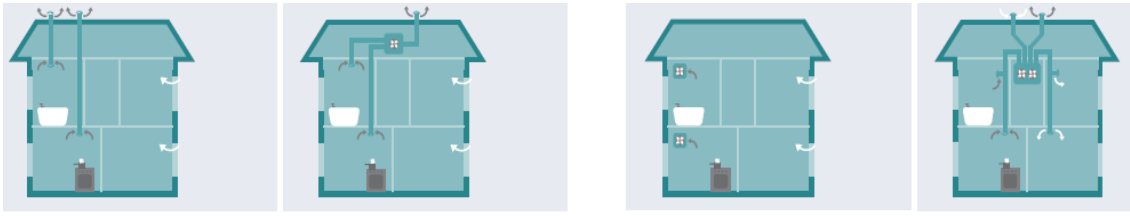

NZEB and Ventilation in Dwellings

Presented by Ian Mawditt | March 2018 | Dublin

IGBC
IRISH GREEN BUILDING COUNCIL

Green Building Network – NZEB and Ventilation in Dwellings

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Disclaimer

- All views expressed today are my own
- Not representing any other organisation, institute or government body

Contents

1. Context
   - Airtightness
   - Pollutants
   - Building Regs Part F in England
2. Findings from field investigations
   - Levels of compliance
   - Ventilation effectiveness

First principles: limit source of pollutants, then dilute by ventilation: *this is not news…*

"A room that contains a rotting dung pile remains, despite all ventilation, a disgusting living quarter, a source of bad air.

The time for ventilation comes only after cleanliness, through removal or careful isolation of air polluting materials."

Pettenkofer, M. von, 1859
Chemist and Hygienist,
Germany 1818 - 1901

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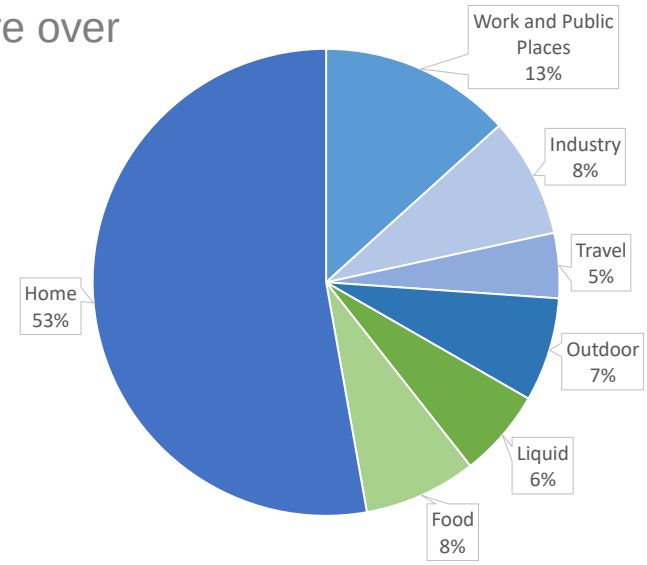
Total pollutant exposure over 70 years

- Most of our exposure to pollutants during the course of our lives occurs in our homes



- Via breathing (little choice)
- Via digestion (greater choice)

Chart recreated from data by Prof Jan Sundell, Tsinghua University Beijing

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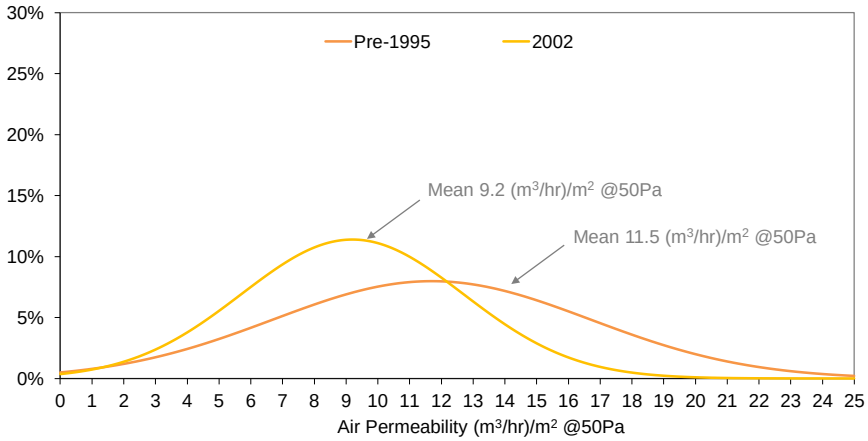
Air permeability trends – context



Sources: Building Sciences (RSK); Leeds Beckett University; ATTMA

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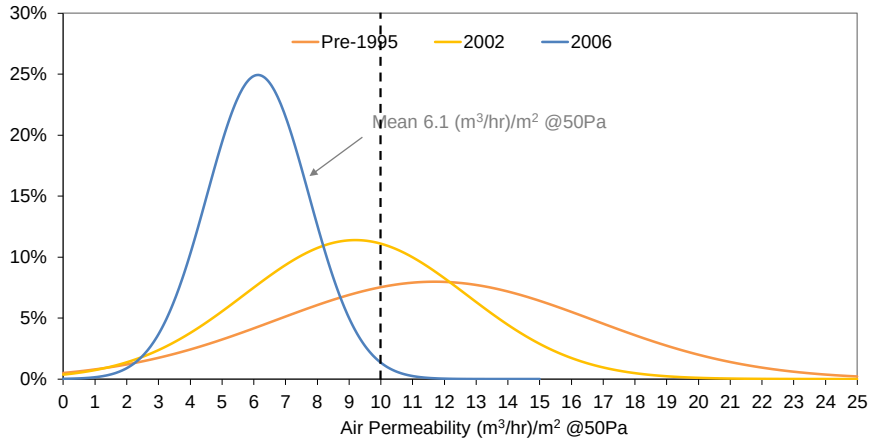
Air permeability trends – context



Sources: Building Sciences (RSK); Leeds Beckett University; ATTMA

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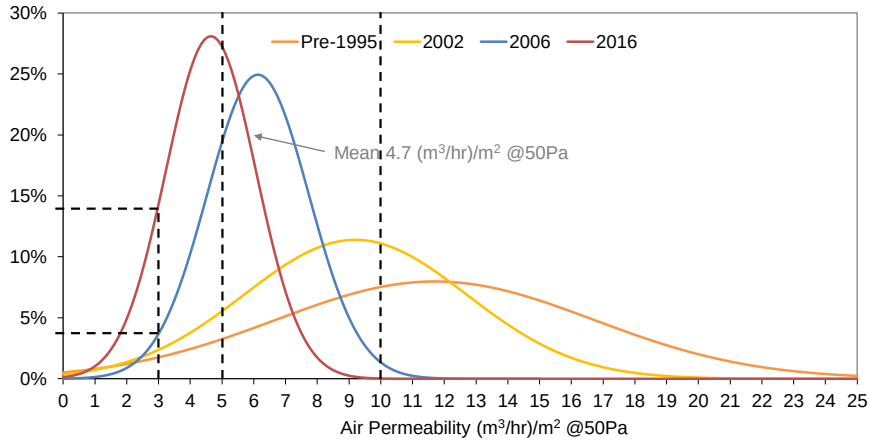
Air permeability trends – context



