Prof Tim Sharpe

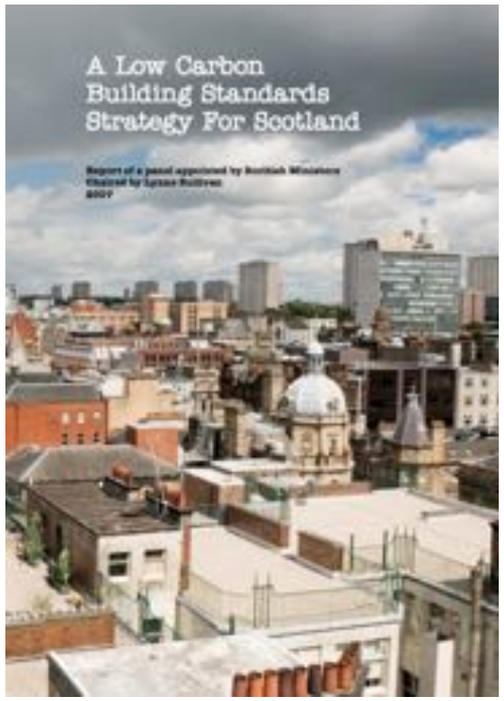
MACKINTOSH
ENVIRONMENTAL
ARCHITECTURE
RESEARCH UNIT
THE GLASGOW
SCHOOL OF ART

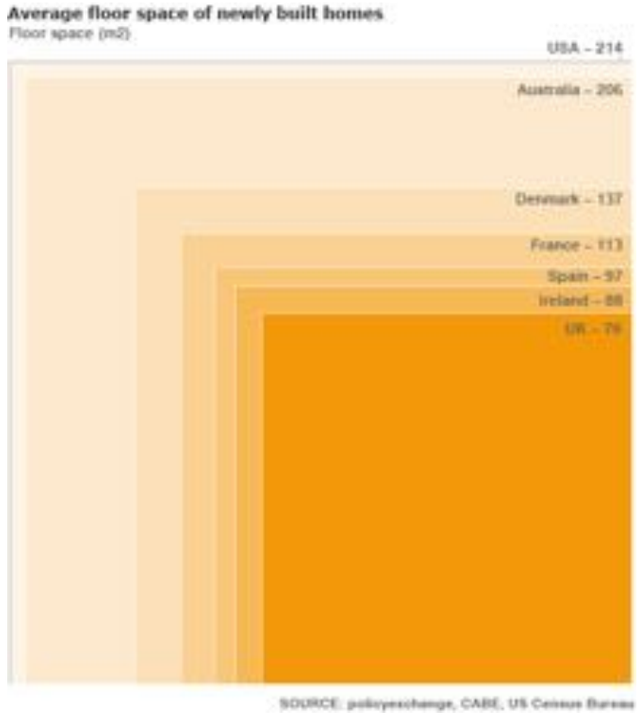
Ventilation Context

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

- Energy reduction targets
- Smaller more intensely occupied buildings

- Air tightness



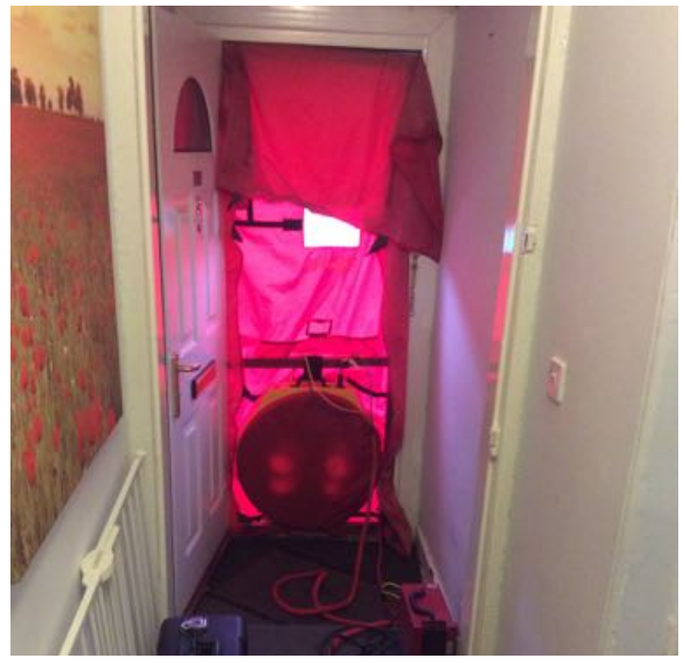


Ventilation Context

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

- Energy reduction targets
- Smaller more intensely occupied buildings

- Air tightness



Ventilation Context

- Energy reduction targets
- Smaller more intensely occupied buildings

- Air tightness

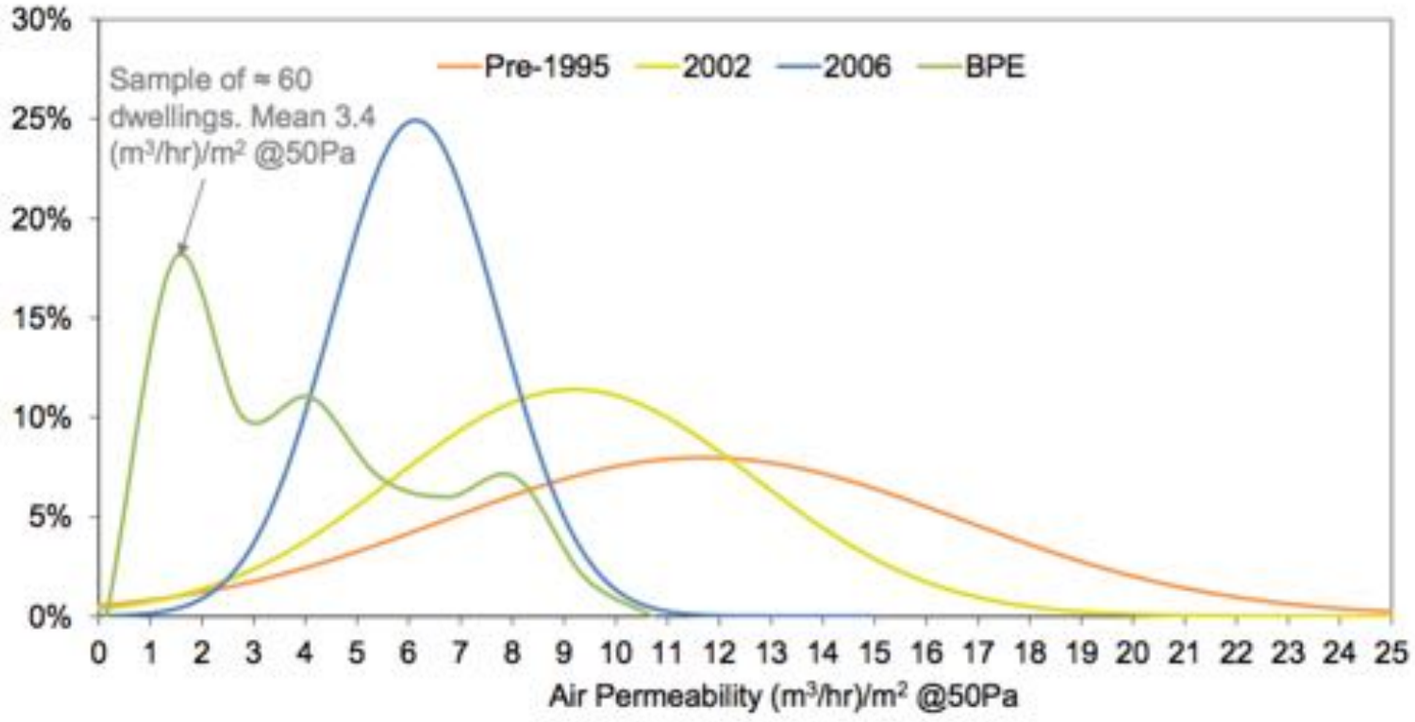
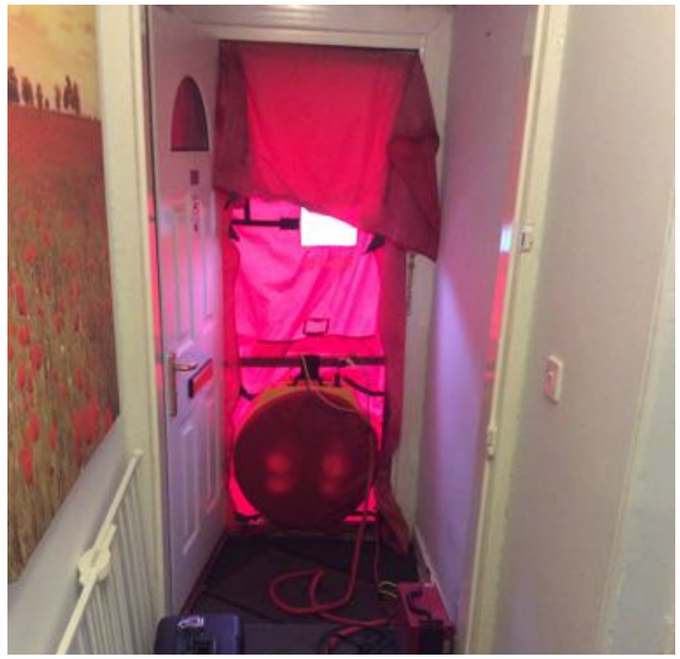


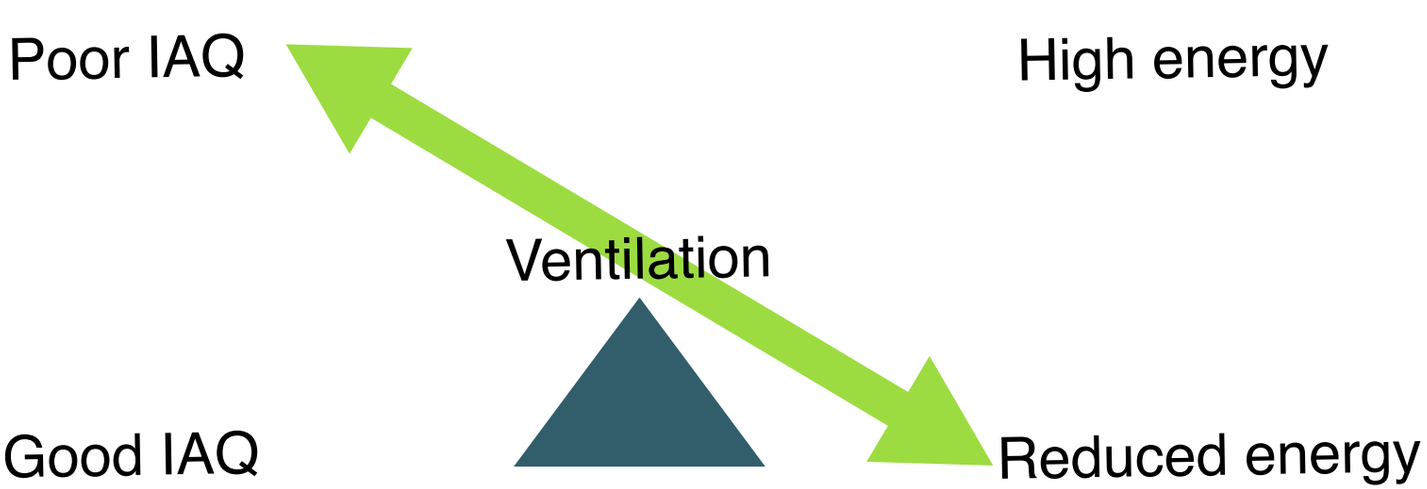
Image - Ian Mawditt, Fourwalls
Source: Building Sciences (RSK); Leeds Beckett University; Innovate UK BPE portfolio, Fourwalls

