NHS Scotland Assure Conference 2022

Excellence in the healthcare environment
3 and 4 November 2022
Crieff Hydro

NHS National Services Scotland

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Natural Ventilation

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An insight to the use of Natural ventilation in healthcare including design principles and infection prevention and control considerations.

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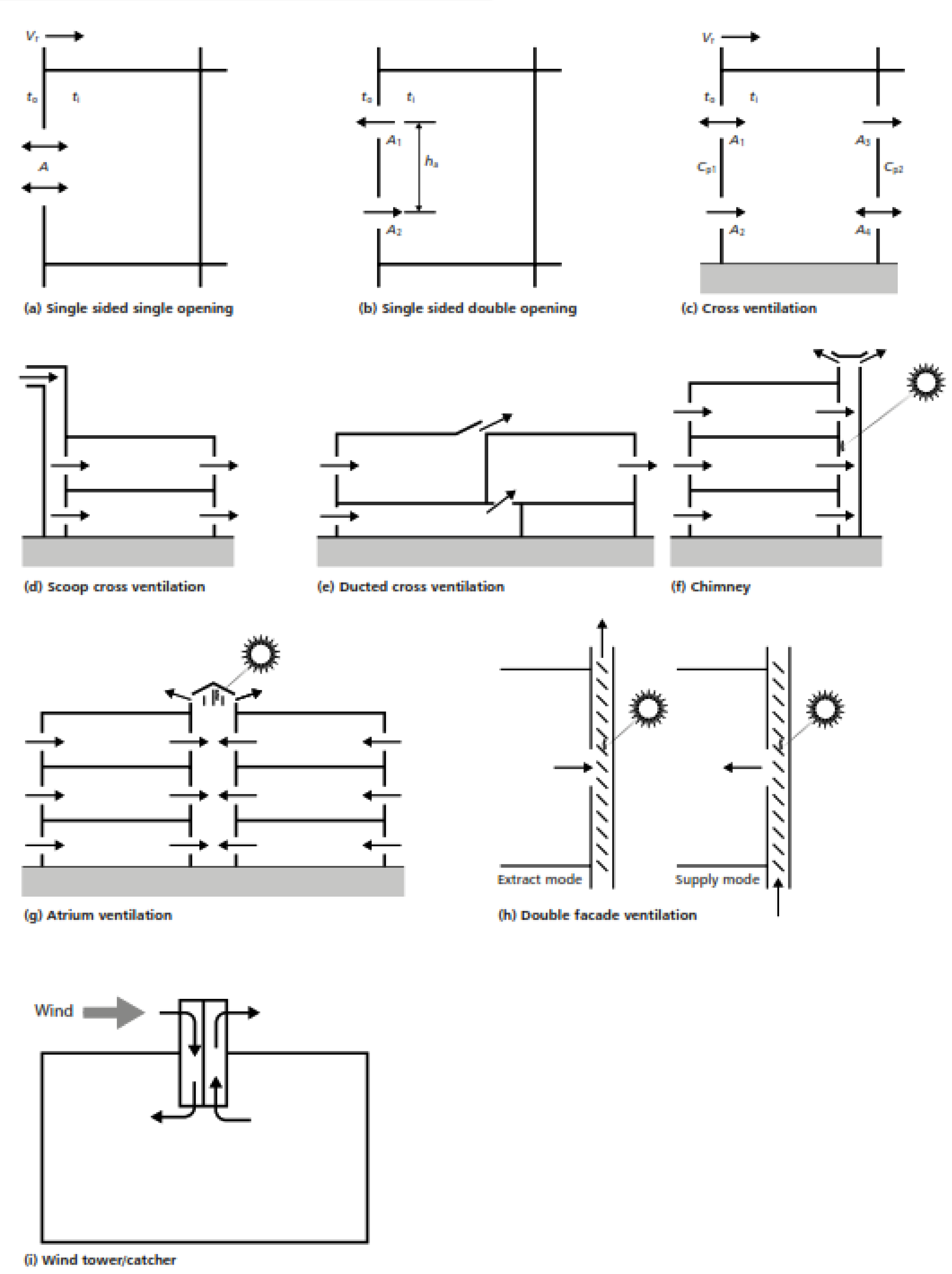

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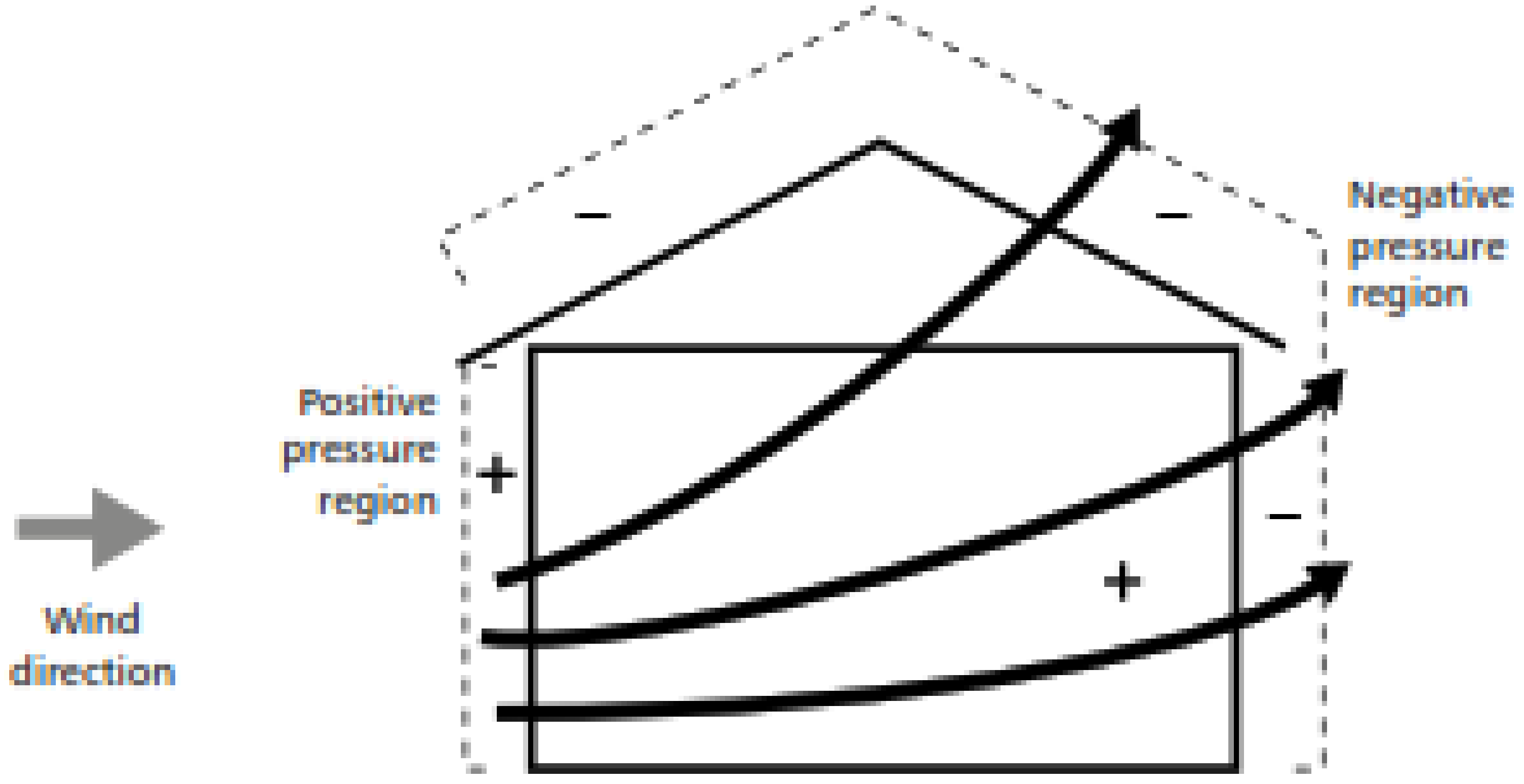

Figure 2.4 Wind-driven ventilation (from *Guide to Ventilation* (AIVC, 1996) reproduced by kind permission of AIVC)

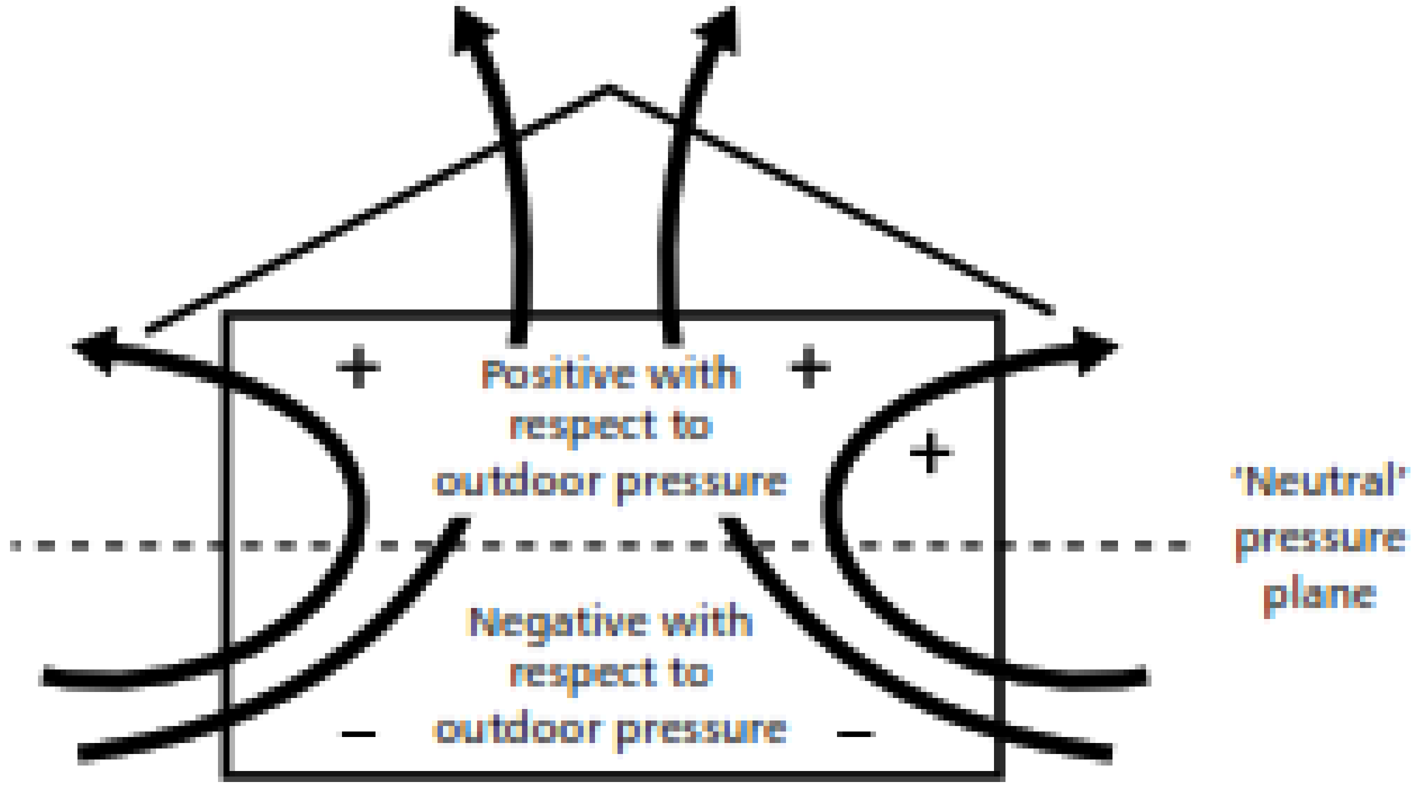

Figure 2.5 Stack-driven ventilation. Flow pattern for outside temperature less than inside temperature (from *Guide to Ventilation* (AIVC, 1996), reproduced by kind permission of AIVC)

