Breathing Buildings

Priority School Building Programme

Making sense of the new Priority School Output Specification from the Education Funding Agency. How is the output specification different from previous guidelines, how do the standard school designs meet the output specification and how Breathing Buildings can help you model the ventilation system energy use in IES.

Background

The Education Funding Agency (EFA) launched their baseline designs for schools in October 2012. The school designs set out to show examples of how the Output Specification for schools to be built under the Priority School Building Programme (PSBP) could be achieved within the set costs and area allowances.
Breathing Buildings worked with the EFA to develop the Output Specification, helping them assess alternative ventilation strategies and review the energy modelling results.
The baseline designs cover 3 standard schools: a 420 place primary, with a nursery of 26; a 1,200 place fingerblock secondary school; and a 1,200 place superblock secondary school.

Key Design Principles

The baseline designs have been developed using the following key principles:

- Functionality
- Health & Safety
- Standardisation
- Future-proofing
- Sustainability

The EFA have stated that they expect contractors to develop their own schemes to meet the Output Specification. The baseline designs are a potential starting point, but if contractors have different ideas they will be accepted so long as they meet the Output Specification criteria and cost targets.

This document lays out the key ventilation design challenges and how Breathing Buildings can help you comply.

GOODBYE BB101

Hello Adaptive Thermal Comfort

Internal Climate

The baseline designs share many of our core beliefs about the importance of a sustainable ventilation strategy in achieving a sustainable building. Notably they incorporate the following:

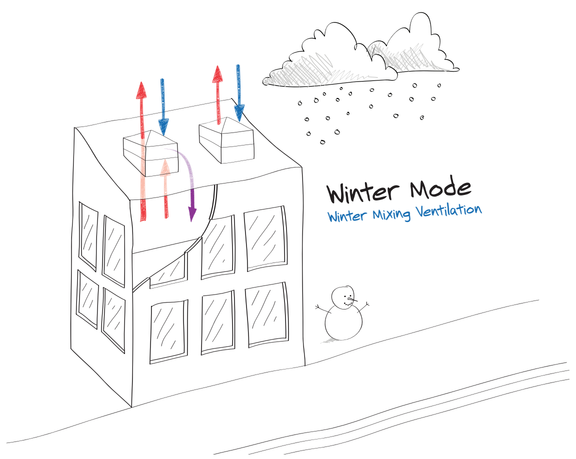
- Cross ventilation (enhanced airflow in all parts of a room leads to improved thermal comfort especially in warmer weather)
- Low energy hybrid (some fan use within an otherwise natural ventilation scheme provides a much more robust way of minimising energy use whilst at the same time preventing cold draughts in winter and managing the risks of overheating in summer)
- Not using windows in winter as these invariably cause cold draughts
- Using thermal mass to manage risks of summertime overheating.

Baseline Designs in IES

For us it is not enough to simply understand the challenges of the output specification, we have demonstrated compliance by modelling the schools in IES and 4DFlo. This shows that we not only meet the output specification but that using our products gives better performance than a MVHR solution.

The Future

We believe that the output specification will drive the development of future issues of BB101 and BB93. Having helped in the development of the output specification we are uniquely placed to help contractors and engineers ensure that their school design project delivers a low energy project with a superb indoor climate.



Weather files

PSBP stipulates the use of the Design Summer Year (DSY) weather files, which makes it more challenging to avoid overheating than BB101 which accepted the use of the cooler Test Reference Year (TRY) weather files.

Operative temperature

PSBP sees the use of operative temperature as a measure of thermal comfort. In CIBSE Guide A operative temperature is defined as:

operative temperature = ½ (air temp) + ½ (mean radiant temp)

We are not aware of a commercially available modelling tool which gives operative temperature as an output without post-processing. However the Breathing Buildings software automatically does this and can be used to make design work easier.

Adaptive Comfort

One aspect of the adaptive comfort philosophy is based on the premise that past thermal history modifies building occupants' thermal expectations and preferences. An example of this would be that during a warm weather spell, occupants would feel comfortable in a building that would otherwise be considered too warm.

