The University Of Sheffield.

BEAU
BUILDING ENVIRONMENTS ANALYSIS UNIT

The BIG Energy Upgrade

Energy Innovation for Retrofitting Deprived Community Housing in the UK

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EUROPEAN UNION
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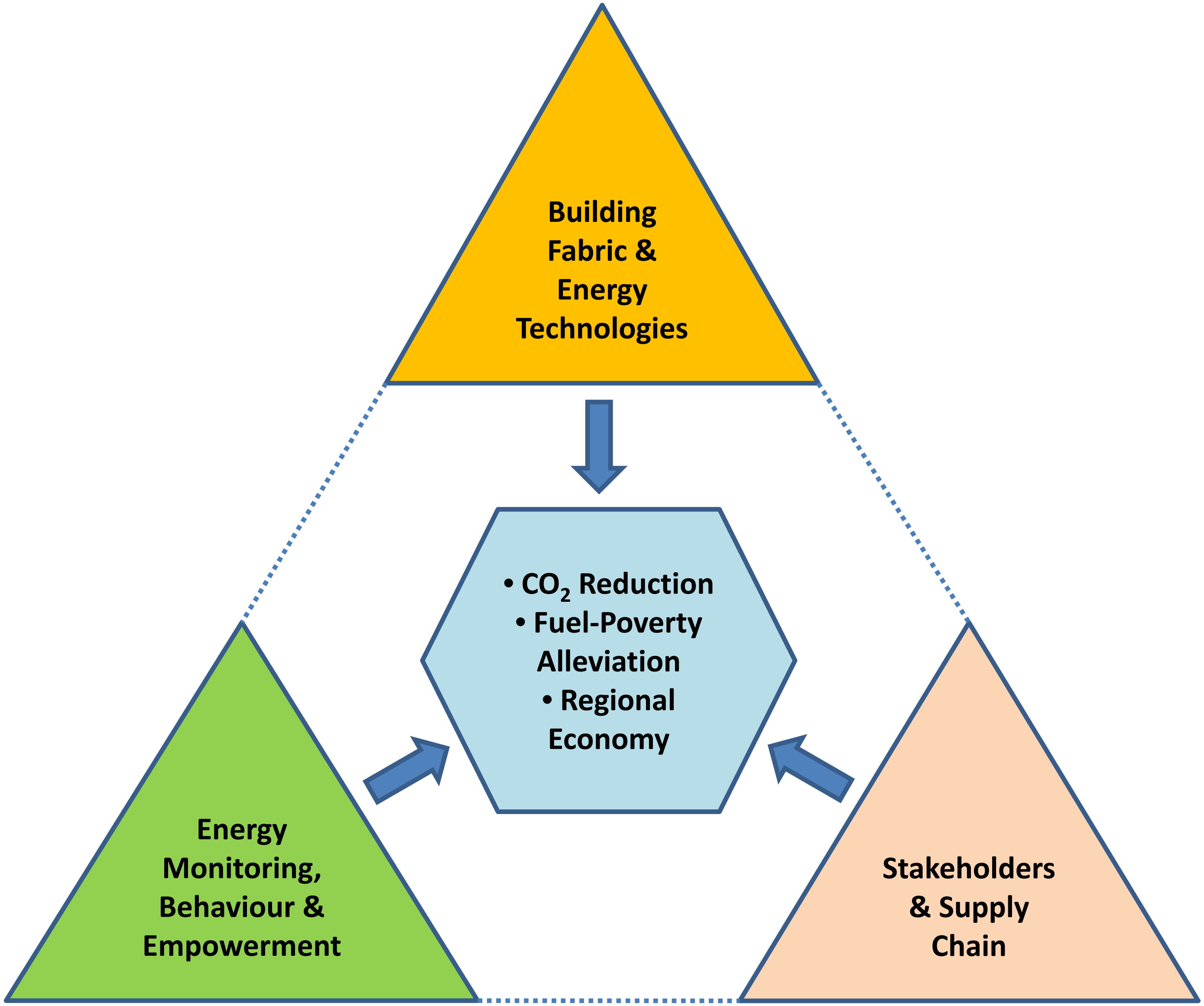
European Regional Development Fund 2007-13

THE BIG ENERGY UPGRADE

The BIG Energy Upgrade: Energy Innovation for Deprived Communities (EIDC) Project

- To deliver a **new approach to energy efficiency** and renewable energy projects;
- The UK has some of the **oldest housing stock** in Europe;
- The properties will be assessed by energy efficiency experts and then brought up to modern standards with a range of measures;
- Academics at Sheffield University has been brought on board (Architecture, Civil & Structural Engineering, Management School, Psychology, Computer Science.


Building Fabric & Energy Technologies
• CO2 Reduction
• Fuel-Poverty Alleviation
• Regional Economy
Energy Monitoring, Behaviour & Empowerment
Stakeholders & Supply Chain

Building Fabric and Energy Technologies

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BEAU Research Centre @ School of Architecture

Work Package 1

Tasks (1&2)

- Identify a **sample of typical homes** for post occupancy monitoring before and after refurbishment;
- Thermal performance of some of the houses **pre- and post-refurbishment** would be determined;
- Develop **building simulation models** using dynamic computer simulation software;
- **Calibrate** computer models with monitoring outputs and to also simulate using **best practice scenarios** and **adapting to changing climate**;
- Carbon dioxide is measured to assess the **indoor air quality**;
- Monitoring **indoor noise**;
- **Airtightness** test of each house would be determined before and after refurbishment;
- Conducting **infrared imaging** to indicate heat leaks in faulty thermal insulation.

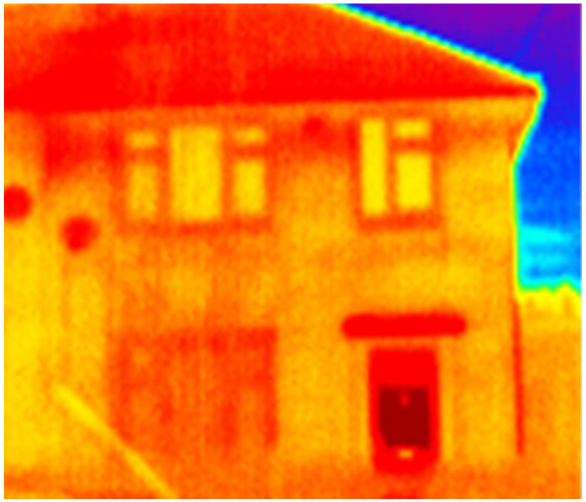
WP1 Task 1

Measuring Indoor Environments of Houses

- Indoor air temperatures, and relative humidity by using HOBO data loggers.
- Indoor carbon dioxide levels using CO_2 Meter.

Additional Variables to be Measured

- Noise measurements
- Pressure testing
- Thermal imaging



Questions to be asked

- **Do indoor variables comply with standard guidelines?**
- **Is there any correlation between indoor variables?**
- **Has refurbishment improved thermal comfort condition?**

Preliminary Results of Pre and Post Refurbishment of Semi-detached Houses

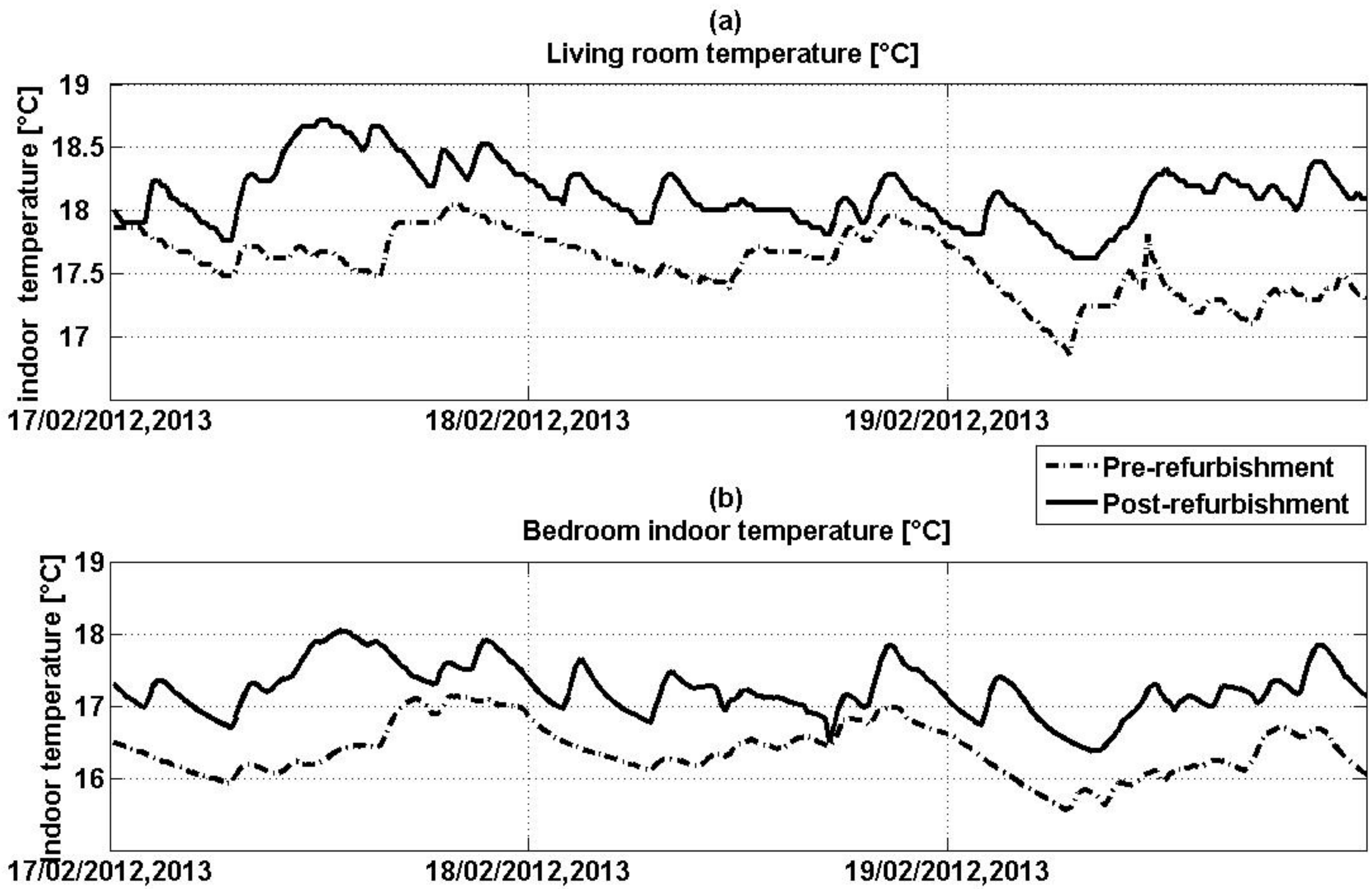
D1

K1

L2

Living room and bedroom were compared with the standard guidelines.