Sources: Building Sciences (RSK); Leeds Beckett University; ATTMA

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Pollutant warning over 'airtight' modern homes

By Eleanor Bradford
BBC Scotland Health Correspondent

26 April 2016

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Consumer products' air quality impact 'underestimated'

By Jonathan Amos
BBC Science Correspondent

16 February 2018 Share

theguardian
website of the year

Indoor and outdoor air pollution 'claiming at least 40,000 UK lives a year'

Report finds air pollution inside and outside the home is costing £20bn a year as well as causing tens of thousands of deaths

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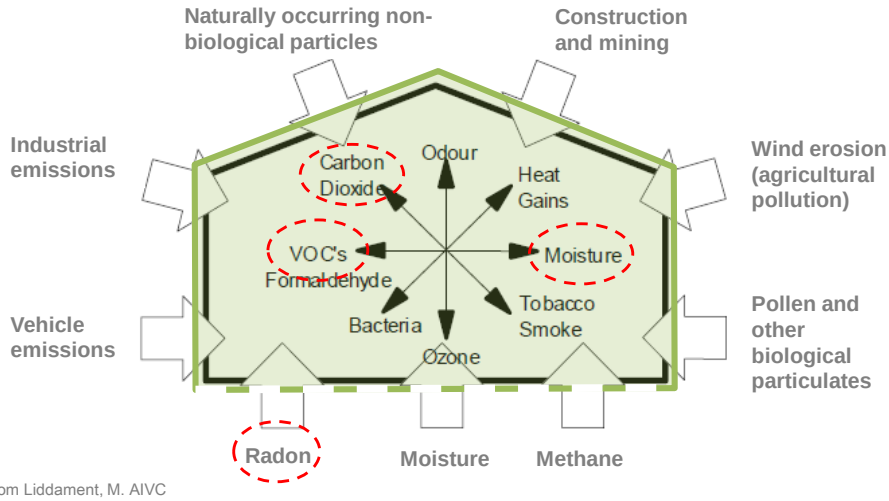
Building envelope: protection from the outside world?



© Diagram adapted from Liddament, M. AIVC

Intermittent and background pollutants: chemical compounds





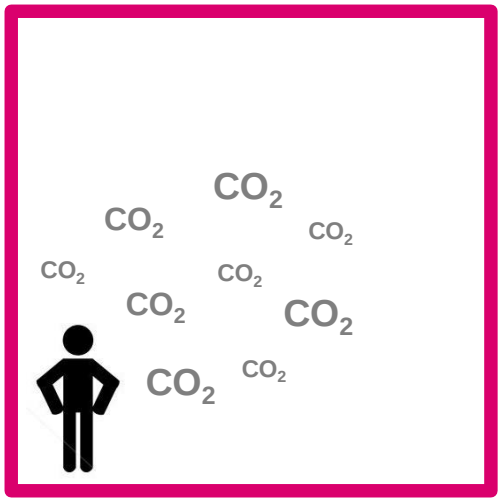



Potential health effects: chemicals

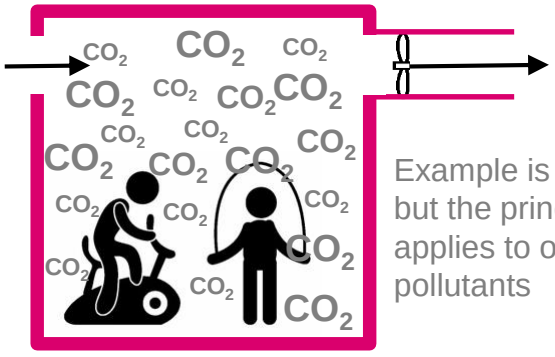
VOC	Effect (end effect)
benzene	CNS effects, convulsions, **(leukaemia)**
ethylbenzene	Fatigue, vertigo, **(chronic organ weight increase)**
hexane	Skin irritation
toluene	Memory loss, visual disturbance, decreased reaction, tremors, impaired balance
vinylchloride	**(Liver cancer)**
1,2,4-trimethylbenzene	**(Tumour formation)**
tetrachloroethene	CNS effects, impaired balance, **(kidney malfunction)**
formaldehyde	Bronchitis, ulcers, irritation, **(lung cancer)**

Sources: World Health Organisation; Crump D, et al BR450

Pollutant concentration:

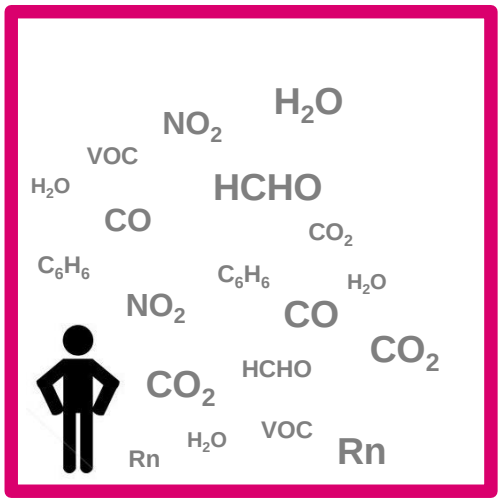


- Is proportional to source emission rate, volume (fresh air reservoir), and…
- …ventilation rate



Example is for CO_2 but the principle applies to other pollutants

Exposure effects



- Depends upon:
  - pollutant concentration
  - toxicity of pollutant
  - exposure time
- Pollutant concentration should not exceed health-based limits set for the period of exposure (e.g. AD F, HSE, WHO, etc)

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Regulations and performance standards – Part F

Approved Document F 2010 revision

- Sets *minimum* background air flow rates for control of bio-effluents and moisture – both considered to be key pollutants in dwellings
- 2010 revision introduced key Part F regulation change: ventilation in homes now a *notifiable service*
- Ventilation systems now subject to air flow testing, or testing and commissioning wherever air flow adjustment is possible

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Moisture Guidance in AD F 2010

- The performance criterion for moisture states:

  "There should be no visible mould on external walls in a properly heated dwelling with typical moisture generation"

- 2010 edition included greater guidance to minimise surface moisture activity in relation to room %RH rolling average limits

Period	Room Air Relative Humidity
1 month	65%
1 week	75%
1 day	85%

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AD F: Performance criteria for gaseous pollutants