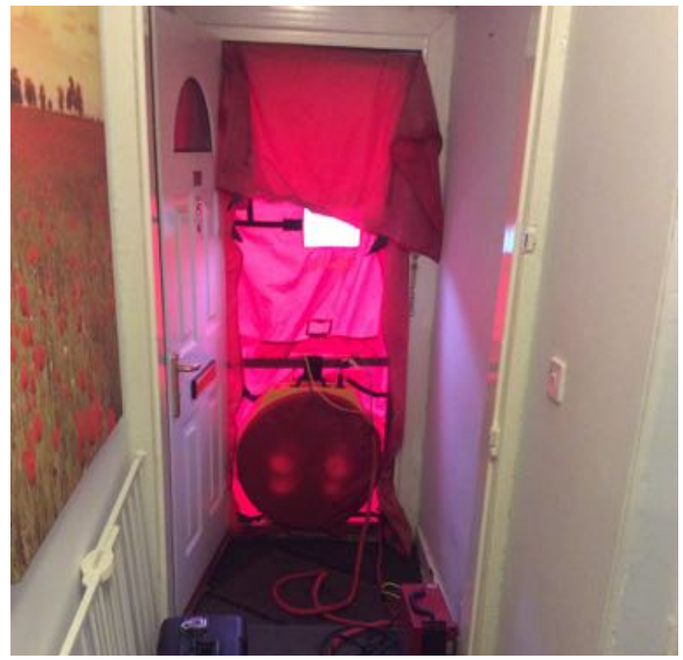


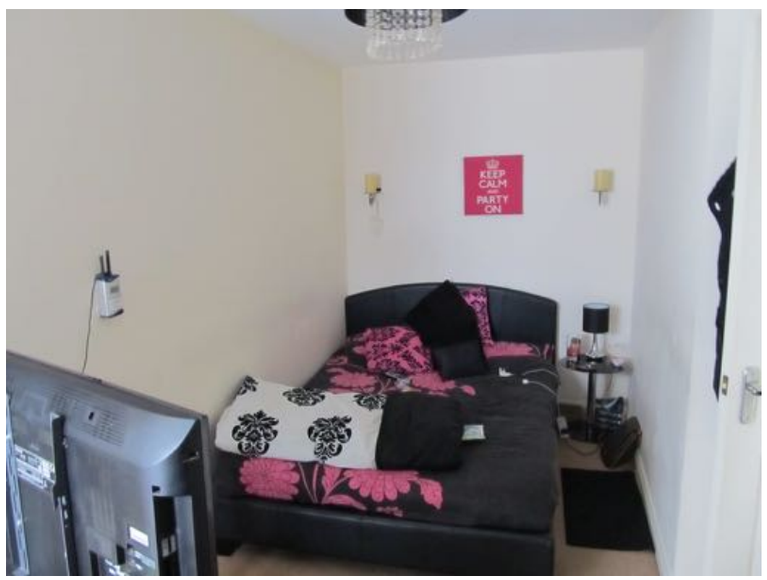
Ventilation Context

- Energy reduction targets
- Smaller more intensely occupied buildings

- Air tightness



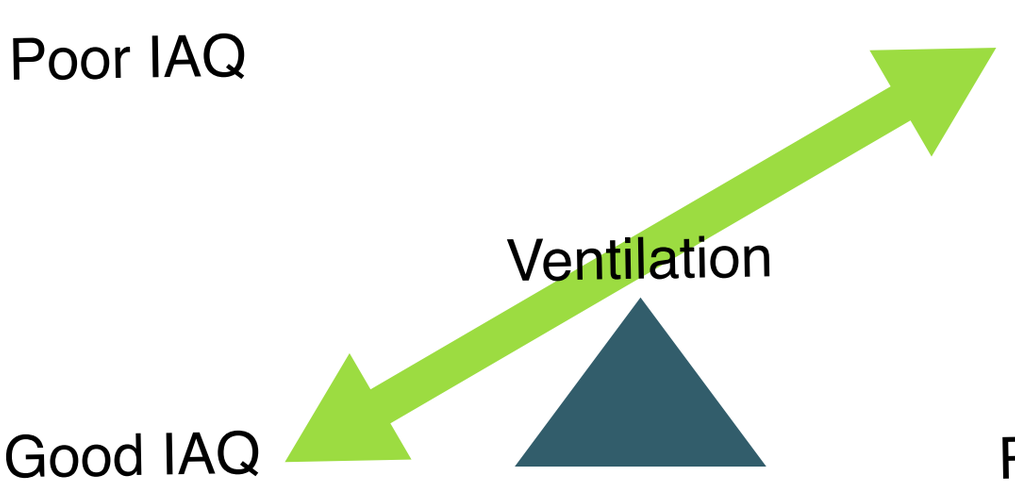


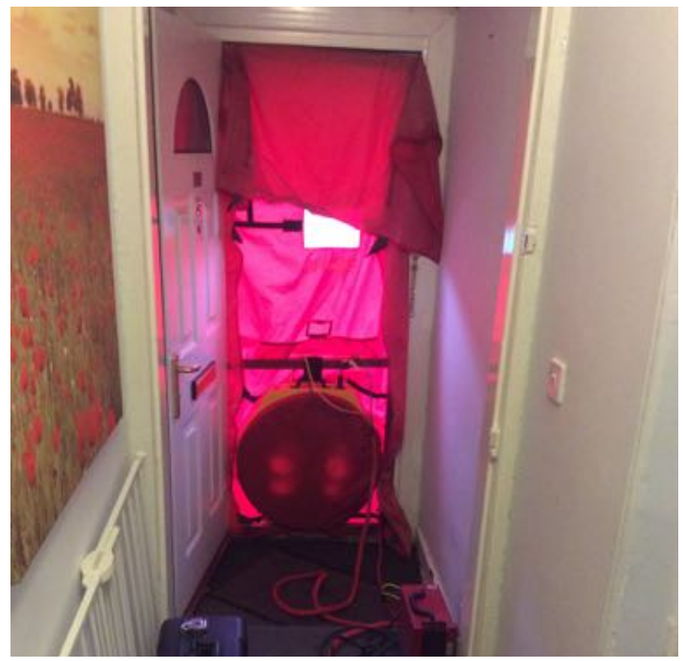


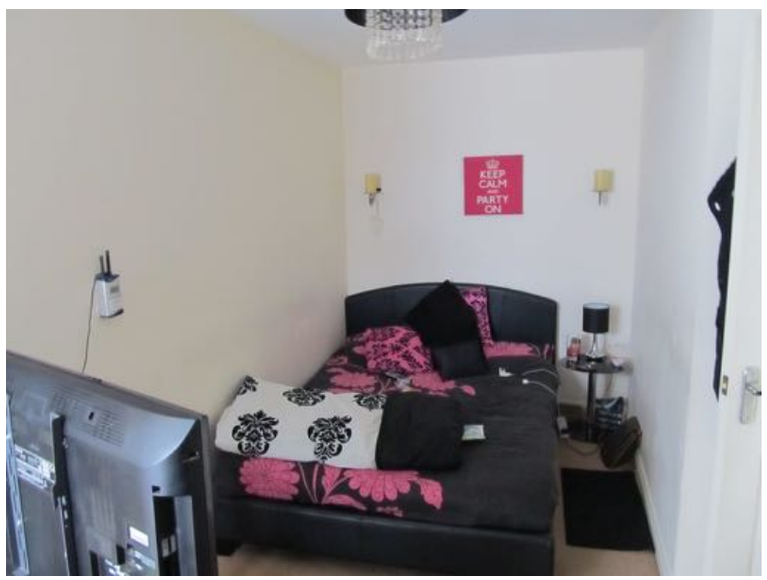
Ventilation Context

- Energy reduction targets
- Smaller more intensely occupied buildings

- Air tightness



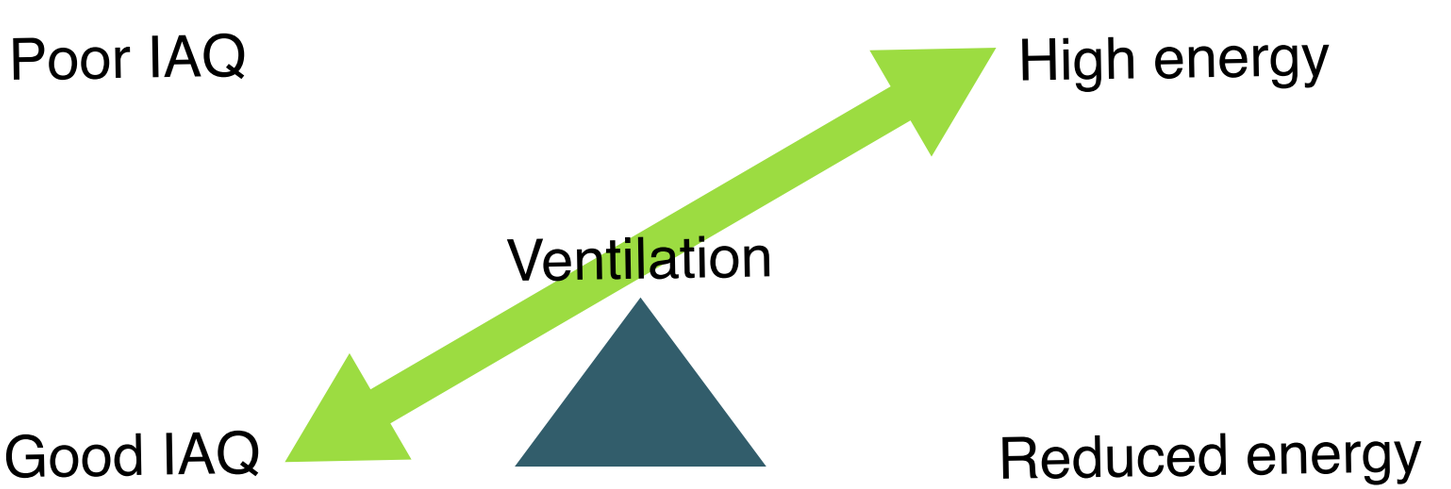


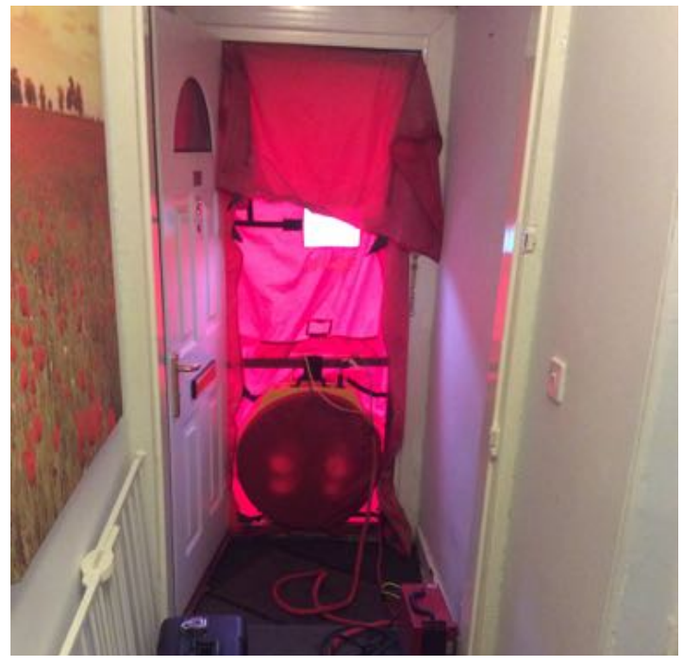


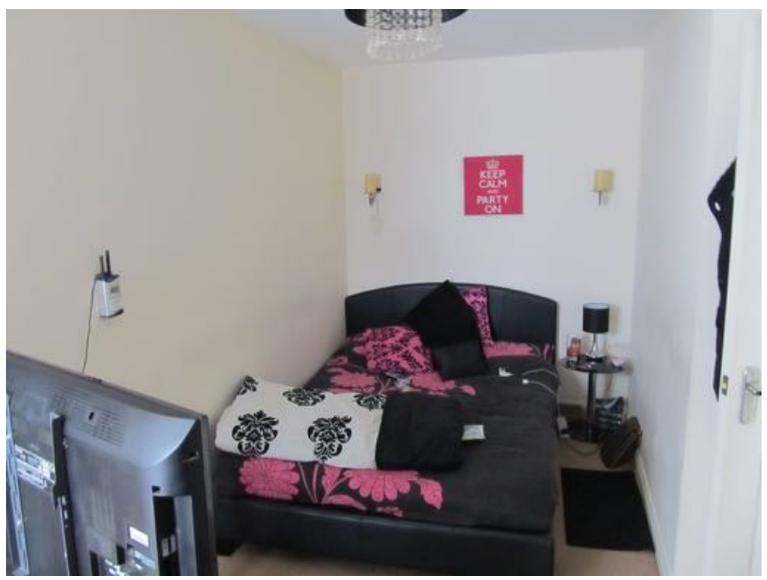
Ventilation Context

- Energy reduction targets
- Smaller more intensely occupied buildings

- Air tightness







- Increasing importance of ventilation - both energy and health
- Performance Gaps - energy and environmental performance
- Potential unintended negative consequences

Relevant recent projects

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

- Assessment of Environmental and Energy effects of Domestic Laundering EPSRC £522k
- Sunshine and well-being in housing, AHRC £52k
- Guidance for Occupants of Low Energy Homes, Scottish Building Standards £15k
- Knowledge Transfer Partnership with Cartwright Pickard Architects, London IUK, £135k
- Research Project To Investigate Occupier Influence On Indoor Air Quality In Dwellings, Scottish Building Standards, £40k
- Building Performance Evaluation - BPE Programme, IUK £520k
  - Expert Evaluator
  - The Glasgow House (Phase 1)
  - Inverness expo (8 houses)
  - Bloom Court Livingston (2 + 6 houses)
  - Ti-na-Cladich, Dunoon (3 houses)
  - Queens Cross, Glasgow (6 houses)
  - Murray Place, Barrhead (3 houses)
  - Dormont Park, Dumfries (4 houses)

- Meta study of MVHR system in domestic properties IUK £60k
- Knowledge Transfer Project - John Gilbert Architects. Unintended consequences of retrofit, IUK, £179k
- Network - Health effects of modern airtight construction, AHRC £52k
- BPE monitoring projects for Glasgow Housing Association - MVHR and naturally ventilated houses.

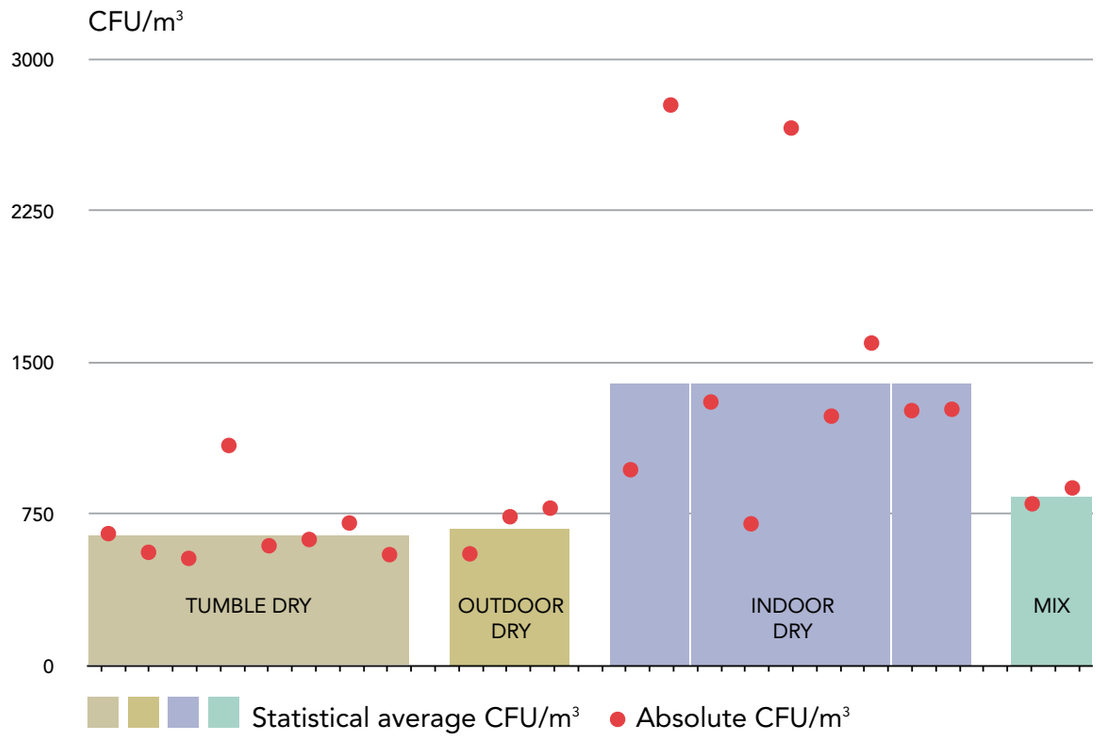
- Gannochy Trust, design advice for low energy, high air quality homes £100k
- Ability of dMEV to act as ‘whole-house’ ventilation systems in new-build dwellings £30k
- Influence of ventilation design on the prevalence of anti-microbial bacteria in homes £250k
- 'A comparison of ventilation rates in bedrooms with lung function of children with asthma'
- 'Indoor environmental quality in homes and children's health

Environmental Assessment of Domestic Laundering

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

- Increasing use of indoor drying - possible moisture and health effects

GRAPH 4 Mould spore concentration (CFU/m³) for predominant drying methods



http://www.homelaundrystudy.net

