



Indoor air quality and thermal comfort in Irish retrofitted energy efficient homes

Title	Indoor air quality and thermal comfort in Irish retrofitted energy efficient homes
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Publication Date	2017-03-14
Publisher	School of Physics, NUI Galway

INDOOR AIR QUALITY & THERMAL COMFORT IN IRISH RETROFITTED ENERGY EFFICIENT HOMES

Dr Marie Coggins

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Environmental Protection Agency



NATIONAL DEVELOPMENT PLAN



NUI Galway
OÉ Gaillimh

NATIONAL UNIVERSITY OF IRELAND, GALWAY



Presentation Outline

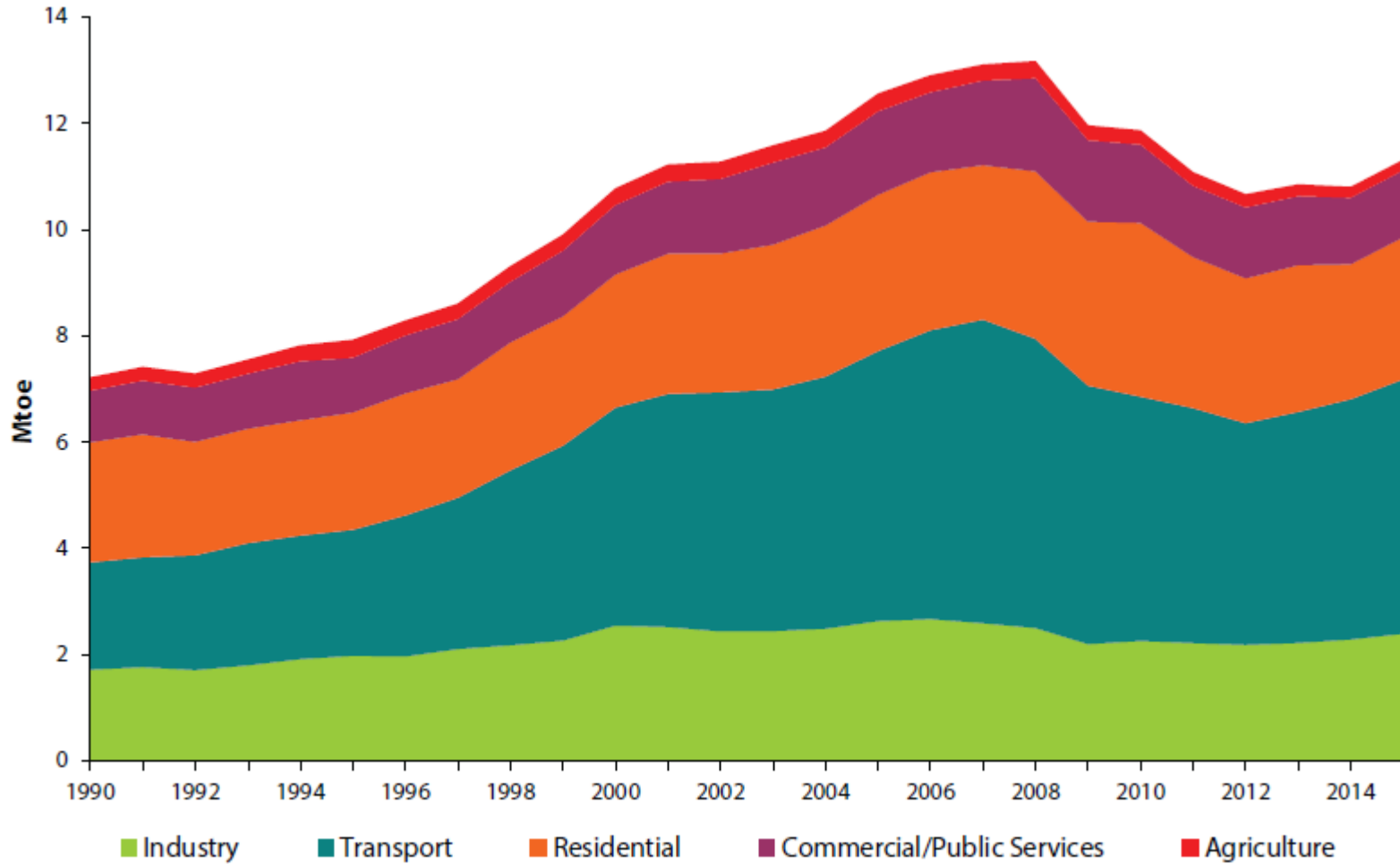
- Objective
- Background
- IAQ
- Study
- Results



Objective

- Energy retrofit of domestic dwellings
 - IAQ
 - Thermal comfort

Residential sector – Energy



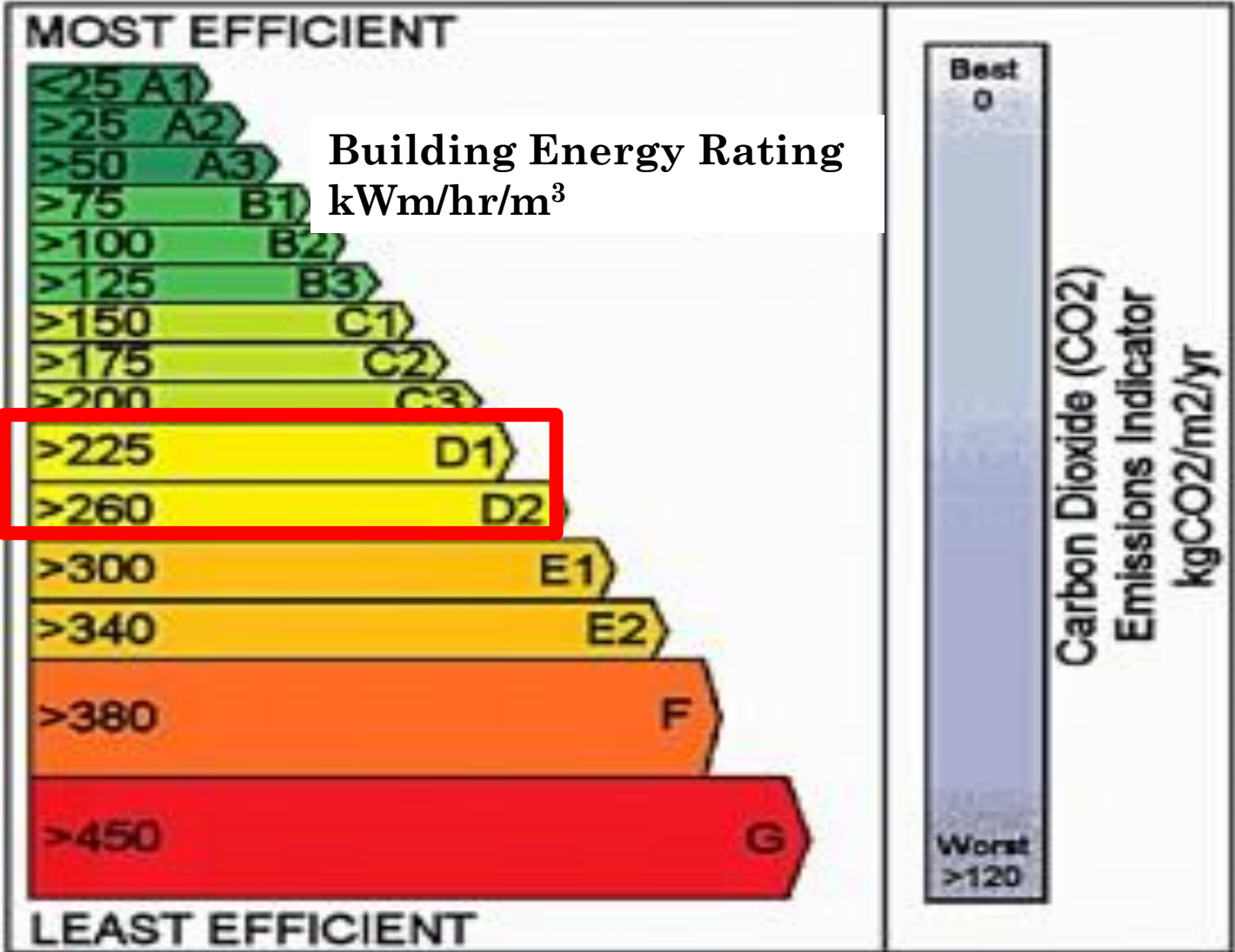
Residential sector – Energy related CO₂ emissions

