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Effects of urban pollution on IAQ in energy-efficient buildings in the UK

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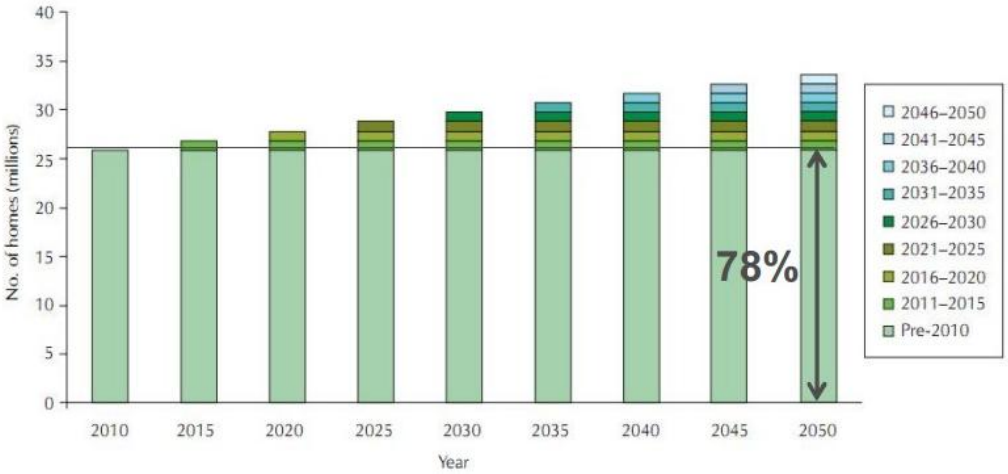
Background

- 80% CO2 reduction by 2050 required
- 78% of current housing stock will still be in existence by 2050



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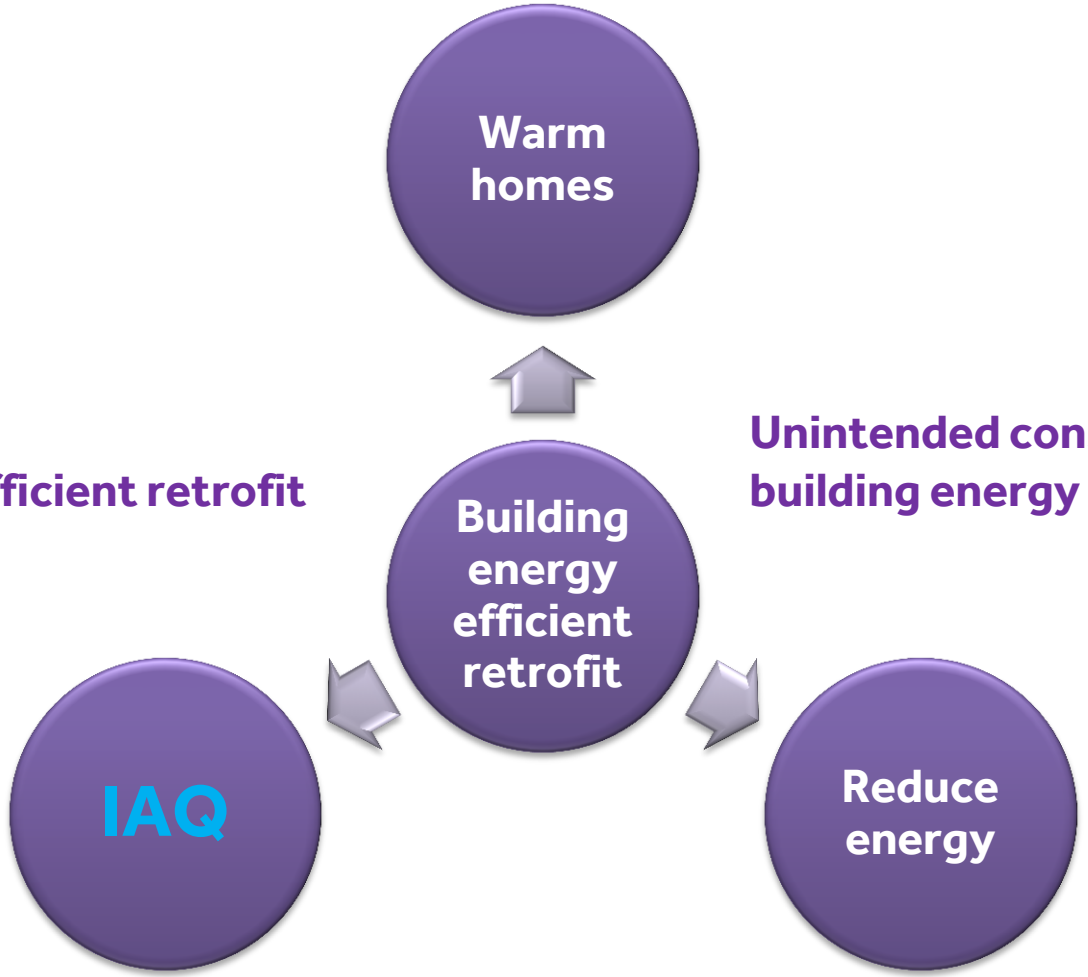
Consequences of building energy efficient retrofit