Porteous, Colin, Sharpe, Tim, Menon, Rosalie, Shearer, Donald, Musa, Haruna, Baker, Paul, Sanders, Chris, Strachan, Paul, Kelly, Nick and Markopoulos, Taso (2013) *Domestic laundering – environmental audit in Glasgow with emphasis on passive indoor drying and air quality.* Indoor and Built Environment. ISSN 1423-0070

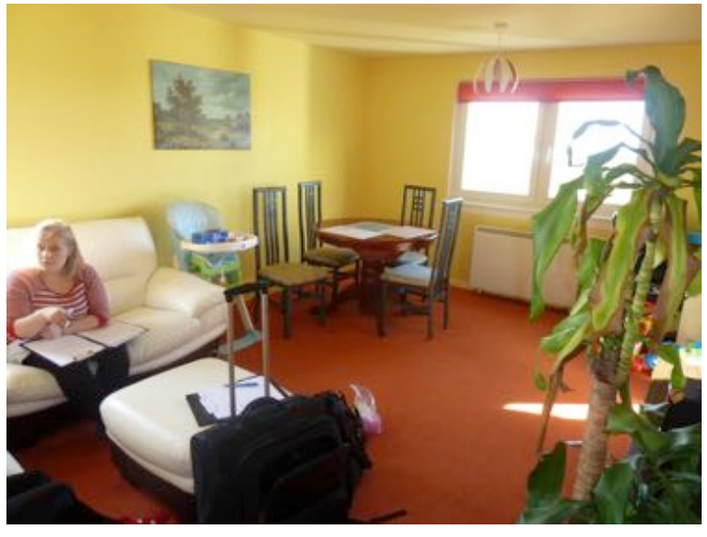
Porteous, Colin, Sharpe, Tim, Menon, R. A., Shearer, D., Musa, H., Baker, P. H., Sanders, C. H., Strachan, P. A., Kelly, N. J. and Markopoulos, A. (2012) *Energy and environmental appraisal of domestic laundering appliances.* Building Research & Information, 40 (6). pp. 679-699. ISSN 1466-4321

Sunshine Health and Wellbeing

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

- AHRC funded study
- Investigating the health effects of sunshine and ventilation
- Survey of high rise blocks in Glasgow
- Microbial Sampling
- Environmental monitoring
- Mental Wellbeing (WEMWEBS)
- Physiological distress (GHQ12)

- Access to sunlight appears to have been an important factor in influencing the psychological health of the participants of the pilot study
- Especially individuals who spent a lot of time at home



Robertson, Lynette, Sharpe, Tim, Swanson, Vivien, Porteous, Colin and Foster, Janice (2015) Sunlight accessibility indoors and mental health: evidence from a social housing community in Glasgow, Scotland [Conference paper]. In: VELUX Daylight Symposium 2015, 2-3 September, London.

Vivien Swanson Tim Sharpe Colin Porteous Colin Hunter and Donald Shearer (2016) Indoor Annual Sunlight Opportunity in Domestic Dwellings May Predict Well-Being in Urban Residents in Scotland . Ecopsychology DOI: 10.1089/eco.2015.0059 (in press)

Innovate UK Building Performance Evaluation (BPE)

- £8m Innovate UK funding – 2010 to 2014 - total four year programme of project activity

- Domestic: 53 projects (350 dwellings)
- 23 Phase 1 projects

- Post construction & initial occupation
- 30 Phase 2 projects

- In-use performance & post occupancy evaluation

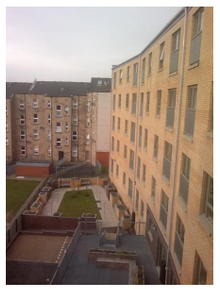
- Non–domestic: 48 projects (55 study buildings)
- 8 Under construction & early occupation
- 40 In-use

Innovate UK
Technology Strategy Board

Ventilation in BPE study houses

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

- MEARU engaged in monitoring 7 domestic projects in Scotland



Ventilation observations

- IUK studies
- Observed through measurements of CO_2
- < 1000ppm = 8 litres/s per person = good ventilation

"..ventilation rates above 0.4 h-1 or CO_2 below 900 ppm in homes seem to be the minimum level to protect against health risks based on the studies reported in the scientific literature" Wargocki, P. The Effects of Ventilation in Homes on Health. *Int. J. Vent.* **2013**; *12*, 101–118.