- 1990 – 2015
 - Building Regulations
 - Irish Government energy saving incentives
 - Behavioural changes
- CO₂ emissions - 25%

- National Energy Authority
 - *Better Energy Homes Scheme*
 - *Warmer Homes Scheme*
 - *Better Energy Communities*
- 2015
 - 300,000 homes
 - Target 75,000 homes /yr 2020

- National Energy Authority
 - *Better Energy Homes Scheme*
 - *Warmer Homes Scheme*
 - *Better Energy Communities*

Energy performance certificate



Selection criteria – construction type

- Cavity wall

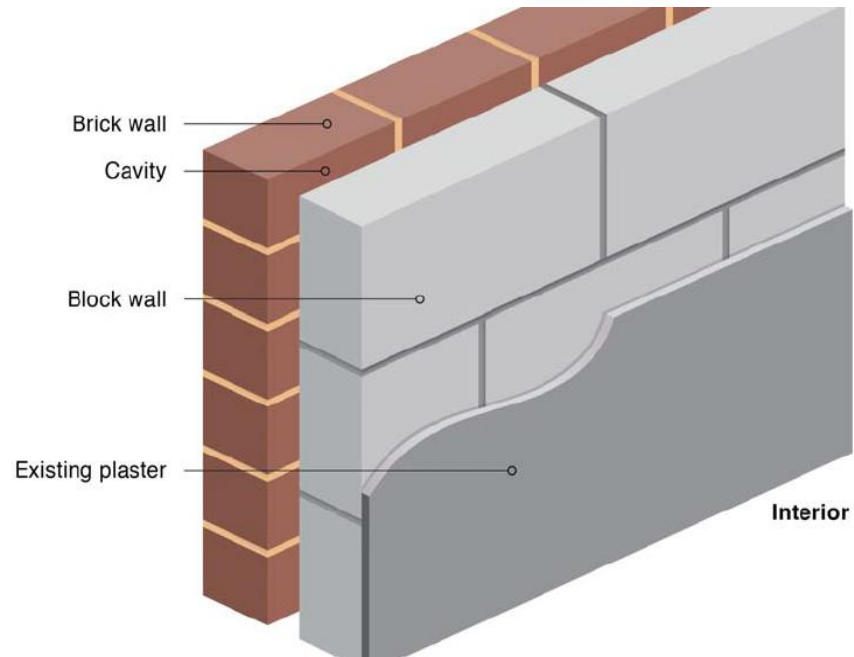
(110 mm cavity, 25 -60 mm)

- 15 homes,

- 2000

- 100 – 126 m³

- 3 bedroomed semi – detached



Selection criteria – construction type

- Cavity wall (CW)

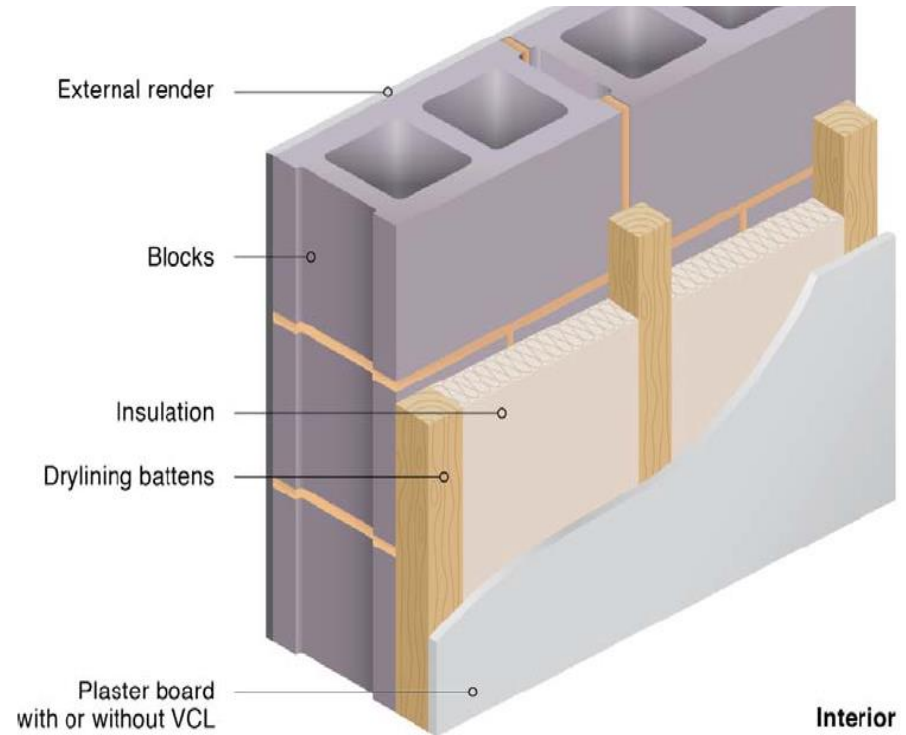
(110 mm cavity, 50 mm)

- 7 CW & 8

Hollow block/CW

- Hollow block

- Concrete block – two hollow cores
- 15 – 25 mm insulation studs -plasterboard lining



Pre Retrofit

**External wall /
CW**

Cavity wall – 50 mm polystyrene insulation board (110 mm cavity)

**External wall/
HB/CW**

plaster board internal lining w/ 15 – 25 mm insulation (cavity wall around front lower window)

