

I am air. And I am everywhere.

**Indoor Air Quality:**

You can't touch me or see me or hear me  
**Health Impacts and Potential Solutions**

But without me you would not be there...

**Sasha Krstanovic (1981)**



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**Introduction**

**IAQ – why talk about it now**

**The science**

**Solutions?**



**Nile Hotel and Conference  
Centre, Kampala Uganda**

**Energoprojekt  
1971**

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# Turnmill, Clerkenwell, London 2015

- **First UK speculative office to be entirely heated and cooled by ground source heat pumps.**
- **15kW PV array.**
- **Exposed ceilings and displacement ventilation.**





# AECOM by the numbers

**+87k**

Over 87,000 dedicated professionals worldwide

**17.4b**

US\$17.4 billion in annual revenue

**+150**

Serving clients in more than 150 countries, within 716 AECOM offices — offering global expertise and tailored local solutions

**#1**

For the eight consecutive year, *Engineering News-Record (ENR)* 2017 has ranked AECOM as the top design firm

**#3**

*Interior Design's* Top 100 Giant Firms

**500**

A Fortune 500 firm, AECOM companies had annual revenue of approximately US\$17.4 billion







# Splashpoint, Worthing





# Siemens HQ, Masdar





# Kula Belgrade







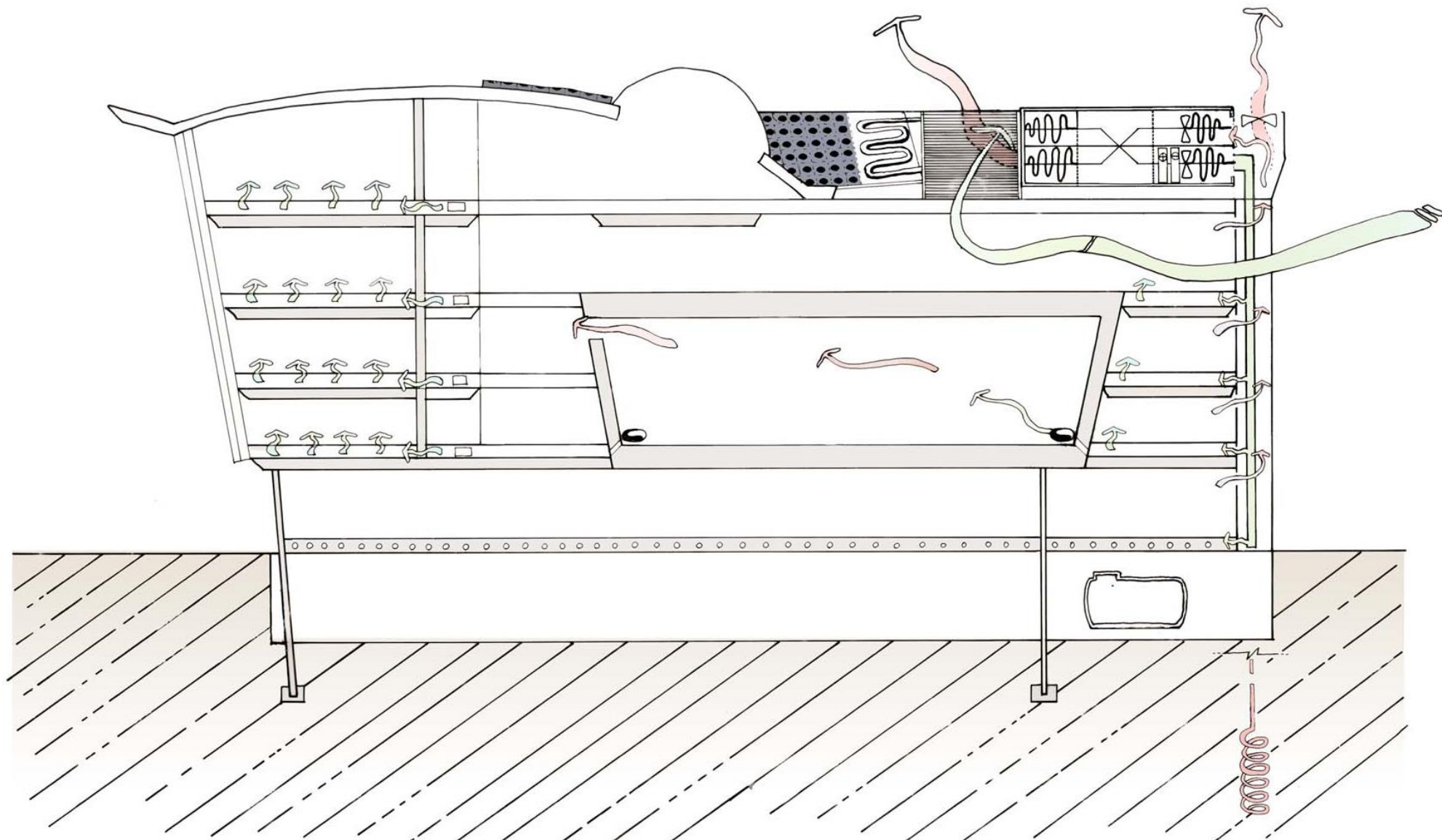
## **Early Learning Village, Singapore**

