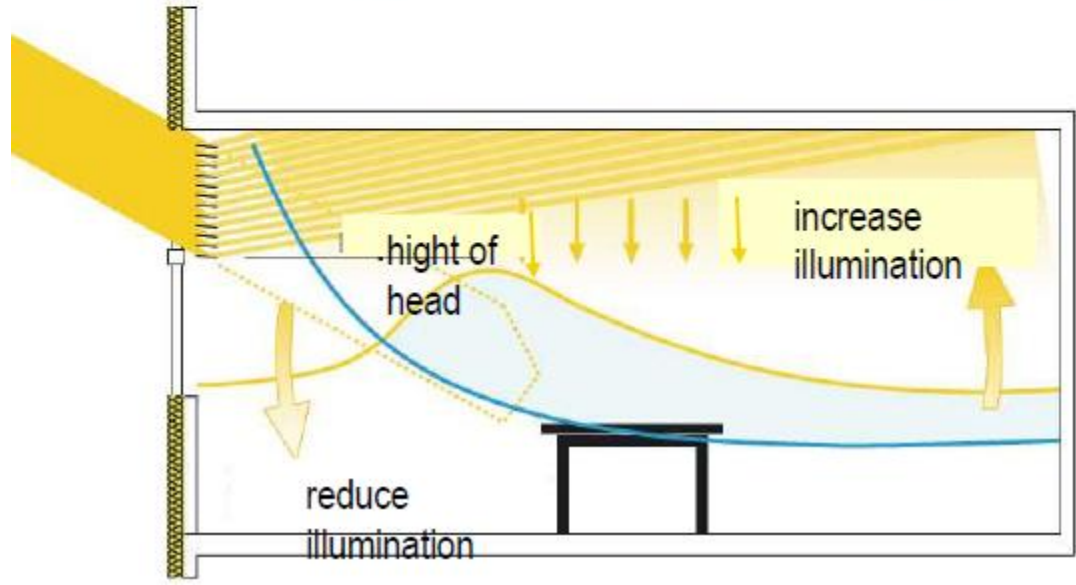
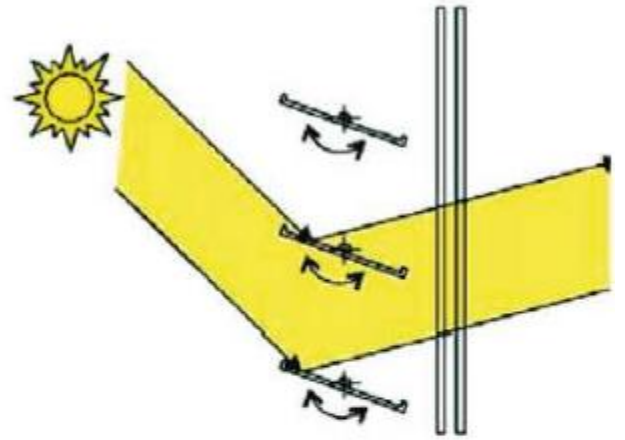
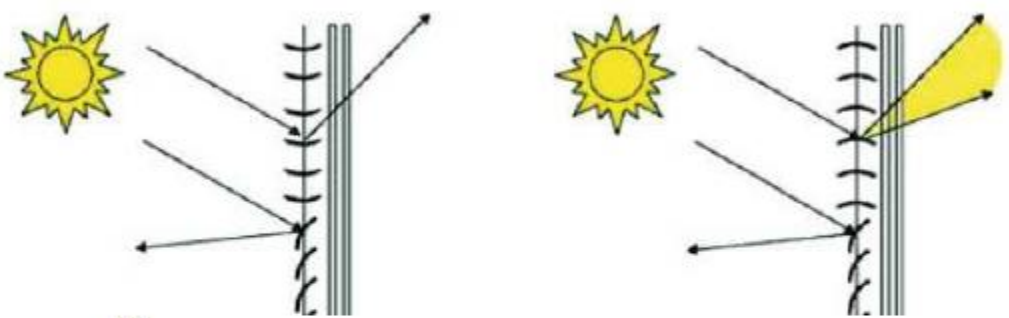
It's mean:

