

CAE 331/513

Building Science

Fall 2015



Week 11: November 3, 2015

Ventilation and indoor air quality

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Today's objectives

- Introduce ventilation and indoor air quality (IAQ)
 - Covers the next 2 lectures
- Assign HW 4

VENTILATION AND IAQ

Why do we care about indoor air quality?

- We spend most of our time indoors
 - Nearly 90% of the time, on average in the developed world
 - Approximately 18 hours indoors for every 1 hour outdoors
- We bring materials, furnishings, appliances, and activities into buildings, most of which emit or release a variety of substances
 - Some harmful, some not
- Buildings also exchange air with the outdoors
 - Outdoor air pollution can both dilute or become indoor air pollution
- Indoor air is a dominant environmental exposure
 - Most of the body's intake of air is done so inside buildings
 - 80-90% inhaled in buildings generally

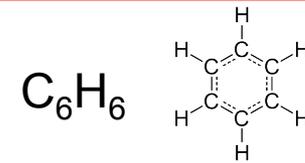
Why do we care about indoor air quality?

- Indoor concentrations of most pollutants are higher than outside
 - Global average of ~3:1 indoor/outdoor ratio
 - Large variability between pollutants
- Increasing number of indoor exposure related diseases/health effects
- We keep sensitive equipment/precious artifacts inside buildings
- We regulate outdoor air based on emissions
 - No indoor air regulations
 - Other than smoking bans and product emission controls at manufacture stage
 - Canada just initiated residential NO₂ standard
 - Disconnect between emissions and exposure
 - Benzene example (outdoor sources include auto exhaust and industry):

SOURCES OF BENZENE EMISSIONS



SOURCES OF BENZENE EXPOSURE



Modern indoor environments



Some important classes of indoor pollutants

- Inorganic gases
 - CO, NO₂, O₃, NH₃, H₂S, SO₂, CO₂
- Organic gases
 - Volatile organic compounds (VOCs, hundreds of these)
 - Semi-volatile organic compounds (SVOCs) (partition/bind to solids)
 - Carbonyls
 - Acids
 - Radicals
- Particulate matter
 - Size, shape, mass, constituents (e.g., chemical species, metals)
- Radioactive gases and particles
- Microbiological
 - Bacteria, viruses, molds, mildew, fungi, dander, allergens

Types of indoor emission sources

- Building materials
 - Wood and composite wood
 - Gypsum wallboard
 - Concrete
 - Carpet
 - Vinyl flooring
- Furnishings
 - Bedding
 - Tables
 - Couches/chairs
 - Drapes
- Architectural coatings
 - Paints
 - Stains
 - Varnishes
- Consumer products
 - Cleaners
 - Fragrances
 - Personal care products
- Combustion
 - Cigarettes, cigars, pipes
 - Gas stoves
 - Space heaters
 - Candles
 - Incense
- Electronic equipment
 - Laser printers
 - Computers
 - Photocopiers
- Volatilization from water
- Soil vapor intrusion
- People, pets, insects

Indoor pollutant concentrations are often greater than outdoors

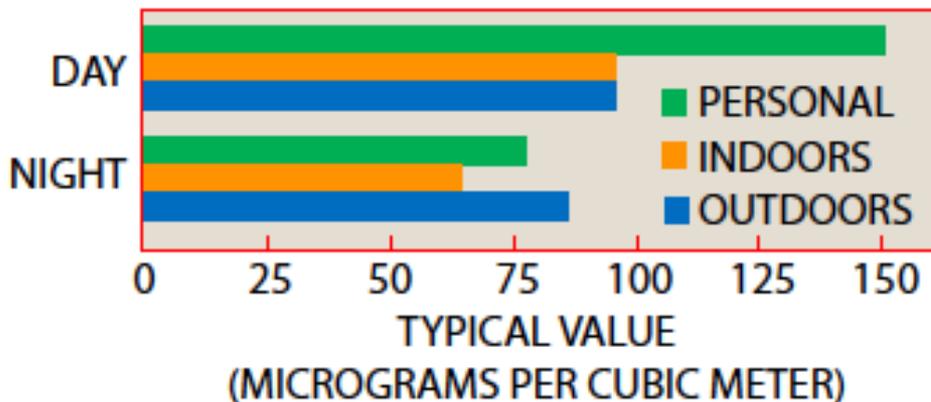
Everyday Exposure to Toxic Pollutants

Environmental regulations have improved the quality of outdoor air. But problems that persist indoors have received too little attention

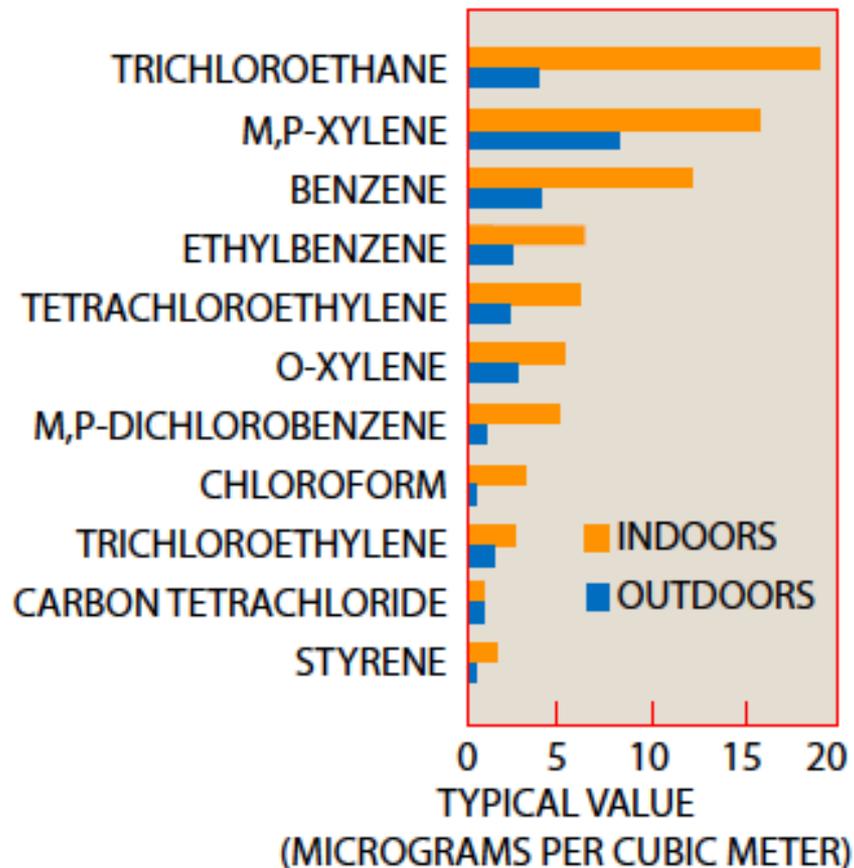
by Wayne R. Ott and John W. Roberts

SCIENTIFIC AMERICAN February 1998

CONCENTRATIONS OF 10-MICRON PARTICLES



VOLATILE ORGANIC COMPOUNDS



Units of measurement for air pollutants

- **Number concentrations** (# per volume of air, #/m³)
 - # of molecules per m³ (highly reactive species, e.g., OH radical)
 - # of particles per m³ (particulate matter)
 - # of cells or colony forming units per m³ (biological)

- **Mass concentrations** (mass per volume of air)
 - ng/m³ typical for metals and SVOCs
 - μg/m³ typical for indoor VOCs and particulate matter
 - mg/m³ big sources, e.g., ETS, cooking, industrial hygiene

- **Molar concentrations** (variations on $y_i = \text{mol}_i / \text{mol}_{\text{air}}$)
 - Mole fraction (y_i) = mol/mol
 - % concentration = moles per 100 moles = 100 * y_i
 - Parts per million by **volume** (ppm_v) (or just “ppm”)

$$1 \text{ ppm} = \frac{1 \text{ mol of } i}{10^6 \text{ moles of air}} = 10^{-6} \frac{\text{moles of } i}{\text{moles of air}} = 10^{-6} * y_i$$

- Parts per billion by **volume** (ppb_v) (or just “ppb”)

$$1 \text{ ppb} = \frac{1 \text{ mol of } i}{10^9 \text{ moles of air}} = 10^{-9} \frac{\text{moles of } i}{\text{moles of air}} = 10^{-9} * y_i$$

For gases, we can use the ideal gas law to convert between molar and mass concentrations

Converting between mass and molar concentrations

- Treat air and its constituents as an ideal gas:

$$PV = nRT \quad \longrightarrow \quad \frac{n}{V} = \frac{P}{RT} \quad \quad P_i = y_i P_{tot}$$



Mole fraction

$$1 \text{ ppb} \Rightarrow \frac{n_i}{V} = y_i \frac{P_{tot}}{RT} = \frac{1 \text{ mol}_i}{10^9 \text{ mol}_{\text{air}}} \frac{1 \text{ atm}}{\left(8.205 \times 10^{-5} \frac{\text{atm} \cdot \text{m}^3}{\text{mol} \cdot \text{K}} \right) \times 293 \text{ K}}$$

20°C, 68°F

- Gives you # of moles per m³ of air
- Multiply by MW_i to get g/m³ of air

$$\# \text{ of } \frac{\text{g}}{\text{m}^3} = \frac{\# \text{ mol}_i}{\# \text{ mol}_{\text{air}}} * \frac{P_{tot}}{RT} MW_i$$

Converting between mass and molar concentrations

- What mass concentration of CO₂ corresponds to 400 ppm?
 - At 20°C (68°F)