**Creche for 2000 infants and young  
children aged 0 months – 6 years**

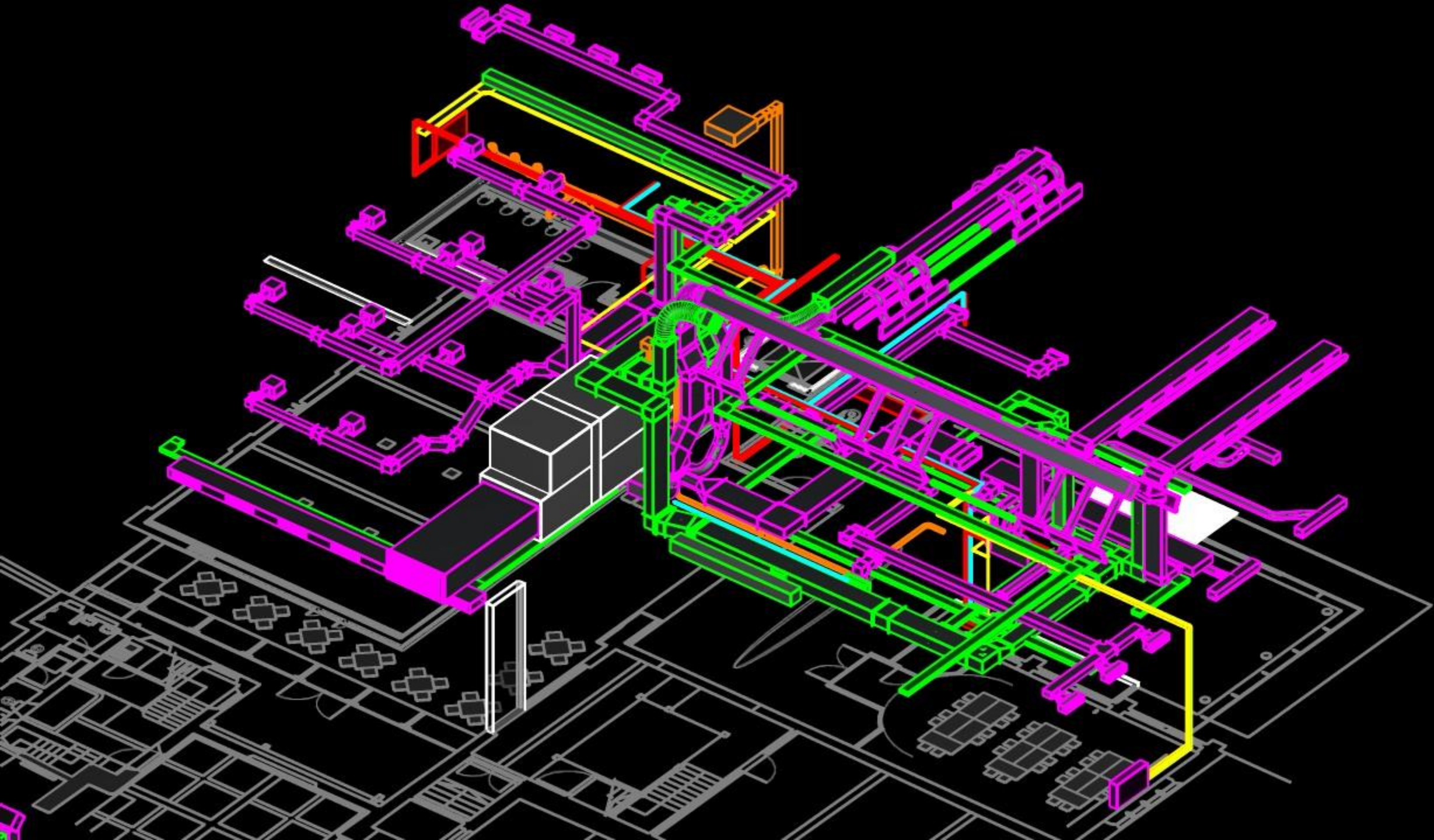




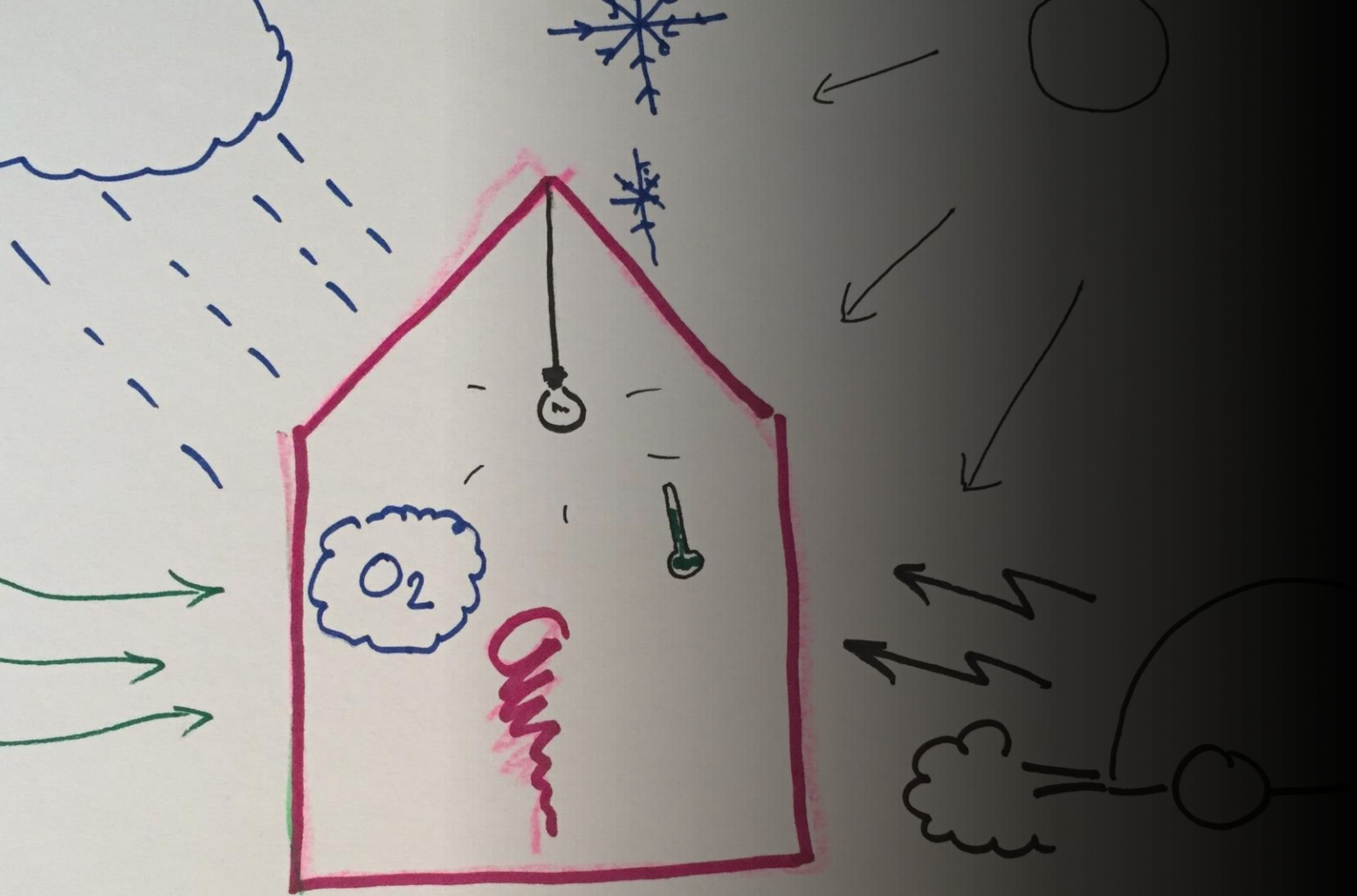




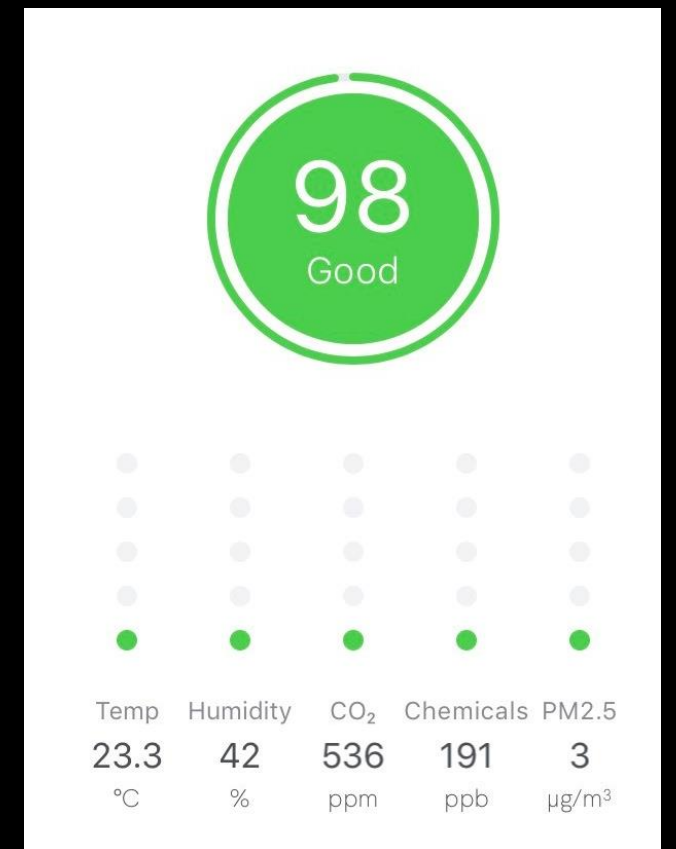




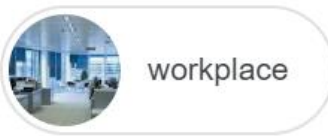




## What is IAQ?



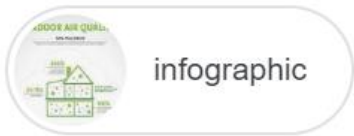




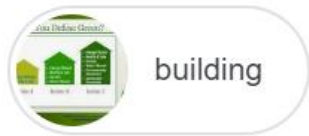
workplace



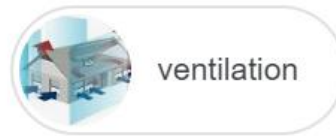
office



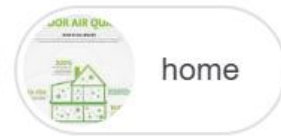
infographic



building



ventilation



home



hvac



residential

IDT IAQ Rating	Reference Level*	Air Information	TVOC (mg/m <sup>3</sup> )	Air Quality
≤ 1.99	Level 1	Clean Hygienic Air (Target Value)	< 0.3	Very Good
2.00 - 2.99	Level 2	Good Air Quality (if no threshold is exceeded)	0.3 - 1.0	Good
3.00 - 3.99	Level 3	Noticeable Comfort Concerns (Not recommended for exposure > 12 months)	1.0 - 3.0	Medium
4.00 - 4.99	Level 4	Significant Comfort Issues (Not recommended for exposure > 1 month)	3.0 - 10.0	Poor
≥ 5.00	Level 5	Unacceptable conditions (Not recommended)	> 10.0	Bad

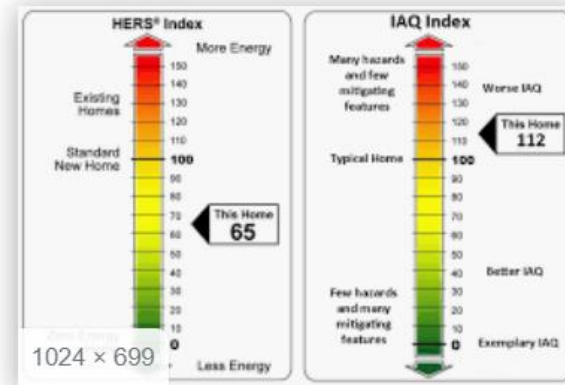
How to Measure Indoor Air Quality | IDT  
idt.com