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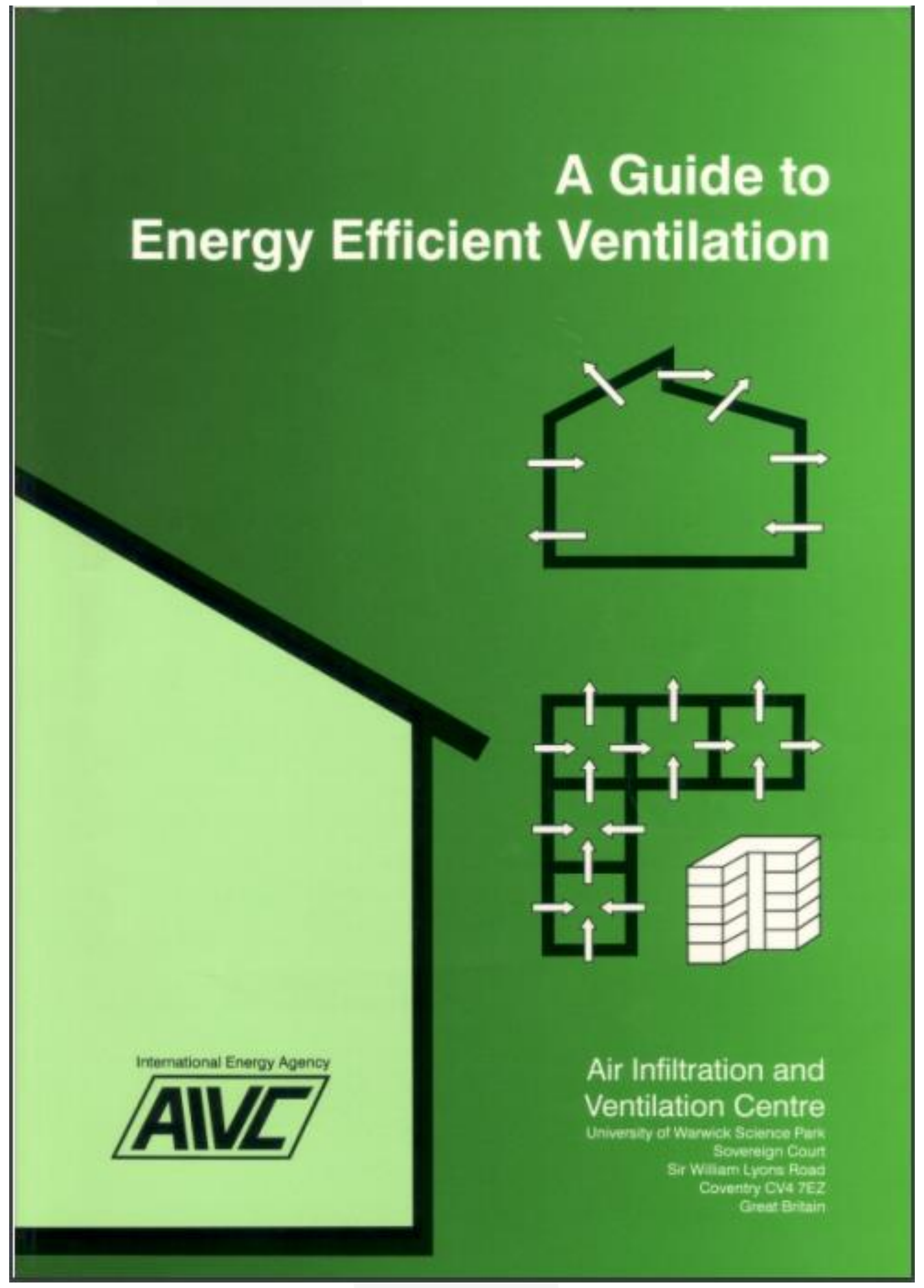
CIBSE make reference to AIVC

- The AIVC (Air infiltration and Ventilation Centre) is the International Energy Agency’s information centre on energy efficient ventilation.



