bere:architects
73 Poets Road
London N5 2SH
T +44(0)20 7359 4503
www.bere.co.uk

(Appendix 6)

3 Passfield Drive, East London

Analysis of Monitored Data

A Deep Retrofit Using Certified Passivhaus Components and Methods

July 2012

bere:architects

: Contents

1: Introduction

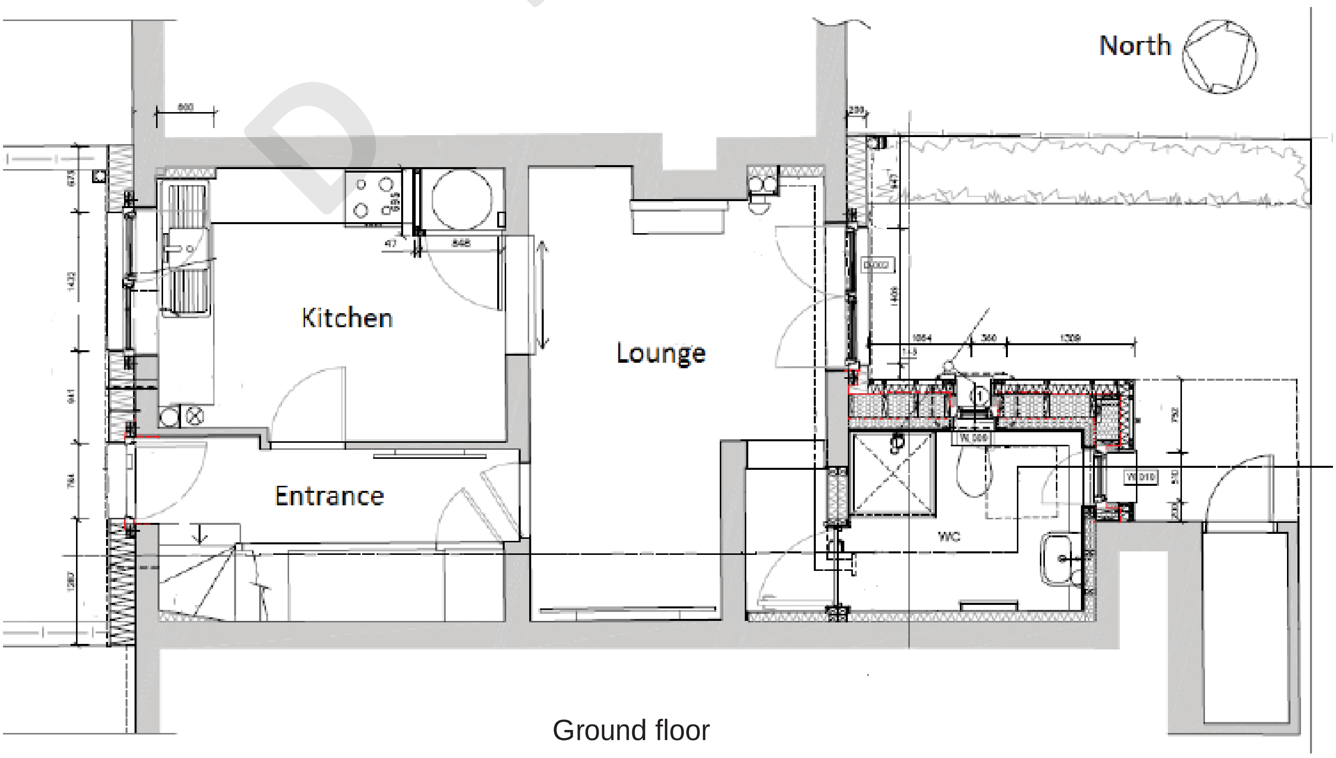
Funded by the Technology Strategy Board's 'Retrofit for the Future' programme, this house in Passfield Drive, East London, although not meeting Passivhaus or Enerphit certifiable standards, has been retrofitted by experienced passivhaus architects using a fabric-first approach, and some passivhaus components.

The retrofit started on the 18th October 2010 and finished on the 12th July 2011. As a result of this deep retrofit the energy efficiency of the house and the comfort of the occupants significantly improved. To monitor the effect of the retrofit several parameters were metered. The analysis in this report is for the period from the 16th May 2011 until the 19 February 2012. Consequently, it covers the time during and after the retrofit. Measurements were being taken remotely every 5 minutes which allowed detailed analysis of the data.

The monitored parameters are as follows:

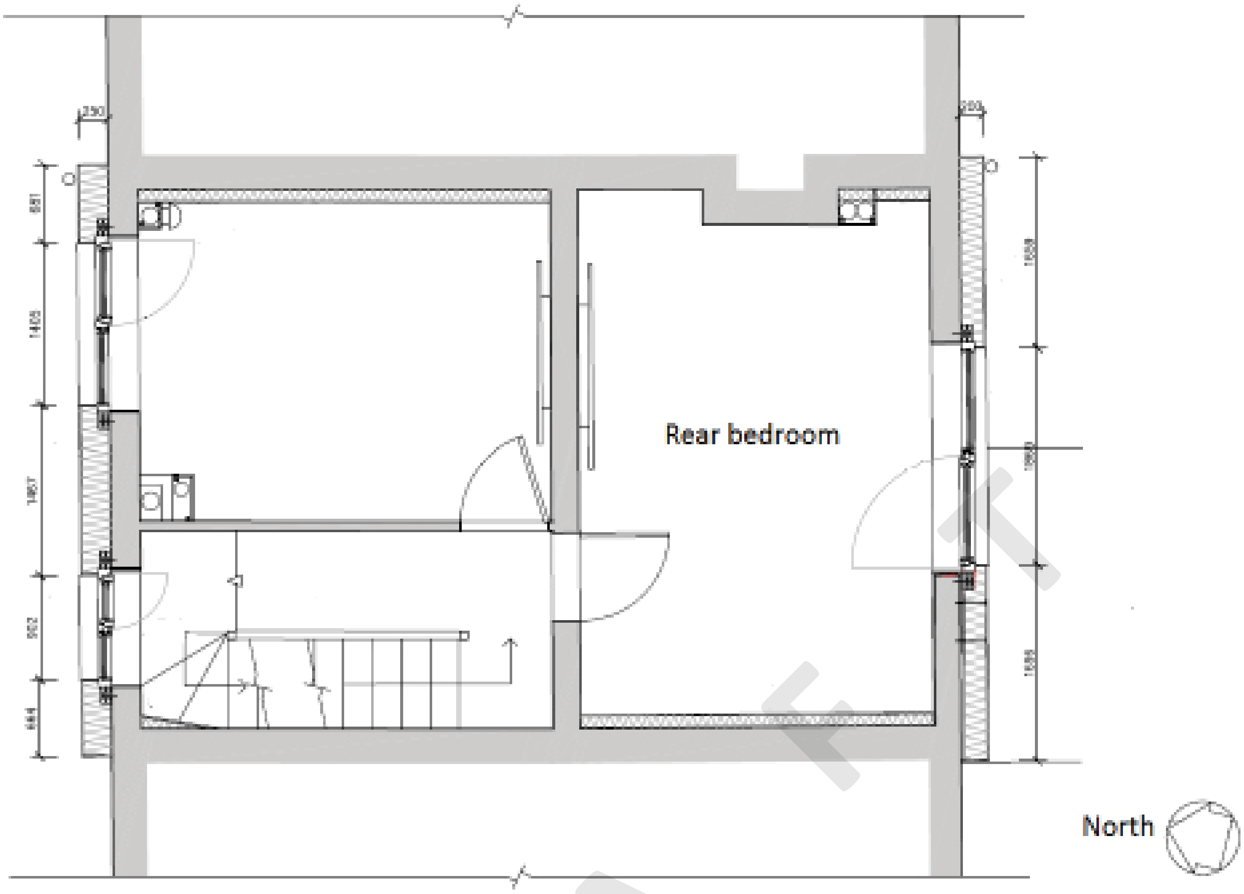
- CO_2 level [ppm];
- temperature [°C]: external, internal (lounge, bedroom 1st floor, bedroom 2nd floor;
- relative humidity [%]: external, internal (lounge, bedroom 1st floor, bedroom 2nd floor)
- solar insolation [W/m^2};
- energy [kWh]:
    - electricity,
    - gas for heating, hot water & cooking (kWh/m^3),
    - thermal panels hot water generation (not included in this report),
    - electricity used by auxiliary components of solar thermal panels (not incuded in this report).

The analysis of the data obtained aims at quantifying the energy efficiency of the house, quality of indoor microclimate and relative occupants' comfort in relation to the external conditions.

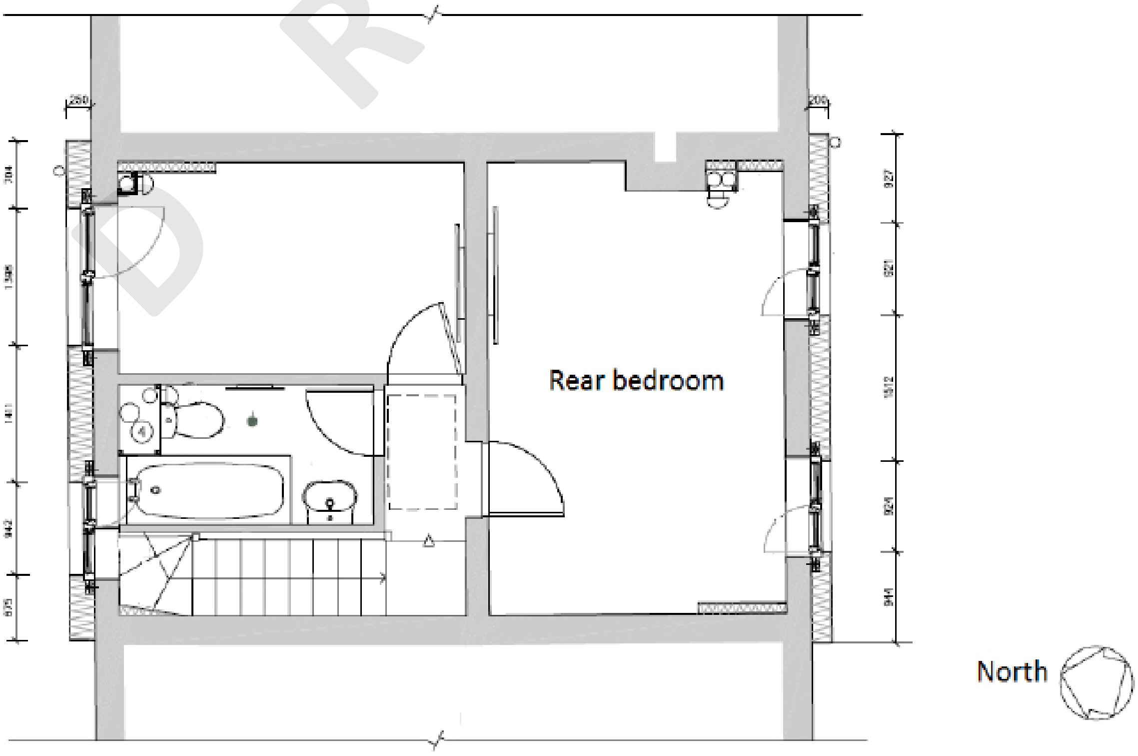


Ground floor

1st floor



2nd floor



2: Analysis and Graphs

2.1: Temperature vs Relative Humidity

The following graphs depict temperature and relative humidity for a week in each month from August 2011 to February 2012. A weekly representation of data has been chosen in order to show diurnal changes in temperatures and relative humidity. All the graphs for the whole analysed period are collated in Appendix that follows this report.

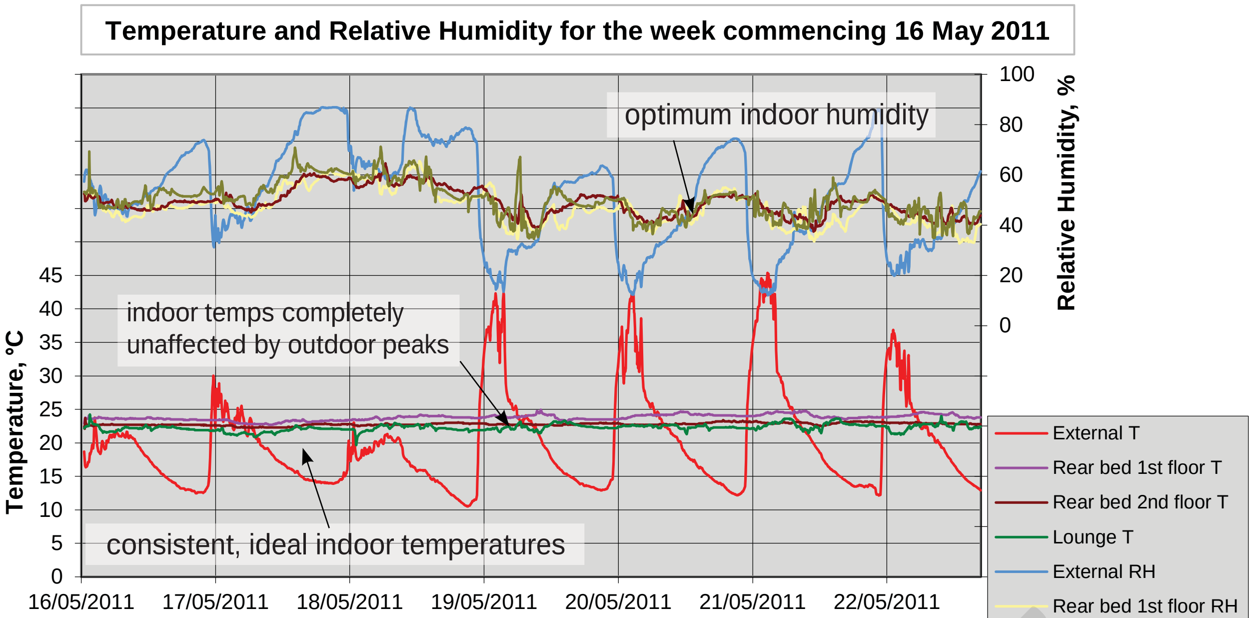
Relative humidity is very closely related to temperature. Generally, the higher the external temperature the lower the external and internal relative humidity. Moreover, if the indoor air is heated then this also reduces the relative humidity, as shown on the graphs representing the data for the winter season. This relation between relative humidity and temperatures affects thermal comfort of the occupants and is reviewed in section 2.2- Comfort Charts.

In the times when no heating is required the internal temperature changes are very small and smooth which is a an indication of good thermal performance of the house. In the colder conditions the temperature fluctuations are higher. This is likely to be attributable to the change of the thermostat set temperature or increased activity (e.g. kids playing, ironing or cooking). The increase or decrease of the associated relative humidity together with the CO_2 concentration has been used as good marker of the occupancy and activity in the house.

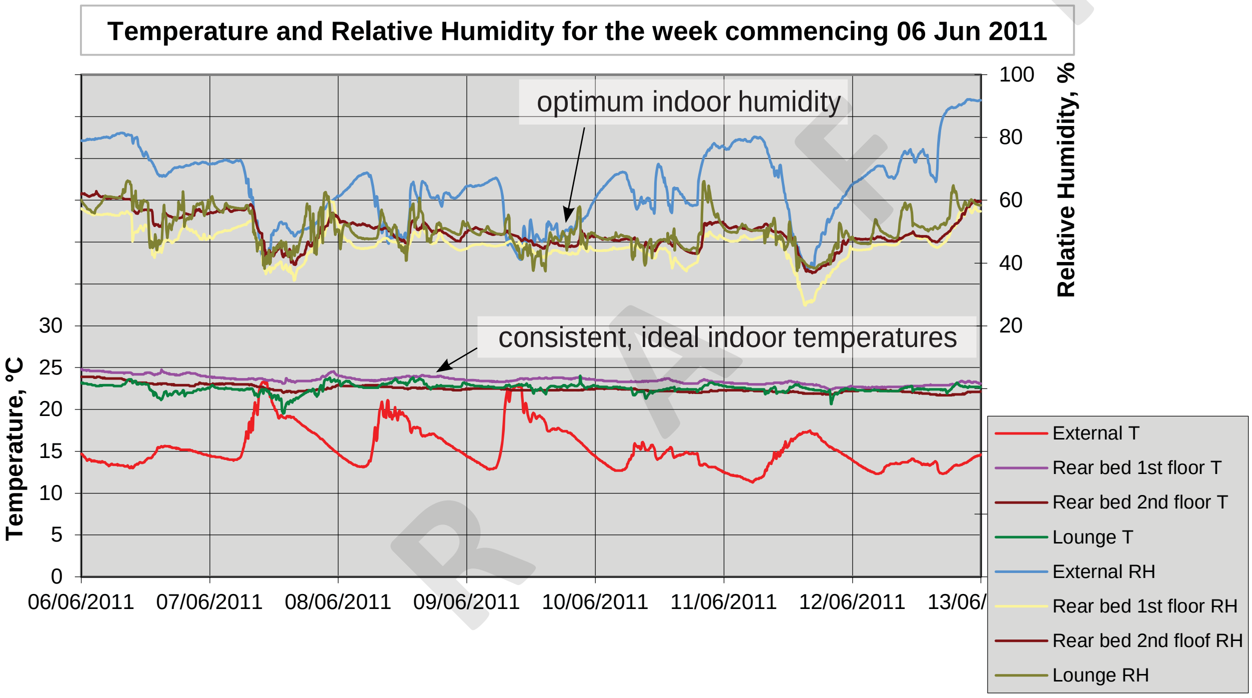
The temperature and relative humidity trends for all three monitored rooms are very similar. This demonstrates effective distribution of the ventilation air and efficient heat recovery by the mechanical ventilation. This also means that the changes in the external conditions have an insignificant effect on the interior conditions.

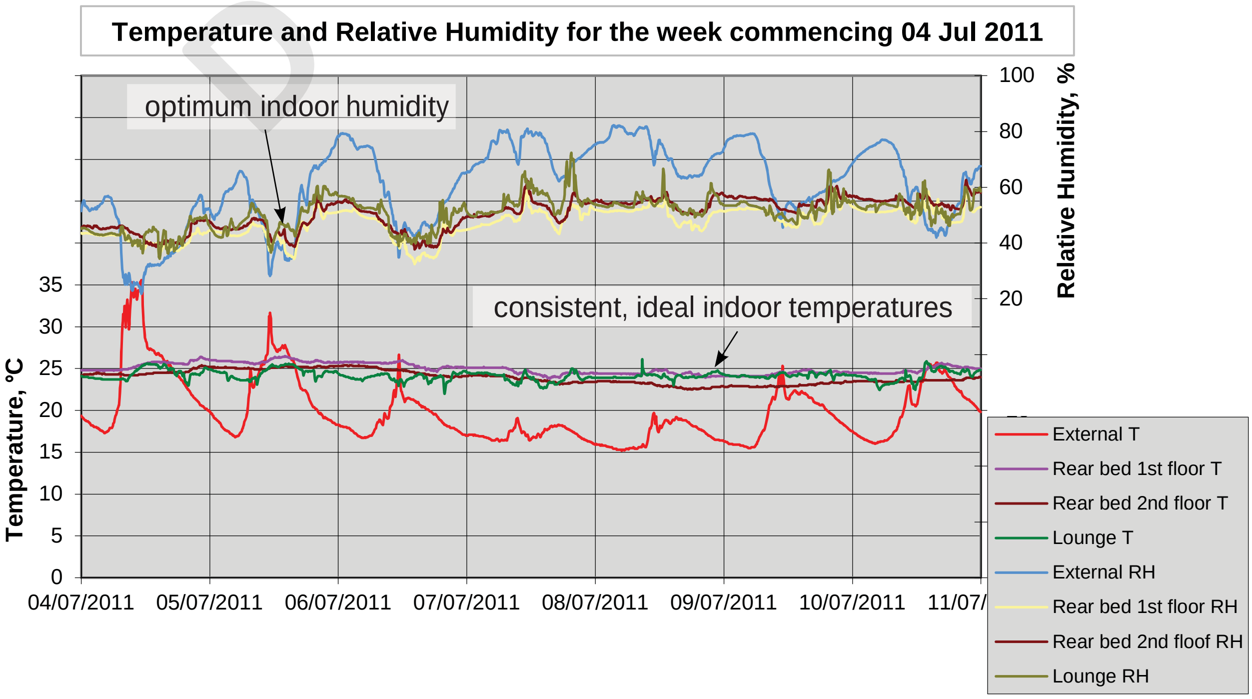
Greater fluctuations of the temperature and relative humidity occur in the lounge. This is expected considering that the lounge is a common area for the occupants and is also in vicinity of the kitchen which is the source of moisture and heat.

