Natural ventilation – does it work?

Beliefs and assertions about Natural Ventilation :

"Ventilation can be provided through a number of methods, the most energy efficient being a natural ventilation strategy." *- CIBSE website*

Its "energy efficient"

But look, for example, at this -- a typical discussion of ‘natural ventilation’

User testimonial

"The windows open and close depending on the temperature of the room... it never gets too hot and stuffy" (*Carbon Trust – Lessons Learned from Low Carbon building with Natural Ventilation)*

Sounds to me like the natural ventilation is doing a wonderful job preventing overheating.

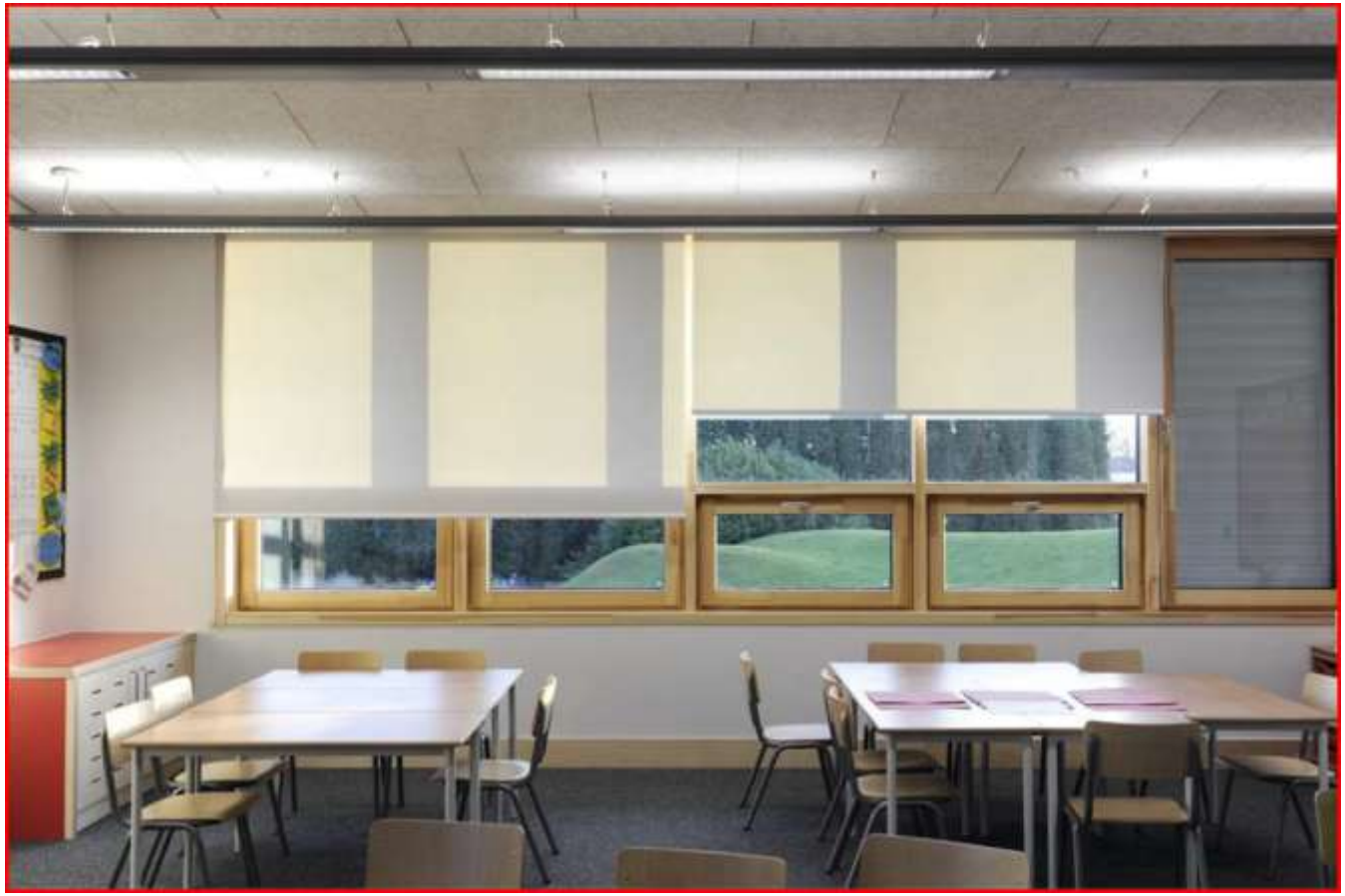
And from the same report, reasons give for opting for natural “ventilation”

- “can require less maintenance than air conditioning.”

I don’t think they mean ventilation, they mean cooling.

Lets stop confusing ventilation with cooling

Yes of course natural ventilation supplies low energy cooling : its invaluable



That’s why this school has easy-to-operate low-level opening windows: classrooms get hot

(photo Juraj Mikurcik, Architype)

The windows aren't the ventilation system here though: this is a Passivhaus school

Purge ventilation for cooling, and background ventilation for all-year air quality, work differently

If the windows were the year-round background ventilation system, would teachers keep the windows open wide enough in winter?

Evidence suggests they don't.