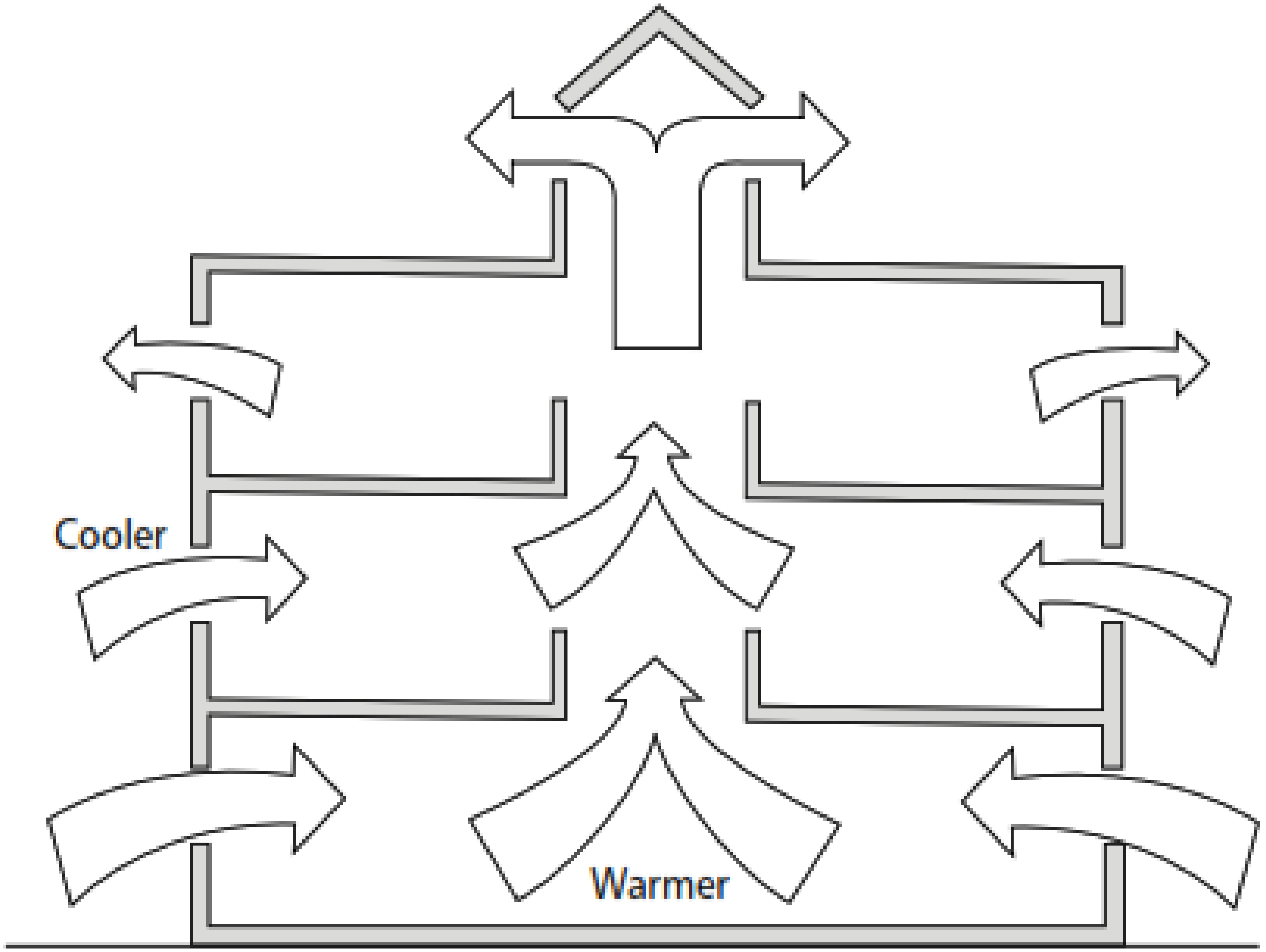


Figure 2.7 Buoyancy-driven ventilation

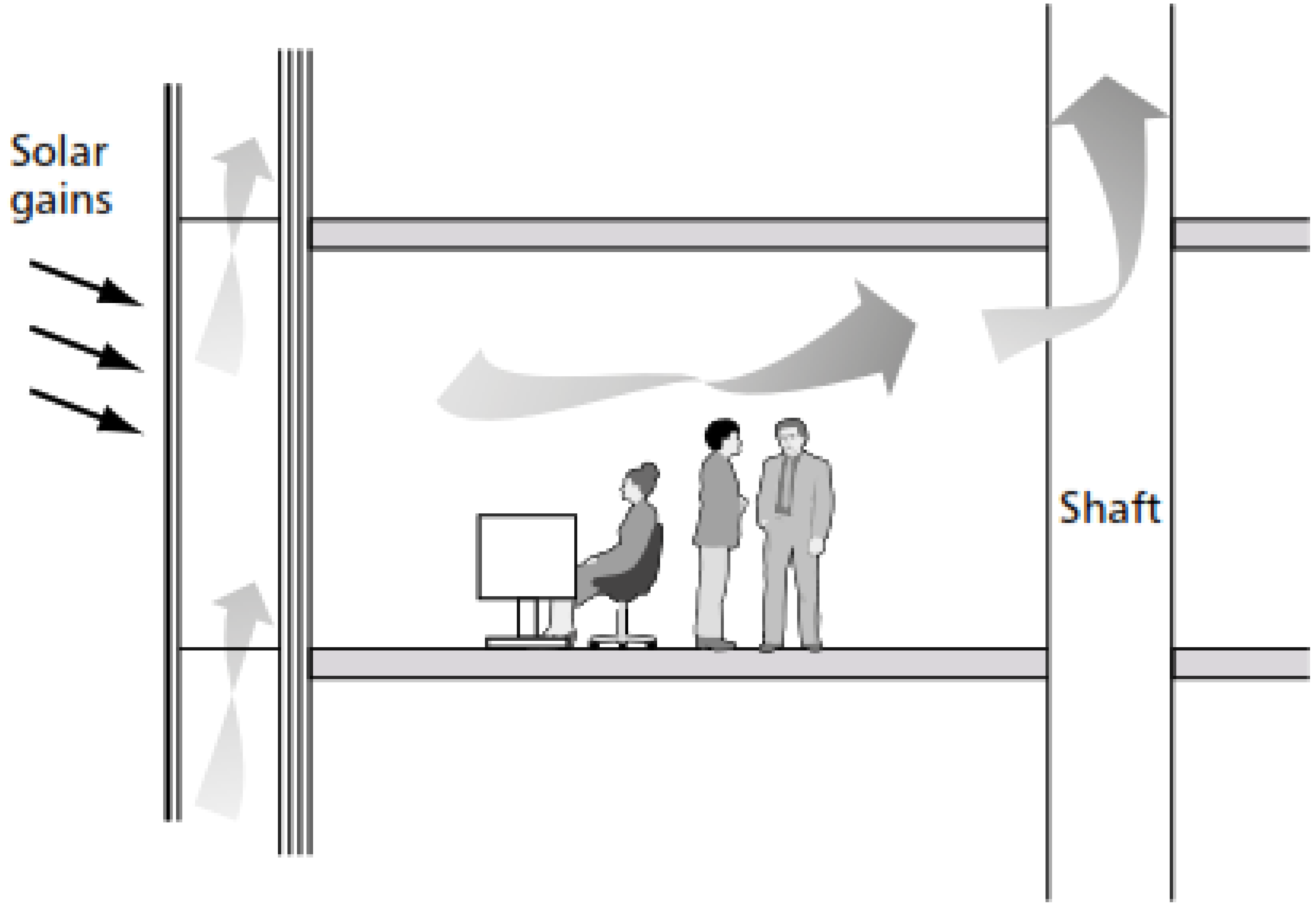


Figure 2.8 Double façade ventilation

Source CIBSE Code B

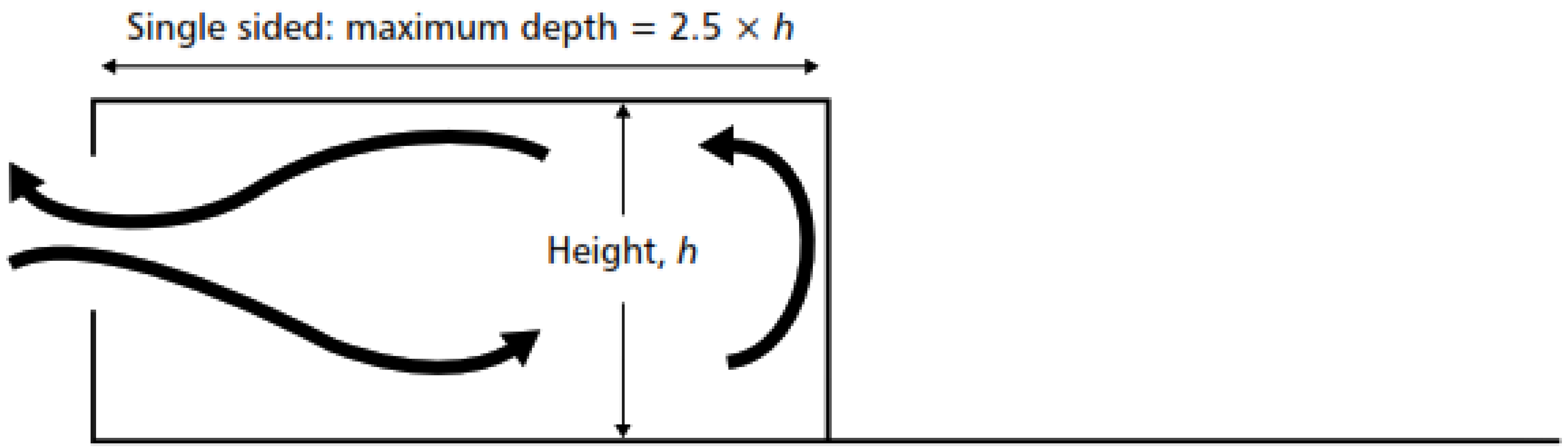


Figure 2.9 Single-sided ventilation maximum penetration (from *Guide to Ventilation* (AIVC, 1996) reproduced by kind permission of AIVC)

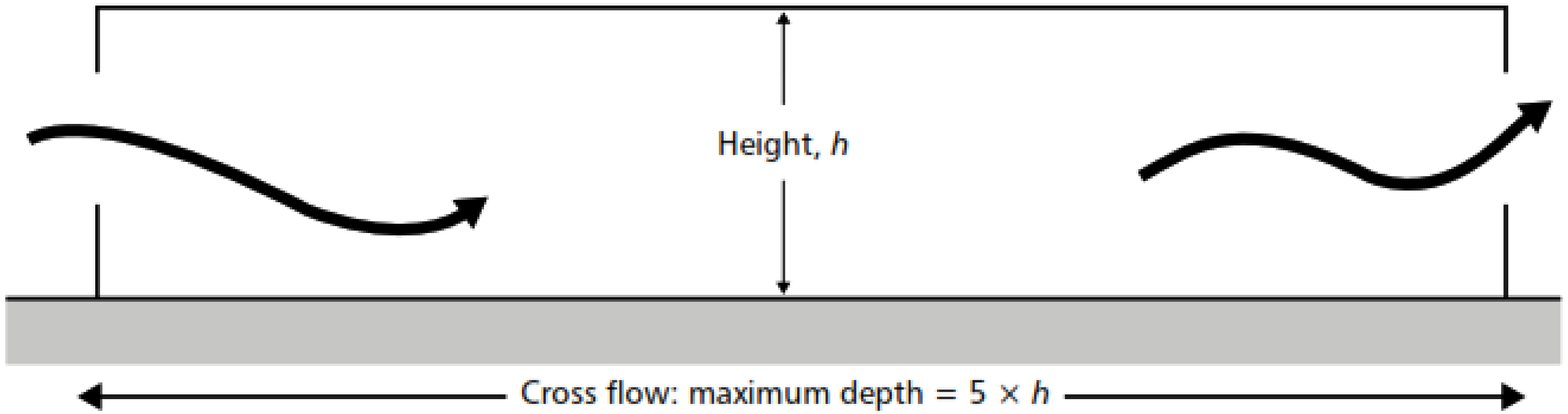


Figure 2.10 Cross-flow ventilation (from *Guide to Ventilation* (AIVC, 1996) reproduced by kind permission of AIVC)

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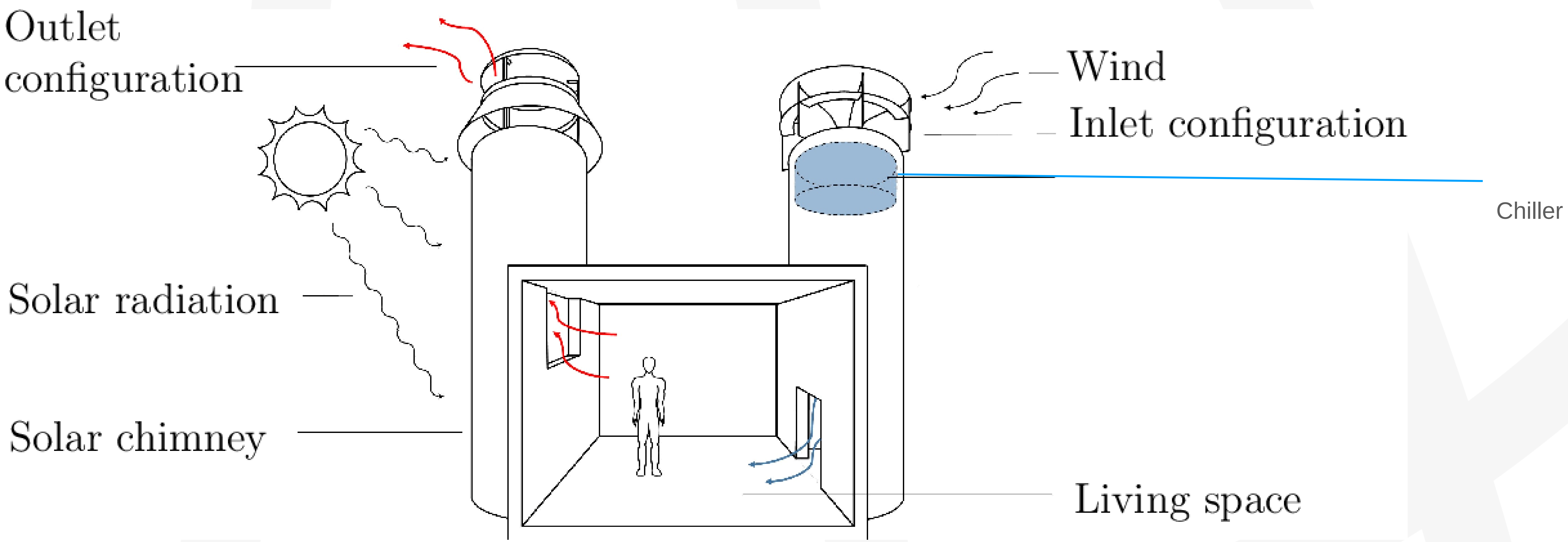
Outlet configuration
Wind
Inlet configuration
Chiller
Solar radiation
Solar chimney
Living space

Most of the natural ventilation solutions show supply air in at low level with discharge at higher level

- This may not be ideal for infection prevention and control
- Supply at high level and extract at low level may provide better infection control in ward areas

Infection control and ventilation – start searching the internet

- Lots of scholarly articles, abstracts and papers
- This is a project in itself to research the published information

Protected zone ventilation and reduced personal exposure to airborne cross-infection.
G. Cao, P. Nielsen, R. L. Jensen, P. Heiselberg, L. Liu, J. Heikkinen · Engineering · Indoor air · 2015
TLDR The measurement results showed that in both the PZV and the HPZV system it is possible to decrease the transmission of tracer gas from one manikin to the oppositeManikin; therefore, it probably would reduce the risk of air borne cross-infection between two people at the same relative positions. Expand
53 · Save · Alert

Secondary exposure risks to patients in an airborne isolation room: Implications for anteroom design
E. Mousavi, K. Grosskopf · Medicine · 2016
11 · Save · Alert

Airborne transmission of exhaled droplet nuclei between occupants in a room with horizontal air distribution
Z. Ai, T. Huang, A. Melikov · Environmental Science · Building and Environment · 2019
29 · Save · Alert

A new possible route of airborne transmission caused by the use of a physical partition
Jinjun Ye, Z. Ai, Chen Zhang · Environmental Science · Journal of Building Engineering · 2021
3 · Save · Alert