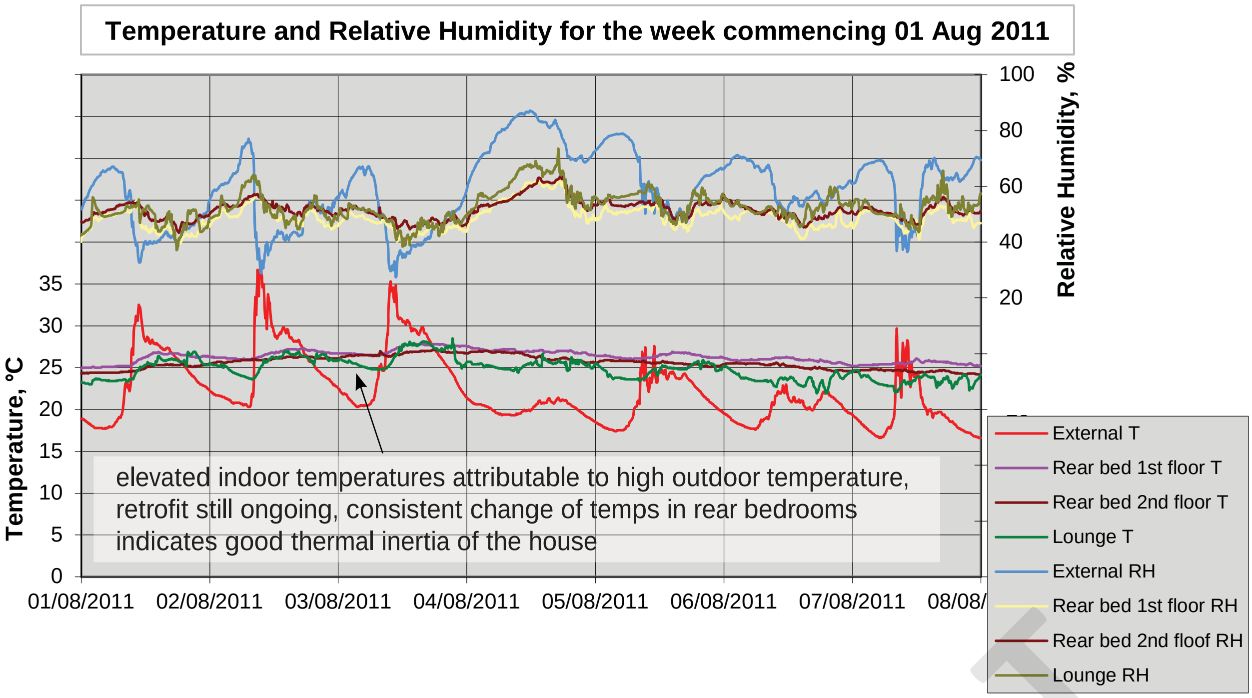
Some of the graphs show very high false external temperatures in midday of sunny days which is caused by exposure of the sensor to direct sunlight. The casing warms up and the sensor's indication is overstated.

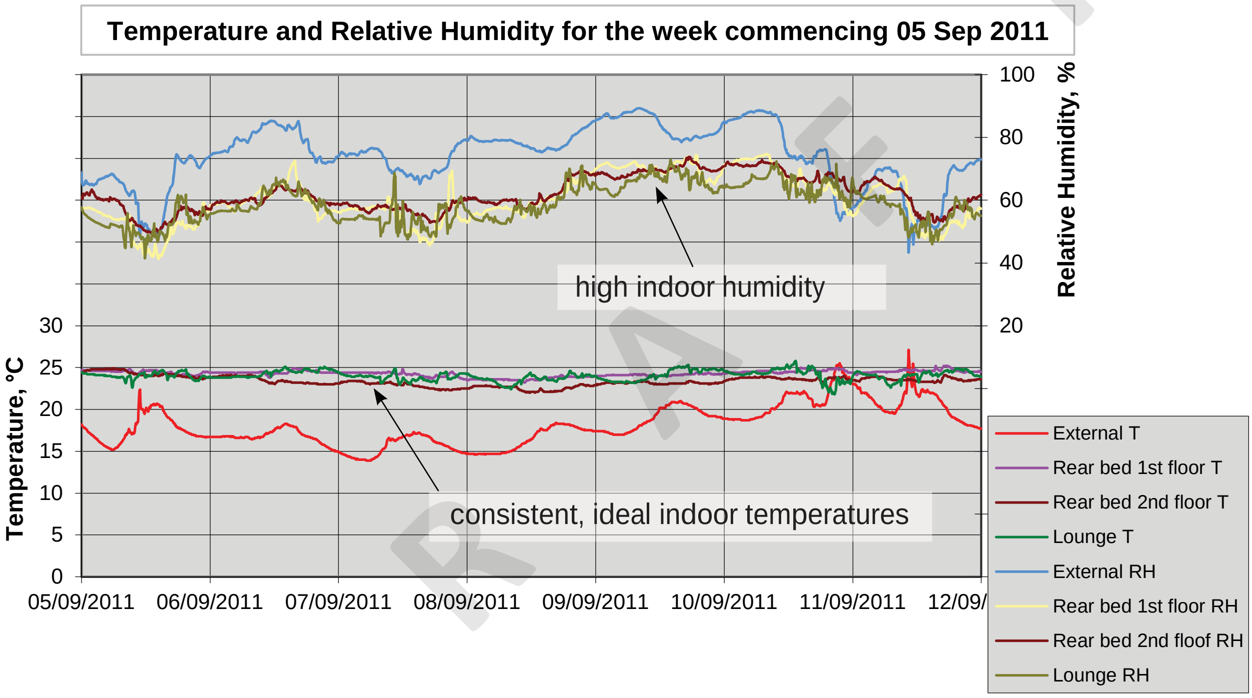


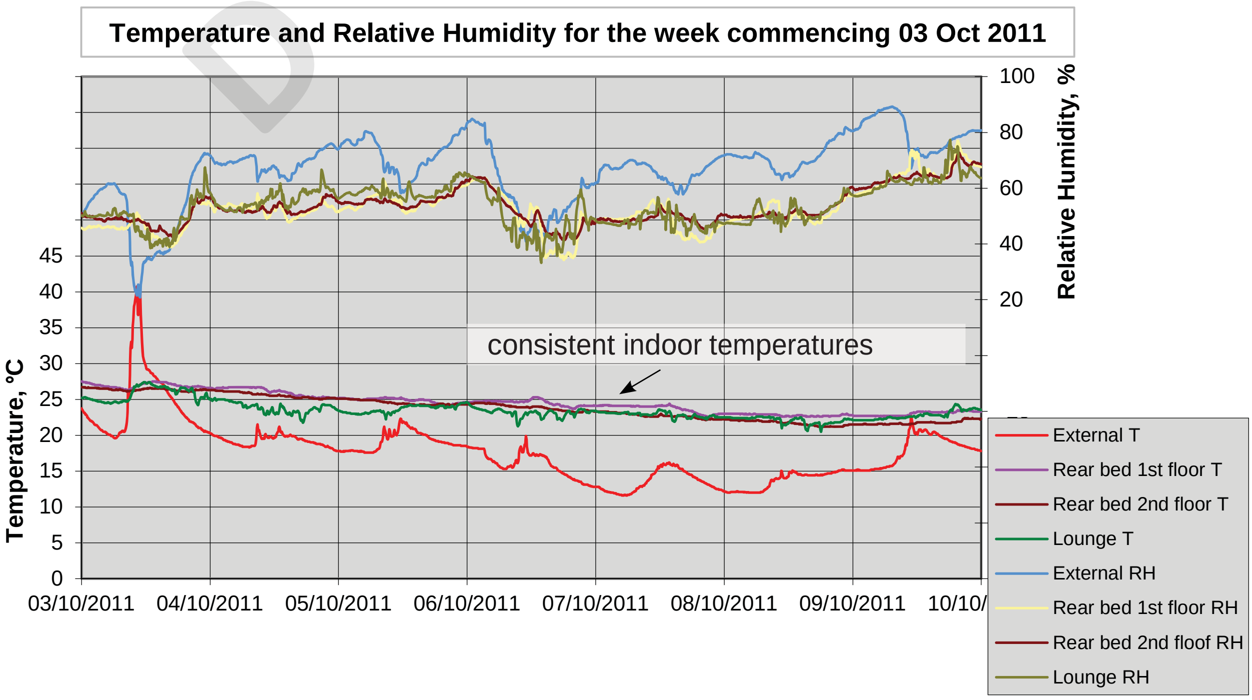
*External temperature sensor is showing false readings in this period due to direct exposure to solar radiation

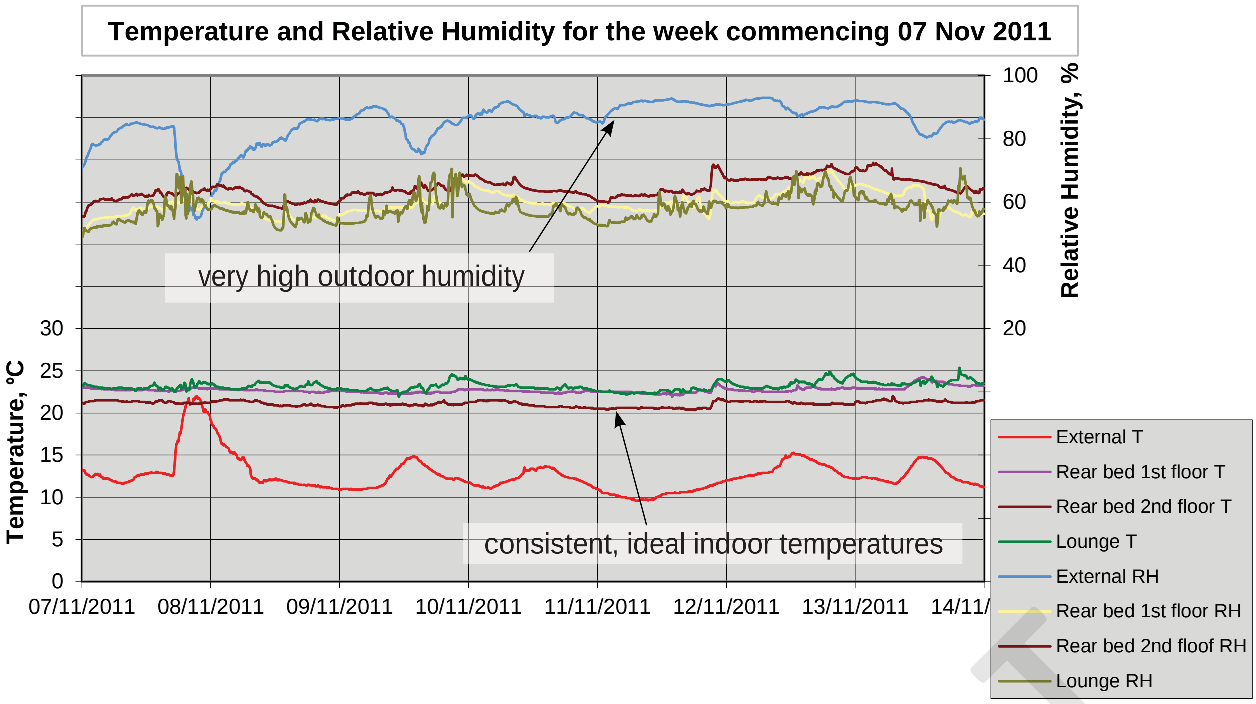




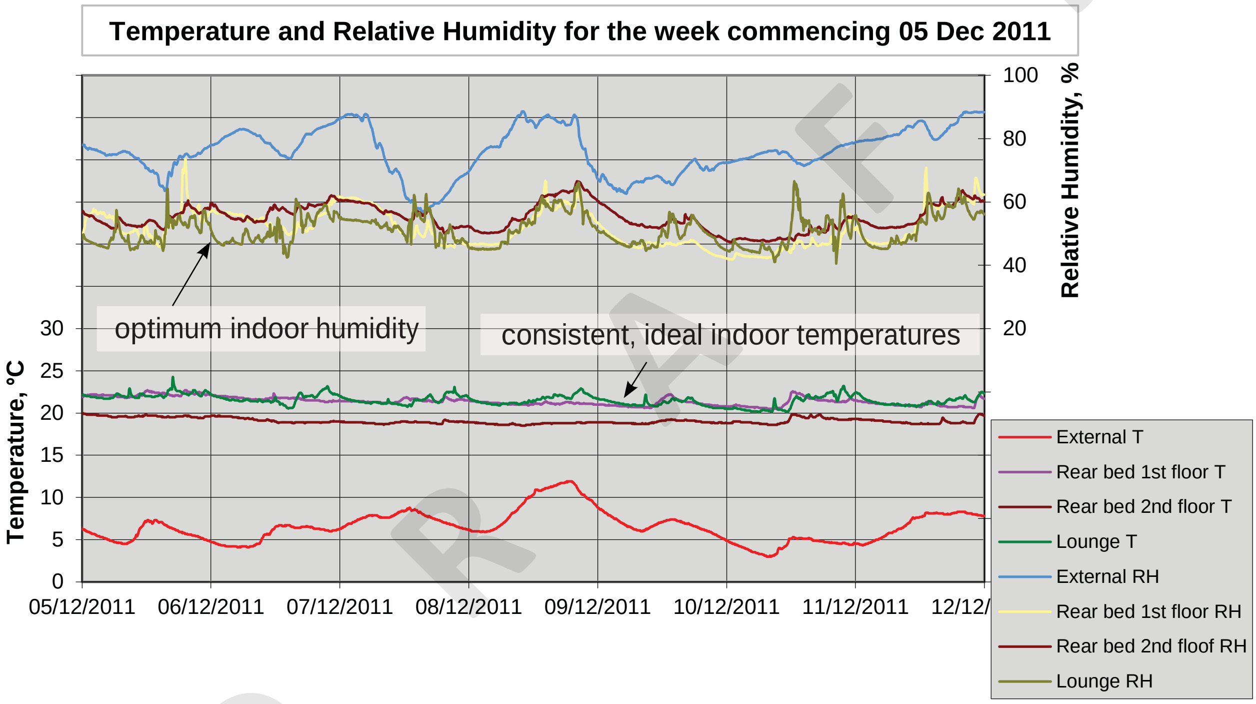

Temperature and Relative Humidity for the week commencing 01 Aug 2011
Temperature, °C
Relative Humidity, %
elevated indoor temperatures attributable to high outdoor temperature, retrofit still ongoing, consistent change of temps in rear bedrooms indicates good thermal inertia of the house
01/08/2011
02/08/2011
03/08/2011
04/08/2011
05/08/2011
06/08/2011
07/08/2011
08/08/
External T
Rear bed 1st floor T
Rear bed 2nd floor T
Lounge T
External RH
Rear bed 1st floor RH
Rear bed 2nd floof RH
Lounge RH


Temperature and Relative Humidity for the week commencing 05 Sep 2011
Temperature, °C
Relative Humidity, %
high indoor humidity
consistent, ideal indoor temperatures
05/09/2011
06/09/2011
07/09/2011
08/09/2011
09/09/2011
10/09/2011
11/09/2011
12/09/
External T
Rear bed 1st floor T
Rear bed 2nd floor T
Lounge T
External RH
Rear bed 1st floor RH
Rear bed 2nd floof RH
Lounge RH

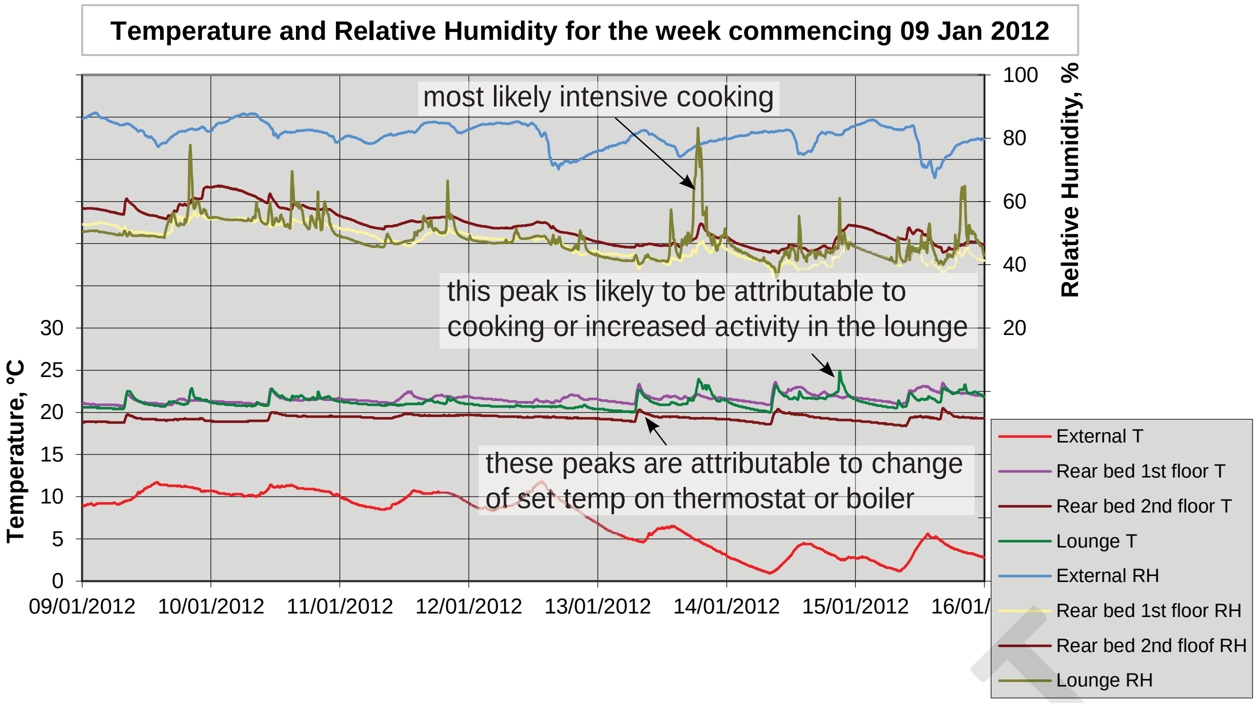

Temperature and Relative Humidity for the week commencing 03 Oct 2011
Temperature, °C
Relative Humidity, %
consistent indoor temperatures
03/10/2011
04/10/2011
05/10/2011
06/10/2011
07/10/2011
08/10/2011
09/10/2011
10/10/
External T
Rear bed 1st floor T
Rear bed 2nd floor T
Lounge T
External RH
Rear bed 1st floor RH
Rear bed 2nd floof RH
Lounge RH

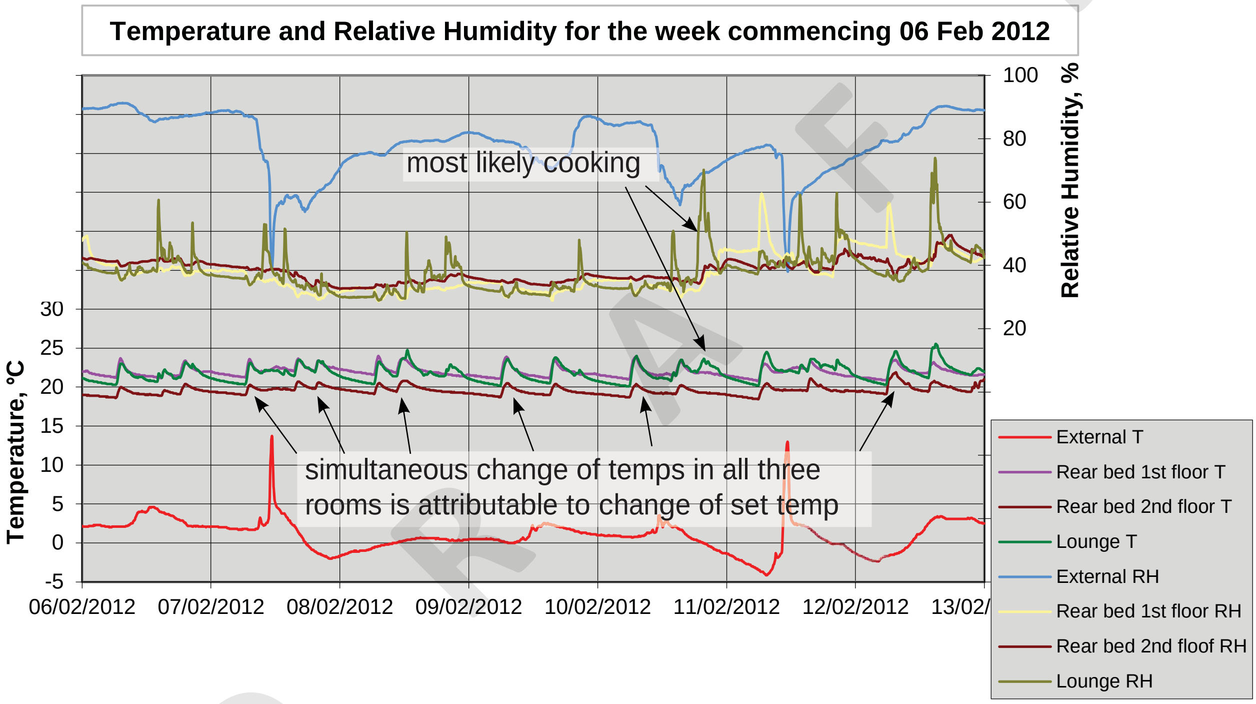


Temperature and Relative Humidity for the week commencing 07 Nov 2011
very high outdoor humidity
consistent, ideal indoor temperatures
Temperature, °C
Relative Humidity, %
07/11/2011
08/11/2011
09/11/2011
10/11/2011
11/11/2011
12/11/2011
13/11/2011
14/11/
External T
Rear bed 1st floor T
Rear bed 2nd floor T
Lounge T
External RH
Rear bed 1st floor RH
Rear bed 2nd floof RH
Lounge RH