- correct orientation to the cardinal
  - shading
  - appropriate insulation design
  - thermal insulation coating
  - reflective coating
  - so-called heat mirror windows in
  - technology PCM (phase change materials)
  - use earth pipe exchanger
  - solar chimney
- and combination of measures

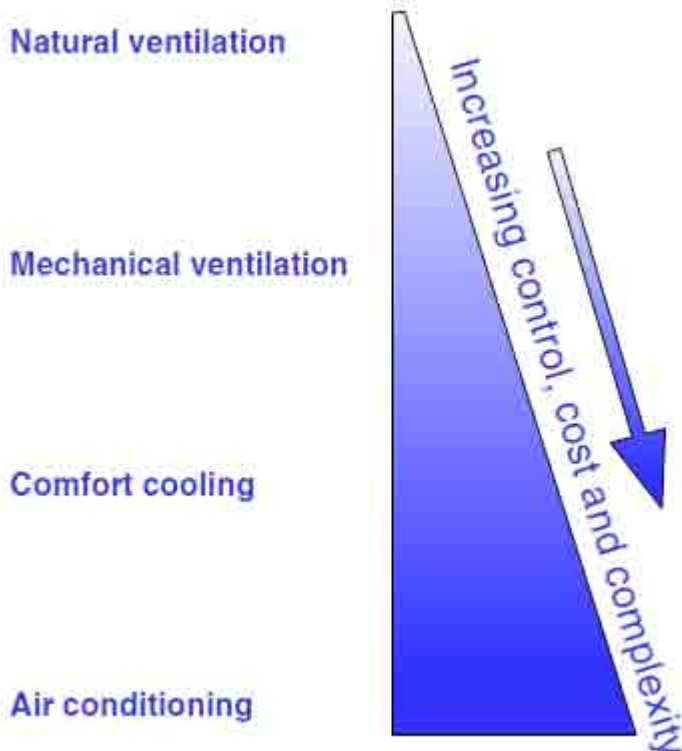
That is the beginning of each energy efficient planning. First reduce the solar gains and use passive cooling.

# Shading

## Combined shading and light deflection



- avoid dazzle
- increase illumination in back area
- reduce illumination close the window



#### Centralised air

- Constant volume (CV)
- Variable air volume (VAV)
- Displacement ventilation

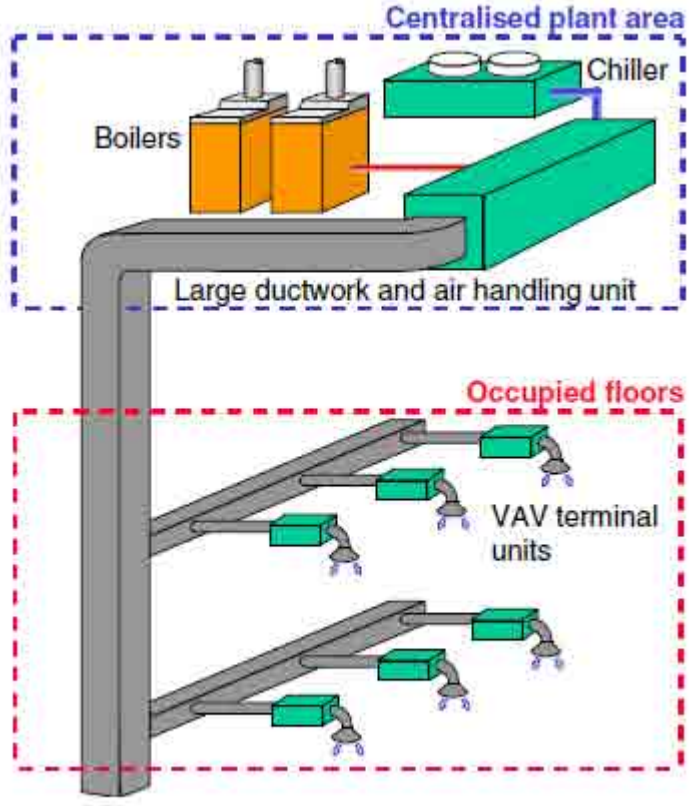
#### Partially centralised air/water systems

