

SPACES AGM Technical Presentation

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**New version of BB101 – “Guidelines on
Ventilation, thermal comfort, and indoor
air quality for school Buildings”**

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Department
for Education

1. Overview of revised BB101 and evidence base
2. Specialist ventilation – challenges of providing specialist ventilation
3. Examples of classroom ventilation solutions in recent schools
4. Challenges and benchmarks of good design



DfE approach to environmental standards

Separate out:

1. Regulations;
2. Minimum performance standards in support of regulations;
3. Non-statutory guidance
4. Where possible use performance in use standards that are measurable rather than use design standards that cannot be measured.
5. Make the performance standards as simple and possible
6. Update the standards as regularly as necessary, usually every 5 years but 10 years at a maximum.



Areas covered in BB101

- **Ventilation**
- **Gas safety**
- **Indoor air quality**
- **Thermal comfort**



Ventilation

Fresh air is critical for learning, health and hygiene

The CO₂ levels required of 1000ppm-1500ppm in classrooms can be exceeded within 20 minutes of the start of a lesson.

What can go wrong?

- *Levels in poorly ventilated classrooms of over 2500ppm throughout the day are common in schools. At these levels concentration fades.*
- Openable areas too small and single sided ventilation does not provide adequate ventilation in summertime mode
- Lack of user/management control



Ventilation standards

- **Building Regulations Approved Document AD F**
- **ASHRAE 62-1**
- **EN 13779 standards for filtration of outside air**
- **CIBSE AM10 will also be revised soon**
- **IGEM UP11 Gas safety in educational buildings**
- **European guidelines on air quality**
- **Other standards**



BB101 requirements on CO₂ level (Ventilation)

In addition to the general ventilation requirements of Section 4 of Approved Document F 2010 (ADF), the following DfE performance standards for teaching and learning spaces are set out in BB101.

Sufficient outdoor air should be provided to achieve:

1. Mechanical ventilation or hybrid systems:
 - daily CO₂ concentration < 1000 ppm (when occupied)
 - max CO₂ concentration < 1500 ppm (for more than 20 min, each)
2. Natural ventilation
 - daily CO₂ concentration < 1500 ppm (when occupied)
 - max CO₂ concentration < 2000 ppm (for more than 20 min, each day)
3. - CO₂ concentration < 800 ppm above the outside CO₂ level for the majority of the occupied time during the year (ie the criteria for a Category II building in the case of a new building)
 - CO₂ concentration < 1350ppm above the outside CO₂ level (ie, a category III building, in the case of a refurbishment).



Key points – Ventilation

Cold draughts in wintertime

Window and ventilation design needs to allow large volume flow for summertime ventilation and prevent dumping of cold air onto occupants during winter.

Blinds and restrictors

Windows, vents and blinds need to be robust and easy to operate:

- Window ventilation openings should not be obstructed by blinds or curtains when these are opened
- Blinds should not cut off all daylight and views out
- Where dim-out blinds are required, they should provide a suitable daylight illuminance in the space and should not restrict ventilation.



BB101 requirements for Specialist ventilation

**Practical space ventilation rates in new BB101 -
based on l/s/m² not air changes per hour –
following ASHRAE 62-1 2014 methodology for
calculation of minimum exhaust rates**

**Fume cupboard extract - chimney heights
increased to 3m minimum.**



Specialist ventilation

BB101 contains detailed guidance on:

Science Labs and fume cupboards

Local Exhaust Ventilation

Food Technology spaces

Design and Technology spaces



Gas Safety

- Gas Safety requirements in Science, Food Technology, Kitchens & Design and Technology spaces. Revision of IGEM UP/11 was published this year and the two documents are carefully aligned
- Environmental carbon dioxide control recommended in food rooms and science labs, BB101 references IGEM UP/19
- polyethylene gas pipes need to be UV protected (IGEM photo shown)



FIGURE 2 - EXPOSED PE PIPEWORK IS NOT PERMITTED



Indoor Air Quality and children's health

- The UK has one of the highest prevalence rates of childhood asthma among European countries, with almost 10% of children (1.1 million) suffering from symptoms (WHO, 2010)
- Data indicates that a sub-population of school-aged children with asthma receive challenges when returning to school that trigger their asthma (Julious et al. 2007)
- Only a few studies address the epidemiological associations with exposure to PM10 in school children and the health impacts of PM2.5 and PM1.
- Particulate matter monitoring (PM) in classrooms is complicated by large differences in studies' design, including duration, number of schools monitored and instrumentation used.

Occupant density of classrooms and perceived IAQ

Average primary class size (Eurostat, 2011)

- **EU countries and US: average 20.8 ± 2.0 pupils; density ranging from 2 to 3.1 ± 0.3 m²/person.**
- **UK recently built classrooms: density of 1.72m²/person**

High occupancy densities in school classrooms result in high internal gains, emissions of body odour together with various indoor pollutants.

The ventilation must be well designed to cope with high occupancy densities.

Recommendations on IAQ

- **WHO Indoor Air Quality Guidelines (WHO, 2010) & UK ambient air quality guidelines (DETR, 2007);**
- **ADF performance levels (2010);**
- **Indoor air pollutants (including Sinphonie's project, 2014);**
- **Sources of indoor air pollutants and source control.**

References

WHO (2010) WHO Guidelines for Indoor Air Quality: Selected pollutants.

DETR (2007) The Air Quality Strategy for England, Wales and Northern Ireland

Approved Document F1 (2010) Means of ventilation

Kephalopoulos et al. (2014) *Guidelines for healthy environments within European schools, Sinphonie project*; ISBN 978-92-79-39151-4

Chatzidiakou et al. (2012) *What do we know about indoor air quality in school classrooms?* Intelligent Buildings International, 4:4, 228-259

Areas covered by BB101 recommendations on thermal comfort in schools

- Operative temperature range
- Categories of thermal comfort for different activities and types of pupils
- Adaptive thermal comfort criteria for the avoidance of summertime overheating for free running buildings
- Cold draughts
- Radiant temperature difference
- Vertical Temperature Difference (stratification)
- Hot or cold feet caused by floor surface temperature



Operative temperature vs air temperature

- **BB101 specifies operative temperatures for design**
- **But uses air temperatures for performance in use checks**



Heating demand - How many school days are colder than 5°C each year?

Classrooms have high internal gains – 30 pupils at 80W each in a 60m² classroom is 40W/m². Add some equipment and the total quickly gets to 50W/m²

If design day heating is 60W/m², internal gains provide all the heat that is needed until the outside air temperature is <5°C.

Around 30? So heating energy in occupied hours is only needed 30 days/year. If your heating boilers are going to be hot for 200+ days/year – that will waste a lot of energy.



Thermal Comfort standards

Values in BB101 are derived from experience but related to EN 15251, PPD related research (Fanger work for adults) and **the following** thermal comfort standards.

- **Workplace Regulations on Ventilation and Temperature**
- **PD CR 1752: 1999 Ventilation for buildings – Design criteria for the indoor environment**
- **BS EN ISO 7730: 2005 Ergonomics of the thermal environment (PMV and PPD indices) –local comfort criteria**
- **EN 15251 for adaptive thermal comfort is being revised and will supersede what is CIBSE TM52**
- **ASHRAE 55**
- **DfE cold draught criterion**



Thermal comfort in summer

High temperatures affect student performance

What can go wrong?

- Design to fixed temperature limits in BB101 e.g. max. 28°C is inadequate for mechanical and hybrid systems.
 - FOS now requires design to CIBSE TM 52/European Standard EN 15251 Adaptive thermal comfort criteria
- High solar gain due to too much glass
- Lack of thermal mass and less openable area than needed for summertime ventilation
- Ineffectiveness of single sided ventilation for summertime ventilation.



Key points – thermal comfort

- Mechanical cooling should not be necessary in classrooms and teaching spaces and minimised elsewhere, e.g. in server rooms.
- We are not designing for legacy equipment but for the loads specified in the FOS of 25W/m^2 for practical spaces and IT rooms and 15 W/m^2 for general teaching spaces.
- Where legacy loads are higher the performance in use criteria for overheating do not apply.
- Criterion 2 is currently a problem as designs usually fail. BB101 revision advisory group is looking at how to deal with this. An option is to revise the criterion to make it a weekly weighted average rather than a daily weighted average. This will resolve the effect of one hot day making the design fail in some locations.

