Lessons in air tightness and air quality from the Japanese ‘sick house’ experience

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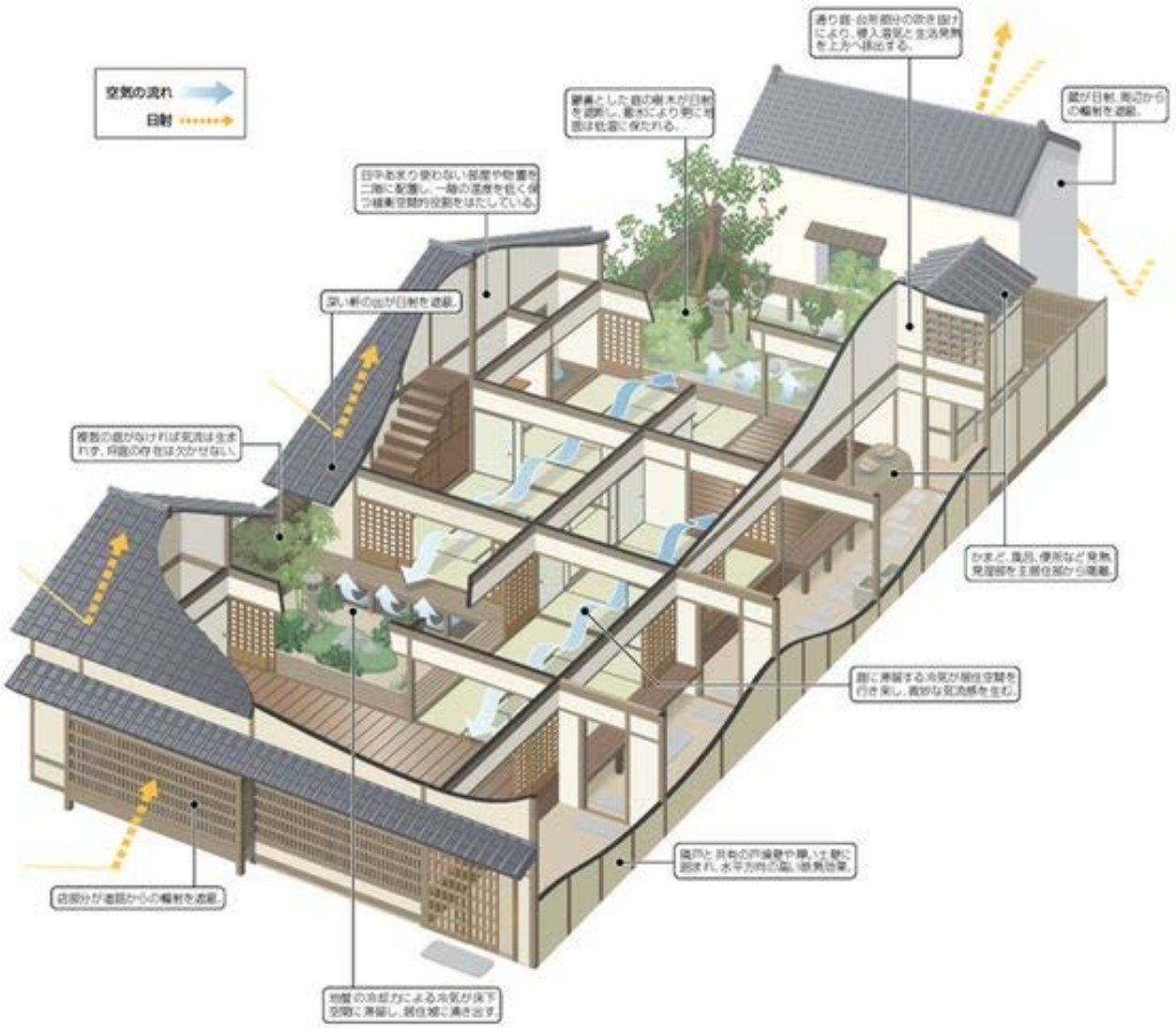
Towards Higher Performing Homes: The Role of Ventilation and Airtightness
Wellington, New Zealand 20th March 2018

- Background to the sick house issues in Japan
- Revision to the Japanese Building Standard Law in 2003 (materials & ventilation provisions)
- Trickle vents – only one side of the equation
- Trickle vents and 24hr mechanical ventilation in Japan
- Drawing parallels with where we are today

Traditional design for climate



Headline news

Why did sick house syndrome become such an issue?

- House price bubble
- 1970s and 80s saw a big increase in supply
- Manufactured wood products (Plywood, MDF etc.) structural, furnishings, vinyl wall paper, carpets, flooring, mineral fibre insulation
- High emissions of VOCs
- Air tightness - low air change rates under 0.2 ach
- Lifestyle changes
- Spread of air conditioning
- High renewal cycle (30 years)

Japanese Ventilation Requirements

- Building Standards Law previously required the supply of outdoor air to habitable rooms.
  - Mechanical Ventilation
  - Natural Ventilation
    - Min ratio of openings to floor area of 1:20 (5%)
    - Local exhaust of bathrooms and kitchens
  - Further new regulation introduced in 2003 to address the sick house problem
  - Also for buildings over 3,000m² & 8,000m² there is a performance requirement and mandatory IAQ testing every 2 months.