- Fan coils
- Chilled beams
- Chilled ceilings
- Room based heat pumps (Versatemp system)

#### Local systems

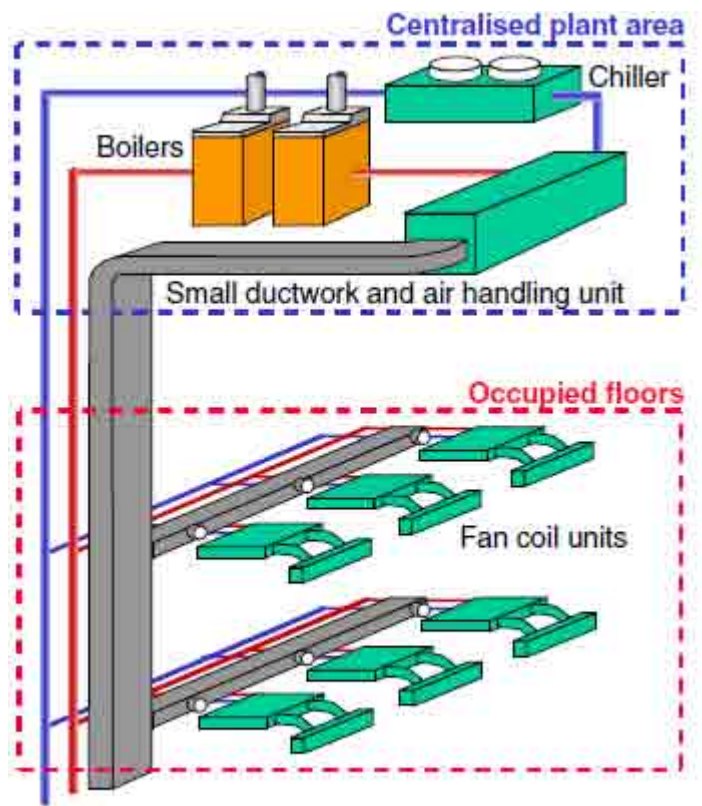
- Split units
- Variable refrigerant flow (VRF)

### Centralised air systems



Centralised air system (VAV example).

### Partially centralised air/water system



Partially centralised air/water system (Fan coil example).

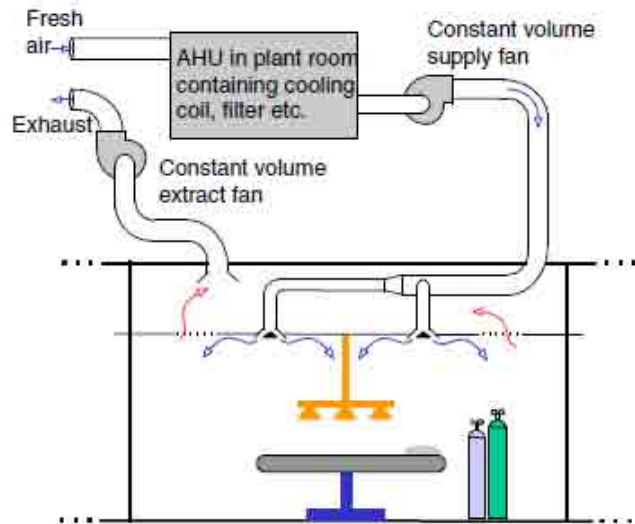
### Air-conditioning systems overview

System type	System performance						Space requirements		
	Control	Noise level	Air distribution	Energy efficiency	CO <sub>2</sub> emission kgm <sup>2</sup> /y	Maintenance costs	Plant room	Occupied area	Duct
Constant volume (CV)	Good but limited	Low	Very good	Good to Average	No data	Low to Average	High	None	High <sup>1</sup>
Variable air volume (VAV)	Good but complex	Low	Very good	Very good <sup>1</sup>	40 <sup>1</sup>	Average to high	High	None	High
Fan coil units	Good	Can be high	Fair to good	Average	50	High	Low	None or moderate	Moderate
Chilled beams	Good	None	See note <sup>4</sup>	Very good	No data	Low to Average	Low	None	None <sup>2</sup>
Chilled ceilings	Good	None	See note <sup>4</sup>	Very good	No data	Low	Low	None	None <sup>2</sup>
Displacement ventilation <sup>2</sup>	Good	Very low or none	Good	Very good	No data	Average	Low	None or moderate	Moderate
Room-based heat pumps (Versatemp)	Very good	Can be high	Good	Very good	No data	Average to high	Low	None or moderate	None <sup>2</sup>
Split systems	Local only	High	Poor	Poor	75	Average to high	Low	None or moderate	None
Variable refrigerant flow (VRF)	Good	Can be high	Fair	Good to average	50	Average to high	Low	None or moderate	None