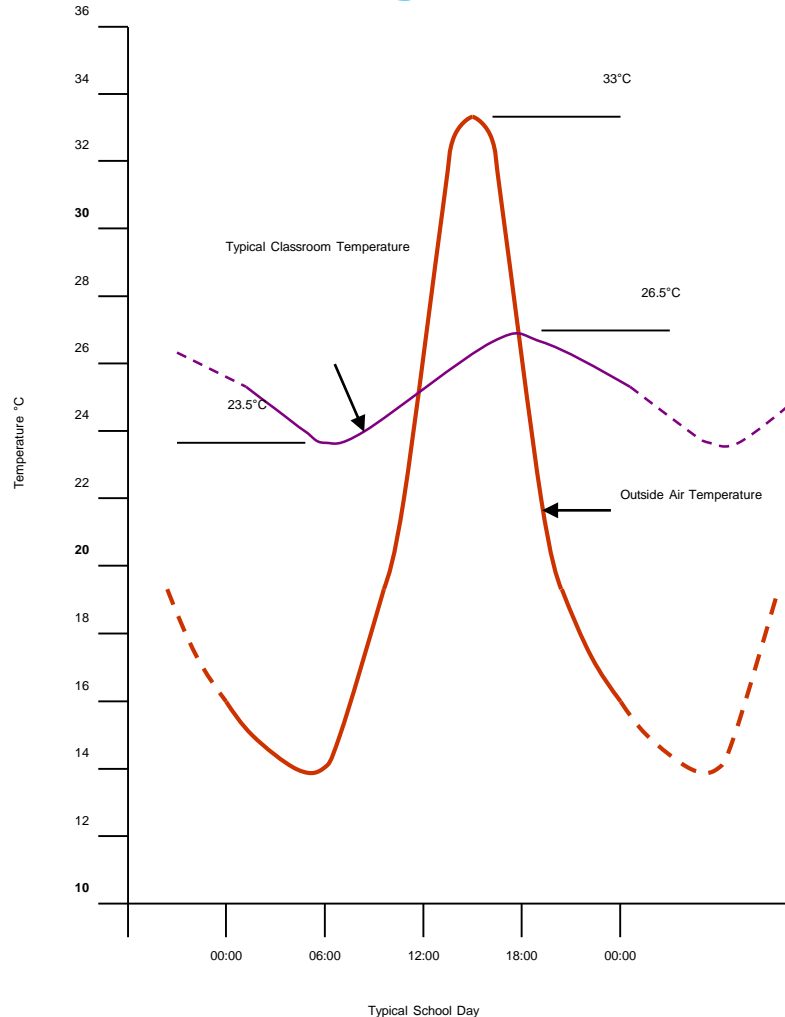


Thermal comfort comparison

	5% Floor Area as Equivalent Area on Façade			7.5% Floor Area as Equivalent Area on Façade		
	Single Sided No Night Purge	Single Sided Night Purge	Cross Vent + Night Purge	Single Sided No Night Purge	Single Sided Night Purge	Cross Vent + Night Purge
BB101						
Criterion 1 - 120 hours < 28°C	PASS	PASS	PASS	PASS	PASS	PASS
Criterion 2 - Mean $\Delta T < 5^{\circ}\text{C}$	FAIL	PASS	PASS	PASS	PASS	PASS
Criterion 3 - Max 32°C Temperature	FAIL	PASS	PASS	FAIL	PASS	PASS
BB101 Compliance	FAIL	PASS	PASS	PASS	PASS	PASS
CIBSE Adaptive						
Criterion 1 - 40 hours < Θ_{max}	FAIL	FAIL	FAIL	FAIL	FAIL	PASS
Criterion 2 - 0 days < ($W_e < 10$)	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
Criterion 3 - 0 hours < Θ_{max}	PASS	PASS	PASS	PASS	PASS	PASS
Adaptive Compliance	FAIL	FAIL	FAIL	FAIL	FAIL	PASS



Design to prevent overheating



Concrete ceilings and timber-frame external walls

Typical classroom held at 26.5°C when outside temperature 33°C

High mass structure and the high levels of thermal insulation mean building damps down the internal temperature variations

Output from BMS 15th July 2006

English Classroom 6



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Design to prevent overheating

Ventilation close to ceiling level is effective for cooling an exposed concrete slab soffit



Underfloor heating

Underfloor heating can cause overheating.

Under-floor heating with surface temperatures above 23°C can seriously over-heat a room. Floor emitter 'slope' is 11W/m² per °C. A floor at 27°C will give >60W/m².

When a class (40W/m²) walks in, it will get so hot that the windows will be opened to dump paid-for heating energy.

Screeded underfloor heating has a thermal time constant far longer than a working day. If you turn the heating off at 9am, the floor is still hot at 4pm – A lot of energy can be wasted because the emitter response is too slow.



Thermal comfort in colder weather

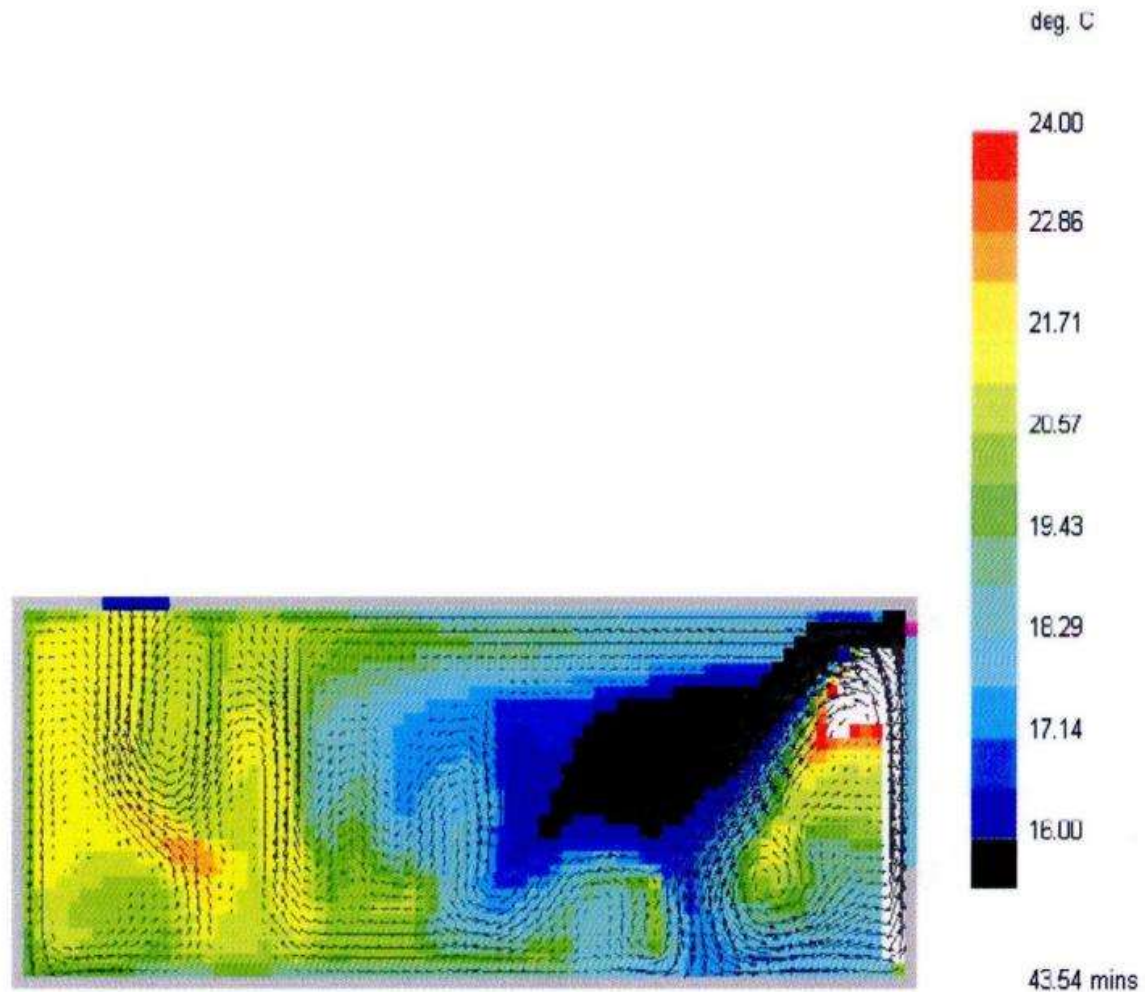


Table 7.4: Recommended draught criteria to provide thermal comfort for mechanical ventilation systems

Category of space/activity	Draught criteria to provide thermal comfort			
	Winter		Summer and mid-season	
	ΔT (Min maintained operative temp - plume local air temp)	Maximum air velocity (m/s)	ΔT ($T_{\text{room, operative}}$ - plume local air temp) When $T_{\text{room}} \leq 25^{\circ}\text{C}$ or T_{comf}	Maximum air velocity (m/s)
I	1.5	0.15	1.5	0.15
II	2	0.2	2	0.2
III	3	0.25	3	0.25
IV	4	0.3	5	0.3

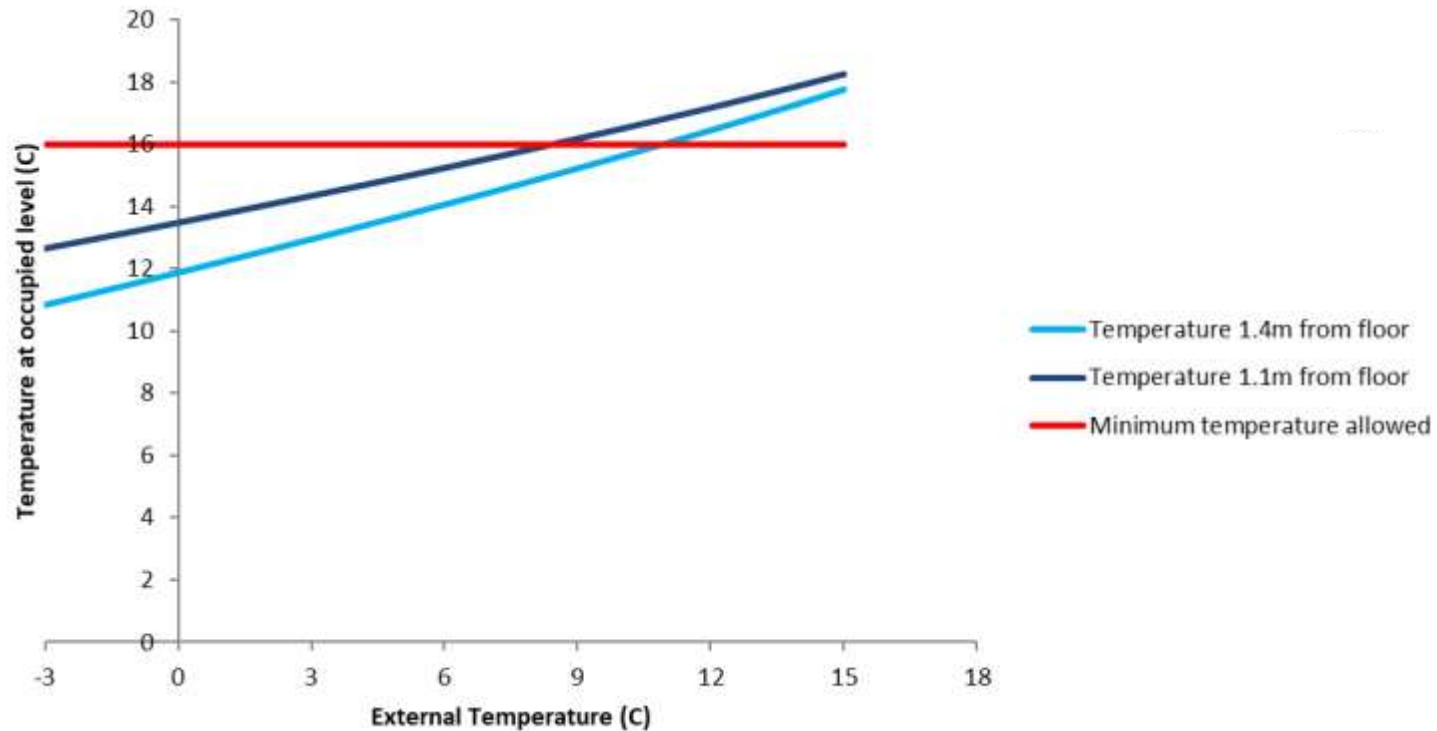
Table 7-4 assumes an activity level of 1.2 met, a clo value of 1.1 in winter 0.9 in mid-season and 0.7 in summer, and a minimum maintained operative temperature as in table 7-2 in winter and mid-season and 23°C in summer.