Temperature and Relative Humidity for the week commencing 05 Dec 2011
optimum indoor humidity
consistent, ideal indoor temperatures
Temperature, °C
Relative Humidity, %
05/12/2011
06/12/2011
07/12/2011
08/12/2011
09/12/2011
10/12/2011
11/12/2011
12/12/
External T
Rear bed 1st floor T
Rear bed 2nd floor T
Lounge T
External RH
Rear bed 1st floor RH
Rear bed 2nd floof RH
Lounge RH





bere:architects

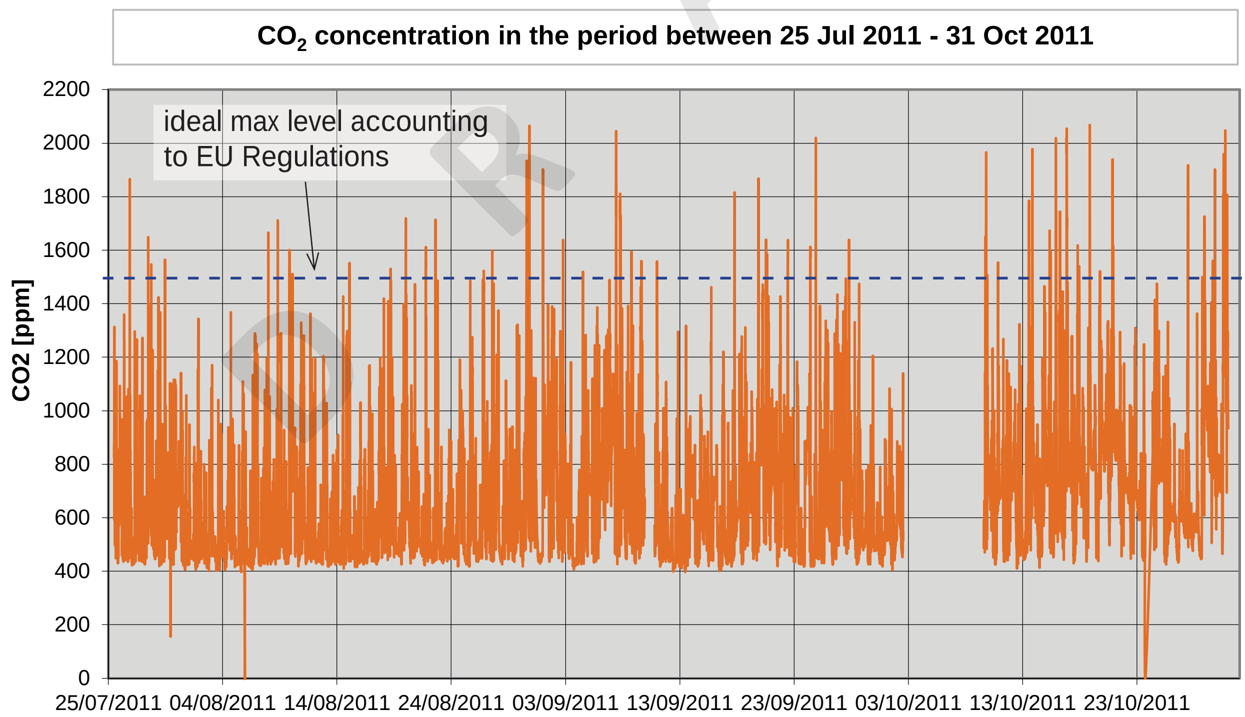
2: Analysis and Graphs

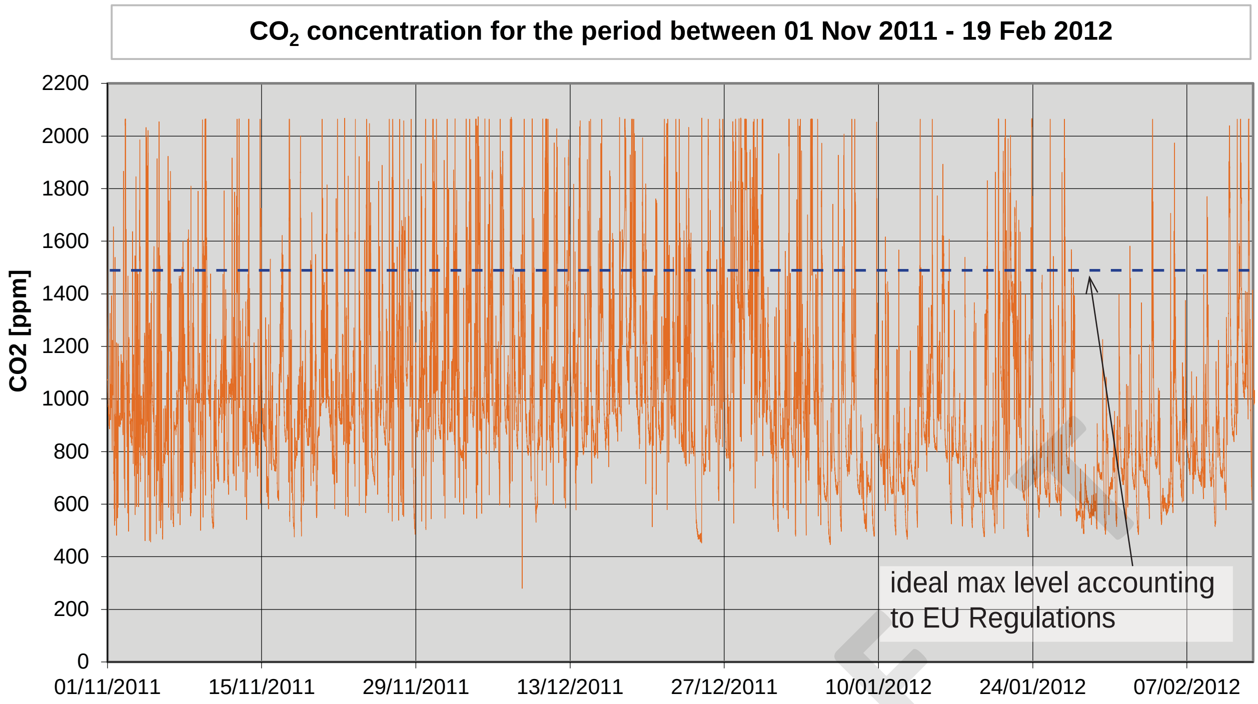
2.2: Comfort Charts

2.2.1: CO_2

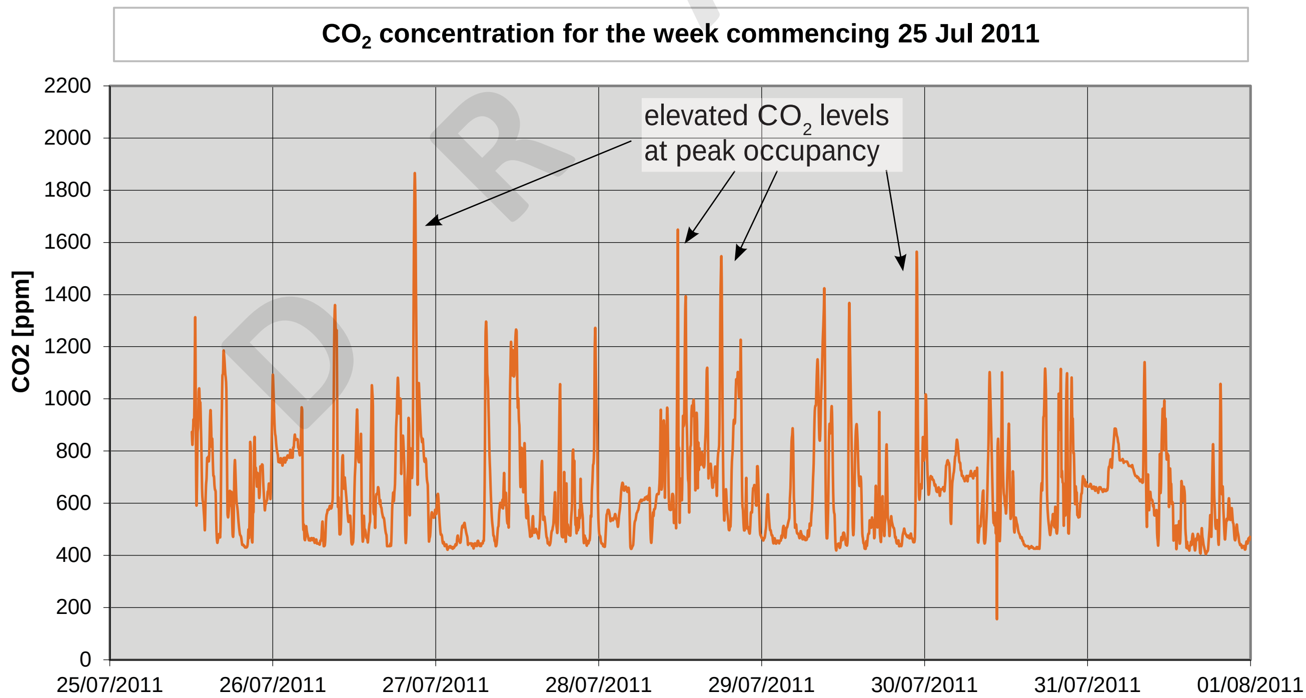
Human comfort depends on thermal comfort and air quality. The thermal comfort perception is very individual. Some people prefer cooler and some prefer warmer air. In addition the relative humidity plays a significant role in creating a feeling of comfort or discomfort. Generally it is possible to say when most people feel comfortable depending on given temperature and relative humidity (see 2.2.3 Temperature vs Relative Humidity). Another factor is the quality of air which except of VOCs (volatile organic compounds) is determined by the level of carbon dioxide in the air.

During peak occupancy the measured CO_2 levels sometimes exceed maximum treshold (1500ppm) of the optimal range accroding EU Regulations. The CO_2 sensor is located in the lounge which is in close vicinity to the kitchen and a gas cooker. Burning gas a significant source of CO_2 which is most probaly contributing to elevated CO_2 levels.

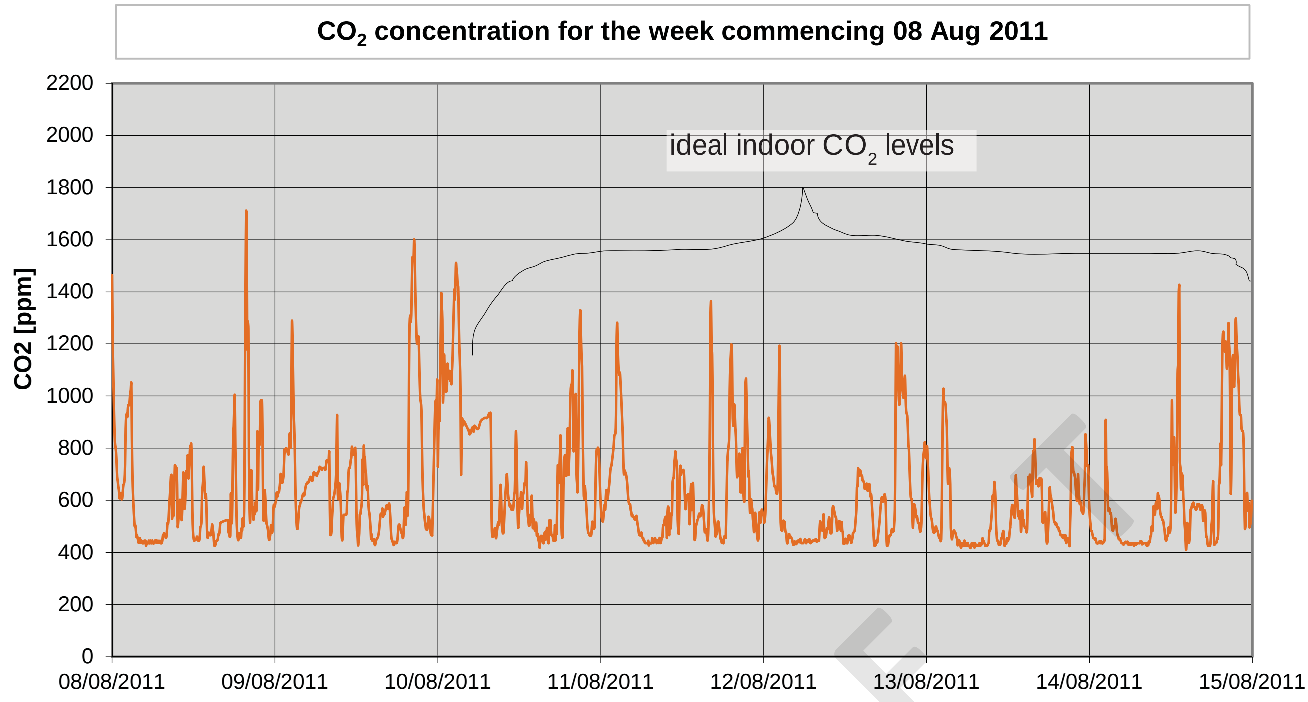


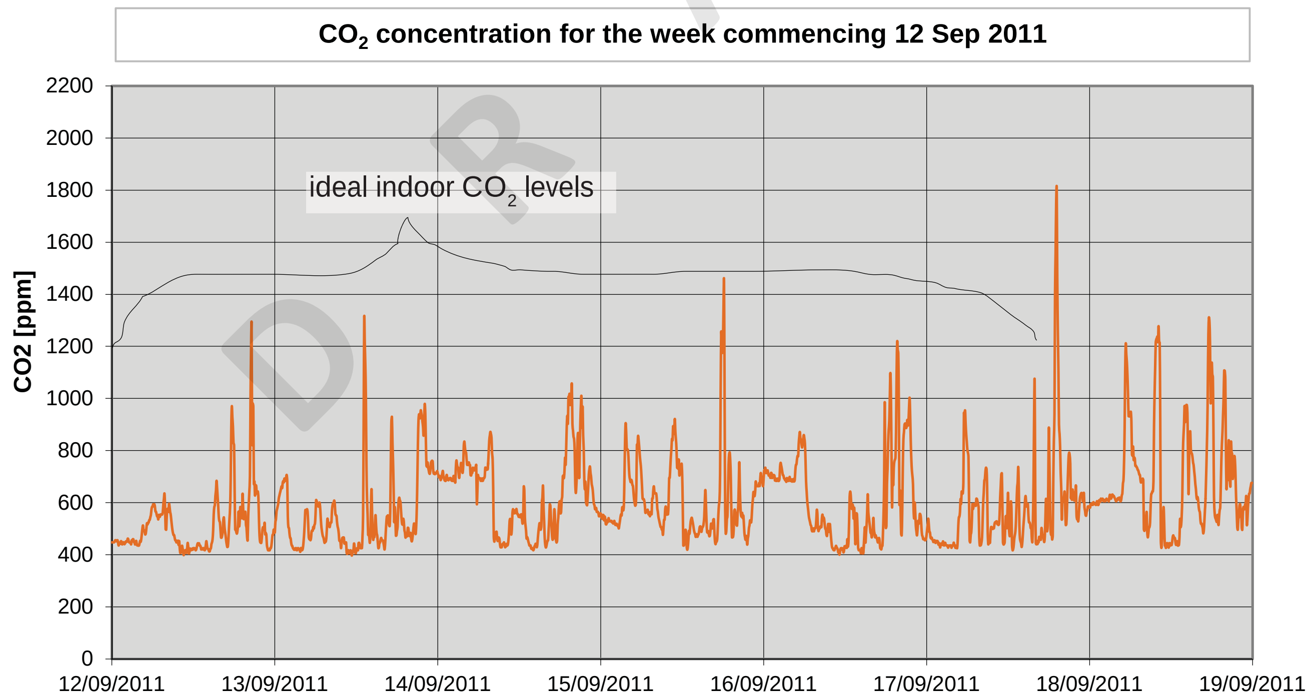


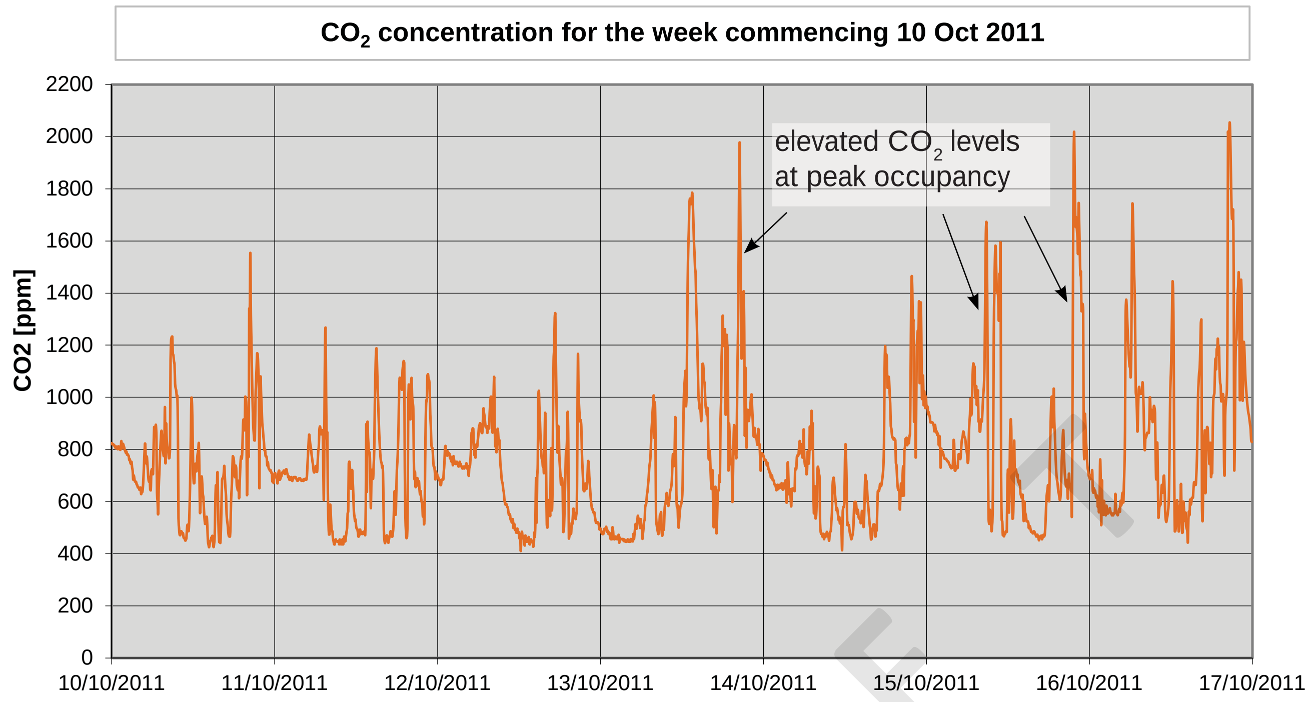
CO_2 concentration for the period between 01 Nov 2011 - 19 Feb 2012
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
01/11/2011
15/11/2011
29/11/2011
13/12/2011
27/12/2011
10/01/2012
24/01/2012
07/02/2012
ideal max level accounting to EU Regulations