Indoor pollutant	Guideline concentration value	Averaging Time
TVOC	300 µg m^{-3}	8 hours
Carbon Monoxide (CO)	100 (87.29) mg m^{-3} (ppm) 60 (52.37) mg m^{-3} (ppm) 30 (26.19) mg m^{-3} (ppm) 10 (8.73) mg m^{-3} (ppm)	15 minutes 30 minutes 1 hour 8 hours
Nitrogen Dioxide (NO_2)	288 (0.15) µg m^{-3} (ppm) 40 (0.02) µg m^{-3} (ppm)	1 hour long-term

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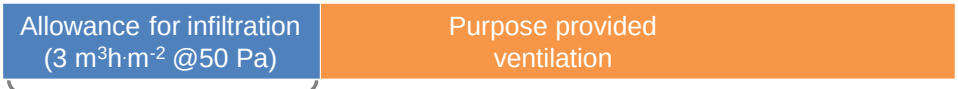
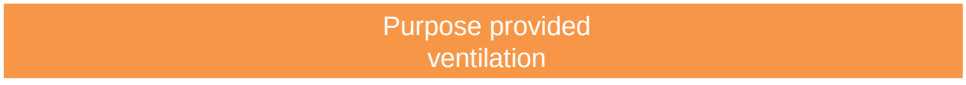
Ventilation rate requirement

Domestic ventilation system design – pre-2010 Part F



Too large?

Domestic ventilation system design – post-2010 Part F



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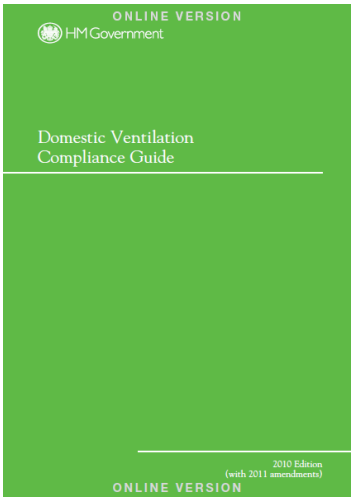
AD F 2010 supported by 2nd tier guidance



- Domestic Ventilation Compliance Guide to assist with installation and commissioning procedures
- Covers most common system types, from natural ventilation through to MVHR
- Includes a template for inspection, testing and commissioning procedures

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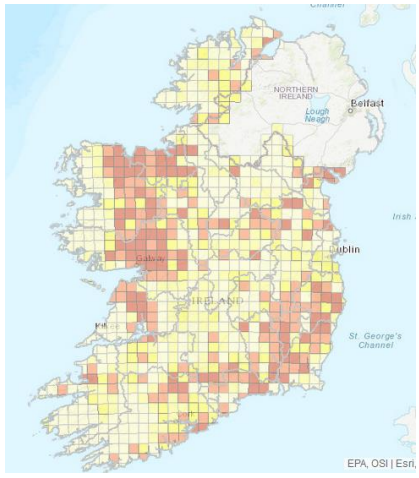
Radon – covered under Part C

- Radon represents around 50% of our annual radiation dose
- It is the leading cause of lung cancer in non-smokers
- Approximately 1100 lung cancer deaths attributed to Radon each year (UK)
  Source: Public Health England / UK Radon
- Radon mitigation measures are fairly simple to apply to new build – retrofit is likely to be more tricky



CO_2 as a performance indicator?

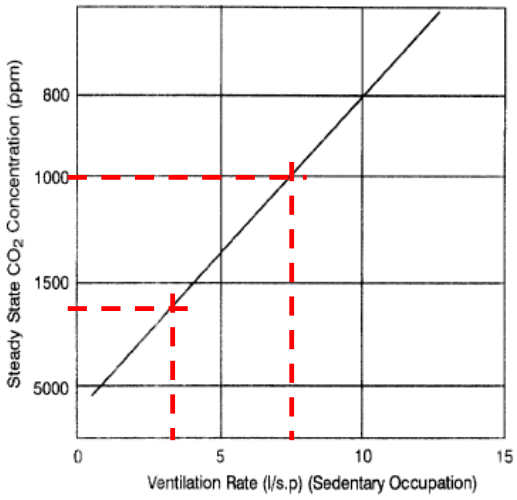
CO_2 is used as a common marker for performance

Guidelines differ according to building type:

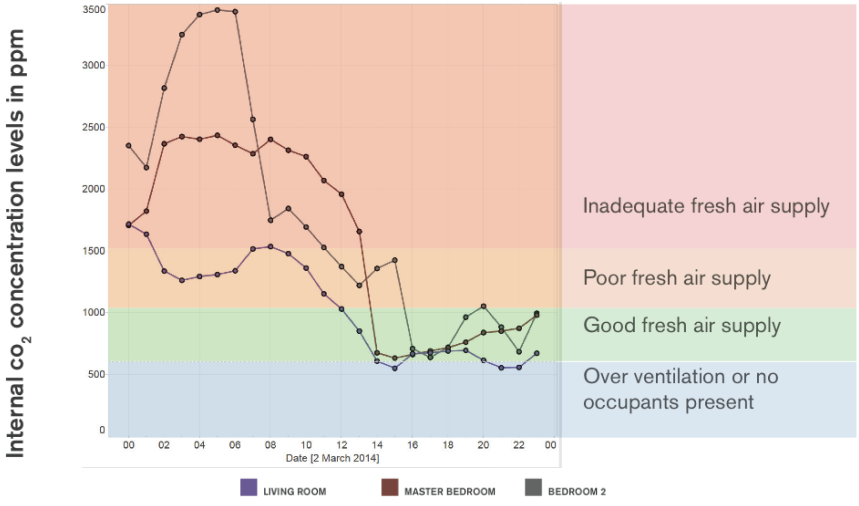
- 1000 ppm ≈ 8 l/s/person
  e.g. office (non-adapted)
- 1800 ppm ≈ 3.5 l/s/person
  e.g. home (adapted)

However, CO_2 concentrations rarely reach steady-state, and requires assumptions relating to metabolic production rates

Correlation CO2 with other pollutants is inconsistent



Bedrooms a concern: no adaptive behaviour



"..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…"

Wargocki, P. The Effects of Ventilation in Homes on Health. *Int. J. Vent.* **2013**; *12*, 101–118.