Indoor Air Quality  
catalysts.basf.com



Indoor Air Quality  
thebesa.com



IAQ Index: Value and Scoring - SVACH  
svach.lbl.gov



Indoor Air Quality Tools for Schools  
epa.gov

Rating	Excellent (0 points each)	Good (14 points each)	Fair (21 points each)	Poor (28 points each)	Inadequate (35 points each)
Temperature (°C)	18-21°C	Plus or minus 1°C (including variance in occupied rooms, seasons and times of day)	Plus or minus 2°C (including variance in occupied rooms, seasons and times of day)	Plus or minus 3°C (including variance in occupied rooms, seasons and times of day)	Plus or minus 4°C or more (including variance in occupied rooms, seasons and times of day)
Carbon Dioxide (ppm)	< 600	601 - 800	801 - 1000	1001 - 1800	> 1800
Relative Humidity (% RH)	30 - 60	< 40 / > 60	< 30 / > 70	< 20 / > 80	< 10 / > 90
Carbon Monoxide (ppm)	0	-	1-7	-	7+
Nitrogen Dioxide (ppm)	< 0.2	-	0.2 - 0.4	-	0.4+
TVOC (ppm)	< 0.1	0.1 - 0.3	0.3 - 0.5	0.5 - 1.0	1.0+

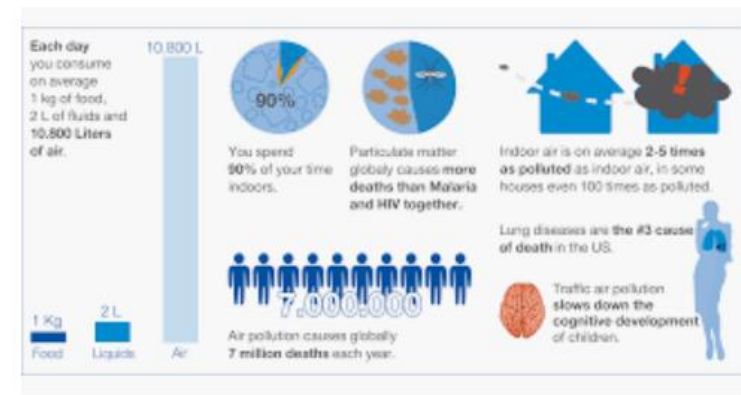
Indoor Air Quality Measurement ...  
hackster.io



Indoor Air Quality Tools for School...  
epa.gov



IAQUK Home  
iaquk.org.uk



What is Indoor Air Quality (IAQ) and ...  
vfa-solutions.com



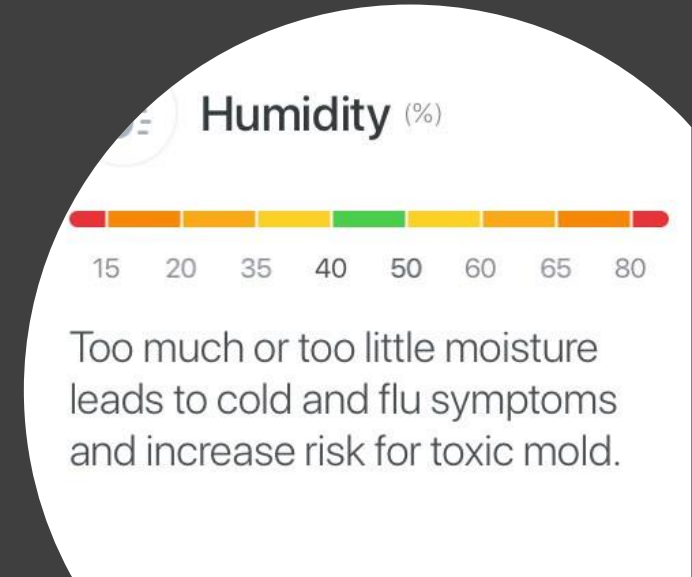
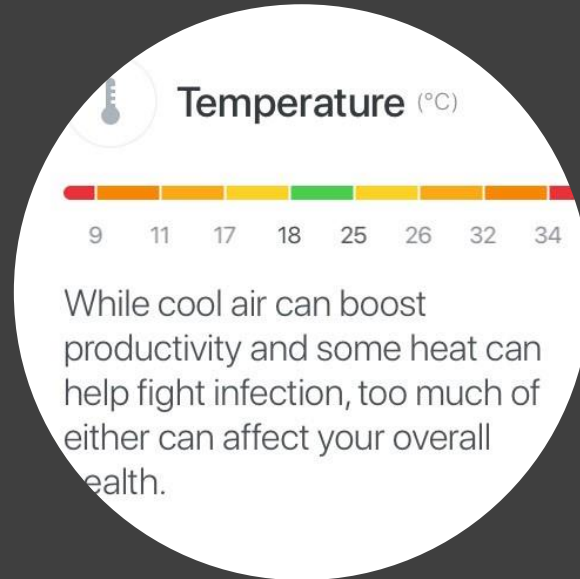
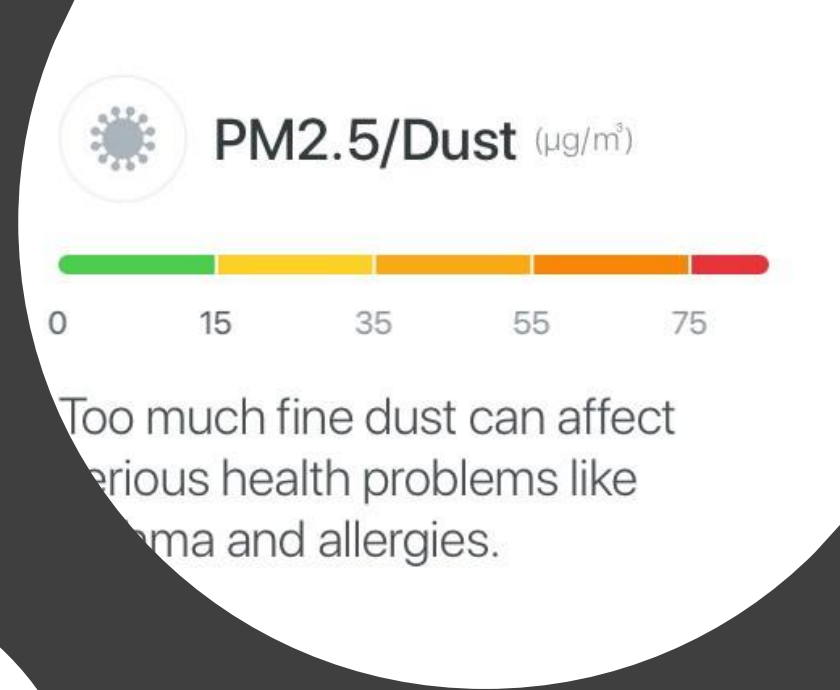
Indoor Air Quality  
airadellc.com



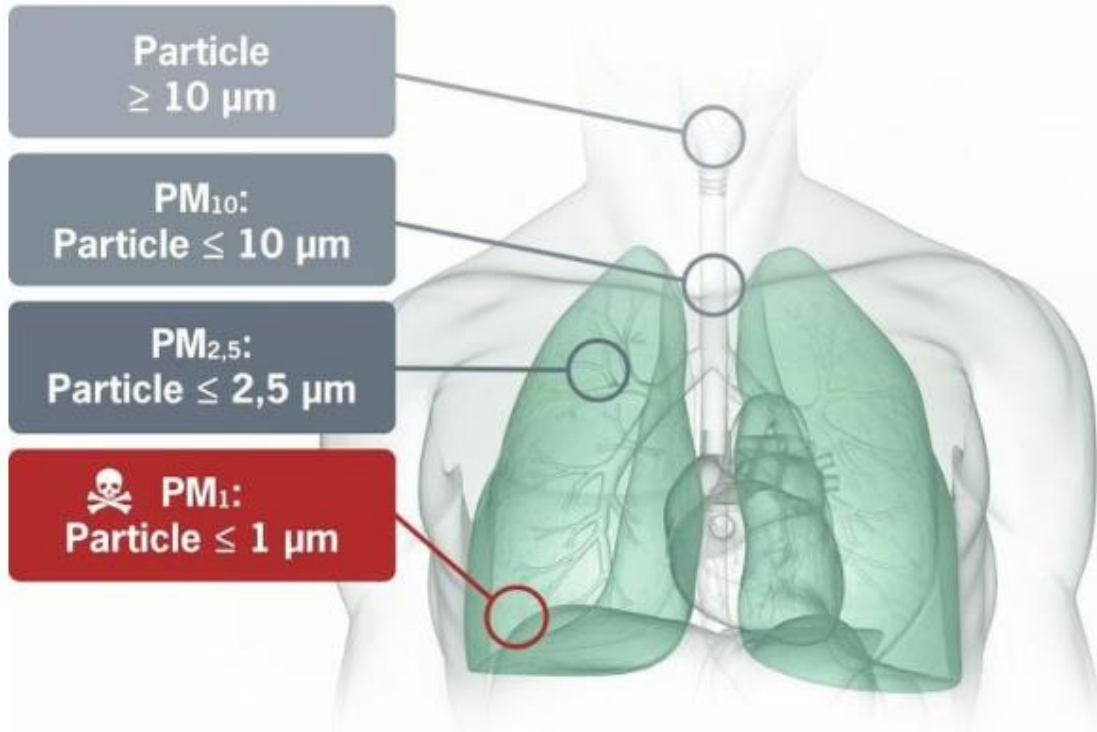
- Hazards**
- Blood stains
- Natural gas range
- Damp basement
- Poor outdoor air quality
- Open combustion furnace
- Lingering odors
- Attached garage
- Uncovered ground in crawl space
- Humidifier
- Evaporative cooler
- Carpet