Drivers for air tightness

- Energy efficiency – effectiveness of insulation
- Thermal comfort – reduce infiltration and improve temperature distribution
- Reduce interstitial condensation

Air tightness in Japan

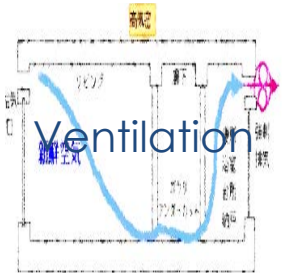
	Specific Leakage Area - cm^2/m^2 (Equivalent ACH @50Pa)		
	Mean	Max	Min
Detached Dwellings			
Post & beam	**5.3 (7.3)**	9.8 (13.3)	1.3 (1.8)
Two by four	**2.2 (3.0)**	3.9 (5.3)	1.0 (1.4)
Multi Residential			
Panel	**1.0 (1.4)**	1.3 (1.8)	0.8 (1.0)
RC	**1.2 (1.7)**	2 (2.7)	0.8 (1.1)

Goal of $2cm^2/m^2$ in the colder regions and $5cm^2/m^2$ in the more temperate regions

Sawachi et al 2008
Multi residential data 1992
Detached dwellings data from 2004

Japan Building Standard Law 2003 - 3 key measures

- Regulation and assessment for formaldehyde and chlorpyrifos.
- Restriction of its use as interior finishing



- Mandatory installation of 24hr mechanical ventilation
- Min 0.5 ACH

- Restriction on materials
- Ceiling air tightness
- Effective roof space ventilation

Regulation of building materials inc. roof space

Formaldehyde Emission Rating	Formaldehyde Emission Rate (mg/m^2h)
F*	> 0.12
F**	>0.02 and ≤0.12
F***	>0.005 and ≤0.02
F****	< 0.005

- F**** can be used without restrictions
- F*** & F** usage limited and determined by formulae that considers the ventilation rate (air changes / hour) and surface area relative to floor area.
- F* prohibited

- F* and F** prohibited in roof space without air tight ceiling and roof space ventilation

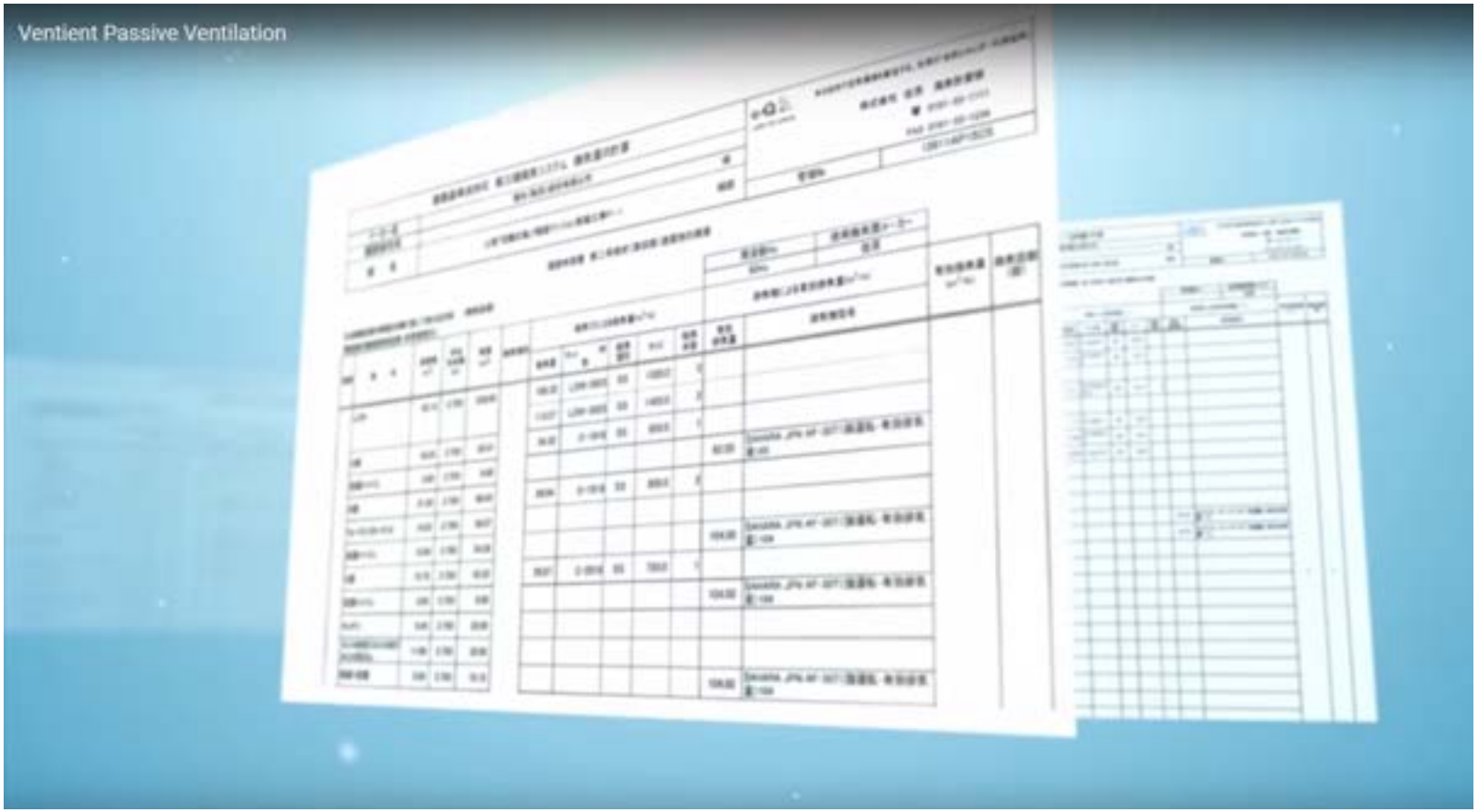
Options for 24hour mechanical ventilation