Attic

100 mm thick mineral wool insulation

Windows and doors

Wood and PVC 12 mm double glazed units

Boiler

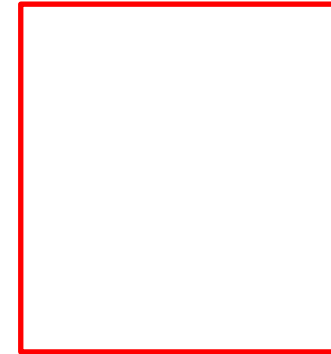
Balanced boiler (66% efficient), manual control - timer control for one zone

**Ventilation (Kitchen
& Bathroom)**

Natural ventilation – extract fan in kitchen only

Background wall vents (only HB)

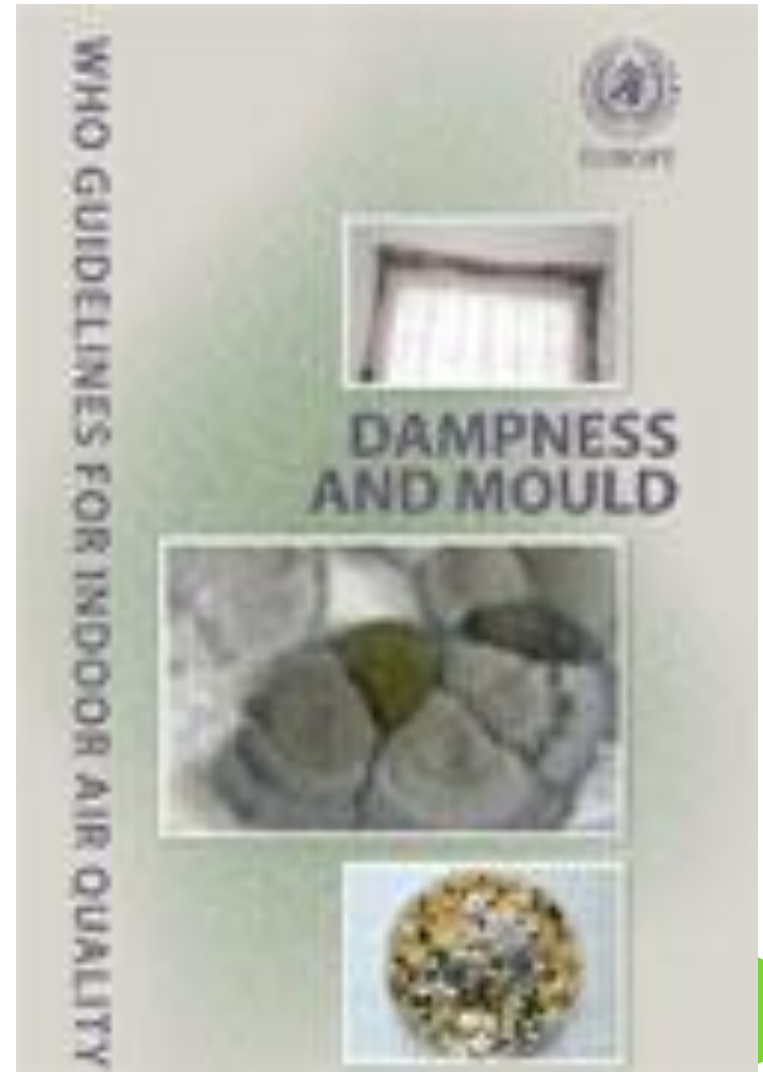
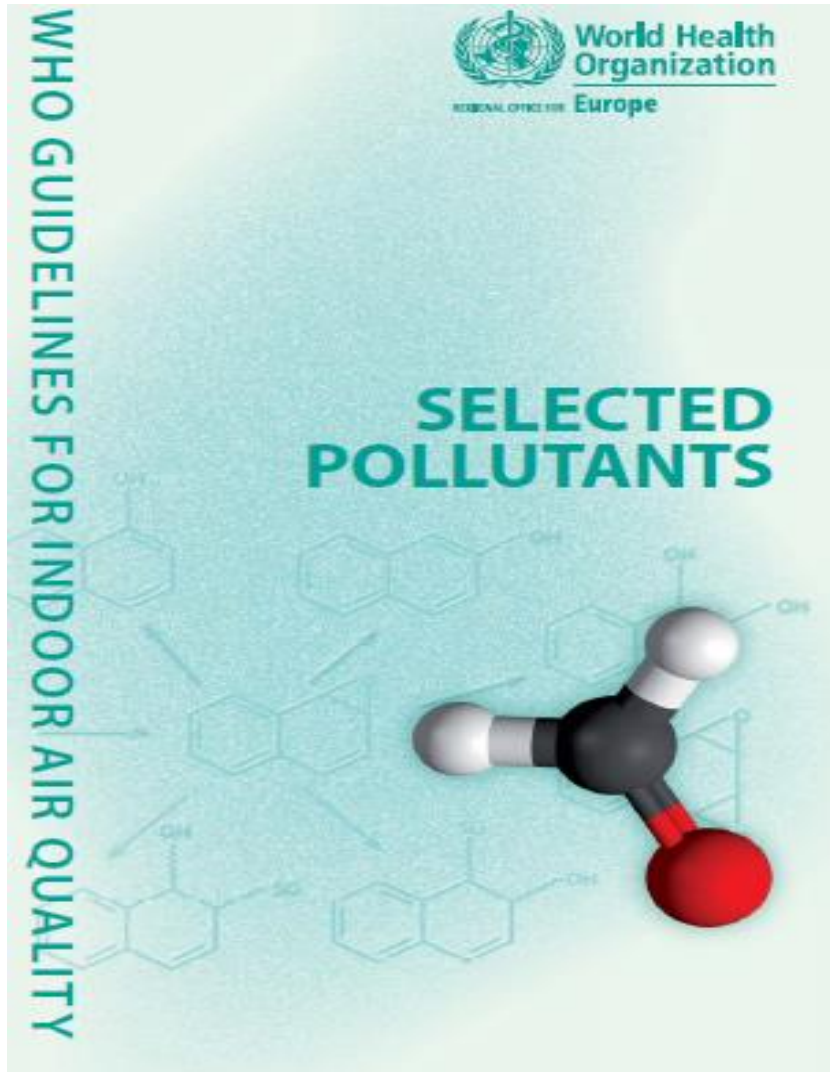
Selection criteria (n=15)



Average occupancy rate in Ireland is 2.7



Selecting pollutants to measure



What did we measure ?

Pollutant	Indoor source
Particulate matter (PM _{2.5})	Solid fuel combustion, outdoor air
NO ₂	Gas/wood/oil/kerosene, traffic pollution
Mould and dampness	Excess humidity, ventilation
Radon	Natural source
TVOCs	Cleaning products, furnishings, varnishes, glues etc



What did we measure ?

Pollutant	Source
BTEX	Smoking, building materials, attached garages
CO	fossil fuels, incense, faulty appliances
Formaldehyde	Cleaning products, furnishings, varnishes, glues etc
Dust mites	Pets, outdoors, poor ventilation



What else did we measure ?

- Building air tightness
- Room Air Exchange Rate
- Temperature
- Relative humidity

How did we measure ?

