School of Civil Engineering
FACULTY OF ENGINEERING

UNIVERSITY OF LEEDS

Controlling IAQ through Ventilation Design

Professor Cath Noakes **CEng, FIHEEM, FIMechE**

June 2018

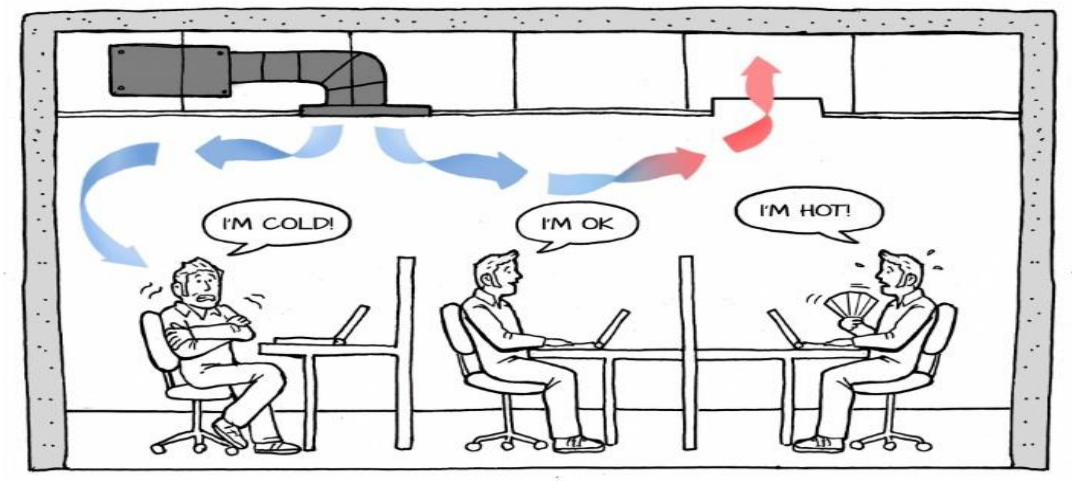
Are you sitting comfortably?

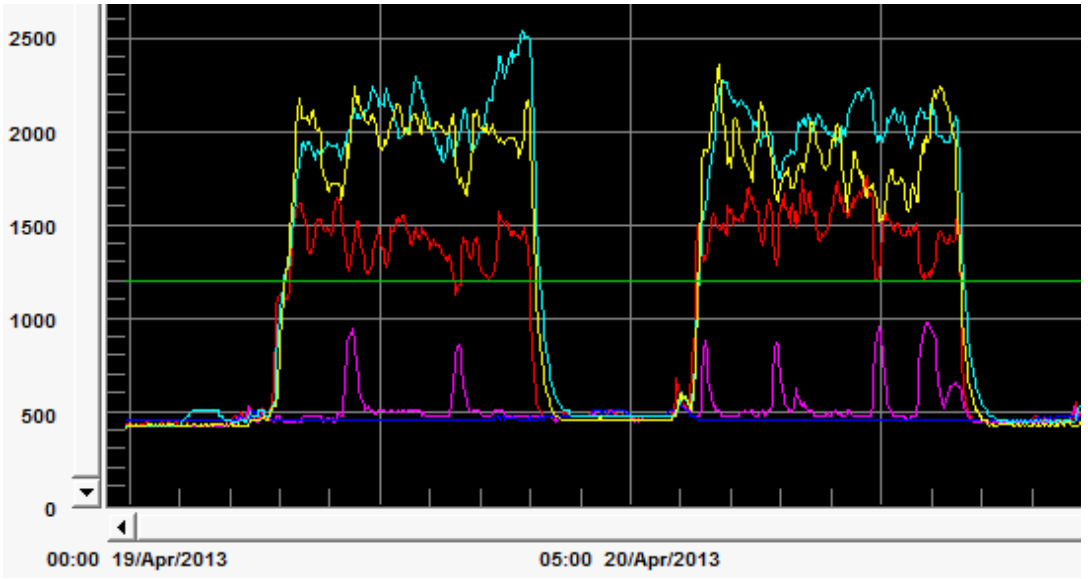
UNIVERSITY OF LEEDS

- Are you hot or cold?
- Can you feel a draught?
- What is the air quality like?
- Who is in the room, who are you sitting next to?

The problem with people

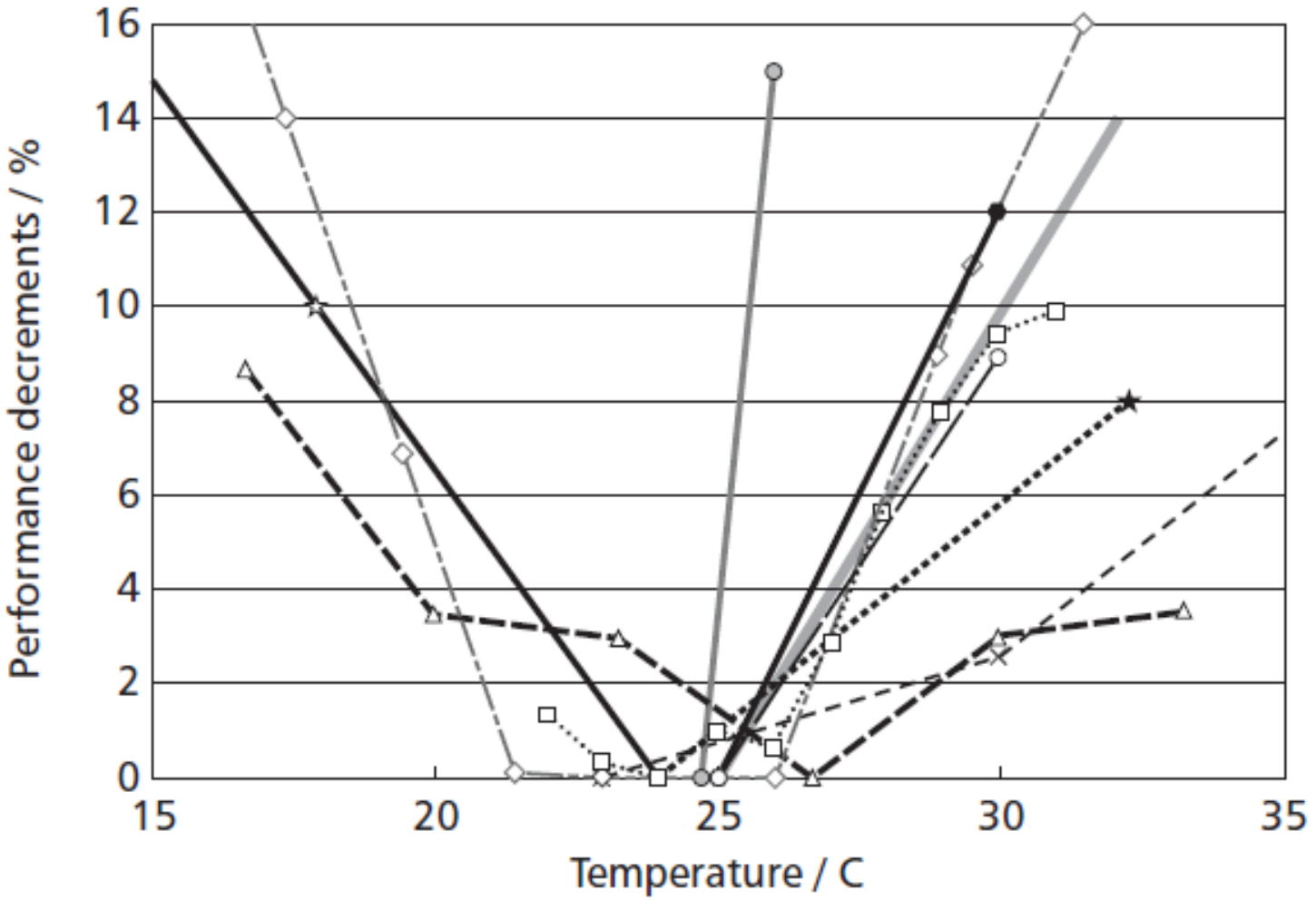
- The primary reason for ventilation
- Variable needs – within and between individuals
- A poor sampler
- Two way connection with indoor air





What does the air do to us?