The values in table 7-4 apply to the supply air plume which delivers air to the occupied zone. The occupied zone should be taken as from 0.6 m to 1.4 m above floor level.

Higher speeds and larger temperature differences are permitted in winter for boost ventilation under the control of the teacher, eg in science or food technology



Window and damper draught Calculator



The tool asks for several simple inputs:

- Dimensions of the room
- Type of inlet (window / damper)
- Height and width of window/damper
- Occupancy
- Flow rates
- Minimum fresh air rate per person



Radiant temperature assymetry

Radiant panels can be too hot overhead.

What is the right temperature?

It is necessary to calculate the radiant temperature increase at head level due to the panels and limit this.

BS7726 gives a calculation method that can be used in two ways to calculate:

1. either the maximum width of a panel directly overhead in a room with a low ceiling; or
2. the percentage of the room ceiling that can be covered by panels in a room with a high ceiling.

BB101 contains simple look up tables based on the BS7726 calculation for most room heights and panel widths.

The simple calculator provided allows other room heights and panel widths to be assessed.



Examples of Ventilation solutions in recent school designs

Room based ventilation systems with CO₂ and temperature control.

Assisted natural mixing ventilation or mechanical ventilation with heat recovery

Daylight design using Climate Based Daylight Modelling

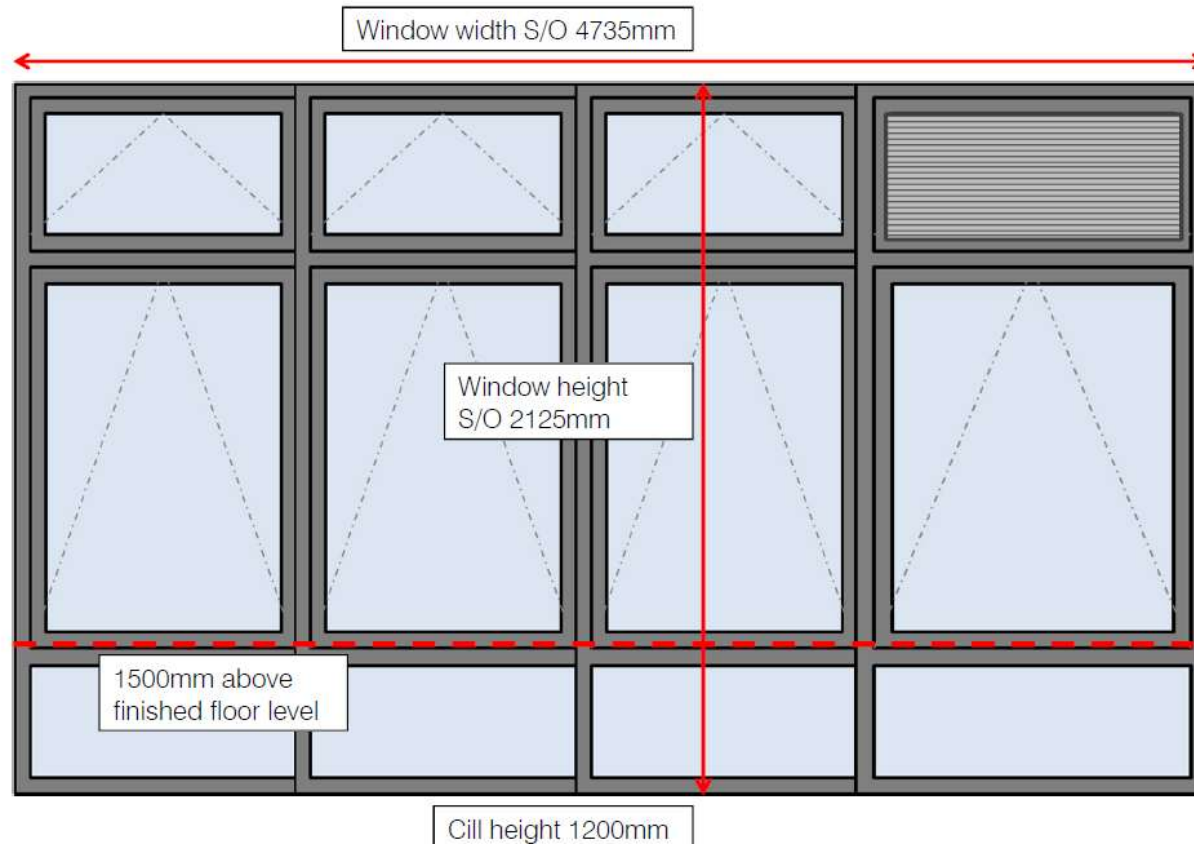
Exposed thermal mass in ceilings

Acoustic absorbers

- **Hanging absorbers or**
- **wings to light fittings or as**
- **as part of radiant panels**



Typical window elevation



Blinds

If light transmission is too high there will be too much glare to see the whiteboard. If it is too low the room will be too dark.



Breathing Buildings(BB) - NVHR unit with cloth duct and lighting raft with acoustic baffle



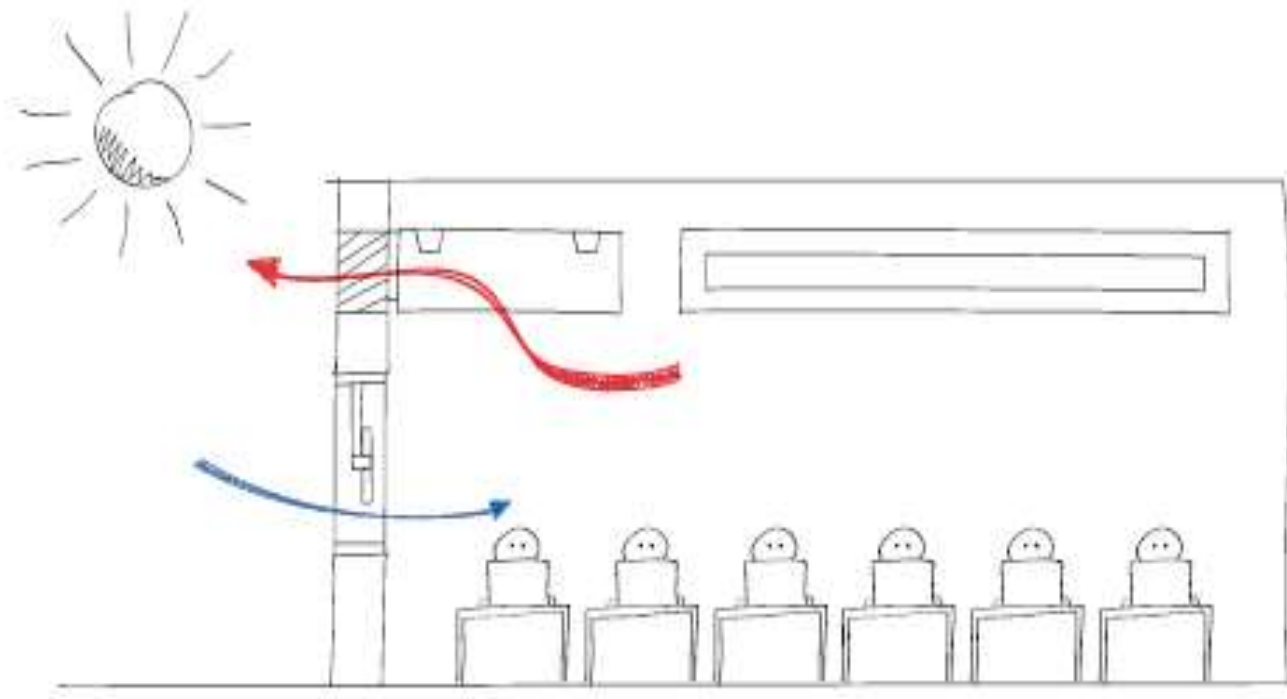
Science lab - BB unit and black out blinds