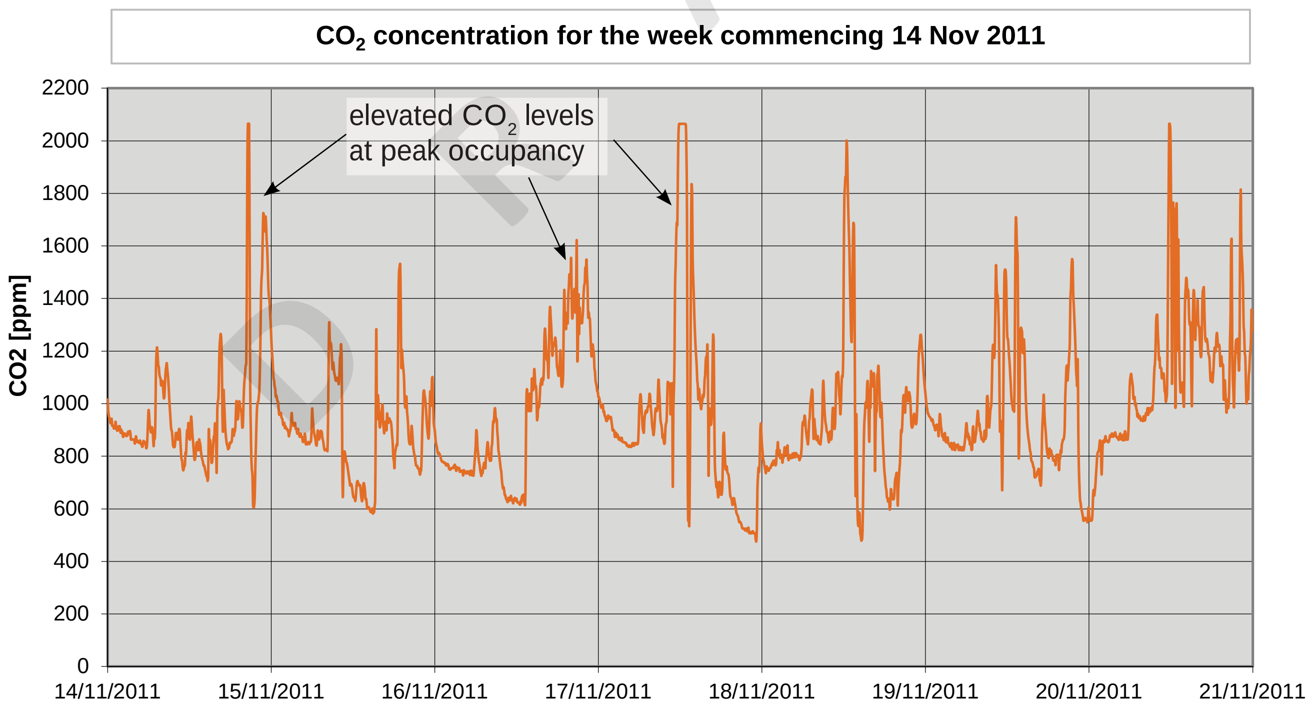
CO_2 concentration for the week commencing 25 Jul 2011
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
25/07/2011
26/07/2011
27/07/2011
28/07/2011
29/07/2011
30/07/2011
31/07/2011
01/08/2011
elevated CO_2 levels at peak occupancy


CO_2 concentration for the week commencing 08 Aug 2011
ideal indoor CO_2 levels
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
08/08/2011
09/08/2011
10/08/2011
11/08/2011
12/08/2011
13/08/2011
14/08/2011
15/08/2011

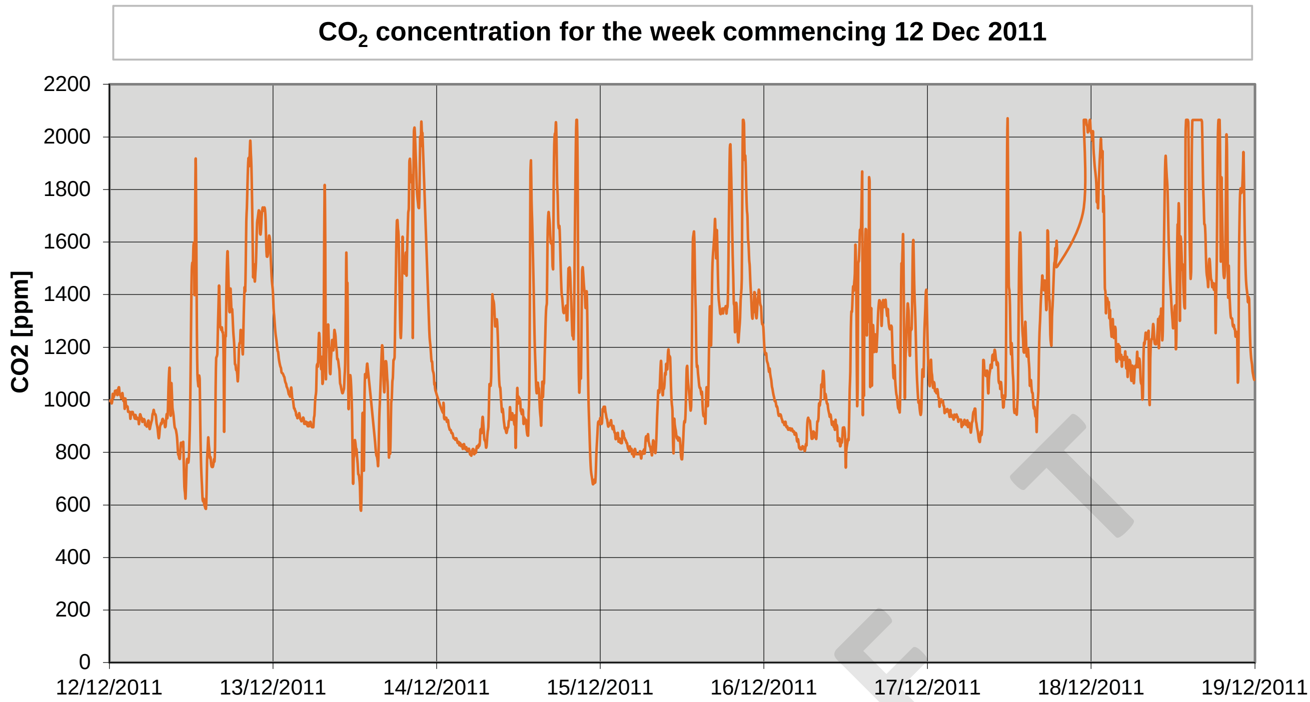

CO_2 concentration for the week commencing 12 Sep 2011
ideal indoor CO_2 levels
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
12/09/2011
13/09/2011
14/09/2011
15/09/2011
16/09/2011
17/09/2011
18/09/2011
19/09/2011

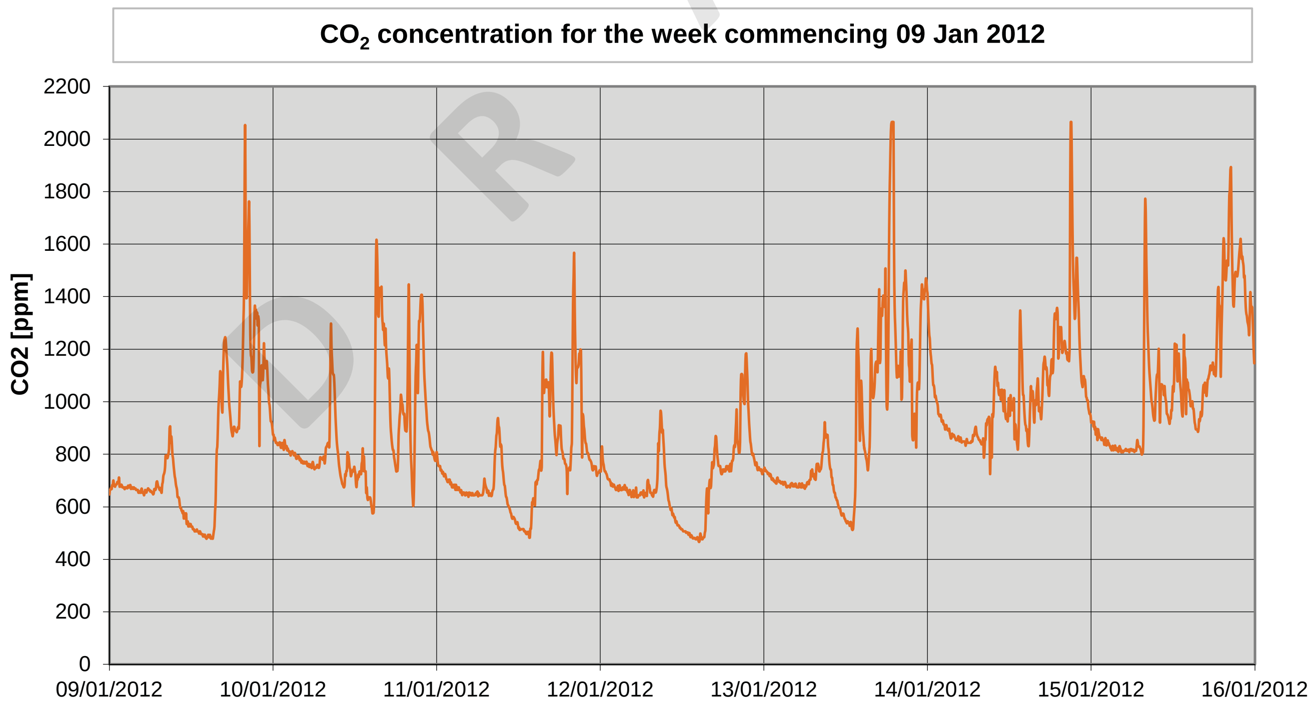


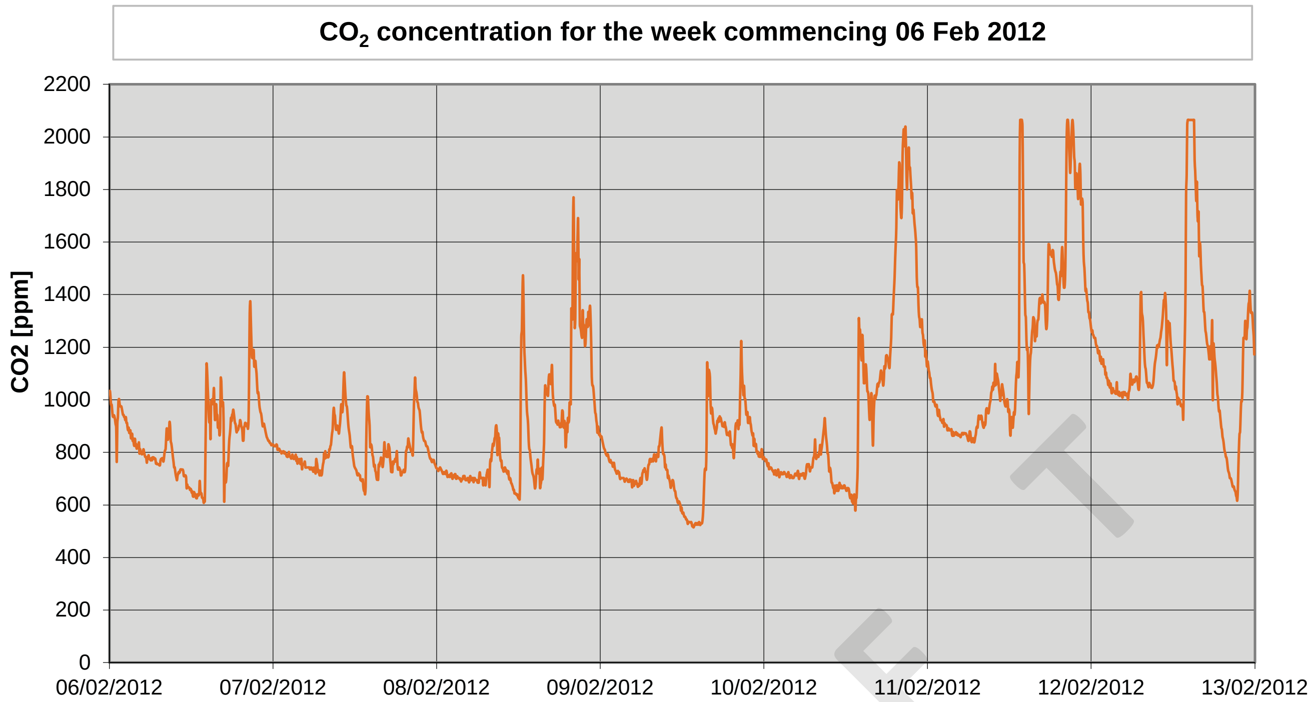
CO_2 concentration for the week commencing 10 Oct 2011
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
10/10/2011
11/10/2011
12/10/2011
13/10/2011
14/10/2011
15/10/2011
16/10/2011
17/10/2011
elevated CO_2 levels
at peak occupancy



CO_2 concentration for the week commencing 14 Nov 2011
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
14/11/2011
15/11/2011
16/11/2011
17/11/2011
18/11/2011
19/11/2011
20/11/2011
21/11/2011
elevated CO_2 levels
at peak occupancy


CO2 concentration for the week commencing 12 Dec 2011
CO2 [ppm]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
12/12/2011
13/12/2011
14/12/2011
15/12/2011
16/12/2011
17/12/2011
18/12/2011
19/12/2011


CO2 concentration for the week commencing 09 Jan 2012
CO2 [ppm]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
09/01/2012
10/01/2012
11/01/2012
12/01/2012
13/01/2012
14/01/2012
15/01/2012
16/01/2012



CO2 concentration for the week commencing 06 Feb 2012
CO2 [ppm]
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
06/02/2012
07/02/2012
08/02/2012
09/02/2012
10/02/2012
11/02/2012
12/02/2012
13/02/2012

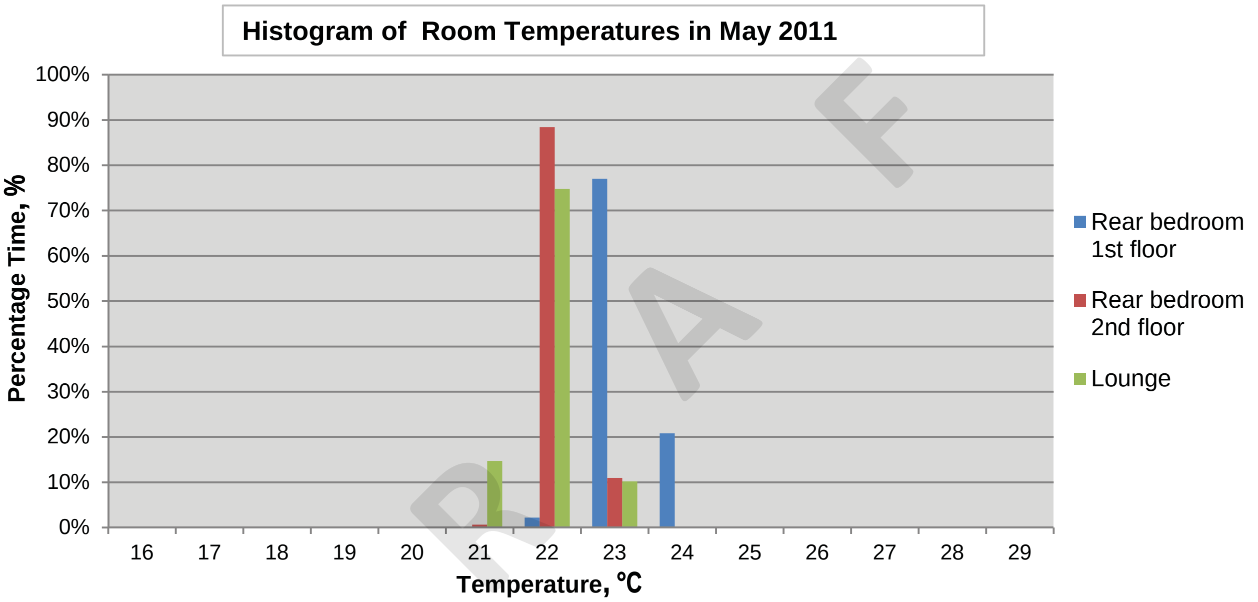
2: Analysis and Graphs

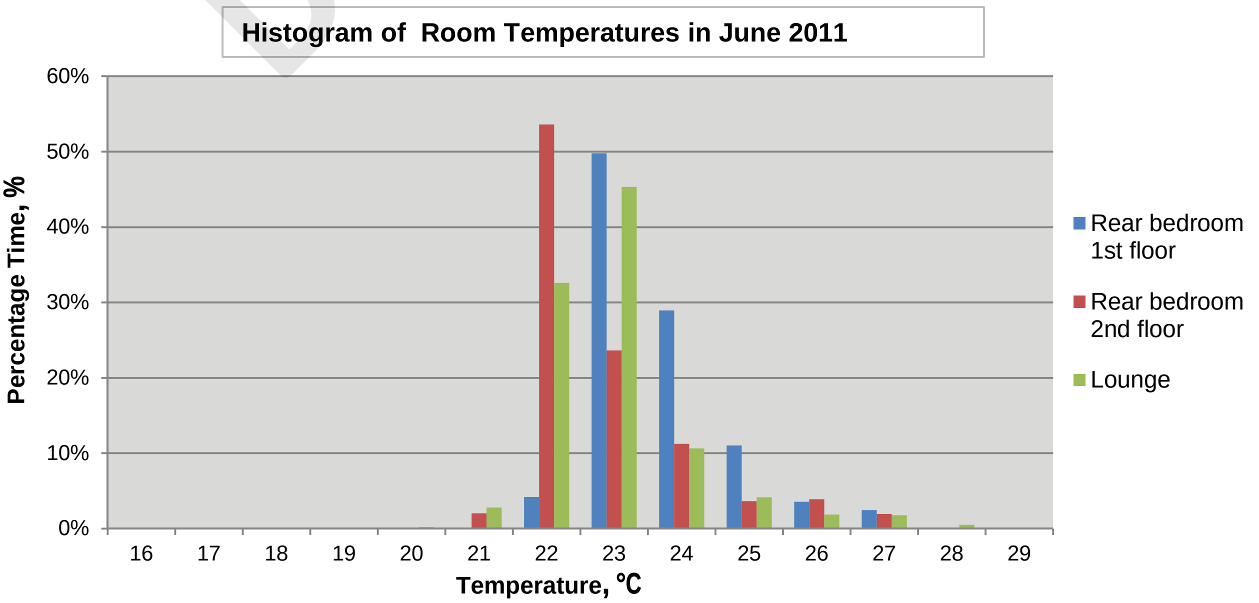
2.2: Comfort Charts

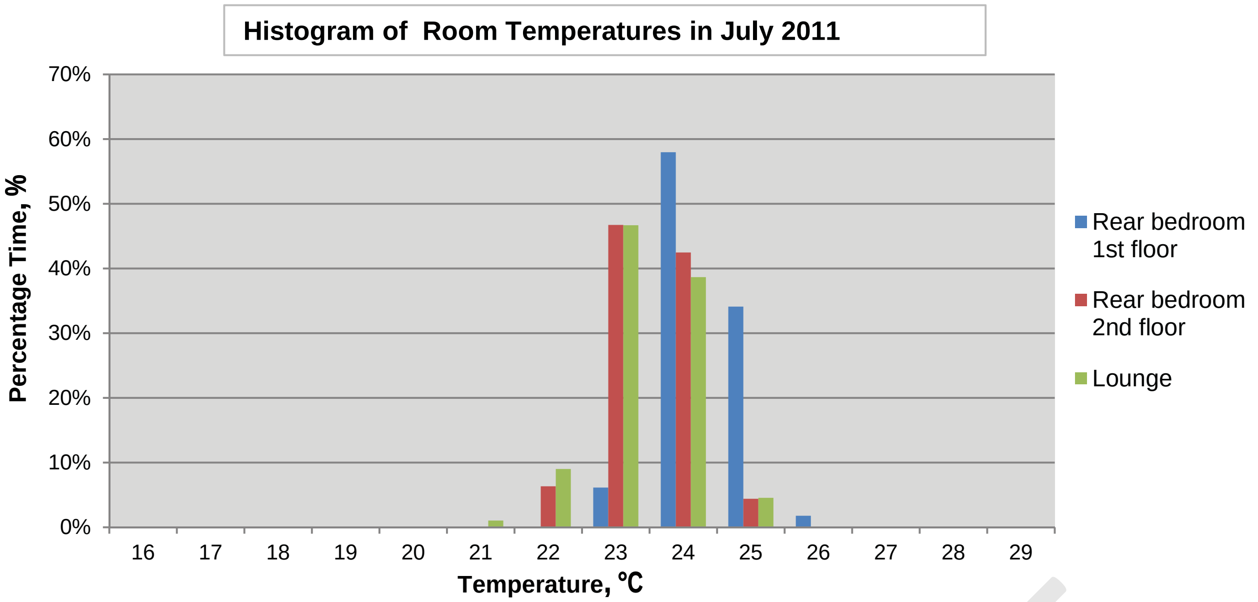
2.2.2: Indoor Temperatures Occurrence

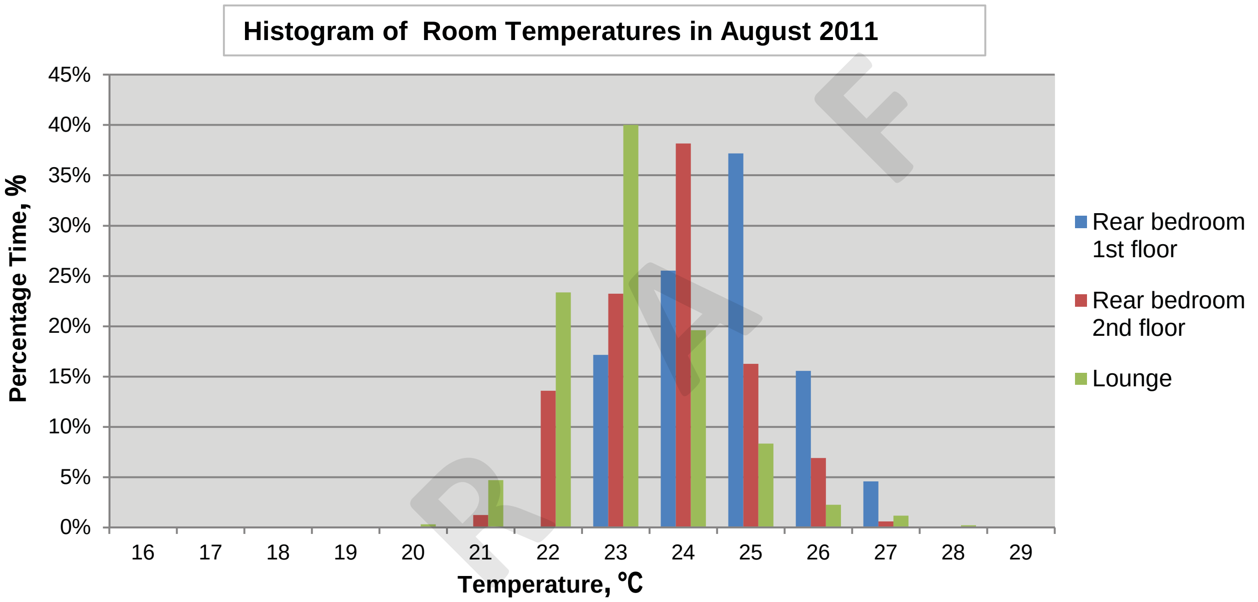
The histograms below represent frequencies of temperatures measured in the monitored rooms after the retrofit. In the cooler external conditions the lounge was kept slightly warmer than the other two rooms and the 2nd floor rear bedroom was kept cooler.