*The smallest particulate matter can cause the most damage*

Image:

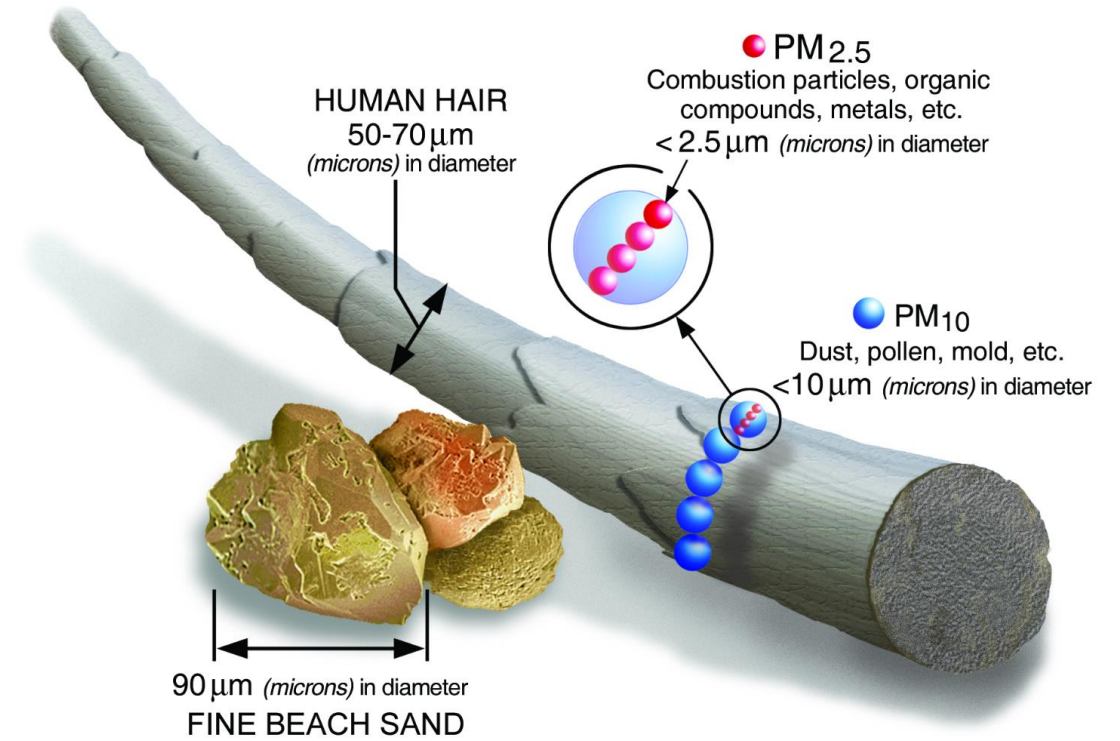


Image:





UCL Institute for Environmental Design and Engineering  
The Bartlett



## **MSc Health, Wellbeing and Sustainable Buildings**



# EVALUATING INDOOR AIR QUALITY MODULE - REPORT BY FAYE WADDINGTON, AECOM @ UCL

## 1.1.1. Carbon Dioxide – CO<sub>2</sub>

There is a large amount of evidence surrounding the impacts of high CO<sub>2</sub> levels on human health, particularly on cognitive functions and productivity. The Green Building Council (2014) state that improved air quality can increase productivity in the office by 8-11%. Seppanen et. Al (1999) discuss that lower ventilation can lead to higher amount of airborne diseases. Fisk et. Al (2003) and Robertson et. Al (1990) has shown a direct link between increase employee absenteeism and poor indoor air quality.

Guideline	Recommended Max CO <sub>2</sub> Concentration	Reasoning
WELL	800ppm	Indoor pollutants in general "can cause discomfort, loss of focus.."
ASHRAE 62.1-2016	800ppm for offices long term 5000ppm short term	15cfm ventilation rate results in approximately 800ppm of CO <sub>2</sub> .
HSE EH40 2005	1500ppm long term (8 hours) 5000ppm short term (15 minutes)	High CO <sub>2</sub> concentrations can cause "headaches, dizziness, confusion and loss of consciousness".

## 1.1.2. Particulate Matter (PM)

Kabir et. Al (2014) claim that particulate matter can be more dangerous to humans than other common air pollutants. Due to the fineness of the particles, PM can easily penetrate humans, leading to heart, lung and respiratory issues (Kabir et. al, 2014). In this report, PM2.5 will be assessed. The main sources of PM2.5 are from emission/combustion processes and naturally occurring particles such as sand and dust (Kabir, 2014).

PM2.5	Daily (µg/m <sup>3</sup> ) max mean	Annual (µg/m <sup>3</sup> ) mean
World Health Organisation	25	10
European Air Quality Standard		25
UK Air Quality Limits (Department for Environment, Food & Rural Affairs)		25

## 1.1.3. Nitrogen Dioxide (NO<sub>2</sub>)

Nitrogen Dioxide both indoors and outdoors is known to have a negative impact on human health. NO<sub>2</sub> is mainly linked to lung cancer and respiratory diseases (Crouse, 2015), and causes inflammation in the airways when at a toxic level (WHO, 2019).

NO <sub>2</sub>	Hourly (µg/m <sup>3</sup> ) max mean	Annual (µg/m <sup>3</sup> ) mean
World Health Organisation	200	40
European Air Quality Standard	200	40
UK Air Quality Limits (Department for Environment, Food & Rural Affairs)	200	40



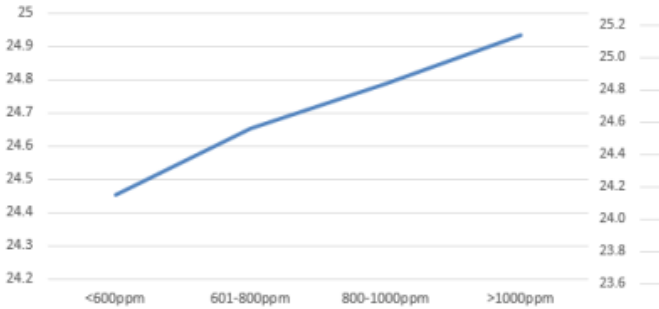


The aim of the report is to interpret what is happening in the rooms throughout the year in terms of the impact of external air pollutants and external weather patterns on the indoor environment, the impact of human preference on the quality of the indoor air, and the effectiveness of the ventilation within the rooms. This report will provide reasoning for the current air quality downfalls within the rooms and give recommendations on how to improve the environment for the occupants.



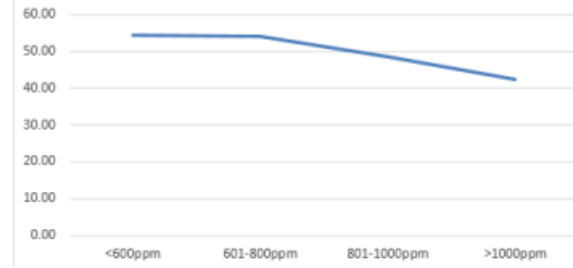
### 3.2.1. Internal Temperature & CO<sub>2</sub>

Internal Temperature vs. CO<sub>2</sub> - Room 413



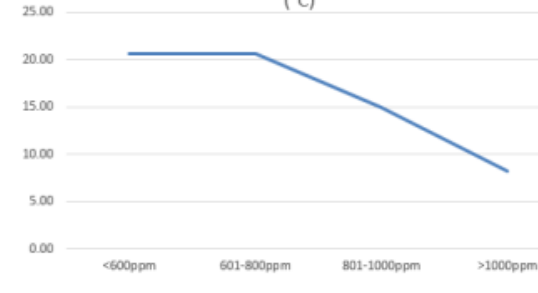
### 3.2.2. Indoor Relative Humidity

RH - INTERNAL vs CO<sub>2</sub> (%) - Room 413



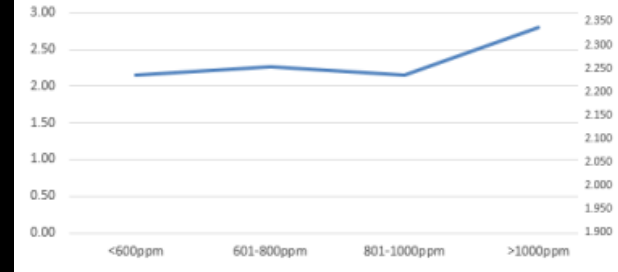
### 3.2.3. External Temperature

External Temp vs CO<sub>2</sub> - Room 413 (°C)