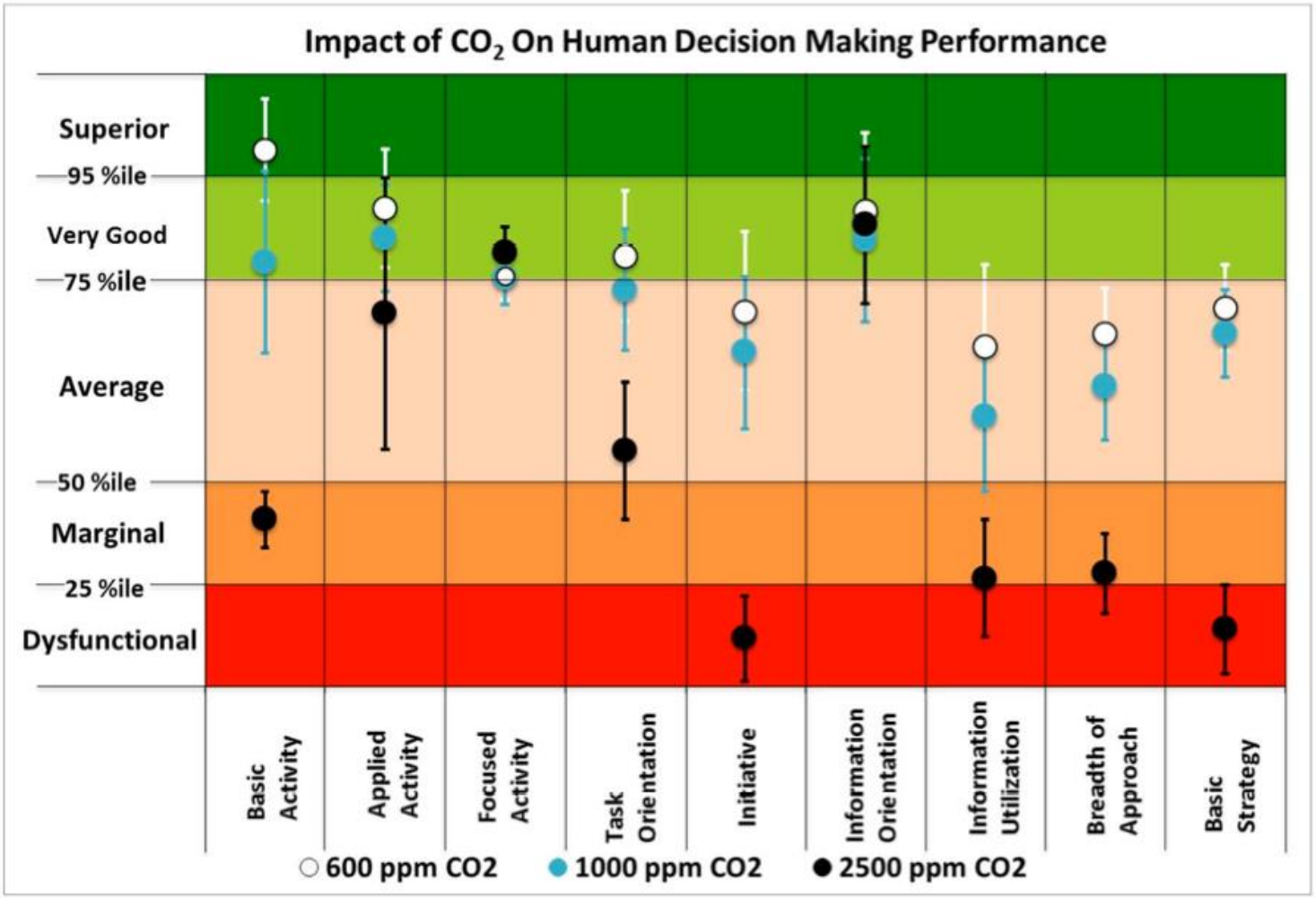
UNIVERSITY OF LEEDS



Performance vs temperature: CIBSE Guide A, 2006

What does the air do to us?

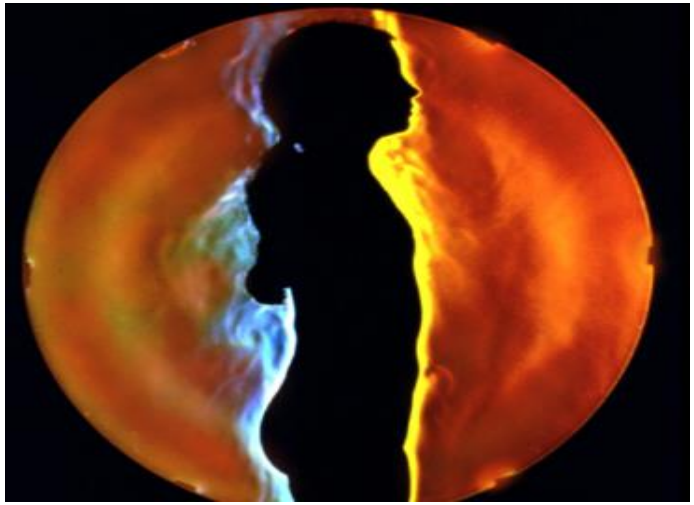
UNIVERSITY OF LEEDS



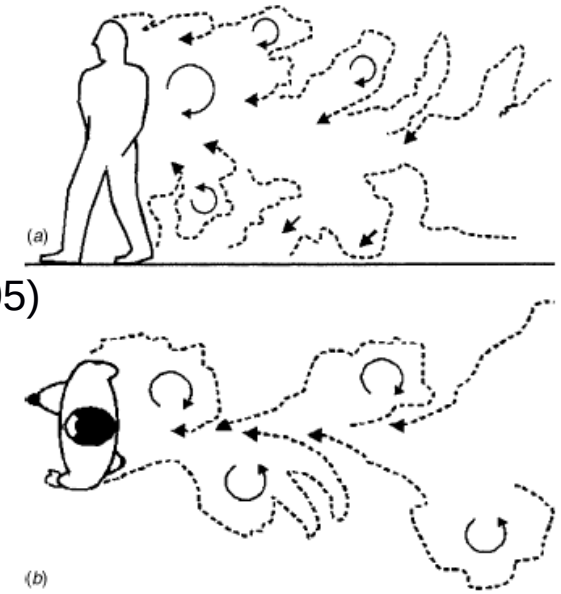
Fisk, William J., Usha Satish, Mark J. Mendell, Toshifumi Hotchi, and Douglas P. Sullivan. "Is CO_2 an Indoor Pollutant? Higher Levels of CO_2 May Diminish Decision Making Performance." *ASHRAE Journal* 55, no. 3 (2013): 84-85.

What do we do to the air?

UNIVERSITY OF LEEDS



G Settles, Penn State



(B. Edge et al., 2005)

J. Fluids Eng.

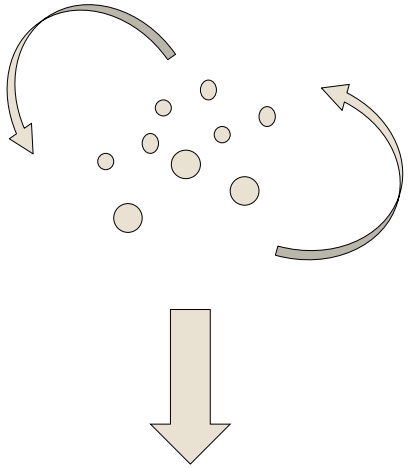
- Heat source – create convection currents
- Movement – turbulence
- Breathing – introduce contaminants
- Behaviour – change settings and flows

Airborne Infection

UNIVERSITY OF LEEDS

Source characteristics

CDC, USA



Transport and deposition

Exposure

Tang J et al. *J Hosp Infect* 2006; **64:** 100-11

Disease characteristics

Human characteristics

Fluid Dynamics

Engineering component

Engineering Control

UNIVERSITY OF LEEDS

Reduce exposure to indoor and outdoor sources

Ventilation: Dilution, Air distribution, Pressure controls, Extraction, temperature and humidity

Technology: Filtration, air cleaning, decontamination, surface technology

Human behaviour: SMART buildings, prompt actions, prevent access

Human centred ventilation

- Traditional focus on ventilating the building – inefficient for energy and limited for IAQ
- What do people need?
  - Temperature, flow rate, air quality?
  - How do they change with time?
- How to bring into design
  - Tools and metrics that properly consider human
  - Performance of existing solutions
  - New technologies and design approaches

Ventilation strategies

- Global strategy
  - Natural – wind and/or buoyancy driven
  - Mechanical – simple extract fan to full air conditioning
  - Hybrid – Nat/Mech together or switching
- Air Distribution Approach
  - Mixing/dilution - aim to create a “fully mixed” room
  - Displacement – create a gradient with clean air supplied from floor or ceiling
  - Personalised – local supply for individuals
  - Local Extract Ventilation (LEV) – contaminant control

ReFresh Project

Explore the impact of urban microclimate on building ventilation for optimal performance of occupants.