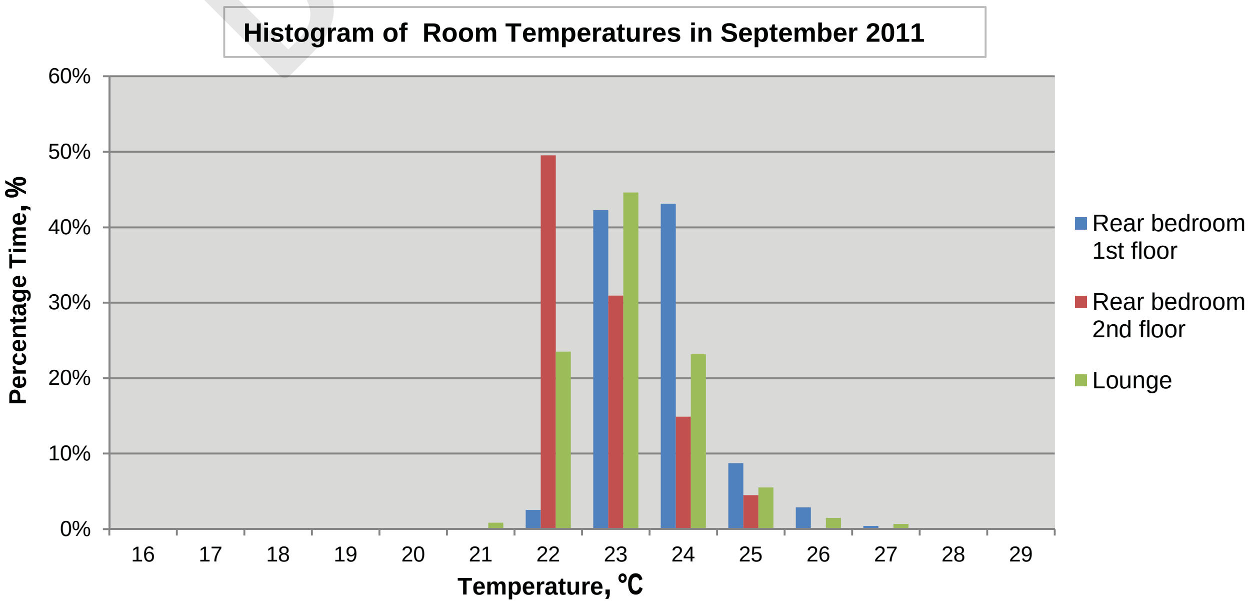
When heating was required the temperatures in the lounge and 1st floor rear bedroom almost never dropped below 20 degrees while it was quite frequent for the 2nd floor rear bedroom. This might indicate that the 2nd floor rear bedroom was unoccupied or the occupants felt the most comfortable in cooler conditions. During summer overheating is noticeable in rear 1st floor bedroom, which is most probably due to the fact that it was not occupied during the day and thus internal conditions were not controlled.

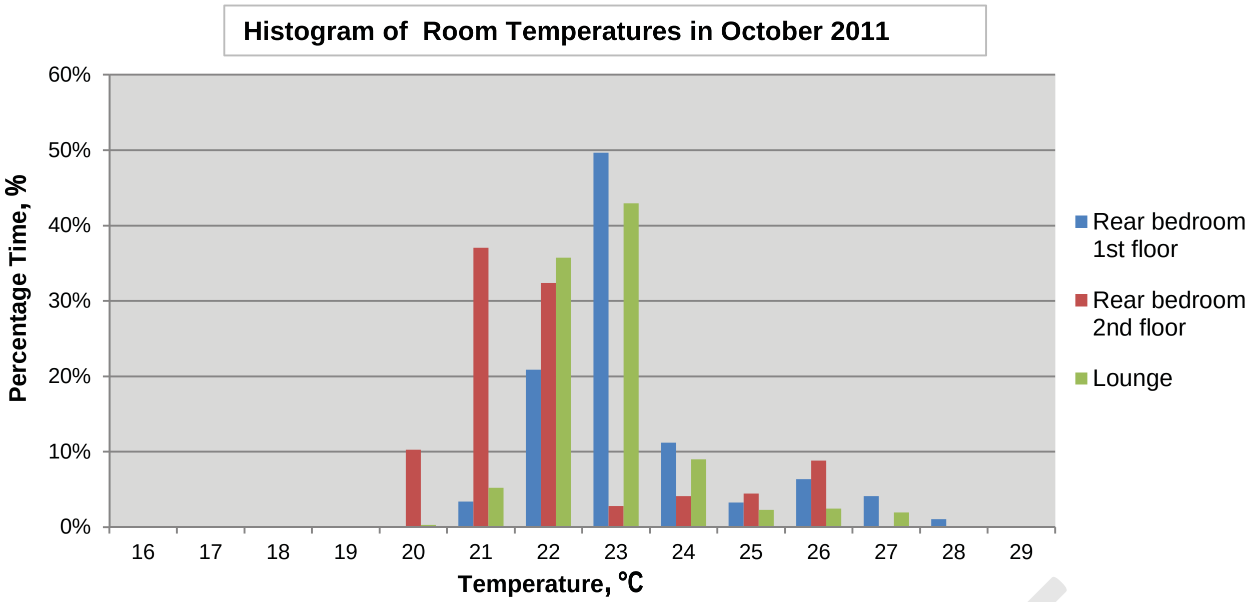


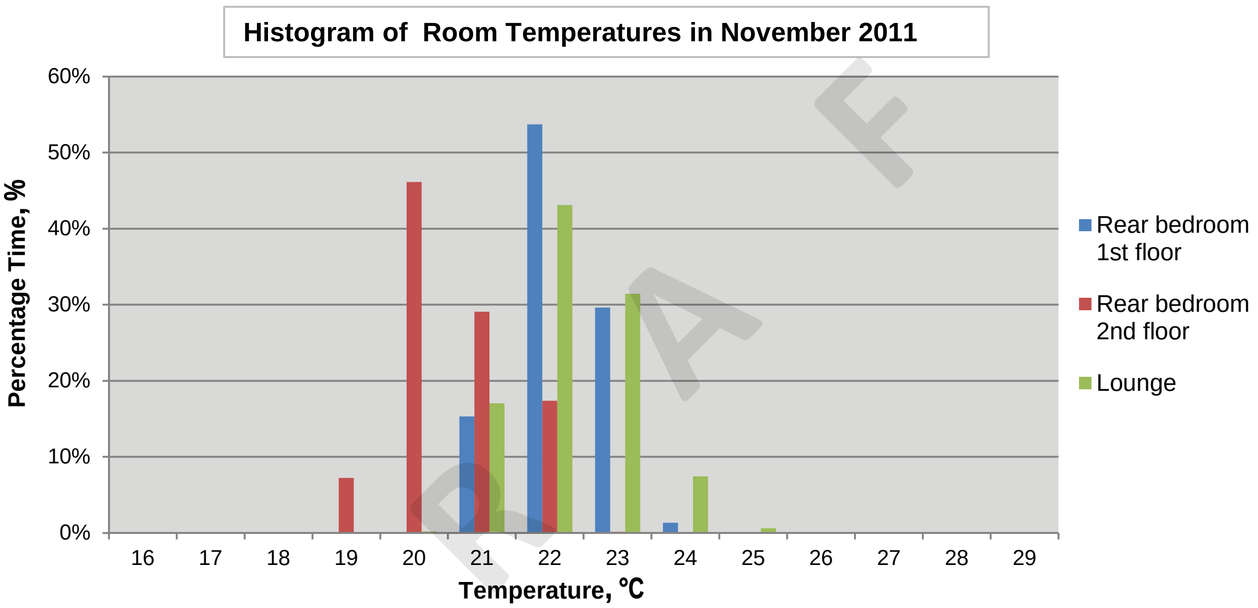


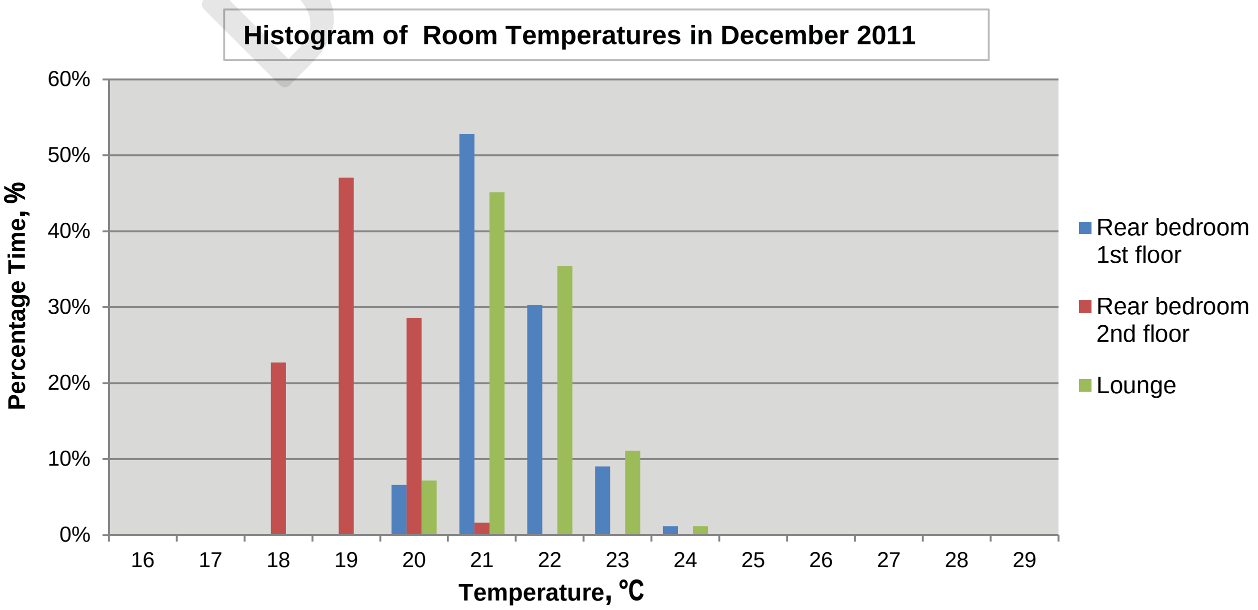

Histogram of Room Temperatures in July 2011
70%
60%
50%
40%
30%
20%
10%
0%
Percentage Time, %
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Temperature, ℃
Rear bedroom 1st floor
Rear bedroom 2nd floor
Lounge


Histogram of Room Temperatures in August 2011
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage Time, %
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Temperature, ℃
Rear bedroom 1st floor
Rear bedroom 2nd floor
Lounge

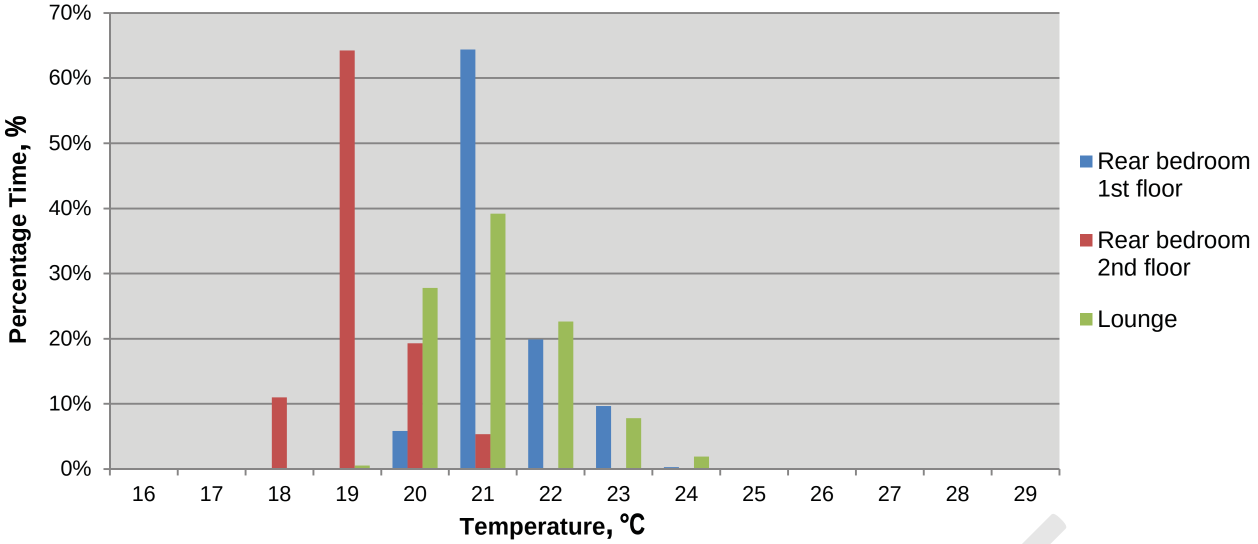

Histogram of Room Temperatures in September 2011
60%
50%
40%
30%
20%
10%
0%
Percentage Time, %
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Temperature, ℃
Rear bedroom 1st floor
Rear bedroom 2nd floor
Lounge


Histogram of Room Temperatures in October 2011
60%
50%
40%
30%
20%
10%
0%
Percentage Time, %
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Temperature, ℃
Rear bedroom 1st floor
Rear bedroom 2nd floor
Lounge

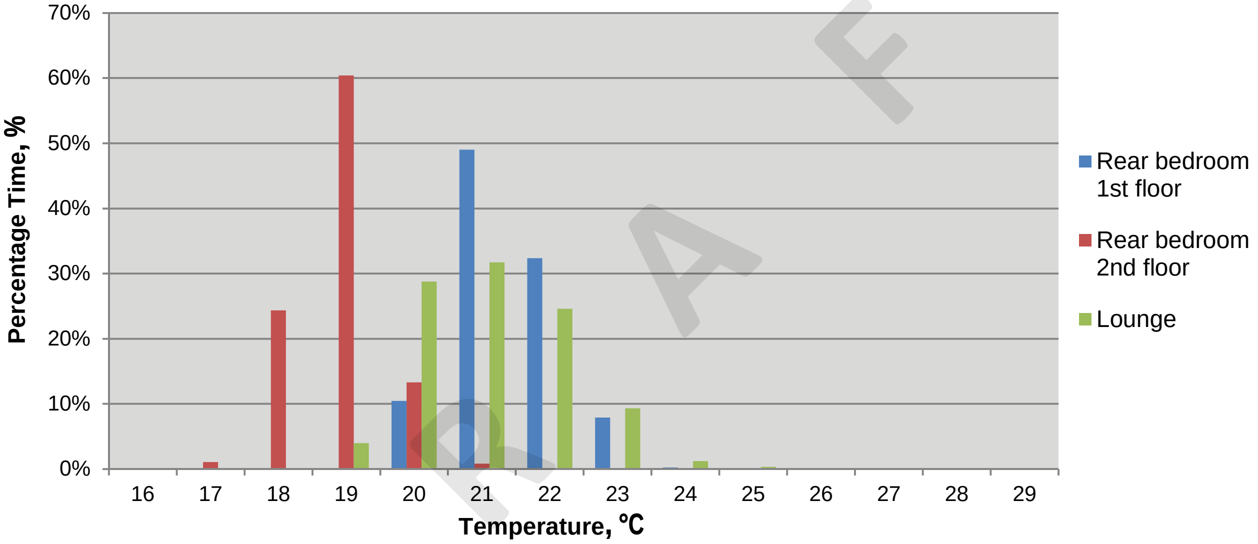

Histogram of Room Temperatures in November 2011
60%
50%
40%
30%
20%
10%
0%
Percentage Time, %
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Temperature, ℃
Rear bedroom 1st floor
Rear bedroom 2nd floor
Lounge


Histogram of Room Temperatures in December 2011
60%
50%
40%
30%
20%
10%
0%
Percentage Time, %
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Temperature, ℃
Rear bedroom 1st floor
Rear bedroom 2nd floor
Lounge