Table 4.1 Ventilation and indoor air quality classification (BS EN 13779)[19]

Classification	Indoor air quality standard	Ventilation range / ($L \cdot s^{-1}$/person)	Default value / ($L \cdot s^{-1}$/person)
IDA1	High	>15	20
IDA2	Medium	10–15	12.5
IDA3	Moderate	6–10	8
IDA4	Low	<6	5

Table 4.2 Approximate maximum sedentary CO_2 concentrations associated with CEN indoor air quality standards (BS EN 13779)[19]

Classification	Rise in indoor CO_2 concentration / ppm	Default value / ppm	Range in outdoor concentration / ppm	Total indoor value* / ppm
IDA1	<400	350	350–400	700–750
IDA2	400–600	500	350–400	850–900
IDA3	600–1000	800	350–400	1150–1200
IDA4	>1000	1200	350–400	1550–1600

* i.e. concentration rise plus outdoor value

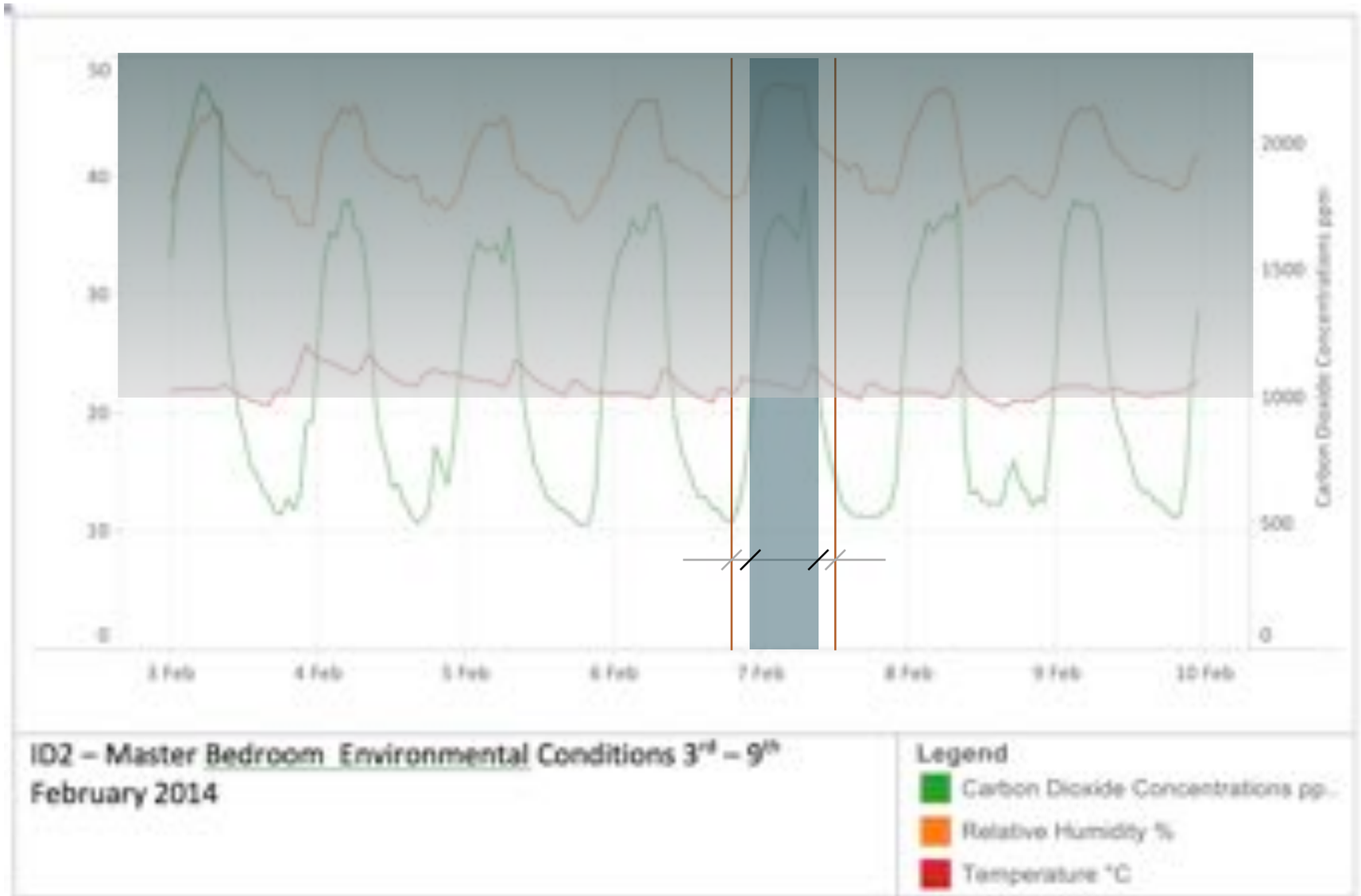
Ventilation observations

- IUK studies
- Observed through measurements of CO_2
- < 1000ppm = 8 litres/s per person = good ventilation

"..ventilation rates above 0.4 h-1 or CO_2 below 900 ppm in homes seem to be the minimum level to protect against health risks based on the studies reported in the scientific literature" Wargocki, P. The Effects of Ventilation in Homes on Health. *Int. J. Vent.* **2013**; *12*, 101–118.

Howieson, S.G., Sharpe, T. and Farren, P. (2013) Building tight – ventilating right? How are new air tightness standards affecting indoor air quality in dwellings? Building Services Engineering Research and Technology, 35 (5). pp. 475-487. ISSN 0143-6244

Bedrooms



Sharpe, Tim, Porteous, Colin, Shearer, Donald and Foster, Janice (2014) An assessment of environmental conditions in bedrooms of contemporary low energy houses in Scotland. Indoor and Built Environment.

Ventilation observations

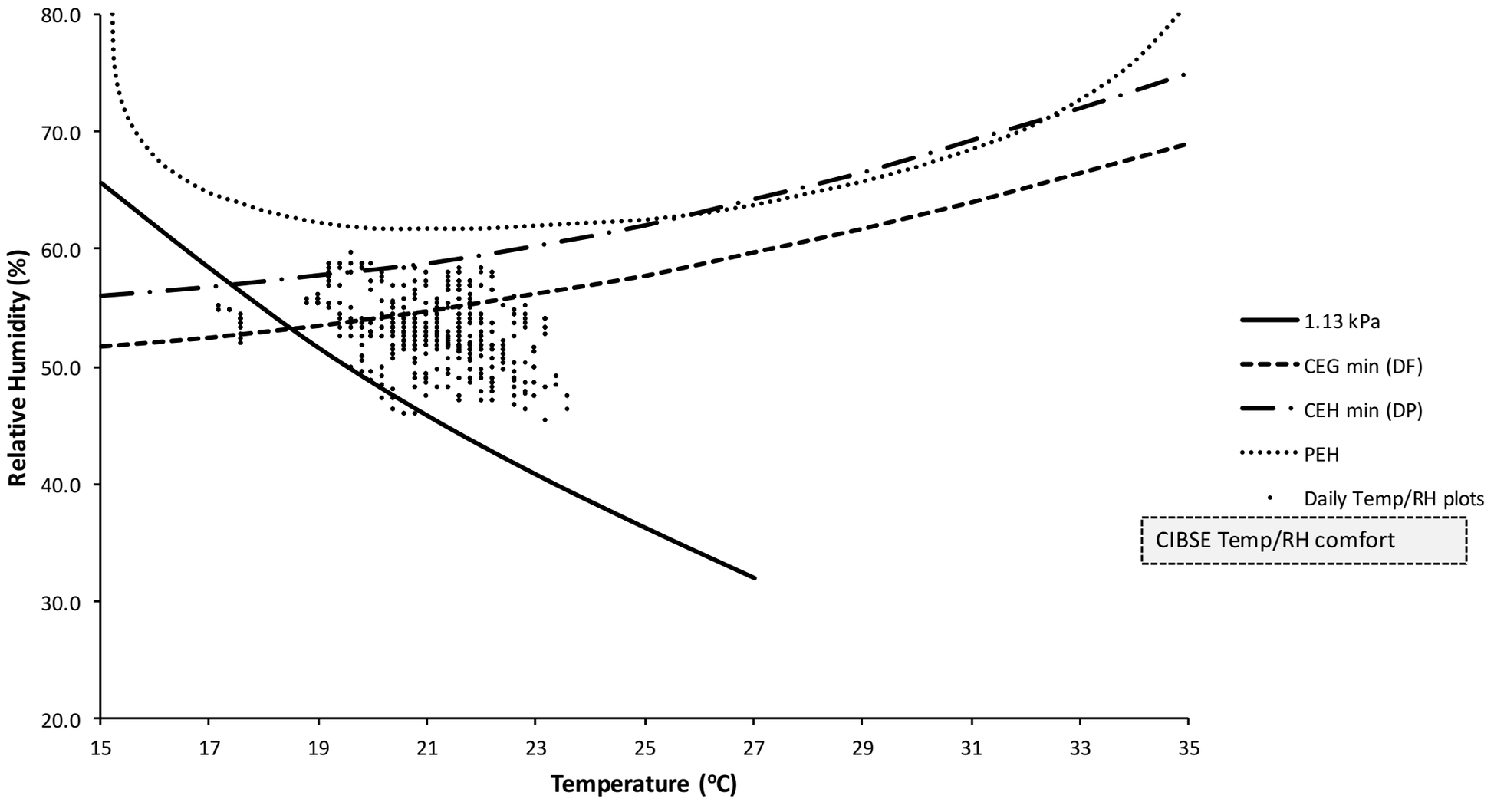
Mechanical extract systems

- 83% underperforming
- 71% failing design performance criteria

Dwelling	Fan	Avg	Design	Pass/Fail
IA1	Kitchen	25.60	60	Fail
	Utility	29.40	30	Pass
	Shower	7.50	15	Fail
	Bathroom	7.50	15	Fail
IA2	Kitchen	34.50	60	Fail
	Utility	31.90	30	Pass
	Shower	3.70	15	Fail
	Bathroom	4.60	15	Fail
IB1	WC	3.20	7	Fail
	Bathroom	4.90	15	Fail
IB2	WC	5.20	7	Fail
	Bathroom	4.00	15	Fail
	Kitchen	62.60	30	Fail
IC1	Kitchen	5.80	60	Fail
	Bathroom	7.30	15	Fail
IC2	Kitchen	8.50	60	Fail
	Bathroom	5.90	15	Fail
ID2	Kitchen	26.10	60	Fail
	Bathroom	6.90	15	Fail
BC1	Bathroom	11.83	15	Fail
	Kitchen	64.27	60	Pass
BB1	Bathroom	17.30	15	Pass
	Kitchen	71.87	60	Pass
BA1	WC	12.40	15	Fail
	Bathroom	2.80	15	Fail
	Kitchen	0.00	60	Fail
GB3	Bathroom	9.20	15	Fail
	Kitchen	32.57	60	Fail
GB1	Bathroom	11.13	15	Fail
	Kitchen	41.43	60	Fail
GB2	Kitchen	30.10	60	Fail
	Bathroom	16.30	15	Pass
LA5	Kitchen	67.80	60	Pass
	Bathroom	4.60	15	Fail
LA6	Kitchen	73.80	60	Pass
	Bathroom	7.40	15	Fail