University of Reading

UNIVERSITY OF Southampton

UNIVERSITY OF LEEDS

Impact of built environment on airflow into buildings

Human cognitive response to static and transient indoor conditions

Present data relating building and person co-interaction

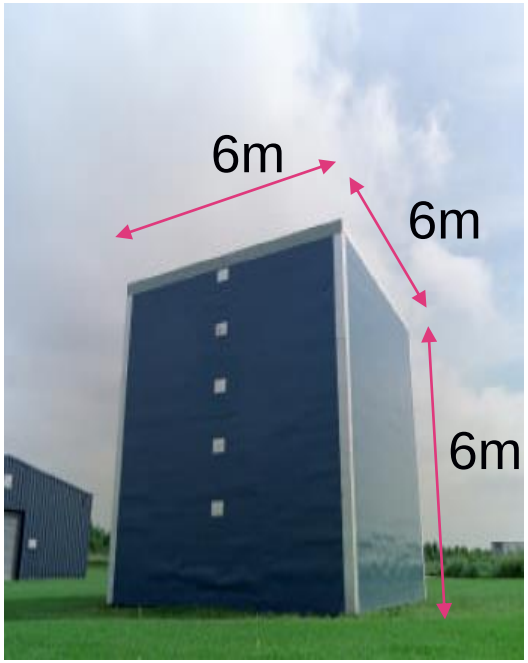
EPSRC

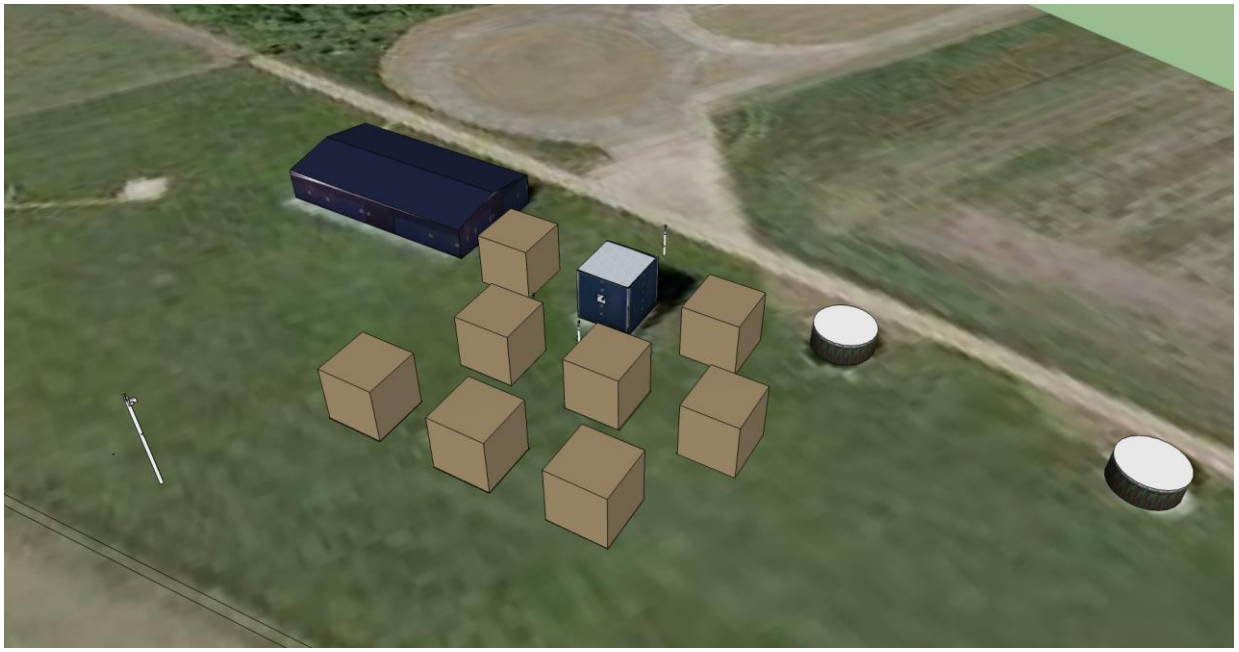
Engineering and Physical Sciences Research Council

Urban Natural Ventilation

UNIVERSITY OF LEEDS

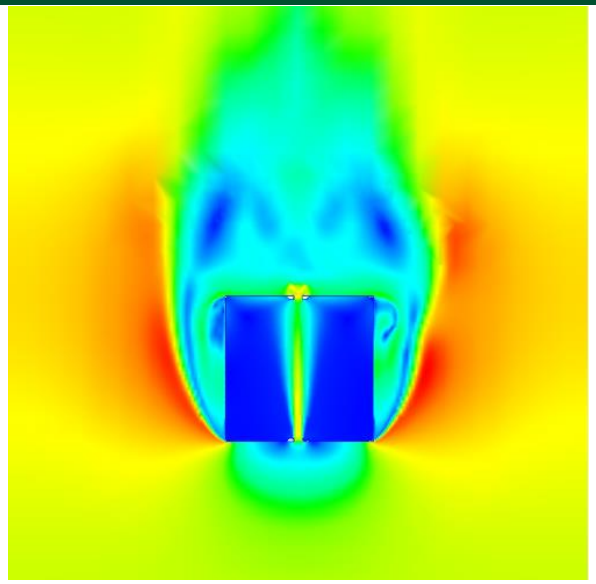
6m cube, Silsoe, Bedford, UK



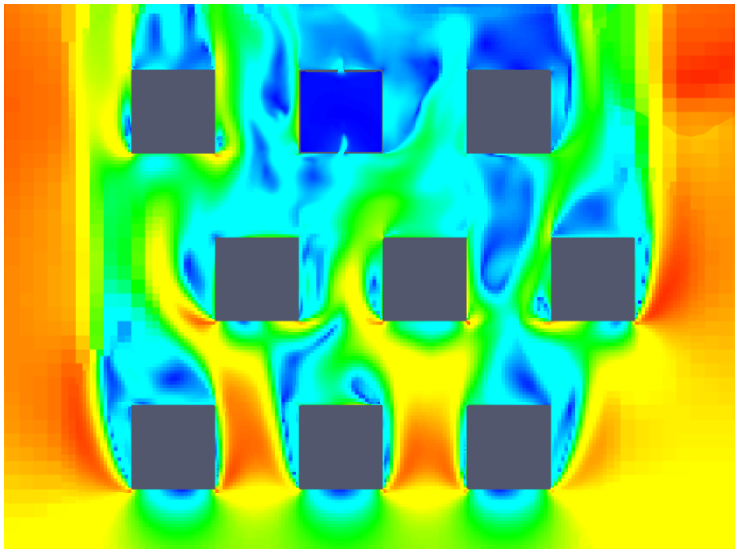


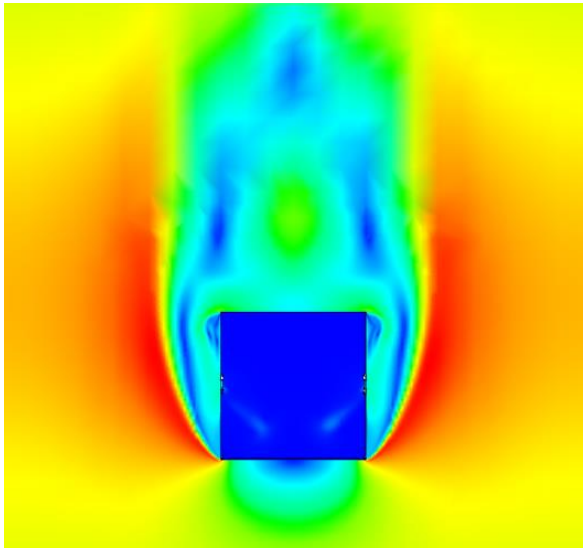
- Quantitive benchmark - ANSYS Fluent vs OpenFoam
- Exp + CFD to explore isolated vs array
- Outdoor and Indoor Flows

Flow patterns

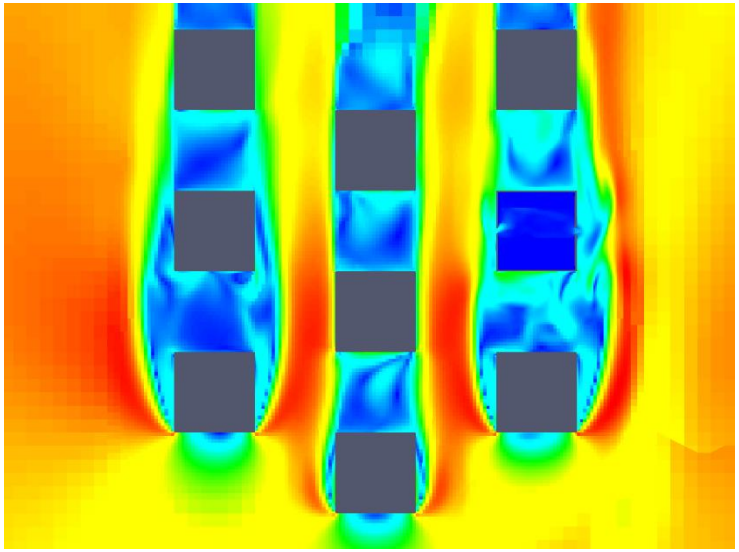


Wind normal
to window



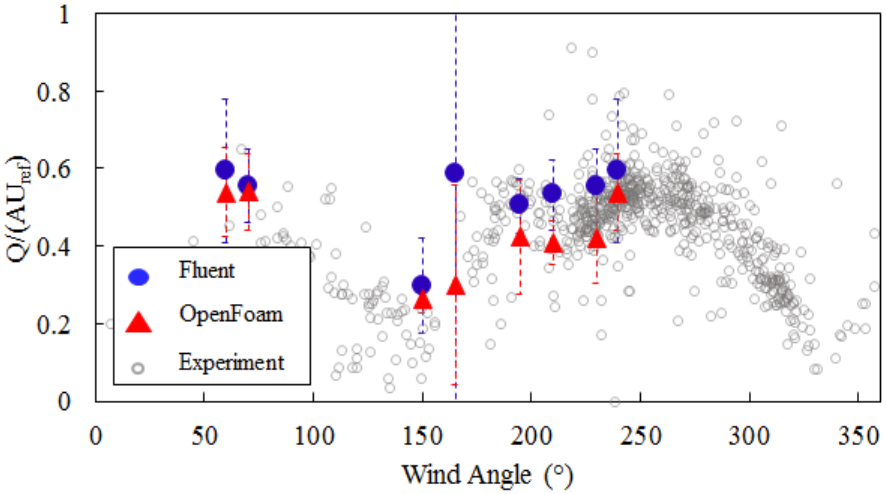


Wind parallel
to window

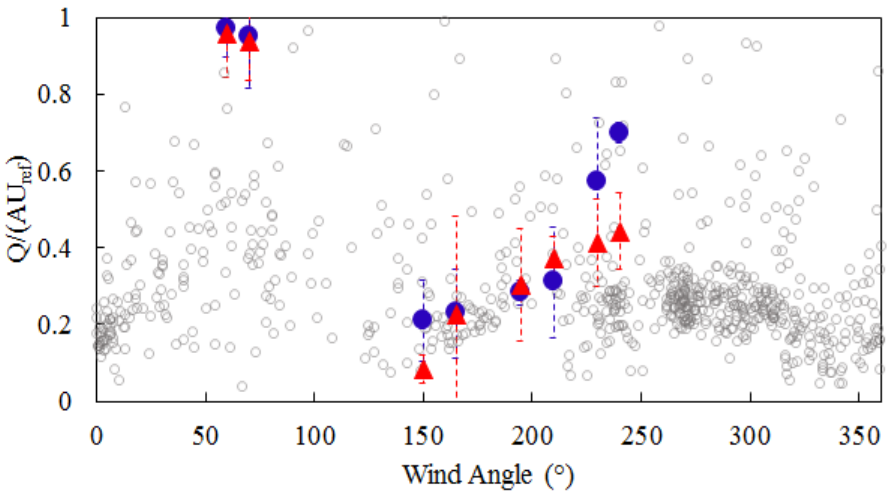


Ventilation Rate

- Isolated cube has higher ventilation rates, but more wind angle dependent
- Array smooths out variation but rates generally lower