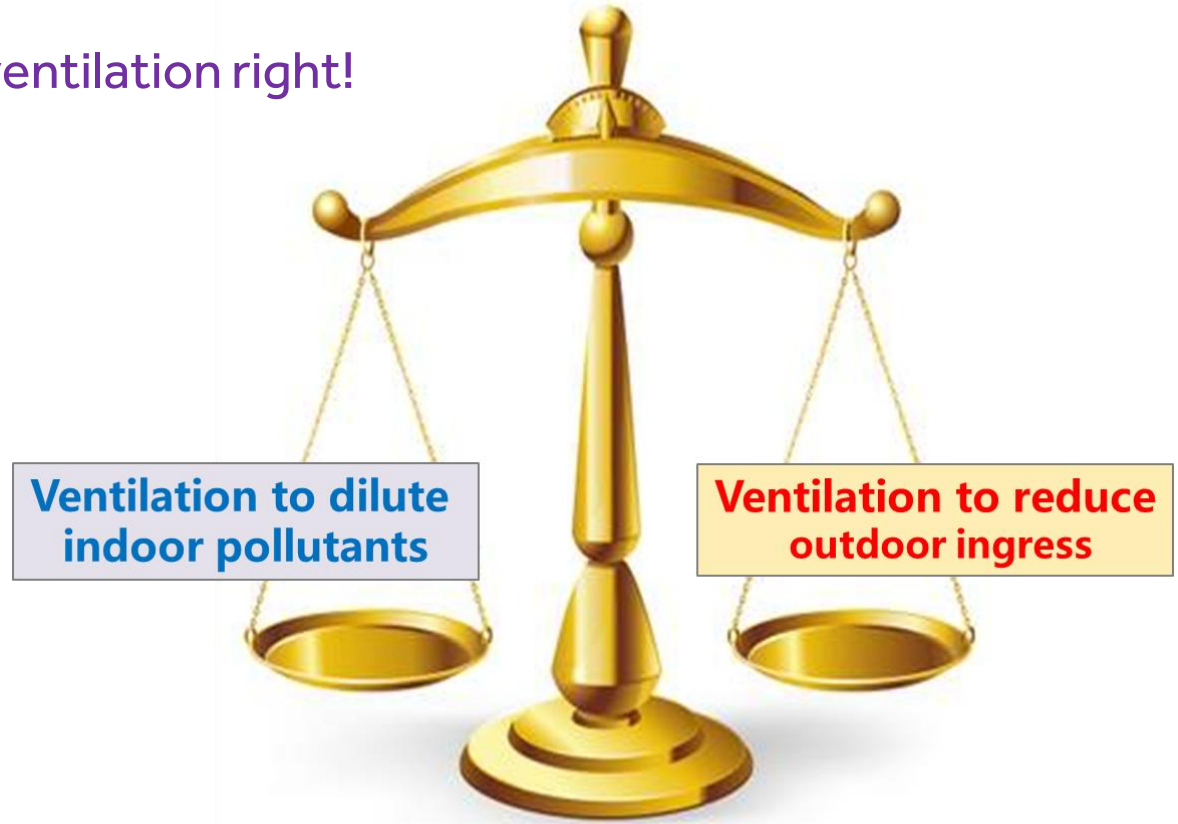
Unintended consequences of building energy efficient retrofit

Unintended consequence: IAQ

- Reductions in envelope permeability without mechanical ventilation produced increases in indoor PM2.5concentrations (Shrubsole et al, 2012).

- Mean indoor radon concentrations increase by an estimated 56.6% and additional annual burden of 4700 life years lost when increasing airtightness (Milner et al, 2014)

Building tight, ventilation right!