Ventilation effects

- Risk of dust mite population
- Particularly in high occupancy which has standard ventilation provision



Research Project To Investigate Occupier Influence On Indoor Air Quality In Dwellings

Building Standards Directorate

Prof Tim Sharpe MEARU
Jonathan McQuillan Anderson Bell Christie
Dr. Stirling Howieson, University of Strathclyde
Paul Farren ASSIST DESIGN ARCHITECTS
Dr. Paul Tuohy ESRU, Strathclyde University

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT THE GLASGOW SCHOOL OF ART

anderson bell+christie architects

University of Strathclyde Engineering

ASSIST DESIGN ARCHITECTS

Key Findings

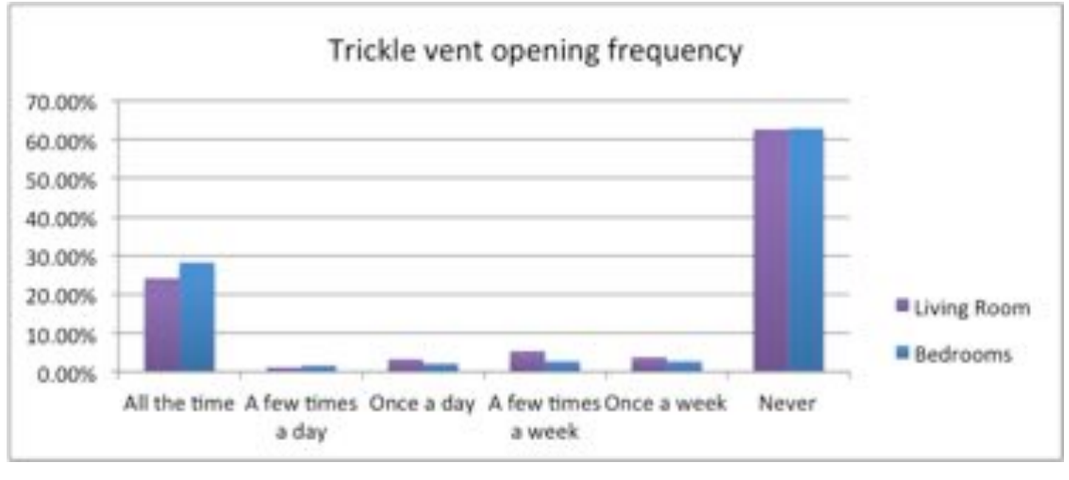
MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

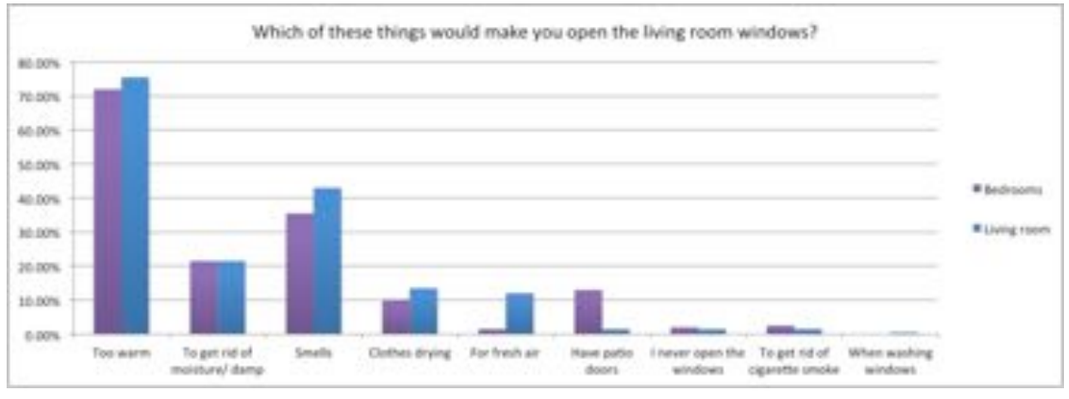
- Survey of ventilation habits

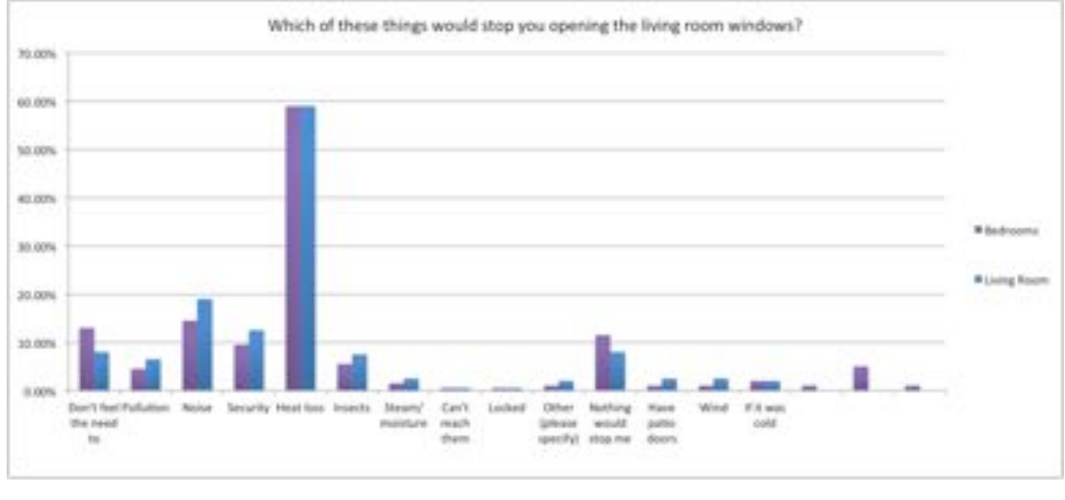
- Most trickle vents closed - 63% closed
- Hardly every changed

- Window opening more frequent - daily
- Drivers - temperature
- Barriers - heat loss
- 20% leave bedroom windows open at night
- 40% have bedroom doors closed at night

- Lack of knowledge - 82% had received no advice on ventilation

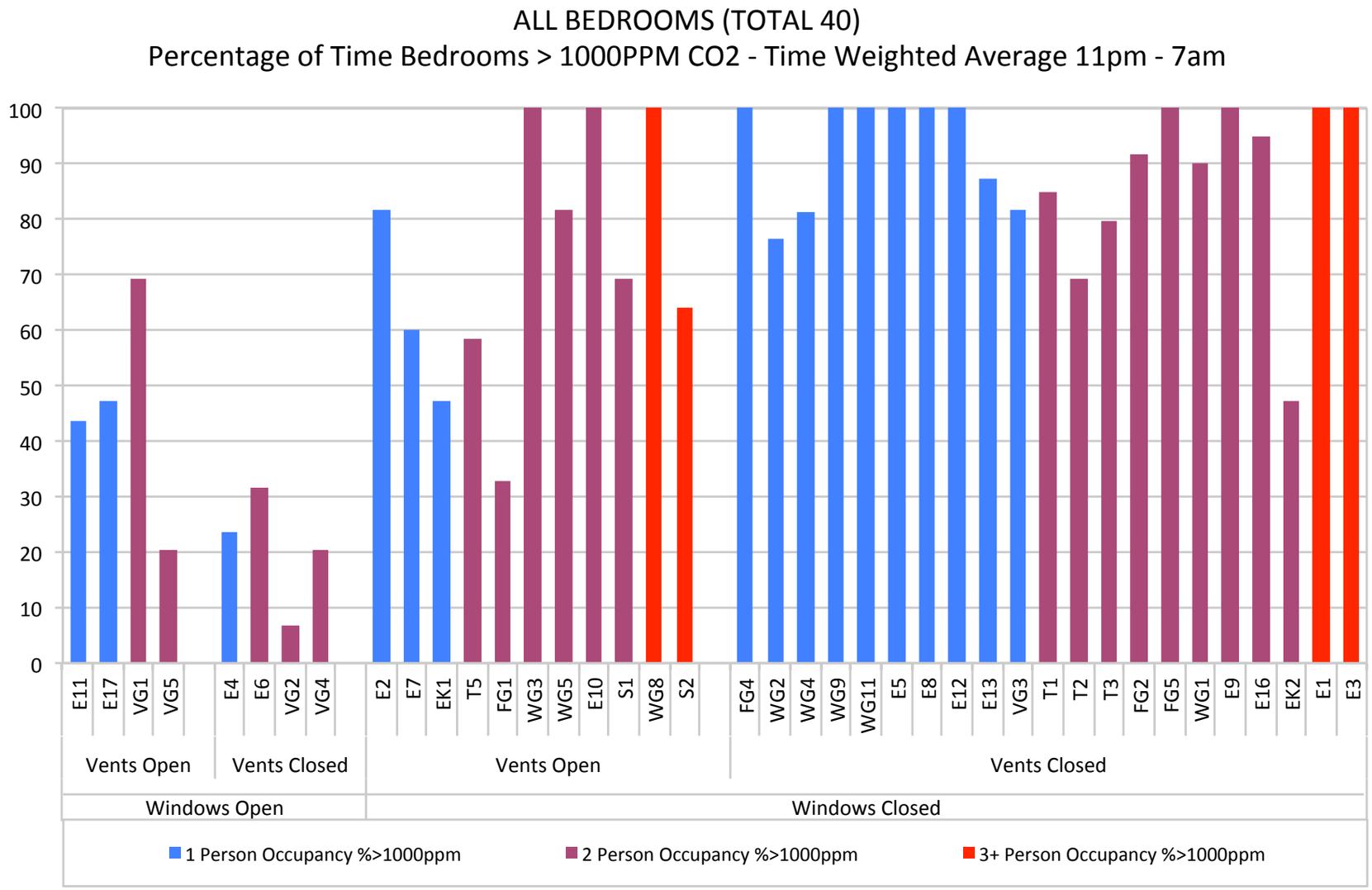






Trickle vent performance

- % time over 1000ppm at night
- Significant periods of time with low ventilation
- Mitigated by window opening
- Better with open vents - but not effective