Indoor Air Quality

Most of us spend 80 – 90 % of our time indoors

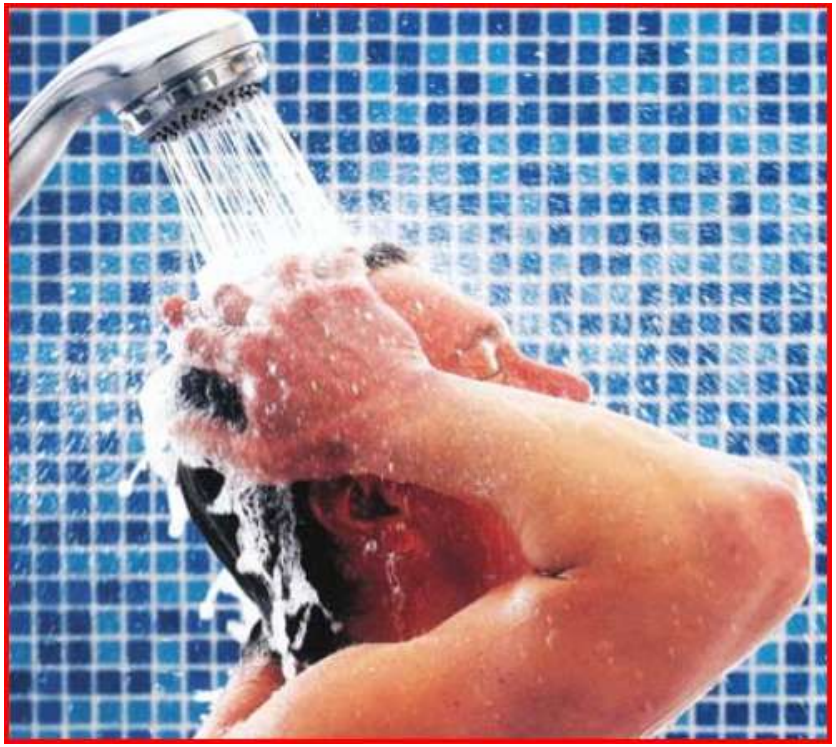
You too: 15% of the time is 31/2 hours outside per day

What do we want from ventilation?

- Supply of fresh air, to displace stale, polluted air
- Cooling

What pollutants are we worried about?

Moisture...



...leading to damp and mould

Picture LHS: CSE – Centre for Sustainable Energy, Bristol

VOCs

www.katedeselincourt.co.uk
AECB Conference, July 2014

More VOCs

VOCs also from

- cleaning products,
- plastics,
- very large quantities from decorating – for weeks or months
- The house itself: chipboard, glues and even plain timber

Anything you can smell in fact, plus plenty you can't

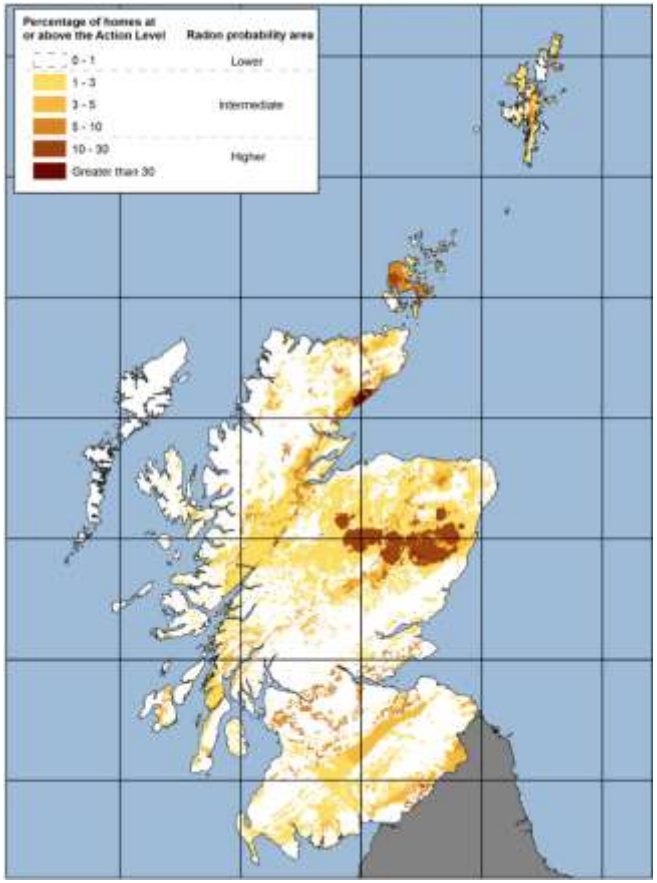
Source control by manufacturers and householders is essential, but you can't stop ordinary life: ventilation is critical too