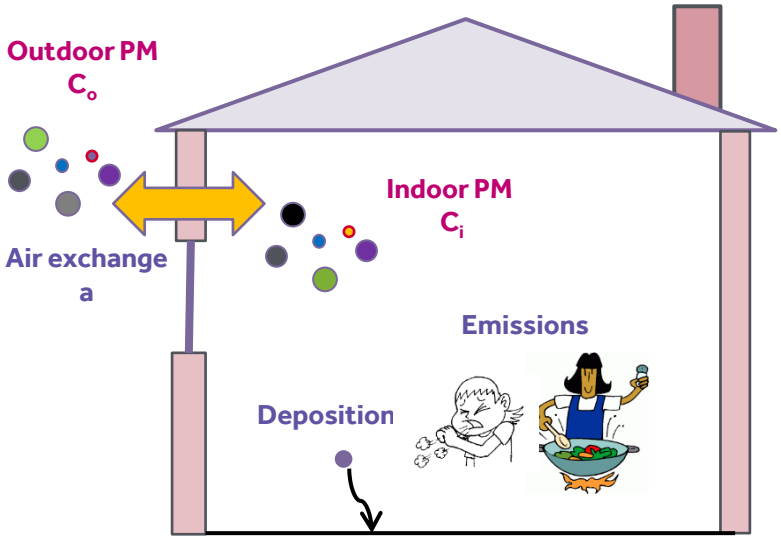
Is there an optimum ventilation strategy for IAQ?

Research question

- In which location the weatherization retrofit (airtightness improvement) is encouraged?

- Is there a balance of ventilation between penetration of outdoor pollution and dilution of indoor-generated pollutants?

One-compartment IAQ model



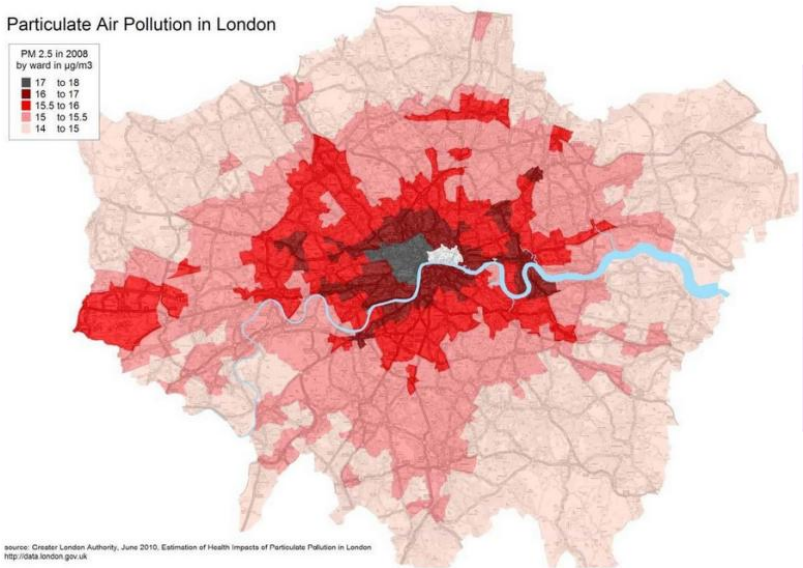
$$V\frac{dC_i}{dt} = P\alpha VC_o - \alpha VC_i - kVC_i + \dot{m}$$

Transient | Penetration | Airflow removal | Deposition | Indoor source

$$C_i = \frac{P\alpha C_o}{\alpha + k} + \frac{\dot{m}}{V(\alpha + k)} = F_{inf}\,C_o + C_{ig}$$

Ref.: WW Nazaroff, Indoor Air **14** (Suppl. 7), 175, 2004.