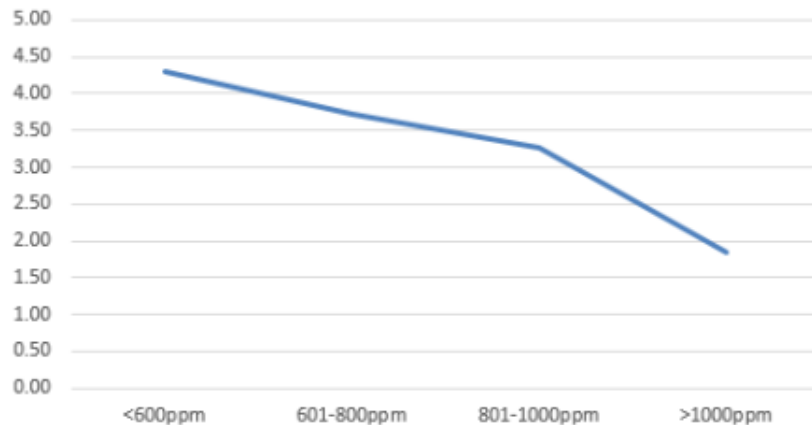
### 3.2.4. Windspeed & CO<sub>2</sub>

Windspeed vs CO<sub>2</sub> - Room 413 (m/s)



### 3.2.5. PM2.5 & CO<sub>2</sub>

PM2.5 vs CO<sub>2</sub> - Room 413



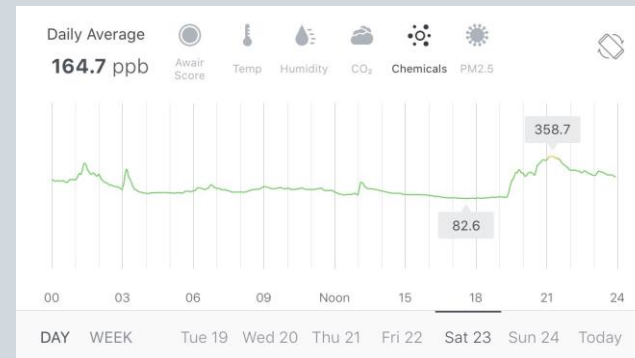
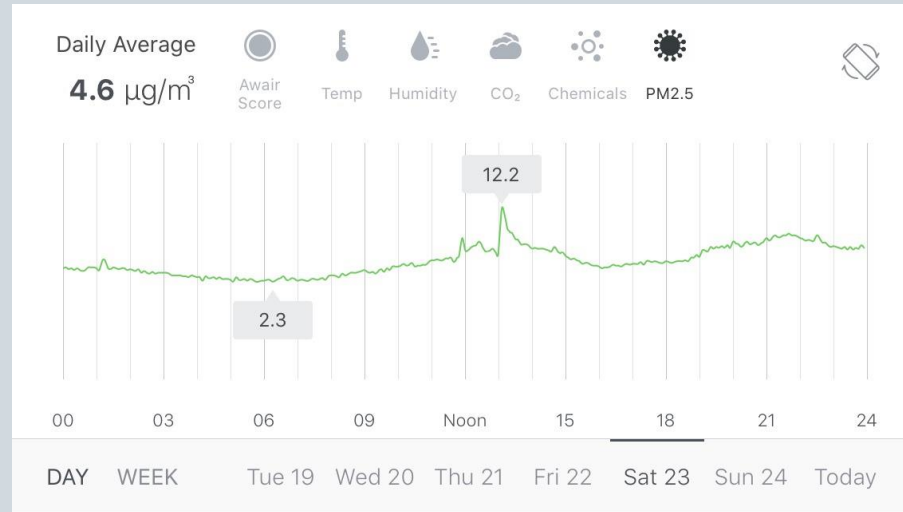
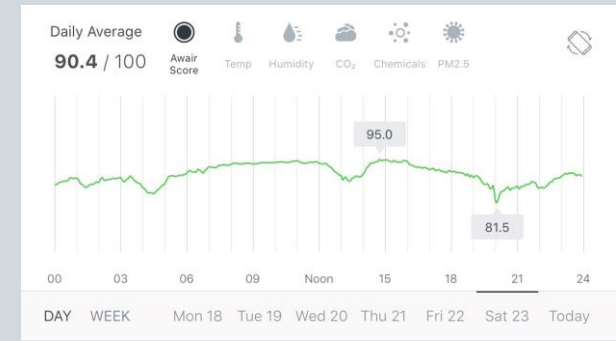
# MONITORING RESULTS

Graphs representing the correlation between natural ventilation and indoor air quality in urban location.

LET'S NOT FORGET THE ENERGY.....



# Correlation between occupancy patterns & activities in residential environment

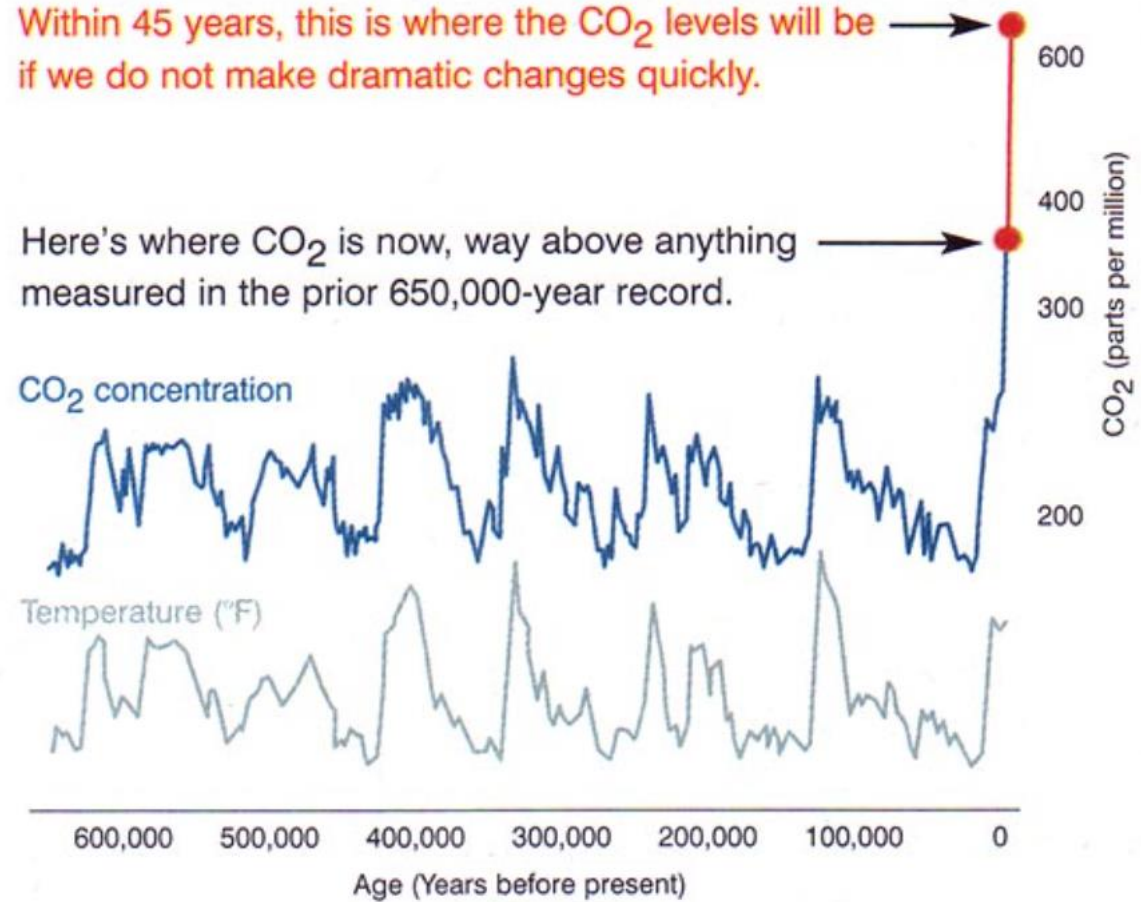




2006

Within 45 years, this is where the CO<sub>2</sub> levels will be if we do not make dramatic changes quickly.

Here's where CO<sub>2</sub> is now, way above anything measured in the prior 650,000-year record.