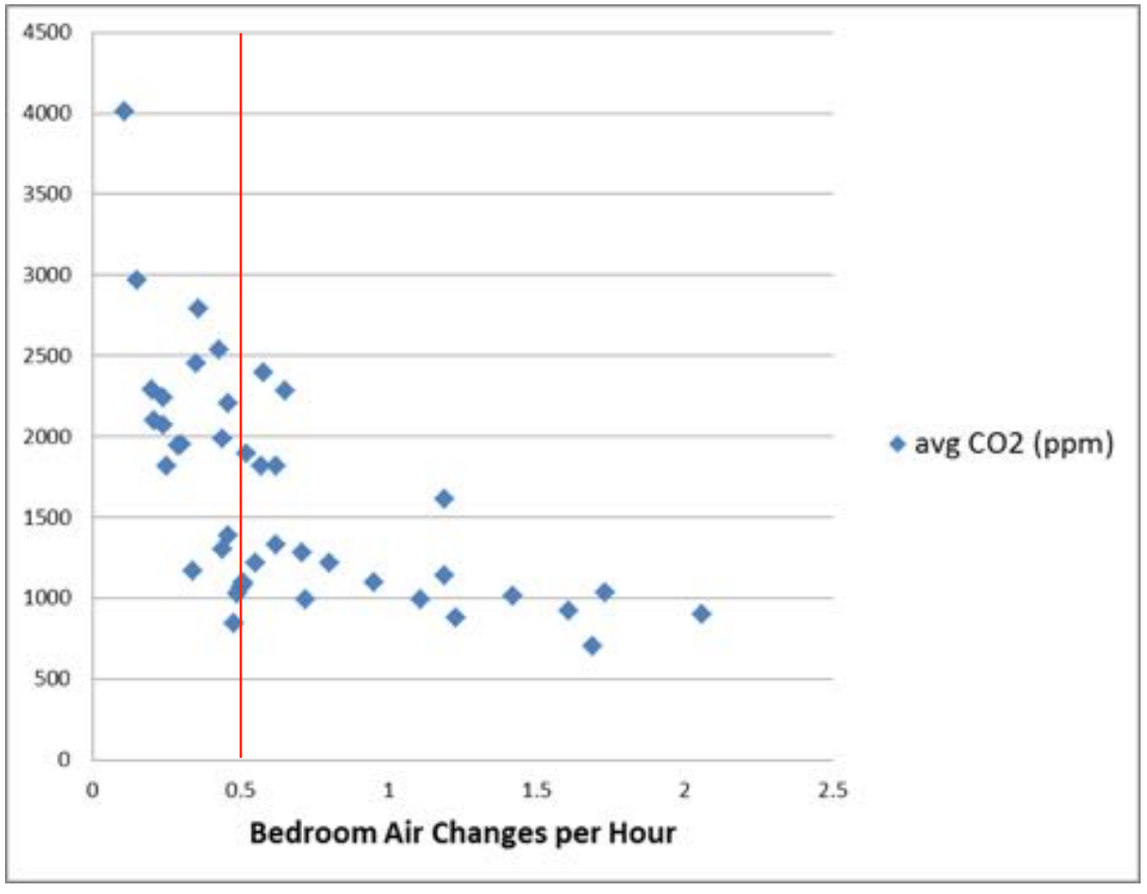


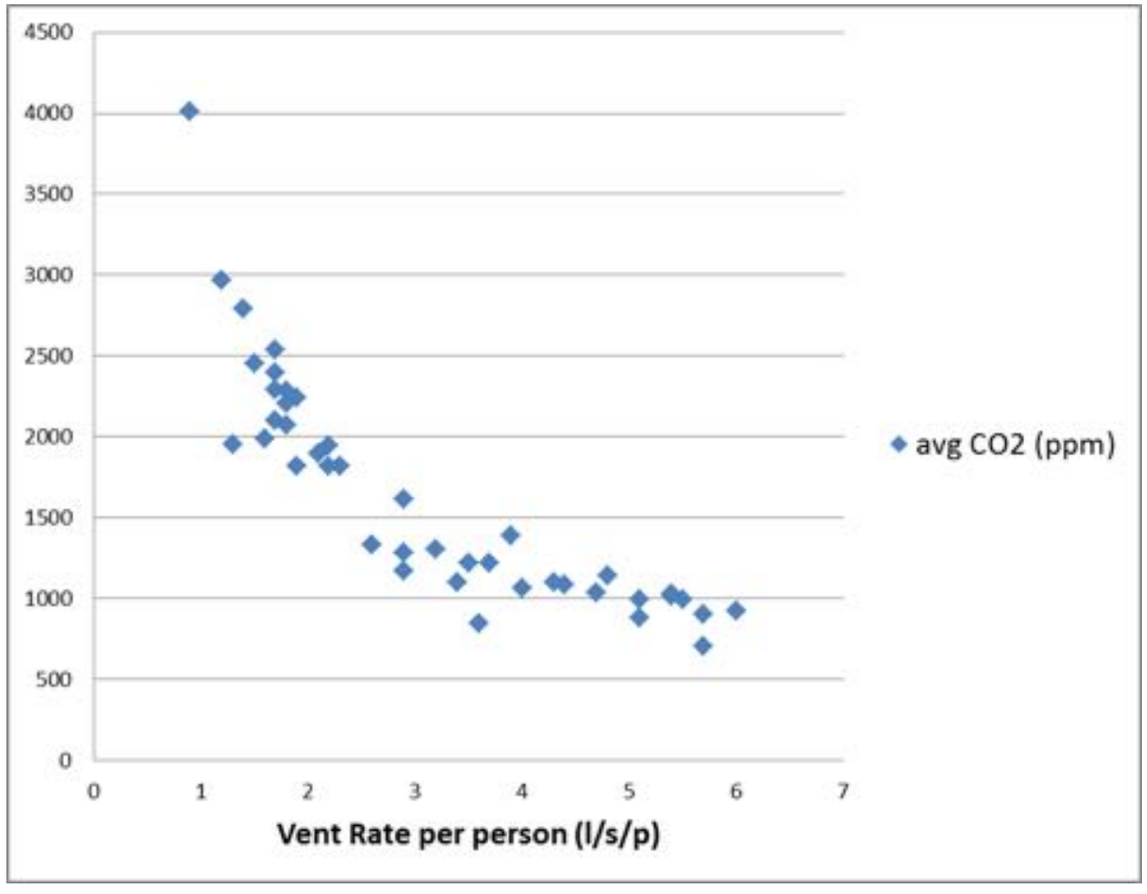
Sharpe, Tim (2014) Investigation of Occupier Influence on Indoor Air Quality in Dwellings. Technical Report. Scottish Government.

Sharpe, Tim, Farren, Paul, Howieson, Stirling, Tuohy, Paul and McQuillan, Jonathan (2015) Occupant Interactions and Effectiveness of Natural Ventilation Strategies in Contemporary New Housing in Scotland, UK. International Journal of Environmental Research and Public Health, 12 (7). pp. 8480-8497. ISSN 1660-4601

Resultant air change rates

- House with closed windows but open trickle vents
- No houses met requirement for IAQ = 8 l/s/p
- 42% below requirements for moisture control in regulation (0.5ach)