Multiple airflow patterns in human microenvironment and the influence on short-distance airborne cross-infection – A review
P. Nielsen, Chun-yu Xu · Environmental Science, Engineering · Indoor and Built Environment · 2021
TLDR The importance of better understanding of the dynamics and transmission routes of the expelled virus-laden droplets or aerosols, which are largely affected by complex flow interactions in human microenvironment, is highlighted. Expand
2 · View 12 excerpts, cites background and methods · Save · Alert

Experimental evaluation of thermal comfort, ventilation performance indices and exposure to airborne contaminant in an airborne infection isolation room equipped with a displacement air distribution system
F. Berlanga, M. R. D. Adana, I. Olmedo, J. M. Villafruela, J. S. José, F. Castro · Engineering · 2018
34 · PDF · Save · Alert

Airborne transmission between room occupants during short-term events: Measurement and evaluation.
Z. Ai, Kaho Hashimoto, A. Melikov · Environmental Science · Indoor air · 2019
TLDR This study experimentally examines and compares the dynamics and short-term events of airborne cross-infection in a full-scale room ventilated by stratum, mixing and displacement air distributions and proposes real-time and average exposure indices to evaluate the dynamics of airborne exposure. Expand
36 · PDF · View 1 excerpt, cites methods · Save · Alert

Direct or indirect exposure of exhaled contaminants in stratified environments using an integral model of an expiratory jet.
Fan Liu, Chongyang Zhang, H. Qian, Xiaohong Zheng, P. Nielsen · Environmental Science, Physics · Indoor air · 2019
TLDR A jet integral model is proposed to predict the dispersion of exhaled contaminants, evaluating the exposure risk and determining a threshold distance to identify the direct and indirect exposures in both thermally uniform and stratified environments. Expand
22 · Save · Alert

Airborne spread of expiratory droplet nuclei between the occupants of indoor environments: a review
Ai, Arsen Krikor · Environmental Science · 2018
This paper reviews past studies of airborne transmission between occupants in indoor environments, focusing on the spread of expiratory droplet nuclei from mouth/nose to mouth/nose for non-specific… Expand
5 · PDF · View 1 excerpt · Save · Alert

Renovation in hospitals: a case study of source control ventilation in work zones
E. Mousavi, K. Grosskopf · Medicine · Advances in Building Energy Research · 2018
TLDR A new source-control ventilation strategy is proposed where the arrangement of supply and exhaust air ventilation is optimized to more effectively contain and remove airborne particulates within hospital work zones, without added operations and maintenance (O&M) costs. Expand
6 · Save · Alert

← 1 2 3 4 5 … →

Natural Ventilation in Thai Hospitals: A Field Study

Vorapat INKAROJRIT
Faculty of Architecture, Chulalongkorn University, Bangkok 10330

Thailand Abstract Natural ventilation has been appraised as the main strategy in environmental control of airborne infection in resource-limited healthcare facilities.

While natural ventilation offers a low-cost alternative in diluting and removing contaminated air, its' performance in actual settings is not fully understood.

This paper reports a cross-sectional field study of six hospitals in Thailand with an emphasis on ventilation performance of naturally-ventilated hospital wards and AII rooms.

The results showed that ventilation rates of 3-26 ACH could be achieved in hospital wards.

Higher ventilation rates of 16-218 ACH were found in AII rooms.

Our measurements also showed that a few locations within hospital wards had little or no air movement due to existing hospital ward designs.

This study concludes that natural ventilation is suitable for resource-limited hospitals in tropical climates when windows are opened and exhaust fans are installed.

Design guidelines that promote natural ventilation were discussed

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What do we initially think of as natural ventilation?

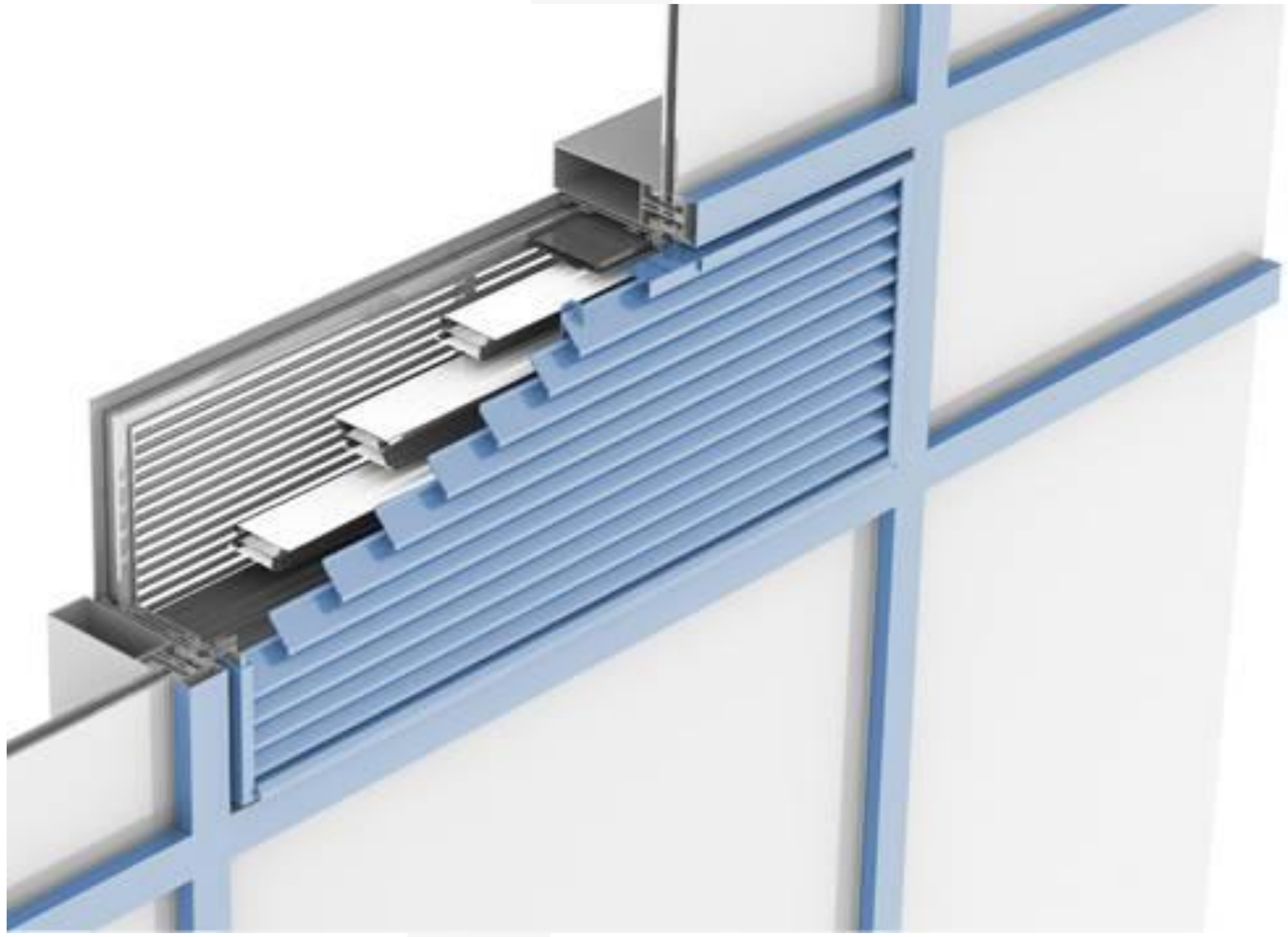
Opening Windows
Louvers

Nightingale wards
High ceilings with unrestricted opening windows
(not the Covid temporary hospitals)
Sanatoriums for TB patients – out in the fresh air
Consulting rooms
Offices

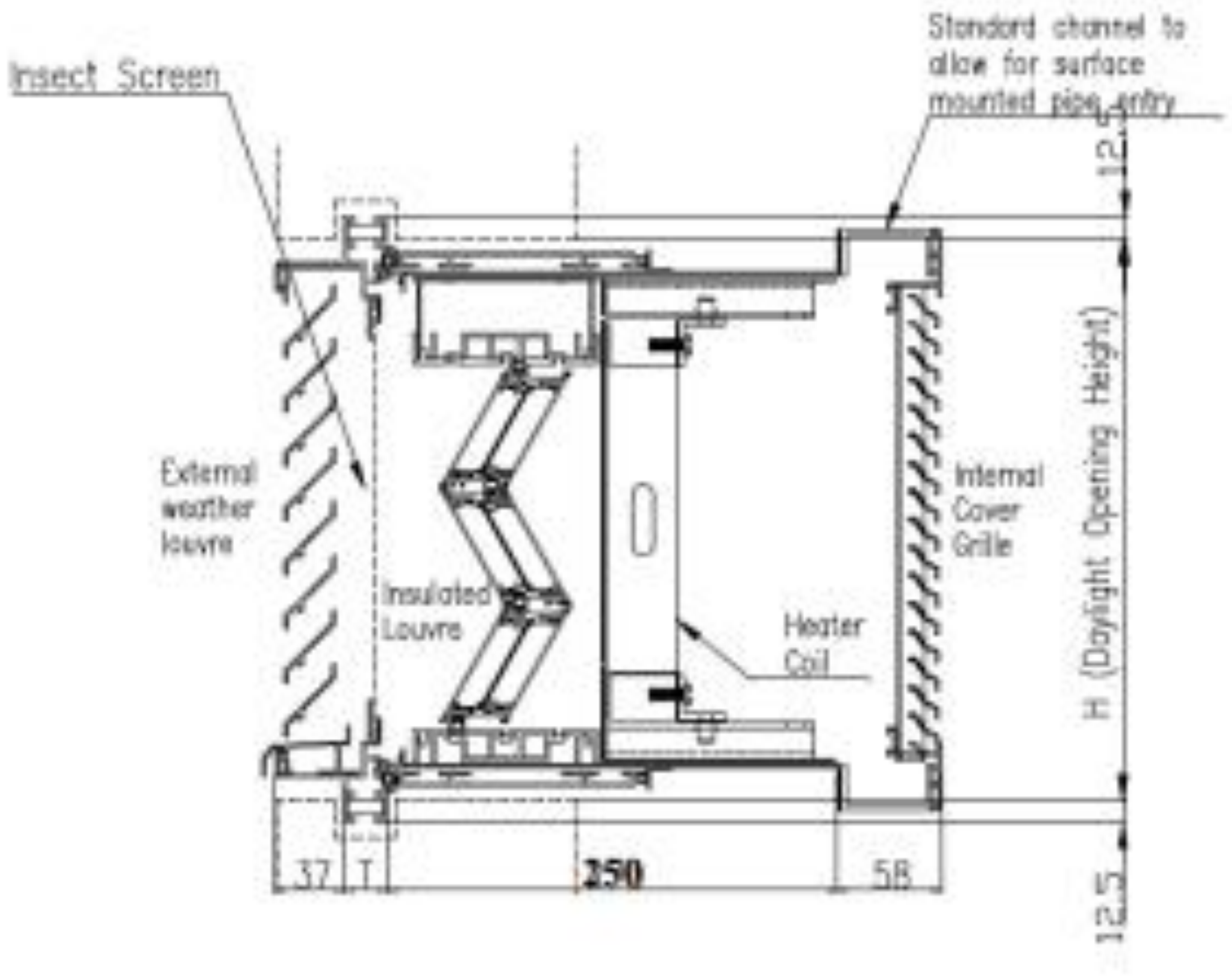
Not critical spaces such as theatres, ITU, Imaging, Endoscopy, treatment rooms etc.