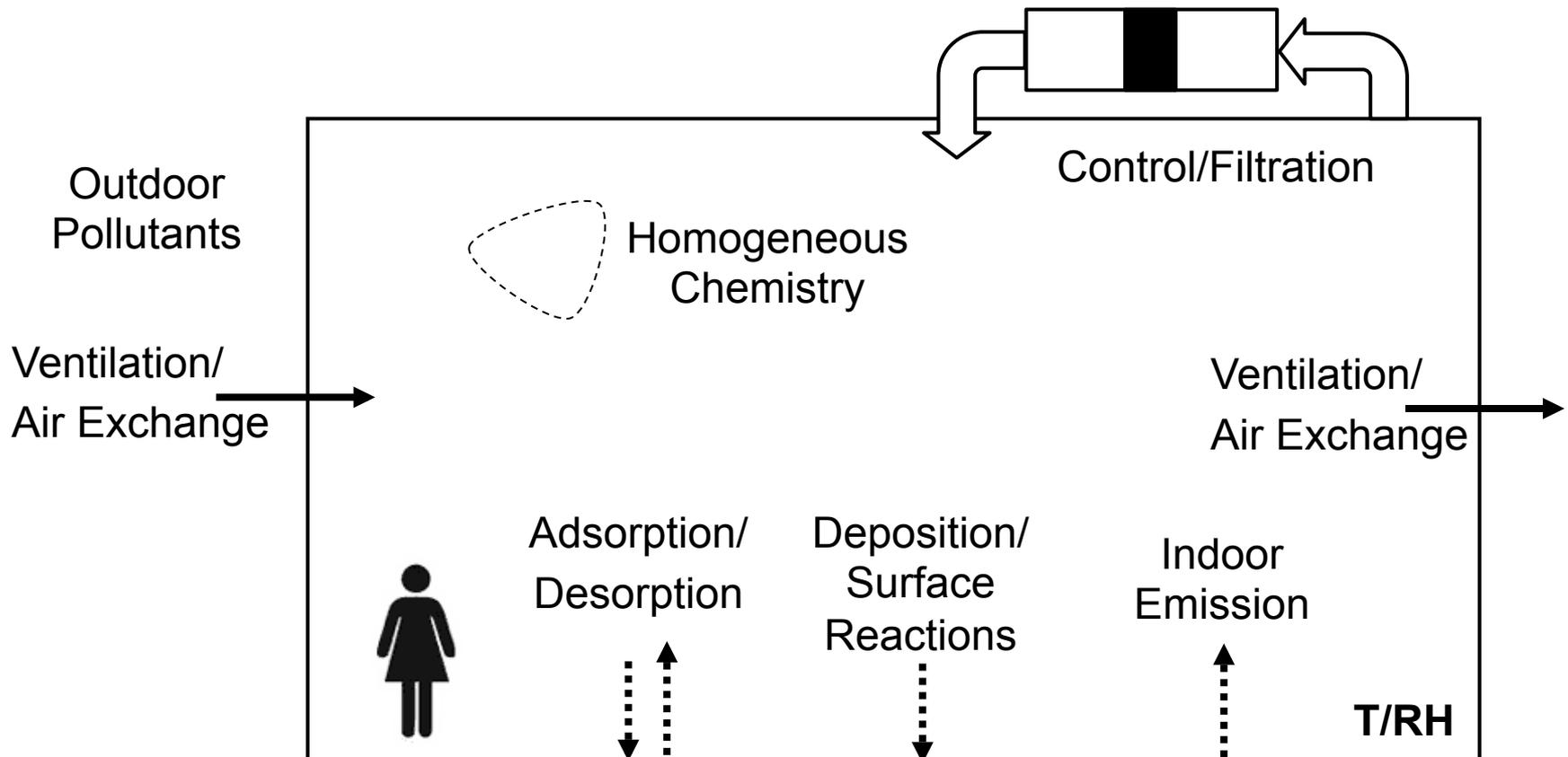
$$\# \text{ of } \frac{\text{mg}}{\text{m}^3} = \frac{\# \text{ mol}_i}{\# \text{ mol}_{\text{air}}} * \frac{P_{\text{tot}}}{RT} MW_i * \frac{10^3 \text{ mg}}{\text{g}}$$

$$MW_{\text{CO}_2} = 44 \text{ g/mol}$$

Answer: 720 mg/m³

Indoor environment: Mass balance

To understand the levels of airborne pollutants that we are exposed to, we need to understand the underlying physical, chemical, and biological mechanisms that drive pollutant emission, transport, and control



Indoor environment: Mass balance

- Simplest case (**inert gas**)
 - Neglecting indoor physics/chemistry
 - No deposition, no reaction

$$\left(\begin{array}{c} \text{Mass} \\ \text{accumulation} \\ \text{rate} \\ \text{[mass / time]} \end{array} \right) = \left(\begin{array}{c} \text{Mass flow in} \\ \text{[mass / time]} \end{array} \right) - \left(\begin{array}{c} \text{Mass flow out} \\ \text{[mass / time]} \end{array} \right) + \left(\begin{array}{c} \text{Mass emitted} \\ \text{[mass / time]} \end{array} \right)$$

$$\frac{dm}{dt} = \frac{dCV}{dt} = V \frac{dC}{dt} + C \frac{dV}{dt}$$

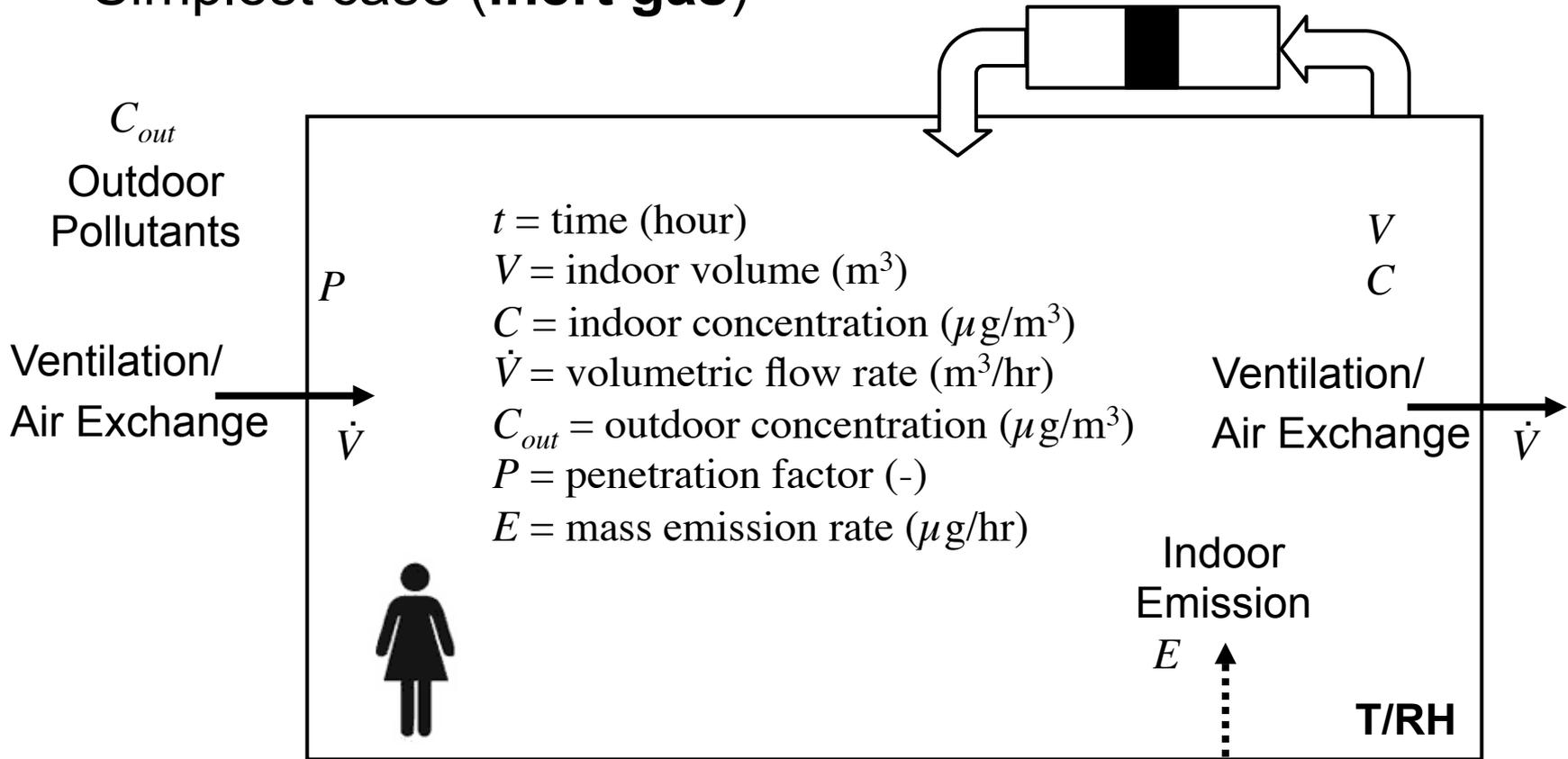
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Assumptions:

- Building/room can be treated as well-mixed
- Ventilation/air exchange rate is constant
- Outdoor pollutant concentration is constant
- Indoor sources emit at a constant rate

Indoor environment: Mass balance

- Simplest case (**inert gas**)



$$V \frac{dC}{dt} = P\dot{V}C_{out} - \dot{V}C + E$$

Indoor environment: Mass balance

- Simplest case (**inert gas**)

$$V \frac{dC}{dt} = P\dot{V}C_{out} - \dot{V}C + E$$

- Divide by volume:

$$\frac{dC}{dt} = P \frac{\dot{V}}{V} C_{out} - \frac{\dot{V}}{V} C + \frac{E}{V}$$

$$\frac{dC}{dt} = P\lambda C_{out} - \lambda C + \frac{E}{V}$$

$$\lambda = \frac{\dot{V}}{V} = \text{air exchange rate } \left(\frac{1}{\text{hr}} \right)$$

Indoor environment: Mass balance

- Assume steady-state conditions:

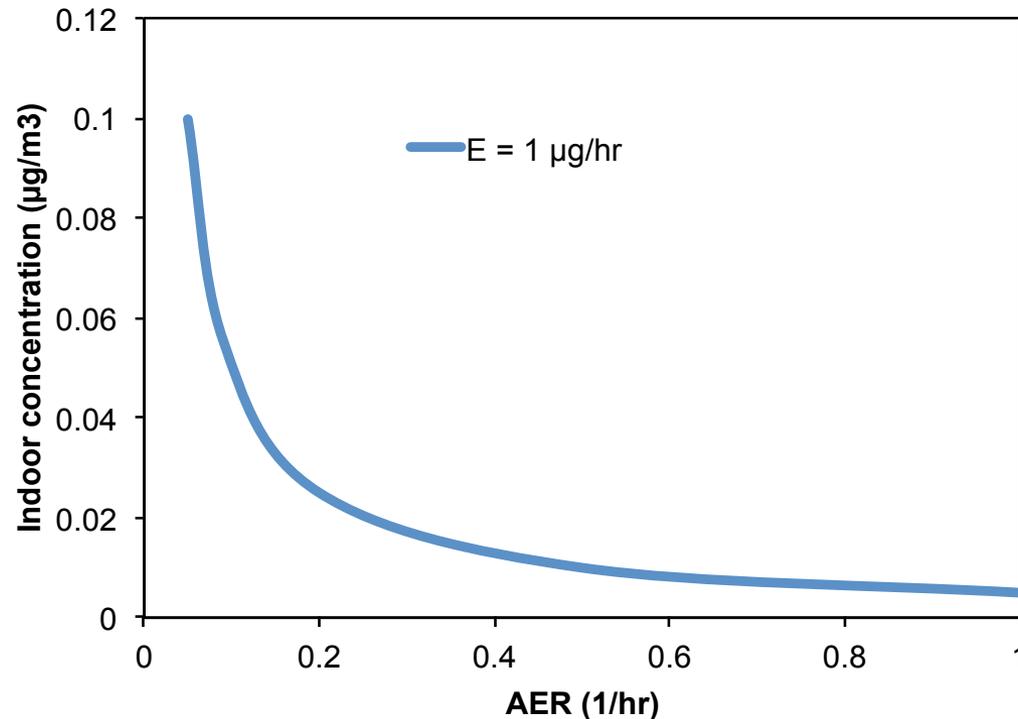
$$0 \swarrow \frac{dC}{dt} = P\lambda C_{out} - \lambda C + \frac{E}{V}$$

$$C_{ss} = PC_{out} + \frac{E}{\lambda V}$$

- If λ is large (and/or E is small): $PC_{out} \gg E/\lambda V$
 - C approaches C_{out} (depending on P)
 - This means outdoor sources are relatively more important
- If λ is small (and/or E is large): $PC_{out} \ll E/\lambda V$
 - C approaches $E/\lambda V$
 - This means indoor sources are relatively more important

Steady state mass balance and air exchange

- Example steady state calculations: $C_{ss} = PC_{out} + \frac{E}{\lambda V}$
- Assume $C_{out} = 0$: $C_{ss} = \frac{E}{\lambda V}$
- Assume $V = 200 \text{ m}^3$ and $E = 1 \text{ } \mu\text{g/hr}$: how are C_{ss} and λ related?



What impacts air exchange rates?

Outdoor air exchange can be divided into two main categories:

Ventilation

Intentional introduction of outdoor air into a building

Subdivided into:

- *Mechanical (forced) ventilation*: The intentional movement of air into and out of a building using fans, intake vents, and exhaust vents
- *Natural ventilation*: The flow of air through open windows, doors, grilles, and other planned envelope penetrations, driven largely by natural or artificially induced pressure differences

Infiltration

Flow of outdoor air into a building through cracks, leaks, and other **unintentional** openings in the envelope (includes normal use of exterior doors) ... i.e., *air leakage*

Dealing with ventilation vs. infiltration

- Mechanical ventilation is straightforward
 - Fans move air through known openings
 - Flow rates typically known or at least measurable
- Natural ventilation is conceptually straightforward but physically complex
 - Known openings but highly varying wind speeds and directions
- Infiltration is complex
 - Typically unknown openings and multiple driving forces
- Need to know airflows through each of these in order to quantify IAQ and energy impacts

VENTILATION

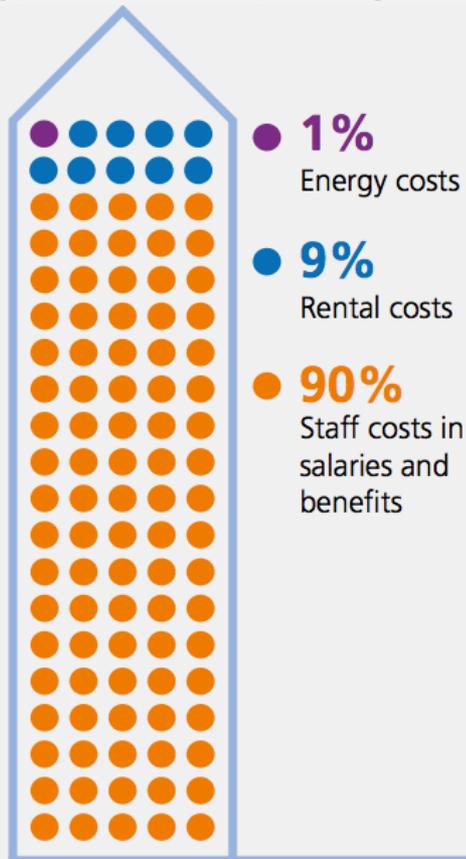
“Four principles for achieving good indoor air quality”

- Minimize indoor emissions
- Keep buildings dry
- Ventilate well 
- Protect against outdoor pollution