Meta-Study Of Dwellings With MVHR Systems

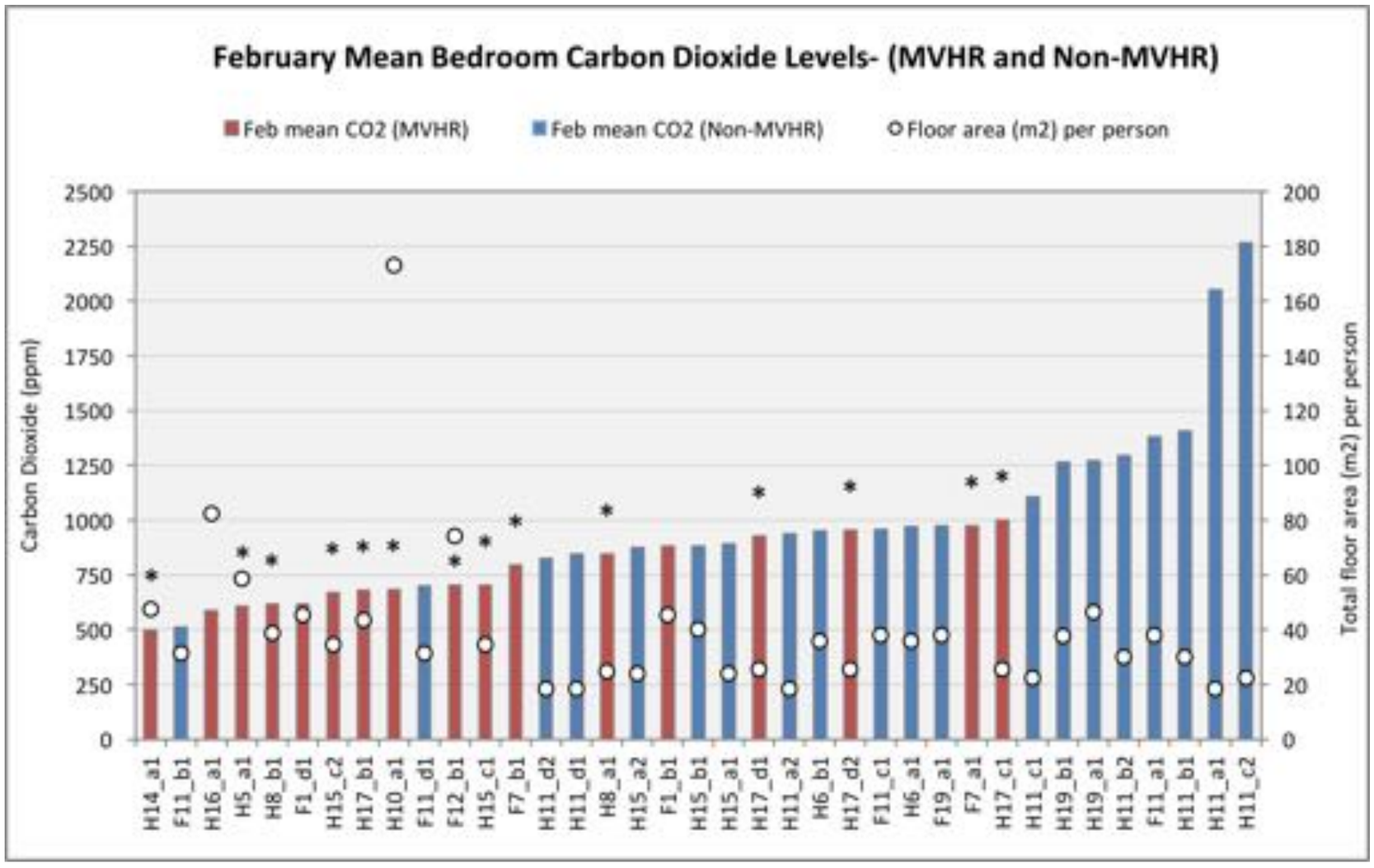
Innovate UK

Tim Sharpe, MEARU
Ian Mawditt, Fourwalls
Rajat Gupta, OBU

Innovate UK
Technology Strategy Board

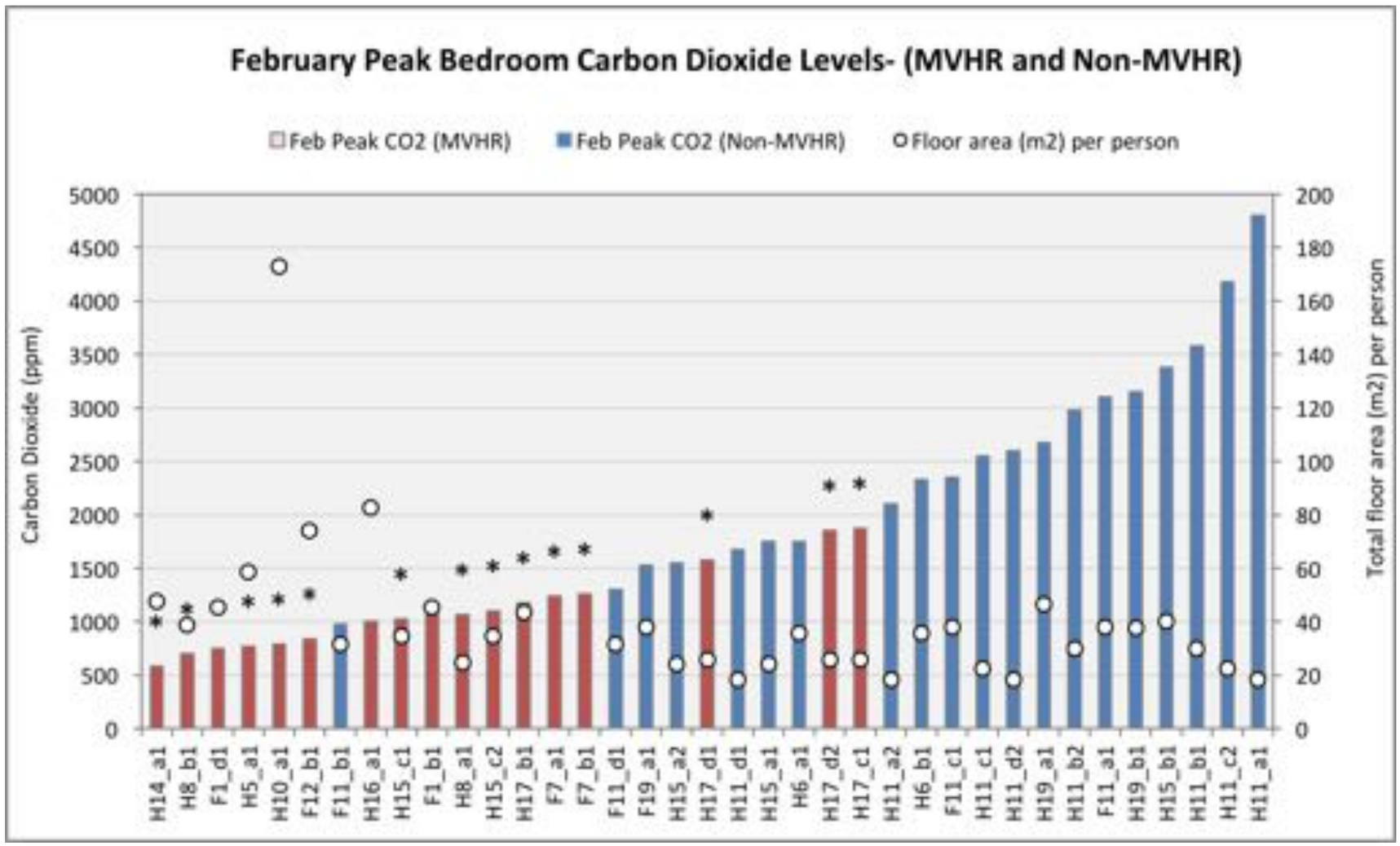
In-use performance

- Comparison of average and peak CO_2 levels in bedrooms of MVHR and non MVHR
  - Not time weighted
  - NB - predominance of Passivhaus MVHR systems
  - Limited datasets



In-use performance

- Comparison of average and peak CO_2 levels in bedrooms of MVHR and non MVHR
  - Not time weighted
  - NB - predominance of Passivhaus MVHR systems
  - Limited datasets



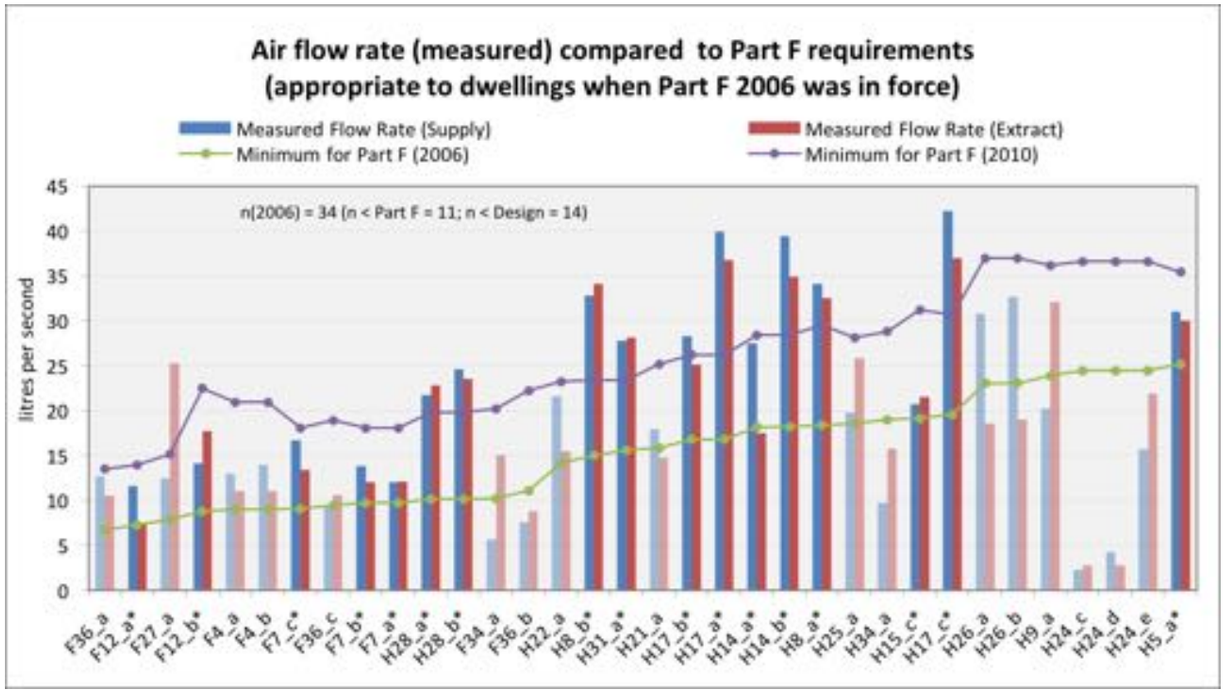
Meta Study - flow rates

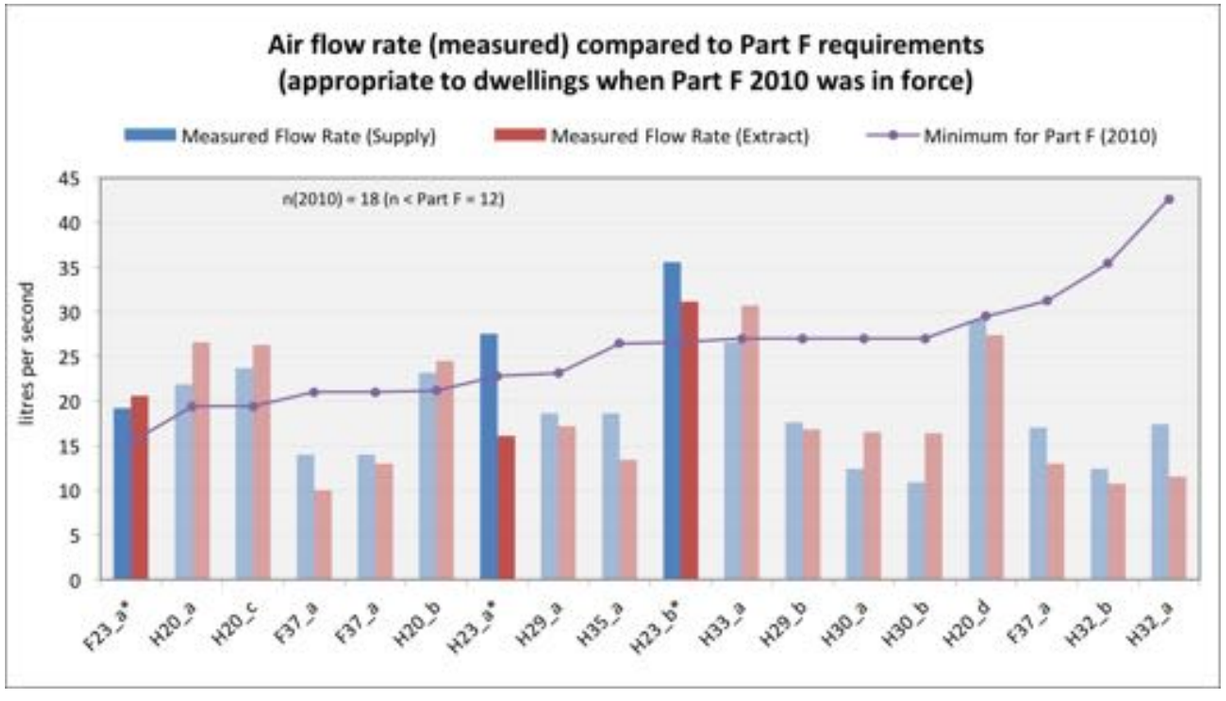
- Building to 2006 and 2010 standards

- For 2006 buildings 32% below
- For 2010 buildings 67% below

- Extract rates below standards:
- 56% kitchens
- 39% bathrooms
- 70% ensuites and 62% utilities