Balfour hospital Orkney

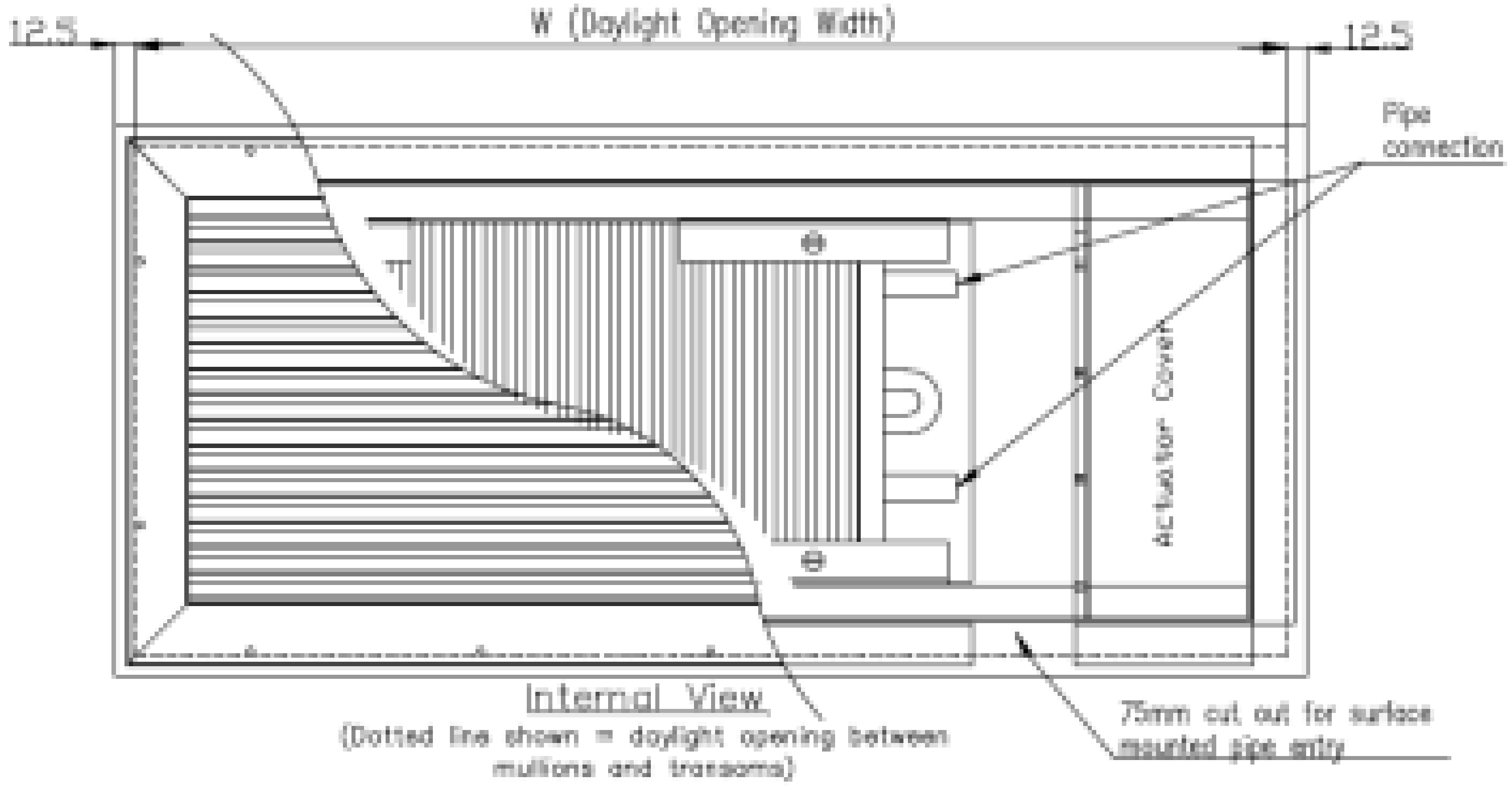
- Patient bedrooms have louvers on the outside with opening windows on the inside
- Allows patients to have the window open as much as they like
- In 2020 – comments made at the hospital were – people here are hardy and are used to windy & cold conditions
- Can this work in an urban densely populated city with traffic pollution?



Side View



Front View
(wall opening shown dotted)



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What are we trying to achieve with natural ventilation

- **Supply of fresh and wholesome air – the oxygen to breath**
- **Removal of contaminants – the carbon dioxide we exhale**
- **Dilution of odours**
- **Dilute airborne infections – Infection Control**
- **Comfortable temperature for patients and staff**
- **Consistency of supply and extract ventilation**

What are we trying to achieve with mechanical ventilation

Ventilate critical areas with sufficient airflow to: -

- Control the spread of infection
- Provide hierarchy of control via pressure cascade
- High air change rates to dilute bacteria
- Create both positive and negative isolation facilities for immune compromised and infected patients respectively
- Comfort for patients and staff
- Control temperature/humidity within high tech imaging environments such as CT and MRI

What are the problems with mechanical ventilation

- Expensive to install
- Expensive to run even before recent energy cost have risen
- Expensive to maintain
- Still a considerable amount of old equipment throughout the NHS
- There is room for improving some old equipment by replacing inefficient belt driven fans with EC fan walls and inverter driven plug fans

What are the problems with natural ventilation

- Can’t just rely on opening windows – due to restrictors
- Who opens and closes the windows?
- External contaminants such as PM_{10} and $PM_{2.5}$
- External airflow is variable and not consistent
- Airflow can reverse in some cases dependent on the weather both thermal and wind
- Lots of old windows screwed closed rather than fixed or replaced
- Many locations with NV unsuitable for AGP and introduction of fallow time reducing number of procedures
- Misconception about ACH – October 2022 IPC person quoted in VSG that rooms with natural ventilation have 5-6 ACH

What are the problems with natural ventilation the Covid 19 Factor

- Ventilation was established as a key method in controlling spread of the virus
- Covid 19 areas needed to be negative to surrounding areas
- Non Covid 19 areas positive to Covid 19 areas
- Isolation facilities are required
- Lots of face to face consultations lost and still not recovered to pre Covid 19 levels
- Many consultation rooms naturally ventilated

One NHS Trust asked should we convert all natural ventilation to mechanical ?

- Review of airflows and ACH in all non critical mechanically and naturally ventilated areas
- Lots of room volumes with no airflow measurements – inability to simply measure natural ventilation and assess ACH
- CO_2 can be measured but doesn't tell us the air change rate only there if there is enough oxygen

Their overview of ventilation at one hospital

General wards

The layout is generic to most wards, each having its own Heat Recovery Unit (HRU) for local supply and extract and dirty extract (for En-suites).

Single bedroom with En-suite

Natural ventilation is provided via an Acoustic Trickle Vent over the window, there is no direct mechanical ventilation to the room. The En-suite has PIR to detect occupancy and dirty air is extracted via an Air Terminal Unit (grille), this is linked to the dirty extract fan with setback damper that closes, following a period of non-occupancy.

Four Bedroom with En-suite

Natural ventilation is provided via an Acoustic Trickle Vent over the windows plus mechanical ventilation supplying fresh heated air through ductwork from a local Heat Recovery Unit (HRU). The En-suite has PIR to detect occupancy and air is extracted via an Air Terminal Unit (grille), this is linked to the dirty extract fan with setback damper that closes following a period of non-occupancy

Pros and cons of natural and mechanical ventilation

Pros	Cons
Natural (simple open window)	
• Inexpensive to install	• Little or no help in controlling spread of airborne infection between patients
• Inexpensive to run	• No ability to chill in summer but room heaters can be used in winter
• Provides some dilution	• Restriction on how far into a room the effectiveness of air supply is
• Ability to open a window in some cases helping to improve feeling of wellbeing	• Summer temperatures may be on the increase due to more frequent hot weather events as a result of the climate change effect.
• Little maintenance required	• Difficult to measure • ACH < 6 and not consistent
Mechanical	
• Provided airflow to meet room use requirements and consistent ACH	• Required detailed design
• Temperature control in both summer and winter	• Expensive to install
• Chilled wards can prevent older people suffering from overheating	• Expensive to run (both ventilation and chilling use energy and currently energy costs are increasing at unsustainable rates)
• Used for infection control with positive and negative pressure rooms. (Hierarchy of control)	• Maintenance required
• Adapted to help in Covid -19 situations	• Retrospective installation requires space to be taken out of use for extended period of time
• Provided greater flexibility on use of space	• Space required for AHU plant
• Controllable from a BMS	• Electrical supply – may need upgrading for additional load • Chilled water supply required , or • DX cooling coils and chiller units