Mechanical supply and exhaust

Mechanical supply

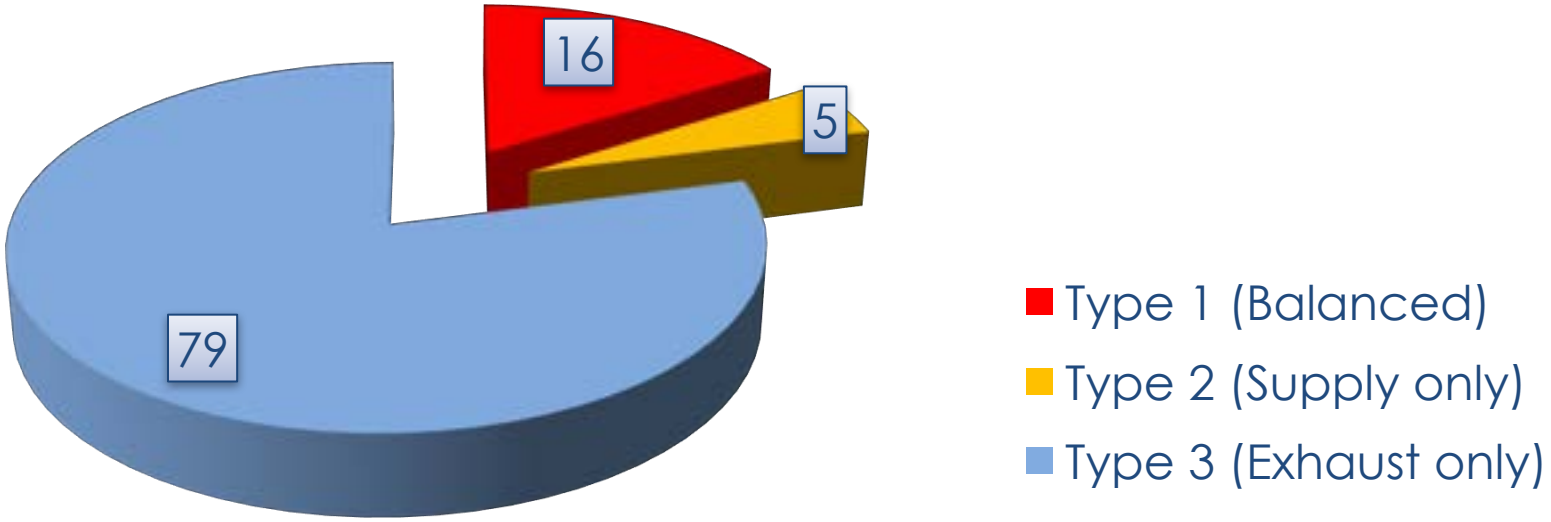
Mechanical exhaust

Requirement for a calculation with min 9.8Pa pressure difference



Market share of ventilation systems

System market share in Japan (%)



Type 3 is much lower cost than type 1
Type 3 shown to be particularly effective in air tight buildings
Type 3 market share is 65% for the major quality national house builders, 85% with local builders and 80% for apartments and units

Japan V.O.C Measurement Association
www.jvma.jp (2009)

Did the new Building Standard Law work?