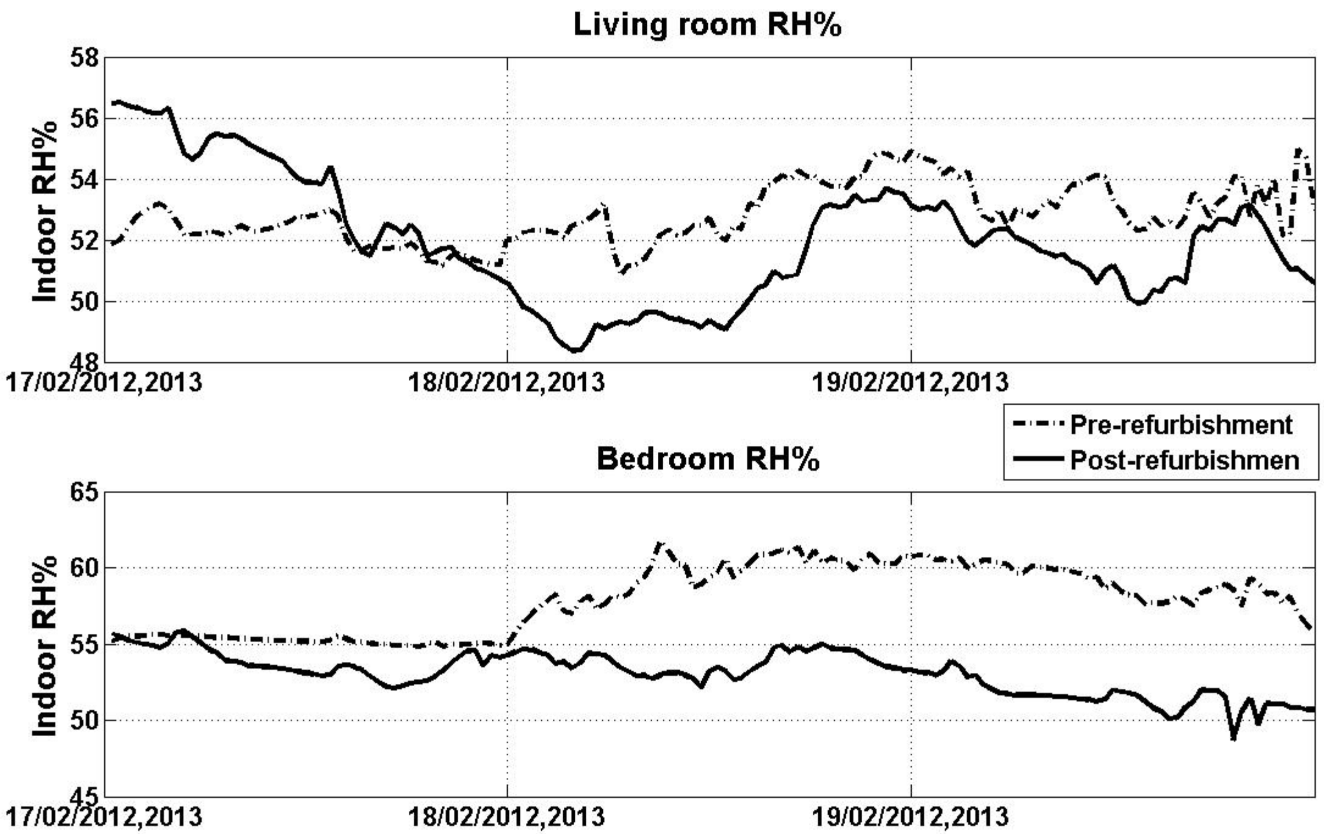
- The living room did not comply with CIBSE recommendation for the range of internal temperatures (22-23°C) for pre and post refurbishment, but the indoor temperature has increased by 1.7°C as seen in figure (a).
- The bedroom indoor temperature did comply with the standard guideline of internal temperatures (17-19°C) and has increased by 1°C as seen in figure (b).



D1

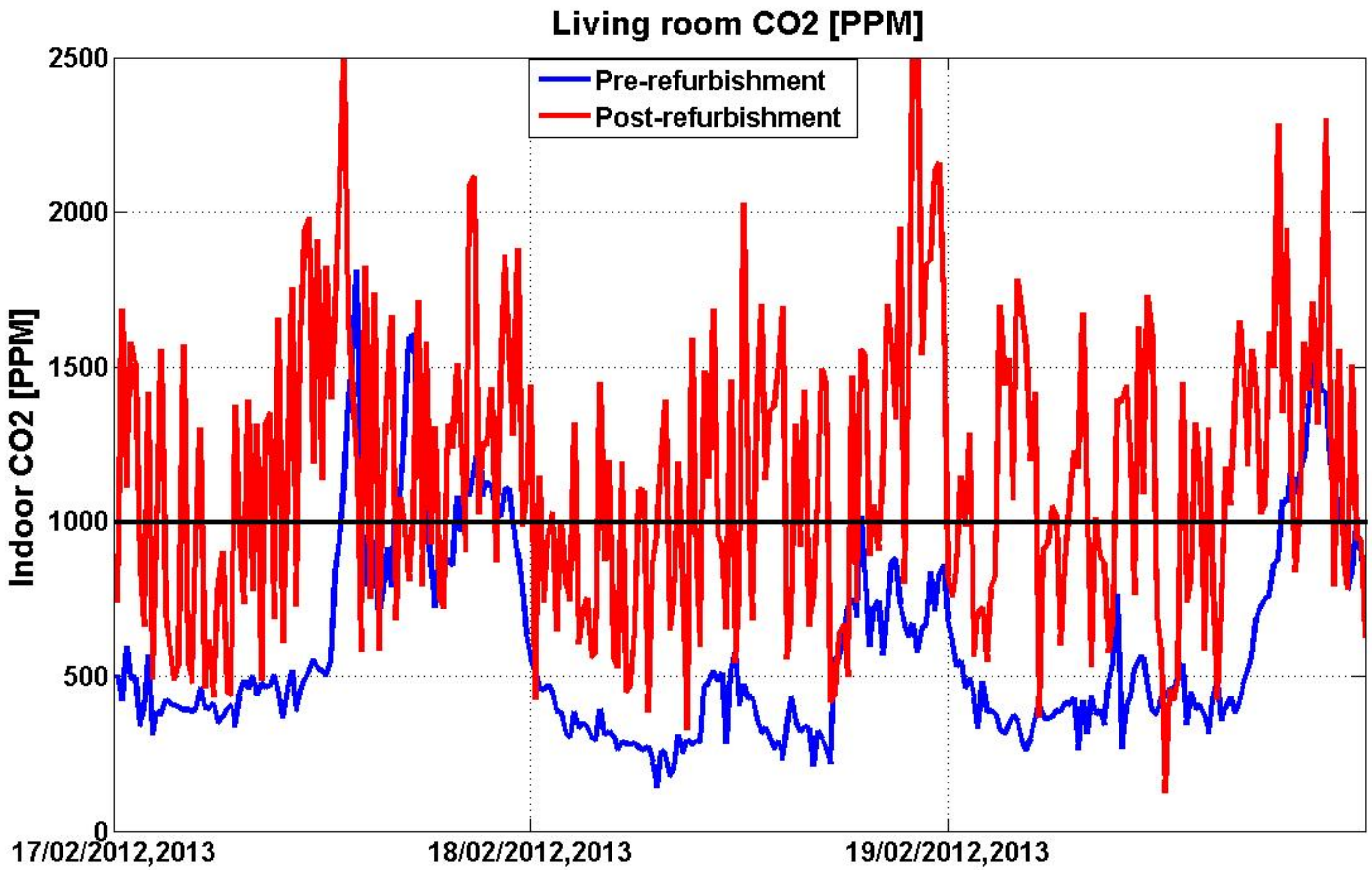
Living room and bedroom were compared with the standard guidelines.

- The average relative humidity RH% for the living room and the bedroom comply with the standard guidelines. The recommended level of indoor relative humidity should be between 40-70% as specified by ASHRAE.



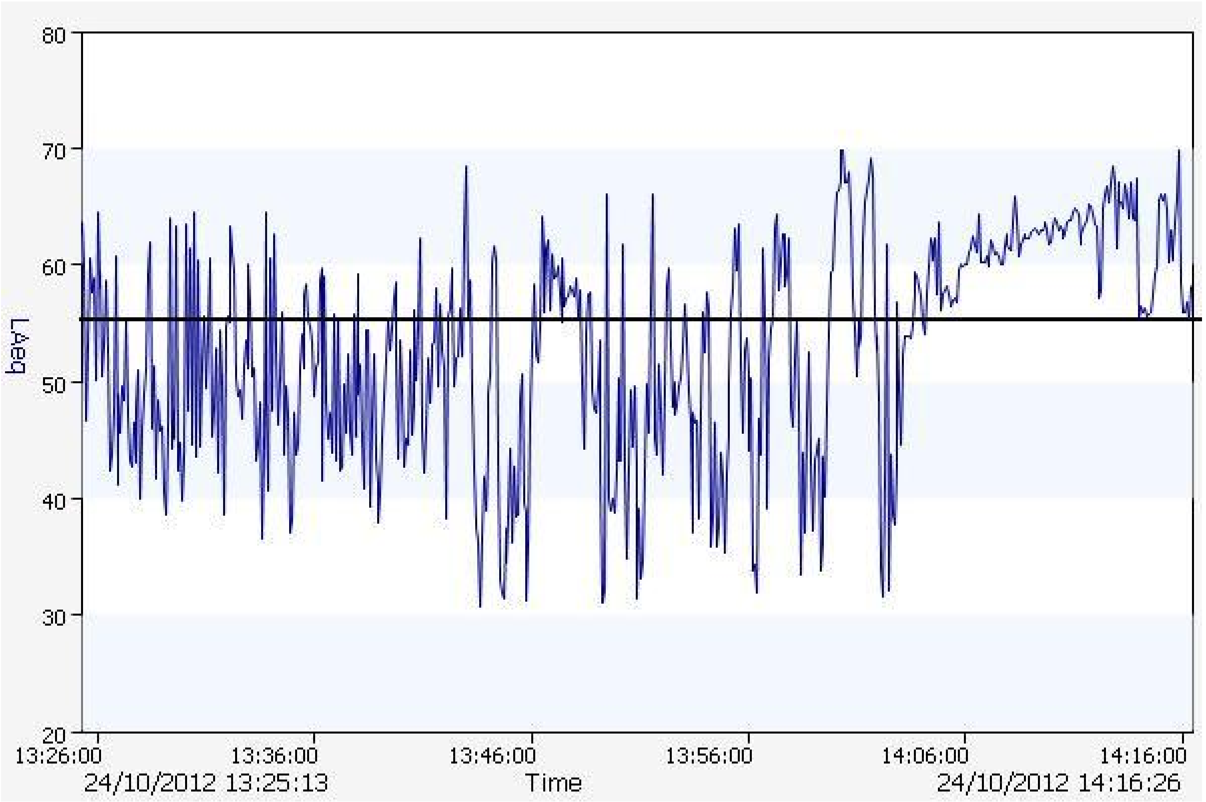
D1

CO_2 increased after refurbishment and this is logical because external insulation has increased the airtightness and hence the CO_2 levels.