To calculate the acceptable temperatures and the number of hours exceeding these, PSBP requires the use of a number of values from thermal modelling. These are currently not a direct and easy to find output of IES:

- Running mean temperature, T_{rm} (calculated from weather files)
- Operative temperature, T_{op} (calculated from dynamic thermal modelling, such as Breathing Buildings 4DFlo but currently not IES)
- Maximum acceptable temperature, T_{max} (calculated from weather files)
- Hours of Exceedance, H_e (calculated from dynamic thermal modelling)
- Weighted Exceedance, W_e (calculated from dynamic thermal modelling)
- Threshold / upper limit temperature, Θ_{upp} (calculated from dynamic thermal modelling)

Air freshness

For naturally ventilated buildings, the maximum daily average carbon dioxide (CO_2) levels are still 1,500ppm (the same as BB101), although the maximum acceptable value for a maximum of 20 minutes has been reduced to 2,000ppm.

For mechanically ventilated buildings, this requirement has been lowered to a maximum daily average of 1,000ppm, with a maximum of 1,500ppm for a maximum of 20 minutes per day.

This has implications involving the amount of heat lost in cold weather, and the fan power required to provide nearly twice as much outside air for a mechanical system compared with a natural system.

Overheating Criteria

In the same way as BB101, there are three criteria, of which you must pass two but can fail one. However in general there is a shift from the use of 28˚C, 32˚C and a 5˚C ΔT as a metric, to the use of Adaptive Comfort (EN 15251) to set the maximum desired internal temp (T_{max}) in the space. For free running (not mechanically cooled) buildings T_{max} is calculated using the equation:

$$T_{max} = 0.33T_{rm} + 21.8$$

Where T_{rm} is the running mean temperature, which is a weighted daily average of external temperatures over the previous 7 days. This can be calculated using the following equation:

$$T_{rm} = \frac{(T_{(ed-1)} + 0.8T_{(ed-2)} + 0.6T_{(ed-3)} + 0.5T_{(ed-4)} + 0.4T_{(ed-5)} + 0.3T_{(ed-6)} + 0.2T_{(ed-7)})}{3.8}$$

The maximum desired internal temperature is $T_{max} = 0.33\,T_{rm} + 21.8$ for normal new school buildings. This is based on the understanding that the target comfort temperature $T_{comf} = 0.33T_{rm} + 18.8$, and $T_{max} = T_{comf}$ + (acceptable range for building type and use, which is 3K for new school buildings).

The following is a brief summary of the three criteria:

2.8.52.1. Criteria 1 is that the number of Hours of Exceedance must be no more than 40 when the predicted operative temperature exceeds T_{max} by 1K, or more, during the five summer months (May-September). (c.f. number of hours above 28˚C <120 in BB101).

2.8.52.2. Criteria 2 is the sum of the Weighted Exceedance (W_e) for each degree K above T_{max} (1K, 2K and 3K) is ≤ 10.0; where $W_e = H_e$ (1,2,3) * $(\Delta T)^2$ (1,2,3) and $\Delta T = (T_{op} - T_{max})$, rounded to a whole number i.e. [0˚C < 0.5˚C ≥ 1˚C]

2.8.52.3. Criteria 3 the measured/ predicted operative temperature should not exceed the T_{max} by 4K or more at any time (c.f. DT<5˚C and T_{max} = 32˚C in BB101)

Thermal comfort - occupants

There is much more emphasis on the conditions in the space being comfortable, in particular the importance of mitigating cold draughts. There is now a requirement for pre-mixing of outdoor air, which rules out simple openings close to the occupant, which then leaves MVHR or e-stack. MVHR is penalised by the requirement for more outside air to meet the new lower CO_2 restrictions, which results in higher energy consumption over the year compared with e-stack.