Chart with permission: MEARU

Findings from field investigations

Characteristics and levels of compliance

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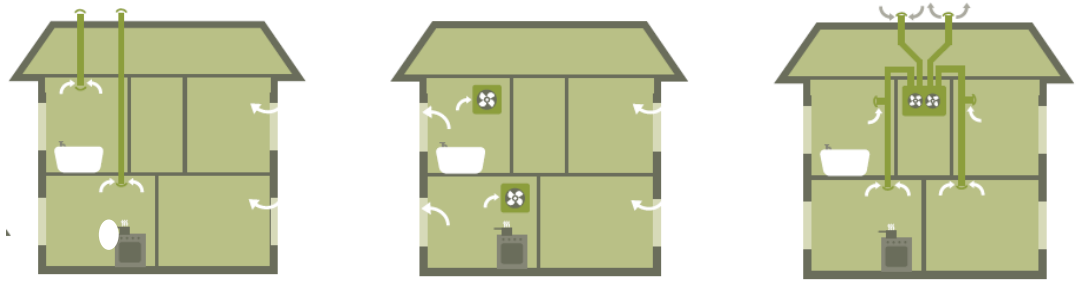
A range of ventilation strategies



Natural ventilation → Continuous mechanical

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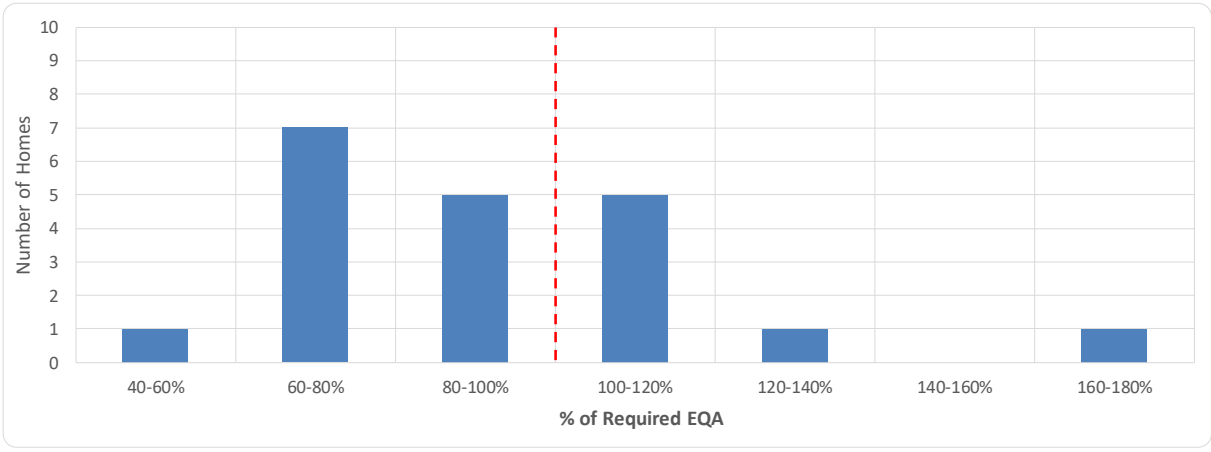
NV: installed ventilator area vs. AD F specification



Data from DCLG 2009: Ventilation and IAQ in Part F 2006 homes study

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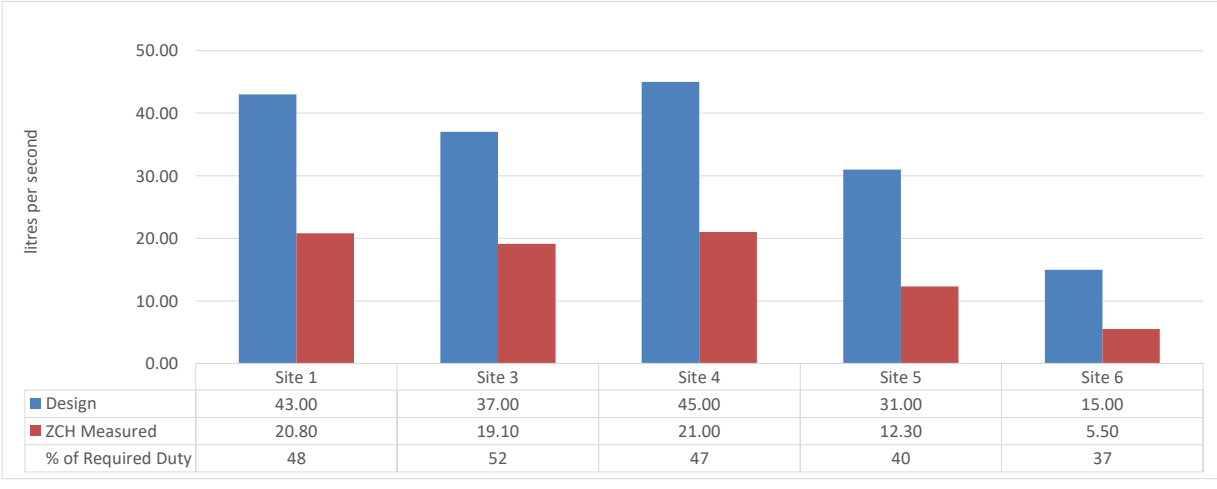
dMEV: extract rates in new homes



	Site 1	Site 3	Site 4	Site 5	Site 6
Design	43.00	37.00	45.00	31.00	15.00
ZCH Measured	20.80	19.10	21.00	12.30	5.50
% of Required Duty	48	52	47	40	37

Chart for Zero Carbon Hub: *Ventilation in New Homes* study

MVHR: flow rates often less than AD F specification

- 68% AD F (2006) systems met minimum required air flow rate.
  - 23% of AD F 2006 systems found to have AD F (2010) flow rates – these were found to be airtight dwellings
  - Two systems failed significantly
- Only 33% AD F (2010) air flow rates met the minimum specification (chart not shown)
- Projects are self-selected – not necessarily typical

* or **bold** stack on any charts indicate certified Passivhaus

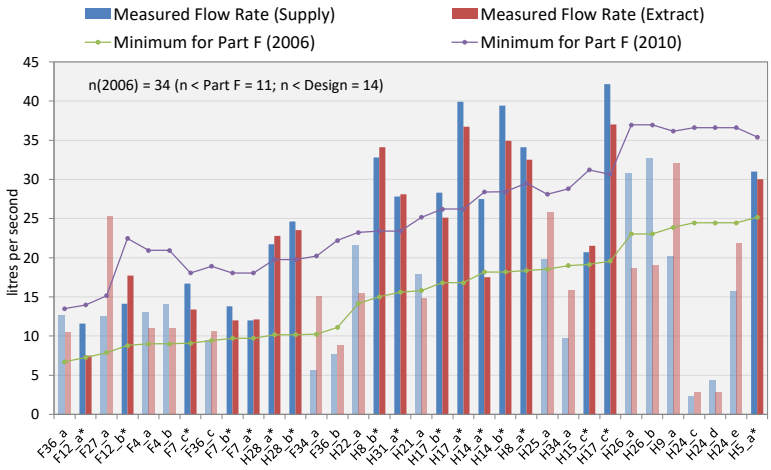


Chart from Characteristics and performance of MVHR systems (meta study): MEARU/OISD/Fourwalls