- 24 hour period
 - TSI SidePak AM510 Personal Aerosol Monitor logged real-time data on airborne $PM_{2.5}$
 - CO & CO₂ - GrayWolf IQ-610
 - TVOC - GrayWolf TG-502
 - Formaldehyde – GrayWolf RM-108
- 2-3 week period
 - NO₂ & BTEX levels - Gradko passive diffusion tubes



How did we measure ?

- 24 hour period
 - Temperature & relative humidity GrayWolf IQ-610
- Building air tightness ($\text{m}^3 \cdot \text{h} \cdot \text{m}^2$)
 - Blower door test – ISEN13829:2000
- Room air exchange rate
 - CO_2 – tracer gas

How did we measure ?

- Grab sample

- Dust mites

SKC Carpet Tester suction sampling kit



- 3 months

- Radon -passive alpha track radon detectors.



What other information did we collect ?

Researcher

Building type
Heating type
Cooking fuel
Occupant rate



Occupant

Thermal comfort
Occupant behaviour



The retrofit - Cavity wall homes



300 mm thick mineral wool insulation



Residual 110 mm cavity filled with extruded polystyrene beads



125 mm core wall vents

Or vents were cleaned out and serviced

Retrofit specification – Cavity wall

	Pre Retrofit	Post Retrofit
Windows and doors	Wood/PVC 12 mm double glazed units	PVC 24/28 mm double glazed units
Boiler	Balanced boiler (66% efficient)	Condensing boiler (90% efficient), zoned heating w/thermostat, pipe work insulated
Ventilation (Kitchen & Bathroom)	Extract fans in kitchen	Extract fan with humidity control

The retrofit - Hollow block/CW homes



300 mm thick mineral rock wool insulation

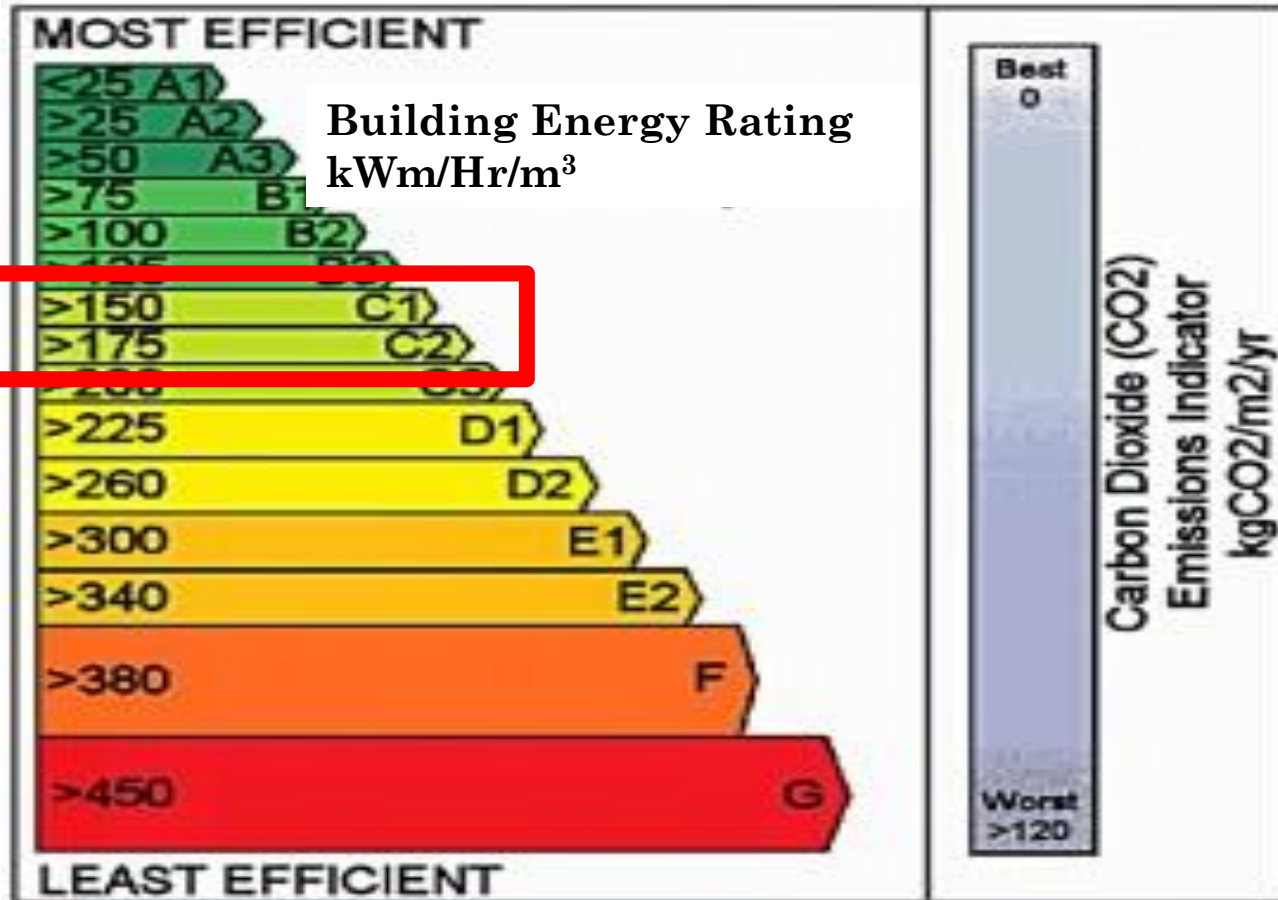


*extruded polystyrene beads only
around the front wall*



vents were cleaned out and serviced

Building performance certificate



Indoor air pollutants – comparison guidelines

- PM_{2.5} – WHO 2006
- Formaldehyde, CO, NO₂, benzene – WHO 2010
- TVOCs – UK building Regulations

Indoor Environmental Quality

	Pre retrofit Mean (n= 7)	Post retrofit Mean (n= 7)	p
Air tightness (m ³ .h.m ²) @ 50 Pa - CW	9.3 (m ³ /(h.m ²))	5.5 (m ³ /(h.m ²))	
Air exchange rate – CW	0.81 ACH	0.55 ACH	<0.001
	Pre retrofit Mean (n= 8)	Post retrofit Mean (n= 8)	
Air tightness (m ³ .h.m ²) @ 50 Pa – HB/CW	9.3 (m ³ /(h.m ²))	8.6 (m ³ /(h.m ²))	
Air exchange rate – HB/CW	0.83 ACH (m ³ /h)	0.7 ACH (m ³ /h)	<0.001

Indoor Environmental Quality

Cavity wall	Pre retrofit Mean (n= 7)	Post retrofit Mean (n= 7)	p
Temperature (°C)	17.8 (0.9) 17.5 (0.8)	18.6 (0.6) 18.6 (0.6)	
Relative Humidity (%RH)	51.4 (3.0) 51.1 (2.0)	54.2(0.9) 54.0 (0.9)	
Hollow Block/CW	Post retrofit Mean (n= 8)	Pre retrofit Mean (n= 8)	
Temperature (°C)	17.3 (1.2) 16.8 (0.6)	18.3 (0.8) 18.0 (0.5)	< 0.005
Relative Humidity (%RH)	50.7 (2.1) 51.0 (2.0)	52.3(0.8) 52.2 (1.0)	