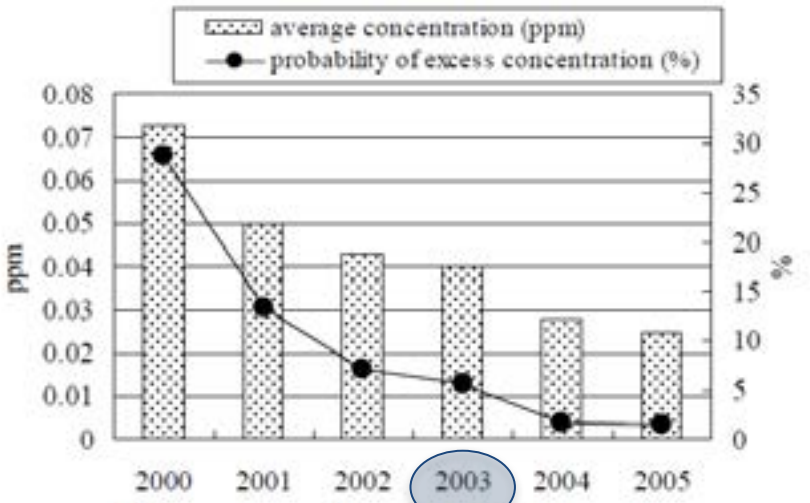


Figure 1 - Result of Survey on Formaldehyde Concentration

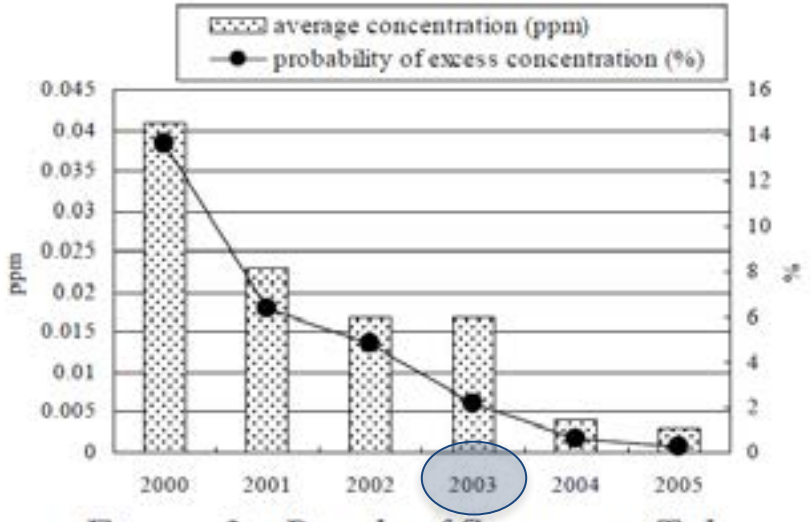


Figure 2 - Result of Survey on Toluene Concentration

Industry had advance notice what was coming

Sawachi et al. (2008)

Survey of 5,000 dwellings 2012

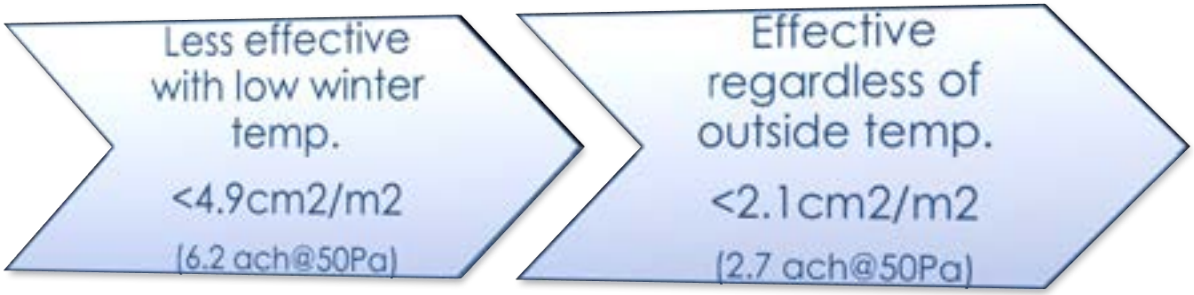
- Condensation and mould used as a proxy for IAQ - did correlate with health conditions.

- 24 hour ventilation much more effective than intermittent or no use of ventilation.
- Mechanical ventilation with heat recovery lower association with condensation & mould.
- Reasons for not operating related to feeling cold / heat loss, economizing, perception that not required, and acoustics.

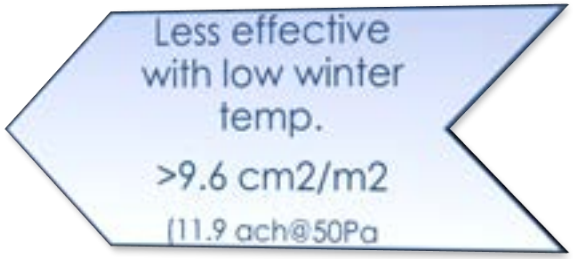
Hasegawa, K & Yoshino, H (2013)

Impact of air tightness (particularly in winter) on effectiveness of passive vents in Japan

- This approach works better in air tight homes



- Door undercuts needed in ductless systems
- Need for sufficient negative pressure
- Continuous operation



Taniguchi et al, (1995)

- Occupant behaviour has a huge influence
- This approach works better in air tight and **compartmentalised** units
- Exhaust is required to create sufficient negative pressure to provide air flow through vents.
- Specification of number and size of passive vents, air change rates /air flow needed and location of passive vents.

Sean Maxwell et al., (2016)

Recent UK evaluation ……. could do better

- 200 interviews
- IAQ sampling of 40 homes in winter

- Previous assumptions in regulations were based on passive ventilation devices and doors being open.
- Only intermittent mechanical ventilation

RESEARCH INDOOR AIR QUALITY

BUILD TIGHT VENTILATE RIGHT?