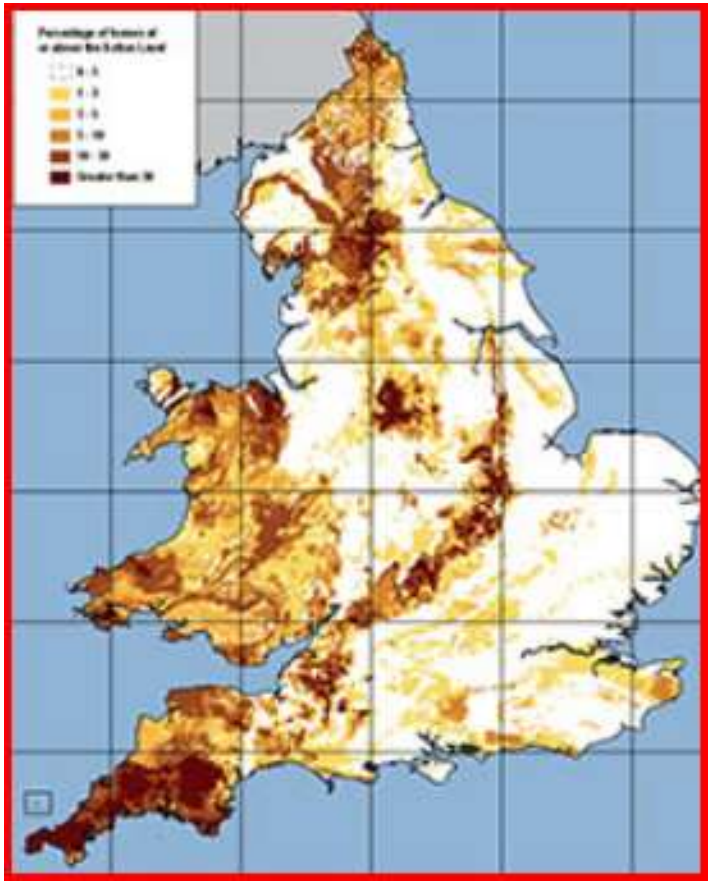
NO2, particulates

Carbon monoxide

- Low-level CO poisoning is probably under-diagnosed by health services: may be disguised, doctors may not suspect.
- Source control again essential, but poor ventilation will make matters worse

Radon





Maps from Public Health England

- A leading cause of lung cancer
- Present in all houses, but problematic levels likeliest where shown darker on maps
- Particular issue with suspended floors

CO2

CO2 tends not to be an issue in itself in homes, where it is most useful as a “flag” that air change rate is too low – different matter in schools (rooms packed with people), where levels can easy rise to 2000ppm+, starts to affect concentration

Overheating is also dangerous: preventing it needs its own ‘purge’ ventilation strategy, considered separately from background ventilation.

Purge ventilation is also very useful when you have burnt toast, boiled pasta for 12 people, or are decorating – ie, for discharging spikes in pollution .

The cost of poor IAQ

Just one condition, asthma:

- The UK has one of the highest rates in Europe
- around 9-10% of adults, 11% children affected
- it kills three people a day
- it costs the NHS millions each year

Role of IAQ in asthma

- VOC pollution
- Allergens from damp and mould – needs RH 65% (or lower if fabric poor?) to control
- House dust mite allergen – dust mites multiply above RH 50% - at 50%+, lower still better than higher (research from UCL)

Other IAQ related illness include

- heart/circulatory problems
- increased infections
- Lung cancer, possibly other cancers (from VOCs and radon)
- mental health issues from degrading living conditions

Does natural ventilation deliver good IAQ?

"Naturally ventilated" homes – air movement through:

- uncontrolled infiltration,
- air flow through vents (may be under occupant control),
- mechanical fan extracts from wet/smelly rooms

or

- As above but extract (assisted) by passive stack ventilators, generally sited in wet rooms.

Infiltration

What do people think it does?

- helps ventilation
- good for the fabric
- “Oh I couldn’t live in an airtight box”
- “A building needs to breathe”

Infiltration and airtightness

Does loss of infiltration mean loss of IAQ?

We often see statements like this: “Building more air-tight dwellings is having a deleterious impact on indoor air quality.”

-- or this:

"Industry" view in Scotland in 2012, as reported by BRE

> "There is a clear concern within the industry that uncontrolled infiltrating air cannot significantly contribute to the ventilation strategy of a house where high levels of air-tightness exist."

But should anyone be relying on infiltration to "contribute to the ventilation strategy"?

Muddle?

- Someone else, complaining that airtightness provisions in Part L means "reducing ventilation rates to improve energy efficiency and lower carbon emissions..."

- But where in Part L are you enjoined to reduce ventilation rates??

This leads to a perceived tension between airtightness and ventilation:

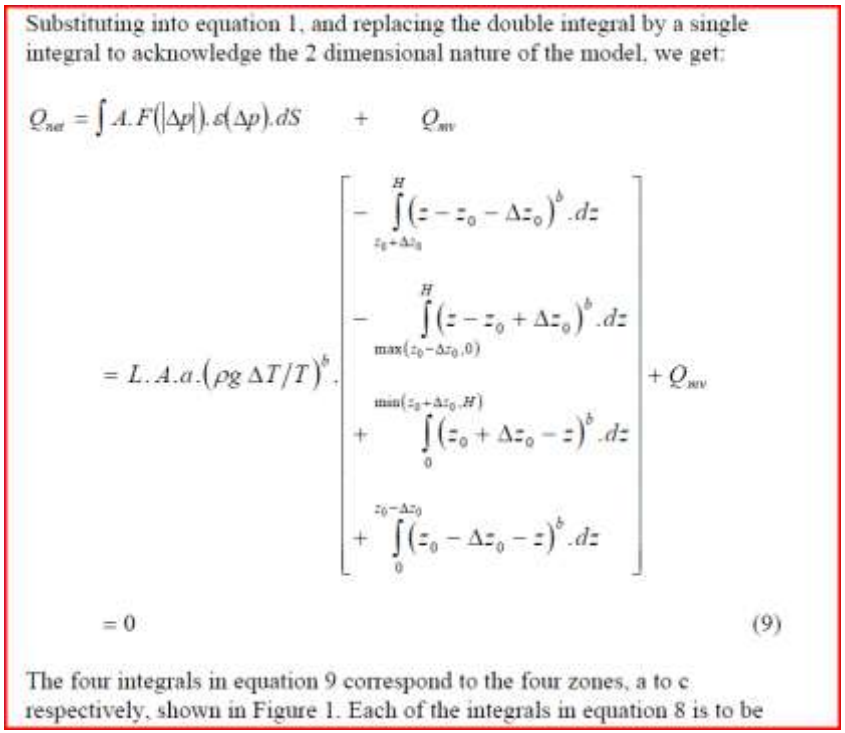
"It is important...to have the **correct balance** between airtight buildings to conserve energy ... whilst at the same time providing effective ventilation for occupants and maintaining good indoor air quality." *BRE, 2012, my emphasis*