Façade - BB unit louvres and openable windows



Natural Mode

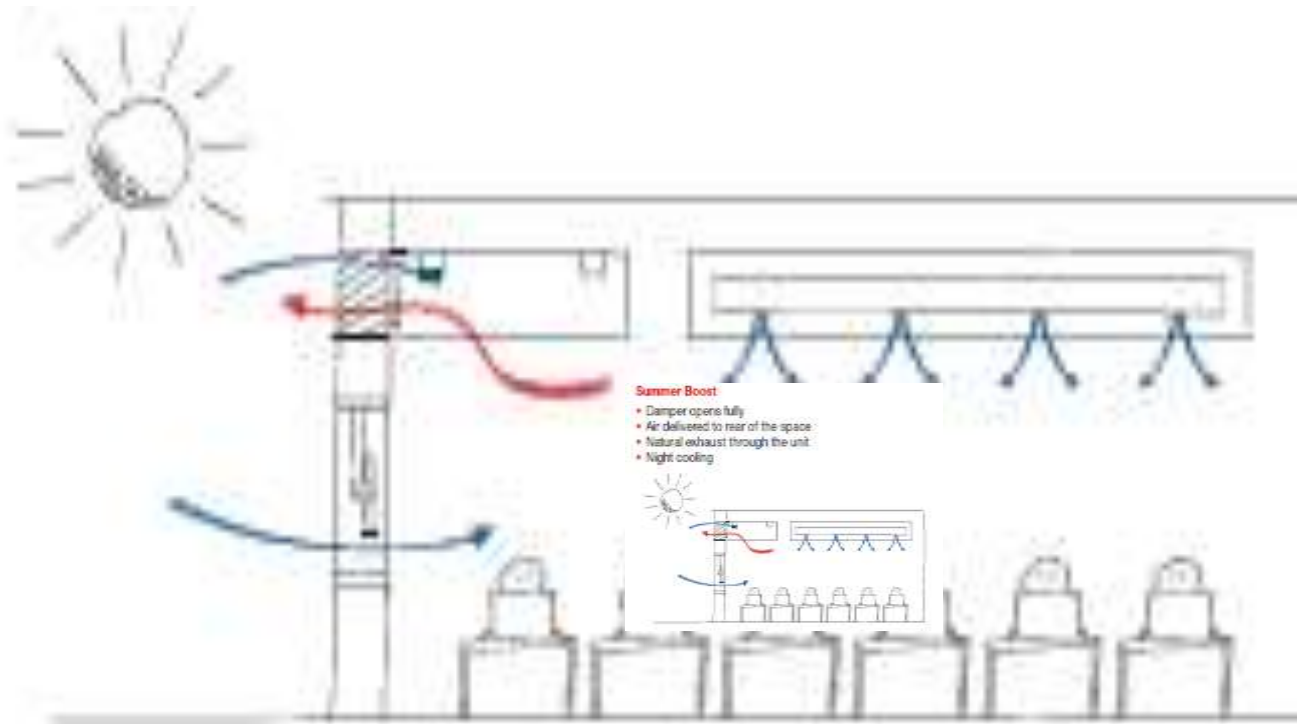


Natural mode: Damper opens, single sided ventilation, works with other openings in space. In peak summertime fan assistance increases cooling

[Diagrams: www.BreathingBuildings.com]



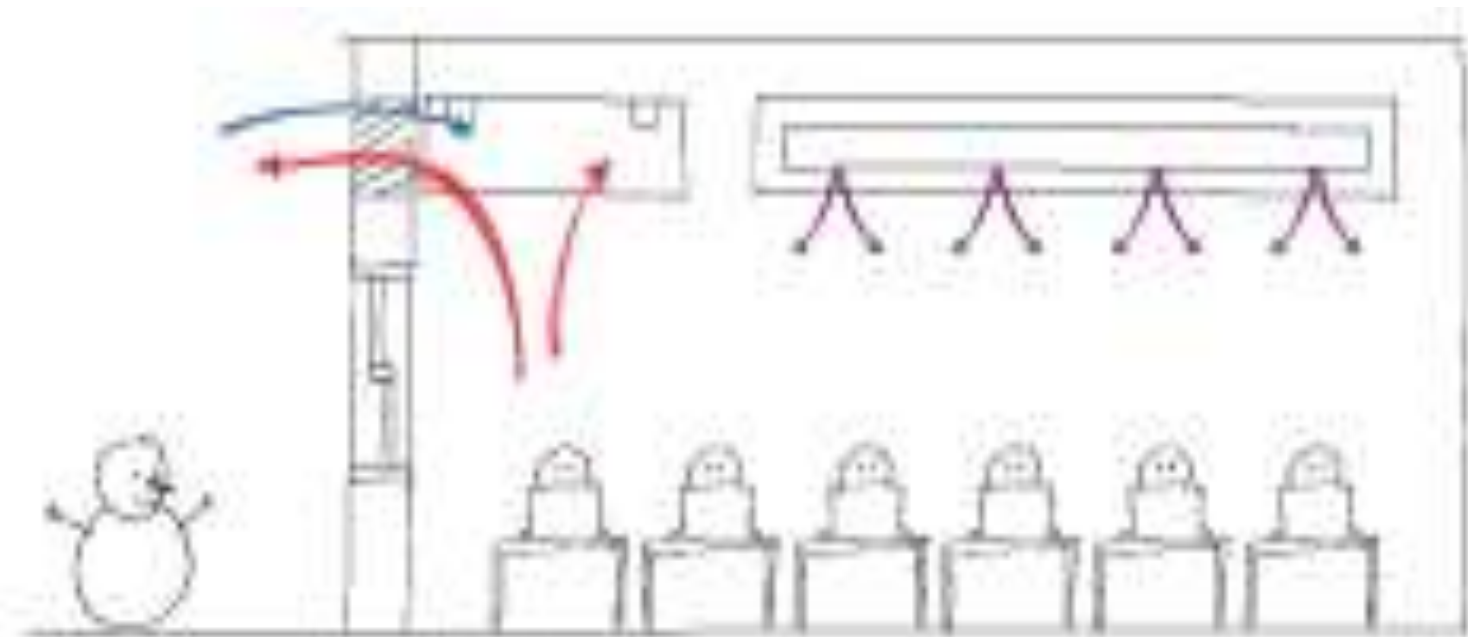
Summer boost



Summer boost: Damper opens fully, air delivered to rear of space; natural exhaust through unit; night cooling