Histogram of Room Temperatures in January 2012



Histogram of Room Temperatures in February 2012



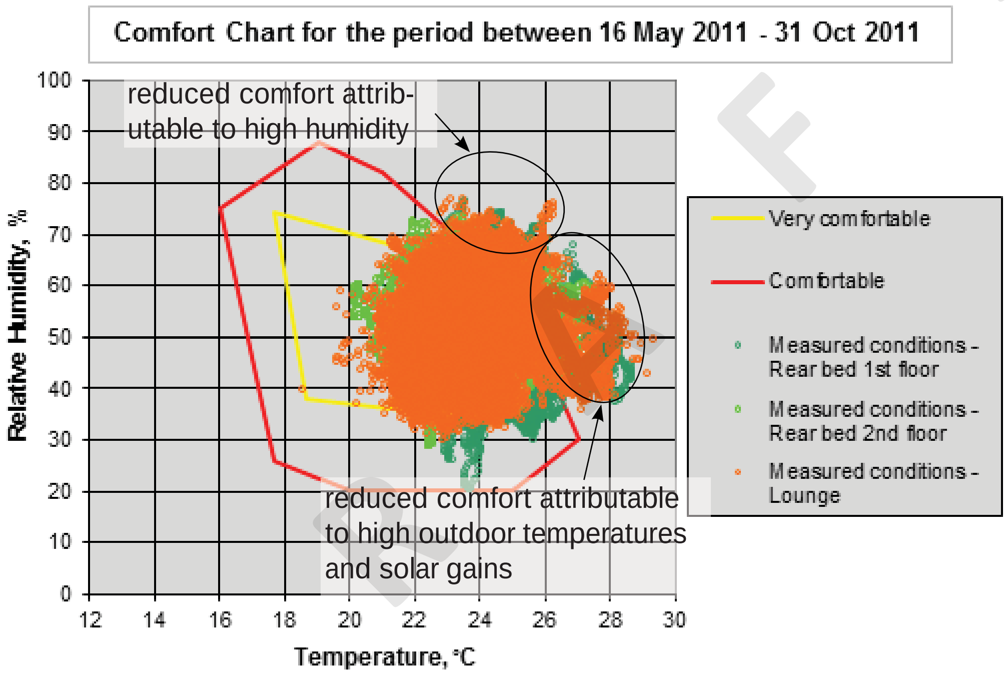
2: Analysis and Graphs

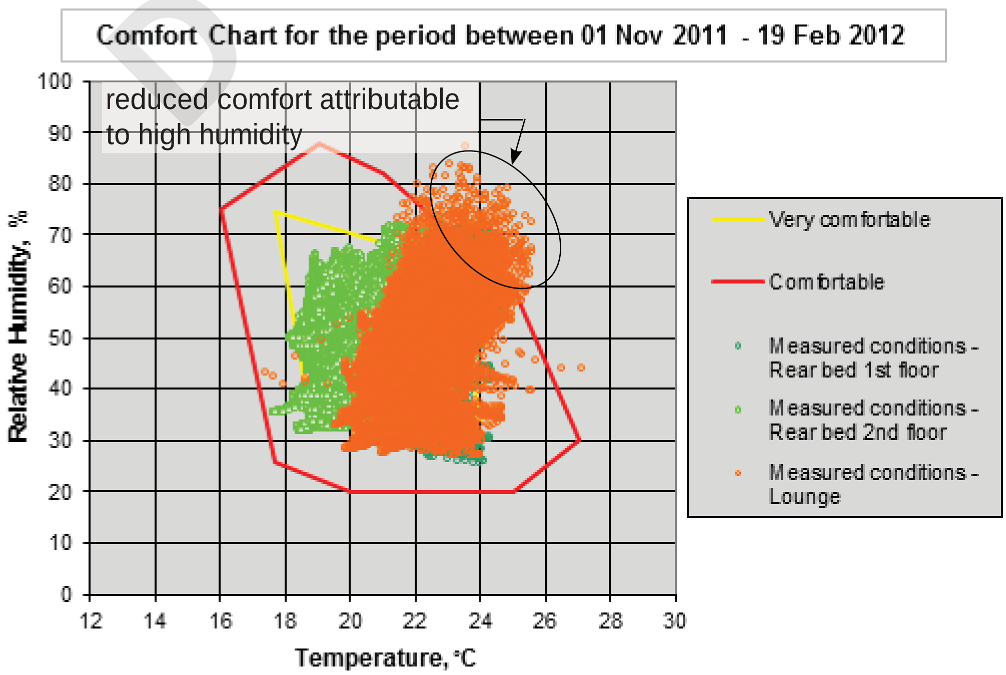
2.2: Comfort Charts

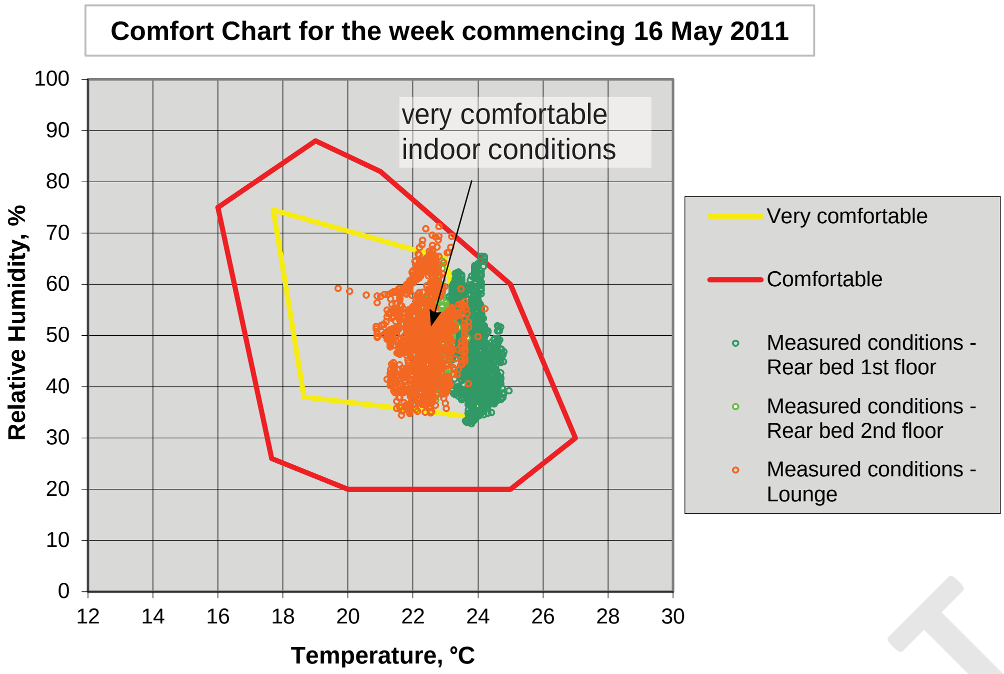
2.2.3: Thermal Comfort

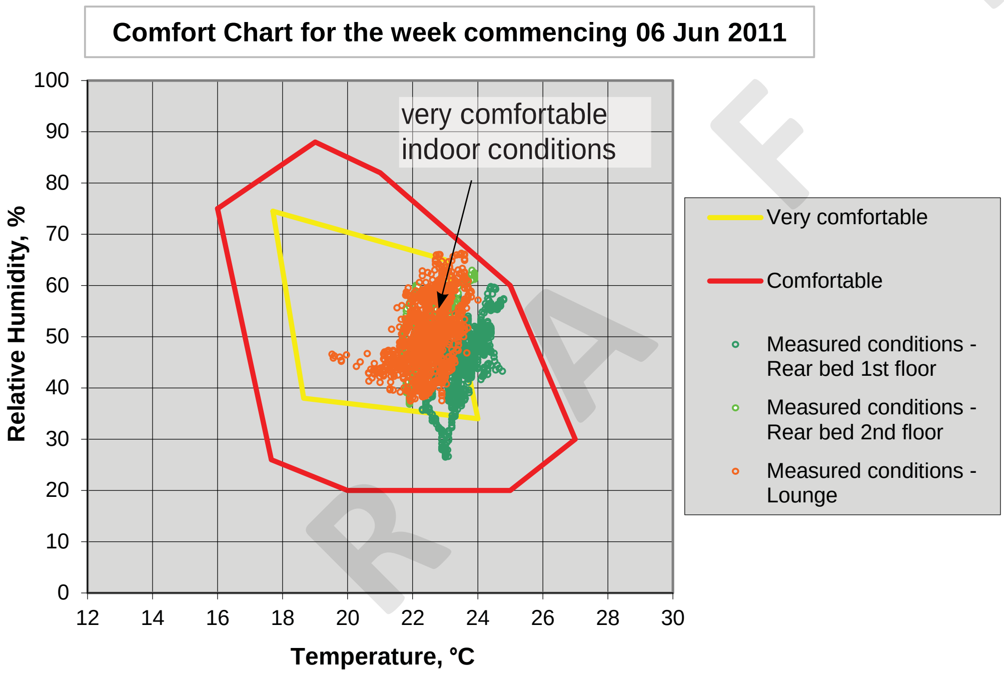
Comfort defined by temperature and relative humidity is crucial for wellbeing. There are variations in individual perception of thermal comfort, however, generalisations can be made. The following graphs show the measured indoor conditions and the outlines for comfortable and very comfortable conditions. The comfort outlines were taken from the following website: http://ecologic-architecture.org/main/index.php?id=48&L=1

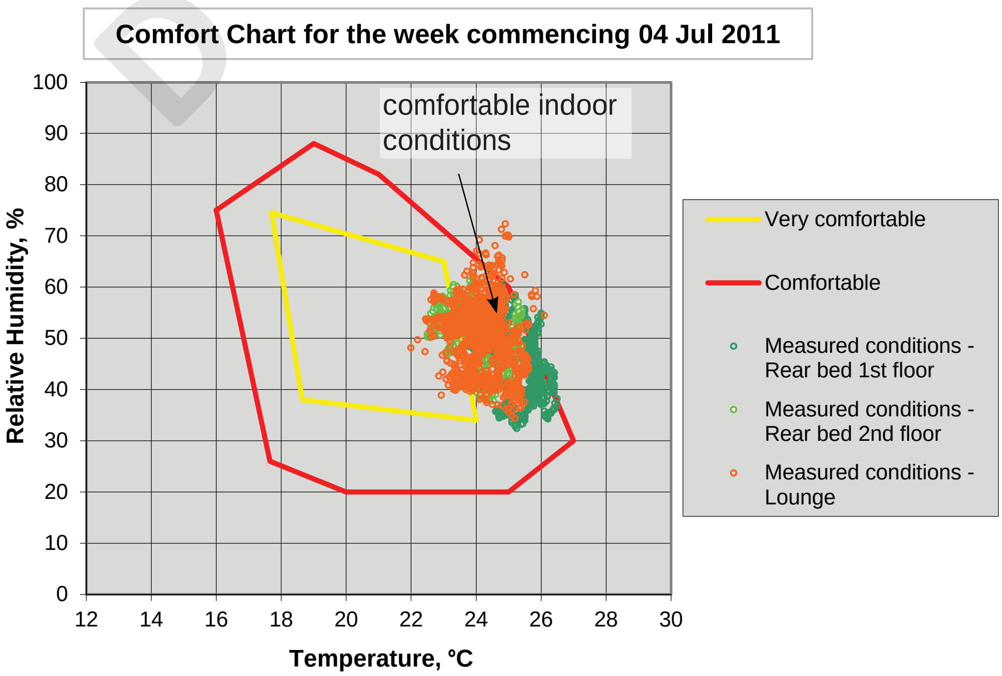
During summer internal conditions are sometimes outside of the comfort zone, which is caused by high external temperatures but sometimes also by high external relative humidity. In the winter and late autumn the measured conditions were most of the time very comfortable. During heating season elevated relative humidity occurs in the lounge which is most probably result of the vicinity of the kitchen and intensive cooking.

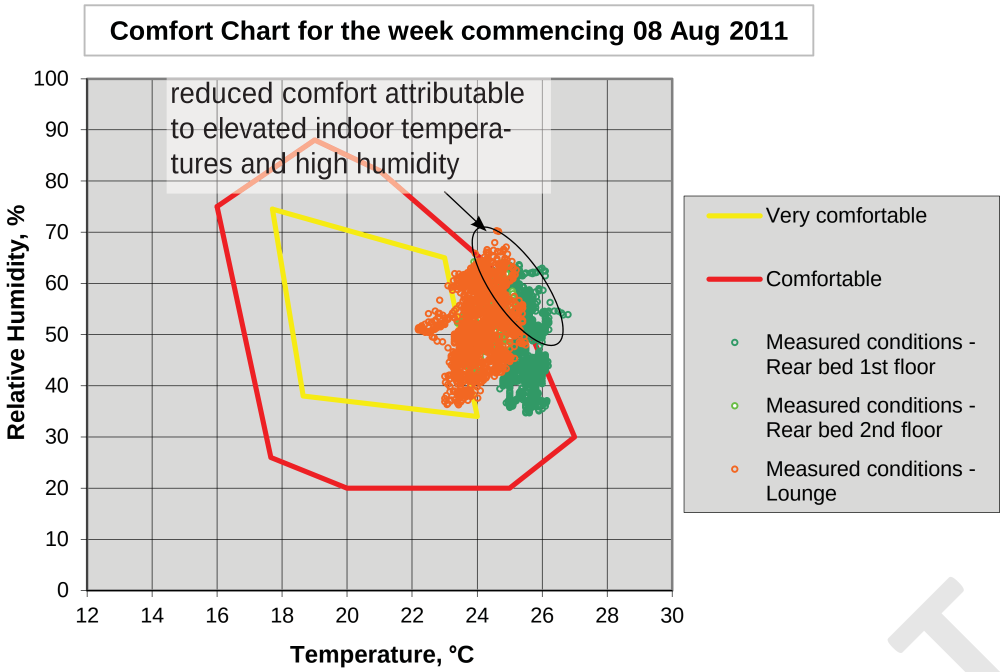


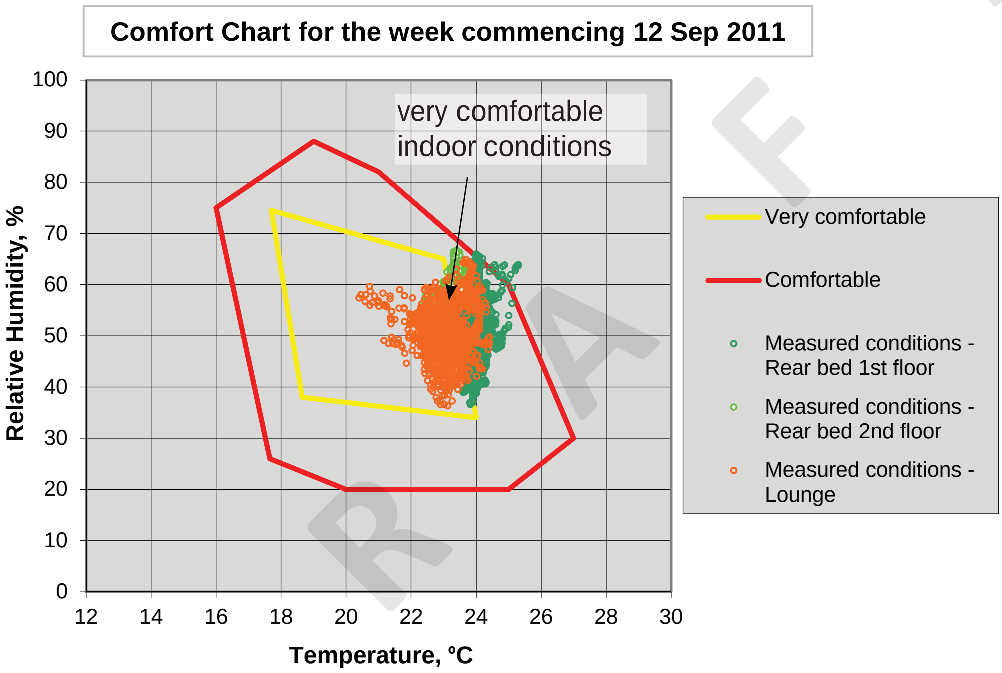


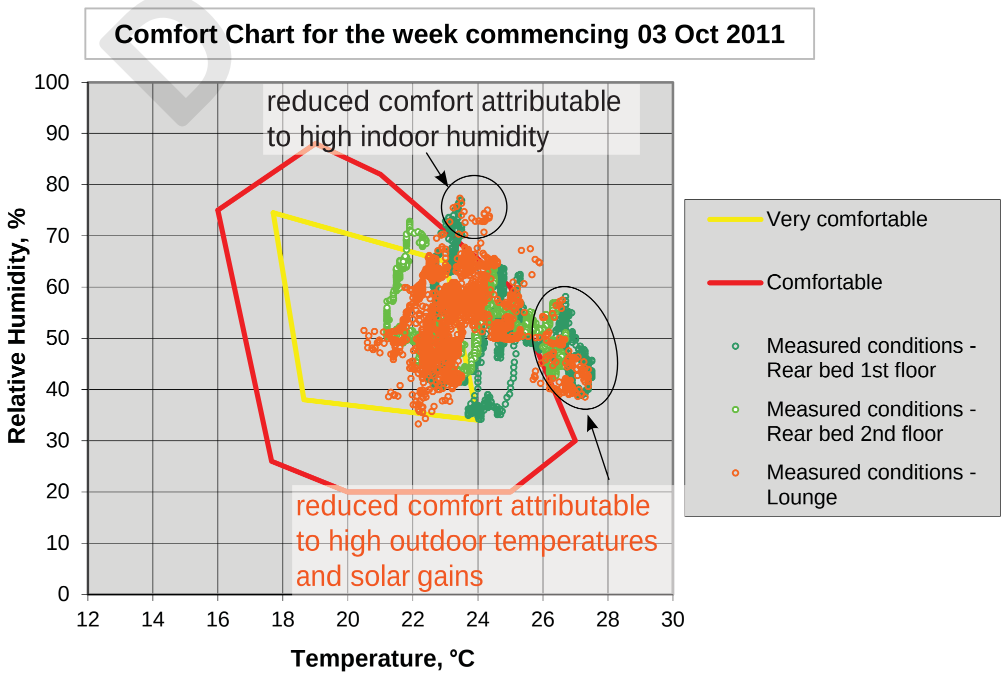

Comfort Chart for the week commencing 16 May 2011
very comfortable indoor conditions
Relative Humidity, %
Temperature, °C
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge


Comfort Chart for the week commencing 06 Jun 2011
very comfortable indoor conditions
Relative Humidity, %
Temperature, °C
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge

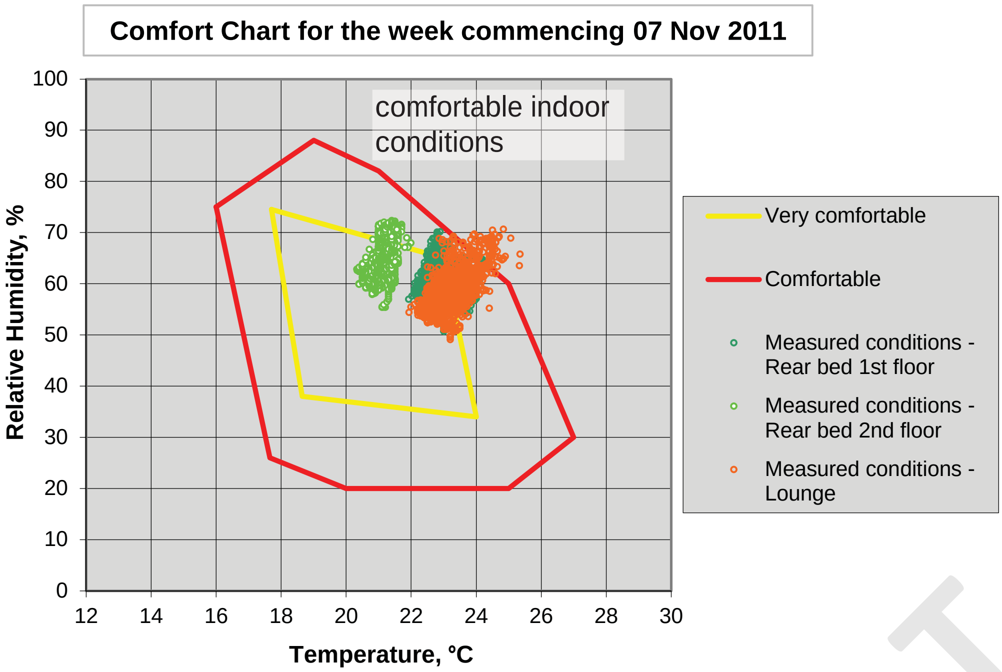

Comfort Chart for the week commencing 04 Jul 2011
comfortable indoor conditions
Relative Humidity, %
Temperature, °C
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge