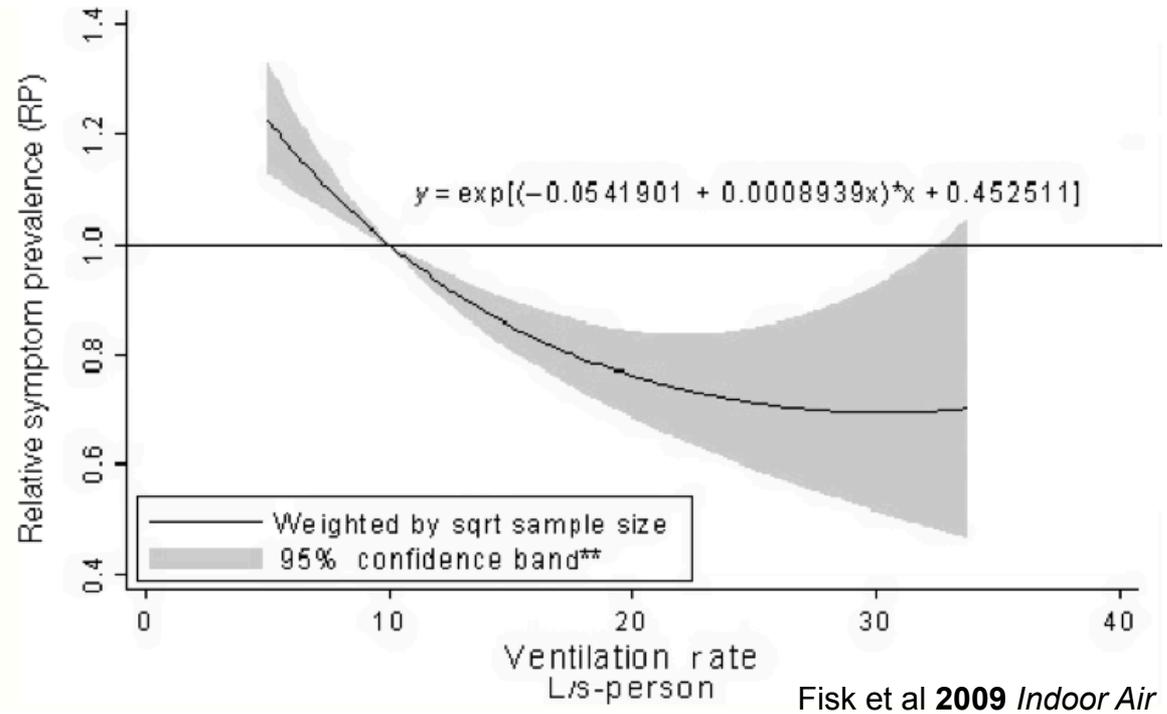
Importance of ventilation

- Outdoor air ventilation is used to dilute indoor-generated pollutants

Typical business operating costs¹



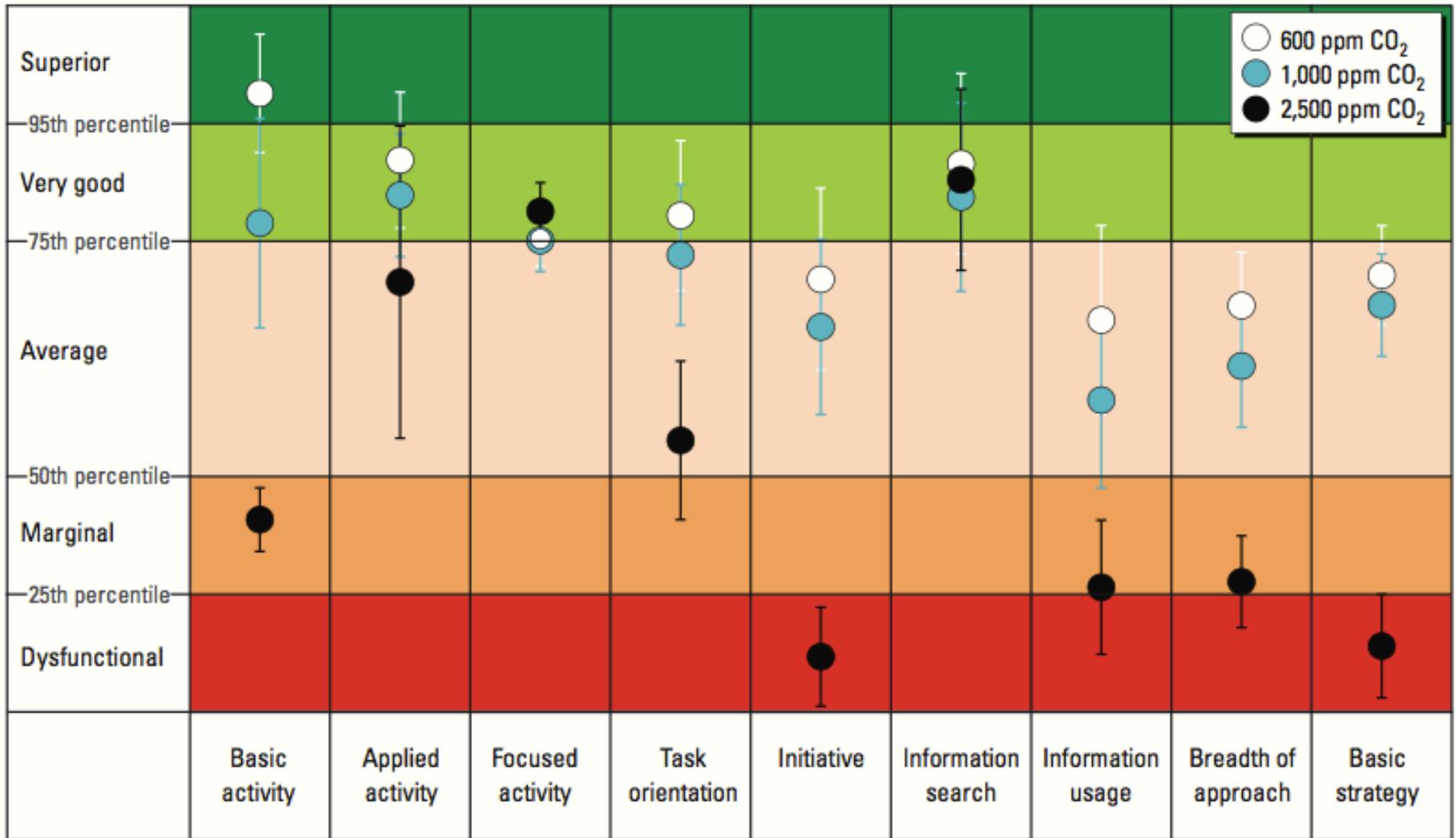
Quantitative relationship of sick building syndrome symptoms with ventilation rates



Ventilation and CO₂

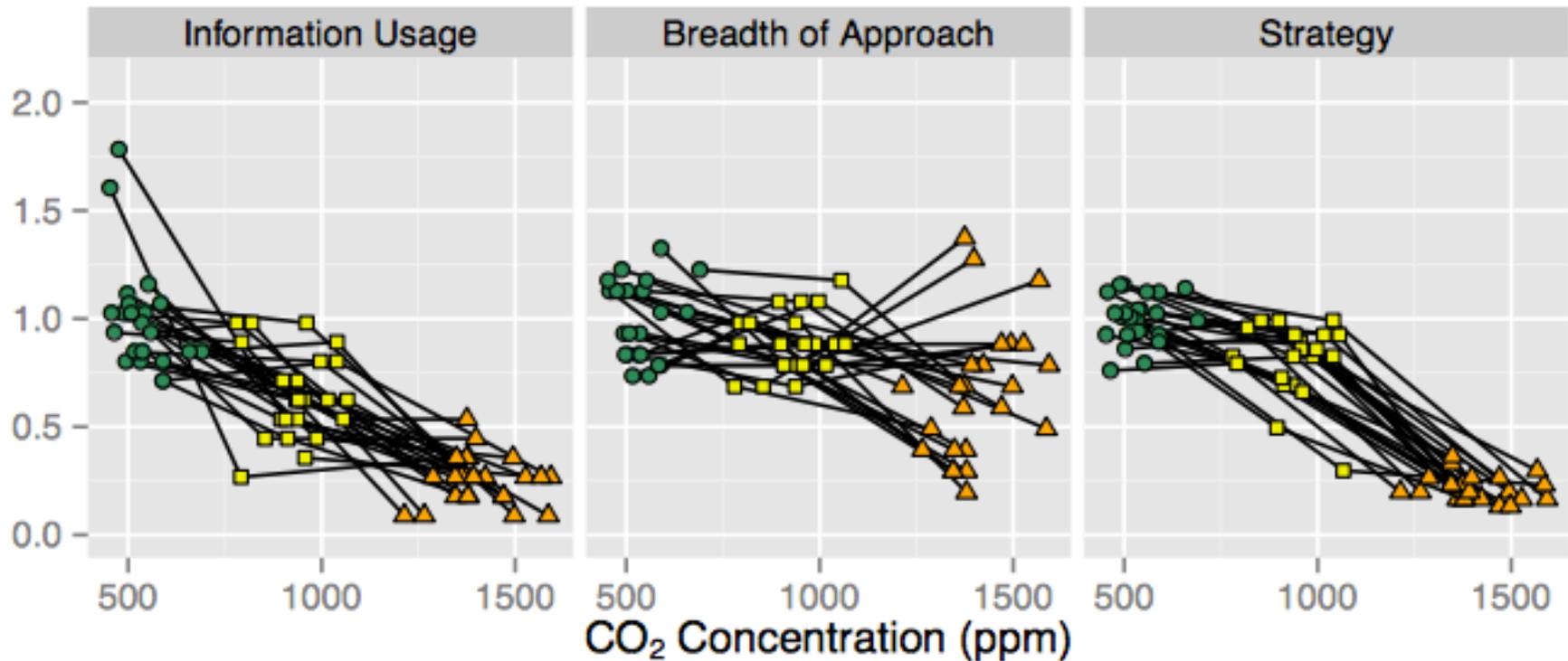
- CO₂ is often used as a surrogate for IAQ
 - Imperfect, but instructive
- The average CO₂ production rate per person at an activity level of 1.2 met is often assumed to be **0.005 L/s**
 - New data suggest typical CO₂ emission rates are ~21 g/hr (or about 0.003 L/s)
 - Either way, CO₂ concentrations will be elevated in poorly ventilated spaces
- Recent evidence also suggests that CO₂ might be a pollutant on its own
 - Affecting decision making

Ventilation and CO₂



Ventilation and CO₂

Scientists report a surprising link between indoor carbon dioxide levels and cognitive function

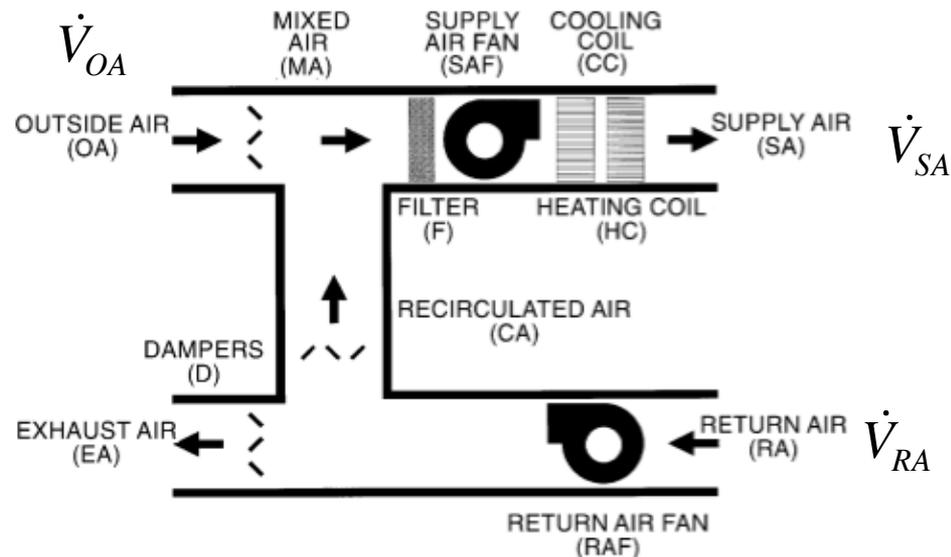


Allen et al 2015 *Environ Health Perspectives*

<https://www.washingtonpost.com/news/energy-environment/wp/2015/10/27/why-your-office-air-could-be-crimping-your-productivity/>

Mass balance example problem w/ CO₂

- In a 150 m³ room with 30 people present, what would be the required (a) air exchange rate, (b) outdoor airflow rate, and © per person ventilation flow rate to keep the indoor CO₂ concentration below 1000 ppm?
 - Assume outdoors is 400 ppm
 - And CO₂ production (activity level of 1.2 met) = **21 g/hr per person**



Ventilation and IAQ

- How do we determine the correct (or at least ***required***) ventilation rate?
 - ASHRAE Standard 62.1 (commercial) and 62.2 (residential)

ASHRAE Standard 62.1: Commercial buildings



ANSI/ASHRAE Standard 62.1-2010
(Supersedes ANSI/ASHRAE Standard 62.1-2007)
Includes ANSI/ASHRAE addenda listed in Appendix J

ASHRAE STANDARD

Ventilation for Acceptable Indoor Air Quality

1. PURPOSE

1.1 The purpose of this standard is to specify minimum ventilation rates and other measures intended to provide indoor air quality that is acceptable to human occupants and that minimizes adverse health effects.

1.2 This standard is intended for regulatory application to new buildings, additions to existing buildings, and those changes to existing buildings that are identified in the body of the standard.

1.3 This standard is intended to be used to guide the improvement of indoor air quality in existing buildings.

2. SCOPE

2.1 This standard applies to all spaces intended for human occupancy except those within single-family houses, multi-family structures of three stories or fewer above grade, vehicles, and aircraft.

2.2 This standard defines requirements for ventilation and air-cleaning system design, installation, commissioning, and operation and maintenance.