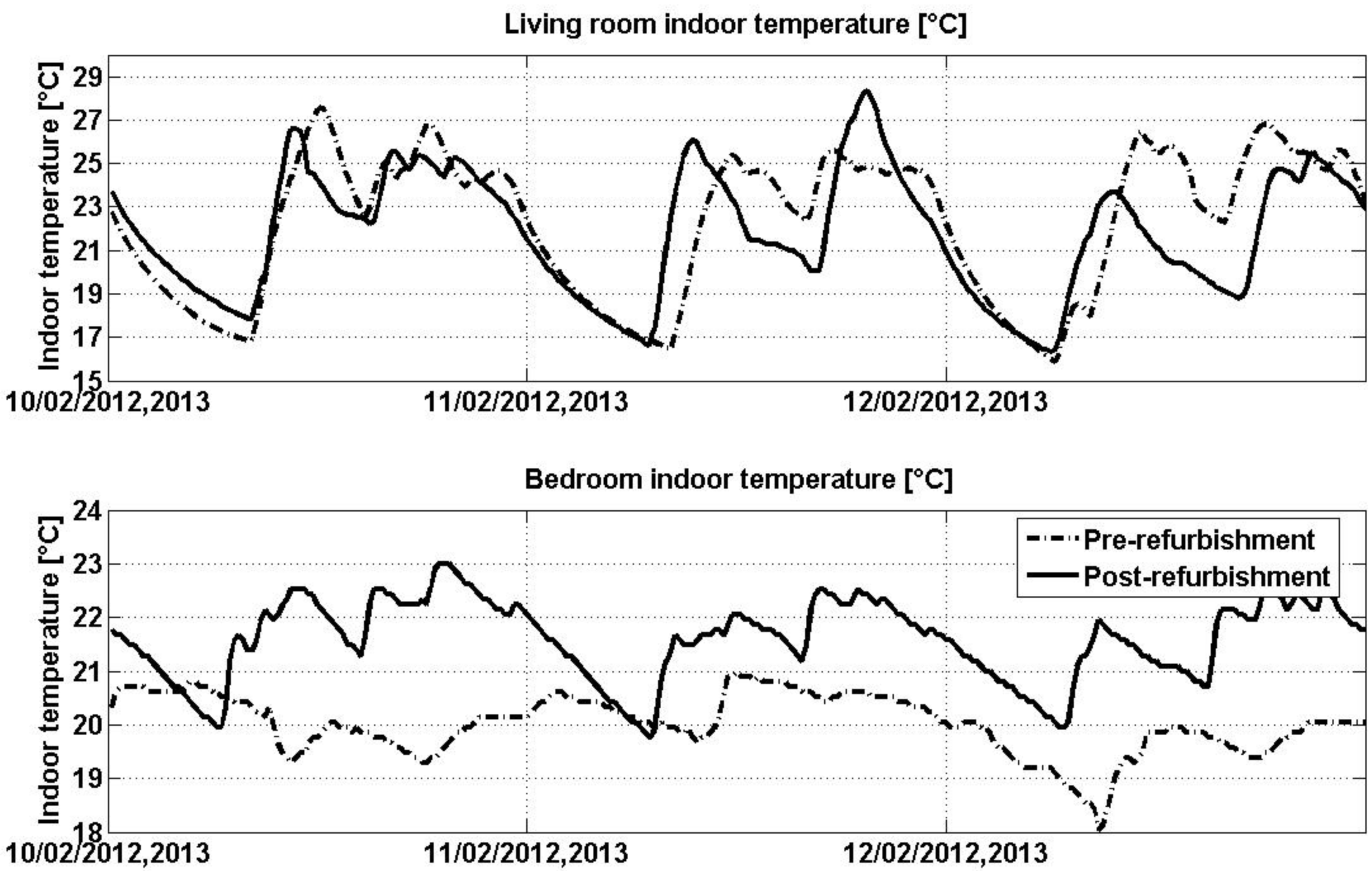
D1

The World Health Organisation (WHO) considers L_{eq}=55 dB to mark a significant annoyance during day time hours.



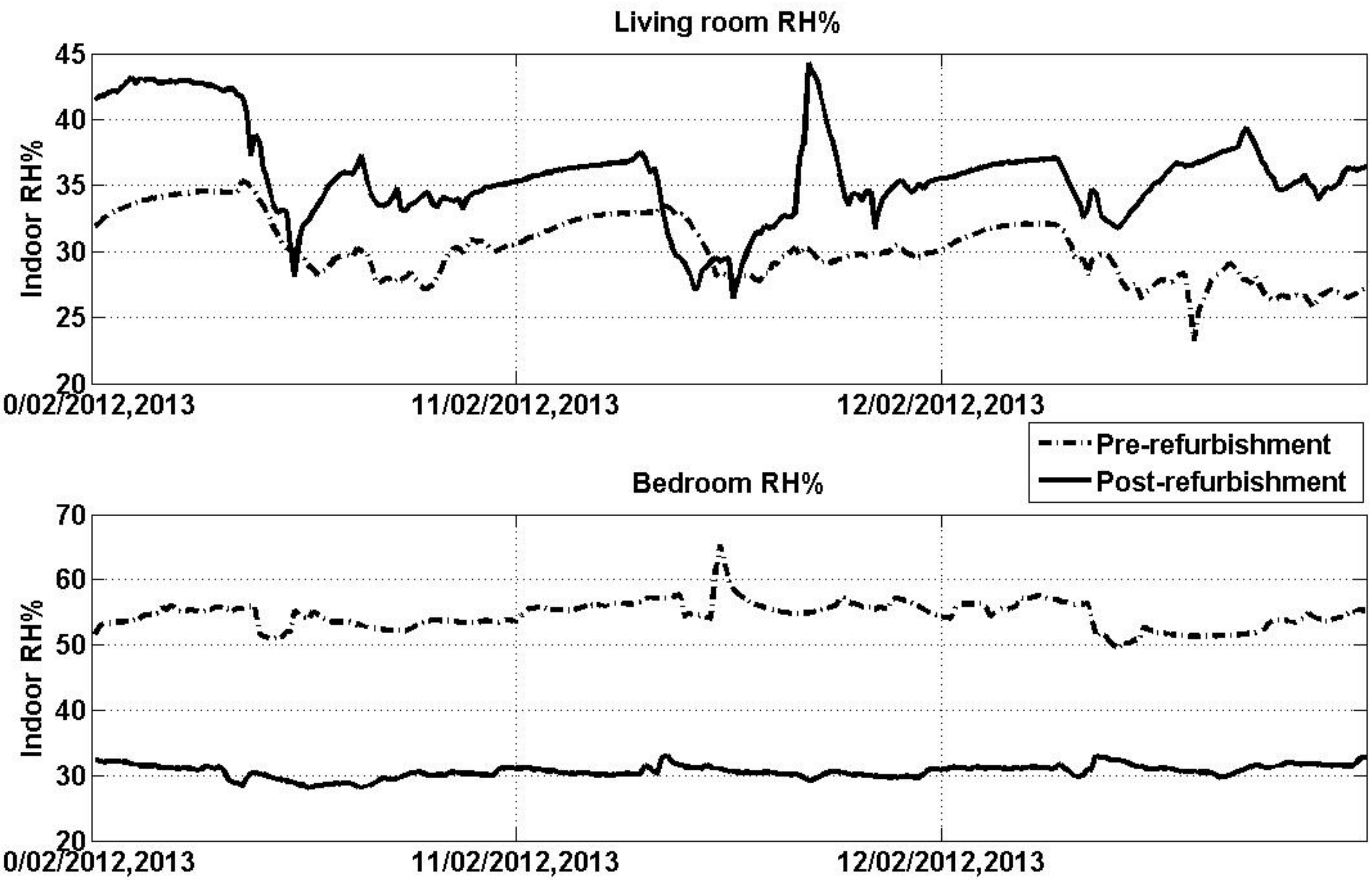
D1

K1



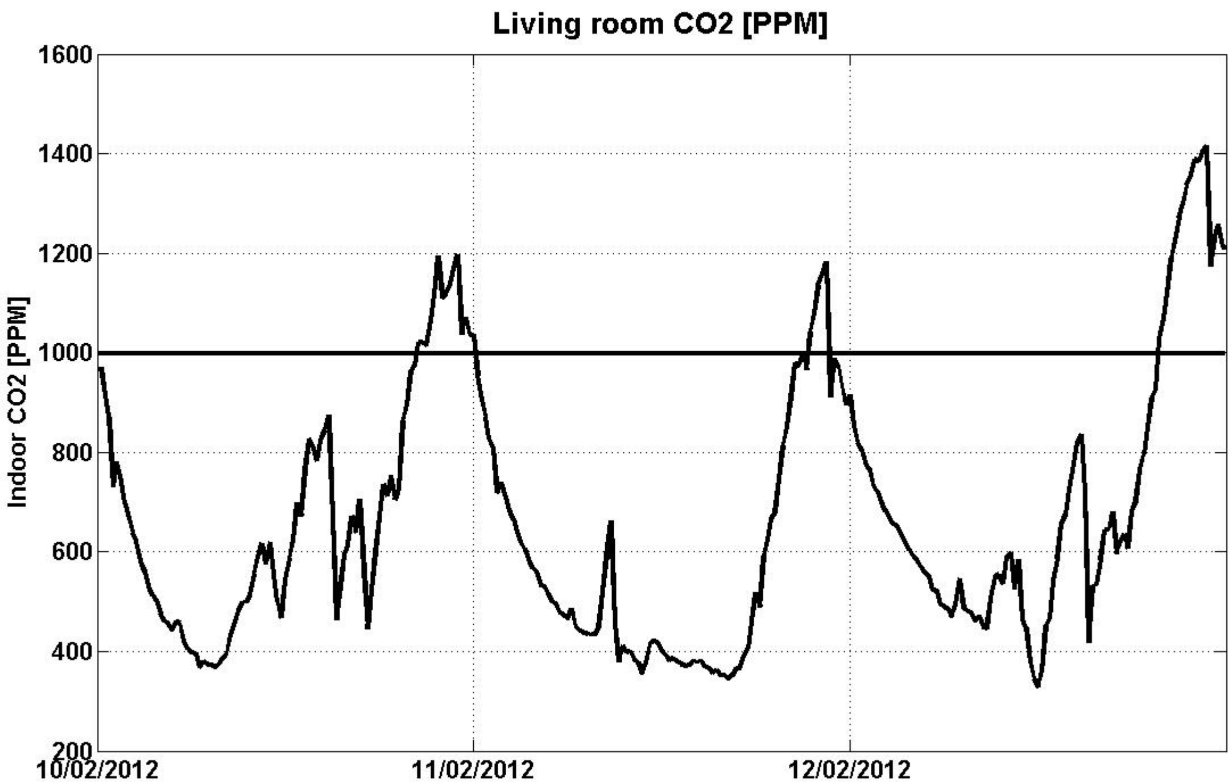
Living room indoor temperature [°C]
Indoor temperature [°C]
29
27
25
23
21
19
17
15
10/02/2012,2013
11/02/2012,2013
12/02/2012,2013
Bedroom indoor temperature [°C]
Indoor temperature [°C]
24
23
22
21
20
19
18
Pre-refurbishment
Post-refurbishment
10/02/2012,2013
11/02/2012,2013
12/02/2012,2013