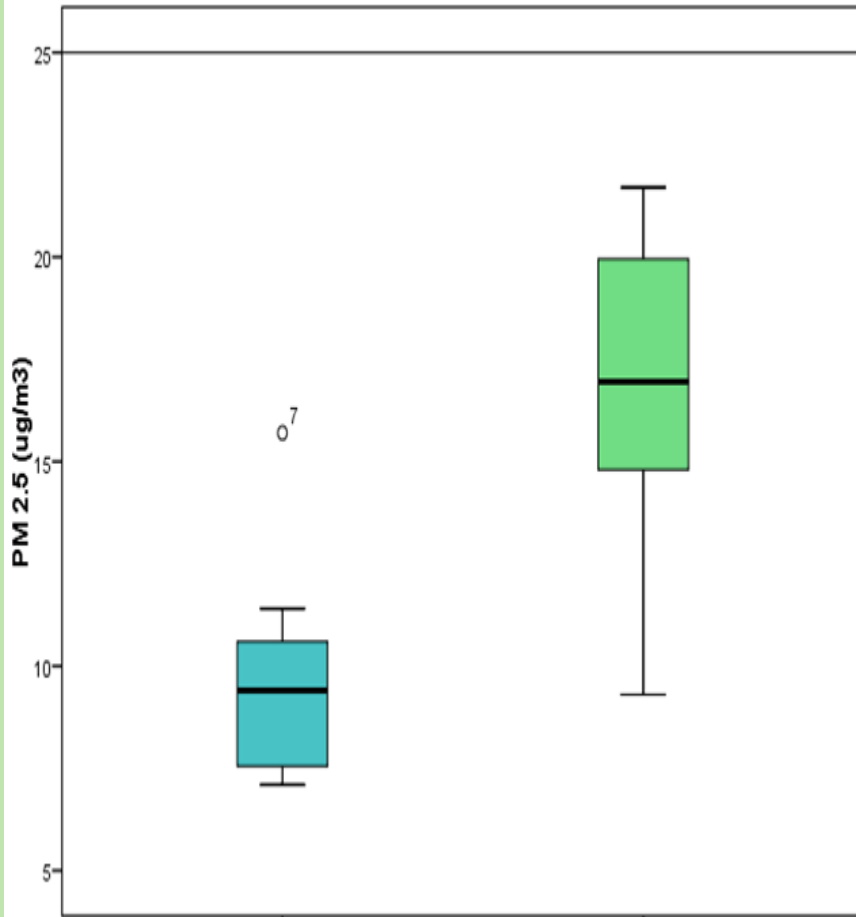
Indoor Air pollutants

- Concentrations of CO, BTEX, NO₂, no significant difference following the retrofit
- All within recommended Health Limits

Indoor Air pollutants – Cavity wall

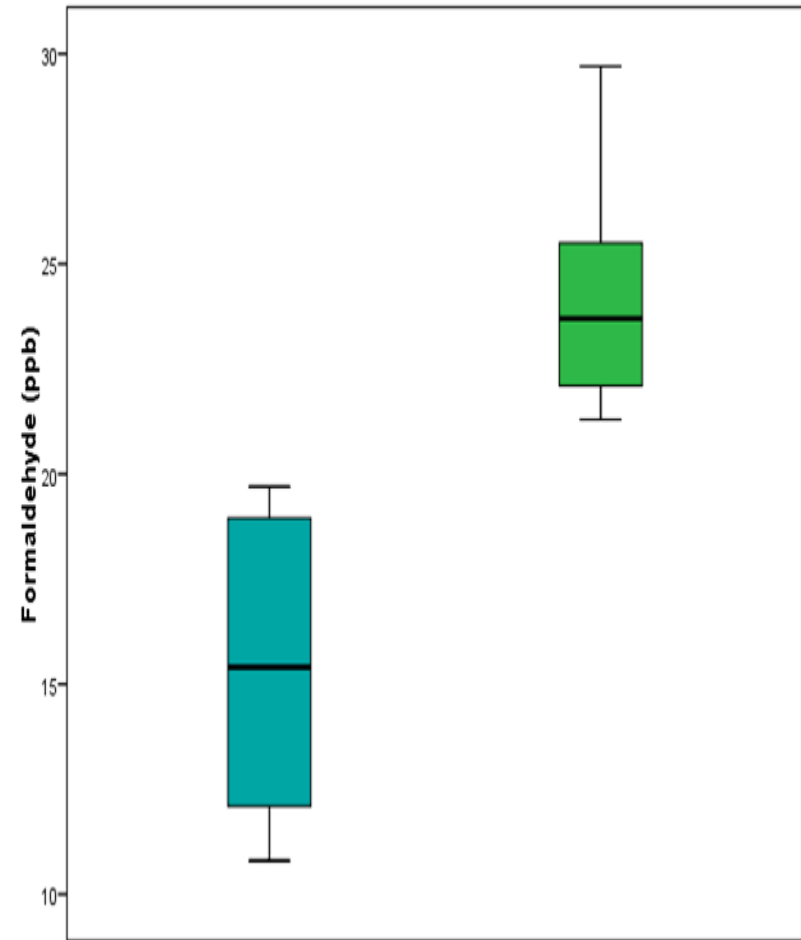
	Pre retrofit Mean (n= 7) (SD)	Post retrofit Mean (n= 7) (SD)	p
Formaldehyde (ppb)	15.4 (3.8)	24.3 (3.0)	0.001*
PM_{2.5} (µg/m³)	10.0 (2.0)	18.0 (2.6)	0.005*
CO₂ (ppm)	578.6 (94.0)	719.4 (114.0)	0.014*
TVOC (ppb)	362.0 (73.0)	477.0 (38.0)	0.009*

PM_{2.5} 24 hr average concentration ($\mu\text{g}/\text{m}^3$) before and after the retrofit