BSRIA AG 15/2002

# CONSTANT VOLUME (CV)

Simple constant volume air-conditioning system



### Key points

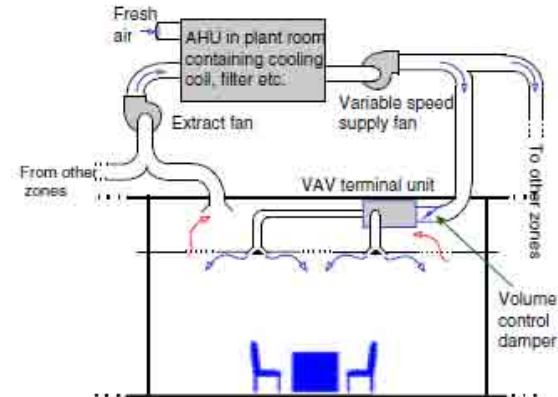
- Suited to certain types of public spaces, foyers, commonly used to provide fresh air in air/water systems such as fan coil and chilled beam installations.
- Can be used for single zone applications, where only one set of internal conditions need to be satisfied.
- Simple and relatively easy to maintain.

### Limitations

- Not generally suitable for multiple-zone applications, such as offices, as each zone will have varying cooling requirements (see Description above).

# VARIABLE AIR VOLUME (VAV)

Simple VAV system



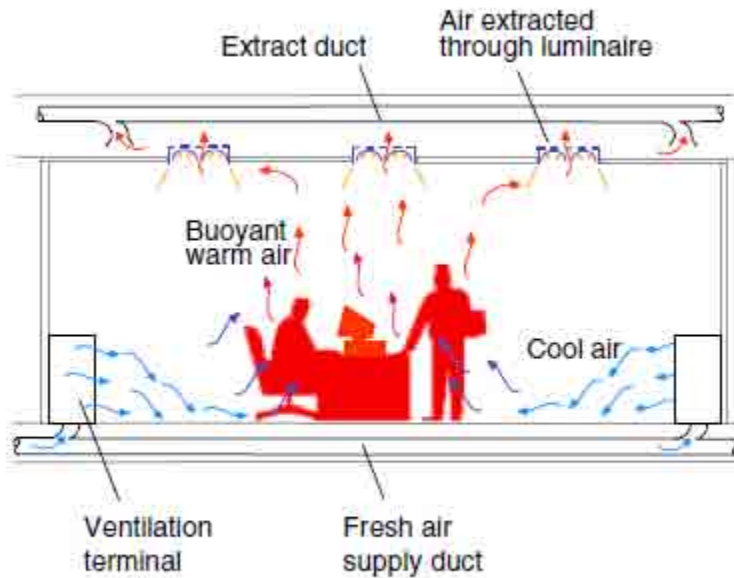
### Key points

- Used in buildings with multiple zones to match the particular cooling/heating demands of each zone.
- Can be relatively energy efficient due to the ability to reduce the speed of the supply/extract fan(s) during periods of low to moderate loads.
- A correctly designed and commissioned system will give good temperature control.
- VAV systems are particularly suited to buildings with a year round cooling load.

### Limitations

- Space requirements are high in both the plant room and ceiling voids.
- Design and commissioning is particularly important if good system performance is to be achieved in terms of comfort and energy efficiency.
- The design of some VAV systems is simplified by allowing the terminal units to bypass air that is not required. However this approach can result in oversized plant and increased capital cost.
- Fan-assisted terminal units generally have higher capital and maintenance costs and the potential for increased noise levels.