MVHR: many systems incorrectly balanced

- Illustration of % imbalance between total supply and extract rates
  - Supply and extract rates should be balanced (theoretical 0%)
- An imbalance of up to 15% is acceptable (PH limit is 10%)
- 48% of systems had an imbalance ≥15%
- Impact on heating energy difficult to quantify
  - High imbalance could cause condensation problems

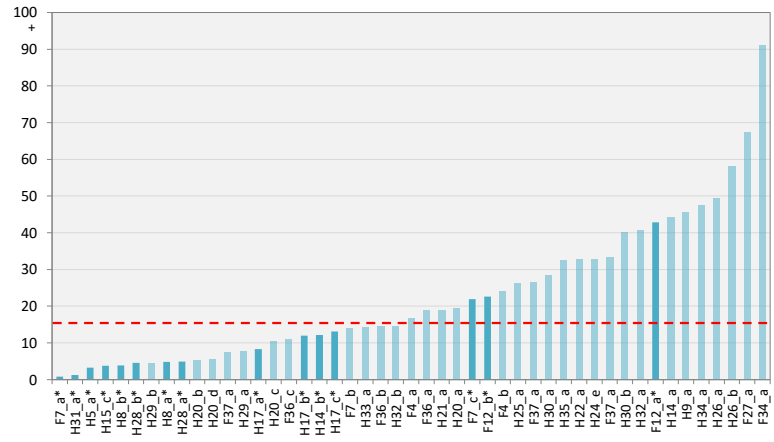


Chart from Characteristics and performance of MVHR systems (meta study): MEARU/OISD/Fourwalls

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Successful ventilation installation requires a full house of happy faces!

One unhappy face in the chain (row) will likely result in failure.

None of the sites visited in this study had a complete row of happy faces.

None of the ventilation systems met the minimum requirements specified in AD F

	Process	Design	SAP Assessment	Installation	Trickle vents	Door undercuts	Commissioning	Controls	Handover/ operation
Site 1	☺	☹	☺	☺	☹	☹	☹	☹	😐
Site 2	☺	😐	☹	☺	☺	☺	😐	☹	☹
Site 3	😐	😐	😐	☹	☹	☹	☹	☹	☹
Site 4	😐	😐	😐	☺	☺	☹	☹	☹	–
Site 5	☹	😐	😐	☹	☹	☹	☹	☹	☹
Site 6	😐	😐	☺	☹	😐	☹	☹	☺	☺

Chart by Zero Carbon Hub: *Ventilation in New Homes* study

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MVHR: reasons for choosing

What was the most important consideration for selecting MVHR as the ventilation strategy?

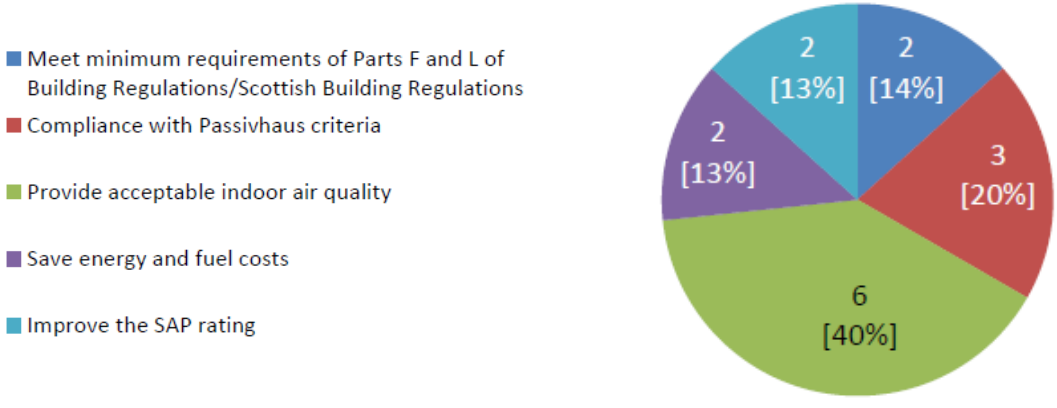

Chart from Characteristics and performance of MVHR systems (meta study): MEARU/OISD/Fourwalls

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Compliance with AD F

Despite greater regulation:

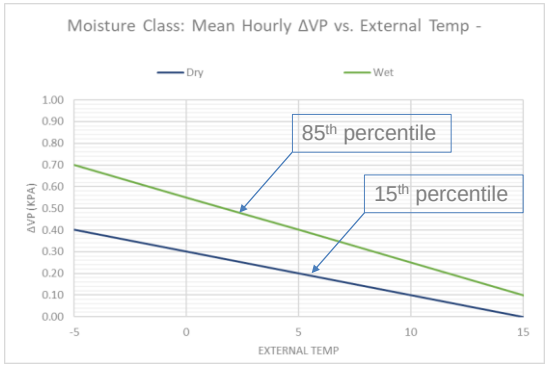
- **Over 90%** of new dwellings fail to meet the *minimum* performance specifications set out in AD F

(aggregated average based on numerous field studies, including a study of 80 homes carried out for DCLG 2016)

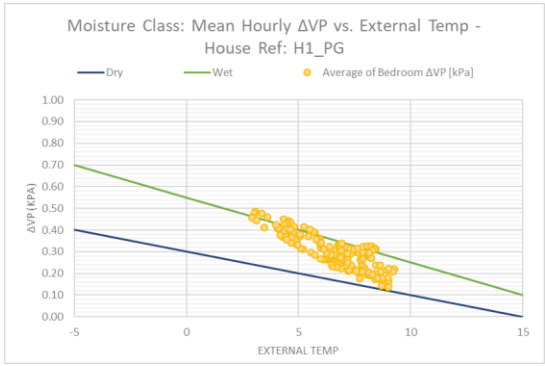
Findings from field investigations

Ventilation effectiveness

Moisture vapour in bedrooms – a comparison of ventilation types (winter condition; APT<6.0)