K1



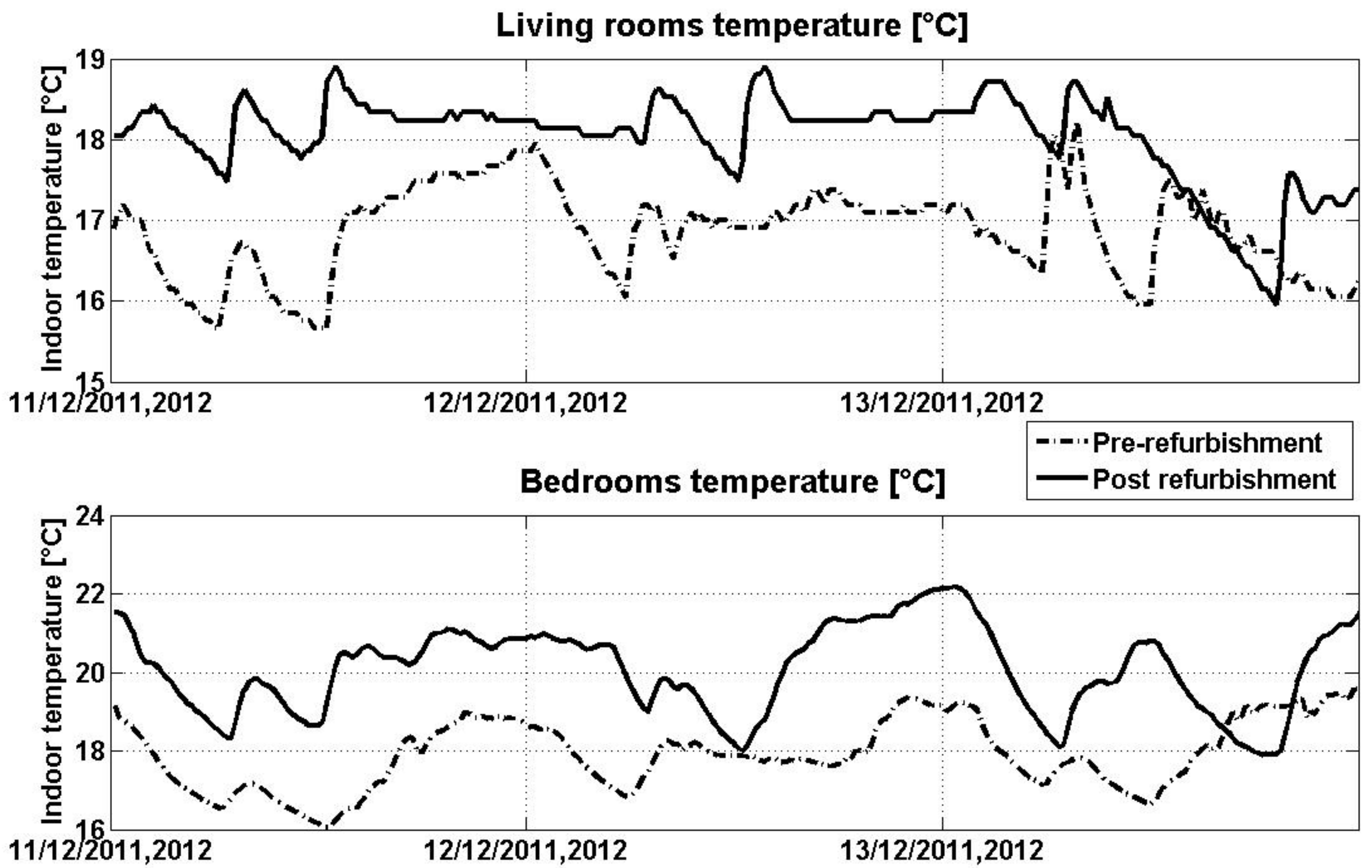
Living room RH%
Indoor RH%
45
40
35
30
25
20
10/02/2012,2013
11/02/2012,2013
12/02/2012,2013
Pre-refurbishment
Post-refurbishment
Bedroom RH%
Indoor RH%
70
60
50
40
30
20
10/02/2012,2013
11/02/2012,2013
12/02/2012,2013

K1

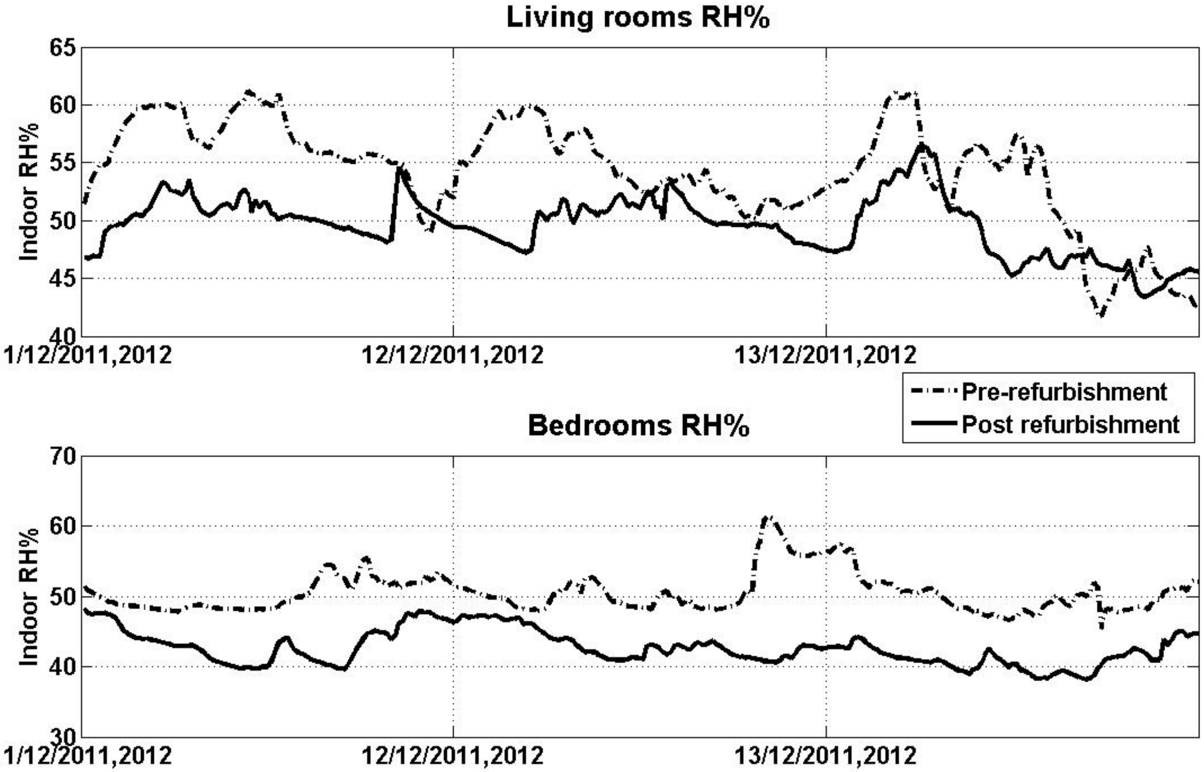


Living room CO2 [PPM]
Indoor CO2 [PPM]
1600
1400
1200
1000
800
600
400
200
10/02/2012
11/02/2012
12/02/2012

L2

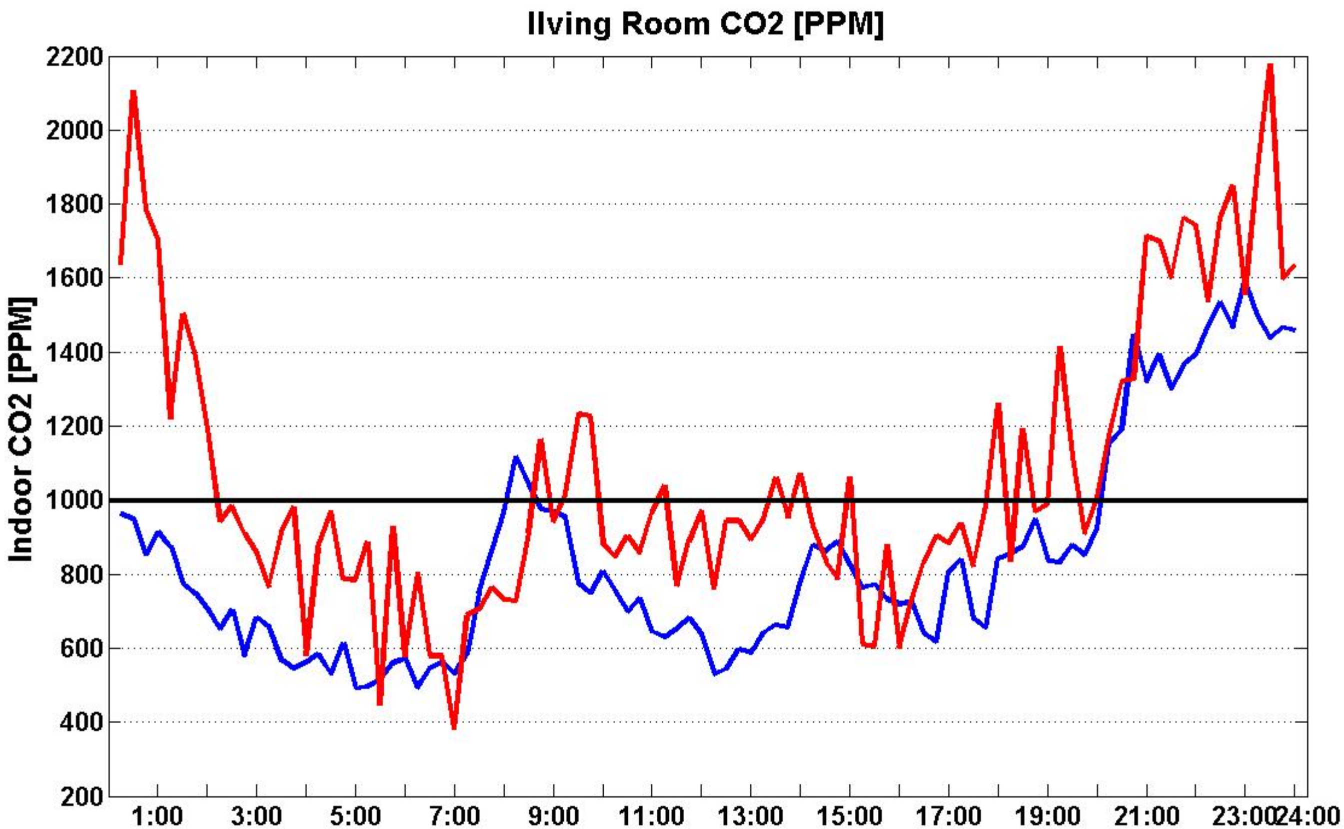

Living rooms temperature [°C]
Indoor temperature [°C]
19
18
17
16
15
11/12/2011,2012
12/12/2011,2012
13/12/2011,2012
Pre-refurbishment
Post refurbishment
Bedrooms temperature [°C]
Indoor temperature [°C]
24
22
20
18
16
11/12/2011,2012
12/12/2011,2012
13/12/2011,2012