Should infiltration be part of your ventilation?

A closer look at how infiltration works...

If you are relying on the natural forces of wind and weather to get fresh air into your building, you are at the mercy of – the wind and weather

Bob Lowe's calculations (small sample of very detailed paper!)



Substituting into equation 1, and replacing the double integral by a single integral to acknowledge the 2 dimensional nature of the model, we get:

$$Q_{net} = \int A.F(|\Delta p|).s(\Delta p).dS \quad + \quad Q_{inv}$$

$$= L.A.a.(\rho g\,\Delta T/T)^b.\left[\begin{array}{l} -\int_{z_0+\Delta z_0}^{H}(z-z_0-\Delta z_0)^b.dz \\ -\int_{\max(z_0-\Delta z_0,0)}^{H}(z-z_0+\Delta z_0)^b.dz \\ +\int_{0}^{\min(z_0+\Delta z_0,H)}(z_0+\Delta z_0-z)^b.dz \\ +\int_{0}^{z_0-\Delta z_0}(z_0-\Delta z_0-z)^b.dz \end{array}\right] + Q_{inv}$$

$$= 0 \qquad (9)$$

The four integrals in equation 9 correspond to the four zones, a to c respectively, shown in Figure 1. Each of the integrals in equation 8 is to be

Modelling the movement of air in and out of a two-storey building, hour by hour, under realistic weather conditions

Bob Lowe (then at Leeds Metropolitan University) this is what he found:

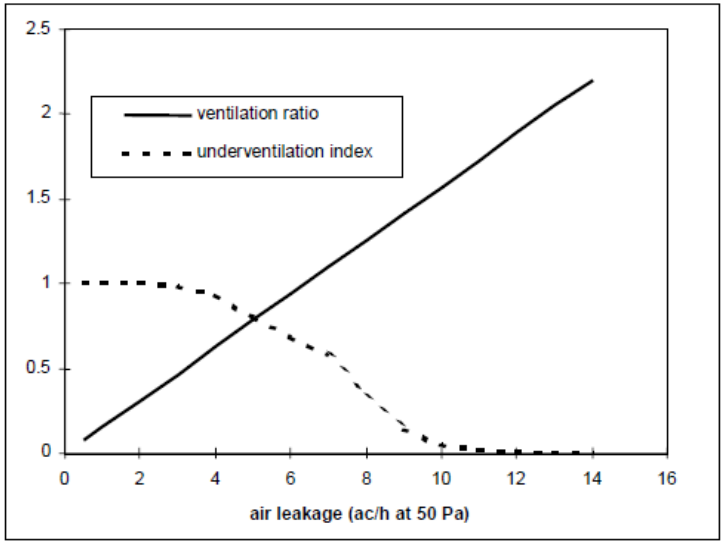


Figure 3 Ventilation and under-ventilation in naturally ventilated dwelling

Black line: Ventilation ratio is how the ventilation rate, averaged over the whole heating season, compares to design (ie, intended) ventilation rate – at varying levels of airtightness

(1= 'just right' – *on average!*)

Dotted line tells you how much of the time ventilation is too low **that hour** – at air leakage of 5ach, its rather a lot (around 80% of the time?) At 100% of the target air change rate overall, still underventilated 60 or 70% of the time