Case study in London



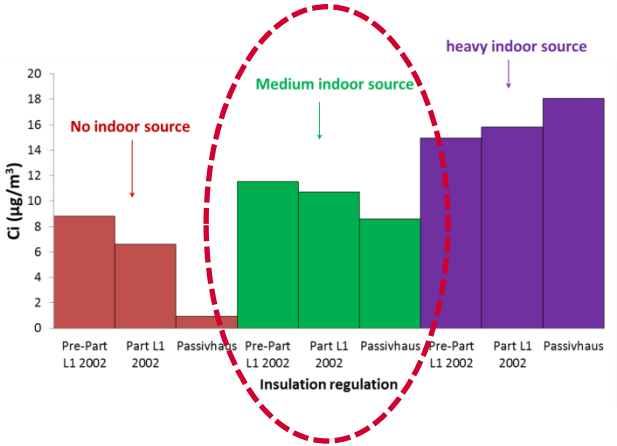
Scenarios	Concentration ($\mu g/m^3$)
Urban roadside (Marylebone road)	22
Urban background (Bloomsbury)	11
Rural (Rochester)	9

Indoor emission

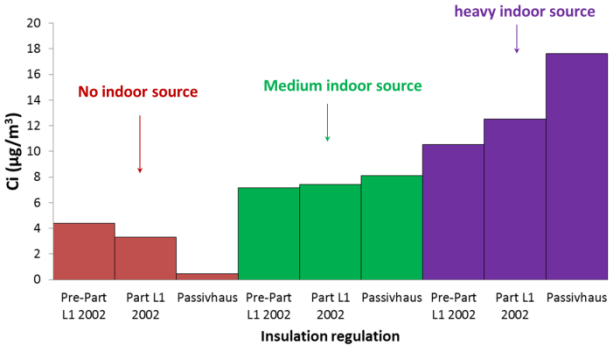
Scenarios	Emission rate
No indoor source	0
Medium indoor source	0.95 (mg/h)
Heavy indoor source (cooking, smoking etc)	1.7(mg/min) for cooking period

Airtightness

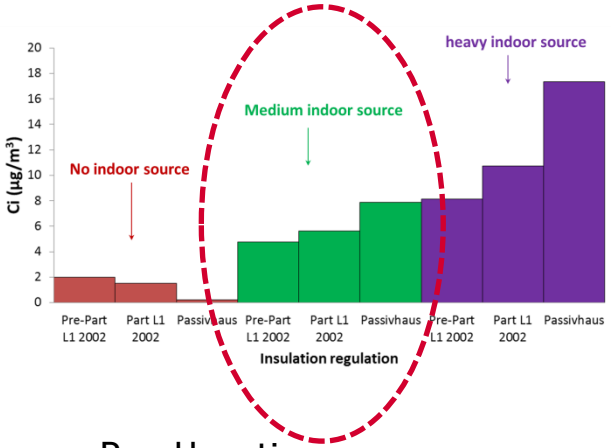
Scenarios	Airtightness
Before Part L1 2002	$20m^3/(m^2h)$ @50 Pa (0.8 ACH)
After Part L1 2002	$10m^3/(m^2h)$ @50 Pa (0.4 ACH)
Passivhaus	0.6 ACH@50 Pa (0.03ACH)