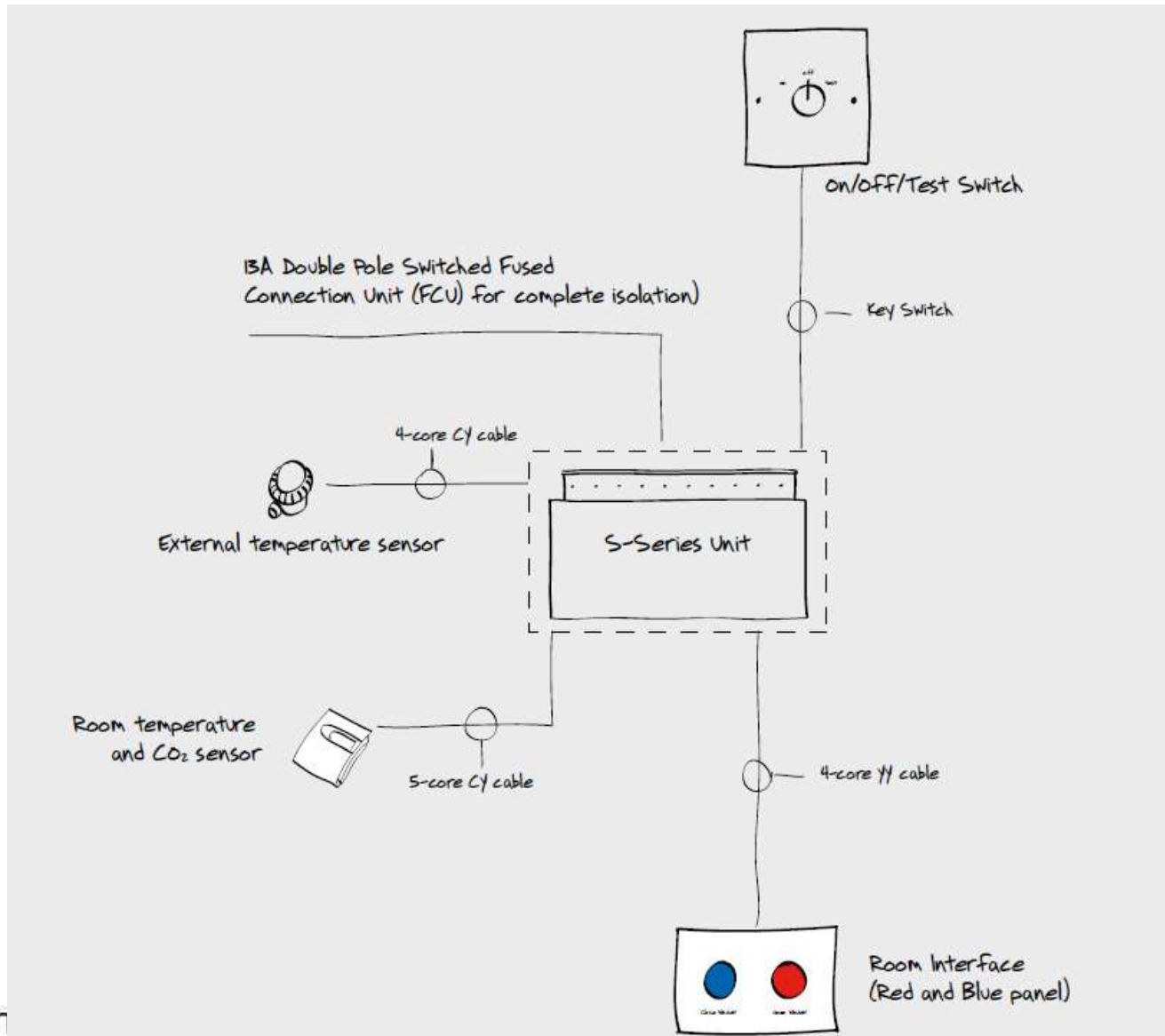
Winter assisted mixing operation



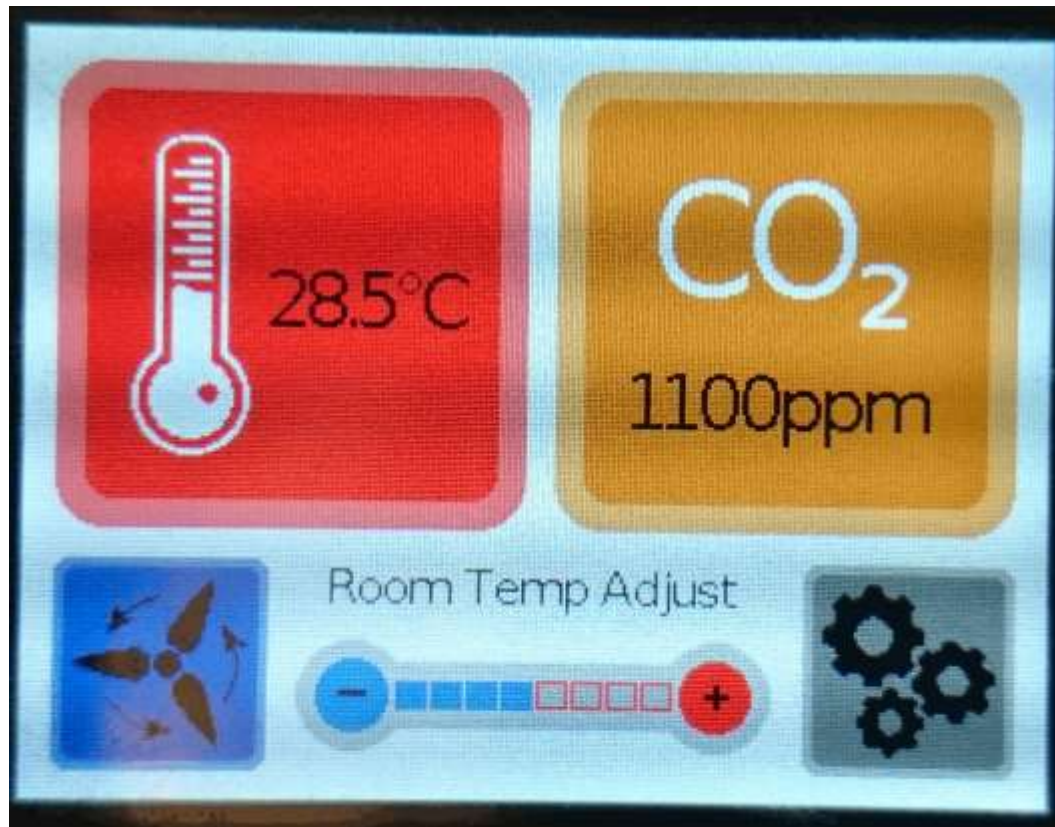
**In winter assisted mixing prevents cold drafts;
mixes warm room air with fresh external air; natural
exhaust through unit**



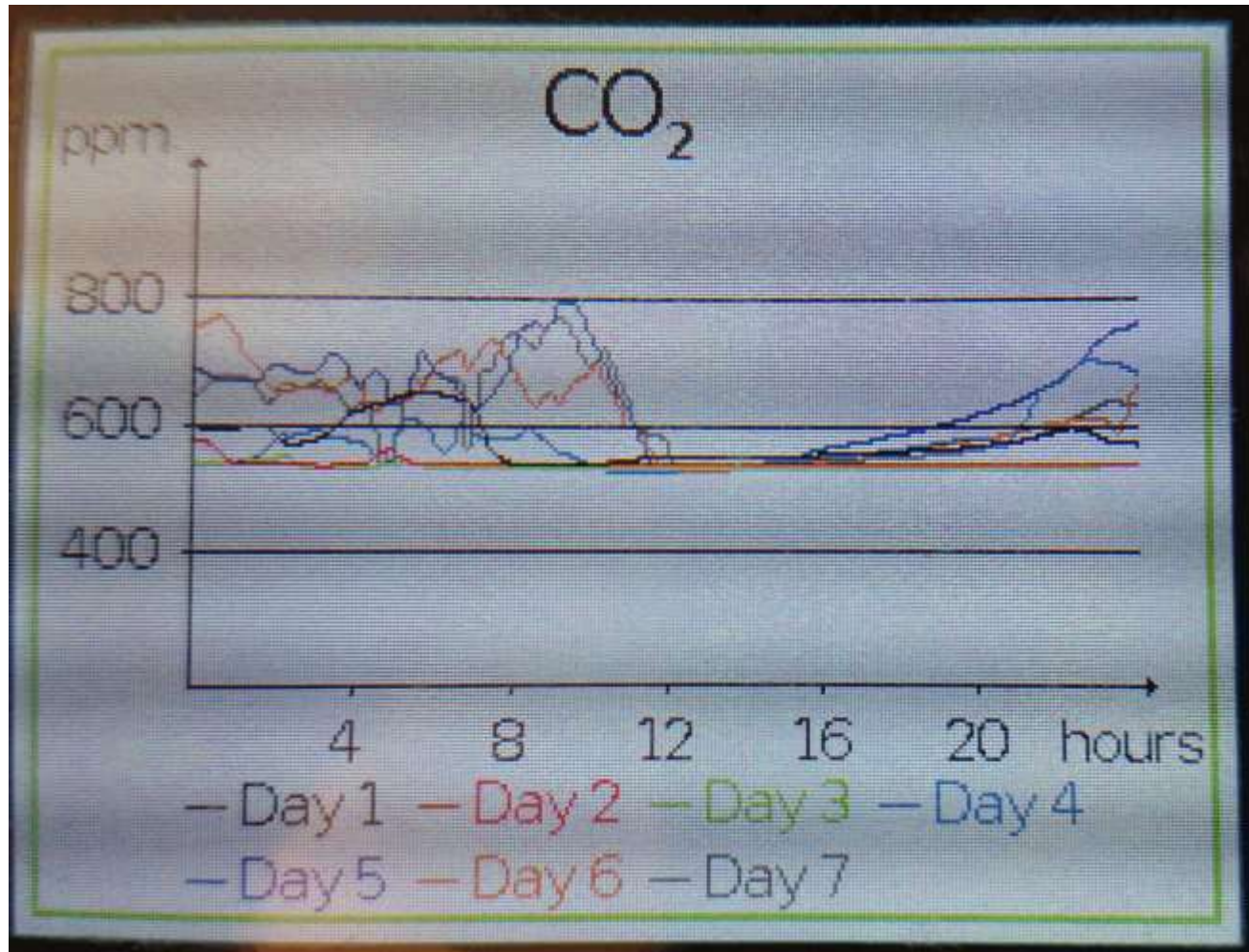
Breathing Buildings - Classroom based control system



Duomo t-sense digital room controller



Digital controller data logging



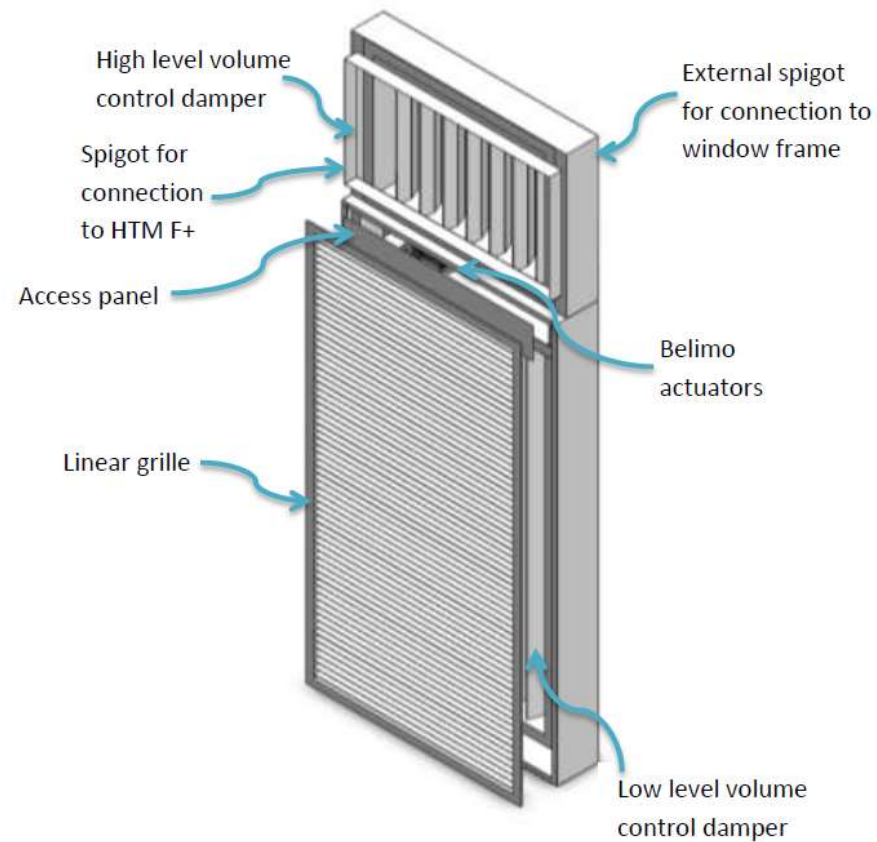
Monodraught mixing unit plus natural ventilation louvre



Monodraught - 1.2m wide automated natural ventilation louvre



Monodraught - Ventair Louvre



Monodraught mixing unit room controller



CONTROLS AND USER INTERFACE

Wall mounted user controls with:

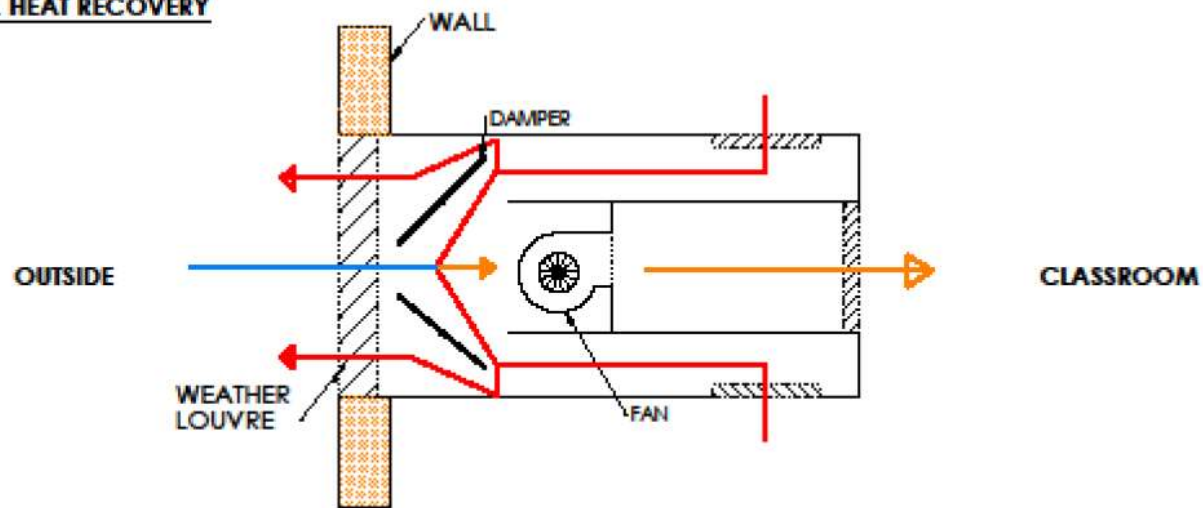
- Room Temperature and CO₂ sensor.
- On/Off control.
- High, Medium(auto) and Low fan speed settings.
- LED wall panel to indicate when to open windows.