a) Isolated cube cross-flow



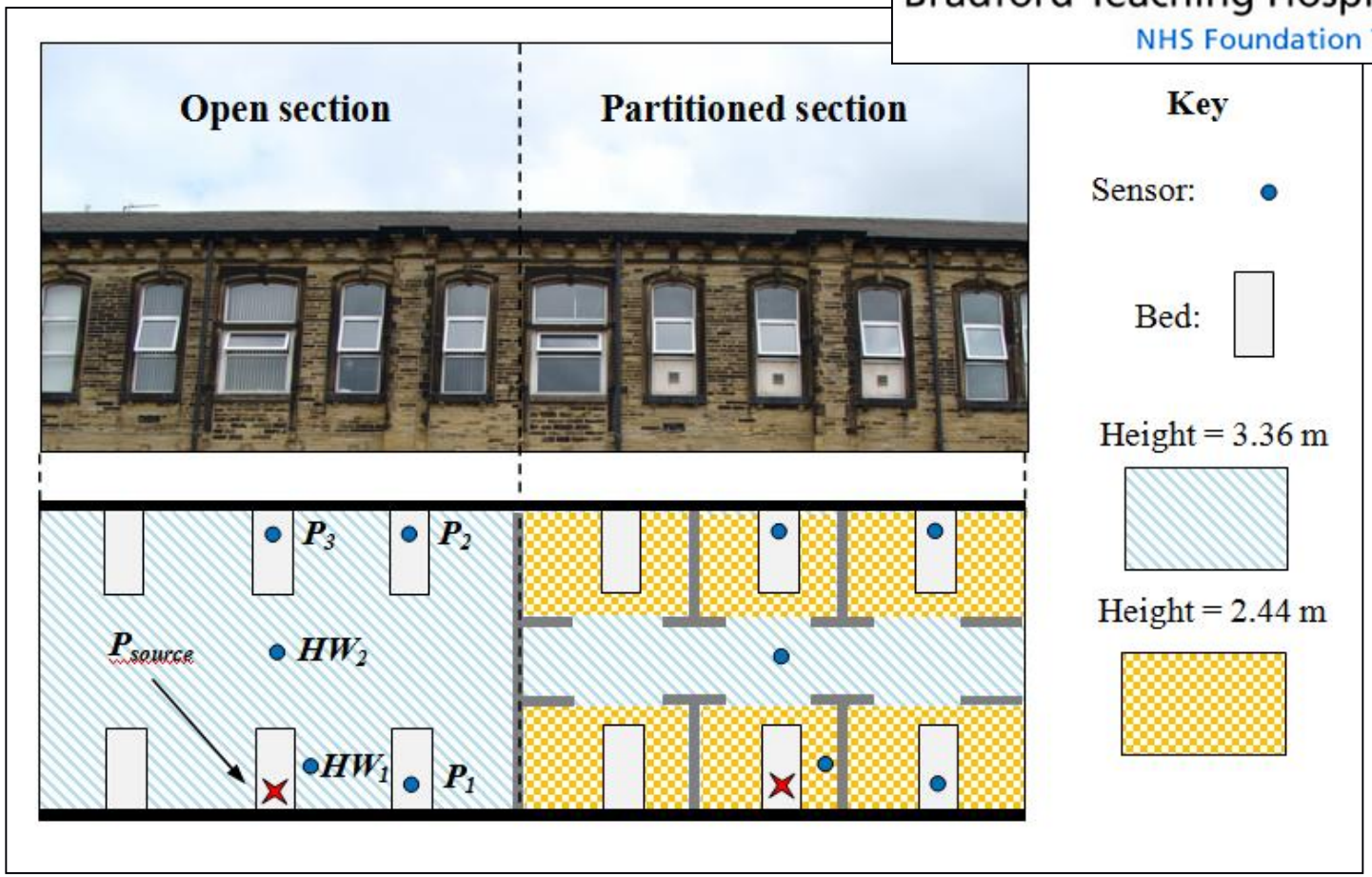
b) Array cross-flow

King M-F, Gough HL et al (2017) Investigating the influence of neighbouring structures on natural ventilation potential of a full-scale cubical building using time-dependent CFD, *Journal of Wind Engineering and Industrial Aerodynamics* 169:265-279

Indoor flow patterns

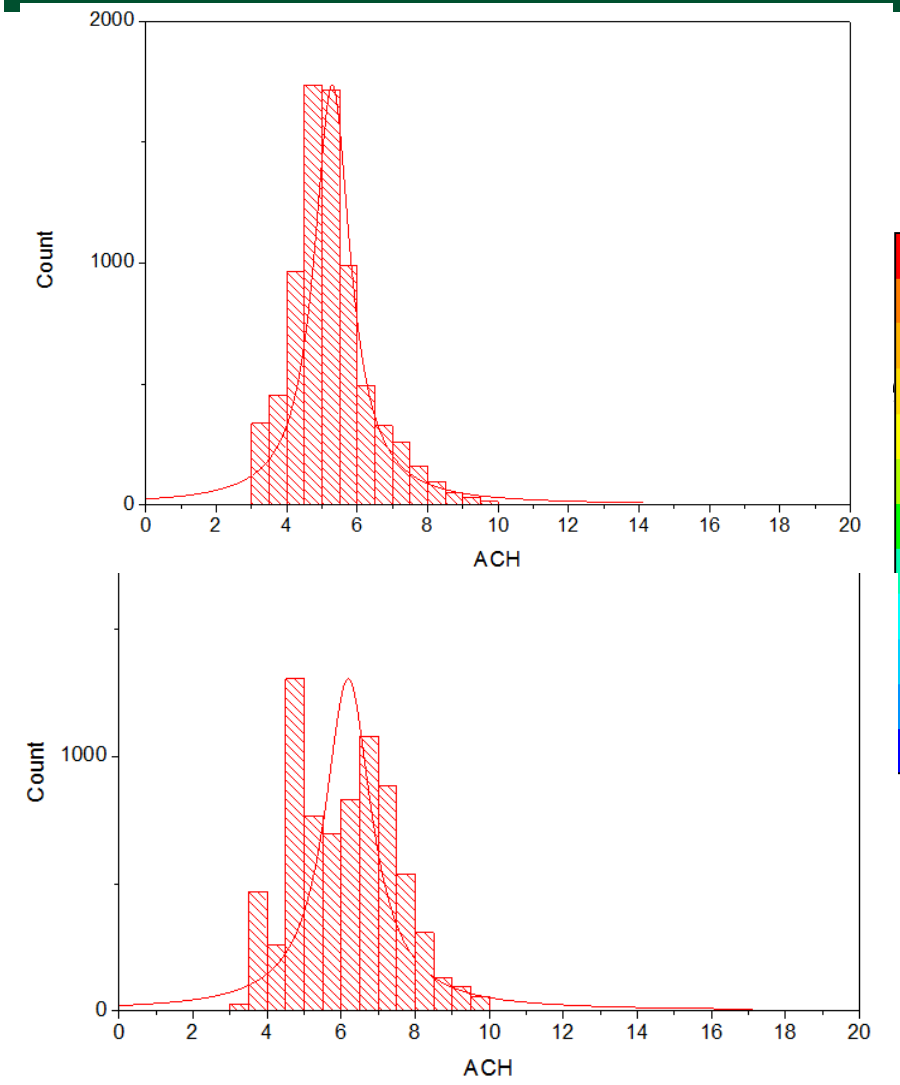
UNIVERSITY OF LEEDS

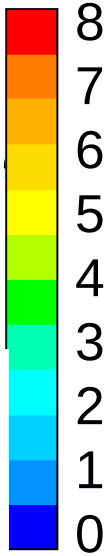
Bradford Teaching Hospitals NHS
NHS Foundation Trust