# DISPLACEMENT VENTILATION



Displacement ventilation – typical air flow pattern.

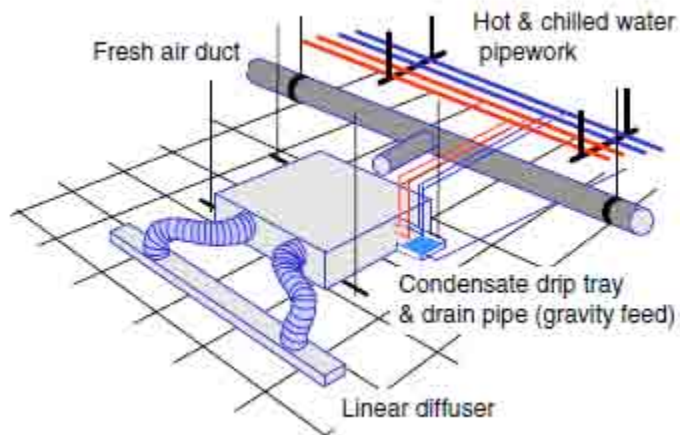
## Key points

- Can help provide high indoor air quality. This is due to the separation of warm, stale air from fresh air by a vertical temperature gradient in the space.
- Silent operation.
- Ideal ventilation system for use in conjunction with chilled ceilings and chilled beams (not suited to fan-assisted active beams).
- Energy can be saved by virtue of free cooling. When conditions permit, mechanical cooling can be avoided. Displacement systems may also use less air than conventional systems.

## Limitations

- Not suited to rooms with low ceilings.
- Low cooling capacity, although displacement systems are normally used in conjunction with another cooling system, such as chilled ceilings.
- Ventilation terminals can be large and take up floor/wall space. Floor outlets avoid this.
- Not suited to spaces in which there is a lot of disturbance to the air, for example from constant movement of individuals and/or from cold down draughts due to poor insulation.
- Furniture must be placed sympathetically in relation to the ventilation terminals.

## FAN COILS



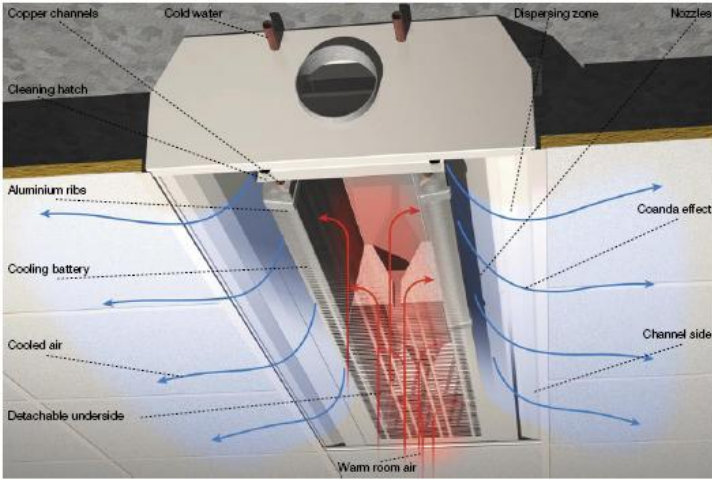
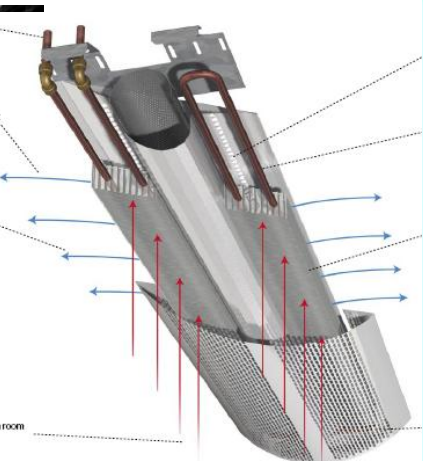
### Key points

- Ideally suited to buildings with multiple zones.
- Excellent temperature control and quick responses to changes in heat gains to the space and/or control settings.
- Compared to an all-air system relatively small diameter ductwork is required since it only has to carry air for ventilation. This can help keep the depth of the ceiling void to a minimum which maximises the height of the occupied space below.
- Fan coil systems only need relatively small air-handling plant for the fresh air. This reduces the space required in the centralised plant area in comparison to an all air system.
- Enclosure for perimeter fan coils can be designed by the architect to achieve a particular appearance, and constructed as part of the builder's work.