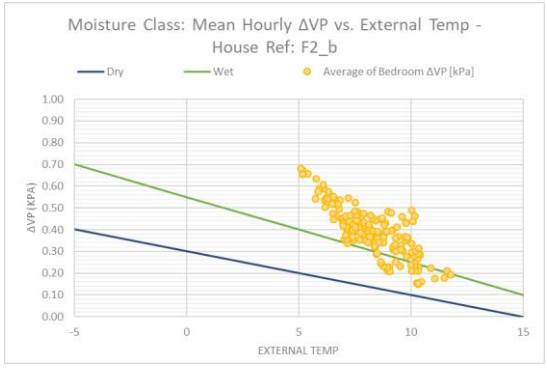


Percentiles from Warmfront dataset of 1600 homes – *study by Ridley et al, UCL*

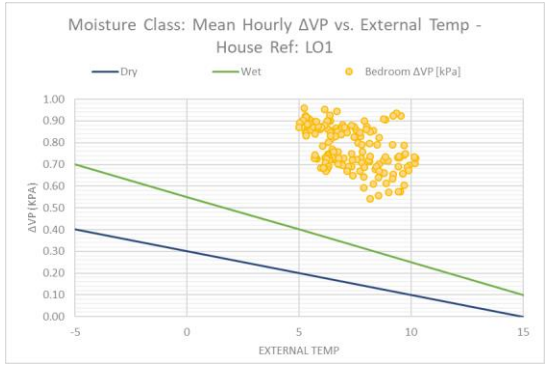


Typical – MVHR
correctly commissioned

Moisture vapour in bedrooms – a comparison of ventilation types (winter condition; APT<6.0)



Typical – MVHR
sub-optimal operation



Typical – NV single-sided
background vents; no cross-flow

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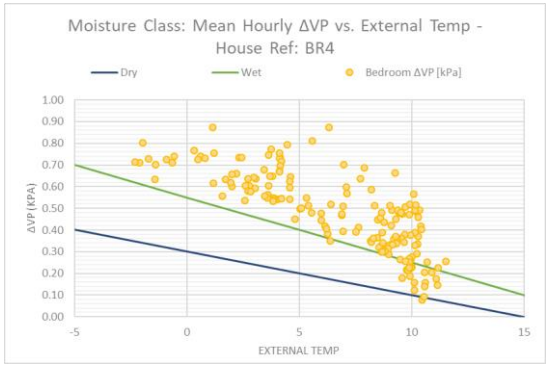
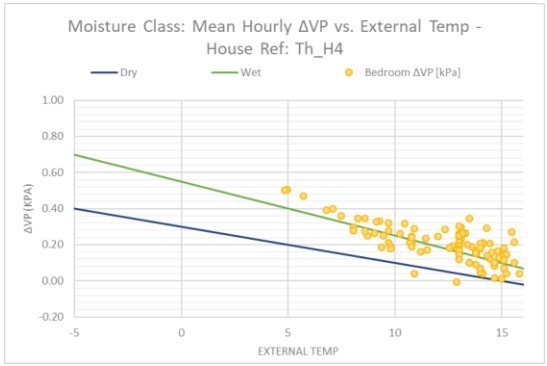
Moisture vapour in bedrooms – a comparison of ventilation types (winter condition; APT<6.0)



Typical – NV
background vents with cross-flow

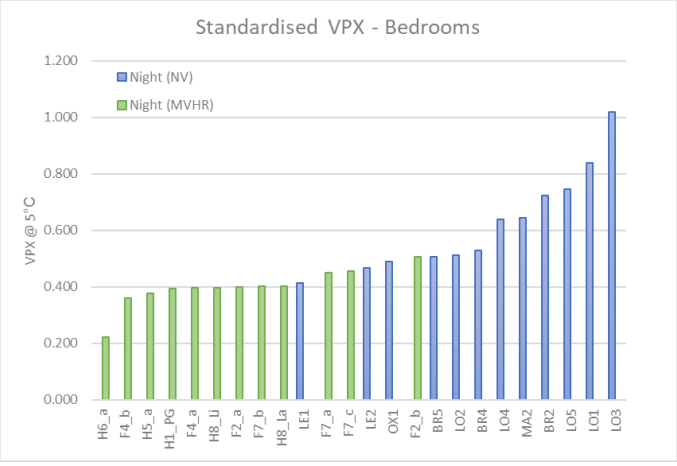


NV using wind-driven passive stack with heat recovery (PSHR)…

What makes this development so iconic – the ventilation design!

- NV can work with care – standard background ventilators are not an NV strategy in airtight buildings.
- Building geometry, volume, and good design of air inlets and outlets are key to NV success

Standardised moisture vapour in bedrooms overnight – a comparison of NV and MVHR (winter condition; APT<6.0)



Summary results (means):

24 homes (12 NV; 12 MVHR) prevailing conditions when external conditions are 5°C, 85 %RH

	MVHR	NV
Standardised VPX (kPa)	0.420	0.627
Standardised internal temp (Ti°C)	20.4	20.8
Standardised internal RH (%)	56.3	63.9

Relative humidity range – MVHR and non-MVHR

- Chart shows RH variance during February between MVHR and non-MVHR dwellings
- Greatest RH stability evident in MVHR dwellings and close to optimal conditions during all monitored seasons
- Note that RH is influenced by numerous factors (i.e. not just down to ventilation)

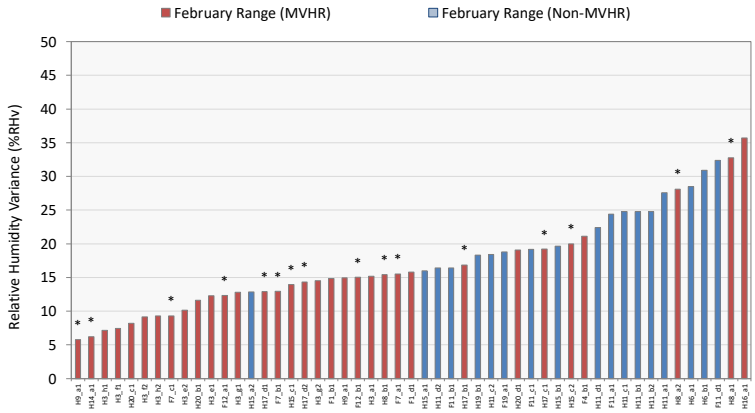
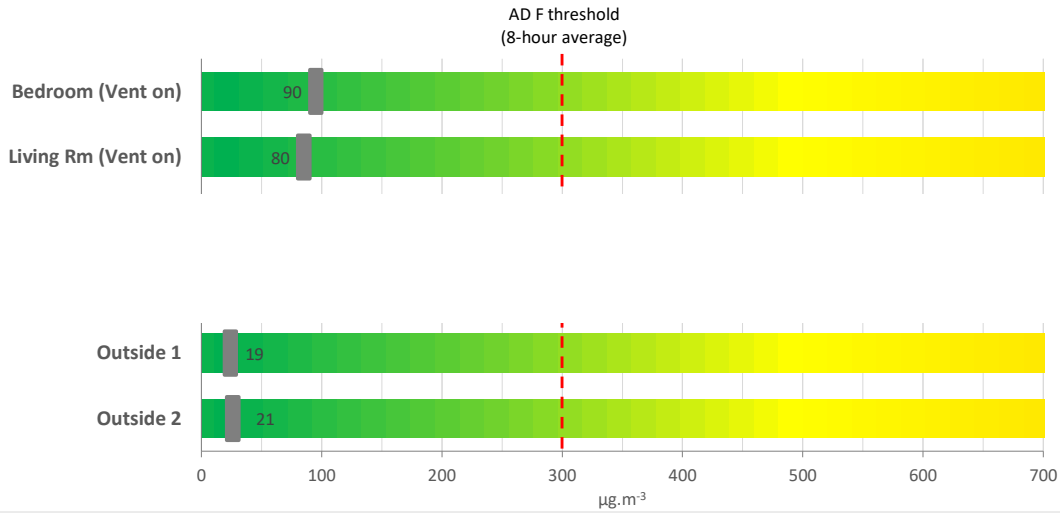