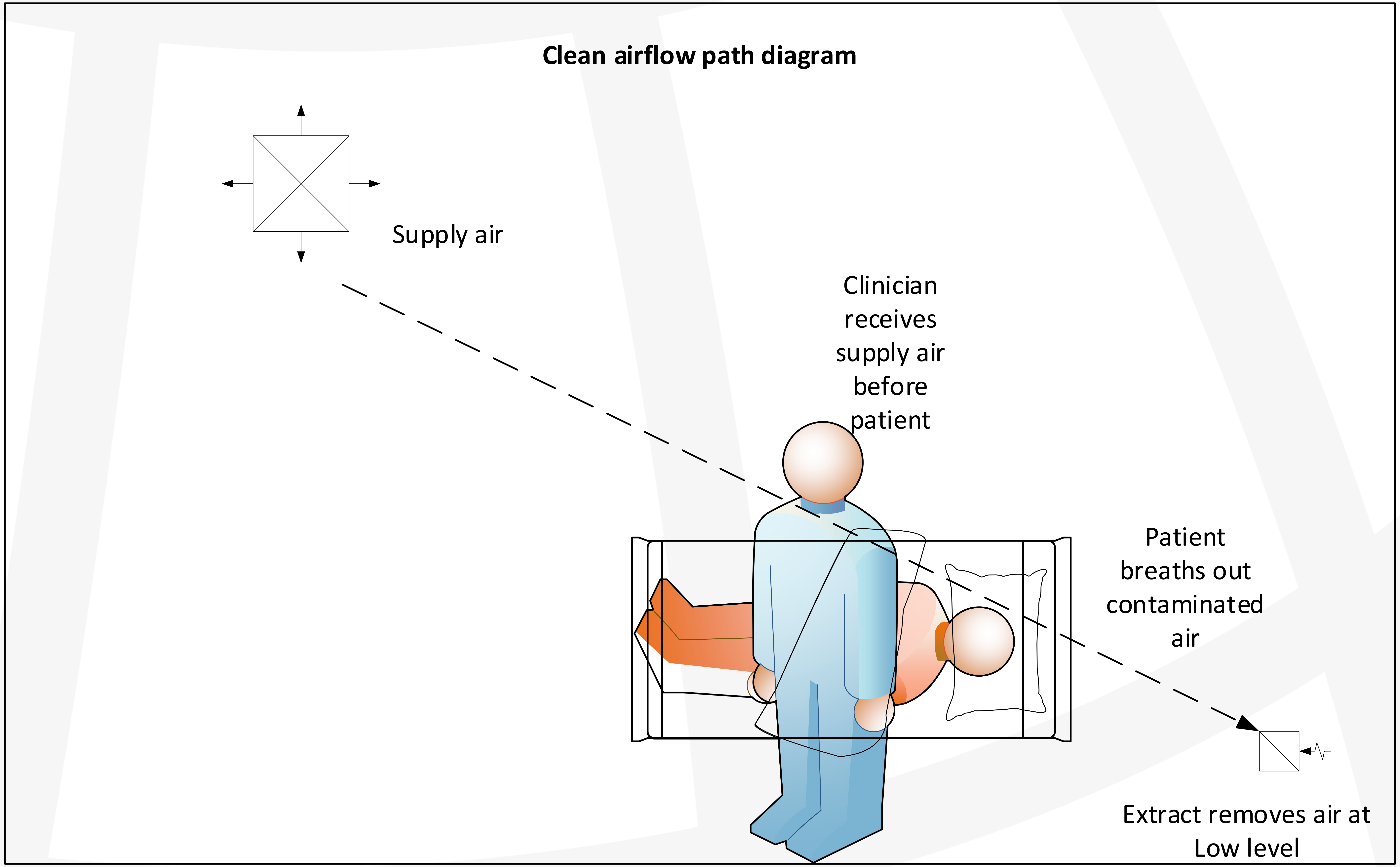
NHS Trust assessment of general ward areas at their 8 sites

Site	General wards 6 air changes per hour	Comment
A		System design is combination of mechanical and natural ventilation, incorporating use of trickle supply vents, Heat Recovery and Air Handling Units for supply and extract, and common extract systems
B		Base site redevelopment project will deliver in scope wards to meet current HTM standards. General ward spaces currently not meeting 6 a/c
C		Air changes range between 0.7 – 1.2 a/c in line with original design (1992)
D		Ventilation installed 1983, delivering between 0.6 – 6 a/c (6 in treatment rooms as per original design, ward bays designed to meet 2.5)
E		Infrastructure upgraded as part of ward refurbishment in 2022 to comply with current HTM in bedded bays.
F		Naturally ventilated - no mechanical ventilation installed
G		Infrastructure is currently being upgraded as part of ward refurbishment to comply with current HTM.
H		Installed 2003 (phase 1) 2005 (phase 3) delivering between 0.7 – 1.2 a/c as per design

What was recommended

- It cant be done
- Disruption too great in live hospitals
- Infrastructure not suitable for upgrades across the estate where is the ductwork and the AHUs being located
- Upgrade projects on as and when basis but try and make the better – spend a bit more
- Repair damaged windows allowing them to open

At one of the same Trust's sites which has recently had a ward upgrade with mechanical ventilation including clean airflow paths. The Trust's IPC nurse reported that they have had a Covid outbreak. Normally that would have spread through the whole ward area but it is currently confined to one small location and their initial thoughts were, the new ventilation system with the clean airflow paths for each bed space had prevented the outbreak from spreading.



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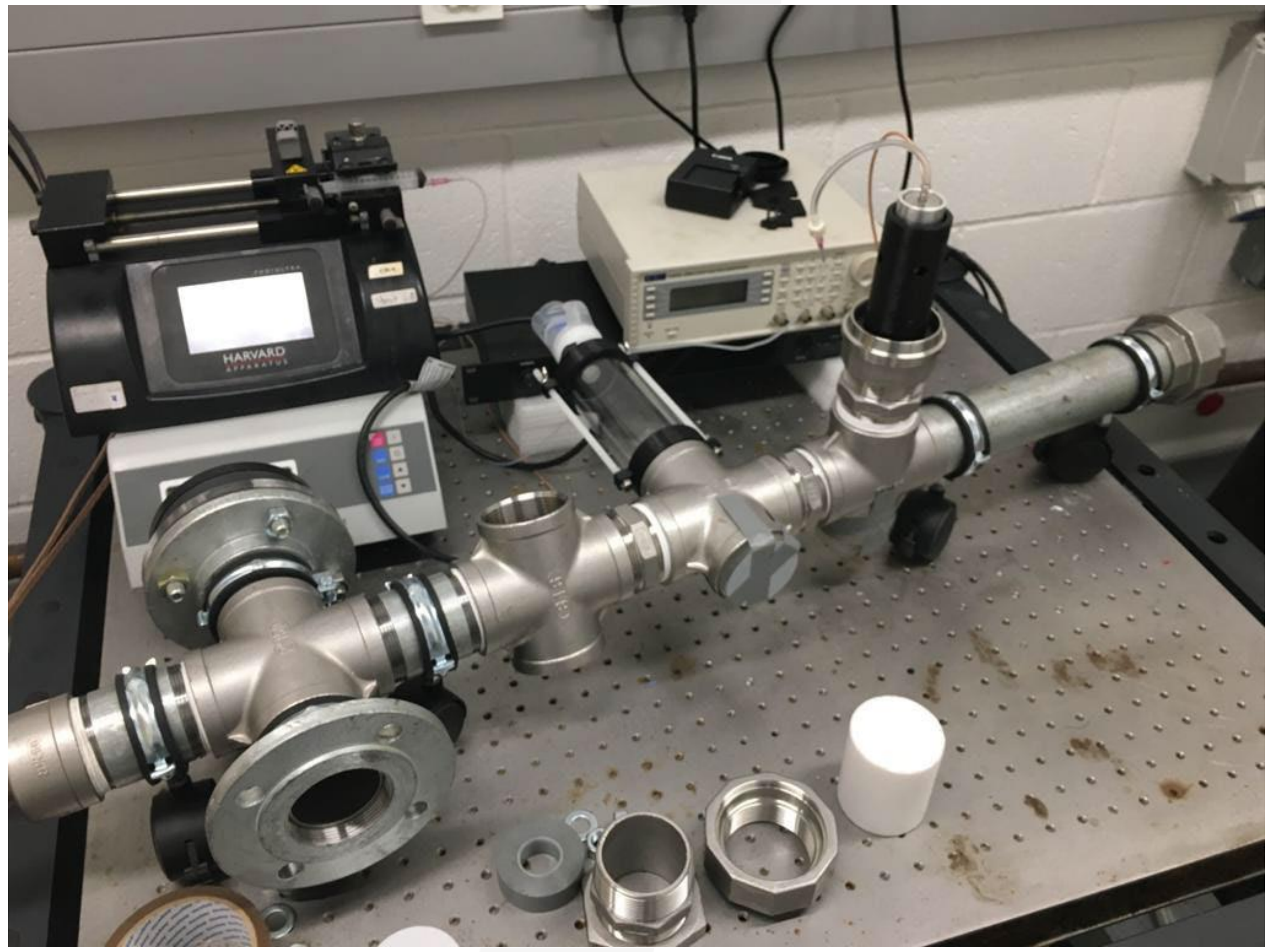
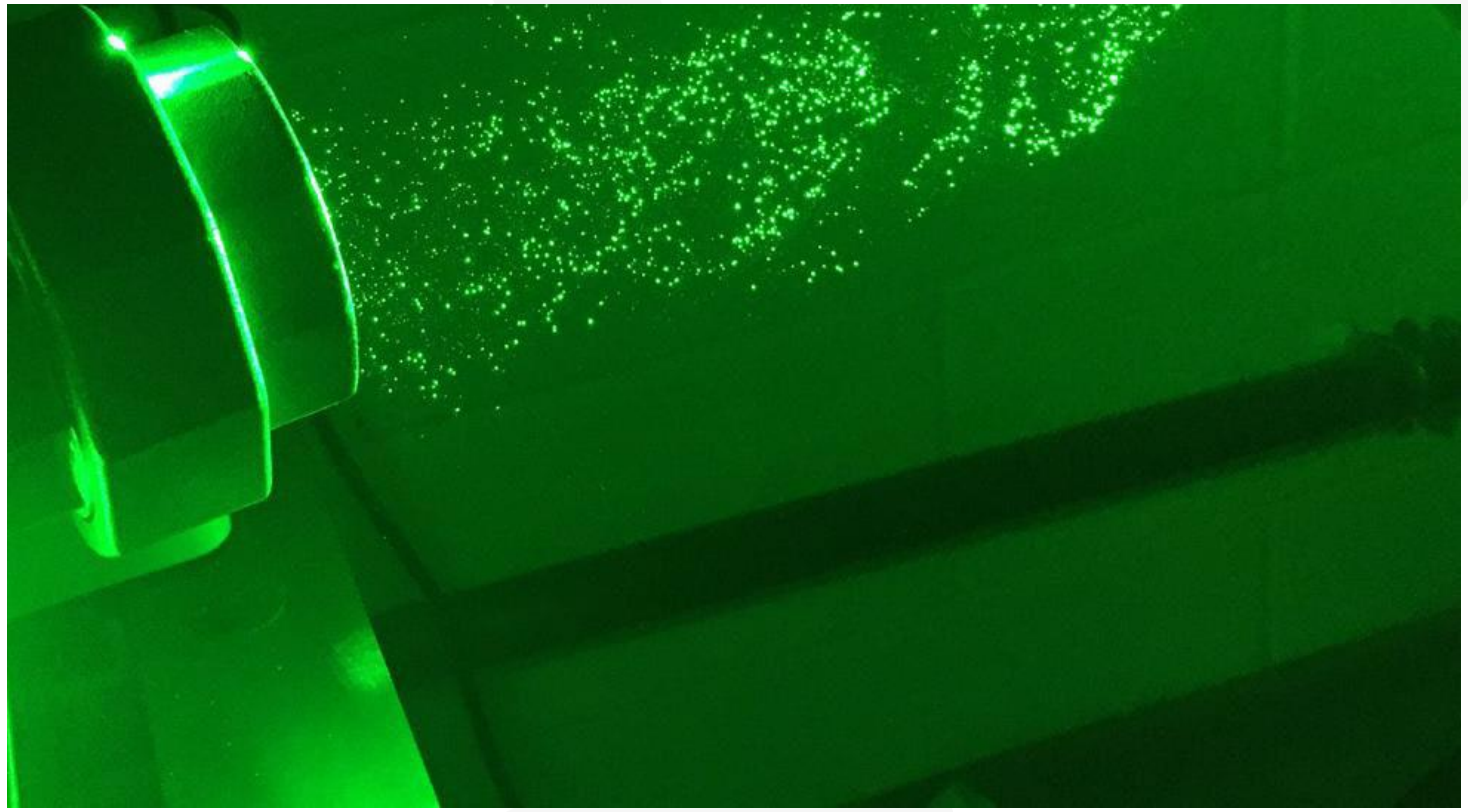
The UCLH SAFE AIR Study