L2



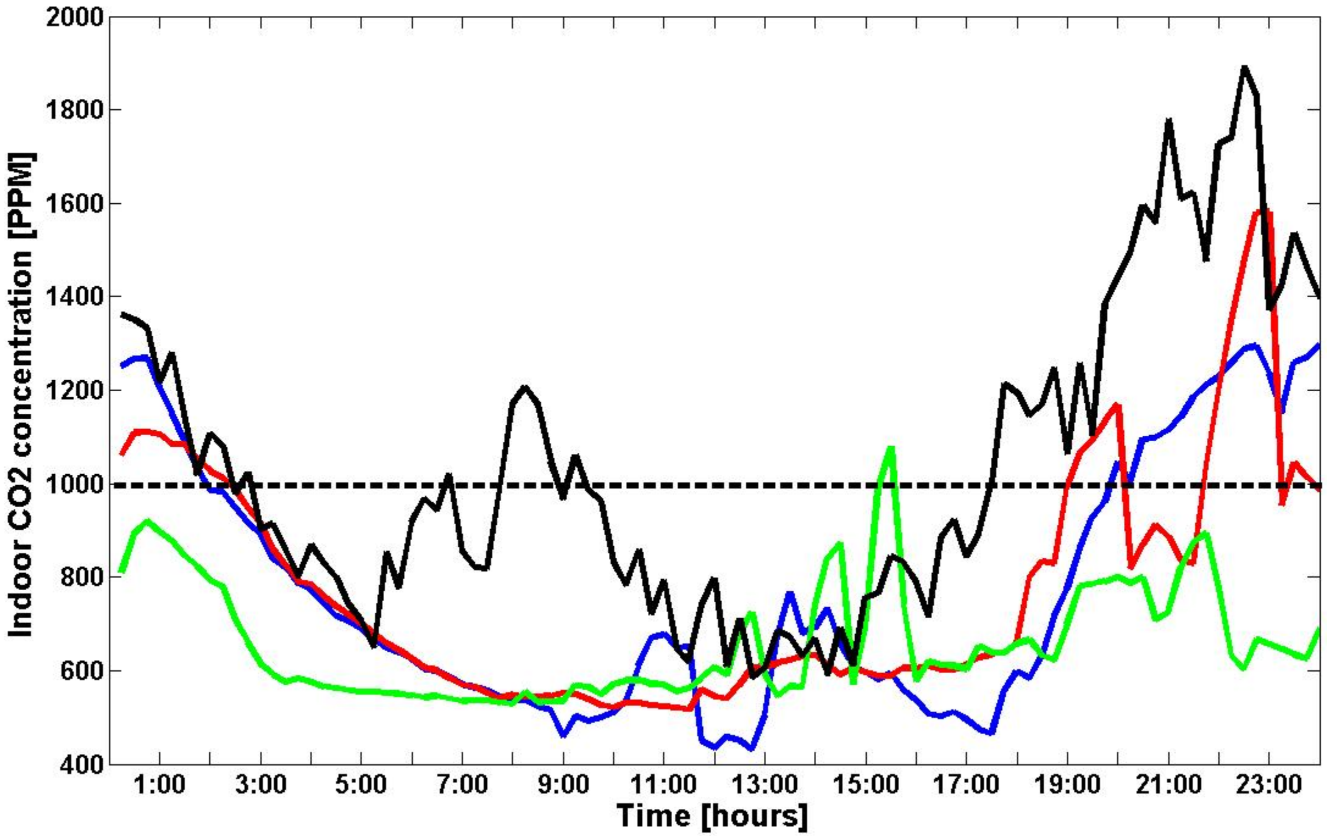
Living rooms RH%
Indoor RH%
65
60
55
50
45
40
11/12/2011,2012
12/12/2011,2012
13/12/2011,2012
Pre-refurbishment
Post refurbishment
Bedrooms RH%
Indoor RH%
70
60
50
40
30
11/12/2011,2012
12/12/2011,2012
13/12/2011,2012

L2



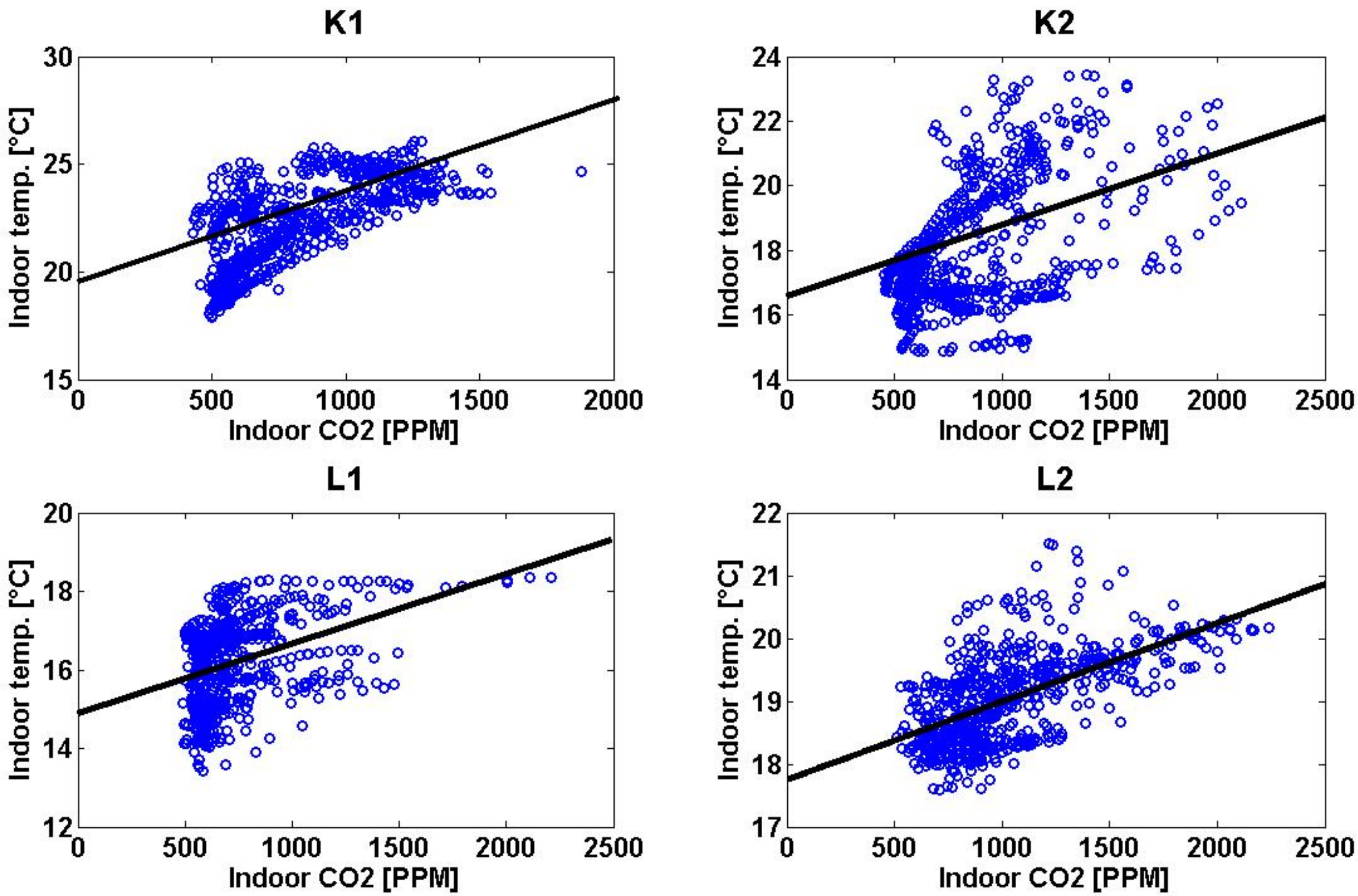
Ilving Room CO2 [PPM]
Indoor CO2 [PPM]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
1:00
3:00
5:00
7:00
9:00
11:00
13:00
15:00
17:00
19:00
21:00
23:00
24:00

CO_2 levels followed a pattern in the four homes. Levels were seen to be **under 1000 ppm during early morning and day time**, later rising at evening and night time due to the **increase of human activity and lack of ventilation**.



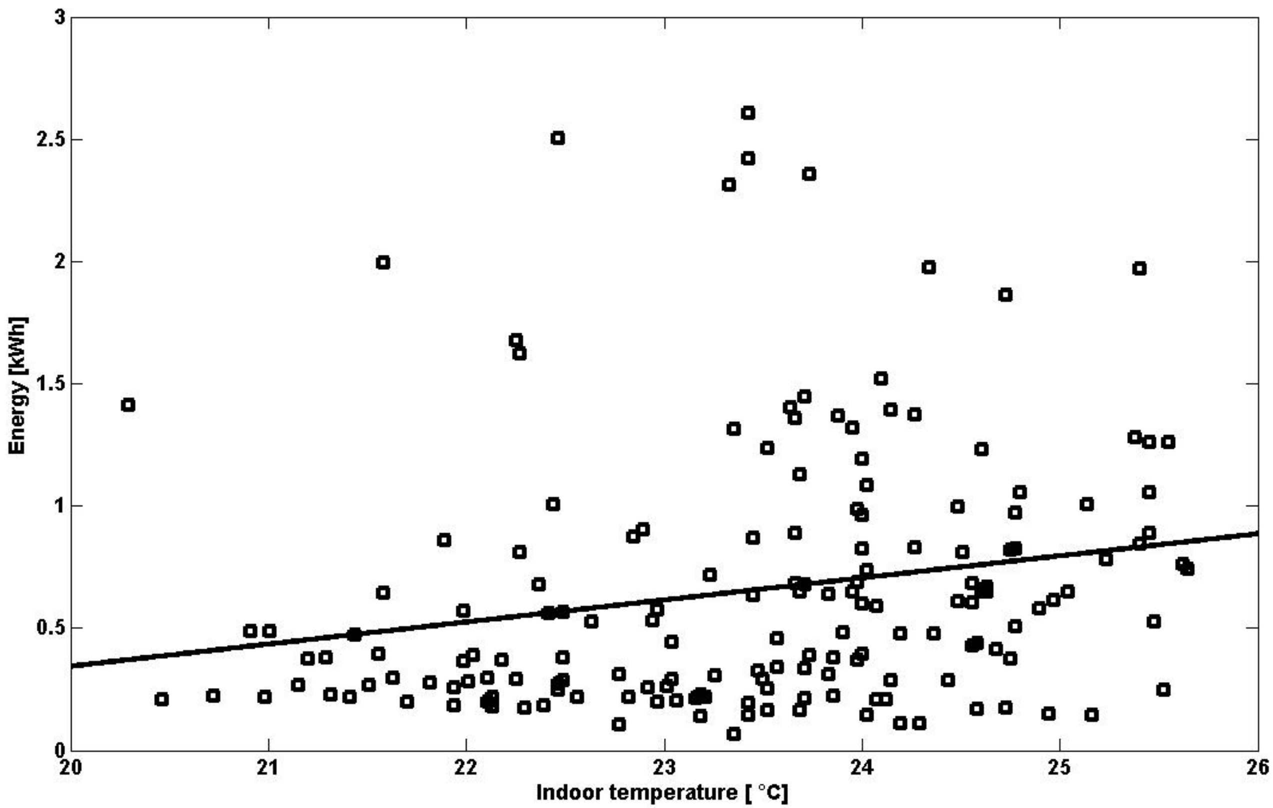
Is there any correlation between indoor variables? (winter season)

Direct relation between indoor temperature and CO_2 for four homes. These results may indicate that the warmer space have lack of air ventilation rates and therefore CO_2 levels are higher, and it also reflects **the dilemma of achieving proper ventilation and indoor thermal comfort**.