Powered by 4DFlo
Dynamic thermal mass simulation

Breathing Buildings

Priority Schools Output Specification Challenge	Breathing Buildings Solution
1.5.5 Page 19 Health and well-being - The health and comfort needs of pupils and staff are recognised through providing a healthy working environment that encourages self-esteem and motivation. Good schools understand the connection between children's physical and mental health and their educational achievement. The Generic Design Brief therefore requires an effective healthy indoor environment to support educational attainment with good daylight, ventilation, thermal comfort and acoustics.	Breathing Buildings provides controlled natural ventilation systems which ensure that teaching spaces are always provided with the necessary amounts of fresh air to ensure high air quality is maintained. The systems also ensure that the spaces are kept comfortable in terms of temperature by maximising the benefits of free cooling in summer, and using the patented e-stack concept to maximise the internal heat gains and deliver warm conditions in winter with the lowest heating use in the natural ventilation industry. On noisy sites we also provide acoustic attenuators which fit within the shafts of the natural ventilation system.
2.5.22.5 Page 42 Optimising the benefits of seasonal daylight and ventilation to be designed-in, in order to design-out the need for active mechanical and electrical services.	The Breathing Buildings range of e-stack equipment and standard dampers, window actuators and controls helps contractors avoid mechanical ventilation in nearly all areas of a school.
2.2.23 Page 42 The Contractor shall ensure that the Building Services and components of the Building are well co-ordinated, work well in full use and are easy to operate. The users should be able to easily adjust or operate components that affect their comfort, such as lighting switches, ventilation controls and opening windows. Wherever possible, systems should default to 'off'.	All Breathing Buildings systems have an interface which is easy to use. The system can be turned on/off and into purge mode as required by the room users.
2.7.18 Page 49 The Contractor shall ensure that windows, vents and shading are designed and constructed to: 2.7.18.1. Provide sufficient light and natural ventilation.	Breathing Buildings equipment is all about natural ventilation. The range of products is there to ensure sufficient natural ventilation is provided at all times of the year, and without cold draughts or excessive heating bills.
2.8.43. Page 67 In naturally ventilated spaces, the Contractor shall provide mixing of ventilation air with room air to avoid cold draughts in the occupied zone during wintertime.	The Breathing Buildings e-stack range of natural ventilation equipment is the only robust solution available to pre-mix the incoming cold fresh air in winter and minimise the risk of cold draughts. Opening windows or vents simply dump cold air in winter.
2.8.44. Page 67 The Contractor shall design the Building so as to limit the maximum internal temperature. The Contractor shall assess its design for overheating using the most relevant weather files from CIBSE's Summer Design Reference Years.	The Breathing Buildings unique engineering team undertake dynamic thermal modelling calculations for every space for which we provide equipment. The modelling is undertaken using our own 4DFlo software which has been developed by academics from the University of Cambridge. We also use IES to support design teams if this is desired.
2.8.45. Page 67 The Contractor shall ensure that mechanical ventilation is not the sole method of summer-time ventilation in occupied spaces and that occupied space should wherever possible also have opening windows or vents, with an effective opening area equal to at least 5% of floor area. The Contractor should also provide controls in each room to switch the mechanical ventilation on or off as required.	Breathing Buildings provides natural ventilation systems which work in conjunction with mechanical systems. We provide a unique solution to the industry by delivering hybrid ventilation systems where purely natural ventilation schemes can't work, such as particularly deep-plan classrooms with no access to the roof or an atrium.
2.8.53. Page 69 The Contractor shall employ passive measures, such as thermal mass with night ventilation and external shading, where possible to reduce the possibility of overheating.	All Breathing Buildings natural ventilation systems include a finely controlled night cooling mode which enables any thermal mass within a building to be exploited for cooling purposes in the summer.
Page 75 Ventilation of densely occupied spaces, such as classrooms, needs careful consideration as raised carbon dioxide levels have been shown to significantly reduce educational performance.	The consulting engineering team at Breathing Buildings is comprised of engineers from Cambridge University with PhDs and Masters degrees. Our team works closely with contractors and design teams to develop the most appropriate ventilation strategy for each teaching space.