ASHRAE Standard 62.1: Commercial buildings

Ventilation rate procedure (VRP)

6.2.2.1 Breathing Zone Outdoor Airflow. The outdoor airflow required in the breathing zone of the occupiable space or spaces in a *ventilation zone*, i.e., the breathing zone outdoor airflow (V_{bz}), shall be no less than the value determined in accordance with Equation 6-1.

$$V_{bz} = R_p \cdot P_z + R_a \cdot A_z \quad (6-1)$$

where

A_z = zone floor area: the net occupiable floor area of the *ventilation zone* ft² (m²)

P_z = zone population: the number of people in the *ventilation zone* during typical usage.

R_p = outdoor airflow rate required per person as determined from Table 6-1

Note: These values are based on adapted occupants.

R_a = outdoor airflow rate required per unit area as determined from Table 6-1

ASHRAE Standard 62.1: Commercial buildings VRP

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate		Area Outdoor Air Rate		Notes	Default Values		Air Class	
	R_p		R_a			Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s-person	cfm/ft ²	L/s·m ²		#/1000 ft ² or #/100 m ²	cfm/person		L/s-person
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1

ASHRAE Standard 62.1: Commercial buildings VRP

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE (Continued)
 (This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate		Area Outdoor Air Rate		Notes	Default Values		Air Class	
	R_p		R_a			Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft ²	L/s·m ²		#/1000 ft ² or #/100 m ²	cfm/person		L/s·person
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Banks or bank lobbies	7.5	3.8	0.06	0.3		15	12	6.0	1
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
General manufacturing (excludes heavy industrial and processes using chemicals)	10	5.0	0.18	0.9		7	36	18	3

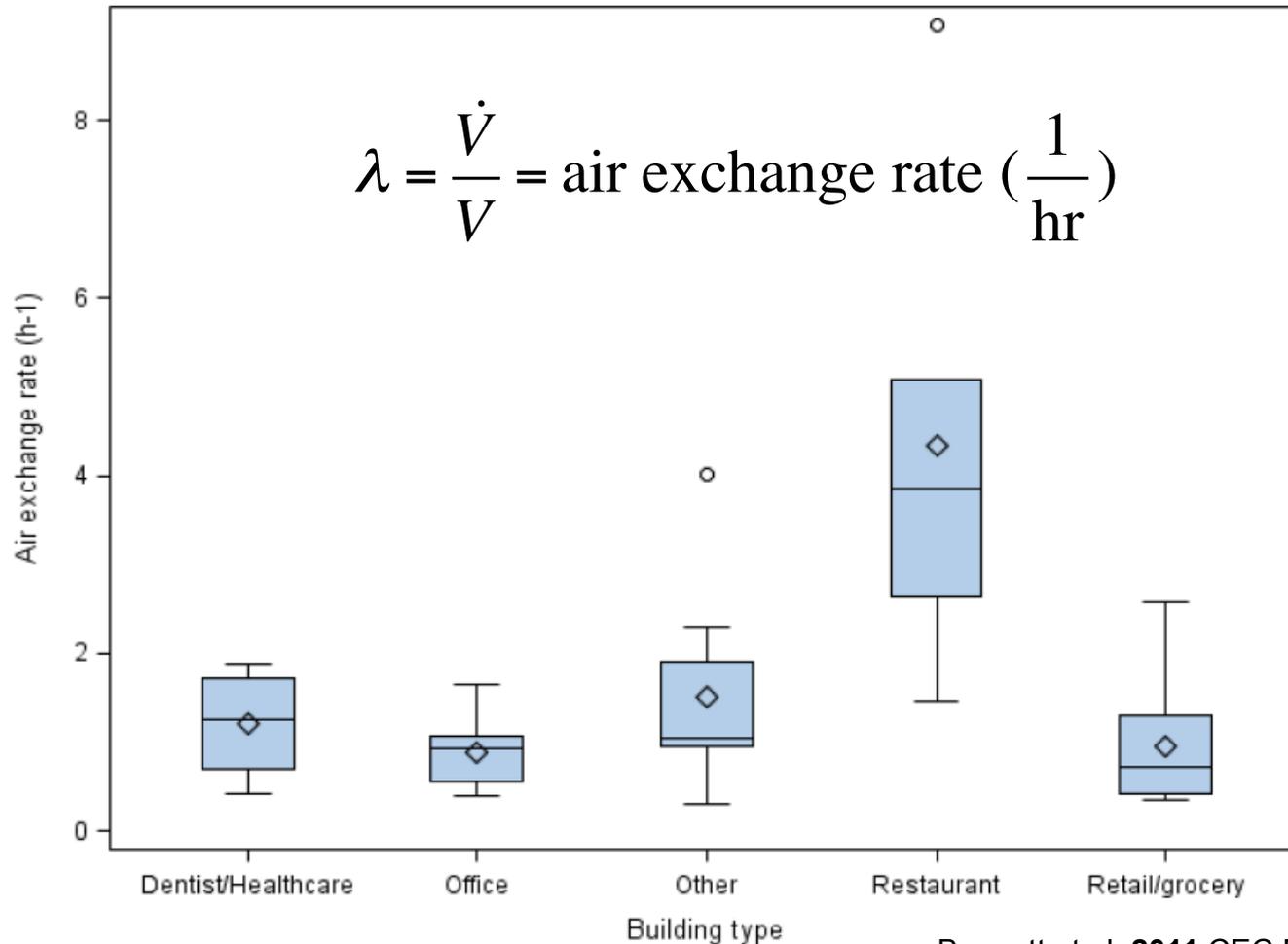
ASHRAE Standard 62.1: Commercial buildings VRP

TABLE 6-4 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft ²	Notes	Exhaust Rate, L/s-unit	Exhaust Rate, L/s-m ²	Air Class
Arenas	–	0.50	B	–	–	1
Art classrooms	–	0.70		–	3.5	2
Auto repair rooms	–	1.50	A	–	7.5	2
Barber shops	–	0.50		–	2.5	2
Beauty and nail salons	–	0.60		–	3.0	2
Cells with toilet	–	1.00		–	5.0	2
Copy, printing rooms	–	0.50		–	2.5	2
Darkrooms	–	1.00		–	5.0	2
Educational science laboratories	–	1.00		–	5.0	2
Janitor closets, trash rooms, recycling	–	1.00		–	5.0	3
Kitchenettes	–	0.30		–	1.5	2
Kitchens—commercial	–	0.70		–	3.5	2
Locker/dressing rooms	–	0.25		–	1.25	2
Locker rooms	–	0.50		–	2.5	2
Paint spray booths	–	–	F	–	–	4
Parking garages	–	0.75	C	–	3.7	2
Pet shops (animal areas)	–	0.90		–	4.5	2
Refrigerating machinery rooms	–	–	F	–	–	3
Residential kitchens	50/100	–	G	25/50	–	2
Soiled laundry storage rooms	–	1.00	F	–	5.0	3
Storage rooms, chemical	–	1.50	F	–	7.5	4

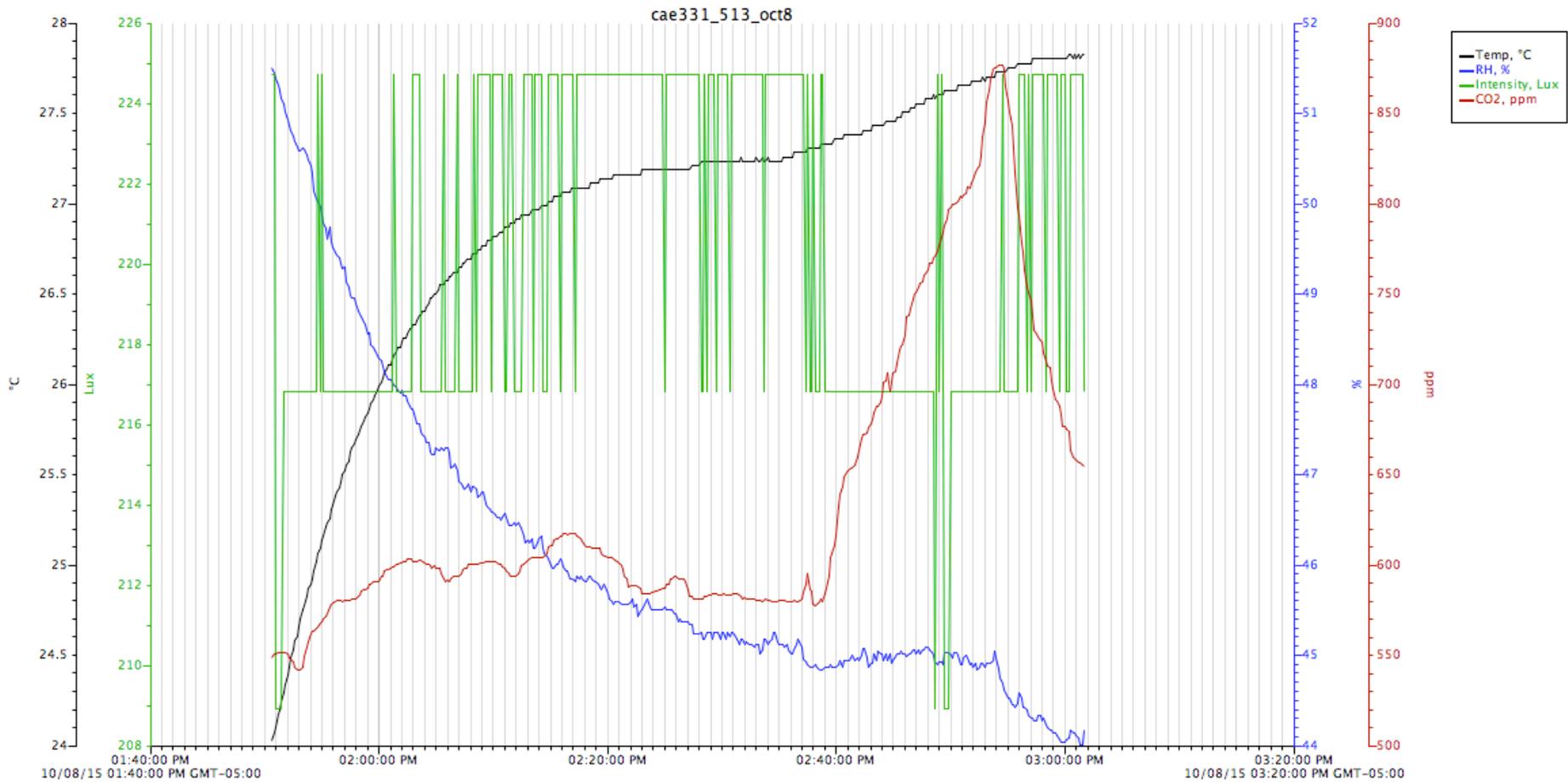
Measured air exchange rates: Commercial buildings