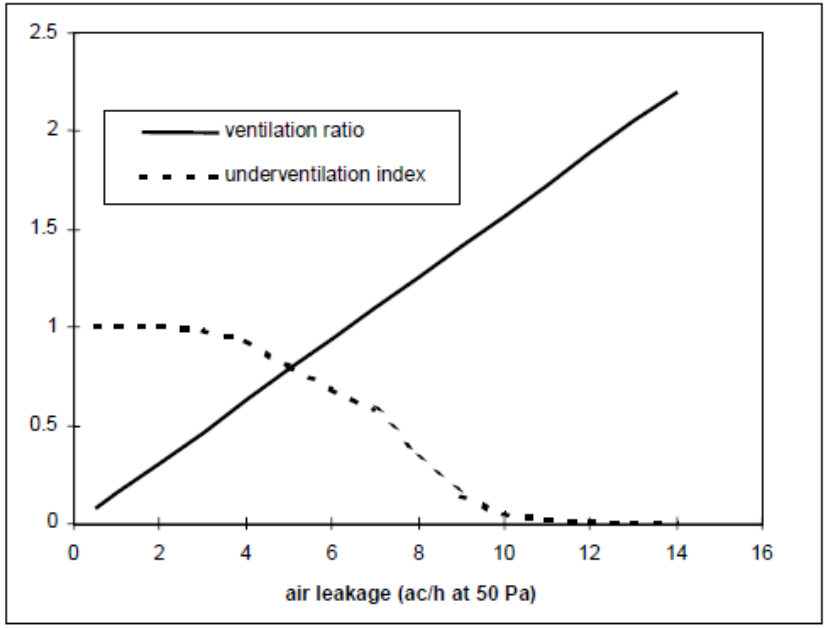


Figure 3 Ventilation and under-ventilation in naturally ventilated dwelling

Dotted line, "Under-ventilation index", is proportion of the heating season for which a naturally ventilated dwelling will be under-ventilated without additional window opening – at varying levels of airtightness. At other times, it will be 'just right', or over-ventilated (unwanted heat loss)

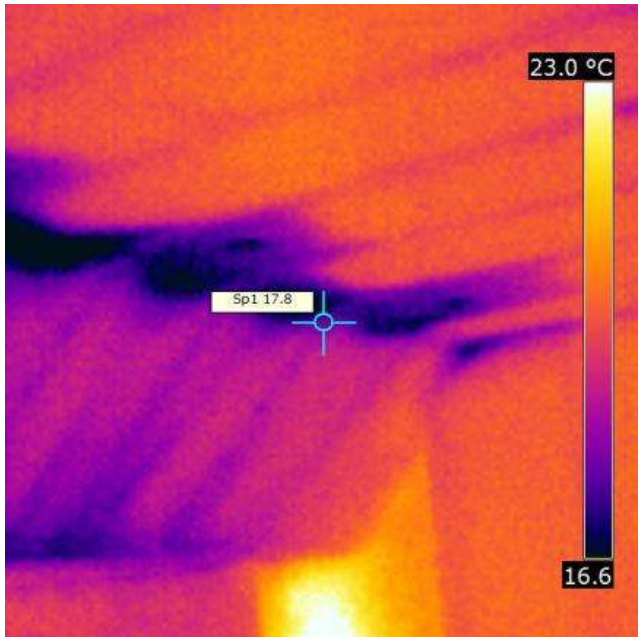
- Still and/or mild weather: low air change rate
- Cold and/or windy weather: high air change rate, but risk excessive heat loss
- Temperature differences drive air movement (buoyancy) – if occupants don't heat (fuel poverty) temp differences will be less, air changes will be less

That’s the theory ...

What does infiltration bring to the party?

- Its uncontrolled – so where is it going?

Infiltration without ventilation?



Leaky construction: Cold air comes in under the soffits and round the back of the ceiling, taking the warmth with it as it goes. Risk of condensation and mould on these cold spots – no help to IAQ

photo by Paul Buckingham

http://www.aecb.net/new-soapbox-we-must-change-our-disgraceful-approach-to-build-quality-or-wave-goodbye-to-energy-savings/

What about air that definitely comes into the living space?

- Kara Rosemeier research into “infiltration-only” homes in New Zealand (similar climate to ours)
- 4-12 ach @50Pa (similar leakiness to our homes)
- Some of the leakiest had the worst IAQ (highest CO2 levels)
- Leaky, but not well-ventilated
- Rosemeier suspects “distribution issue”