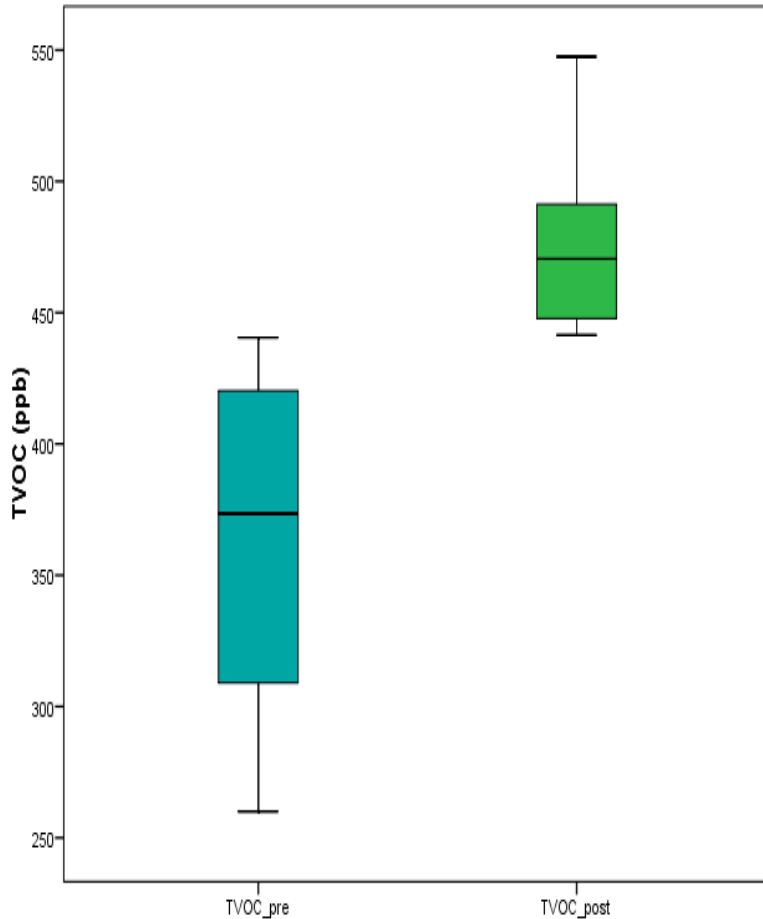
Before retrofit After retrofit
Group CW

Formaldehyde 24 hr average concentration (ppb) before and after the retrofit



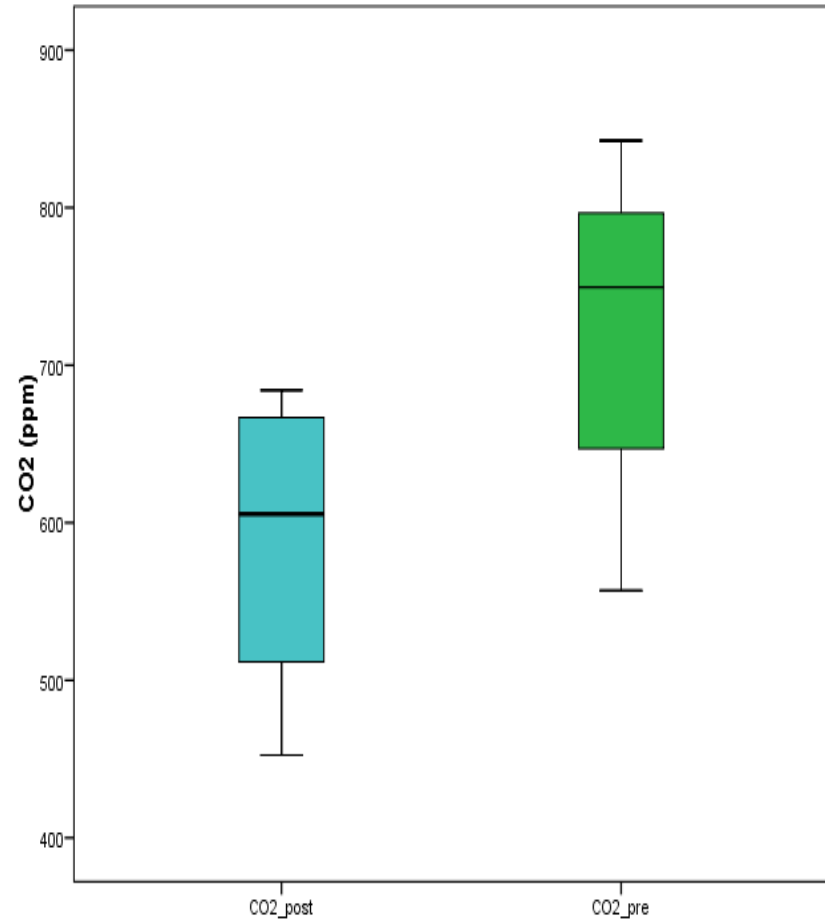
Before retrofit After retrofit
Group CW

TVOC (ppb) 24 hr average concentration ($\mu\text{g}/\text{m}^3$) before and after the retrofit