- Recent study of ~40 commercial buildings in California



Bennett et al. 2011 CEC Report

CO₂ concentration in the classroom (Oct 8)



INFILTRATION

Typical air leakage sites in residential buildings



General models for air flows through leaks

- Given an opening:

$$\dot{V} = AC\Delta P^n$$

A = area of opening, ft² (m²)

ΔP = pressure difference between inside and outside, in WG (Pa)

C = flow coefficient, ft/(min inWG ^{n}) [m/(s Pa ^{n})]

n = exponent, between 0.4 and 1.0 (usually 0.65 for buildings)

- For a combination of i openings:

$$\dot{V} = \sum_i A_i C_i \Delta P_i^{n_i}$$

Driving forces of ventilation and infiltration: ΔP

- Three primary mechanisms generate pressure differences (**driving forces**)
 - **Stack effect (natural buoyancy)**
 - Caused by the weight of a column of air located inside/outside a building
 - Depends on air density and height above a neutral reference level
 - Density is also a function of temperature
 - **Wind**
 - Caused by wind impinging on a building, creating a distribution of pressures on the exterior surface
 - Depends on wind direction, wind speed, air density, surface orientation, and surrounding conditions
 - **Mechanical air handling equipment (fans)**
 - Fans are used to supply, recirculate, exhaust, and otherwise balance pressures and flows in buildings

$$\Delta P = \Delta P_{wind} + \Delta P_{stack} + \Delta P_{vent} \quad (\text{"+" when causing flow to interior})$$

Stack effect

- **In wintertime**

- Air within a building acts like a bubble of **hot** air in a sea of **cold** air
- **Rises** to the top
- Draws **outdoor air in from** cracks/gaps/openings in the **bottom**
- Indoor air flows out through openings in the top

- **In summertime**

- Air within a building acts like a bubble of **cold** air in a sea of **hot** air
- **Falls** to the bottom
- Drives **indoor air out through** cracks/gaps/openings in **bottom**
- Outdoor air is drawn in through openings in the top
 - Temperature differences usually lower in the summer time so the amount of flow is smaller

$$\Delta P_{stack} = \rho_{in} C_d \left(\frac{T_{out} - T_{in}}{T_{in}} \right) g (H_{NPL} - H)$$

Wind pressures

- From velocity component of Bernoulli Equation:

$$P_{velocity} = \frac{1}{2} \rho_{air} U_h^2$$

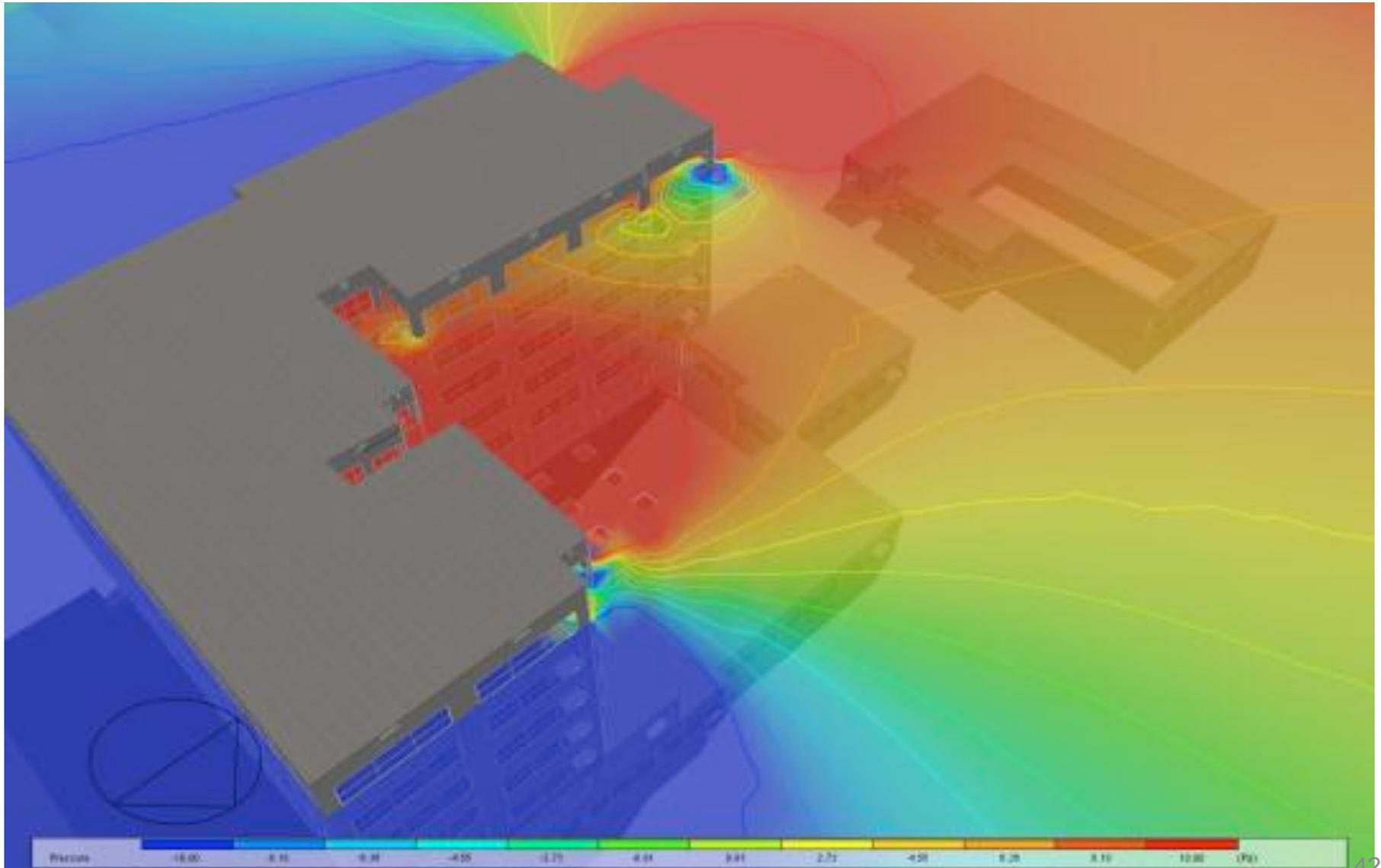
$P_{velocity}$ = wind velocity pressure; U_h = air velocity at building height, h ; ρ_{air} = air density

- To convert velocity pressure to the difference between surface pressure and local atmospheric pressure:
 - Multiply by local wind pressure coefficient, C_p

$$P_{wind} = \Delta P = C_p P_{velocity} = \frac{1}{2} C_p \rho U_h^2$$

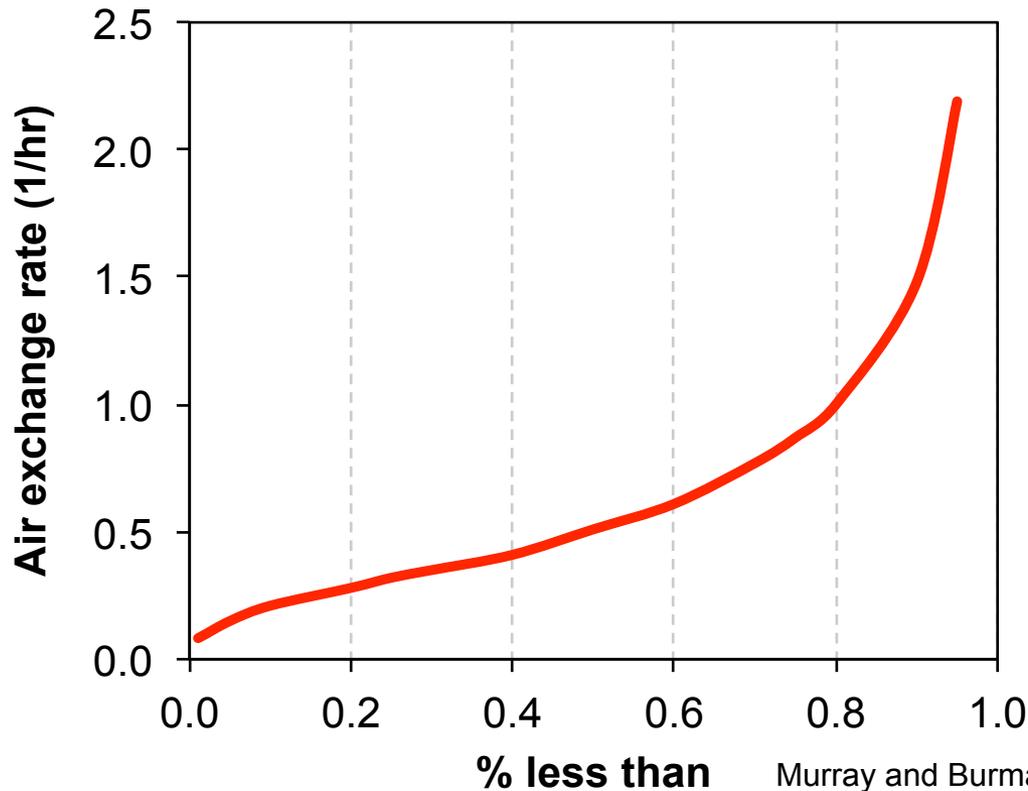
- Get C_p (+ or -) from measurements or from *ASHRAE Handbook of Fundamentals 2013* Chapter 24 “Airflow around buildings”

Wind pressure coefficients (C_p) vary around buildings



What are typical air exchange rates (AERs) in homes?