Kara Rosemeier's findings

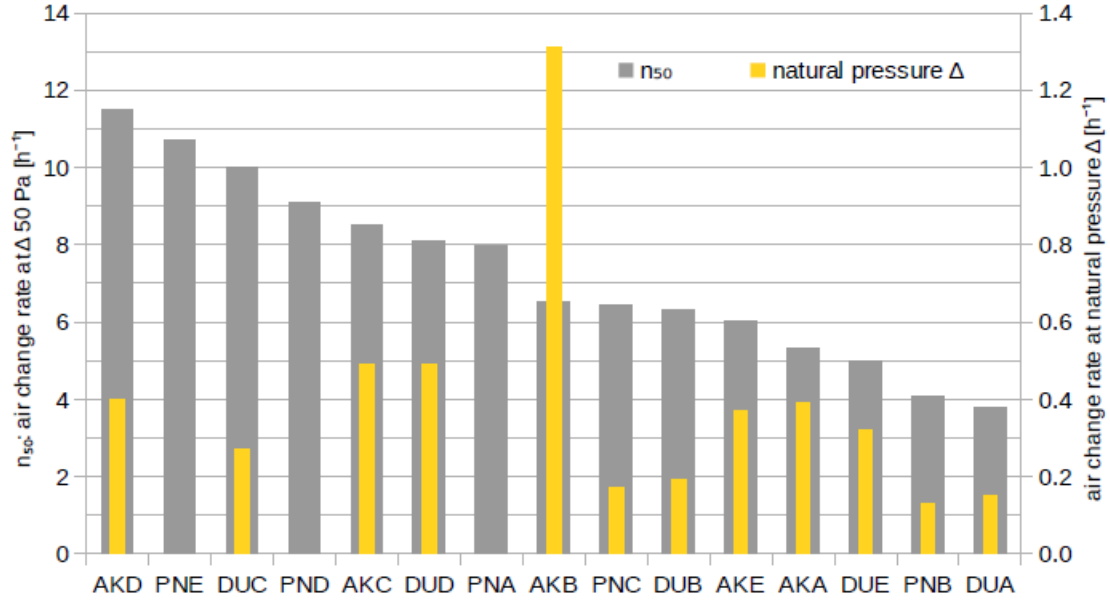


Figure 59: Air change rates at 50 Pa and average natural pressure differential

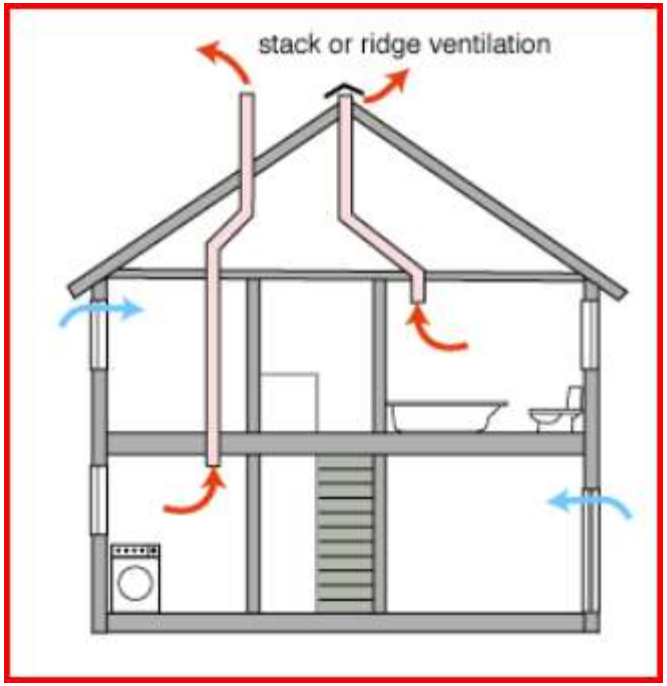
Grey = leakiness/airtightness;

yellow = air changes in normal use (over 3 weeks)

It looks as though leaky fabric can't be relied on to contribute to decent air quality.

Here, unlike in New Zealand..

..we are expected to install 'purpose-provided' ventilation as well


stack or ridge ventilation

“based on the traditional brick kiln which evolved to take advantage of the principle that warm/hot air naturally rises” (Hanson home)

More beliefs & assertions about natural ventilation (#2,3,4)

- easy to understand,
- culturally familiar,
- puts the occupant in control

But how does the ‘purpose-provided ventilation’ part of natural ventilation work out in practice?

Neil Jefferson, *director of the NHBC and chief executive of the Zero Carbon Hub*

"....The trickle vents left open or closed, dependent on the weather on moving-in day; cooker hoods not used because you can't hear the telly; and, let's be honest, who ever cleans the filter?"

Is he right?

We aren’t sure

Remember:

- If you are relying on the natural forces of wind and weather to get fresh air into your building, you are at the mercy of the wind and weather

What research did I find?

Studies of ventilation and IAQ in nv homes

Trickle vents with or without passive stack extract

And/or + mech extract from wet areas

- 2002 37 homes
- 2006 22 homes
- 2011 6 homes
- 2011 3 homes
- 2013 24 homes

What did it show?

Pollutants recorded varied, but included CO2, RH, CO, NO2, formaldehyde, VOCs

2009 study, 22 homes

Ventilation and Indoor Air Quality in Part F 2006 Homes for DCLG, 2010

- Built under 2006 regs regime
- Average fabric a/t 6 ach @50pa

With all vents open & extract fans in use:

- All flats and 40% houses failed to achieve recommended part F air change rate
- 4 of 22 excess NO2,
- over 50% of those sampled, excess VOCs

- Note, in these homes, ventilation as installed failed to meet Part F recommendations in size/power. Thus not so much a test of Part F 2006, also a test of the construction industry.

2013 Scottish study, 24 homes, NV

- *"*CO2 levels measured in occupied bedrooms were found to be two to four times above the 1000ppm threshold"
- Indicator of poor ventilation, likely to indicate high RH, and possibly high VOCs too.

Author: Stirling Howieson, Univ. Of Strathclyde. Abstract published, full paper in press

Urbed study (part of Retrofit for the Future)

- Cold wet week
- The two homes with passive stack ventilation (with trickle vent inlets) RH 50% - 70%, one bedroom high 70s – 90%
- One home with passive vents plus mechanical extract RH 60% - 80%, consistently above 70% in 2 of 3 rooms monitored.

Older, leakier houses – a golden age?

"Occupants have successfully lived in passively ventilated homes from time immemorial.

"Therefore, there is technically no indication that the natural variability of weather driven ventilation rates has any particular indoor air quality or health implications"

(Building Research Establishment: **The effect that increasing air-tightness may have on air quality within dwellings** Report for Scottish Government, April 2012)

- No IAQ measurements from time immemorial, but going back to 2002:
- 37 new(ish) homes – ach @50Pa from 5 to 20, averaging around 12 – similar to average UK stock; leaky
- This study, occupants free to ventilate as per usual practice

- 68% below recommended 0.5 ach in winter, 30% too low even in summer.
- poorest example only showing 0.19 ach
- In kitchens in winter, excess CO in 18%, excess NO2 in 16%

Might these results have been affected by the weather at the time?