Chart from Characteristics and performance of MVHR systems (meta study): MEARU/OISD/Fourwalls

TVOC concentrations – ventilation interventions



Air exchange rates and CO_2 concentration

- Exponential increase in CO_2 concentrations as air change rate reduces below 0.5 ach^{-1}

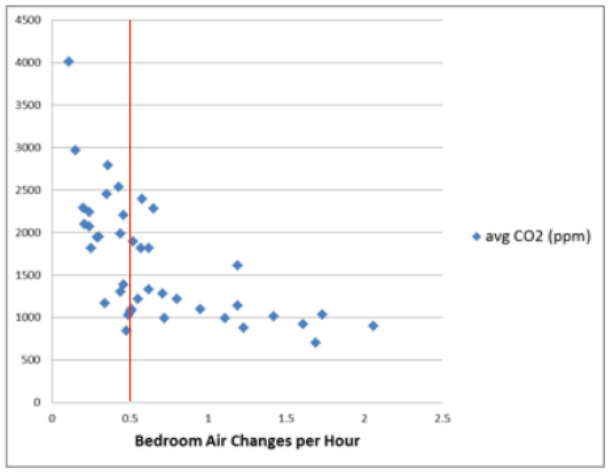


Chart courtesy MEARU

Seasonal performance – MVHR and non-MVHR

- Peak CO_2 levels across winter, spring and summer
- CO_2 is still higher in non-MVHR dwellings through spring and summer
- Increasing CO_2 levels in MVHR dwellings in summer may indicate shift toward natural vent during warmer periods

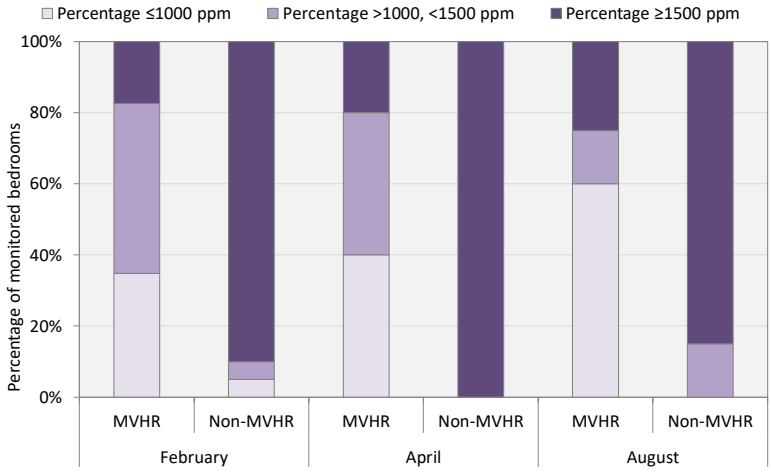
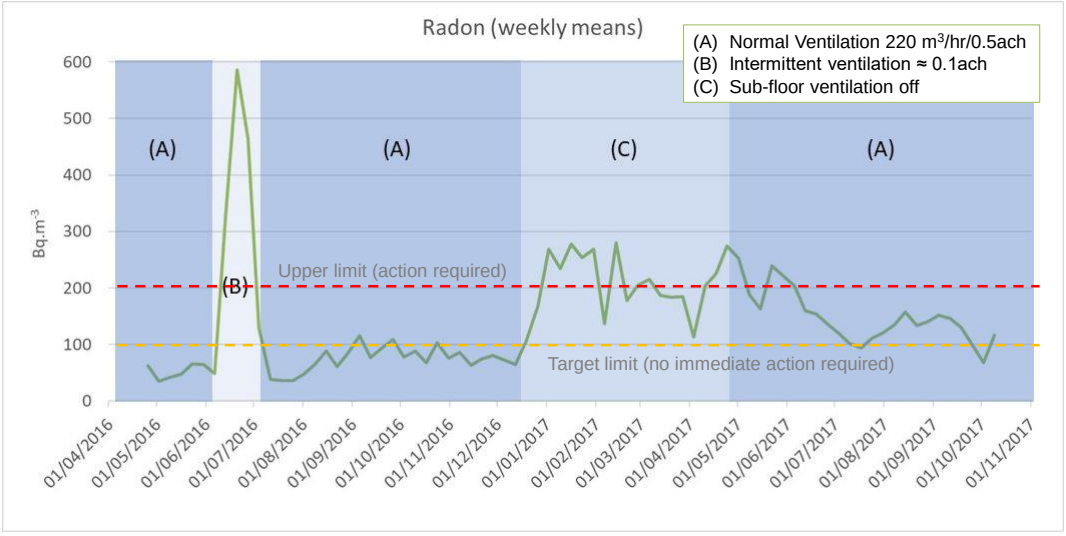


Chart from Characteristics and performance of MVHR systems (meta study): MEARU/OISD/Four Walls

Managing Radon – can we rely on ventilation?



MVHR: user satisfaction

- BUS Methodology – end-user / occupant survey relating to comfort levels
- Despite problems with correct commissioning, occupants are mostly satisfied with comforts conditions (relating to perception of air quality)

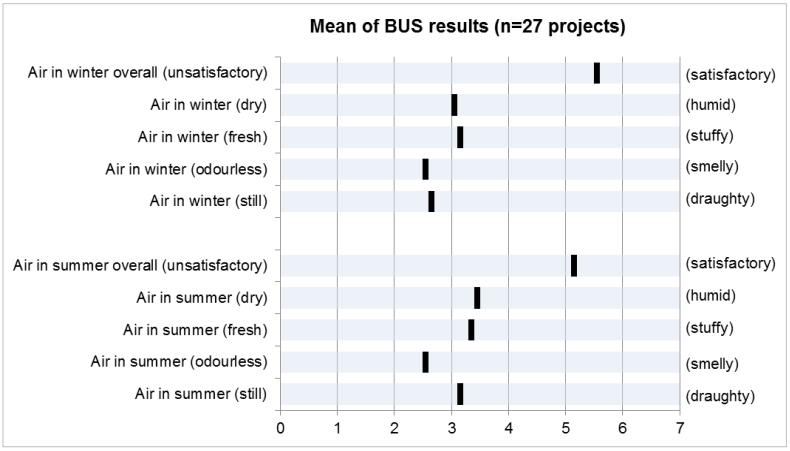


Chart from Characteristics and performance of MVHR systems (meta study): MEARU/OISD/Fourwalls

NV in airtight properties needs careful consideration

Ask:

- Will background ventilators above windows (sized for winter conditions) be sufficient?
- Does the geometry of the building encourage or hinder natural air flow?
- Will occupants use background ventilators effectively?