Urban location



Urban background



Rural location

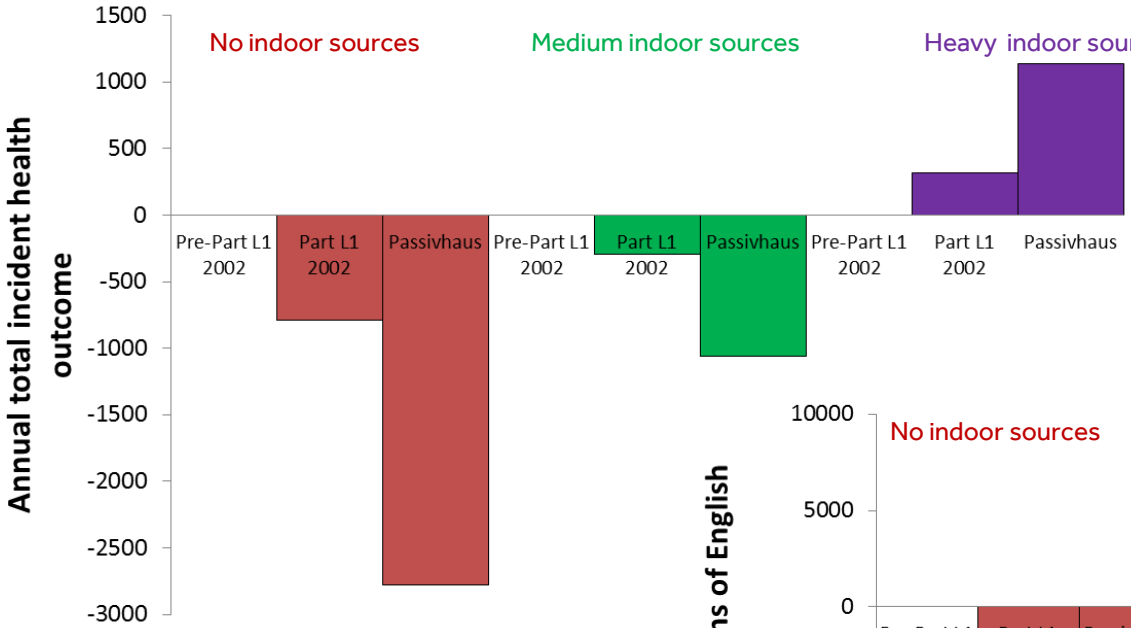
Health and economic implications

The change in health outcomes due to the change in indoor PM2.5 concentration

C-R function: $\Delta y = y_0 P(e^{\beta \Delta x} - 1)$

Concentration–response functions. This table provides the coefficients for the concentration–response functions, the formulas for each function varies among the studies and can be found directly from the references in the final column.

Pollutant	Outcome	Concentration change β coefficient (95% CI)	*B*-coefficient standard deviation	Baseline prevalence of illness per year y_o	Reference
PM2.5 [μg/m^3]	Total mortality	5.8E−3 (2.0E−3, 1.0E−2)	1.9E−03	7.40E−3	Pope et al. [6]
	Chronic bronchitis	9.1E−2 (7.8E−2, 1.1E−1)	6.8E−03	4.00E−4	Abbey et al., [34]
	Asthma attack	1.4E−3 (3.1E−4, 2.5E−3)	5.6E−04	2.70E−2	Whittemore and Korn [35]
	Minor restricted activity days	7.4E−3 (6.0E−3, 8.8E−3)	7.0E−04	2.14E−2	Ostro and Rothschild [36]
	All hospital admissions–all respiratory	1.5E−3 (0, 5.0E−3)	1.8E−03	2.58E−5	Burnett et al. [37]
	Non-fatal stroke	2.5E−2 (2.0E−3, 4.8E−2)	1.2E−02	2.00E−4	Peters et al. [38]



Mortality

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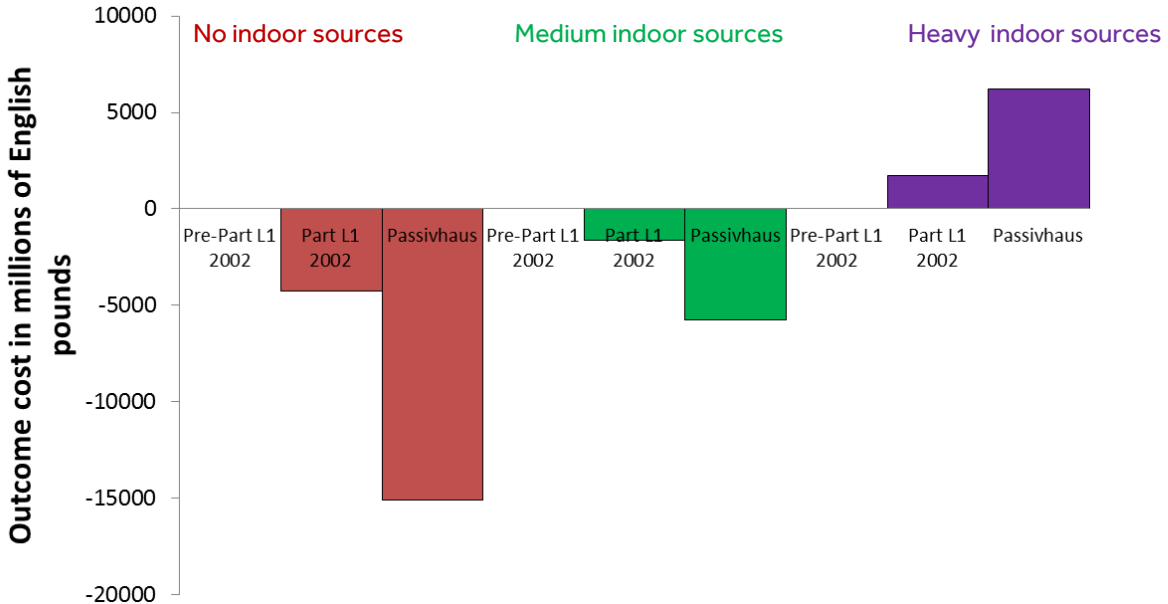