Before retrofit After retrofit
Group CW

CO2 (ppm) 24 hr average concentration (ppb) before and after the retrofit



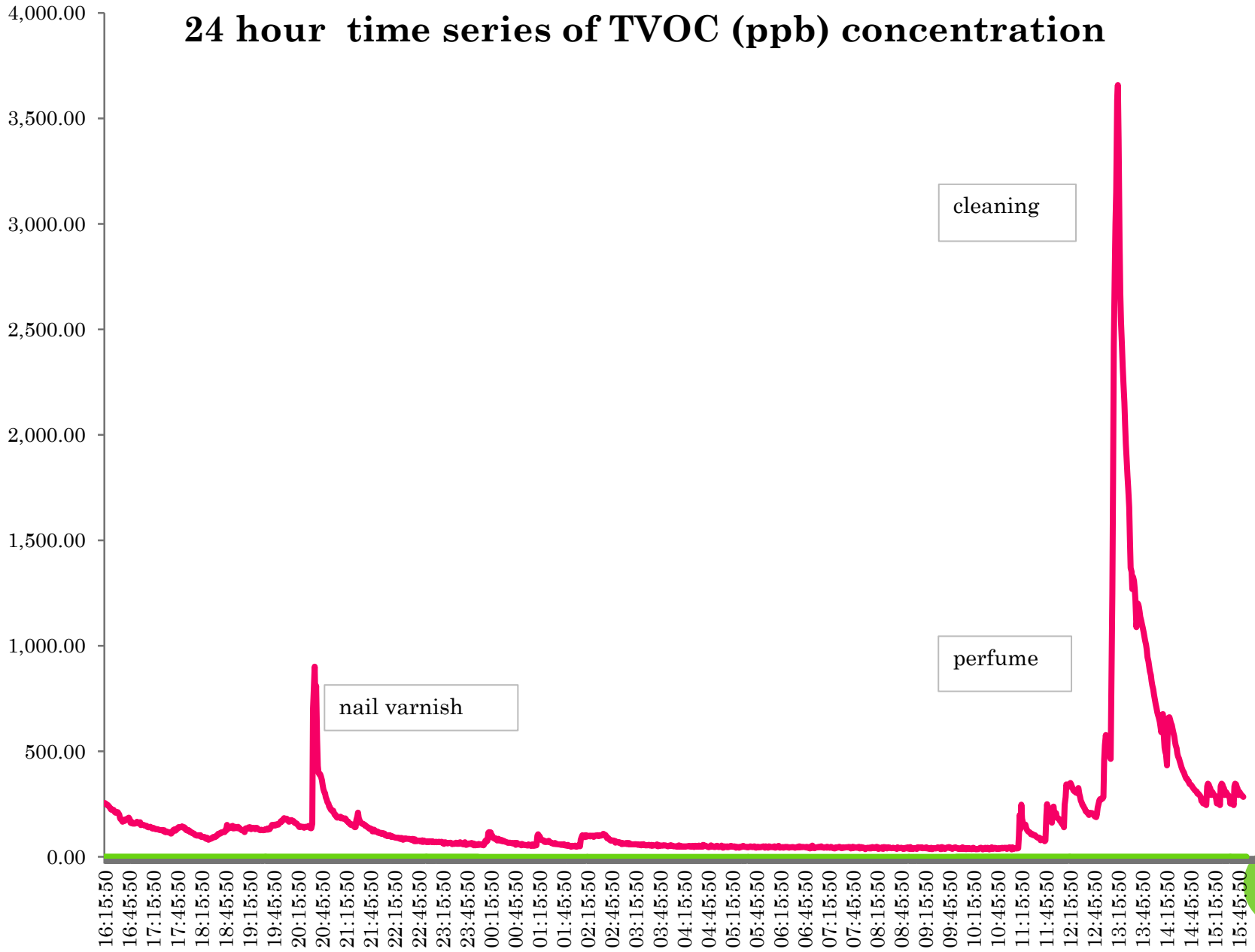
Before retrofit After retrofit
Group CW

Indoor Air pollutants – Hollow block/CW

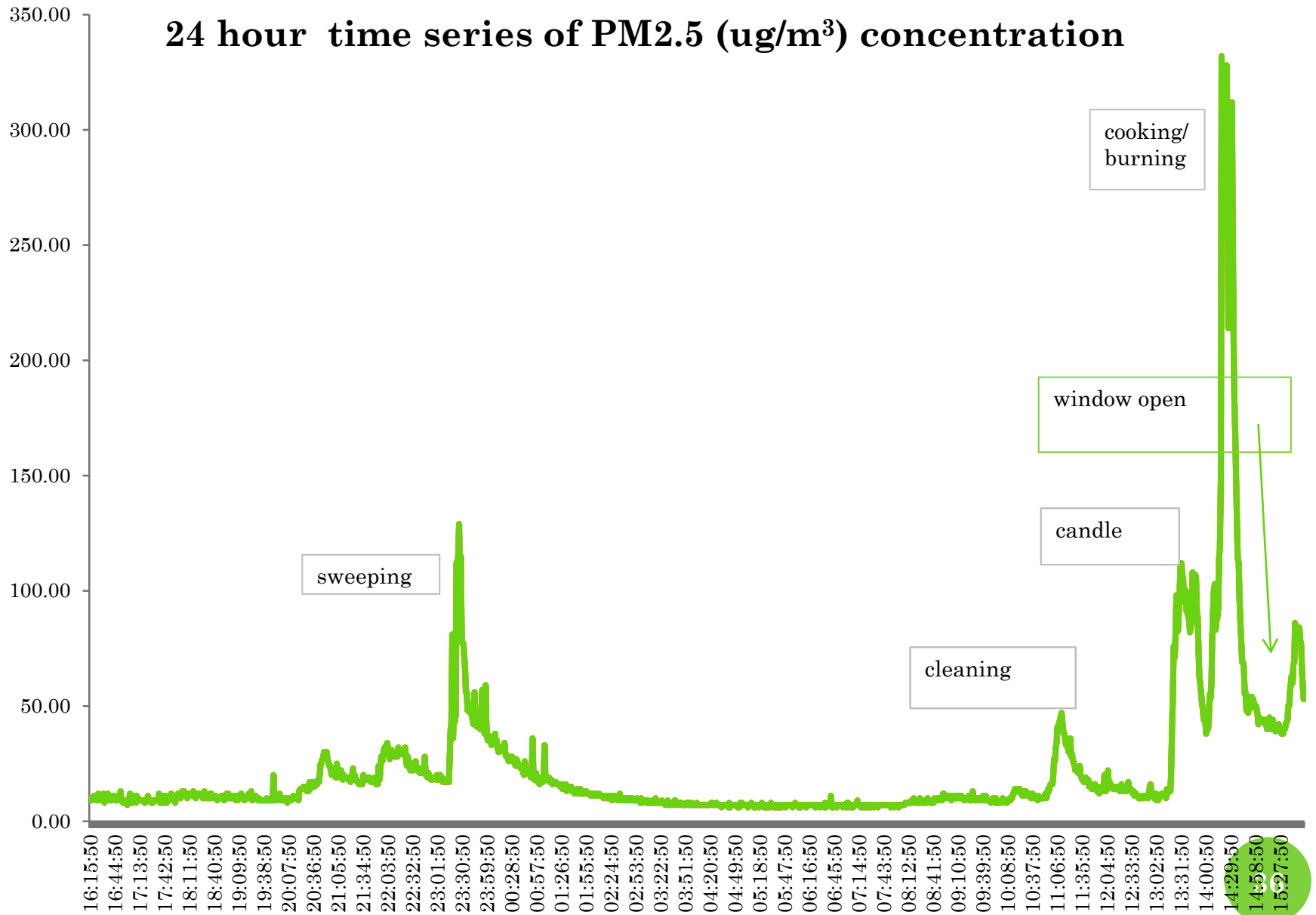
	Pre retrofit Mean (n= 7) (SD)	Post retrofit Mean (n= 7) (SD)	p
PM_{2.5} (µg/m³)	9.33 (2.6)	15.34 (4.0)	0.008*
CO₂ (ppm)	566 (66.0)	671.0 (59.0)	0.003*
TVOC (ppb)	375.6 (74.4)	462.0 (52.2)	0.032*

P value is significant at the 5% level of significance

24 hour time series of TVOC (ppb) concentration



24 hour time series of PM2.5 (ug/m³) concentration



- Room Air Exchange rate correlated ;
 - PM_{2.5} (μg/m³) (R² = 0.4)
 - Formaldehyde (ppb) (R² = 0.4)

CONCLUSION

- Increase in airtightness and reduced ACH
- Improved occupant comfort
- levels of all IAP increased post retrofit
 - PM2.5, Formaldehyde, TVOC's
- What are IAP concentrations 12 months post retrofit?
- Education

Project team:

Aine Broderick (PhD Candidate)