Priority Schools Output Specification Challenge	Breathing Buildings Solution
2.8.84. The Contractor shall ensure that where natural ventilation is used, the system is capable of providing enough fresh air so that the average concentration of carbon dioxide during the Required Period is less than 1500ppm and so that the maximum concentration does not exceed 2000ppm for more than 20 minutes each day.	We model the ventilation requirements for all teaching spaces based on the occupancy profiles at design stage, and size the equipment accordingly. In addition, the systems we provide always include room CO_2 sensors. The Breathing Buildings control systems use this information to ensure that the dampers are adjusted to deliver the required amount of fresh air.
2.8.85. The Contractor shall endeavour to design a mechanical ventilation or hybrid ventilation systems with heat recovery designed to reduce energy consumption in order to meet the space heating and thermal energy targets given in the Energy and Utilities section of this document.	The patented e-stack range is the only natural ventilation system available which reduces energy consumption whilst at the same time minimising the risk of cold draughts. Breathing Buildings also provides a patented integrated heating and ventilation controller to minimise the heating energy used in a building. The controller first ensures that the ventilation system never fights the heating system, but in addition, uses a regulating algorithm so that the energy use of the heating system is minimised.
2.8.86. The Contractor should also incorporate thermal mass and night cooling into the design to prevent summertime overheating.	All Breathing Buildings natural ventilation systems include a finely controlled night cooling mode which enables any thermal mass within a building to be exploited for cooling purposes in the summer.
2.8.88. The Contractor shall ensure that when outside air is introduced into a teaching space ventilation air and room air will be mixed to avoid cold draughts during wintertime.	The Breathing Buildings e-stack range of equipment is the only robust solution available to pre-mix the incoming cold fresh air in winter and minimise the risk of cold draughts. Opening windows or vents simply dump cold air in winter.
2.8.89. The Contractor shall ensure that the control of natural ventilation systems in densely occupied spaces such as classrooms is provided by means of an indoor air quality or carbon dioxide sensor that provides a clear and easily understood indication of indoor air quality to alert the teacher and possibly the pupils to the need to increase the ventilation by opening windows or vents; or an indoor air quality or carbon dioxide sensor linked to a ventilation system or an automatic window or vent opening system.	Every Breathing Buildings natural ventilation system includes a number of temperature and CO_2 sensors. We monitor: The exterior temperature to assess whether it is acceptable to bring fresh air in directly onto occupants the interior CO_2 levels to determine the fresh air requirements in terms of air quality the room temperature to determine whether more than the minimum fresh air rate is needed to help cool the space the temperature of the mixed air in winter mode to determine the mixing ratio which the e-stack units need to achieve to mitigate the risk of cold draughts.
2.8.90. The Contractor shall ensure that all ventilation systems are capable of dealing with localised conditions and responding to changes in demand.	Every Breathing Buildings natural ventilation system includes a number of temperature and CO_2 sensors. We monitor: a) the exterior temperature to assess whether it is acceptable to bring fresh air in directly onto occupants. b) the interior CO_2 levels to determine the fresh air requirements in terms of air quality. c) the room temperature to determine whether more than the minimum fresh air rate is needed to help cool the space. d) the temperature of the mixed air in winter mode to determine the mixing ratio which the e-stack units need to achieve to mitigate the risk of cold draughts.

Breathing Buildings

E-Stack System for the PSBP Fingerblock School

In response to the release of the Facilities Output Specification for the Priority Schools Building Programme, Breathing Buildings have used IES-VE software to model a low energy natural ventilation solution which will meet the requirements of the Output Specification.

The Facilities Output Specification states that;
"2.8.43. In naturally ventilated spaces, the Contractor shall provide mixing of ventilation air with room air to avoid cold draughts in the occupied zone during wintertime."

This functionality is provided by the e-stack system, which provides a lower energy alternative than a mixed mode system which operates natural ventilation in the summertime (when external temperature is greater than 16˚C) and switches to MVHR when external temperature is below 16˚C in order to prevent cold draughts.