UCL Study Team Scientists/Engineers working with UCLH Clinicians carrying out research into effective ways of making unventilated rooms available for clinical use in order to get face to face consultations back to pre Covid 19 numbers. Additionally reducing downtime between procedures in ENT Gastroenterology and Dental procedure rooms

The UCLH SAFE AIR Study

Virtual Human Exhalation Replicator
(VALUATOR)





Images courtesy of UCL

The UCLH SAFE AIR Study

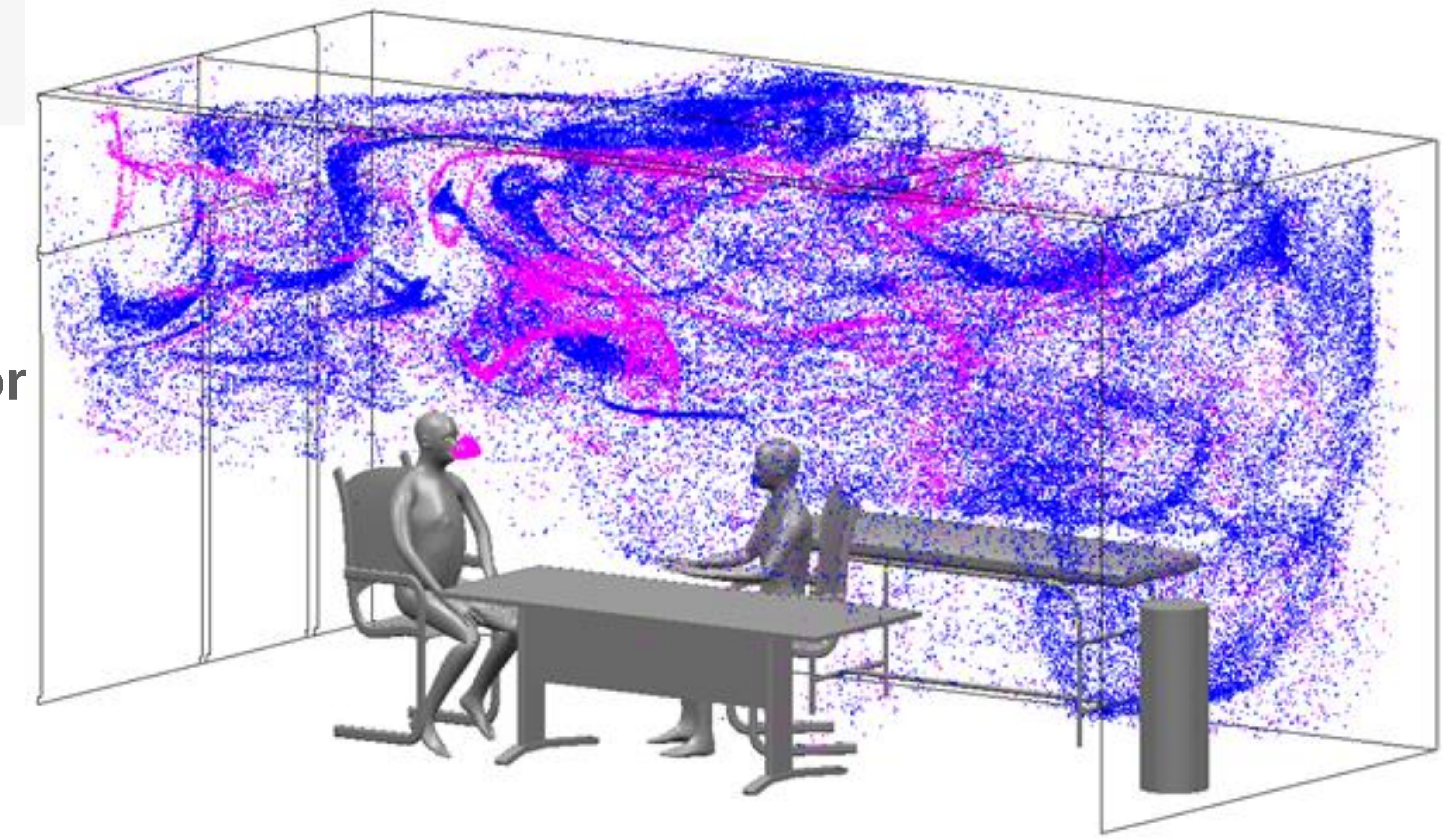
Images courtesy of UCL

Consulting room in NHNN UCLH

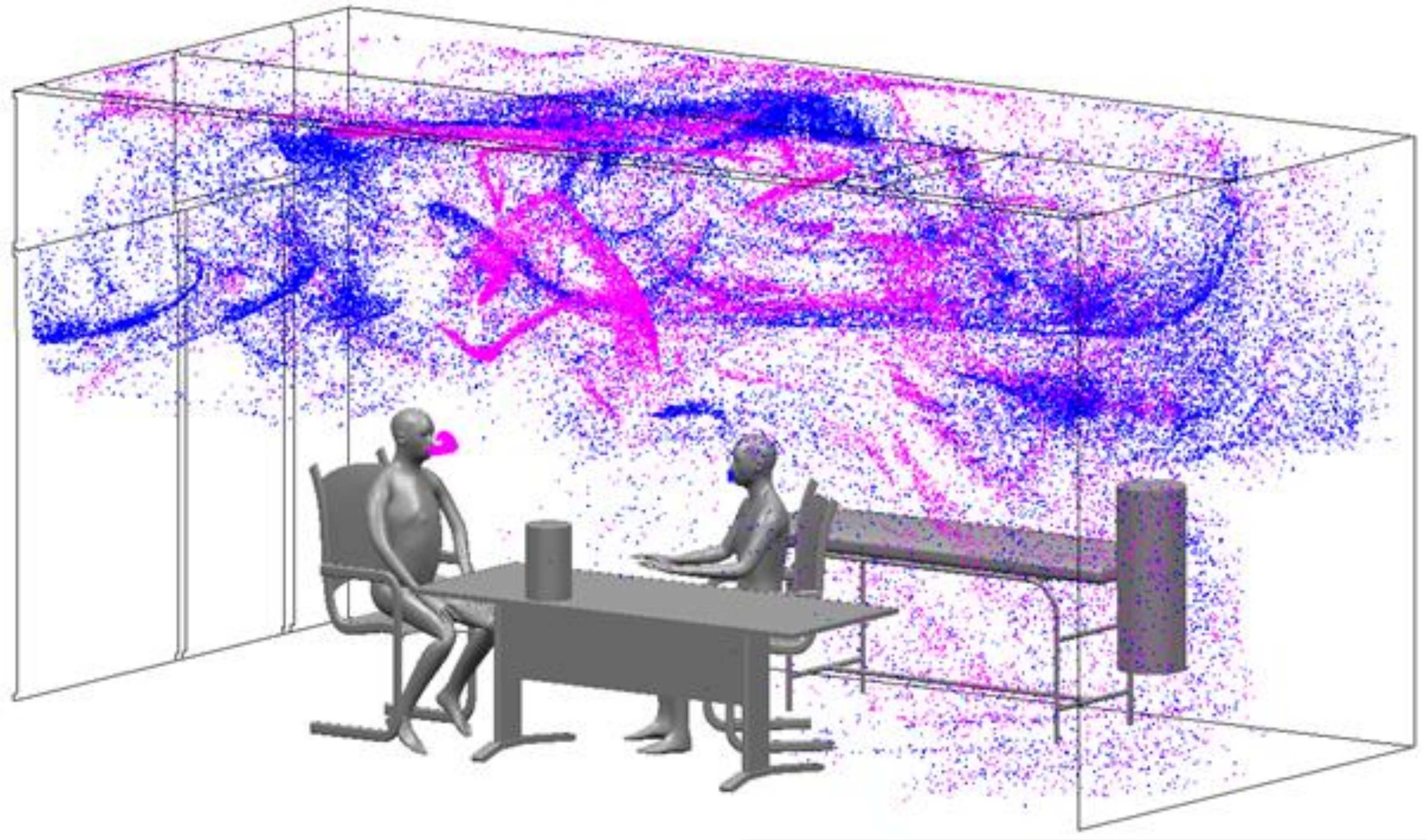
Images courtesy of UCL

Images courtesy of UCL

Air purifier I on the floor

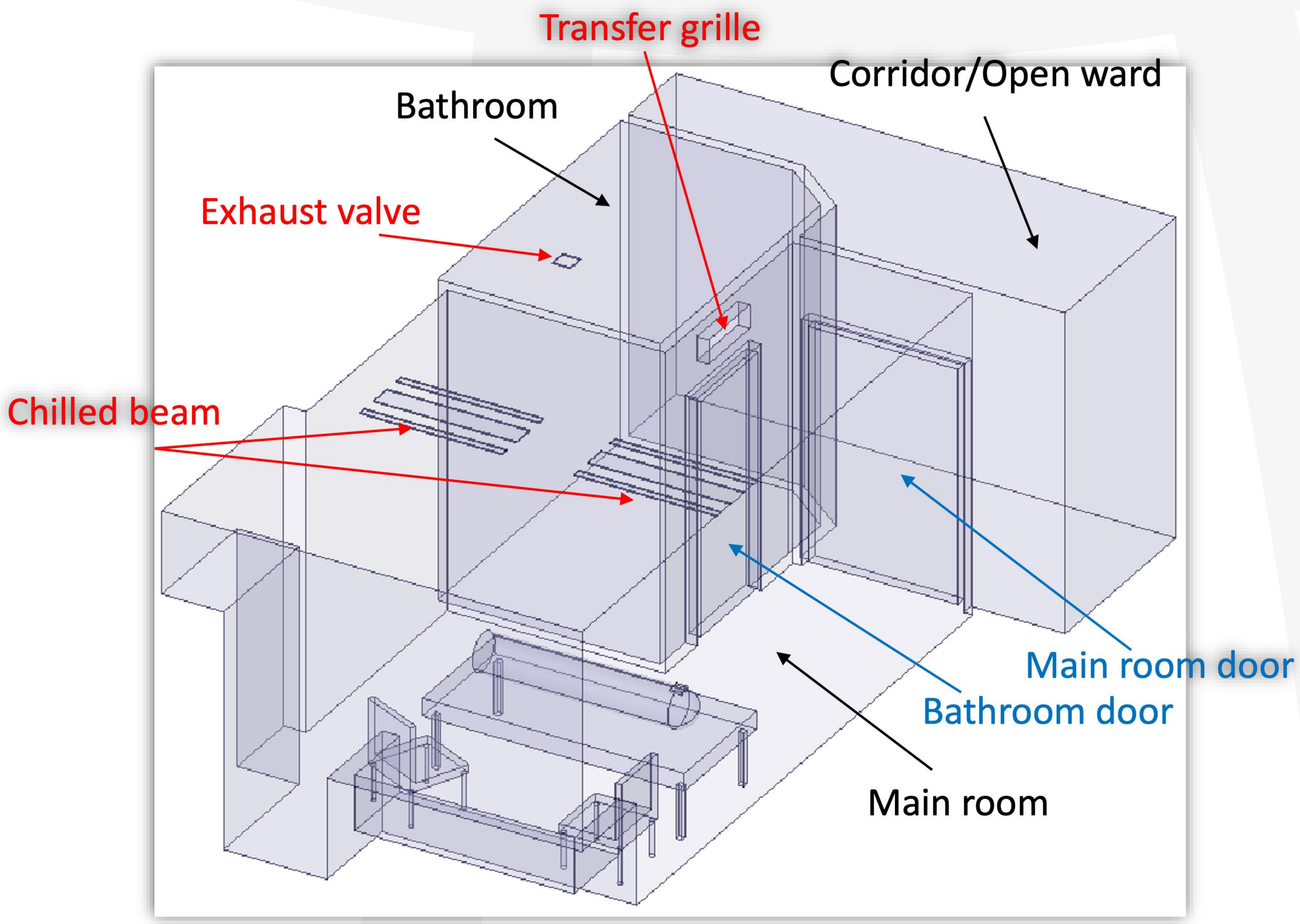


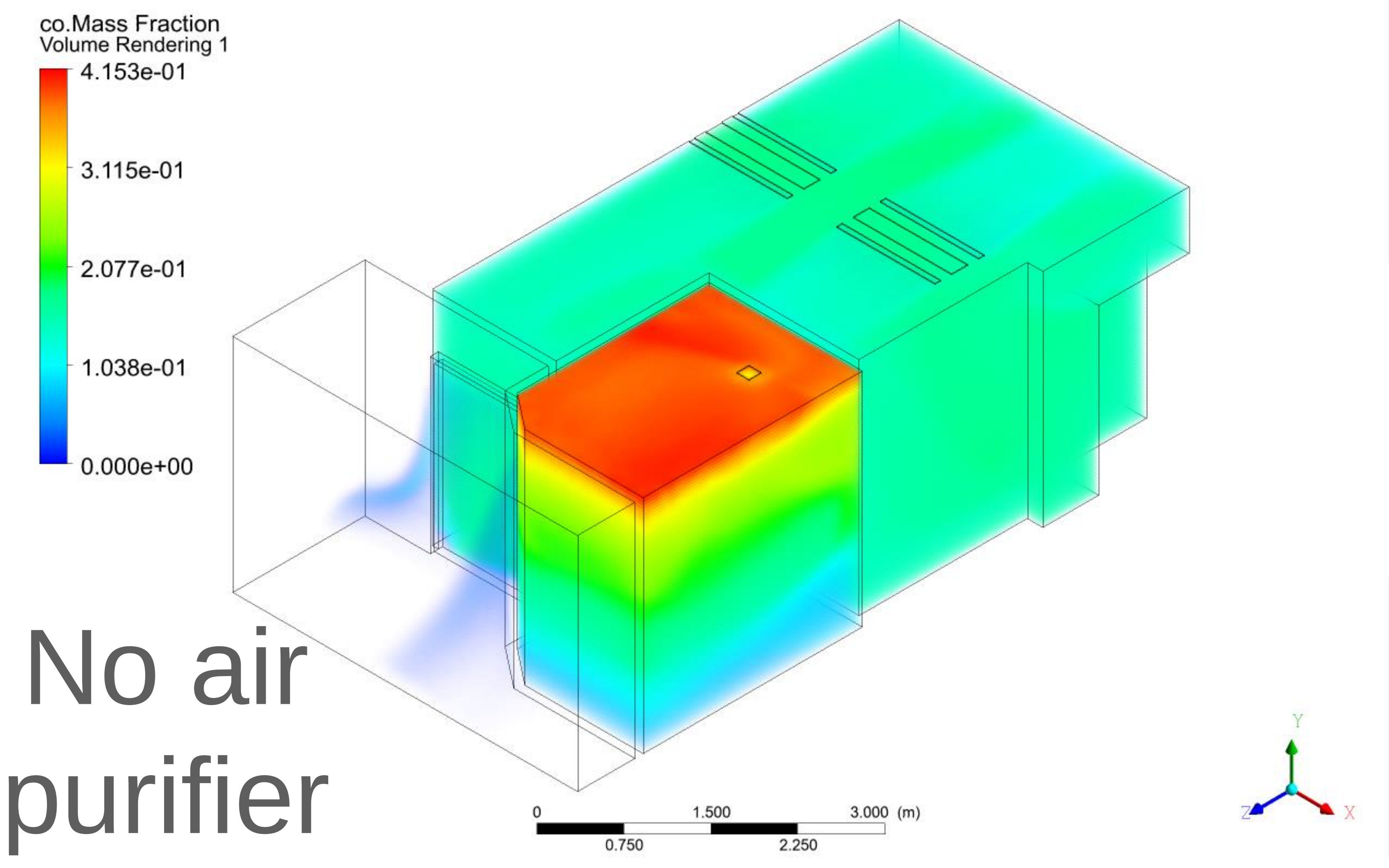
Air purifier I (0.5 m above floor) + II (desk)



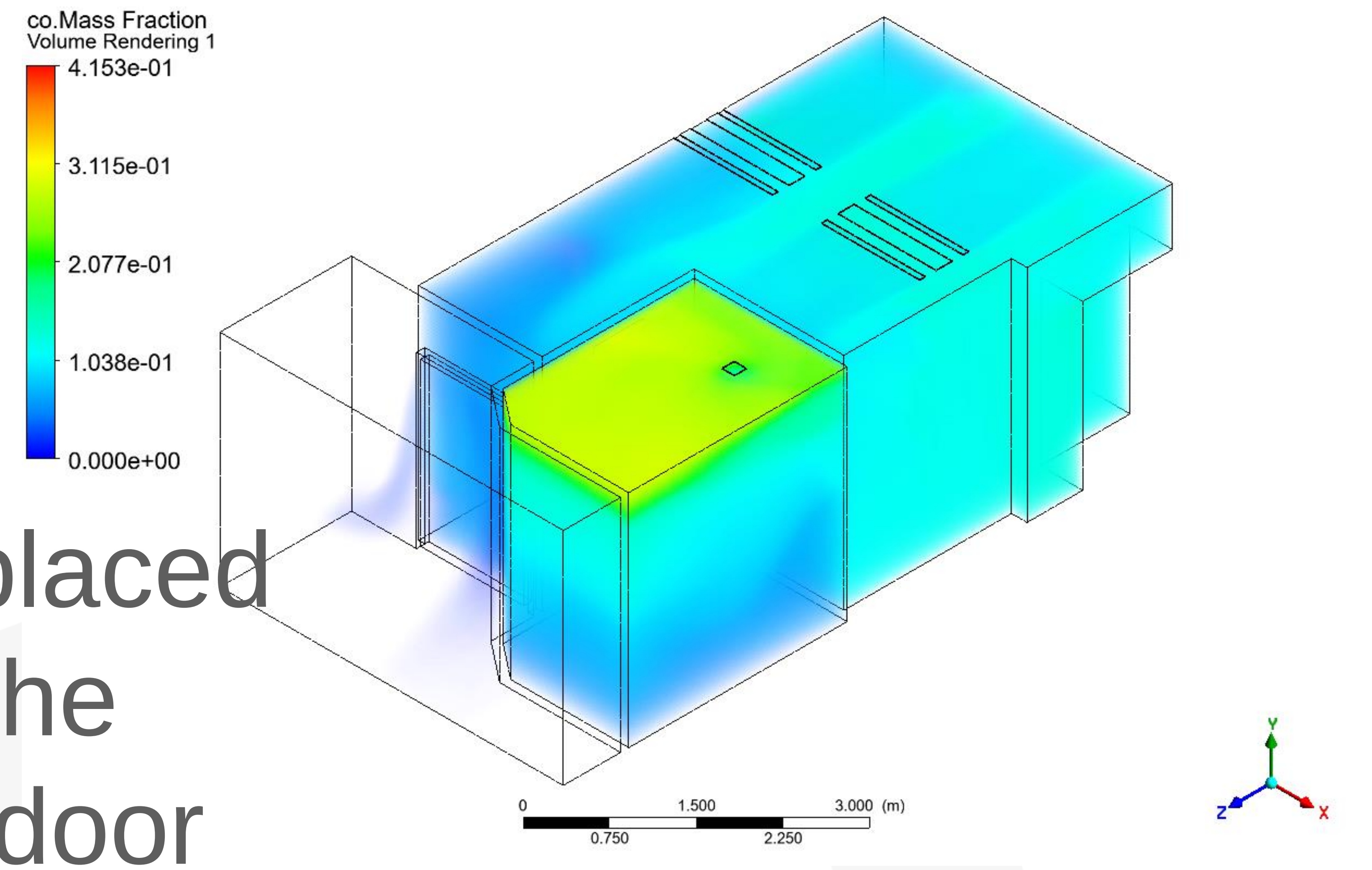
Single-bed ward

Slide courtesy of UCL





No air purifier



Air purifier placed outside the bathroom door

Could mix mode be a partial answer ?

- Natural ventilation may not be the panacea to the net zero –carbon reduction we need and want to achieve however
- Mixed mode may be a partial answer to helping us along the way
- Natural ventilation with mechanical fan assistance to get air in or out via a spine or central duct. Not all ventilation via AHUs.
- Assisting the natural stack effect with thermal gain from people and equipment to assist up draught
- This would need suitable building size and space for ductwork – Space required which is always at a premium and often gets value engineered out
- Due to the lack of opening windows sufficiently there may be a need for damper controlled louvres to allow air into the building,
- Not all incoming air is good enough and would need to be filtered or risk bringing pollution into the building
- Incoming air would need to be tempered and the system would need to be capable of dealing with changes in outside air temperature
- Service space may be required for some future proofing to allow changes

Some thoughts

- Every year Huge amount of money spent on ventilation systems both in upgrades new builds
- Should the NHS spend money on research to review ventilation ideas, test the viable options in full scale mock up
- NHS power cost of ventilation vs research into how alternative methods can safely cut power consumption
- Do procurement help or hinder – writing of guidance for example
- We haven’t got the answers
- We have got a lot of talented engineers/scientists in healthcare, wider industry and academia
- We have experience of what works well and what doesn’t work at all.
- Fully naturally ventilated hospitals have been considered in the past, but not happened here
- Backdrop of NHS UK energy costs heading to £1.2 Billion
- Maybe its time to rethink how we go forward

- Thank You -

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