Of course

But so is real life ventilation

Occupant behaviour

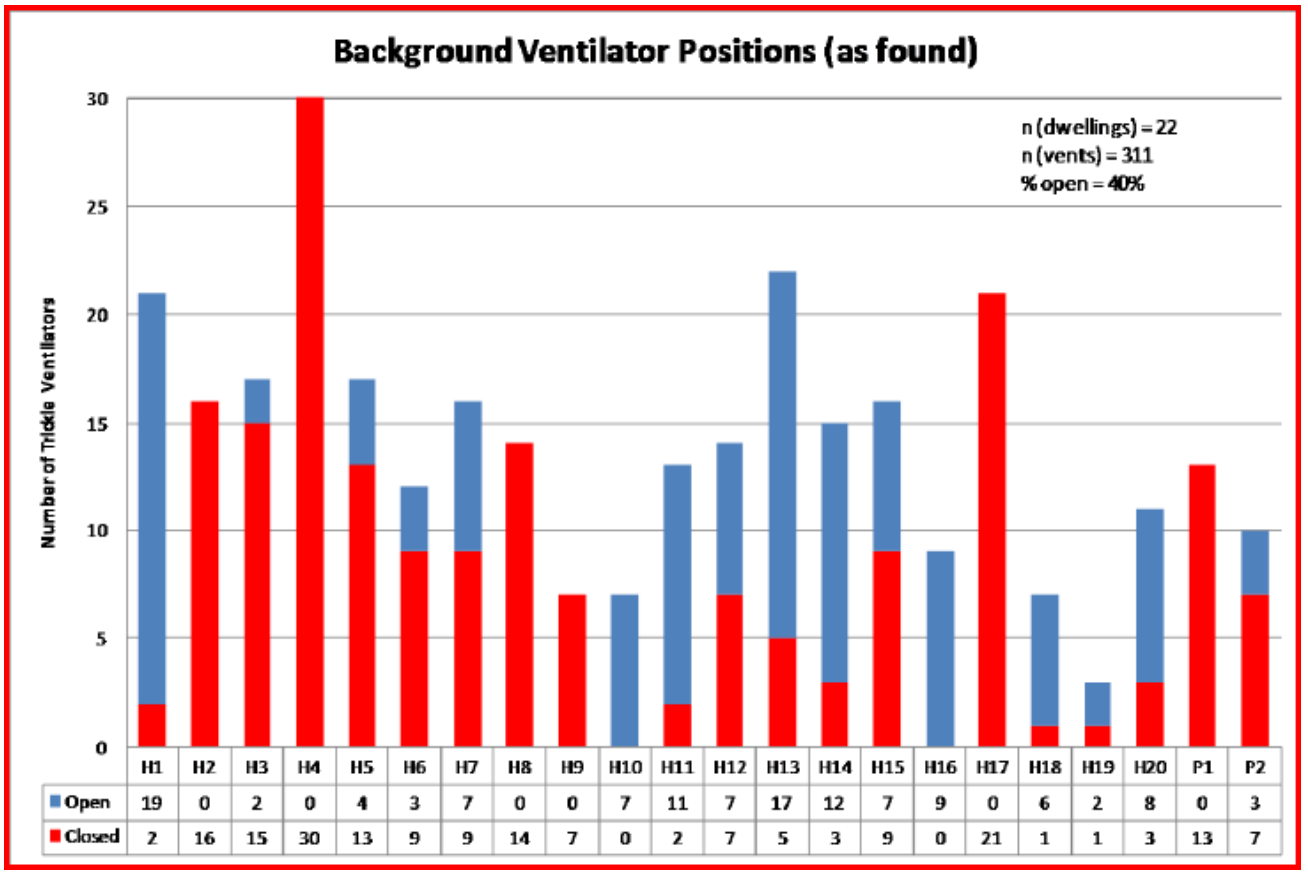
Is she just enjoying the relaxing ambience – or is she, like I used to, using candles to avoid putting on the light, so she doesn't have to endure the roar of the extract fan?

Am I the only one? (don't worry, I'm a reformed character now)

- The research team in the 2009 study (above) asked occupants if they used their ventilation – oh, yes, they said.