Gilberts - Mistral Unit

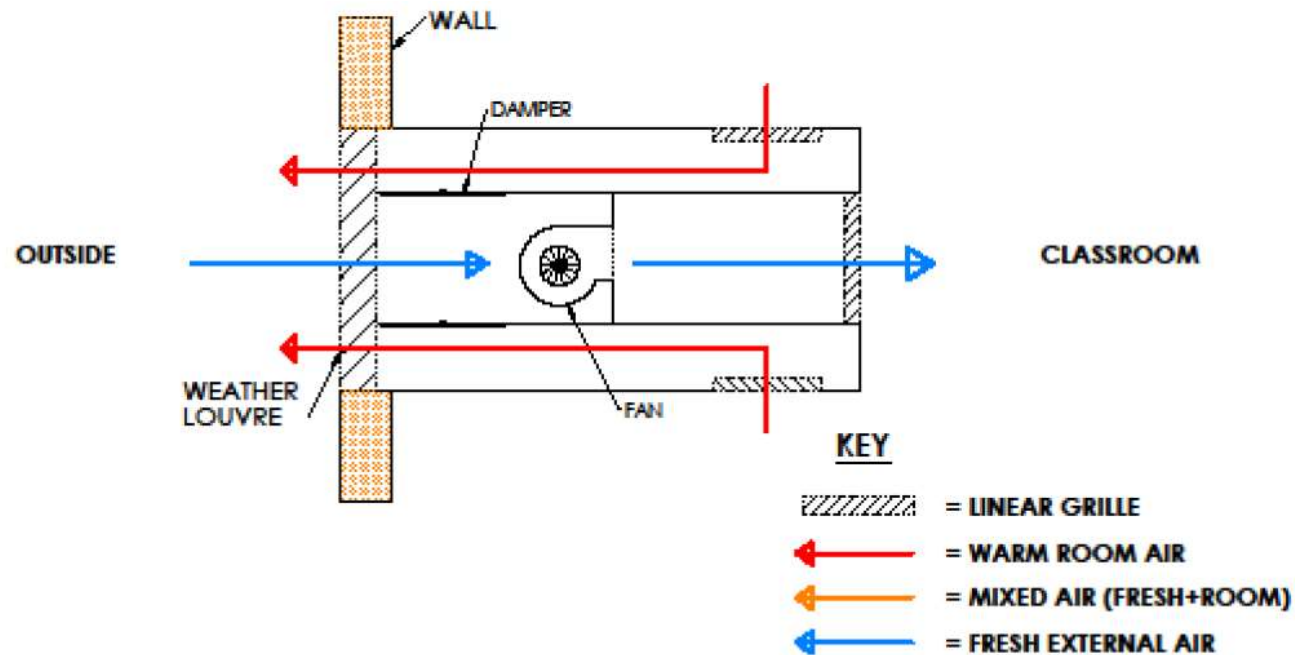


Heat recovery mode

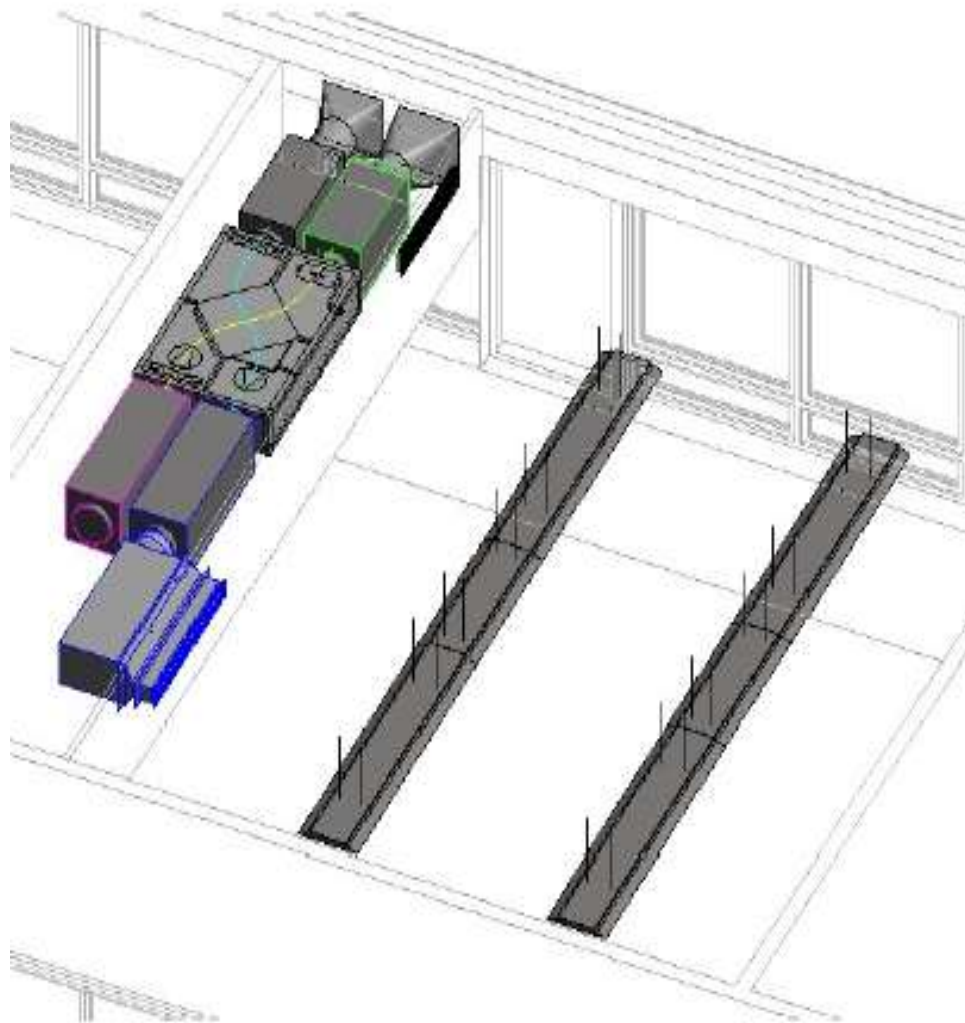
2. HEAT RECOVERY



Full fresh air



Mechanical Ventilation with Heat Recovery

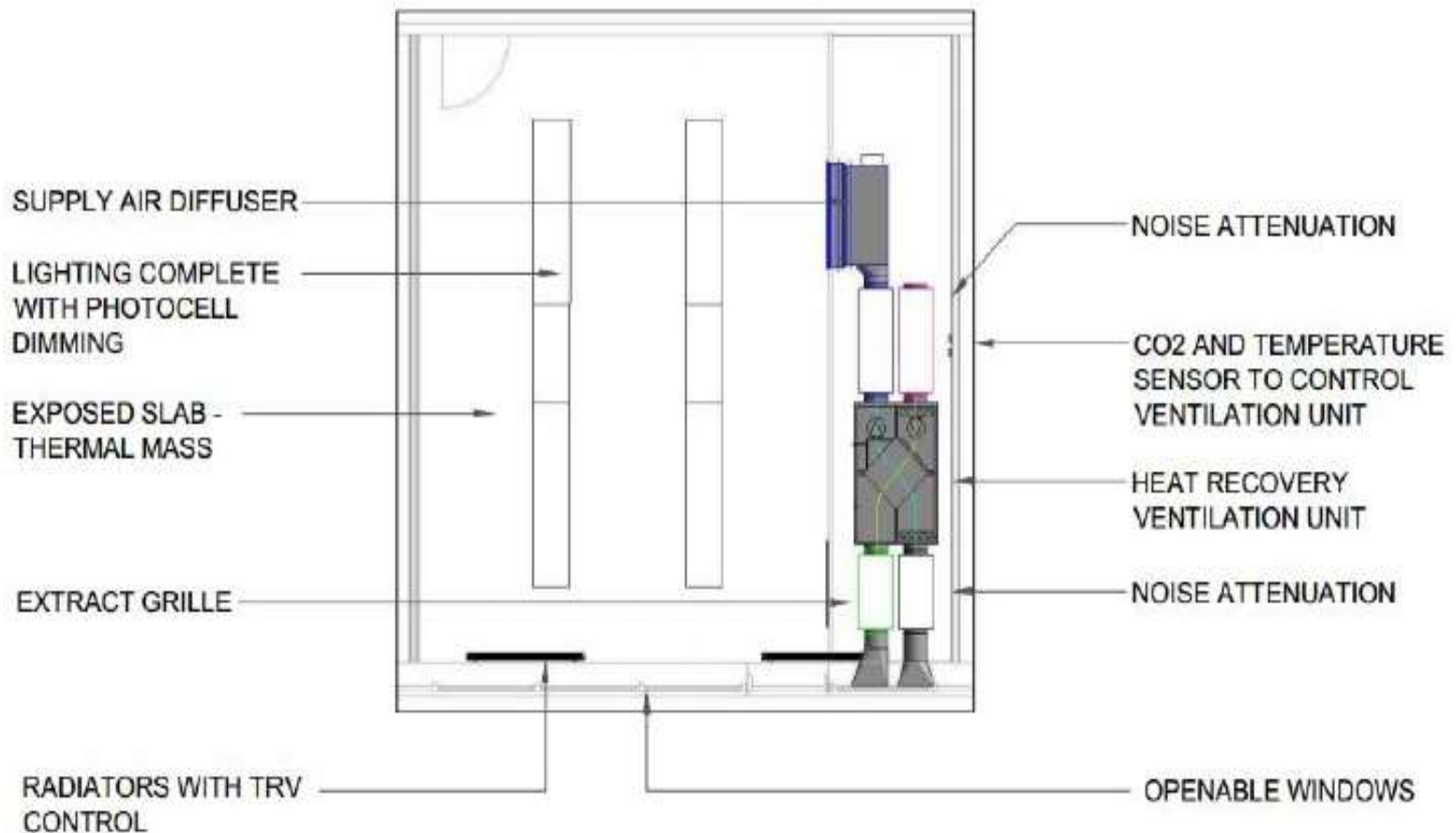


Nuaire MVHR units

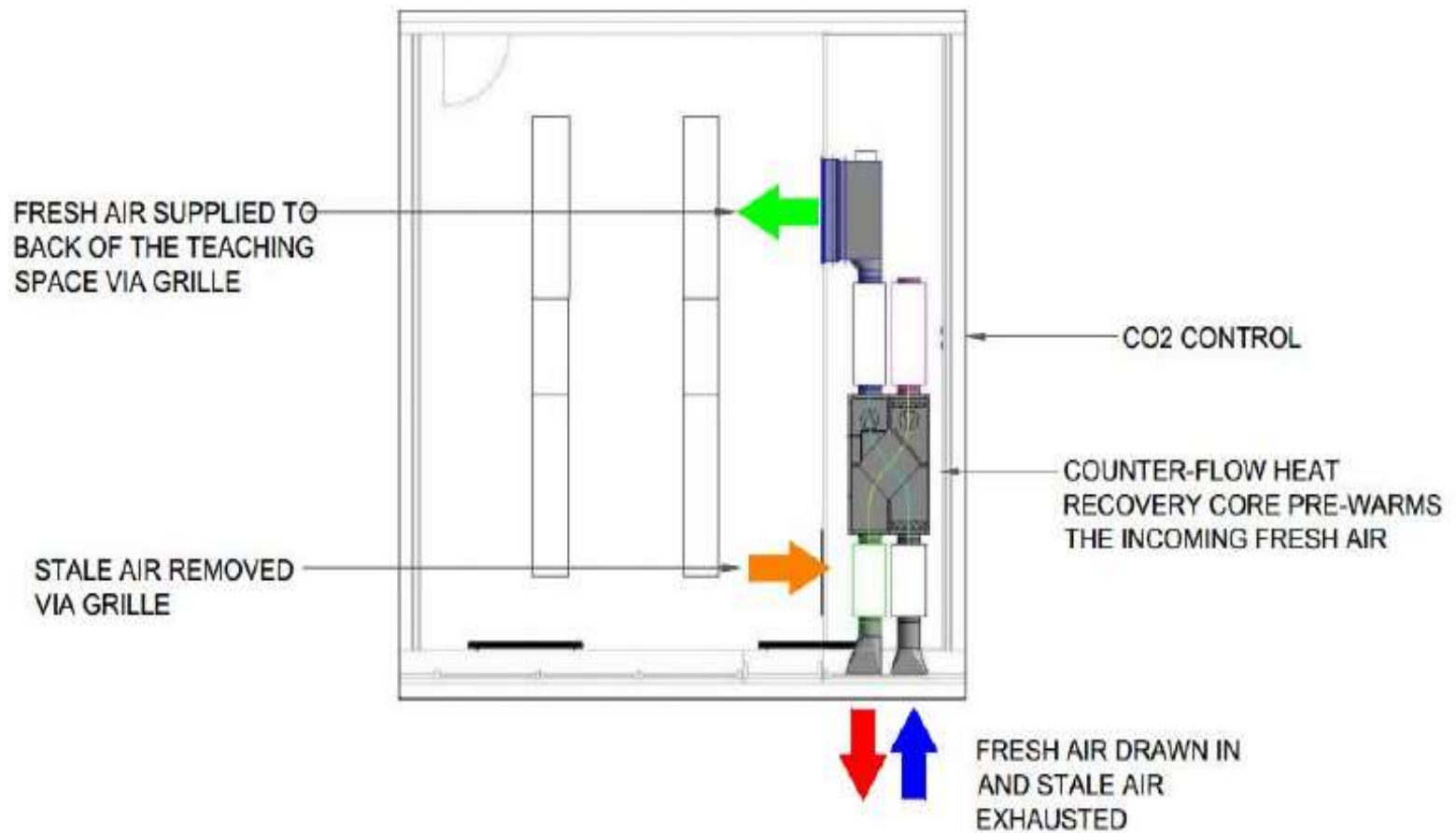
XB-EFA-8 UNIT



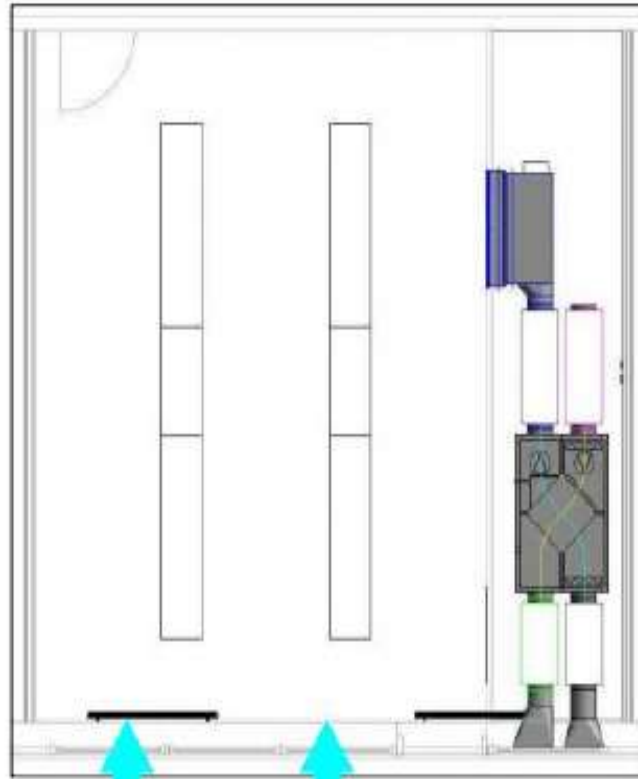
Nuaire - Classroom based mechanical ventilation system with heat recovery