### Limitations

- Each fan coil unit incorporates a filter which requires regular cleaning/changing and can be difficult to access.
- Systems operating with a low chilled-water temperature will create condensation on the cooling coils and will consequently require each unit to be connected to a condensate drain.
- The internal fan can be noisy when operating at high speed settings (the speed of the fan can be varied to provide the required output).
- General maintenance requirements can be more onerous than an all air system.
- A separate ducted air system is required to provide ventilation (see constant volume air-conditioning).
- There is a risk of water leaking from overhead fan coils into the space below.
- Perimeter fan coils can occupy valuable floor space.

# CHILLED BEAMS – ACTIVE AIR COOLING



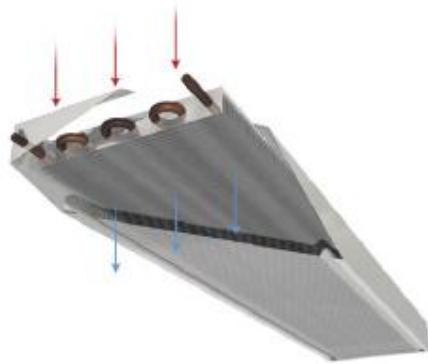
**Key points**

- Provide a quiet, draught-free operation.
- Chilled beams require a relatively small ceiling void depth, which can free up space for raised floors in a building with low floor to ceiling heights.
- Maximum cooling outputs are in the order of  $100 \text{ W/m}^2$  -  $160 \text{ W/m}^2$ , which is significantly higher than chilled ceilings (see chilled ceilings).
- Relatively high chilled water temperatures are used, offering the potential for sources of chilled water other than chillers, such as rivers, cooling towers, dry coolers and ground water.
- Minimal maintenance requirements.
- Good for perimeter heat gains.
- Some types of chilled beam are designed to allow ventilation air to be ducted directly into the unit, which can increase the cooling output.

**Limitations**

- A separate ducted ventilation system is likely to be required (see constant volume air-conditioning).
- Control of water flow temperatures can be relative to room dewpoint temperature, provided a suitable differential is maintained to avoid condensation.
- Insufficient cooling capacity for spaces with very high heat gains, such as greater than  $150 \text{ W/m}^2$  -  $160 \text{ W/m}^2$ , although additional cooling may be provided by an accompanying ventilation system.

## CHILLED CEILINGS – PASSIVE AIR COOLING



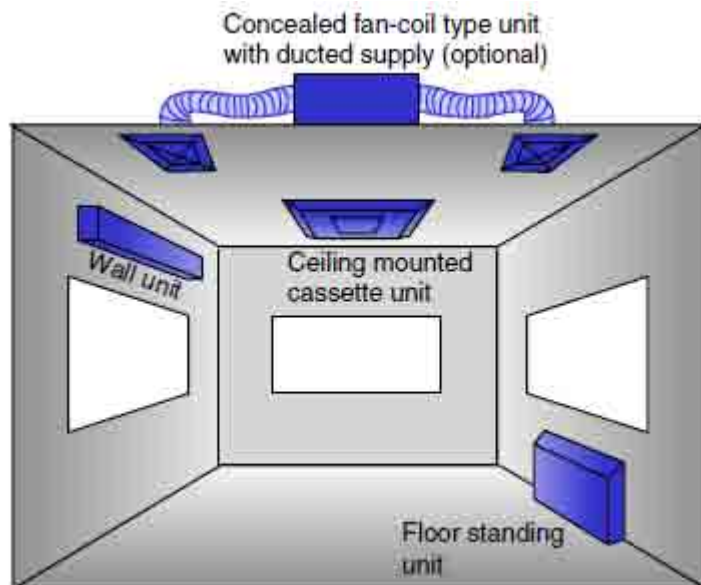
### Key points

- Can be accommodated in a very shallow ceiling void of around 60 mm – 70 mm. This can free up space for raised floors in buildings with low floor to ceiling heights.
- Provide a quiet, draught-free operation.
- Relatively high chilled water temperatures are used, offering the potential for sources of chilled water other than chillers, such as lakes, rivers, cooling towers, dry coolers, and ground water.
- Minimal maintenance requirements.