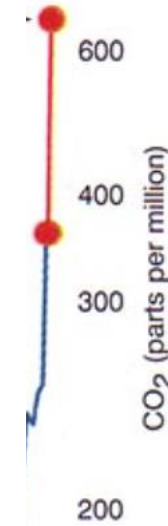


# Weekly CO<sub>2</sub>

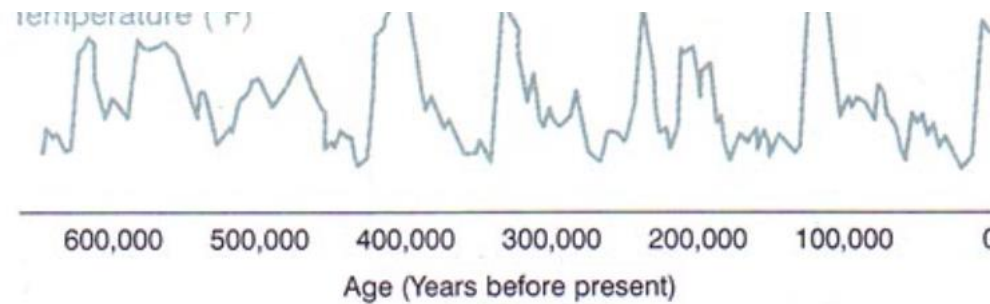
Mauna Loa Observatory | NOAA-ESRL

Period	Week	Atmospheric CO <sub>2</sub>
Last Week	November 17 - 23, 2019	<b>410.19 ppm</b>
1 Year Ago	November 17 - 23, 2018	<b>408.52 ppm</b>
10 Years Ago	November 17 - 23, 2009	<b>386.36 ppm</b>

**Data Updated:** November 24, 2019  
**NOAA dataset:** Web + .txt



weekly mean concentrations | ppm = parts per million



2019

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“No sooner had I left behind the oppressive atmosphere of the city [Rome] and that reek of smoking cookers which pour out, along with clouds of ashes, all the poisonous fumes they’ve accumulated in their interiors whenever they’re started up, than I noticed the change in my condition...”

Roman philosopher and statesman Seneca year 0061.



Press release

# Government launches world leading plan to tackle air pollution

Government has launched an ambitious new clean up our air and save lives.

CLEAN AIR  
STRATEGY 2019

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Published 14 January 2019

From: [Department for Environment, Food & Rural Affairs](#), [Department of Health and Social Care](#), [The Rt Hon Michael Gove](#), and [The Rt Hon Matt Hancock](#)

# Parliament.uk - November 2010

## Overview

- Indoor air pollutants are potentially important but the extent to which they affect health is not fully known.
- Currently no single government department has ownership of this issue.
- Heating and cooking appliances and environmental tobacco smoke are the most important indoor sources of pollution in UK homes.
- The main health effects are to the lungs and heart.
- Children and those who are already ill are most at risk.
- Future concerns include the potential chronic (long-term) health effects of pollutants at low levels of exposure.

Table 1 Pollutants, Sources and Health Impacts

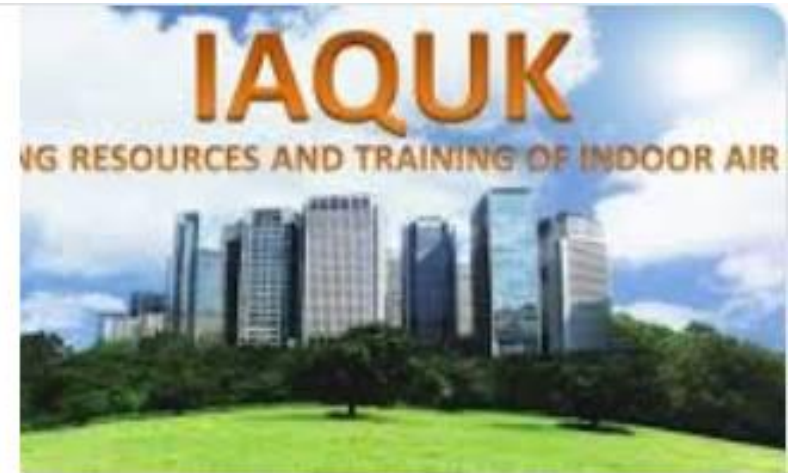
Pollutant	Sources	Health Impacts
nitrogen dioxide (NO <sub>2</sub> )	heating and cooking appliances	associated with respiratory symptoms
carbon monoxide (CO)	heating and cooking appliances	lethal at high levels, potential chronic effects at low levels
particulate matter (PM)	cooking and aerosols	reduced lung function and increased risk of heart and respiratory disease
radon	ground gases especially in defined areas	lung cancer
environmental tobacco smoke (ETS)	cigarettes, cigars and pipes	lung cancer, chronic obstructive pulmonary disease, asthma and reduced lung function
allergens	moulds and house dust mites	worsening of symptoms of asthma; causation of wheezing
volatile organic compounds and ozone	cleaning products, paints and printers	respiratory tract irritation, possible effects on asthmatics



However, there are currently no **regulations** on the **quality of indoor air** in the **UK**. ... Building **Regulations F** (Department for Communities and Local Government, 2006) consolidate energy efficiency, requiring further ventilation designs to be incorporated within airtight buildings. This has been an encouraging step.

## IAQUK About Us

[www.iaquk.org.uk](http://www.iaquk.org.uk) › about



## Scale of the problem

It is estimated that **long-term exposure to man-made air pollution in the UK** has an annual effect equivalent to:



**28,000 to 36,000 deaths**

Over the following 18 years a **1  $\mu\text{g}/\text{m}^3$  reduction in fine particulate air pollution in England** could prevent around:



**50,900** cases of coronary heart disease

**16,500** strokes



**9,300** cases of asthma

**4,200** lung cancers



# IAQ Rating Index



Rating	Excellent (5 points each)	Good (4 points each)	Fair (3 points each)	Poor (2 points each)	Inadequate (1 point each)
Temperature (°C)	18-21°C	Plus or minus 1°C (including variance in occupied rooms, seasons and times of day)	Plus or minus 2°C (including variance in occupied rooms, seasons and times of day)	Plus or minus 3°C (including variance in occupied rooms, seasons and times of day)	Plus or minus 4°C or more (including variance in occupied rooms, seasons and times of day)
Carbon Dioxide (PPM)	< 600	601 - 800	801 - 1500	1501 - 1800	> 1801
Relative Humidity (% RH)	40 - 60	< 40 / > 60	< 30 / > 70	< 20 / > 80	< 10 / > 90
Carbon Monoxide (mg/m <sup>3</sup> )	0	-	1 - 7	-	7 >
Nitrogen Dioxide (mg/m <sup>3</sup> )	< 0.2	-	0.2 - 0.4	-	0.4 >
TVOC (mg/m <sup>3</sup> )	< 0.1	0.1 - 0.3	0.3 - 0.5	0.5 - 1.0	1.0 >
Formaldehyde (mg/m <sup>3</sup> )	< 0.02	0.02 - 0.05	0.05 - 0.1	0.1 - 0.2	0.2 mg/m <sup>3</sup> >
Radon (Bq m <sup>3</sup> )	0	-	0 - 20 Bq m <sup>-3</sup>	20 - 100 Bq m <sup>-3</sup>	100 + Bq m <sup>-3</sup>
Particulate matter (mg/m <sup>3</sup> )	0 - 0.023	0.024 - 0.041	0.042 - 0.053	0.054 - 0.64	0.065 >
Laser Particle counter					
0.3 ug	0 - 100,000		100,001 - 50,000		250,001 >
0.5 ug	0 - 35,200		35,201 - 87,500		87,501 >
1.0 ug	0 - 8,320		8,321 - 20,800		20,801 >
2.5 ug	0 - 545		546 - 1,362		1,363 >
5.0 ug	0 - 193		194 - 483		484 >
10.0 ug	0 - 68		69 - 170		171 >
Viable air sampling (CFUs)	< 500	500 - 1,000	1,000 - 10,000	10,000 - 100,000	> 100,000
Occupant's perception of comfort (%)	100% of population satisfied	90-99% of population satisfied	80-89% of population satisfied	70-79% of population satisfied	Under 70% of population satisfied
Odour	80% > of occupants described any odours as "Clearly acceptable"	80% > of occupants described any odours as "Acceptable"	80% > of occupants described any odours as "Neutral"	80% > of occupants described any odours as "Just not acceptable"	80% > of occupants described any odours as "Clearly not acceptable"
<b>Overall Rating</b>	<b>61 - 65</b>	<b>52 - 60</b>	<b>39 - 51</b>	<b>26 - 38</b>	<b>&lt; 25</b>

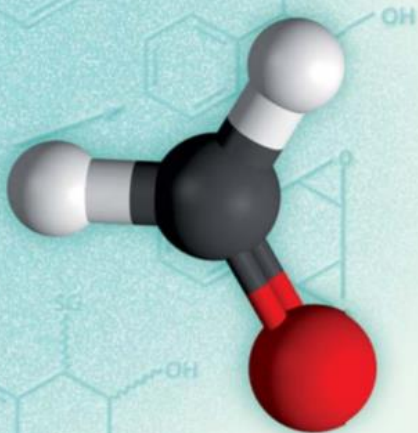
[Dr. Julie Riggs \(Middlesex University\) in the Exposure magazine:](#)

We spend 90% + of our time indoors

Despite health being an important issue in people's lives, people remain unaware and often apathetic of the health risks posed from indoor air. It has become clear that the plethora of data and research has not been transferred effectively into society. We are not managing indoor air quality proactively. Therefore to raise the agenda, we need to bridge the gap between our academic knowledge, our professional practice and society's risk perception using tangible, story telling topics that make IAQ accessible.