Indoor air quality in housing is being compromised because ventilation scenarios in Building Regulations are not realistic, says Strathclyde University's **Stirling Howieson**, who co-wrote the paper that won the 2015 Napier Shaw Bronze Medal

Sharpe et al. (2015)

Bedrooms - Open vs closed trickle vents and doors

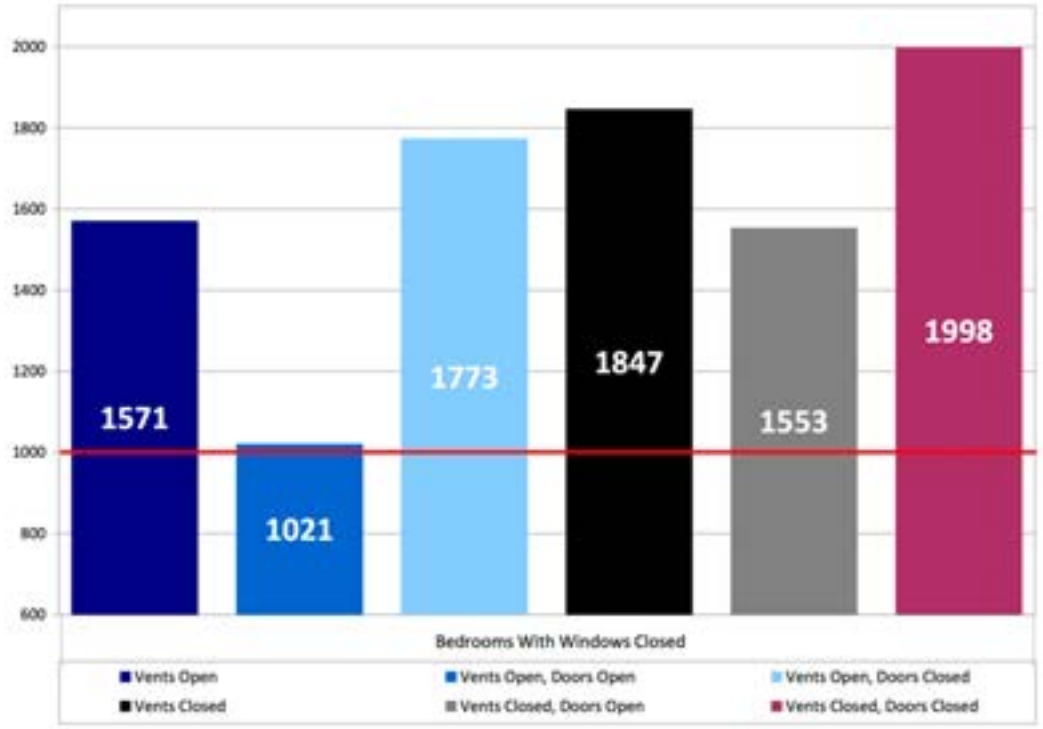


Figure 5. Bedrooms with windows closed-average CO_2 ppm, time weighted average between 11 pm and 7 am.

Sharpe et al. (2015)