- Distribution of AERs in ~2800 homes in the U.S.
 - Measured using PFT (perfluorocarbon tracer) in the early 1990s



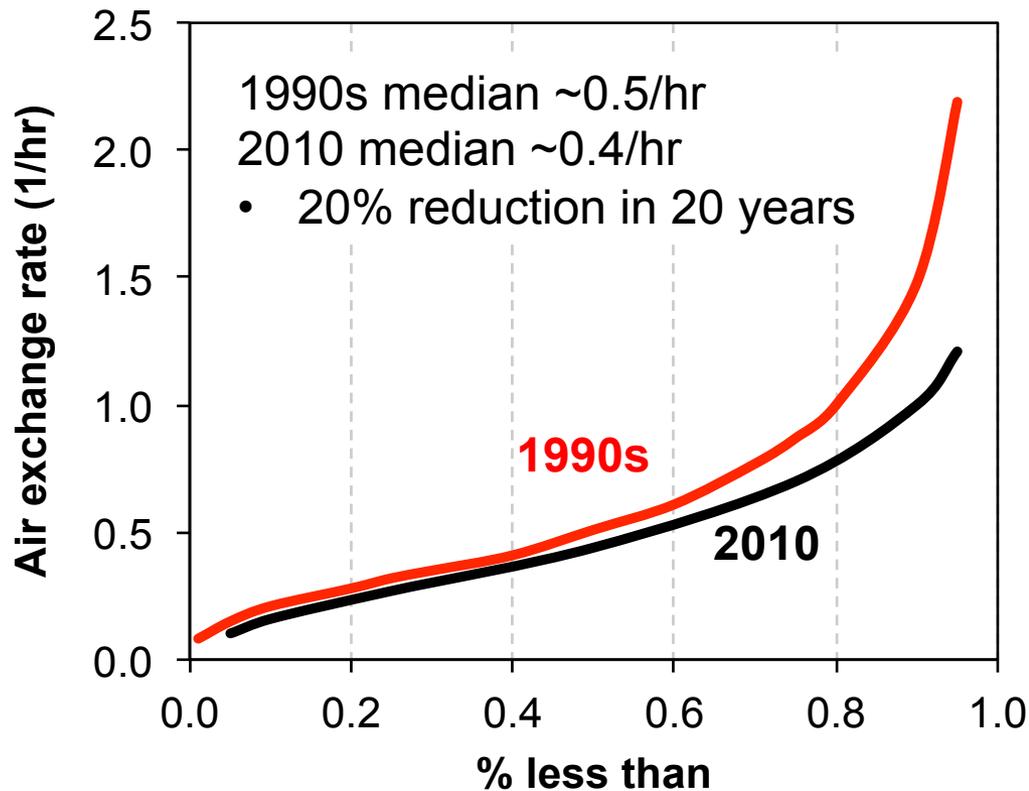
Mostly due to infiltration

In the past, we seldom used mechanical ventilation systems in single-family homes, but this is changing

- What do you think this curve looks like now?

What are typical air exchange rates (AERs) in homes?

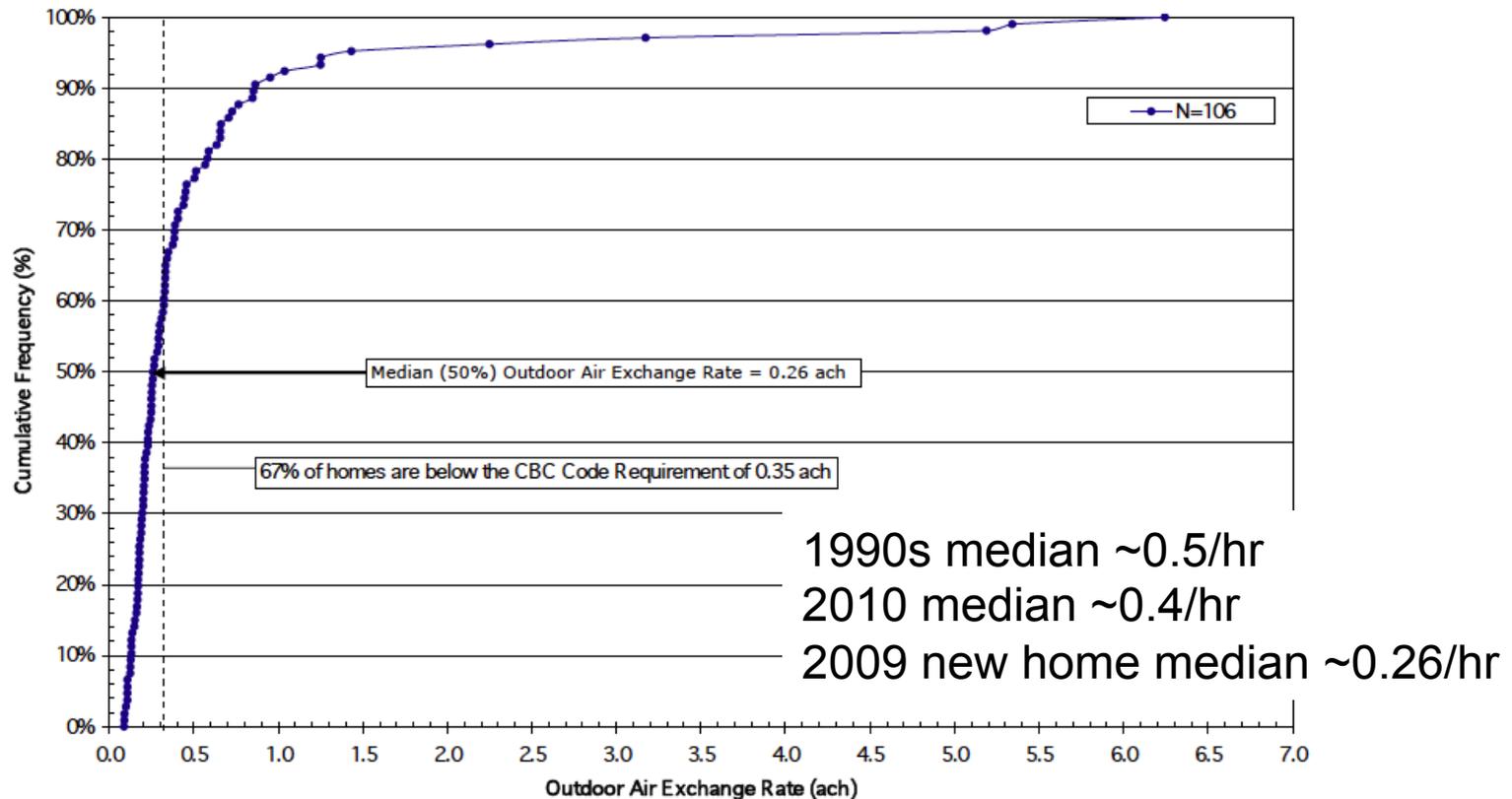
- New distribution of AERs U.S. homes
 - Early 1990s and revisited in 2010 (Persily et al. 2010)



Murray and Burmaster, **1995** *Risk Analysis*
Persily et al. **2010** *Indoor Air*

What are typical air exchange rates (AERs) in homes?

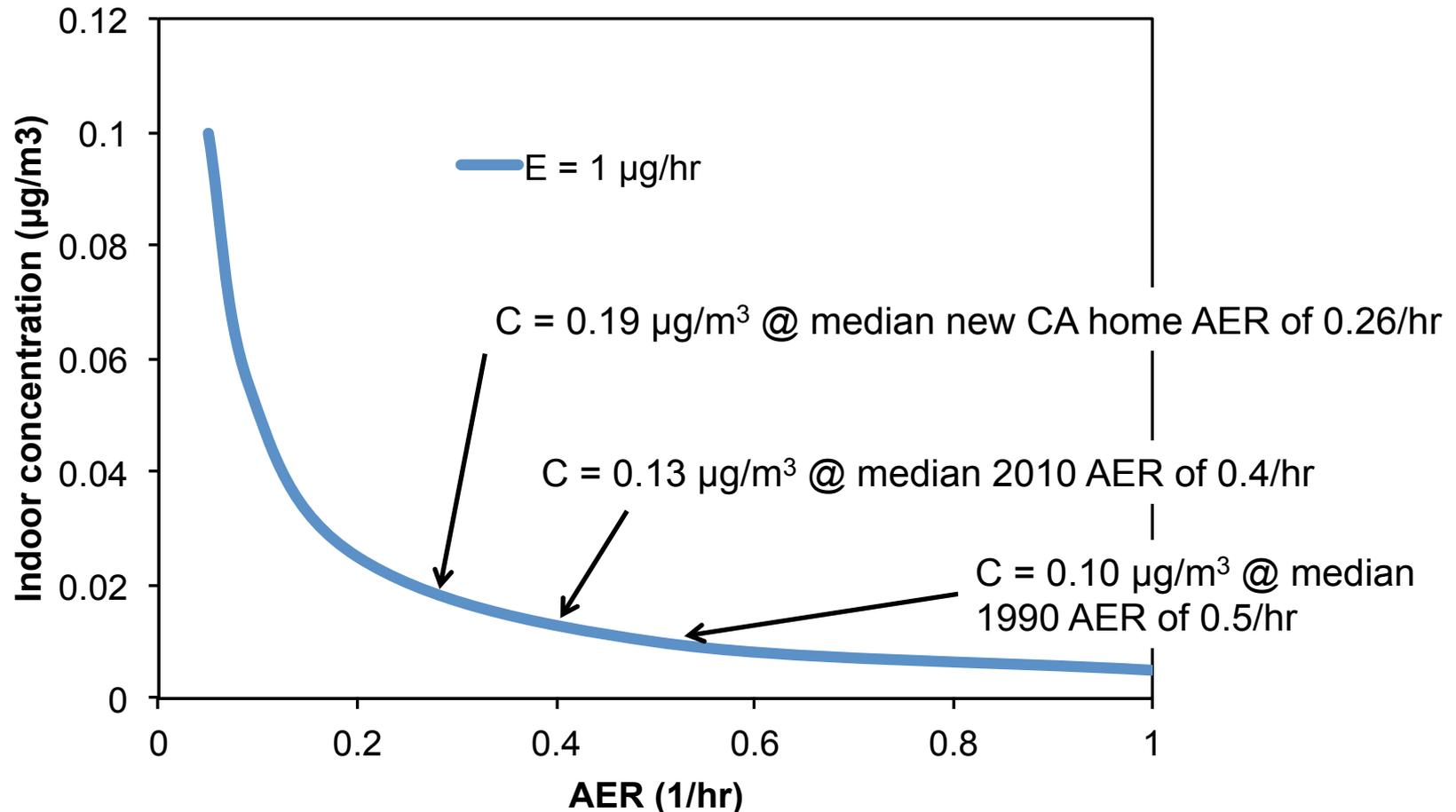
- Distribution of AERs U.S. homes: infiltration
 - Addition of 106 new homes (Offermann et al., 2009)