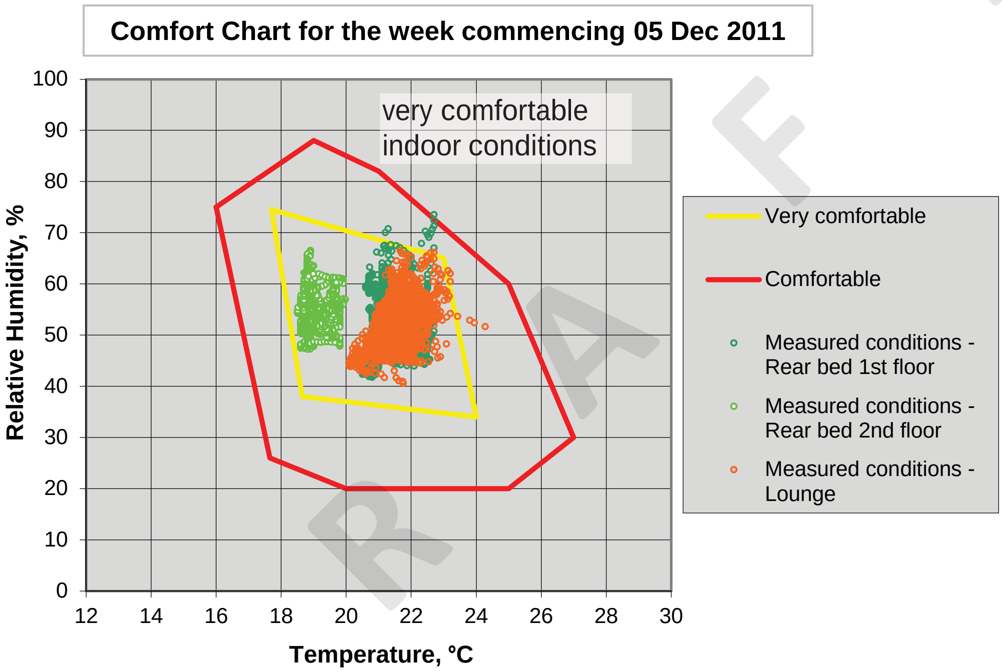




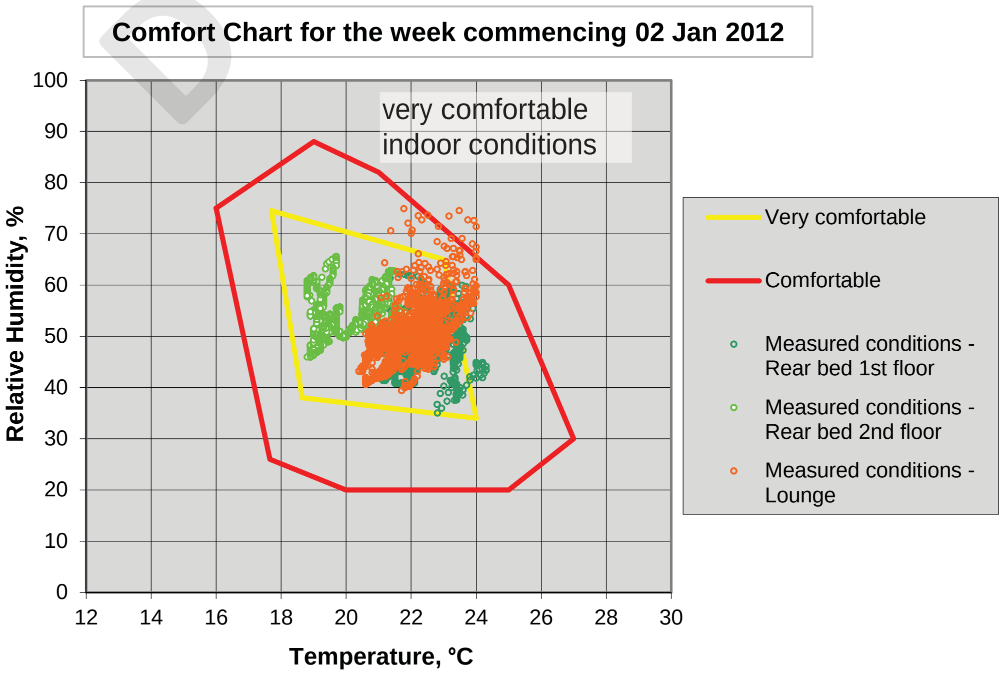
bere:architects



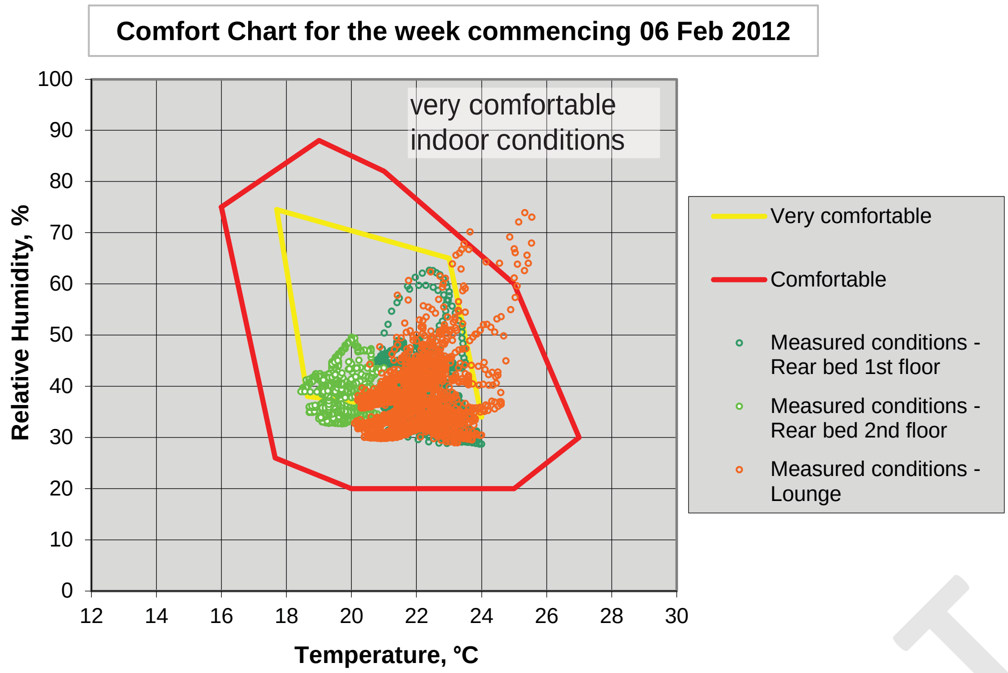
Comfort Chart for the week commencing 07 Nov 2011
comfortable indoor conditions
Relative Humidity, %
Temperature, °C
100
90
80
70
60
50
40
30
20
10
0
12
14
16
18
20
22
24
26
28
30
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge



Comfort Chart for the week commencing 05 Dec 2011
very comfortable indoor conditions
Relative Humidity, %
Temperature, °C
100
90
80
70
60
50
40
30
20
10
0
12
14
16
18
20
22
24
26
28
30
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge



Comfort Chart for the week commencing 02 Jan 2012
very comfortable indoor conditions
Relative Humidity, %
Temperature, °C
100
90
80
70
60
50
40
30
20
10
0
12
14
16
18
20
22
24
26
28
30
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge



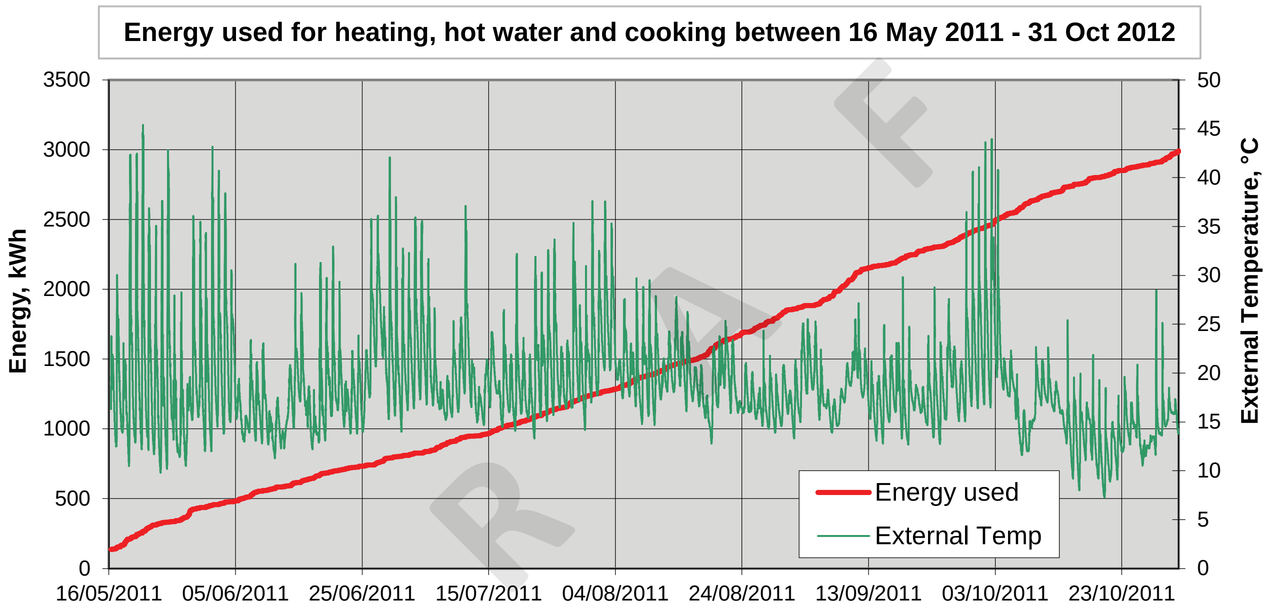
Comfort Chart for the week commencing 06 Feb 2012
very comfortable indoor conditions
Relative Humidity, %
Temperature, °C
100
90
80
70
60
50
40
30
20
10
0
12
14
16
18
20
22
24
26
28
30
Very comfortable
Comfortable
Measured conditions - Rear bed 1st floor
Measured conditions - Rear bed 2nd floor
Measured conditions - Lounge

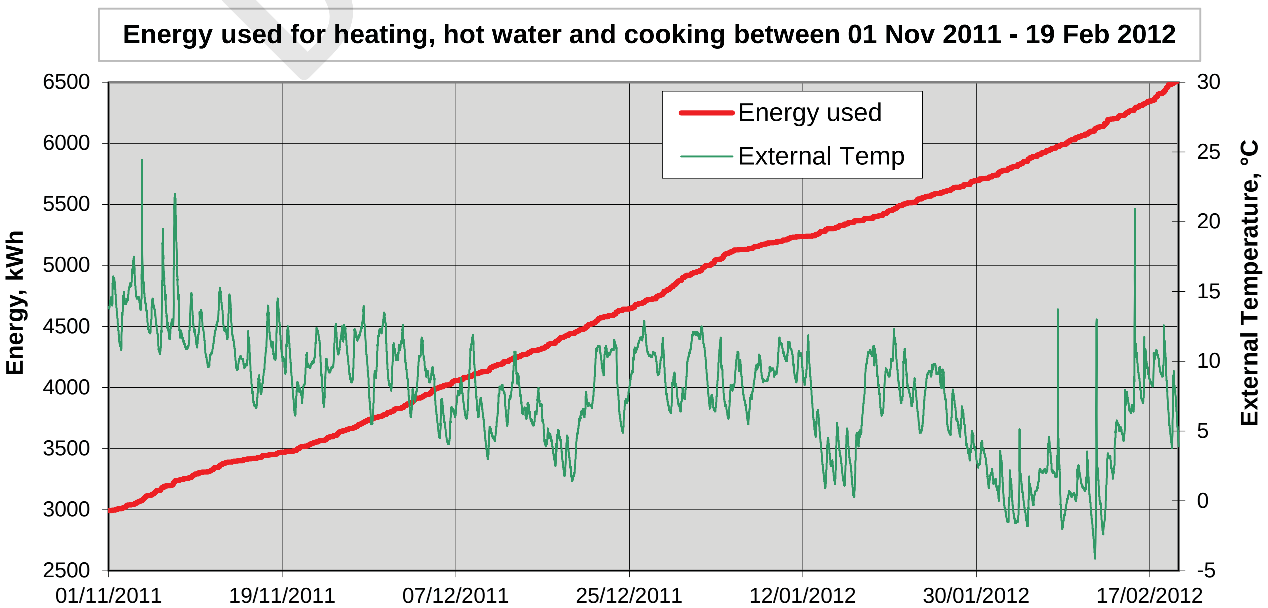
2: Analysis and Graphs

2.3: Energy for Heating, Hot Water and Cooking

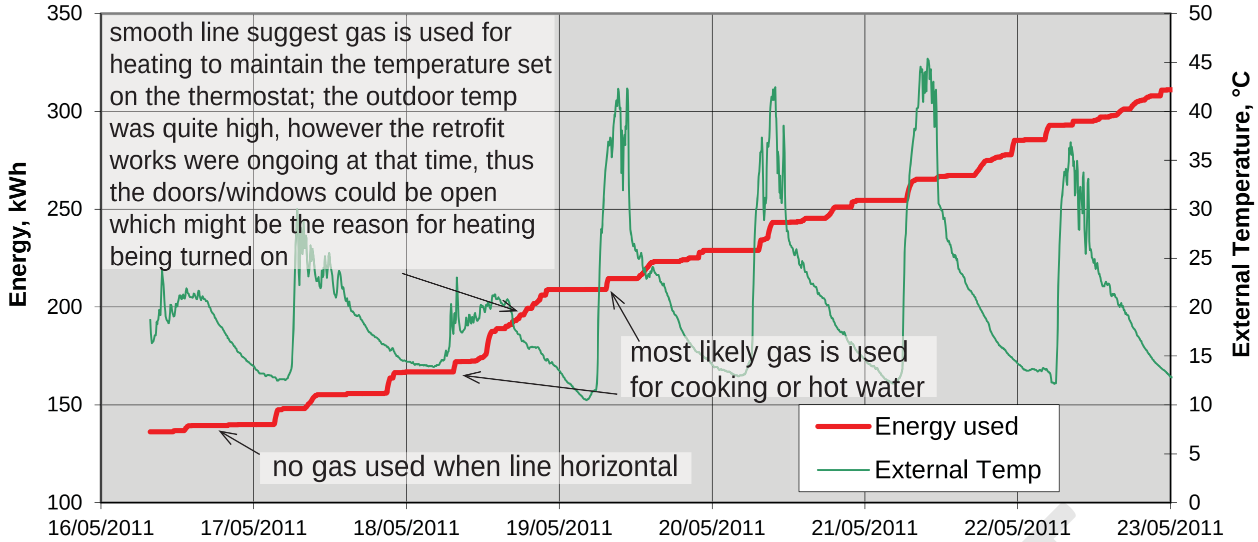
In the retrofitted house gas is used for space and water heating and for cooking. Some of the gas use shown in the following graphs is attributable to hot water consumption, however it is highly probable that in the summer greatest portion of hot water demand is met by the solar thermal panels installed on the roof.

In the late spring and summer the gas usage was relatively high. This might be attributable to ongoing retrofit works. It is probable that the thermostat was set to maintain the temperature in the lounge while the doors or windows were left open, allowing free flow of outdoor air through the house.

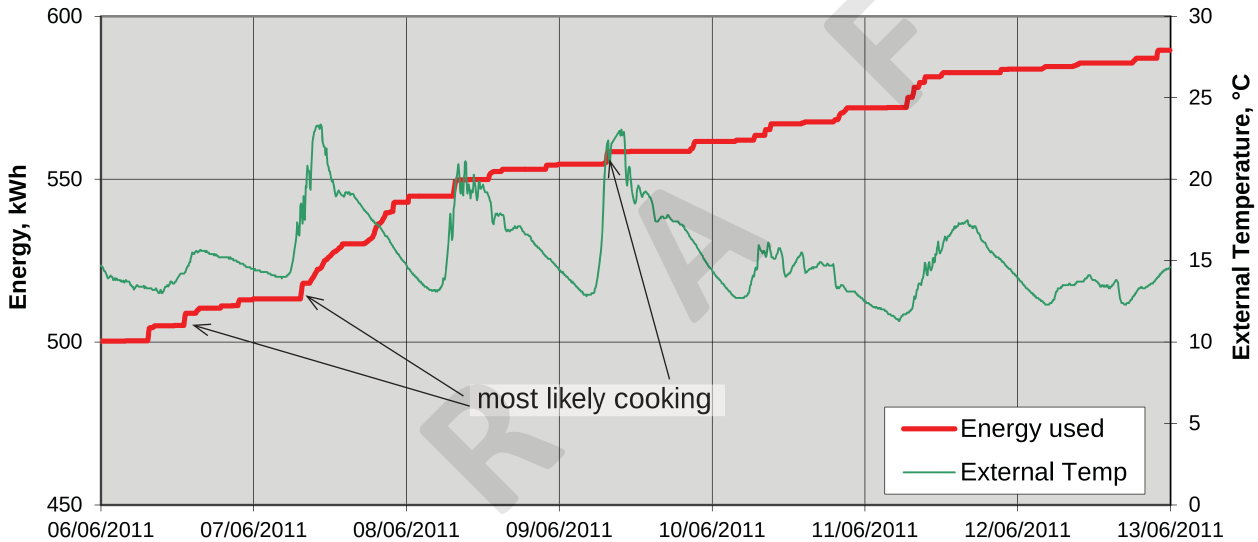




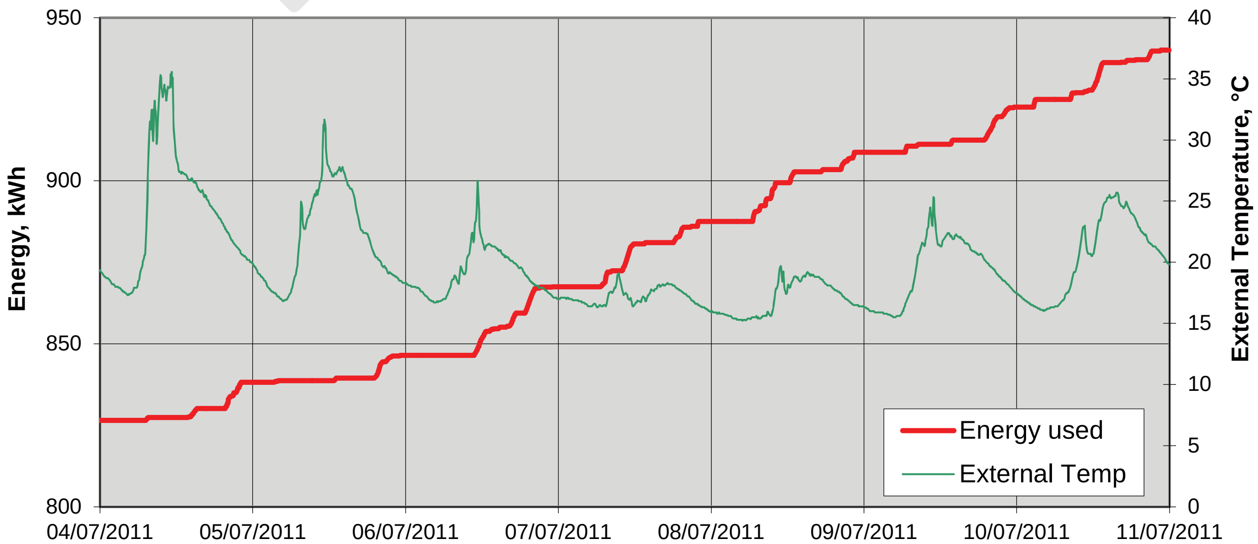
Energy used for heating, hot water and cooking for the week commencing 16 May 2011



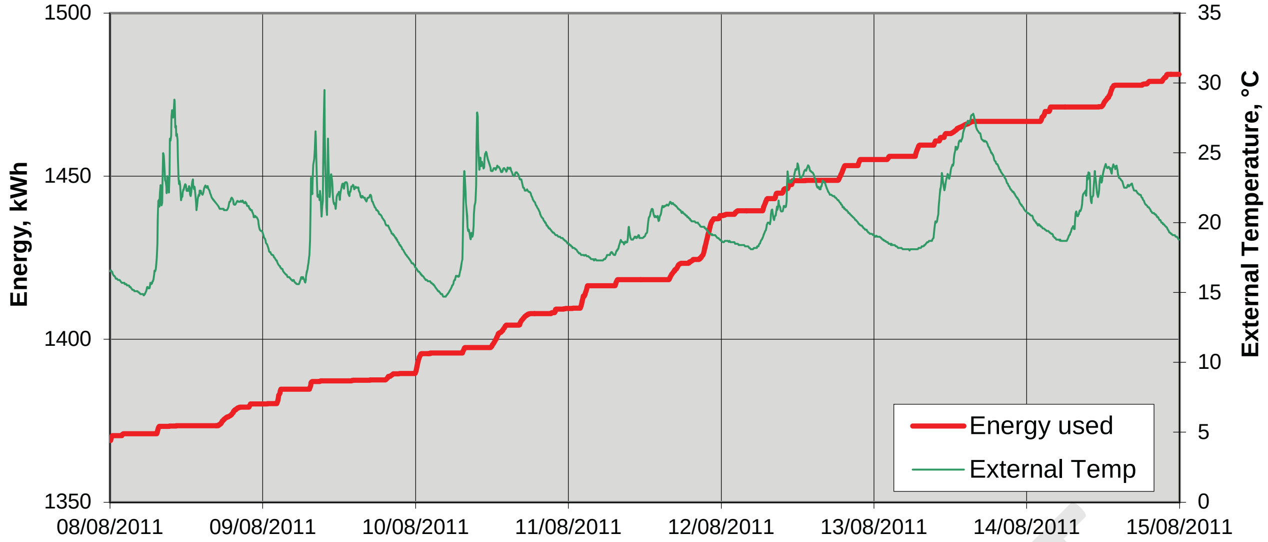
Energy used for heating, hot water and cooking for the week commencing 06 Jun 2011