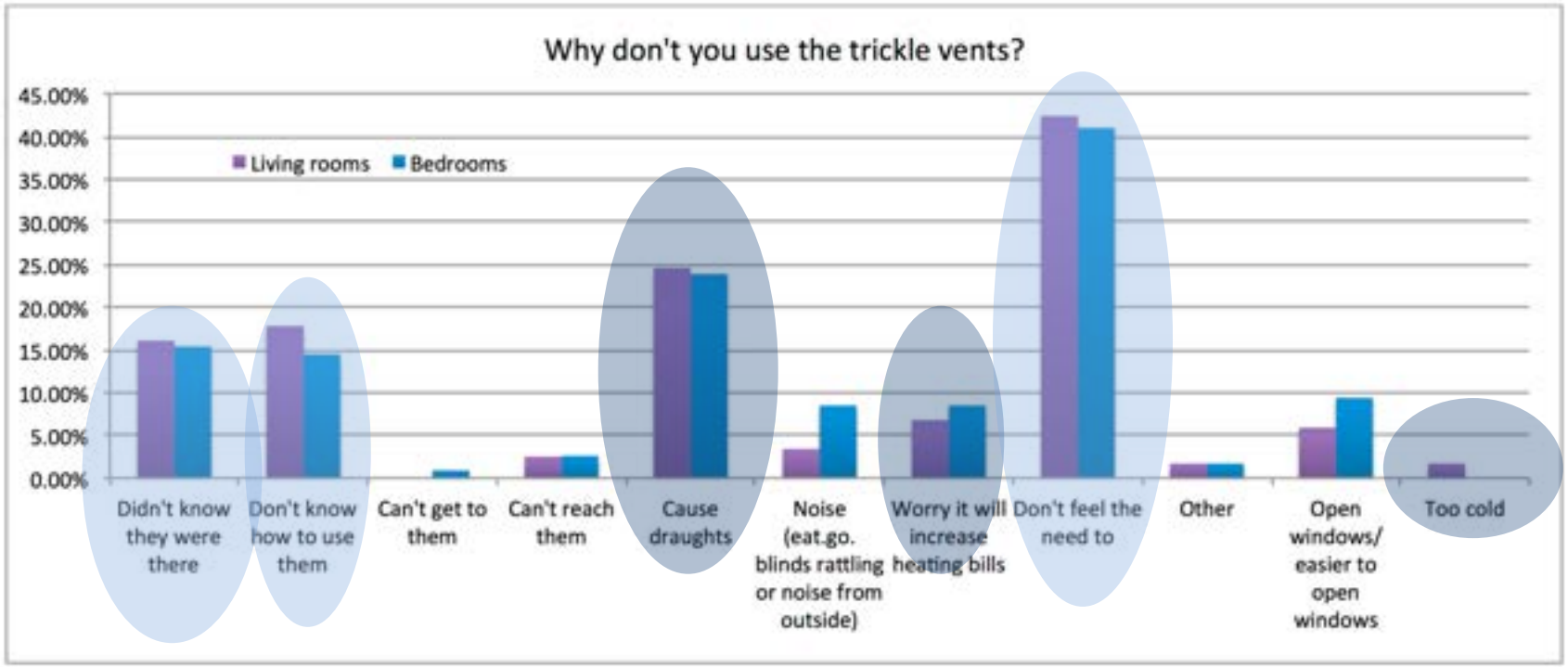
Occupant Interaction

	Bedrooms	Living Areas
Always closed	63%	63%
Always open	28%	24%
Weekly adjustment	9%	13%

- 92% of respondents described air quality in the bedroom as "good" or "very good"
- But CO2 was an average 1,847ppm for those with the vents closed (83% over 1,000ppm)

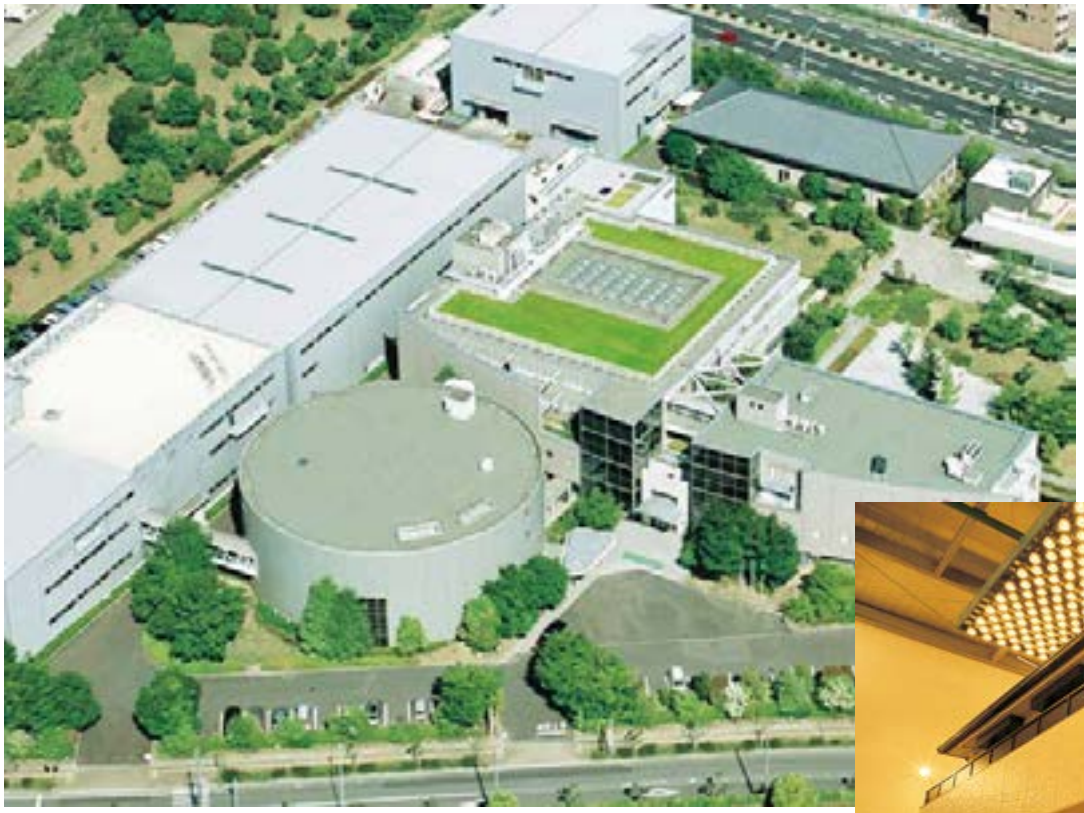
Sharpe et al. (2015)

Why are trickle vents staying closed ?