- The UK has the highest asthma rate in the world
- Indoor environments are 10x more pollutant than outdoor
- US EPA recognise IAQ as one of the top 5 health hazards
- 20 toxic compounds (cancer/birth defects) 200-500x higher indoors
- According to the AMA, 50% of all illnesses are caused or aggravated by polluted indoor air
- 70% of occupants are dissatisfied with their environment
- 73% of Facility Managers have installed..... a fake thermostat to reduce air complaints

## SELECTED POLLUTANTS



CIBSE KNOWLEDGE SERIES

Indoor air quality  
and ventilation

# KS17: INDOOR AIR QUALITY AND VENTILATION

Environmental design

CIBSE Guide A





Table A1.5 Recommended comfort criteria for specific applications — *continued*

Building/room type	Winter operative temp. range for stated activity and clothing levels*			Summer operative temp. range (air conditioned buildings†) for stated activity and clothing levels*			Suggested air supply rate / (L.s <sup>-1</sup> per person) unless stated otherwise	Filtration grade
	Temp. / °C	Activity / met	Clothing / clo	Temp. / °C	Activity / met	Clothing / clo		
<b>General building areas:</b>								
— corridors	19–21	1.4	1.0	21–23	1.4	0.65	10 <sup>[2]</sup>	— <sup>[14]</sup>
— entrance halls/lobbies	19–21	1.4	1.0	21–23	1.4	0.65	10 <sup>[2]</sup>	— <sup>[14]</sup>
— kitchens (commercial)	15–18	1.8	1.0	18–21	1.8	0.65	— <sup>[17]</sup>	G2–
— toilets	19–21	1.4	1.0	21–23	1.4	0.65	> 5 ACH	G4–
— waiting areas/rooms	19–21	1.4	1.0	21–23	1.4	0.65	10 <sup>[2]</sup>	— <sup>[14]</sup>
<b>Museums and art galleries:</b>								
— display <sup>[24]</sup>	19–21	1.4	1.0	21–23	1.4	0.65	10 <sup>[2]</sup>	F7–
— storage <sup>[24]</sup>	19–21	1.4	1.0	21–23	1.4	0.65	10 <sup>[2]</sup>	F7–
<b>Exhibition halls</b>	19–21	1.4	1.0	21–23	1.4	0.65	10 <sup>[2]</sup>	G3–
<b>Restaurants/dining rooms</b>								
	21–23	1.1	1.0	24–25	1.1	0.65	10 <sup>[2]</sup>	F5–
<b>Places of public assembly:</b>								
— auditoria <sup>[26]</sup>	22–23 <sup>[1]</sup>	1.0	1.0	24–25	1.1	0.65	10 <sup>[2]</sup>	F5–
— changing/dressing rooms	23–24	1.4	0.5	23–25	1.4	0.4	10 <sup>[2]</sup>	F5–
— circulation spaces	13–20 <sup>[1]</sup>	1.8	1.0	21–25 <sup>[1]</sup>	1.8	0.65	10 <sup>[2]</sup>	G4–
— foyers <sup>[27]</sup>	13–20 <sup>[1]</sup>	1.8	1.0	21–25 <sup>[1]</sup>	1.8	0.65	10 <sup>[2]</sup>	G4–
— multi-purpose halls <sup>[28]</sup>	—	—	—	—	—	—	—	—

CIBSE

**CIBSE PSYCHROMETRIC CHART**

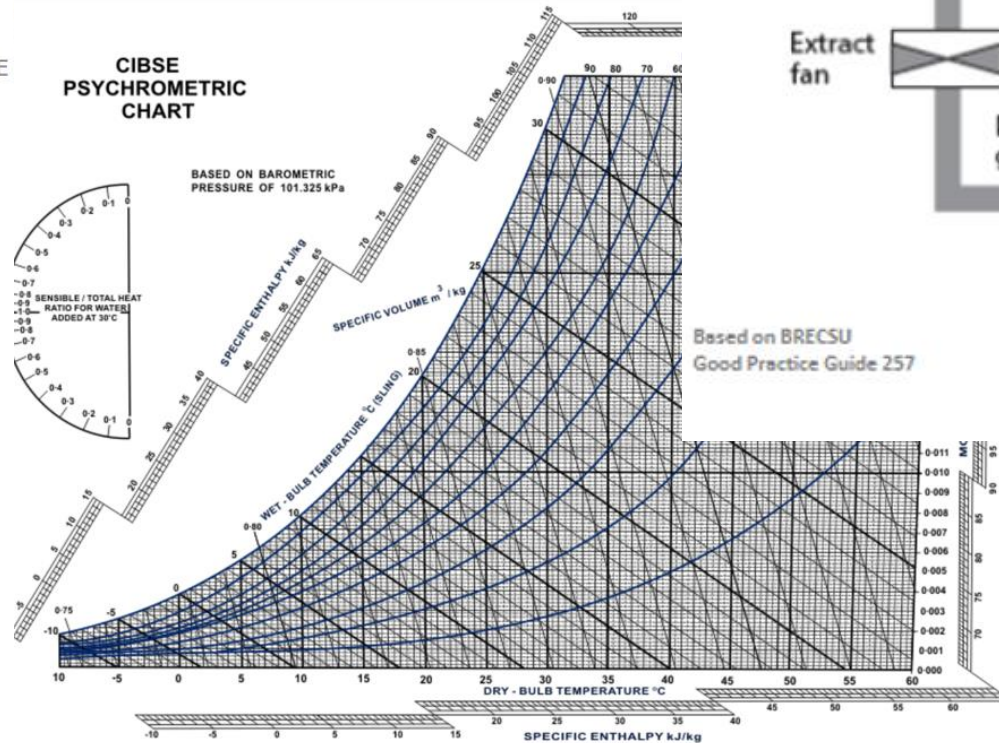
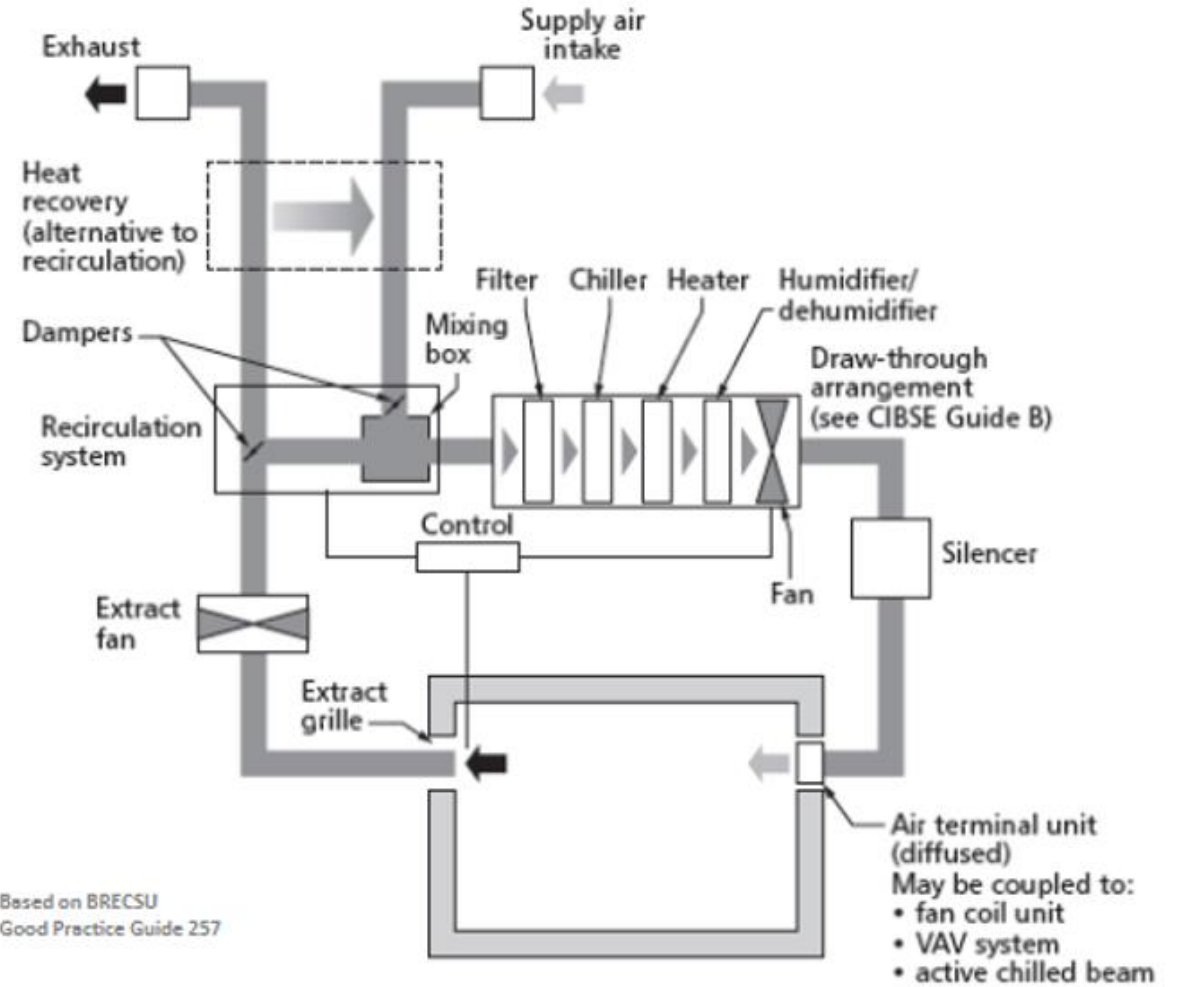