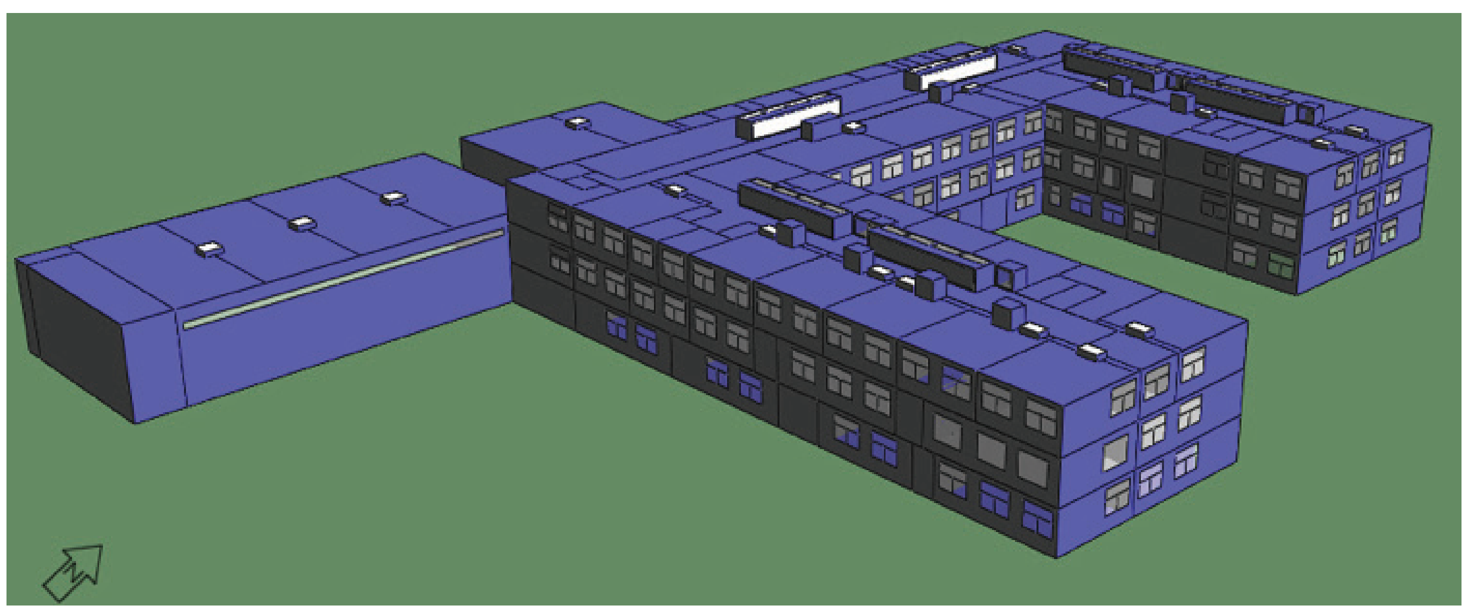
The fingerblock school is well suited to the e-stack atrium system. The rooms on the ground floor and the first floor will use A Series units which connect the classrooms to the central atria, providing a pathway for summertime upwards displacement ventilation and also allowing a mixing ventilation strategy for the wintertime. On the second floor, it is most effective to use a stack based system for summertime and wintertime ventilation strategies. Our R Series system works in conjunction with low level openings in the summertime and in the wintertime operates a mixing ventilation strategy, using low powered fans to mix warm room air with incoming, cold, external air.

Some types of room are not suited to natural ventilation, such as server rooms etc. which are highlighted in the Facilities Output Specification as rooms with heat gains of more than 15W/m². Also, small rooms such as single person offices have not been included in the e-stack strategy. The rooms which have been included are highlighted on the adjacent page. In order to demonstrate compliance with the Facilities Output Specification, Breathing Buildings have modelled the baseline building using the following parameters for the typical classroom;

Our IES-VE modelling demonstrates that each room which uses the e-stack system will also meet the criteria for overheating, when simulated using the Manchester DSY weather file. For more extreme weather files such as London DSY it is necessary to reduce internal gains in order to meet the overheating criteria, for example by reducing the glazing G-value to around 0.32.

2.8.52.1. Criteria 1 - Hours of Exceedence (H_e)
2.8.52.2. Criteria 2 - Weighted Exceedance (W_e)
2.8.52.3. Criteria 3 - Threshold/Upper Limit Temperature (θ_{upp})

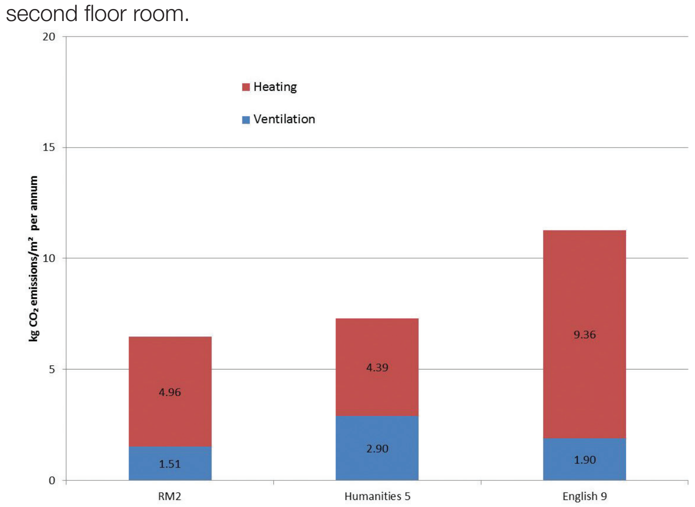
Occupancy (people)	32
Occupancy Heat Gain (W/person)	75
Occupied Hours	9am - 12pm 1pm - 4pm
Lighting (W/m²)	10
Additional Small Power (W)	1,000
Low Level Opening Effective Free Area	0.5m² per std window
Glazing G-value	0.64
Heating Setpoint Classrooms	21˚C
Heating Setpoint Class Pre-heat	18˚C
Heating Setpoint Atria	18˚C
U-value of Walls (W/m²K)	0.35
U-value of Roof (W/m²K)	0.25
U-value of Floor (W/m²K)	0.25
U-value of Windows (W/m²K)	2.2
Infiltration (ach)	0.25
Thermal Mass	100mm exposed concrete soffit