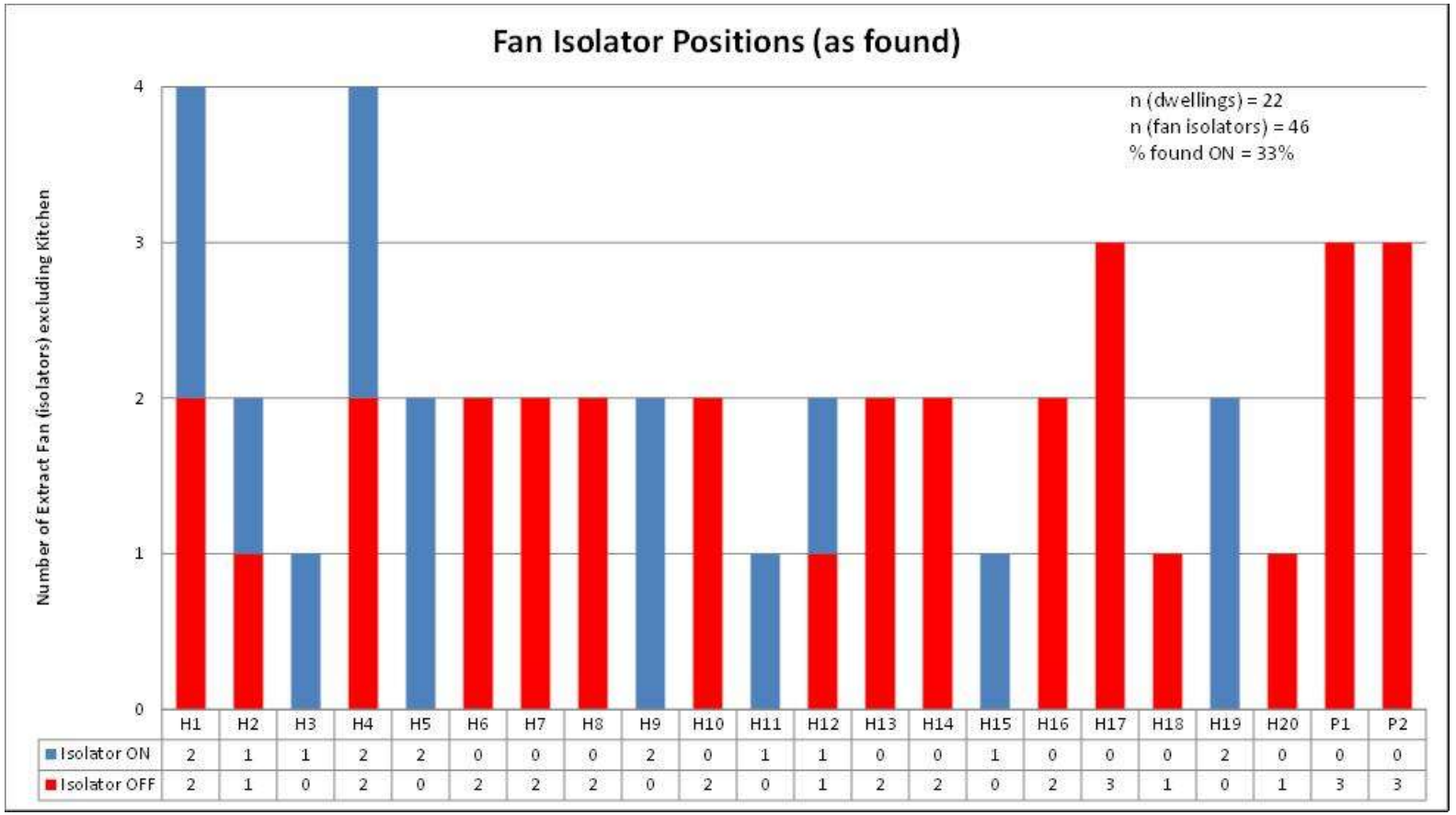
- However, this is how the researchers found the vents when they arrived:

Vents – as found: red = closed, blue = open



	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

Fans – as found: red = closed, blue = open



	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	P1	P2
Isolator ON	2	1	1	2	2	0	0	0	2	0	1	1	0	0	1	0	0	0	2	0	0	0
Isolator OFF	2	1	0	2	0	2	2	2	0	2	0	1	2	2	0	2	3	1	0	1	3	3

(Similar observations have been made in other studies)

How user friendly is the system really?

- occupants thought the vents caused draughts
- Reasons for switching off fans were: noise and run-on timer a “nuisance”.
- 19/22 households did not put kitchen extracts on boost (or on at all) while cooking;
- one household had requested and received a lower-power fan because the original was too noisy for them.

Who should control it?
Theory is:

- “Natural Ventilation makes occupants feel more comfortable and puts them in control”

- “A rapid, detectable response in IAQ correlates with satisfaction”

What can we actually detect?

- Smell
- Visible “steam” and condensation
- Temperature

GHA study

- House with mean CO_2 1160ppm, RH averaging near 70% and peaking at 90%.
- Occupant described the indoor air quality as ‘good’
- GHA pointed out: “The IAQ in this dwelling is not ‘good’ and is presented for information only”

- How can we control something if we can’t detect it?

Common concerns that are voiced about ventilation in this country

- inadequate ventilation for the number of occupants
- poor user understanding of system: occupants need to understand how the system works and how to operate it
- energy performance and reliability still needs to be assessed
- any air infiltration adds directly to the total air change and thus can considerably weaken energy effectiveness

- I think we have seen these are all valid concerns about natural ventilation systems as installed and used.
- All of those statements were actually made about problematic MVHR systems. But natural ventilation seems easily as bad.

Do we really know how to use it?

We often hear that mechanical ventilation systems require a “whole culture change” or impose a “new lifestyle” on occupants.

Yet it appears that a significant lifestyle change is required for many occupants to adapt to living safely in most naturally ventilated British homes now.

Can this be fixed?

To make natural ventilation effective, it needs to:

a) Be understood & valued
b) Move enough air to keep pollutants below harmful levels
c) NOT waste more heat (through overventilation) while doing so
d) Be more congenial/quiet/unobtrusive, **so its used**.

Does natural ventilation work in homes?

Evidence suggests that as designed, installed and used at the moment – not well enough

Might things improve?

- *More careful design to avoid drafts when cold & windy, yet assure flow even when mild/still???*
- *CO2 or RH sensors – "demand controlled"?*
- *Data still needed*

Need to see both IAQ with systems in use, and overall energy use of building – not found studies doing both together, would be interested to see them