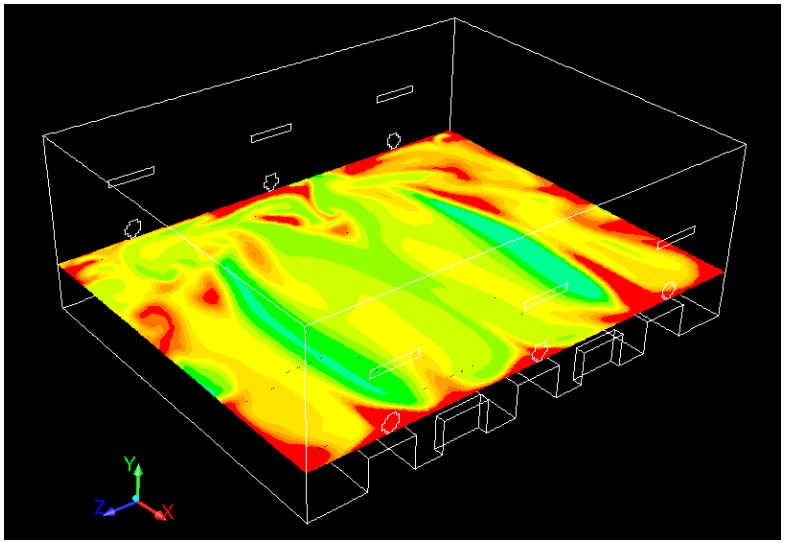


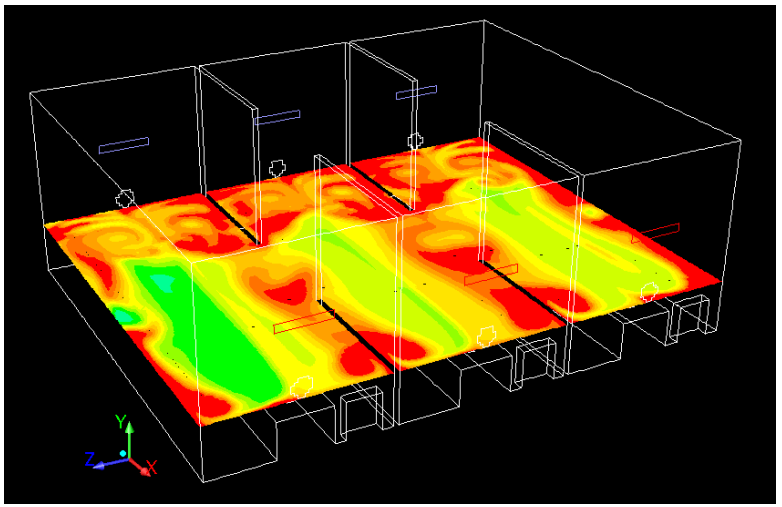
Air distribution

UNIVERSITY OF LEEDS





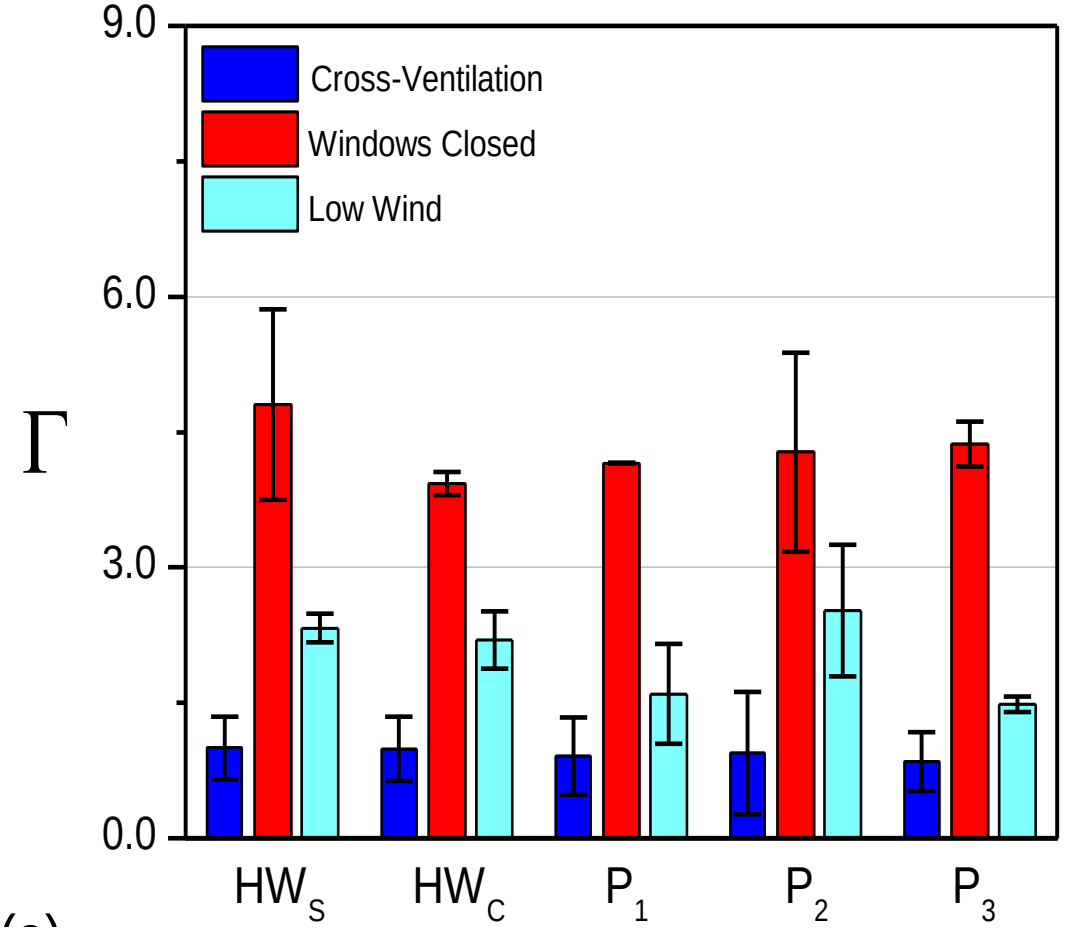


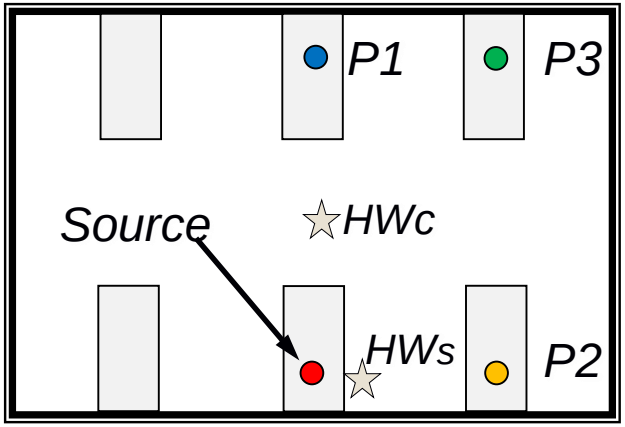


Short CA; Noakes CJ; Gilkeson CA; Fair A (2014) Functional recovery of a resilient hospital type. *Building Research & Information*, vol. 42, pp.657-684