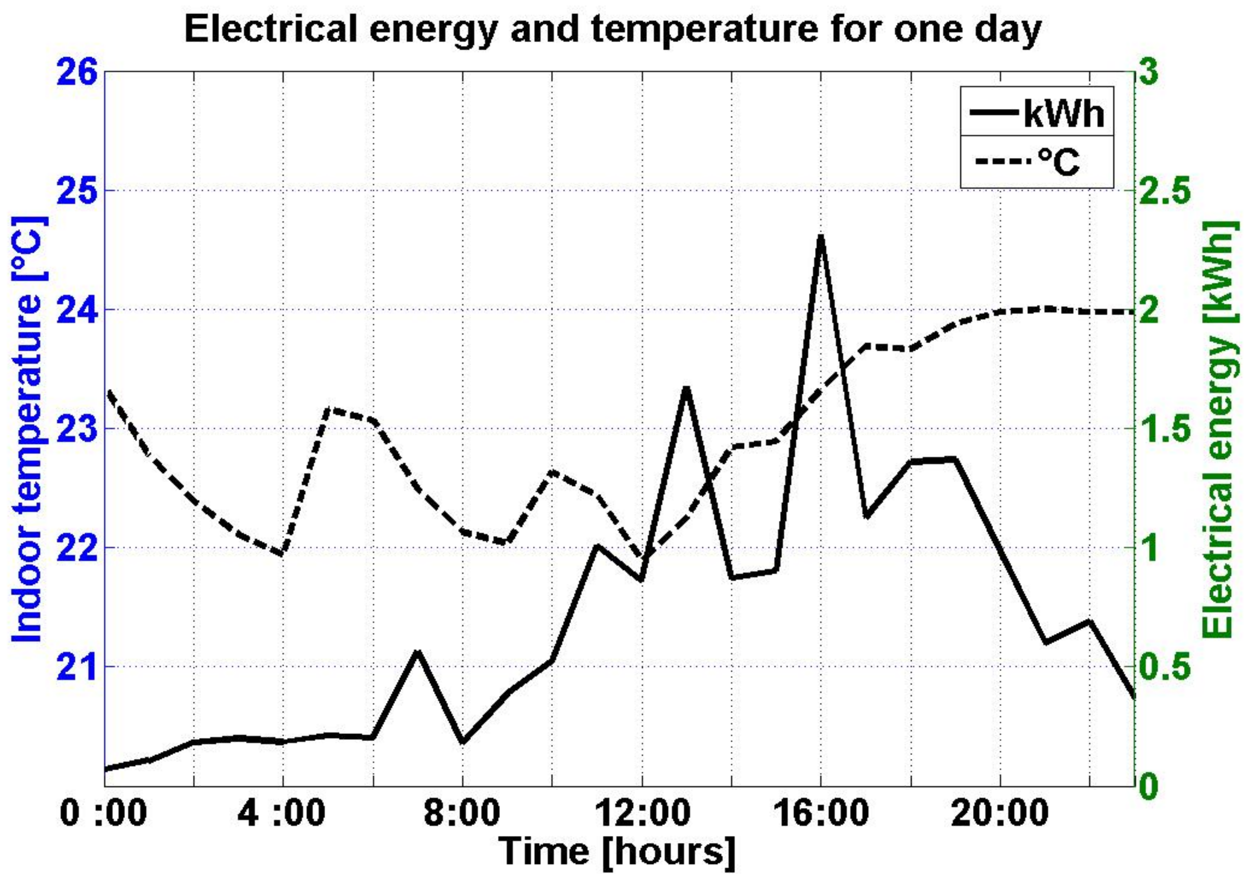


Is there any correlation between indoor variables? (winter season)

Direct correlation between electrical energy use and indoor temperature, and the results indicate that the higher the energy use the warmer the dwelling gets due to the **casual heat gains** from lighting and electrical appliances.



The **electric energy consumption increased** from 12:00pm till 16:00pm also temperature increased from 22°C to 24°C and stayed on that level till 22:00 pm due to the **lack of ventilation** during that time.



Conclusions

- The **average relative humidity** for the living room and the bedroom do agree with the standard guidelines before and after refurbishment.
- The results after refurbishment of **carbon dioxide** (CO_2) of the living room showed that **the level has increased** and is fluctuating around the recommended value (1000ppm) for indoor space.

The Impact of Refurbishment on the Indoor Environment

- By installing the external insulation the **indoor temperature level has increased**, although the temperature of living room **did not comply with the standard guidelines**.
- The reason for this is the **older dwellings may be expected to be less airtight** and so experience higher ventilation rates i.e. the external insulation cover cracks and holes, and **increases the airtightness** of the building.
- The results may indicate that the **warmer space has lack of air ventilation rates** and therefore CO_2 levels are higher, and it also reflects **the dilemma of achieving proper ventilation and indoor thermal comfort**.

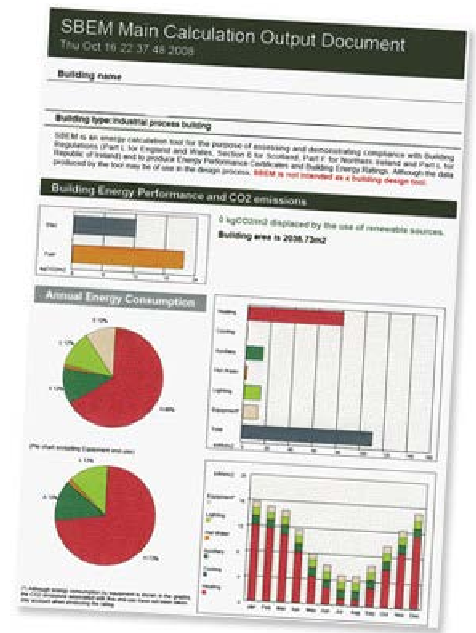
WP1 Task 2
Dynamic Simulation Modelling of Houses

SURVEYING | **MODELLING** | **ANALYSING**

EDSL Tas

INTEGRATED ENVIRONMENTAL SOLUTIONS (ies)

DesignBuilder SOFTWARE


SBEM Main Calculation Output Document

Building name

Building Energy Performance and CO2 emissions

Annual Energy Consumption

Example Case Home

Site Visit

Before (external insulation)

After (external insulation)

Building Information Survey Form

Reference number :	
Building address or name:	
Surveyor :	
Date and time:	

Modelling

Before (external insulation)

After (external insulation)

Best Practice Standards for Refurbishment

- Draught proofing: Improve airtightness up to $5m^3/(h.m^2)$ @ 50Pa;
- Loft insulation: 0.16 W/m^2K or up to 270mm of level of insulation;
- Cavity wall insulation: Target U-value as 0.5 W/m^2K;
- Replacement of front door: Improve airtightness up to $5m^3/(h.m^2)$ @50Pa;
- New boiler and controls: Over 90% of seasonal efficiency or A+;
- Internal wall insulation: Target U-value as 0.3 W/m^2K;
- External insulation: Target U-value as 0.3 W/m^2K;
- Floor insulation: Target U-value as 0.25 W/m^2K;
- New windows: Best practice level or above BFRC rating in band C (1.5 W/m^2K).

Domestic Measures
Insulations and Glazing

Insulation Measures		Cost (£)		Savings			Payback (years)	U-Value
		Professional	DIY	Bill (£)	Energy (kWh/yr)	CO_2 (kg CO_2/yr)		
Loft	0 to 270 mm	around 300	250	180	3,687	730	from 2 years	-
	100 to 270 mm	up to 300	150	25	556	110	from 5 years	-
Wall	Cavity	450~500	-	140	2,830	560	4 years	0.3 W/m²K
	Solid (Internal)	5,500~8,500	-	460	9,090	1,800	12~18.5	
	Solid (External)	9,400~13,000	-	490	9,600	1,900	19.2~26.5	
Floor	Timber	530	-	60	1,200	240	8.8	-
Draught Proofing		200	100	120	2430	480	1.6 (Pro) less than 1 year (DIY)	-
Windows/Glazing		around 2,500	-	170	3440	680	14.7	
Door (front)		-	-	30	610	120	-	-
Hot Water Tank Warm Jacket		-	15	45	860	170	less than 6 months	-
Pipe Insulation		-	10	15	300	60	around 1 year	-

Heating and Hot Water System

Upgrading Boiler

From	To	Cost (£)	Savings			Payback (years)
			Bill (£)	Energy (kWh/yr)	CO_2 (kg CO_2/yr)	
G (<70%)	A rated condensing boiler (>90%)	2,300	310	6,060	1,200	7.5
F (70 ~ 74%)			205	4,090	810	11.2
E (74 ~ 78%)			155	3,080	610	14.8
D (78 ~ 82%)			105	2,170	430	22

Heat recovery unit can save up to 17% of the energy used in heating water;
Upgrading hot water cylinder can save around £45 a year;
Replacing electric heating with a wood-burning system could save £630 a year;
Installing a room thermostat can save £70 and 280kg carbon dioxide a year;
Fitting a hot water tank thermostat can save £30 and 130kg carbon dioxide a year;
Turning down room thermostat by one degree can save around £65 and 260kg carbon dioxide a year;
Replacing old heater to modern storage heaters cost between £200~500 each and can save between £120~180 a year on electricity bills.