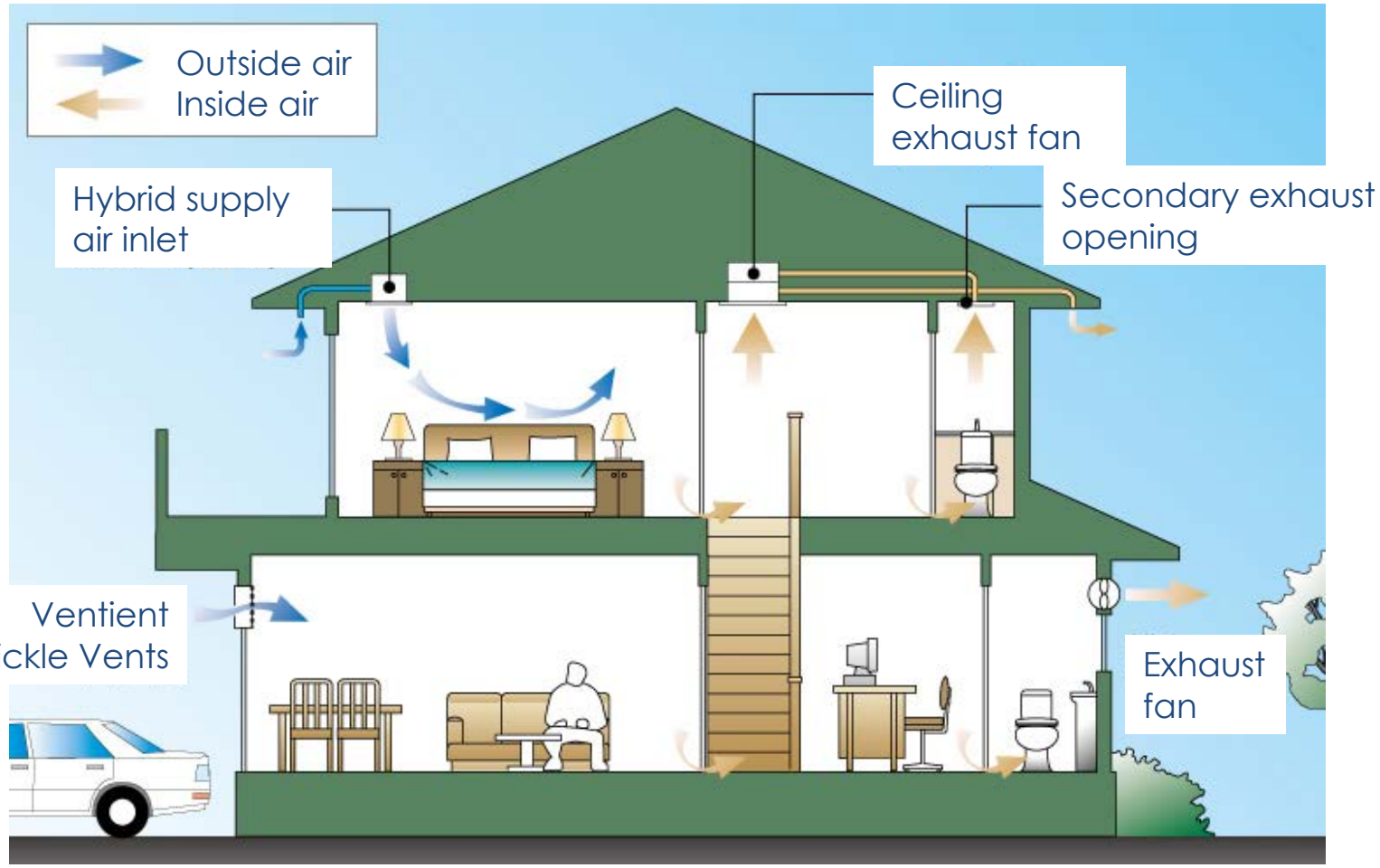
Sharpe et al. (2015)

Daiwa House Research and Development Laboratory, Nara



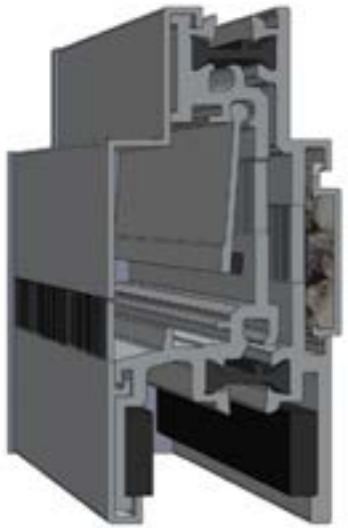
http://www.daiwahouse.co.jp/lab/about/device.html