Infection Risk

UNIVERSITY OF LEEDS



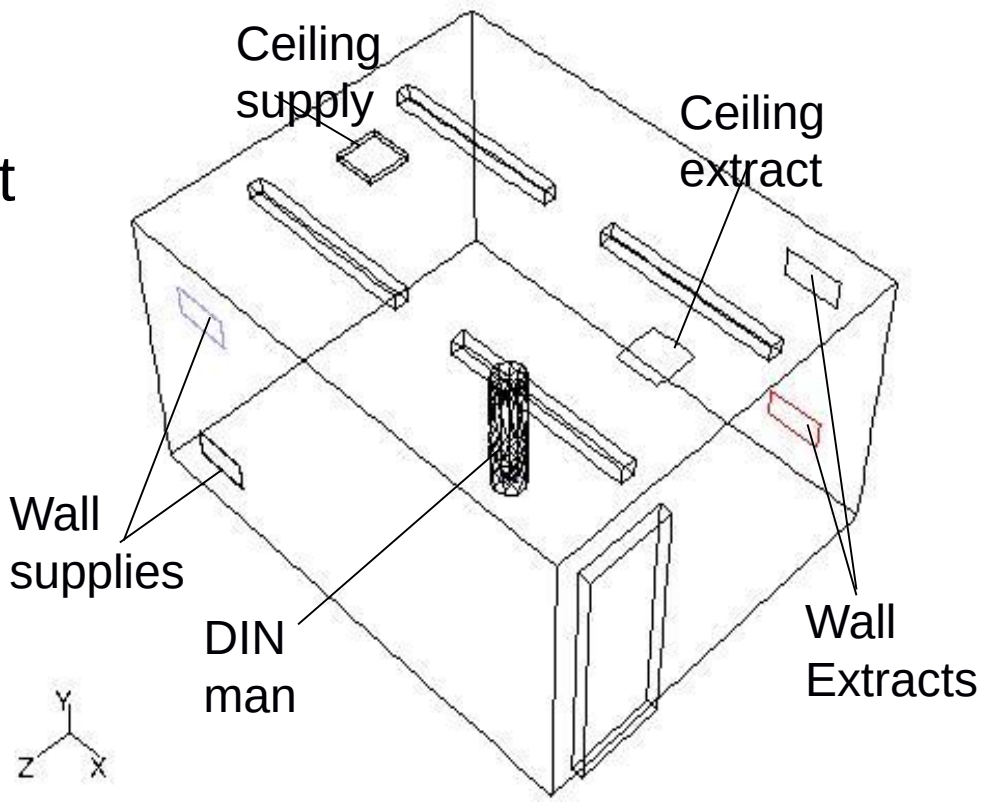


- Ward air is well mixed
- Shut the windows = increase the risk

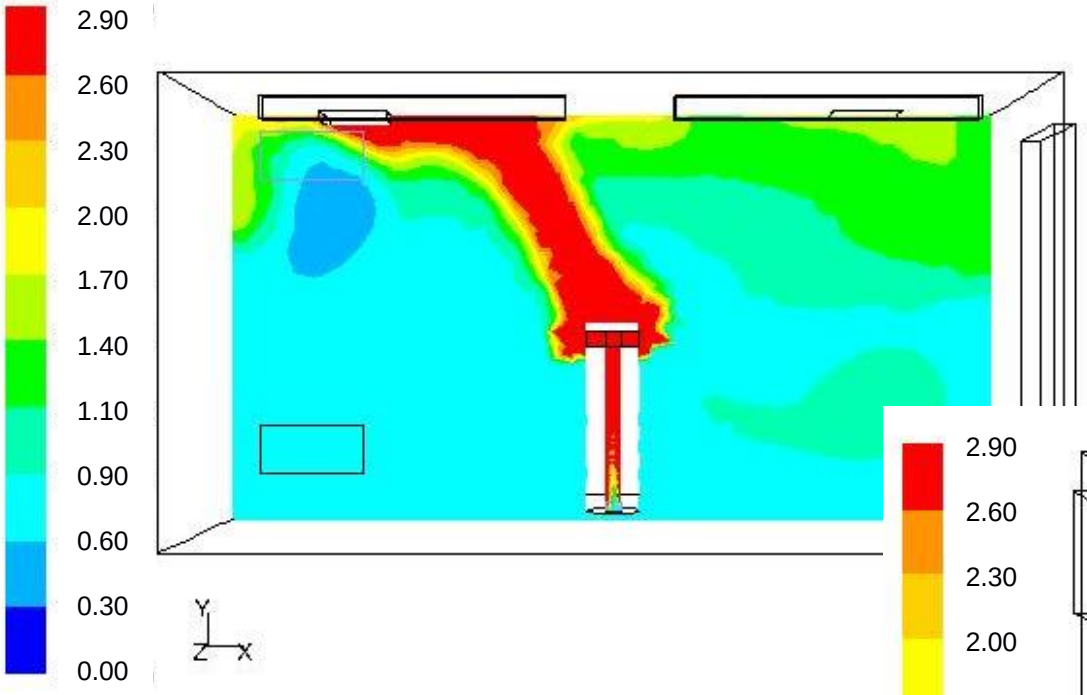
Gilkeson CA, Camargo-Valero MA, Pickin LE, Noakes CJ (2013) Measurement of Ventilation and Airborne Infection Risk in Large Naturally Ventilated Hospital Wards *Building and Environment,* 65:35-48

Mechanical Distribution

- Simulation of airflow in an isolation room
- Steady state simulations at 10 ACH
- Passive scalar released from DIN man - represent human source
- Dispersion of tracer with ventilation supplied:
  - High – mixing flow
  - Low – displacement flow