Wintertime ventilation



Mid-season ventilation



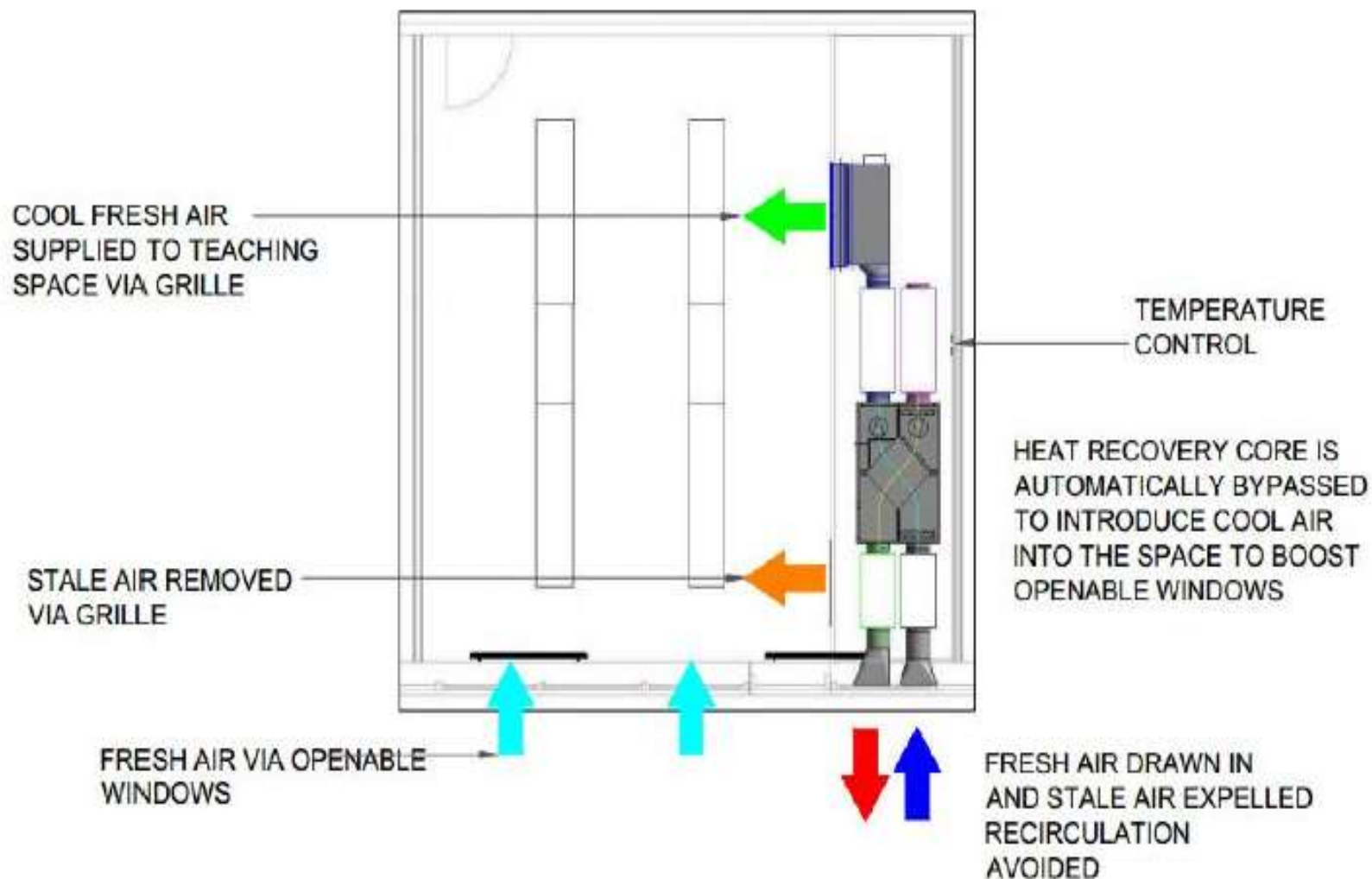
IN SPRING OR AUTUMN, WHEN THE EXTERNAL TEMPERATURE IS MILD, THE TEACHER CAN OPEN THE WINDOWS TO ALLOW FRESH AIR IN TO VENTILATE THE SPACES SAVING ENERGY AS THE RUNNING OF VENTILATION UNIT IS MINIMIZED

FRESH AIR VIA OPENABLE WINDOWS AS REQUIRED TO PROVIDE VENTILATION

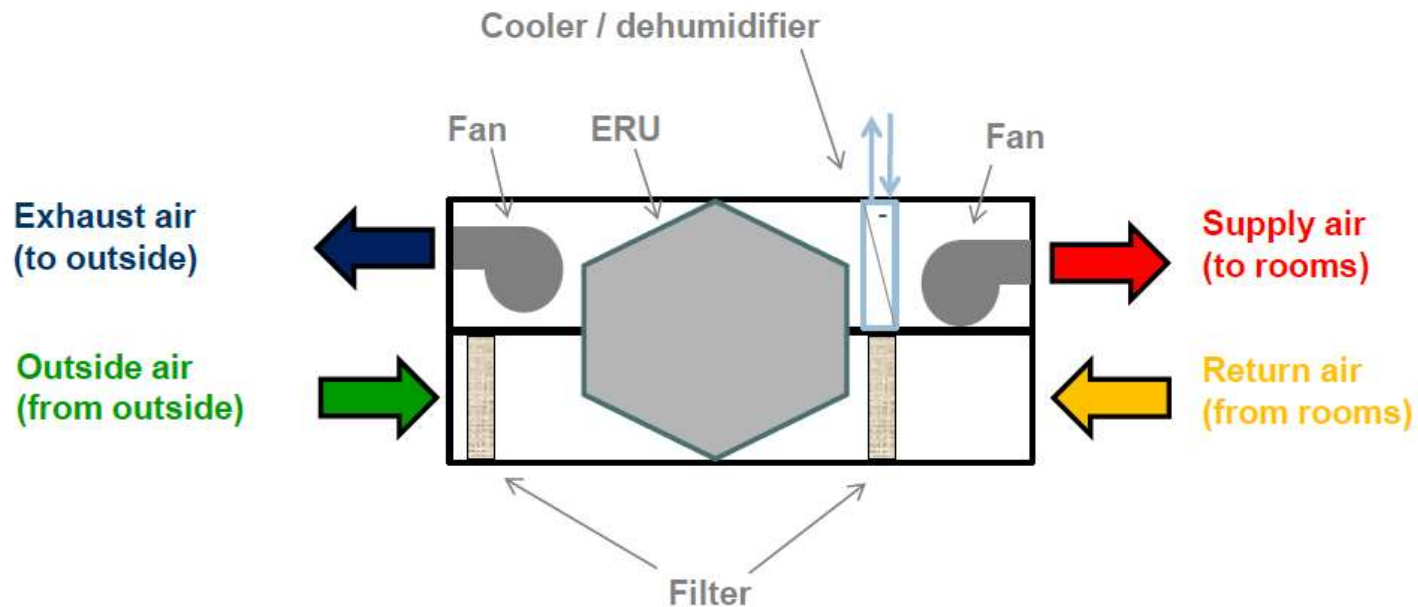


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Summertime Ventilation



Heat recovery - heat



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Heat recovery unit - washable

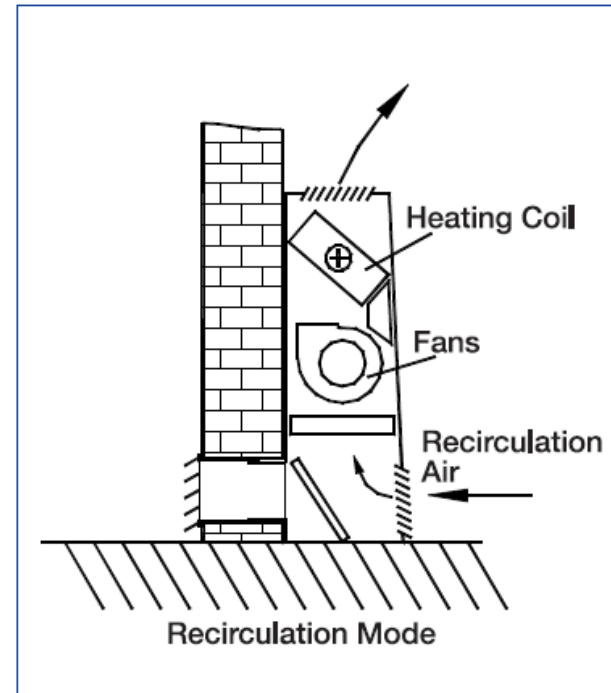
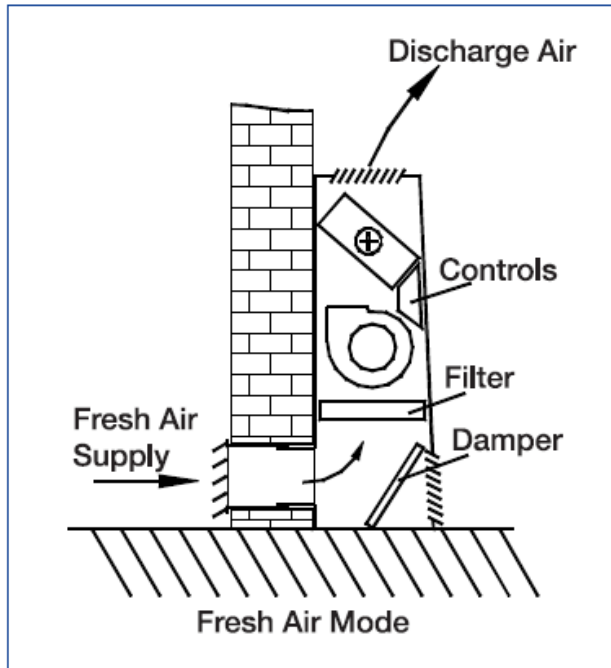


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Biddle Innovair Units



Biddle unit in dining hall – heating



SAV - Airmaster MVHR units with external shading



SAV - Quick release panel for maintenance



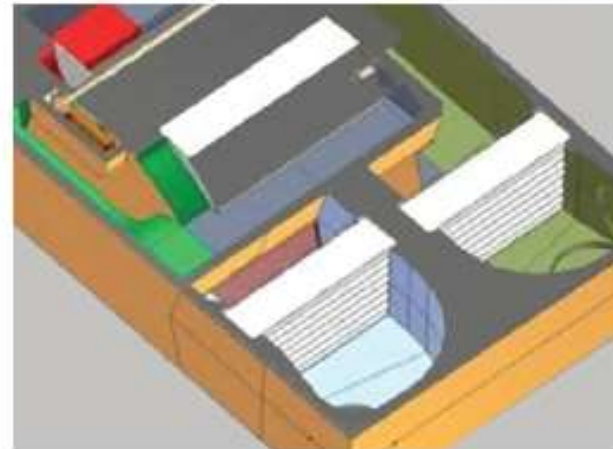
SAV Airmaster – MVHR requires air filters

EN 13779 - M5 Filters as Standard / F7 Optional



Indoor air quality

AirMaster AHU units are provided with filters in both the fresh air intake and exhaust pathways. The filters conform to the requirements of EN 13779, (European Norm which includes guidance on filter selection - ventilation equipment installed in non-residential buildings). M5 Class filters are included as standard, with F7 offered as an alternative where external environments are expected to have a high burden of contaminants.



Benchmark design

- **Passive design using thermal mass**
- **Cross and stack ventilation with shading to prevent summertime overheating**
- **Adaptive environments with easy to understand and responsive to user control**
- **Systems that are easy to monitor, commission, and control**

Challenges

- **Climate change and heat waves**
- **Reduction in capital budgets**
- **Inexperienced client bodies, trusts and sponsors**
- **Lack of experience of contractors and construction industry**
- **Clarity of design brief**
- **Centralised delivery and procurement remote from the users**



For more information

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