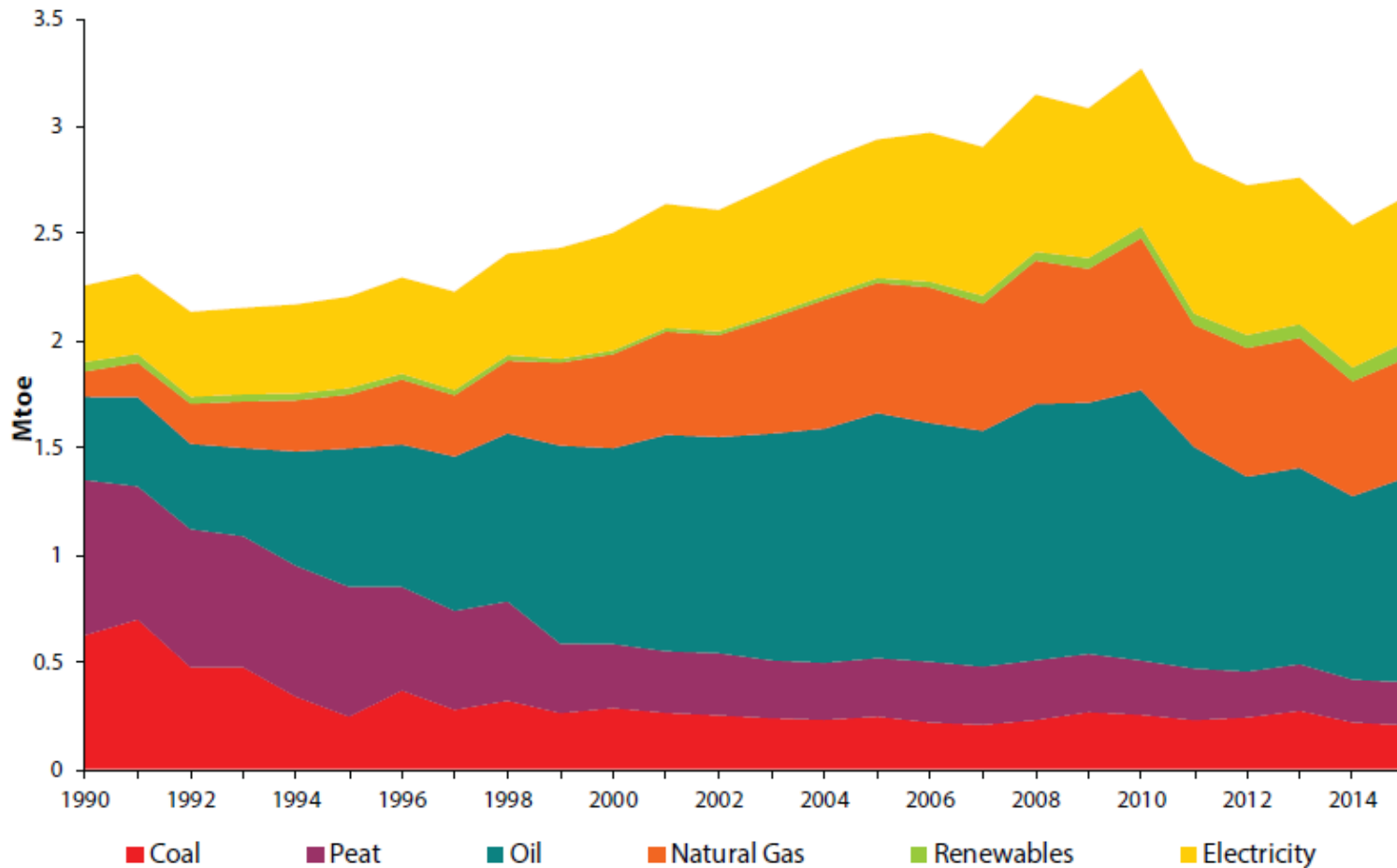
Dr. Miriam Byrne,

Mr. Sean Armstrong, Department of the Environment,
Community and Local Government (DECLG)



Ionad Aeráide agus Truailliú Aeir
Centre for Climate & Air Pollution Studies

RESIDENTIAL FINAL ENERGY USE BY FUEL



PARTICULATE MATTER

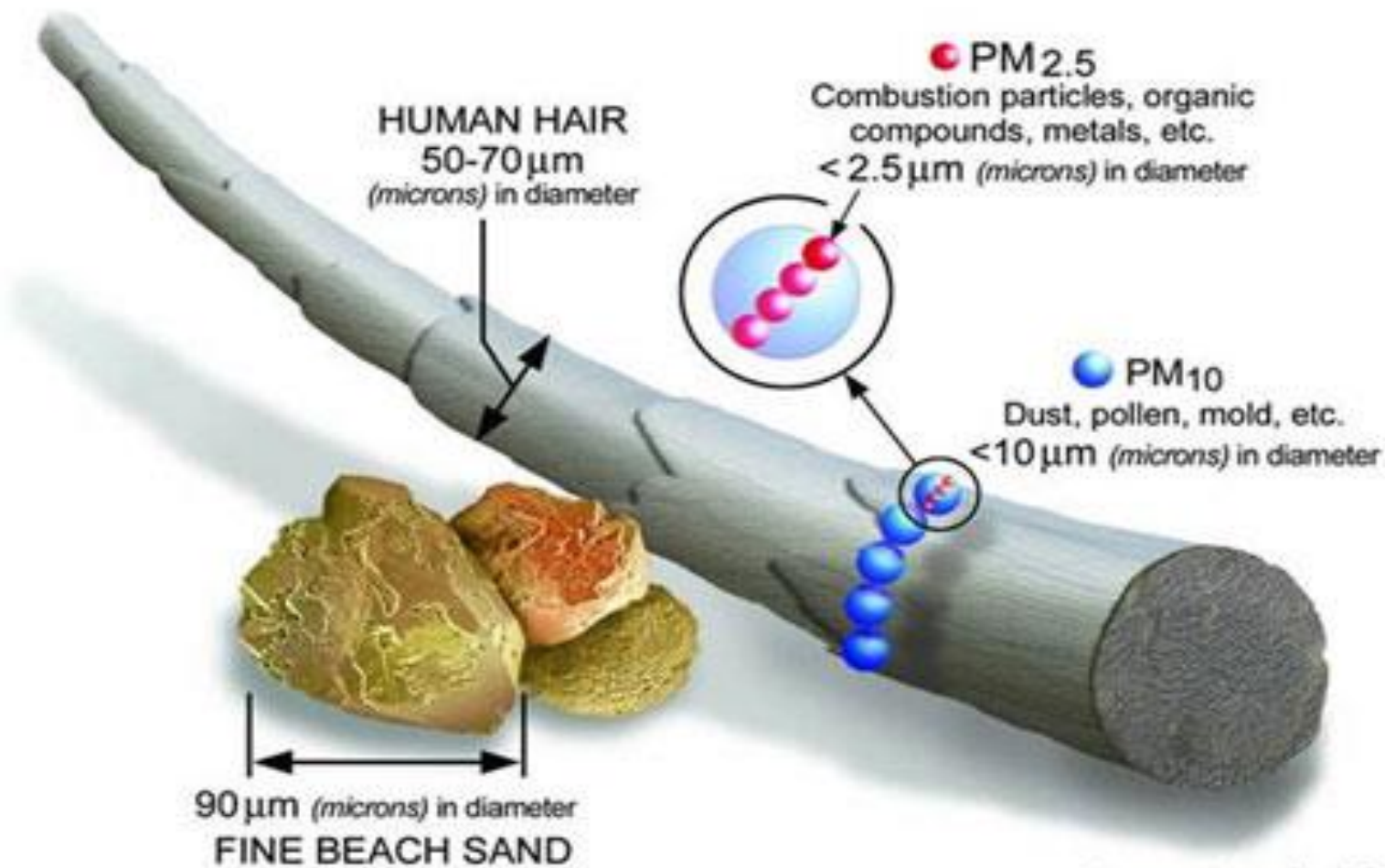


Image courtesy of the U.S. EPA