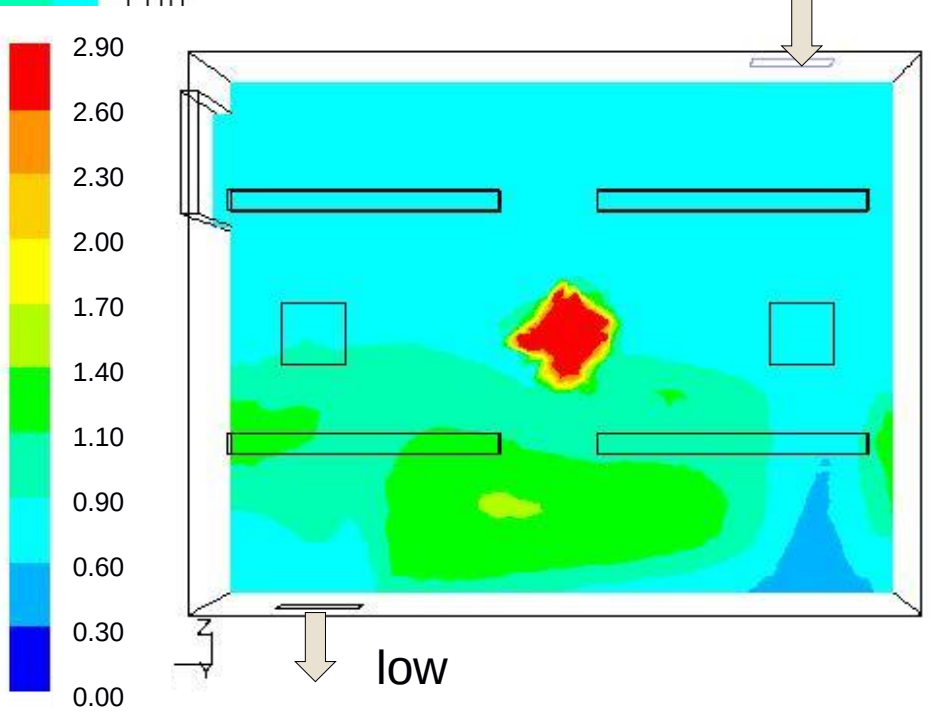


High supply, low extract

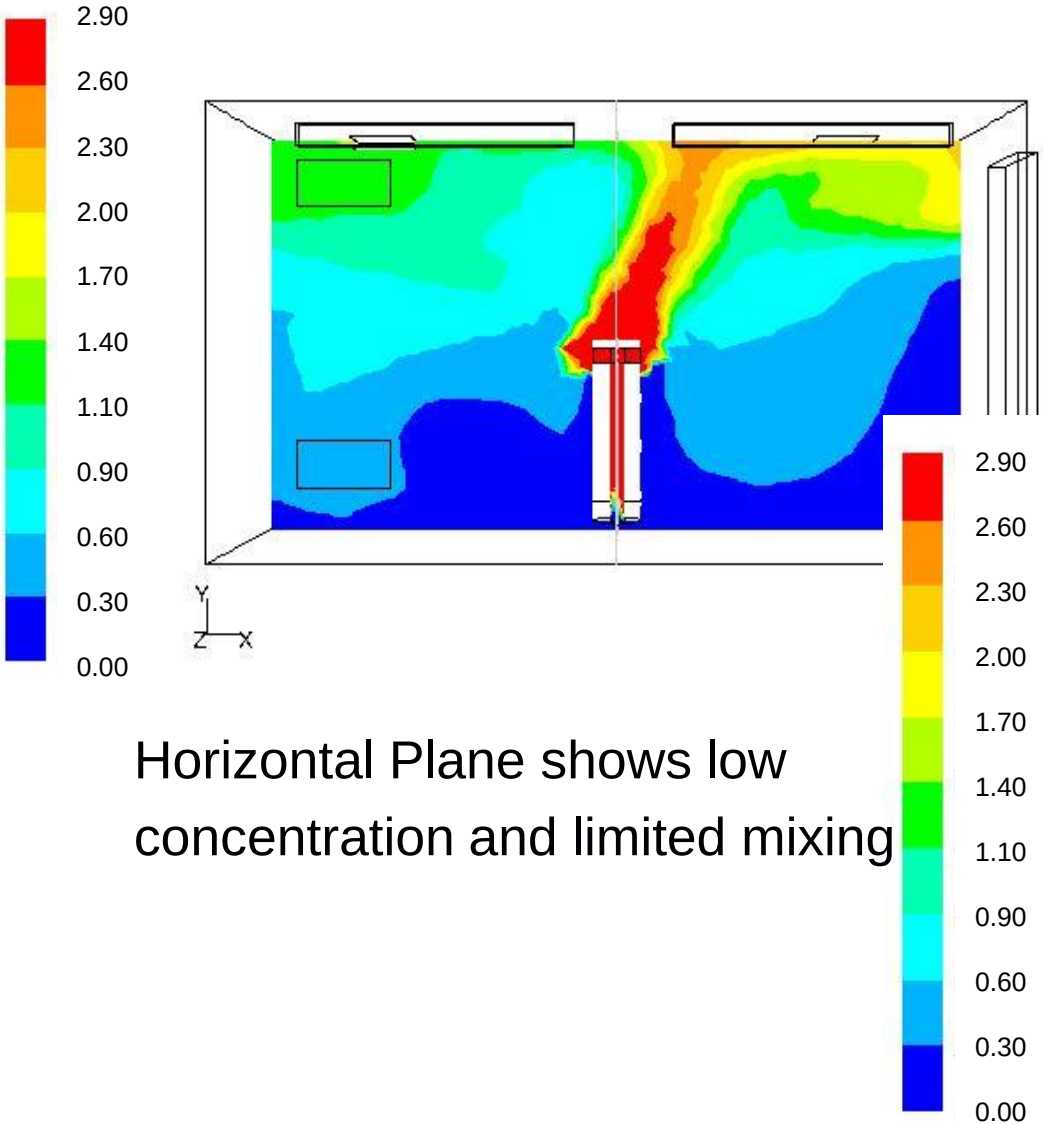


Vertical Plane shows plume and slight gradient

Horizontal Plane shows good mixing - similar to experiment

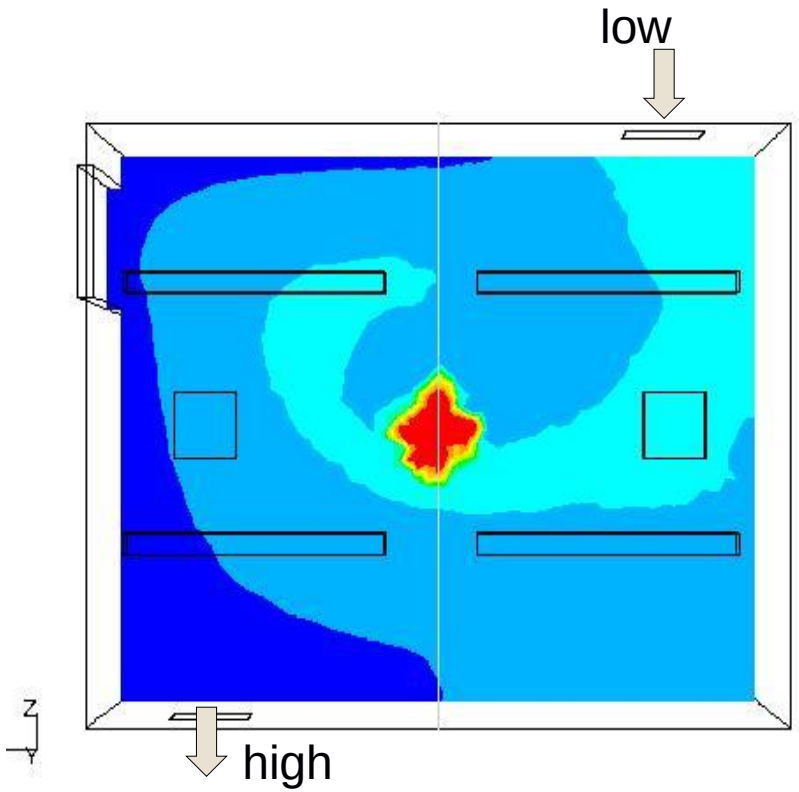


Low supply, high extract



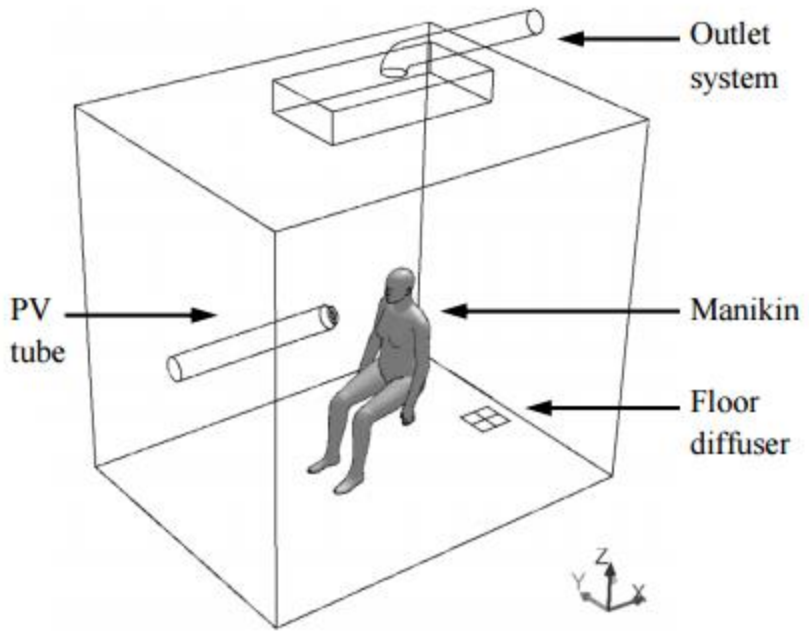
Horizontal Plane shows low concentration and limited mixing

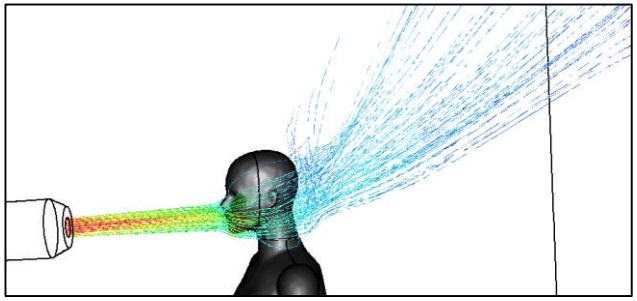
Vertical Plane shows plume and significant gradient

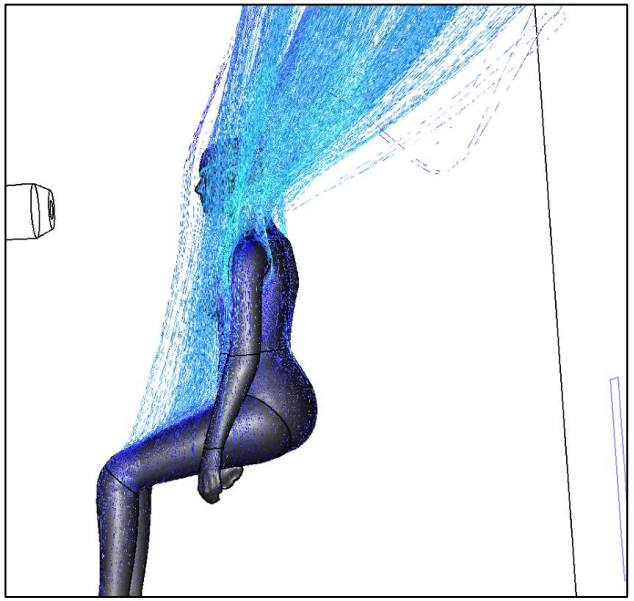


Personalised ventilation

- Local provision of fresh air
- Reduced ventilation of unoccupied zones
- Study to explore optimisation
  - comfort, energy