### Limitations

- Maximum cooling output is in the order of only 70 W/m<sup>2</sup>. However, chilled-ceiling systems are often installed with a displacement ventilation system which provides a further 25 - 65 W/m<sup>2</sup> of cooling.
- Control of water flow temperatures can be relative to room dewpoint temperature, provided a suitable differential is maintained to avoid condensation.

## SPLIT SYSTEMS



Basic options for locating split system indoor units.

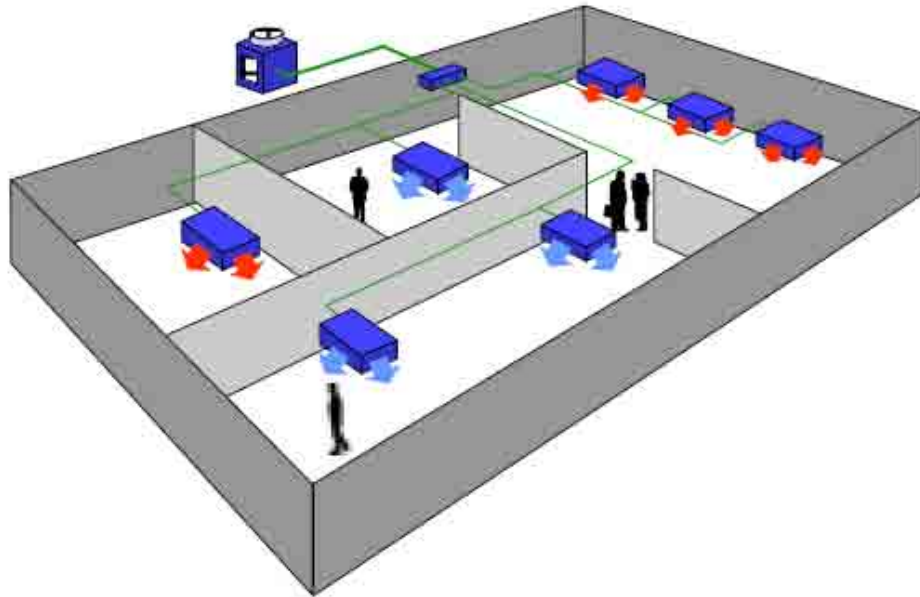
### Key points

- Relatively quick and easy to install.
- Do not require any form of plant room/area within the building.
- Heat pump systems provide heating and cooling.
- Indoor unit can be concealed if required.
- Simple occupant control provided, with the option of an infrared remote control.
- Some concealed indoor fan coil-type units can be configured to provide fresh air in addition to re-circulating room air.

### Limitations

- Only suitable for relatively small spaces.
- Typically require a specialist service engineer for repairs and maintenance.
- Can only service a single internal zone; systems with multiple indoor units cannot provide simultaneous heating and cooling in different areas (see VRF systems).
- Simple split systems only re-circulate room air and cannot provide ventilation.
- Outdoor units can be unsightly.

# VARIABLE REFRIGERANT FLOW SYSTEMS (VRF)



Many VRF systems can provide simultaneous heating and cooling to match the comfort requirements in different parts of the building.

## Key points

- Capable of providing simultaneous heating and cooling.
- Relatively quick and easy to install.
- Does not require any form of plant room/area within the building.
- Simple occupant control provided, with the option of an infrared remote control. Alternatively, a centralised control system can be specified.
- Some concealed indoor fan coil type units can be configured to provide fresh air in addition to re-circulating room air.
- Low operational noise levels.

## Limitations

- Significant amount of refrigerant passes through occupied spaces. This could potentially cause a problem if a leak occurs.
- Typically require a specialist service technician for repairs and maintenance.
- The system must be installed to a high standard to ensure good performance and reliability.

**THANK YOU FOR THE ATTENTION!**