Figure 1. Psychrometric chart.





[Overheating and Indoor Air Quality](#)

<https://www.cibse.org/.../bser-t-special-issue-overheating-and-indoor-air-qu>

BSE&T Special Issue - Overheating and **Indoor Air Quality**. As cities grow and pressures from a c... increase, these ...

[Effects of Indoor Air Quality on Children and Young People's Health](#)

<https://www.cibse.org/.../Effects-of-Indoor-Air-Quality-on-Children-and-Youn>

Royal College of Paediatrics and Child Health (RCPCH), in collaboration with the Royal College ...

[Realities of building for Indoor Air Quality to be explored at the ...](#)

<https://www.cibse.org/.../the-realities-of-building-for-indoor-air-quality-t>

Feb 2019 ... But what are the realities of building for better **Indoor Air Quality** and wha... lored in the 2019 ...

[Training and Solutions for Improvement](#)

<https://www.cibse.org/.../training-events/event?id...>

of the latest thinking and technologies to improve the **air quality** of buildings, a... Air.

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KS17: **Indoor Air Quality** & Ventilation. This guide presents an overview of **indoor air quality** (IAQ) in buildings, and outlines how IAQ impacts on occupants' ...

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**Indoor air quality** is to a large extent dependent on outdoor air pollution; in addition, the indoor environment contains many sources of air pollutants from ... building ...

[Draft guideline on Indoor air quality at home](#)

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Draft guideline on **Indoor air quality** in residential buildings. Objectives of the consultation. This draft guideline, developed by the National Institute for Health and ... **air quality** and reducing energy consumption – a criti...



















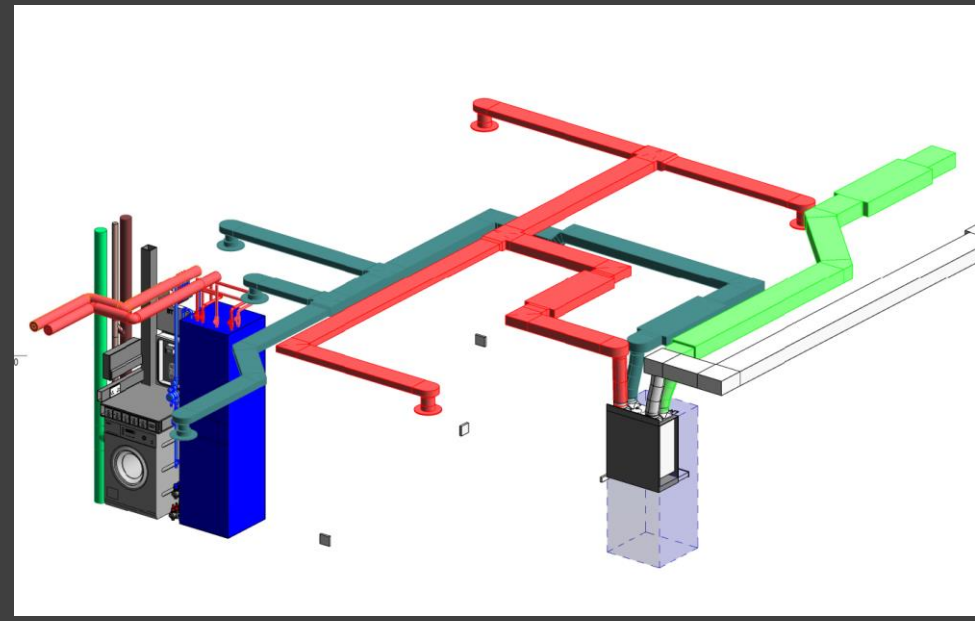
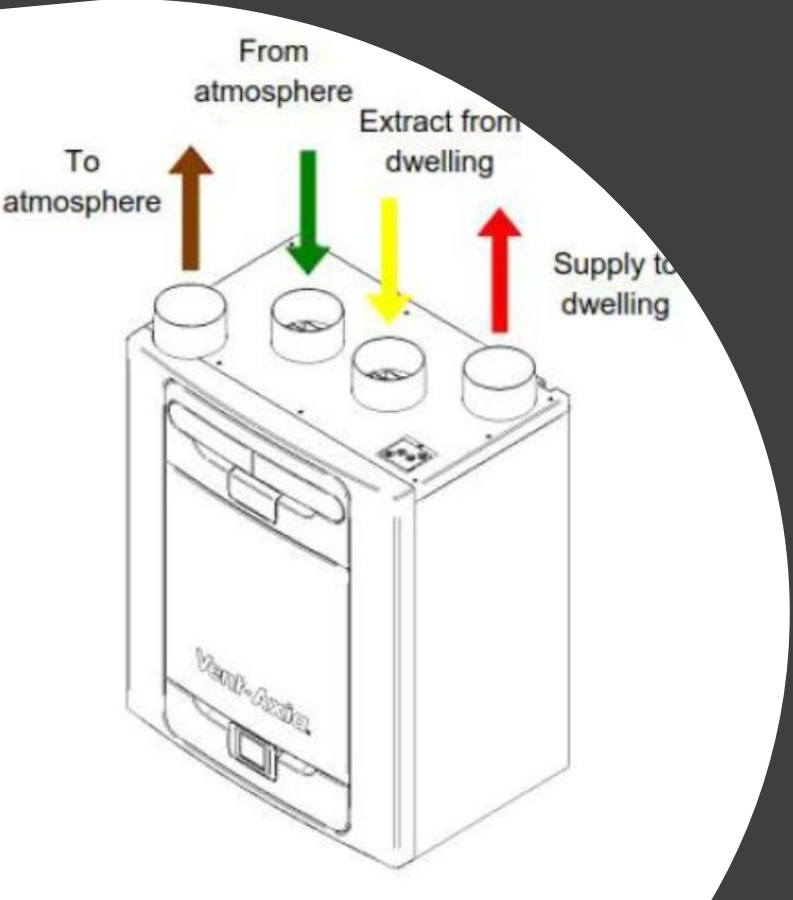
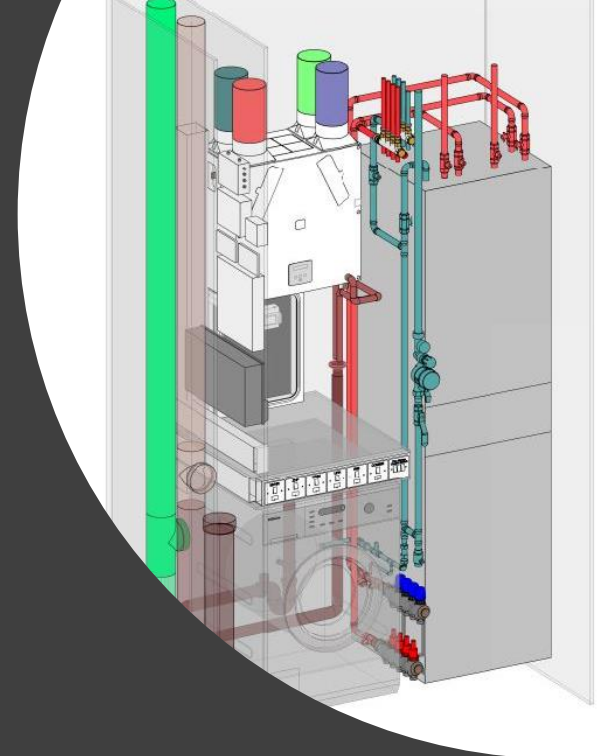
**When is natural  
ventilation a good  
solution.....**





**...and when  
do we  
do this?**





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