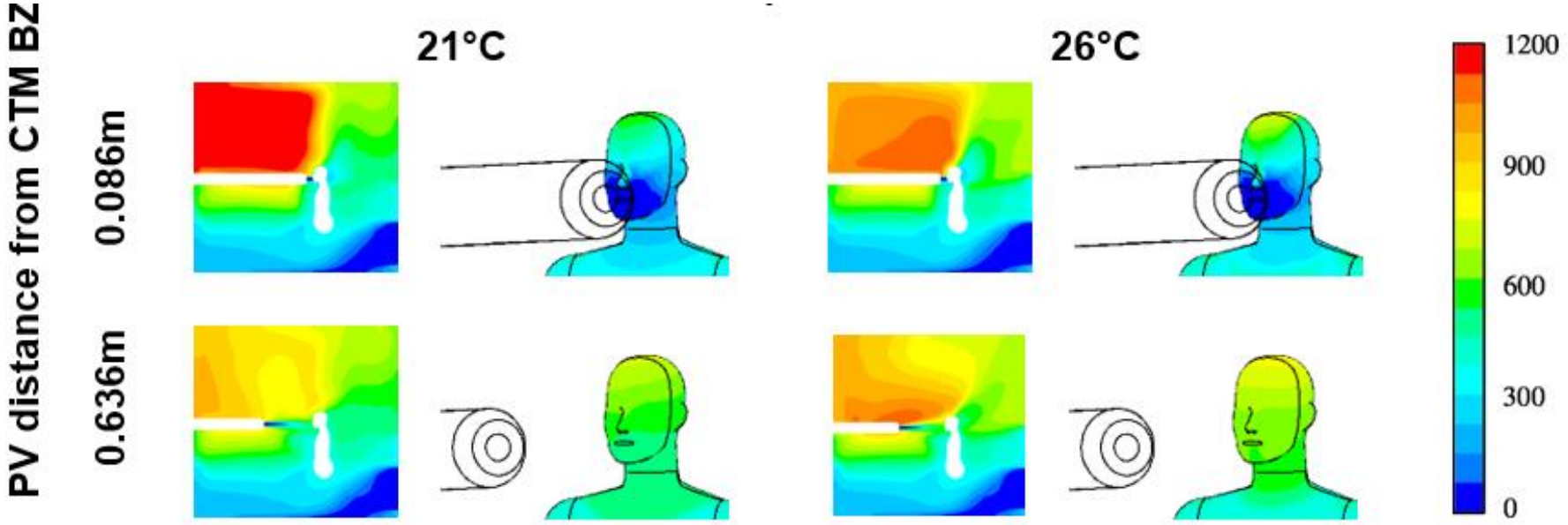




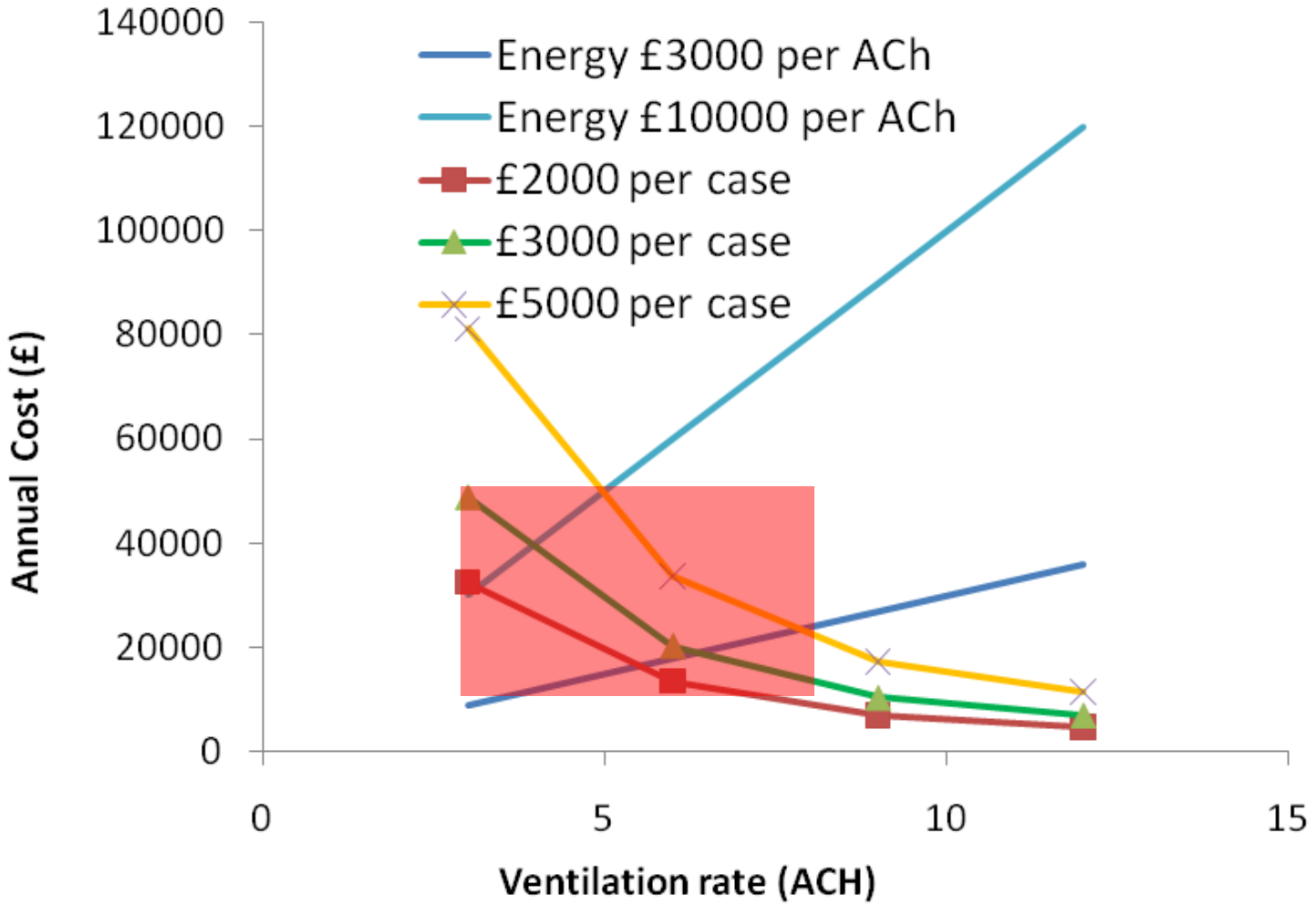
Natalie Gilkeson, PhD ongoing

Personalised ventilation

- PV nozzle flow consistent with empirical jets
- Distance of jet has significant influence on age of air
- PV flow also changes room airflow pattern



Ventilation metrics – energy vs infection

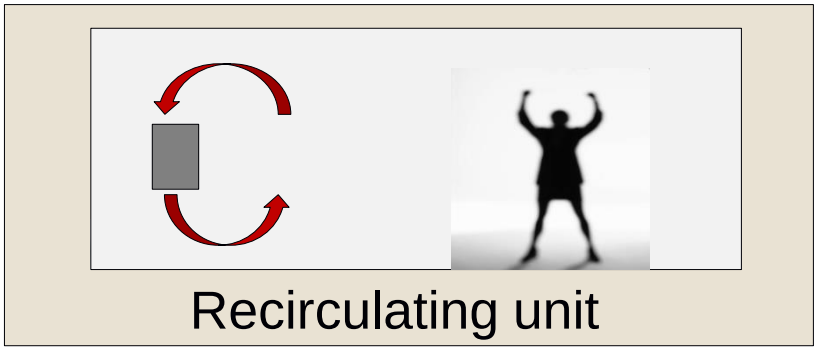


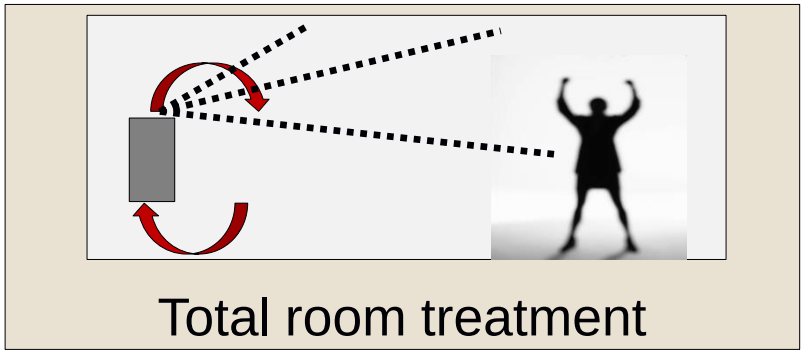
Noakes CJ, Sleigh PA, Khan A, (2012) Appraising Healthcare ventilation from combined infection control and energy perspectives. *HVAC&R Research,* 18(4); 658-670

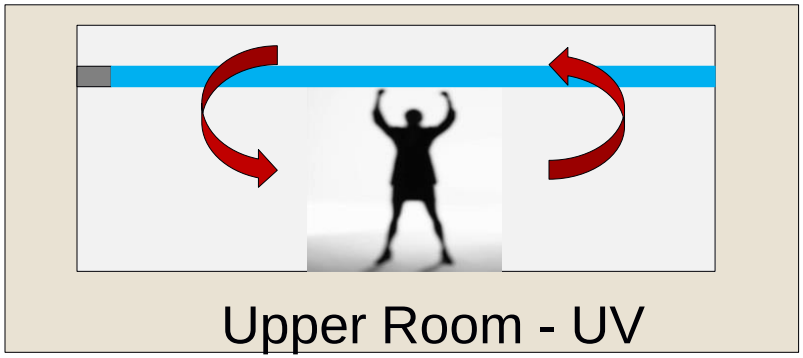
Air disinfection/cleaning

UNIVERSITY OF LEEDS

- Separate flow and IAQ
- UV-C irradiation, chemical, filters, electrostatic methods
- Widely marketed
  - How well do they work?
  - Where should they be used?
  - Are they safe?
- Complex – interaction between airflow, device, microorganisms, chemistry





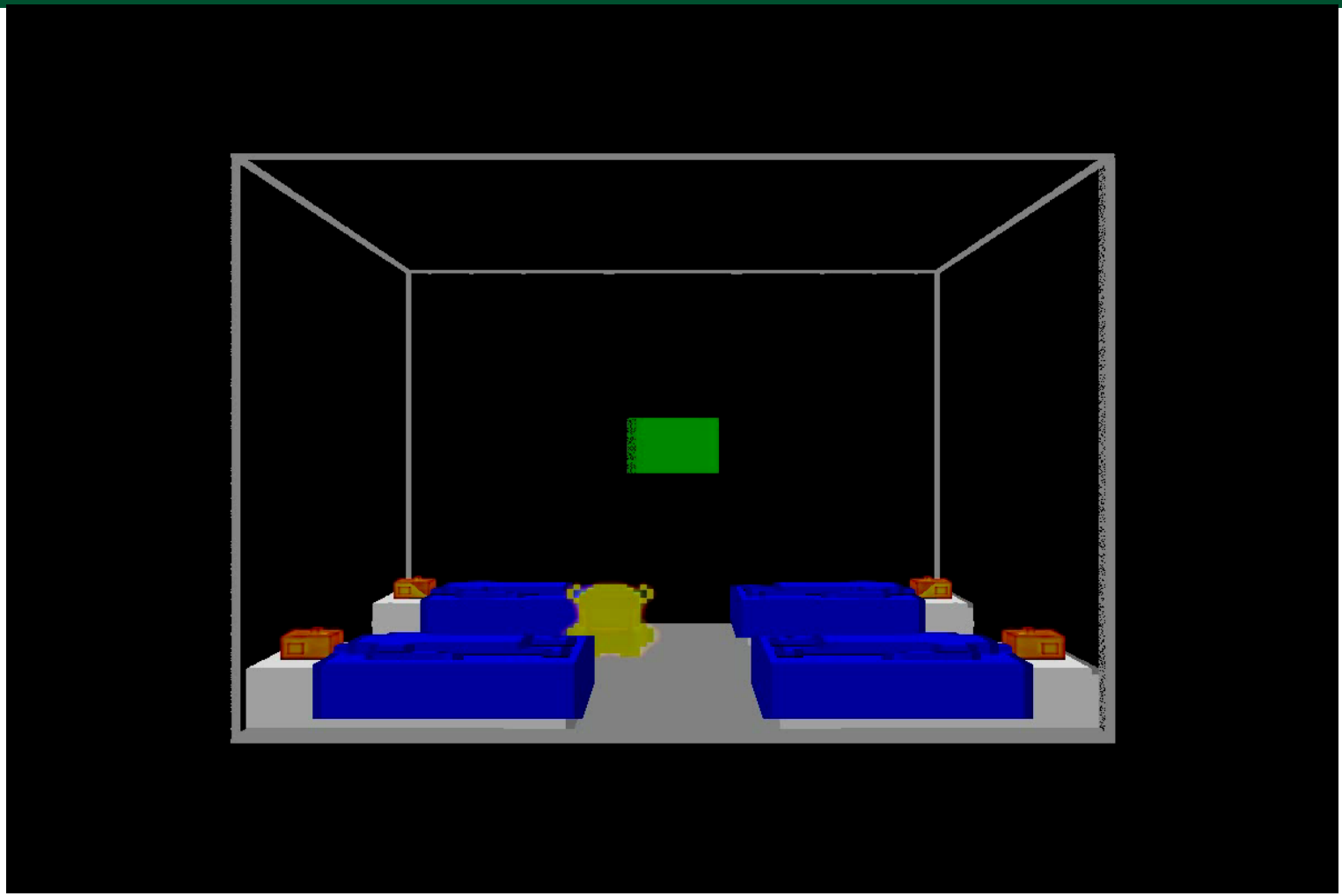


Some thoughts for future research

- Ventilation is not a bulk parameter – treating it this way is bad for people and energy
- Need a better understanding of many aspects
  - How buildings and IAQ affect people – and when and for how long.
  - Transient effects – how this affects environment, where there could be advantages, how to measure/model
  - Potential for technology approaches to contribute
- Sustainability and design metrics to give equal importance to human aspects

Real Time Transient flows

UNIVERSITY OF LEEDS



Amir Khan, Nick Delbosc, Leeds

Any Questions?

C.J.Noakes@leeds.ac.uk