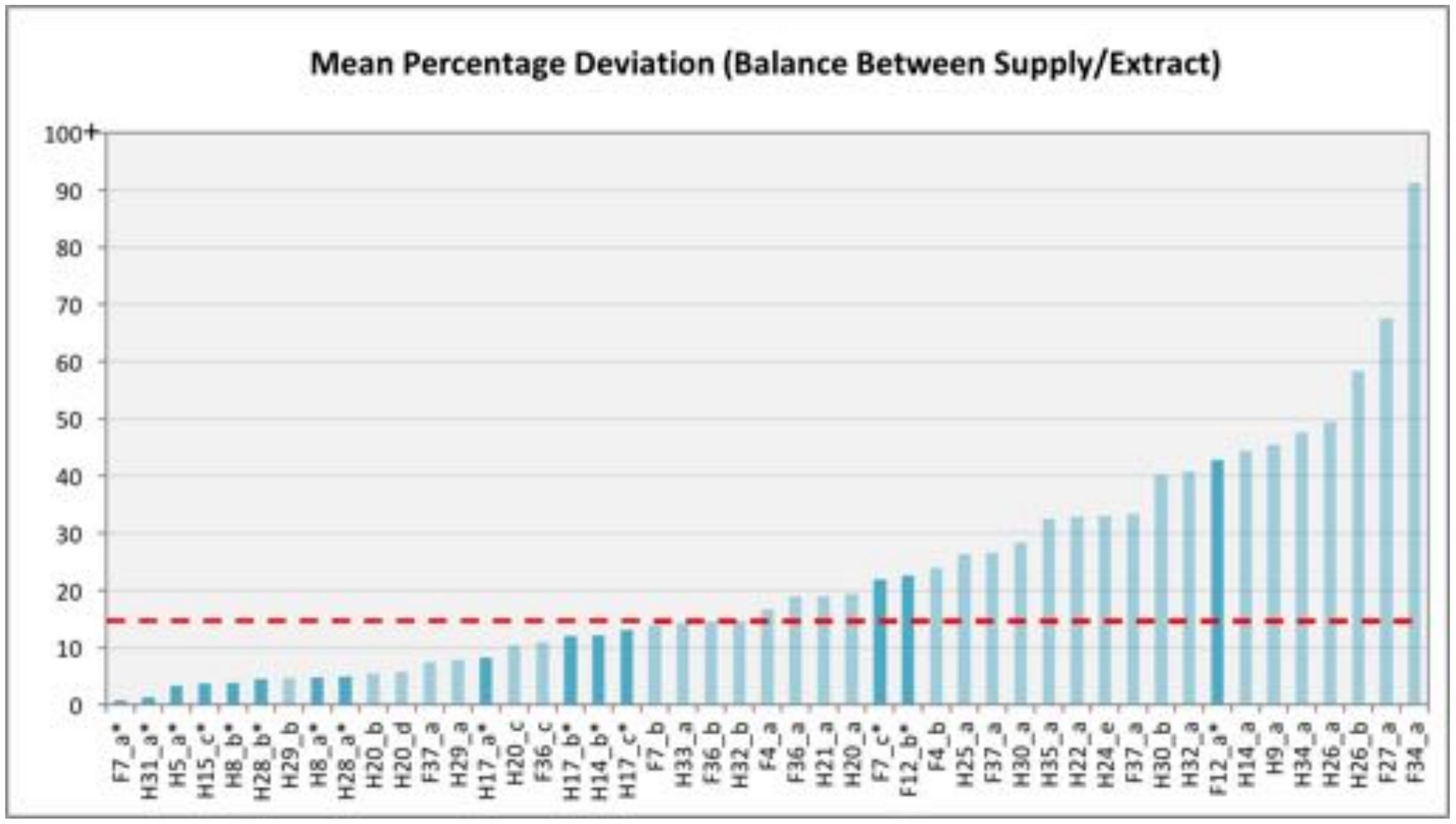
- Passivhaus is generally better, 85% met regs





Meta Study - balance

- 60% more than 15% out of balance
- Imbalance will impact on energy recovery - hard to quantify
- Other consequences - interstitial leaks of moisture



Building Performance Evaluation

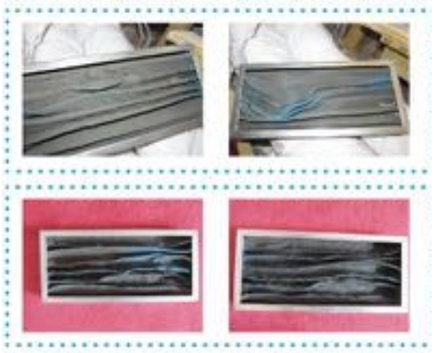
- Knowledge Transfer Partnership with Cartwright Pickard Architects
- Evaluation of 20 dwellings across London
- 24,000 similar homes in 2012

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

CARTWRIGHT PICKARD

MVHR issues

- Design intentions
- Design integration
- Ducts type and size
- Missing vents in bedrooms
- Unbalanced systems
- Unit location for filter cleaning
- Construction debris
- Noise
- Occupant understanding
- Lack of maintenance strategy



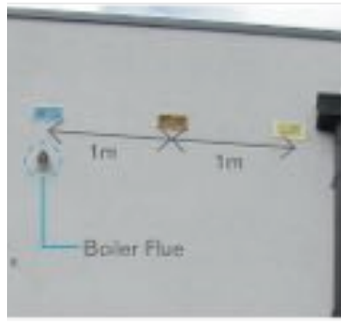
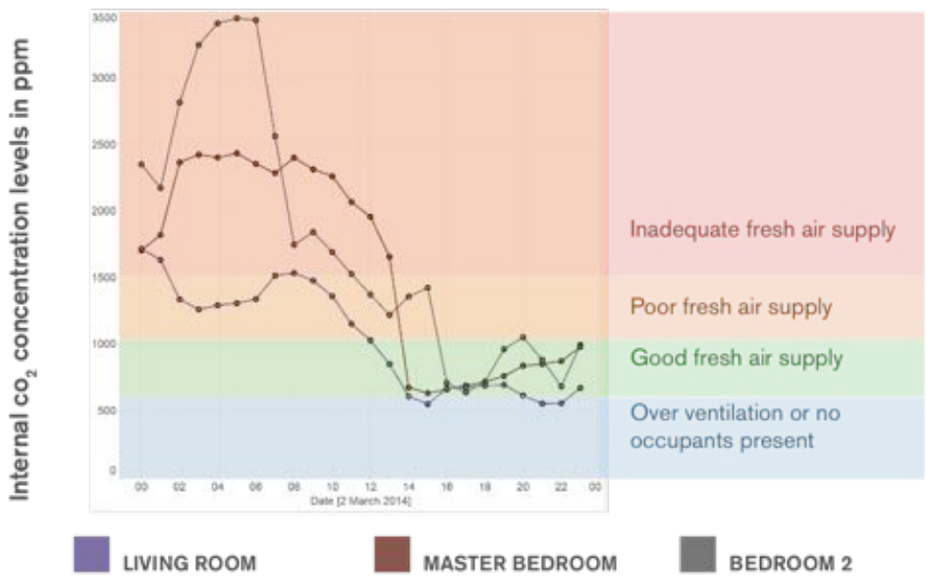


Figure 20. CO_2 levels in dwelling no. 10, on a typical day in winter



Air Quality in Passivhaus

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT THE GLASGOW SCHOOL OF ART

- Airborne Bacteria and Fungi Concentrations in Airtight Contemporary Dwellings
- Ventilation issues in Passivhaus projects - overheating

House No.	Occupancy A=Adult, C=Child	Reported presence of mould	Monitored bedroom conditions	Main heating fuel
No.1	2A, 1C	Yes	Spare room	Natural gas (fire)
No.2	2A, 1C	No	Playroom	Natural gas (fire)
No.3	2A, 2C	Yes	Childs bedroom	Natural gas (fire)
No.4	2A, 1C	No	Childs bedroom	Electric (fire)
No.5	2A	No	Spare room	Electric (fire)
No.6	4A, 1C	Yes	Teenagers bedroom	Natural gas (fire)

McGill, Grainne, Sharpe, Tim, Oyedele, Lukumon, Keeffe, Greg and McAllister, Keith (2015) An Investigation of indoor air quality in UK Passivhaus dwellings. In: Smart Energy Systems and Buildings for a Sustainable Future. Springer.

McGill, Grainne, Oyedele, Lukumon, Keeffe, Greg, McAllister, Keith and Sharpe, Tim (2015) Bedroom environmental conditions in airtight mechanically ventilated dwellings. In: Healthy Buildings Conference, Europe, 18-20th May, Eindhoven.

McGill, Grainne, Moore, John, Sharpe, Tim, Downey, Damian and Oyedele, Lukumon (2015) Airborne bacteria and fungi concentrations in airtight contemporary dwellings. In: Healthy Buildings America.

Sharpe, Tim and Morgan, Chris (2014) TOWARDS LOW CARBON HOMES – MEASURED PERFORMANCE OF FOUR PASSIVHAUS PROJECTS IN SCOTLAND. In: Eurosun 2014, 16 - 19 September 2014, Aix-les-bains, France.

Health effects of modern airtight construction

- AHRC Network Funding
- With medical researchers University of Aberdeen
- Investigating health effects

- 3 networking events in the next 12 months
- Multidisciplinary

- http://hemacnetwork.com

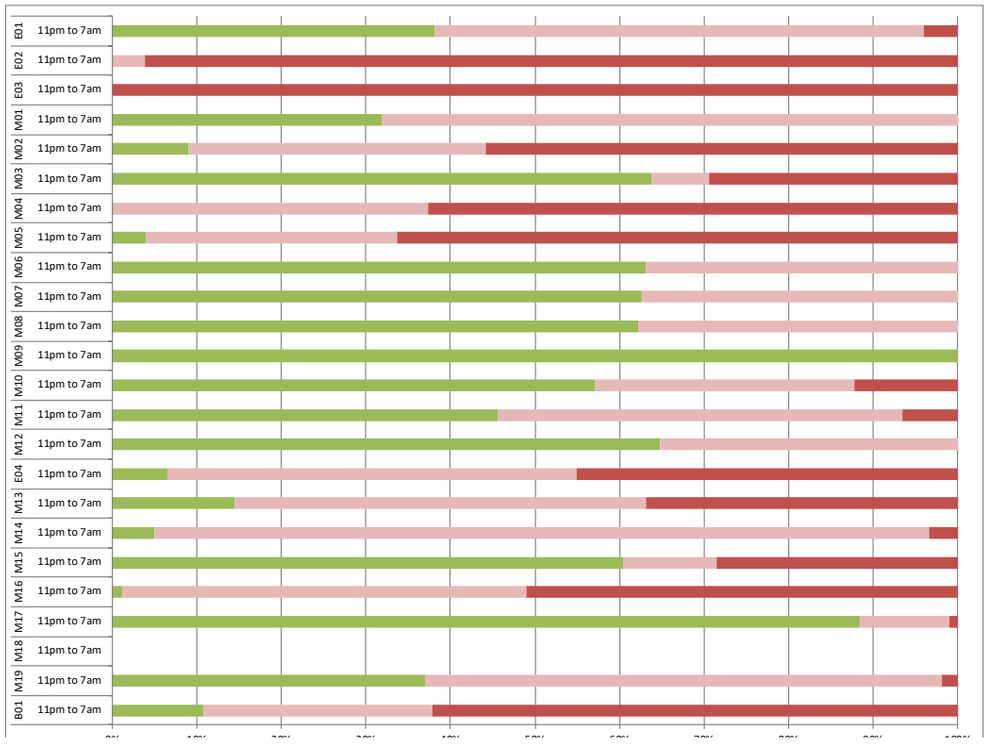
- Symposium Sept
  - platform for participants to present their research findings
- Workshop Nov/Dec
  - develop research and output ideas
- Sandpit Mar/Apr
  - Further refine and peer review
  - Develop network outputs

Ability of dMEV to act as ‘whole-house’ ventilation systems in new-build dwellings’

- Scottish Government Building Standards

- 200 house survey
- 50 houses detailed monitoring

- Indicative:
- circa 70% houses
- High CO_2 levels in bedrooms



Influence of ventilation design on the prevalence of anti-microbial bacteria in homes

- AHRC funded - part of AMR pump priming initiative

- Prof. Cath Noakes, Leeds University
- Prof. Stephanie Dancer, NHS Lanarkshire

- 200 house survey
- 100 house microbiological sampling
- 20 houses detailed monitoring and sampling

Conclusions

- Ventilation is not being designed
- Compliance is prescriptive and achieved at design stages
- The process and the product is fragmented
- No-one has an overview of the whole process
- BUT
- Nothing will change without robust medical evidence of health effects
- Construction is trial and error

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

Thank you

- http://tinyurl.com/qzrbumo

- Tim Sharpe t.sharpe@gsa.ac.uk 0141 353 4658