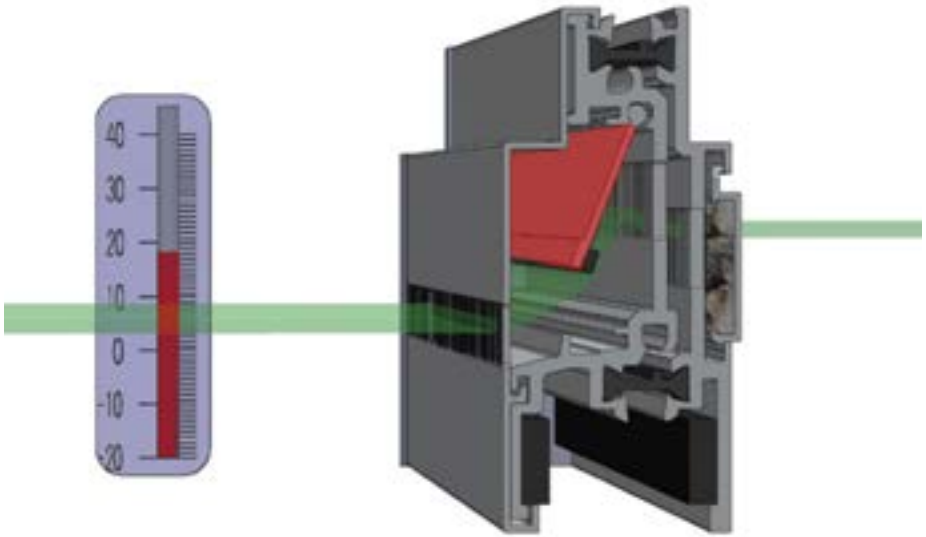
Daiwa House 24hr ventilation system



https://www.daiwahouse.co.jp/jutaku/technology/sigma/residential/air.html

Shape memory alloy based passive flow regulation





Use of trickle vents at Daiwa House

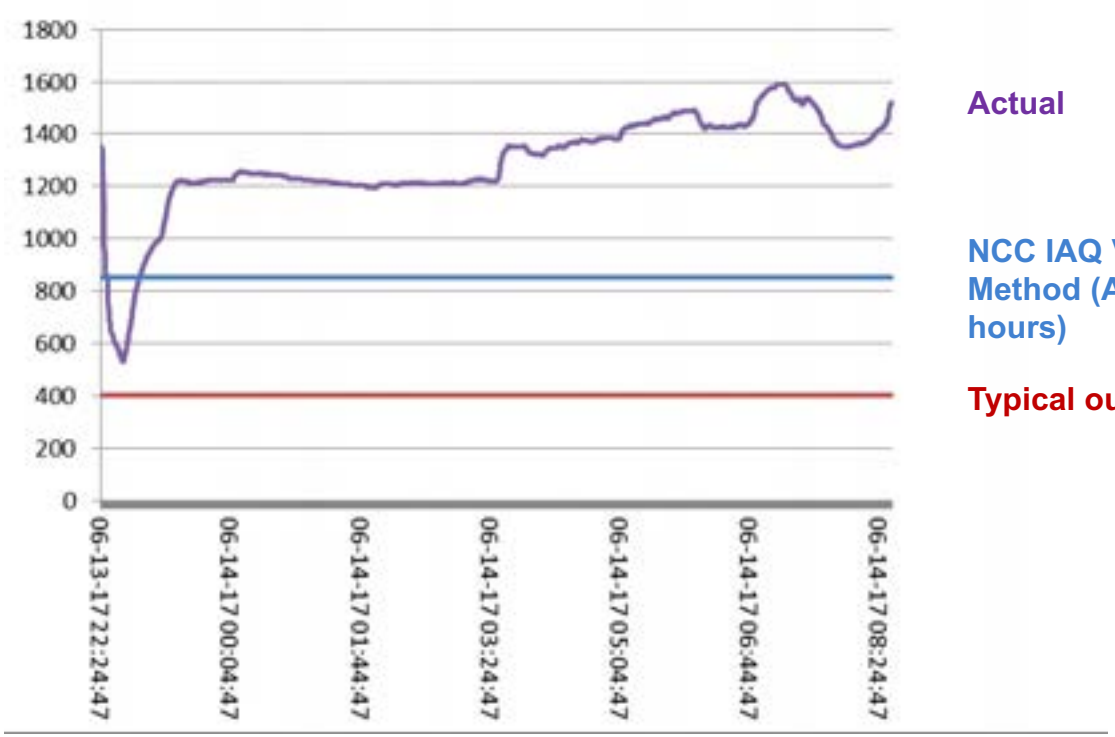
- Standard trickle vents installed prior to 2003
- Use of “Auto Breathe” (Ventient) since 2003
- Used in all single detached dwellings
- All low rise multi residential up to 5 stories
- Some high rise apartment building

Trickle vent use in a Daiwa House home

- Please leave in ‘auto ‘mode
- ‘Close’ under extreme wind driven rain storms

Are “operable” windows meeting the NCC Ventilation Performance Requirements

Sydney Unit Bedroom (14th June 2017) Built circa 2007



Actual

NCC IAQ Verification Method (Averaged over 8 hours)

Typical outdoor level

Why don’t we open windows ?

- Security
- Noise
- Cold drafts
- Increased heating costs
- Unpredictability of weather
- Insects
- Not being present (unoccupied apartments)

There are moves across the Tasman in Australia

- Based on the nationwide condensation survey, more than 40% of new buildings have condensation and mould.
- ….any Class 1 or Class 2 building with a measured ACH@50 of under 5 should include an automated mechanical ventilation system for fresh air supply within the building.

Improving Australian Housing Envelope Integrity (October 2016)
Building Commission of WA (2014)
Dewsbury, M et al., (Sept 2016)
Roxburgh, T, ABC News (March 2017)

The roles for passive trickle ventilation

- A qualitative IEQ benefit.
- If used as part of a performance or dts solution then 24hour mechanical exhaust is needed.
- Lower cost approach
- Ensure occupants keep passive vents open.
- Shift the balance away from infiltration providing make up air.
- Opportunities to address acoustics and IAQ where windows won't we opened.

Many parallels between now in Australia/ New Zealand and Japan in the 1990s

- Regulatory background (material selection and ventilation)
- High growth in construction
- Levels of air tightness improving
- IAQ, condensation and build quality issues

www.netatmo.com
www.vtt.fi

Some lessons

- Increased air tightness will lead to increased risk….
- …. but also increased opportunity
- Background trickle ventilation with 24hour mechanical exhaust can be an effective and affordable solution (install, maintenance, running costs & space)
- Keeping passive supply open
- Considering the source of contaminates
- Ambitious regulation with advance notice

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