Urban location

- **When we should increase airtightness?**
- **When we should open windows?**

Balance-point concentration

$$\frac{C_i}{C_o} = \frac{P\alpha}{\alpha + k} + \frac{\dot{m}}{V(\alpha + k)C_o} = P$$

Balance-point outdoor concentration

$$C_{oe} = \frac{\dot{m}}{kVP}$$

$$\frac{C_i}{C_o} = P + \frac{KP(C_{o,e} - C_o)}{C_o(a + K)}.$$

$$\text{If } C_{o,e} > C_o \text{ then} \frac{C_i}{C_o} > P,$$

$$\text{If } C_{o,e} < C_o \text{ then} \frac{C_i}{C_o} < P.$$

Li et al. 2003

Conclusions

- Building tight, ventilate right. Indoor and outdoor fight.

- The increase of airtightness level by more stringent insulation towards Passivhaus standard in UK can lead to either increase or decrease of indoor pollution concentration depending on the relative strength of outdoor concentration and indoor emission rate

- Balance-point concentration will be an important parameter to determine when open the window.

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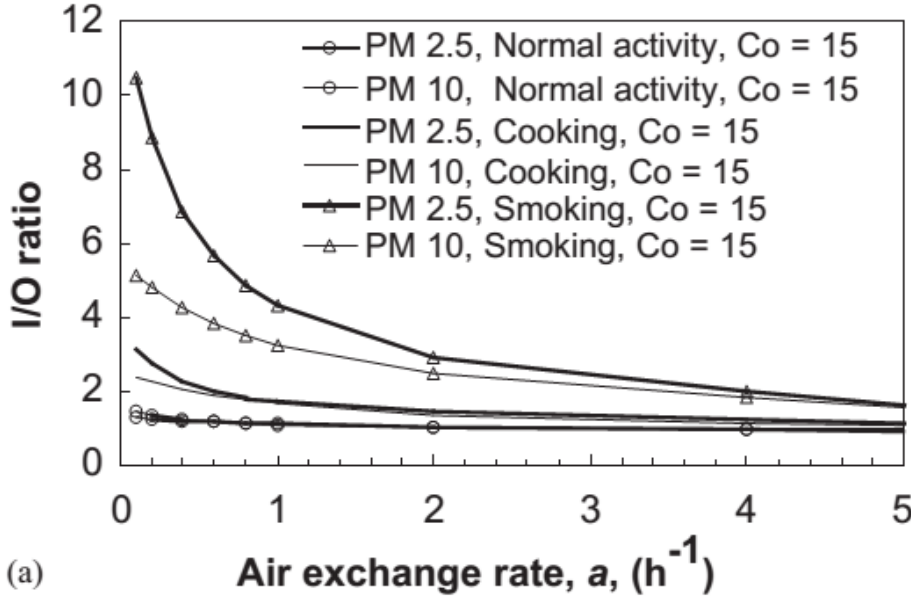
THANK YOU



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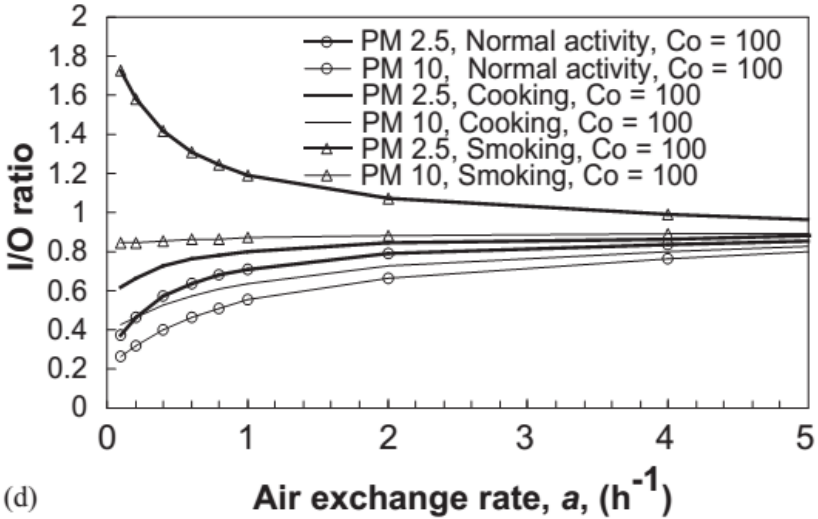

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