The e-stack system is the low energy solution for compliance with the Facilities Output Specification. In the summertime the system uses buoyancy and wind with fan boost and night cooling modes where required. In the wintertime, the two low energy fans in the units use a maximum of 50W each which is many times lower energy than the fans used by heat recovery devices. The e-stack units ensure that during occupied hours in winter, the warm room air is used to temper the incoming air, so that additional heating is not required in the space until external temperatures drop below around 7˚C.

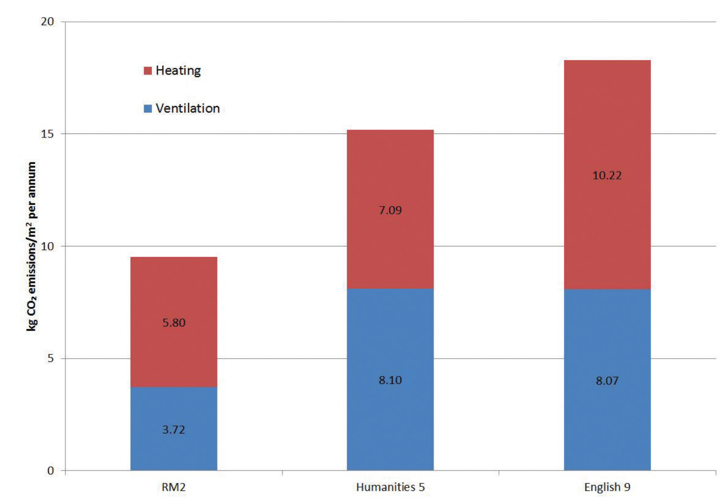
Breathing Buildings System

The carbon emissions of a typical, highly glazed, South facing classroom from the Fingerblock School baseline design can be seen adjacent. RM2 is a ground floor room, Humanities is a first floor room and English 9 is a second floor room.



MVHR System

The Carbon emissions of the same rooms using MVHR can be seen in the chart below.



In addition both systems have identical Equipment (15.63 - 30.05 Kg/m²) and Lighting (13.13 - 27.88 Kg/m²) loads, which have been omitted for clarity.

Summary

A review of the BSF schools found that although many of them were intended to be low energy, the heating bills are significantly higher than forecast. Furthermore, a number of them still overheat. The new PSBP Output Specification has been created to help overcome these issues. The Breathing Buildings unique approach to natural ventilation is the easiest and most robust way of meeting the new Output Specification thermal comfort and energy targets.

Breathing Buildings

Proving it works

We are proud of our understanding of natural ventilation and our ability to deliver low energy buildings with great internal environments. We have monitored many installations to make sure that they are ventilating properly and mitigating cold draughts. These charts show data from Linton Village College where we installed R Series units.

Winter supply

In winter it is important to manage the ventilation requirements with heating and thermal comfort. As you can see from Figure 01 even when the outside temperature is below 5˚C we are able to successfully mitigate cold draughts with the supply temperature remaining at a comfortable level.

Figure 02 looks at the daily average CO_2 levels in the space during the winter months, which BB101 and the EFA Facilities Output Specification require to be below a daily average of 1,500ppm. The Breathing Buildings system delivers this using CO_2 sensors in the space and our patented winter mixing system. Independent research of our competitor systems has shown that without a draught mitigation strategy occupants simply turn the system off in winter, the space does not ventilate and CO_2 rises significantly.