B1 Simulation Results (semi-detached and uninsulated cavity wall)

Base case features

Element	Fabric U-value
Roof insulation (100mm)	0.41 W/m²K
Unfilled brick cavity walls	1.23 W/m²K
Uninsulated solid floor	0.84 W/m²K
Pre 2001 Double glazing	2.77 W/m²K

Other features

- Envelope air leakage rate: 16 $m^3(h.m^2)$ @ 50Pa
- 58% Boiler efficiency

Improved features

Element	Fabric U-value
Roof insulation (270mm)	0.16 W/m²K
Filled brick cavity walls	0.53 W/m²K
New double glazing	2.0 W/m²K

Other features

- Envelope air leakage rate: 3 $m^3(h.m^2)$ @ 50Pa
- 90% Boiler efficiency

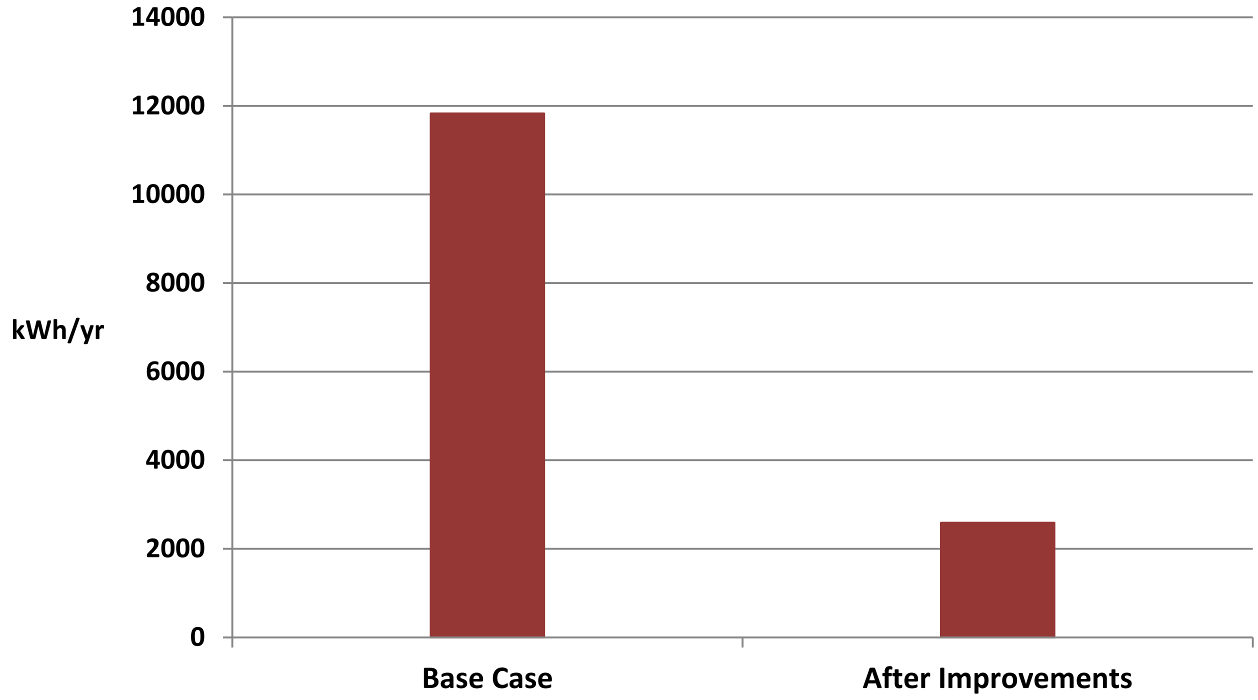
Energy, bills and Carbon emissions

Heating energy demand	11,828 kWh/yr
Heating bills	£367
Carbon emissions	2,342 kg/yr

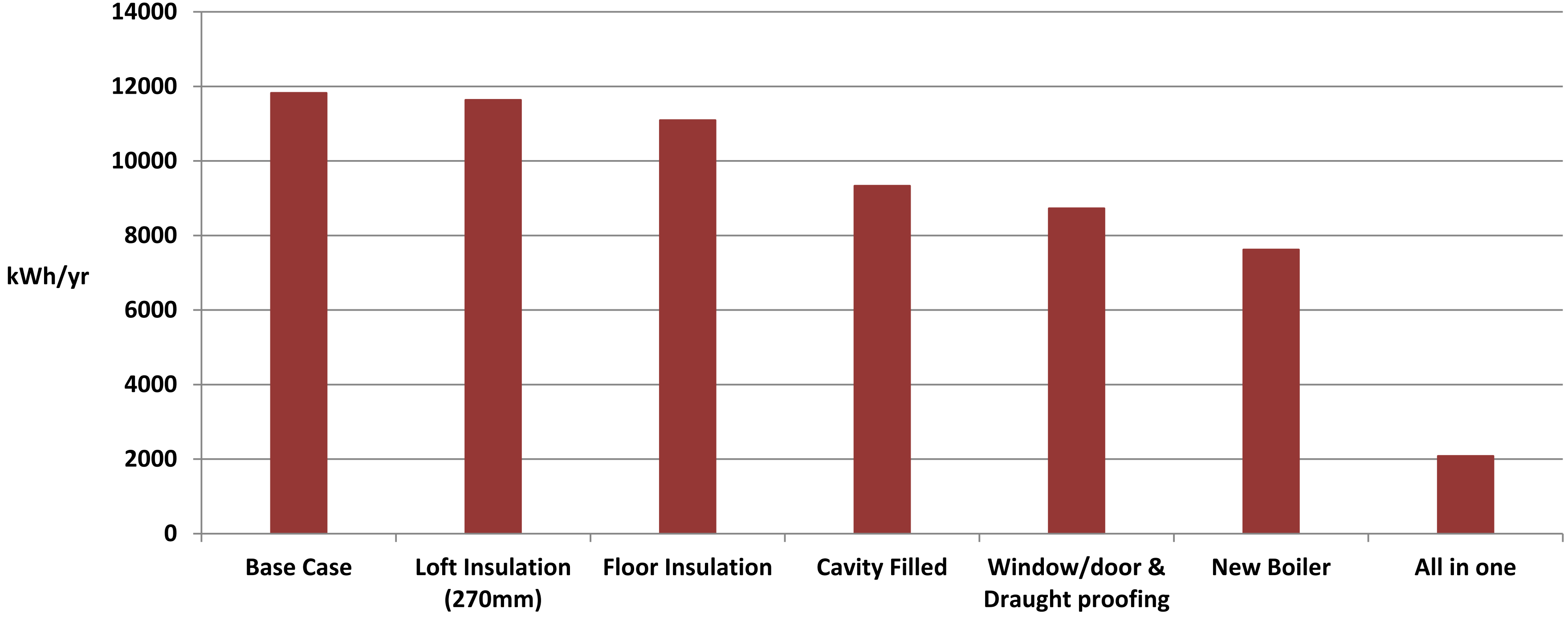
After retrofitting

Heating energy demand	2,588 kWh/yr
Heating bills	£80
Carbon emissions	512 kg/yr

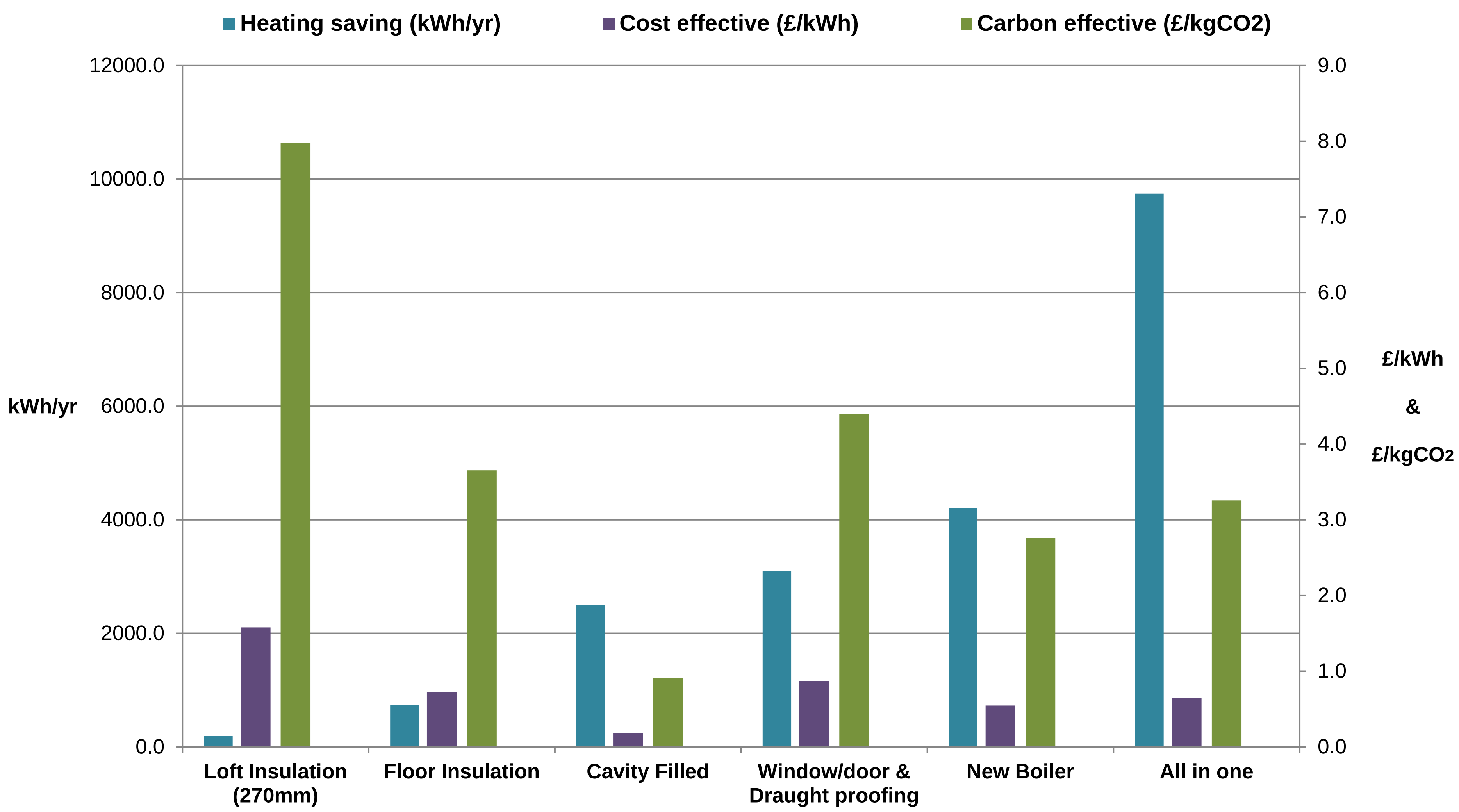
Heating energy consumption (before and after)



Various energy efficient measurements impact on heating demand



Heating energy saving, Cost and Carbon effective energy saving by various energy efficient measures (B1)



NEL1 Simulation Results (mid-terraced and uninsulated solid wall)

Base cases features

Element	Fabric U-value
Roof insulation (75mm)	0.43 W/m²K
Uninsulated solid walls	2.1 W/m²K
Uninsulated solid floor	1.1 W/m²K
Pre 2001 Double glazing	2.77 W/m²K

Other features

- Envelope air leakage rate: 16 $m^3(h.m^2)$ @ 50Pa
- 90% Boiler efficiency

Improved features

Element	Fabric U-value
Uninsulated solid wall with external wall insulation	0.3 W/m²K

Energy, bills and Carbon emissions

Heating energy demand	9,021 kWh/yr
Heating bills	£280
Carbon emissions	1,786 kg/yr

After retrofitting

Heating energy demand	6,252 kWh/yr
Heating bills	£194
Carbon emissions	1,238 kg/yr

K1 Simulation Results (Semi-detached and BISF wall)

Base cases features

Element	Fabric U-value
Roof insulation (75mm)	0.43 W/m²K
BISF walls	2.5 W/m²K
Uninsulated solid floor	0.84 W/m²K
Pre 2001 Double glazing	2.77 W/m²K