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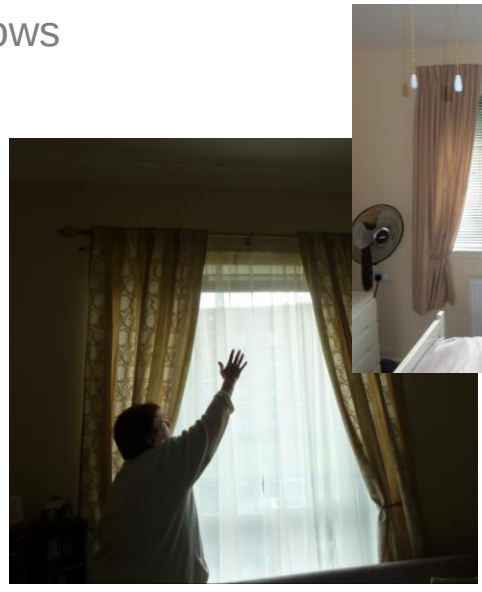
NV ventilators in windows

- Trickle vents often out of reach due to height, furniture obstacles, position of blinds and curtains
- Ventilators in window heads is common and compliant.
- But curtains will be closed overnight and may restrict the air flow into a room



Photos with permission: MEARU

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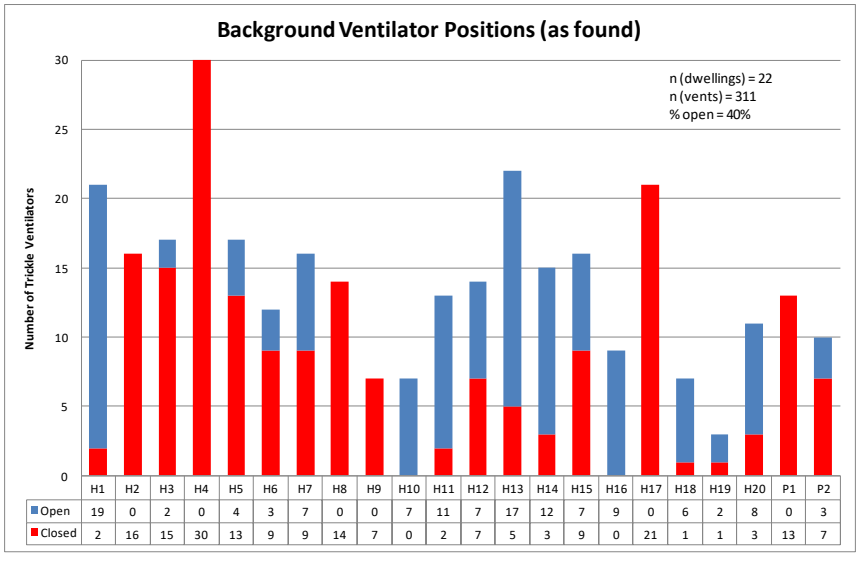

	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	P1	P2
Open	19	0	2	0	4	3	7	0	0	7	11	7	17	12	7	9	0	6	2	8	0	3
Closed	2	16	15	30	13	9	9	14	7	0	2	7	5	3	9	0	21	1	1	3	13	7

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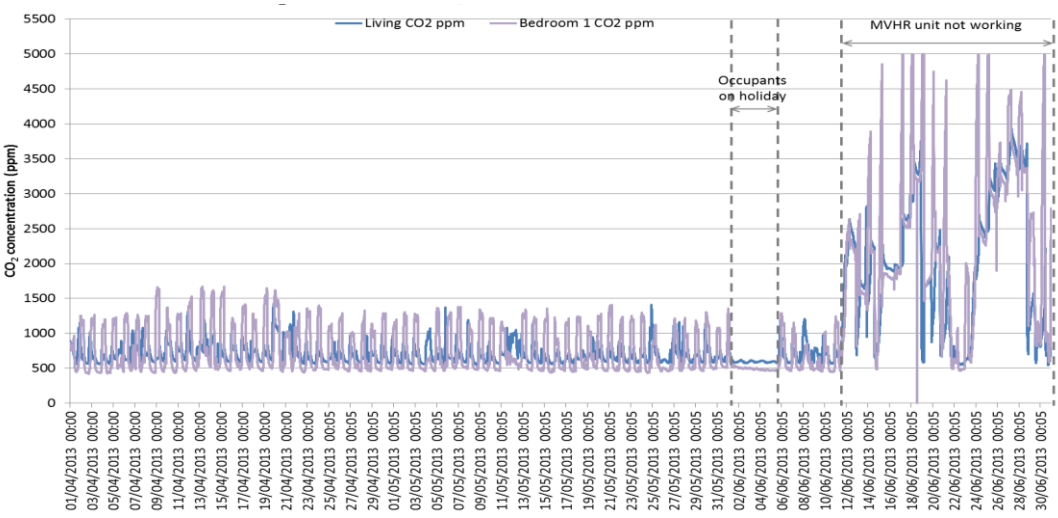
MVHR and MEV operation needs to be maintained



Source: Innovate UK BPE Programme

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Guidance for occupants

Residents in homes with MVHR are often furnished with **engineer's manuals**, which are "*far too technical to understand*" BBC News 26th April 2016

Operation and maintenance: critical

Whatever the strategy, it's correct use is **vital**

Greater guidance and understanding of related health-risks associated with under-ventilation and poor IAQ is **vital**

We need to avoid residents taking adverse action due to thermal or acoustic discomfort associated with poor design

Airtight – Ventilation = No Ventilation + Poor IAQ

Summary

- ALL ventilation systems need to be DESIGNED
- Building regulations technical guidance should **not** be used as the design specification: it sets the absolute minimum performance criteria – **not the target**!
- There are significant, non-compliant issues with domestic ventilation installations. BUT, the ability to move some air is still better than allowing it to stagnate and become increasingly polluted.
- Natural or mechanical?
  - No guarantees of effective performance with background ventilator NV strategy in airtight properties
  - NV can work, but the building should be designed to 'drive' air through
  - MEV/MHVR – more consistent, but care needed to ensure nuisance-free operation – switch off scenario = no contingency