- Not uncommon for new homes to have AER = 0.05-0.20 per hour

Steady state mass balance and real AERs

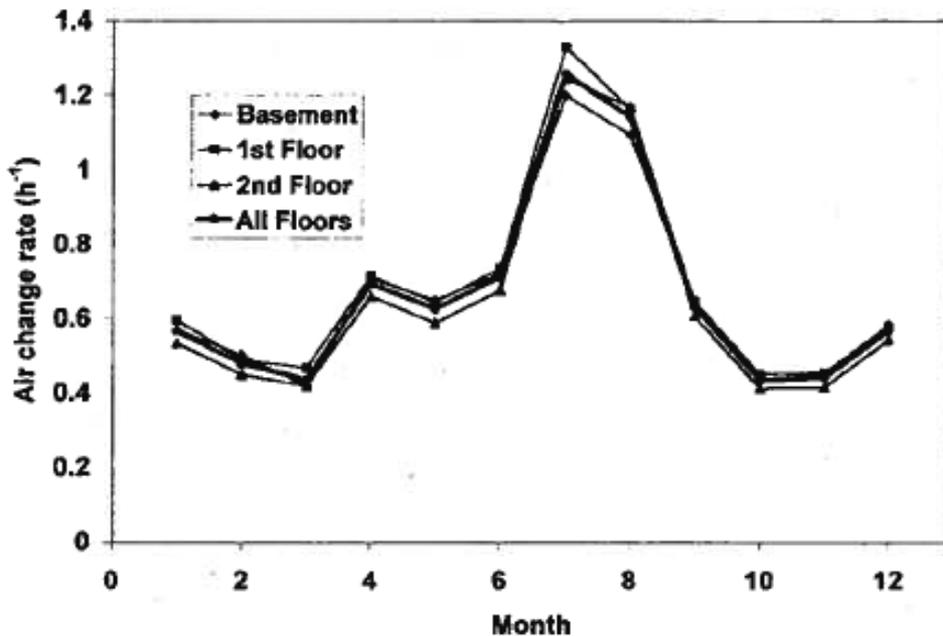
- Assume $V = 200 \text{ m}^3$ and $E = 1 \text{ } \mu\text{g/hr}$
- Lower AER \rightarrow higher C_{ss}



Variation in infiltration AER with driving forces

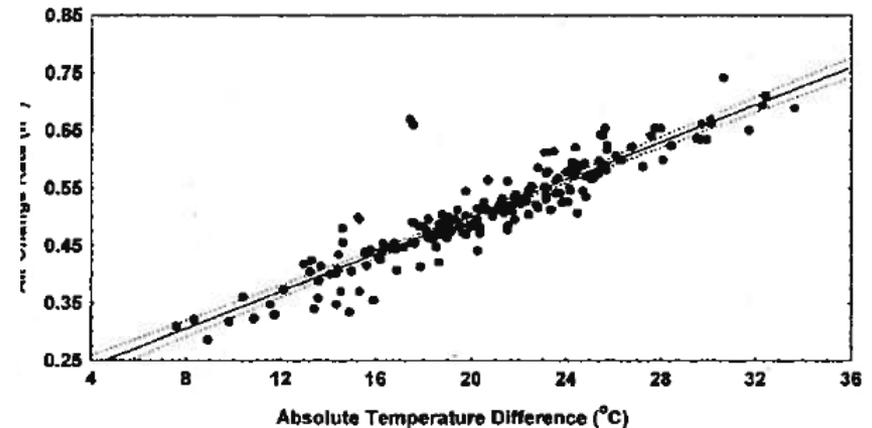
- Air exchange rates differ both between buildings and within buildings
 - Differences vary by driving forces and building characteristics
- Example: 4600 AERs measured by automated SF₆ system in a house for 2 years:

Air Change Rates by Floor: Reston 2000 (N = 4,451)



AERs can vary by I/O temperature within seasons

Air Change Rate vs Indoor-Outdoor Temperature Difference
Overnight Values: Winter 2000 (N = 183)
AIRX = 0.176 (0.011 SE) + 0.0164 (0.0005) DELTA T (r = 0.915)



AERs in individual buildings can vary by season
• **Driving forces: temperature, wind speed**

Modeling air leakage (infiltration only)

- There are several models for estimating infiltration rates in buildings
- One common model is the LBL Model for Air Leakage
 - aka Sherman-Grimsrud Model

$$\dot{V}_{\text{inf}} = A_{\text{leak}} \sqrt{a_s \Delta T + a_w v_w^2} \quad [\text{L/s}]$$

A_{leak} = building equivalent leakage area [cm^2]

ΔT = interior-outdoor temp difference [K]

a_s = stack effect coefficient [$\frac{(\text{L/s})^2}{\text{cm}^4 \text{K}}$]

a_w = wind coefficient [$\frac{(\text{L/s})^2}{\text{cm}^4 (\text{m/s})^2}$]

v_w = wind speed [m/s]

LBL Air Leakage Model

Table 4 Basic Model Stack Coefficient C_s

	House Height (Stories)		
	One	Two	Three
Stack coefficient	0.000 145	0.000 290	0.000 435

Table 5 Local Shelter Classes

Shelter Class	Description
1	No obstructions or local shielding
2	Typical shelter for an isolated rural house
3	Typical shelter caused by other buildings across the street from the building under study
4	Typical shelter for urban buildings on larger lots where sheltering obstacles are more than one building height away
5	Typical shelter produced by buildings or other structures that are immediately adjacent (closer than one house height): e.g., neighboring houses on the same side of the street, trees, bushes, etc.

Table 6 Basic Model Wind Coefficient C_w

Shelter Class	House Height (Stories)		
	One	Two	Three
1	0.000 319	0.000 420	0.000 494
2	0.000 246	0.000 325	0.000 382
3	0.000 174	0.000 231	0.000 271
4	0.000 104	0.000 137	0.000 161
5	0.000 032	0.000 042	0.000 049

ASHRAE Standard 62.2: Residential ventilation



ANSI/ASHRAE Standard 62.2-2007
(Supersedes ANSI/ASHRAE Standard 62.2-2004)
Includes ANSI/ASHRAE addenda listed in Appendix C

ASHRAE STANDARD

Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings

1. PURPOSE

This standard defines the roles of and minimum requirements for mechanical and natural ventilation systems and the building envelope intended to provide acceptable indoor air quality (IAQ) in low-rise residential buildings.

2. SCOPE

This standard applies to spaces intended for human occupancy within single-family houses and multifamily structures of three stories or fewer above grade, including manufactured and modular houses. This standard does not apply to transient housing such as hotels, motels, nursing homes, dormitories, or jails.

2.1 This standard considers chemical, physical, and biological contaminants that can affect air quality. Thermal comfort requirements are not included in this standard (see *ANSI/ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy*).

2.2 While acceptable indoor air quality is the goal of this standard, it will not necessarily be achieved even if all requirements are met

ASHRAE Standard 62.2: Residential ventilation

4. WHOLE-BUILDING VENTILATION

4.1 Ventilation Rate. A mechanical exhaust system, supply system, or combination thereof shall be installed for each dwelling unit to provide whole-building ventilation with outdoor air each hour at no less than the rate specified in Tables 4.1a and 4.1b or, equivalently, Equations 4.1a and 4.1b, based on the floor area of the conditioned space and number of bedrooms.

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1) \quad (4.1a)$$

where

Q_{fan} = fan flow rate, cfm

A_{floor} = floor area, ft²

N_{br} = number of bedrooms; not to be less than one

$$Q_{fan} = 0.05A_{floor} + 3.5(N_{br} + 1) \quad (4.1b)$$

where

Q_{fan} = fan flow rate, L/s

A_{floor} = floor area, m²

N_{br} = number of bedrooms; not to be less than one

TABLE 4.1a (I-P)
Ventilation Air Requirements, cfm

Floor Area (ft ²)	Bedrooms				
	0-1	2-3	4-5	6-7	>7
<1500	30	45	60	75	90
1501-3000	45	60	75	90	105
3001-4500	60	75	90	105	120
4501-6000	75	90	105	120	135
6001-7500	90	105	120	135	150
>7500	105	120	135	150	165

TABLE 4.1b (SI)
Ventilation Air Requirements, L/s

Floor Area (m ²)	Bedrooms				
	0-1	2-3	4-5	6-7	>7
<139	14	21	28	35	42
139.1-279	21	28	35	42	50
279.1-418	28	35	42	50	57
418.1-557	35	42	50	57	64
557.1-697	42	50	57	64	71
>697	50	57	64	71	78