Other features

- Envelope air leakage rate: 16 $m^3(h.m^2)$ @ 50Pa
- 90% Boiler efficiency

Improved features

Element	Fabric U-value
BISF walls with external wall insulation	0.3 W/m²K

Energy, bills and Carbon emissions

Heating energy demand	12,952 kWh/yr
Heating bills	£401
Carbon emissions	2,564 kg/yr

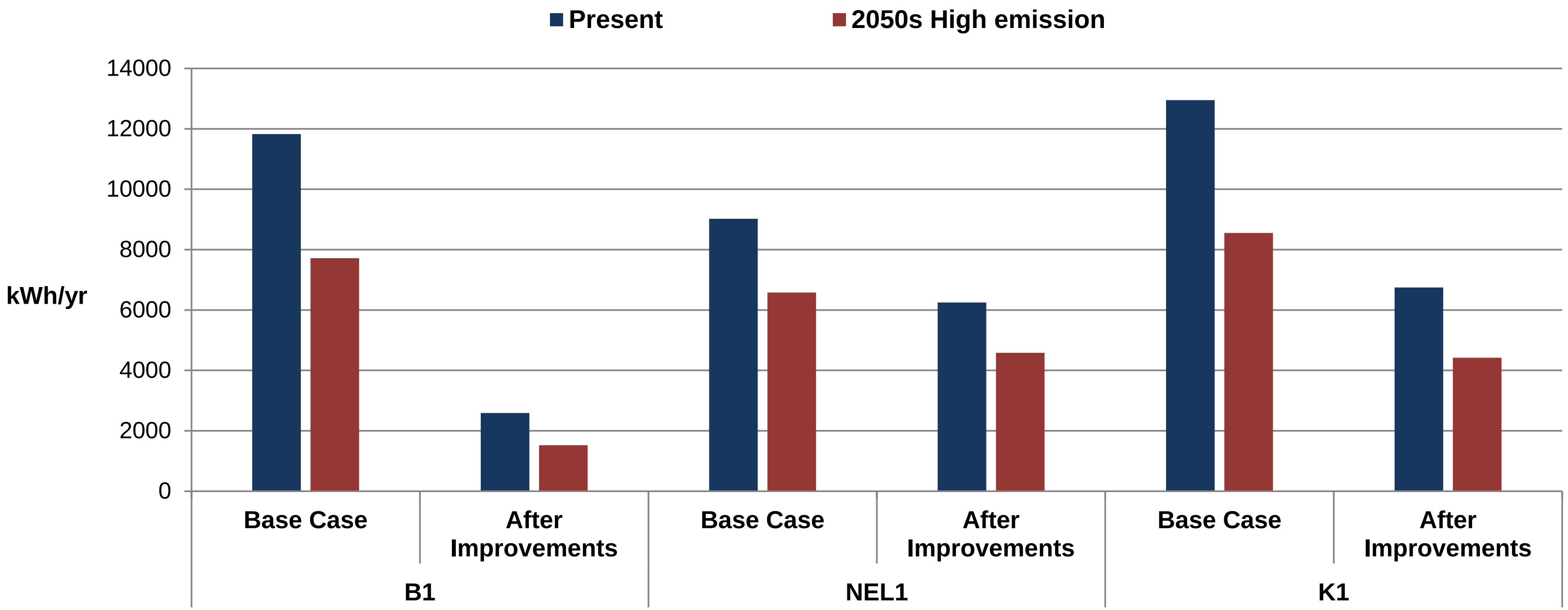
After retrofitting

Heating energy demand	6,746 kWh/yr
Heating bills	£209
Carbon emissions	1,336 kg/yr

Adapting to Changing Climate

Heating Energy Consumption

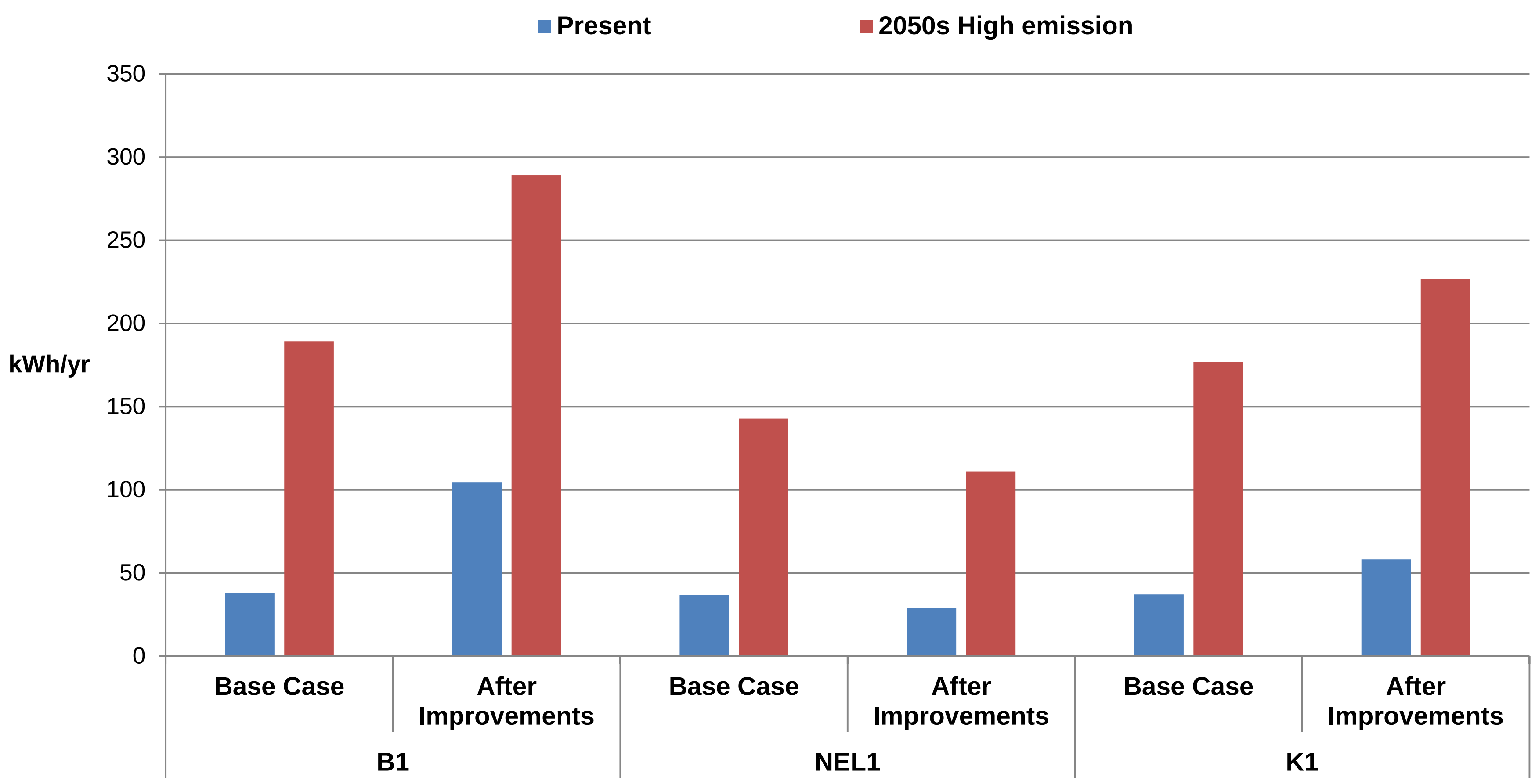
(Case Home in 2050s High Emissions Scenario)



Adapting to Changing Climate

Cooling Energy Consumption

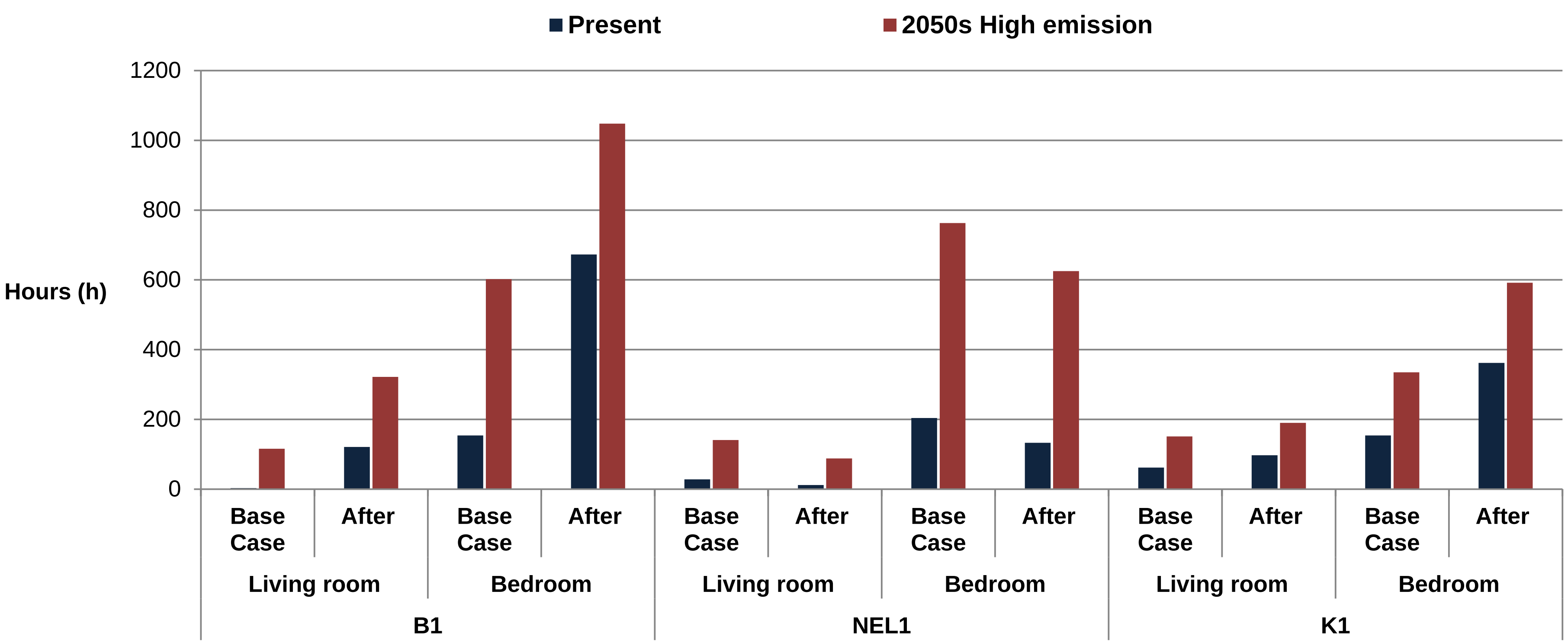
(Case Home in 2050s High Emissions Scenario)



Adapting to Changing Climate

Thermal Comfort Study

(Case Home in 2050s High Emissions Scenario)



- Simulation undertaken for 3 months (June to August) and considered during occupied hours only.

- CIBSE Guide A : Overheating criteria adopted (above 26°C for bedroom and above 28°C for living room).

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Thank You.

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