Modelling

We are often asked what IES shows for natural ventilation and alternative ventilation strategies. The short answer is the e-stack system provides significant energy savings not just compared with traditional natural ventilation but also with MVHR, as shown in Figures 03 and 04. But don't take our word for it, let us help you to model your classroom with different ventilation strategies using IES.

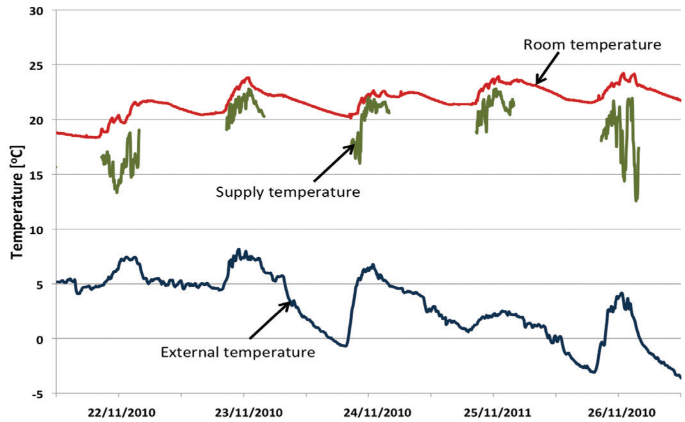


Figure 01

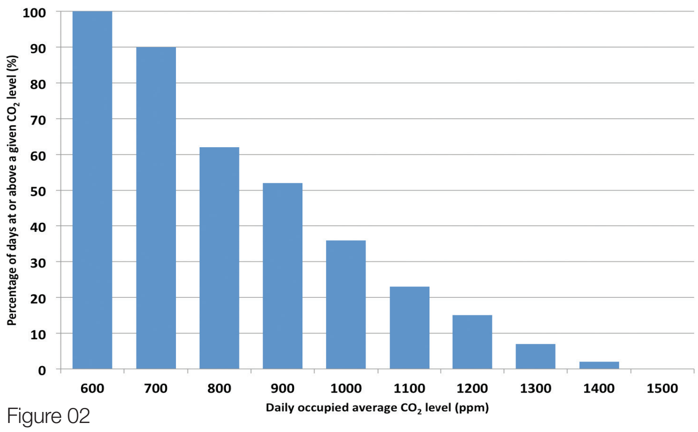


Figure 02

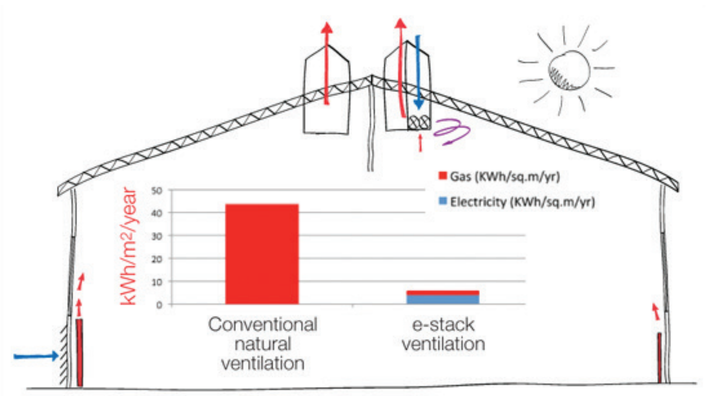


Figure 03

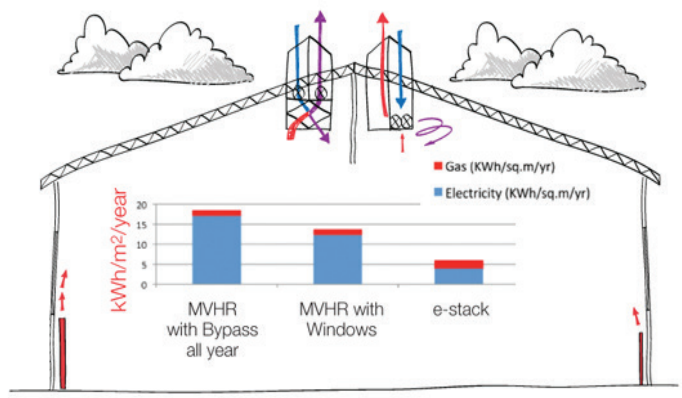


Figure 04

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