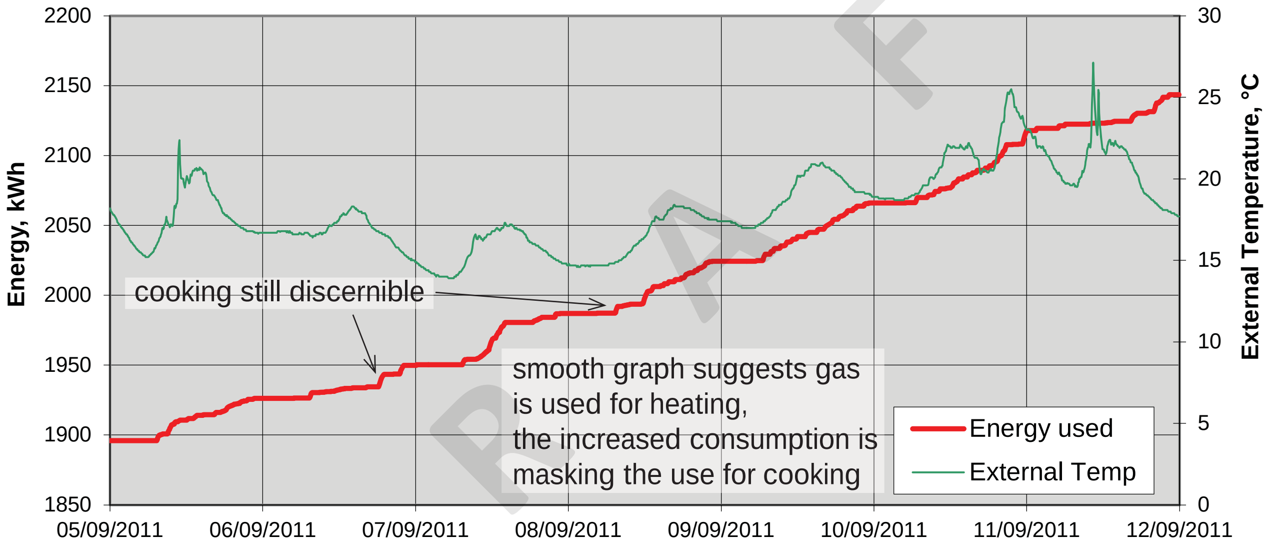
Energy used for heating, hot water and cooking for the week commencing 04 Jul 2011



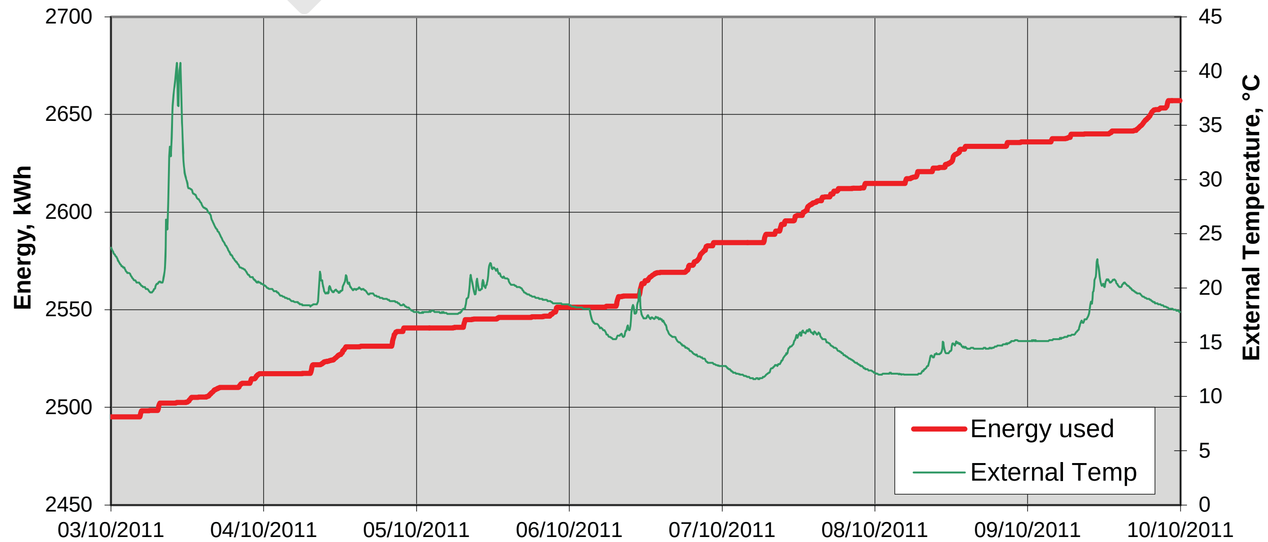
Energy used for heating, hot water and cooking for the week commencing 08 Aug 2011



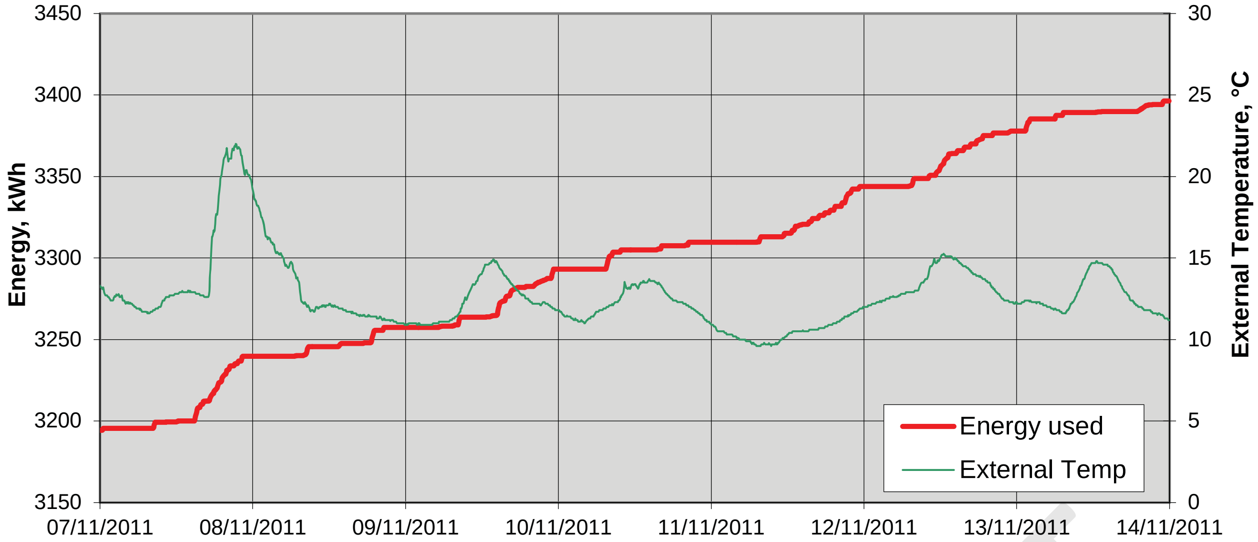
Energy used for heating, hot water and cooking for the week commencing 05 Sep 2011



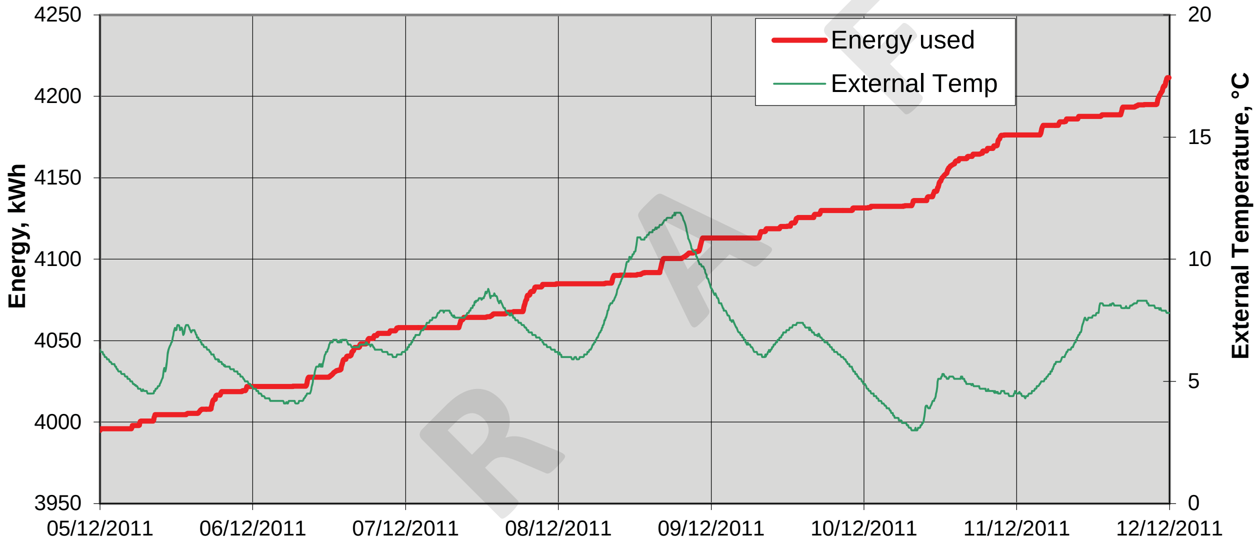
Energy used for heating, hot water and cooking for the week commencing 03 Oct 2011



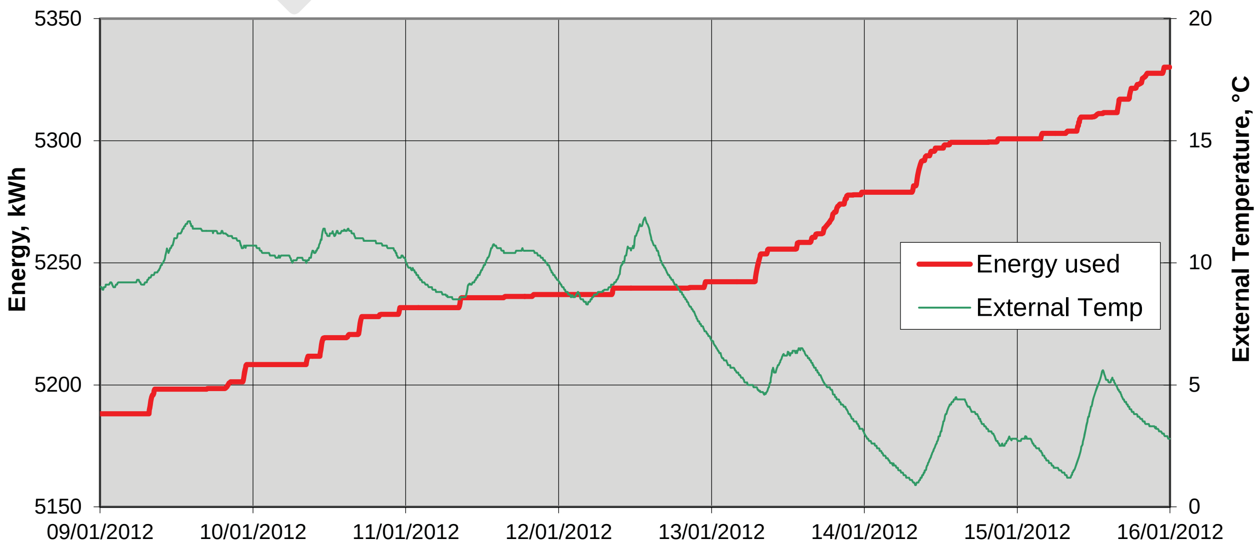
Energy used for heating, hot water and cooking for the week commencing 07 Nov 2011

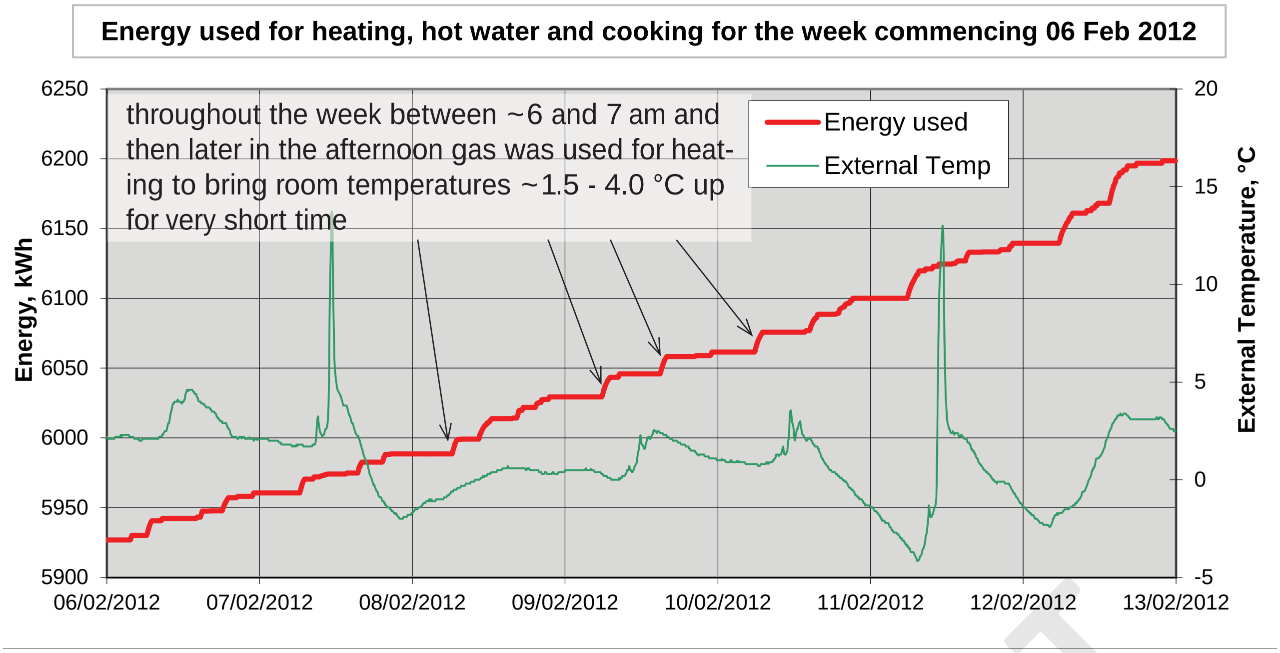


Energy used for heating, hot water and cooking for the week commencing 05 Dec 2011



Energy used for heating, hot water and cooking for the week commencing 09 Jan 2012





bere:architects

2: Analysis and Graphs

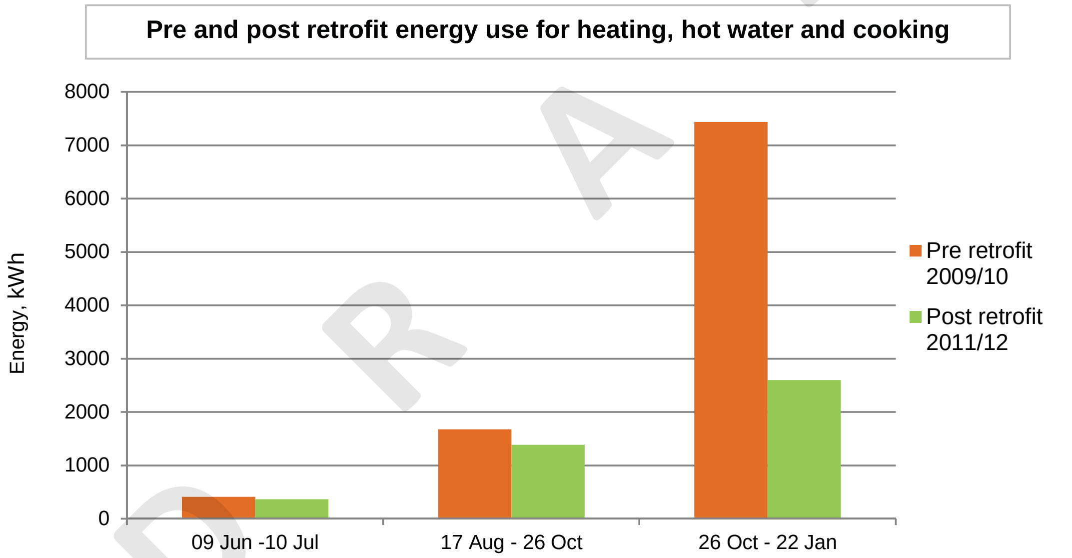
2.3: Energy for Heating, Hot Water and Cooking

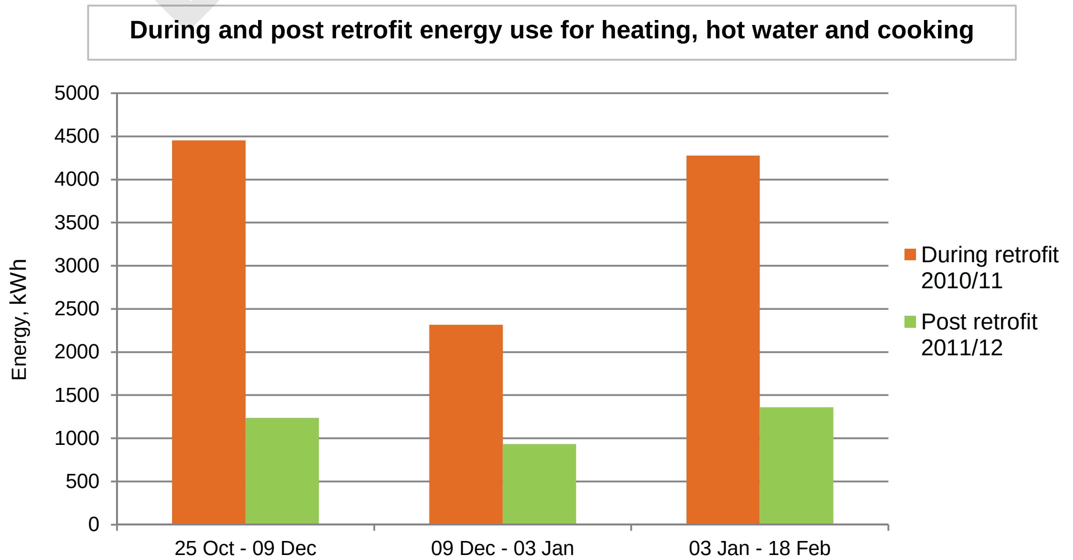
2.3.1: Pre and Post Retrofit Gas Usage

The retrofit started on the 18th October 2010 and finished on the 12th July 2011. This analysis is for the period between the 16 May 2011 and 19 February 2012. The pre and during the retrofit figures are based on the utility bills and the post retrofit figures are based on the readings taken remotely every 5 minutes. Therefore comparison of the electricity usage is limited by the dates when the bill readings were taken. Moreover the time lines of the retrofit and the analysis makes comprehensive comparison even more difficult.

The first of the following graphs depicts pre and post retrofit energy use for space and water heating and cooking. Heating spaces is usually the biggest energy use in domestic properties thus the difference in the pre and post retrofit uses is the greatest in the winter. In the period between 26 October and 22 January the post retrofit energy use was 35% of the pre retrofit use.

The second graph compares the energy used between 26 October 2010 and 18 February 2011, which is during the retrofit, with the post retrofit use in the same period of time the year after. The post retrofit energy use is 32% of the energy used during the retrofit.

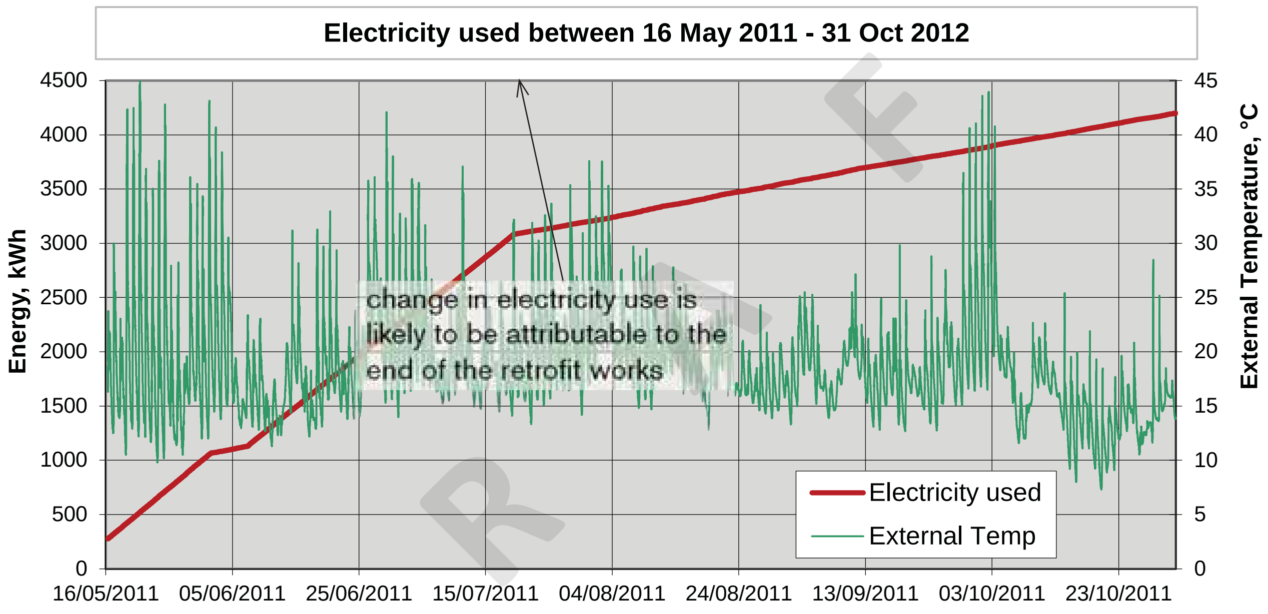


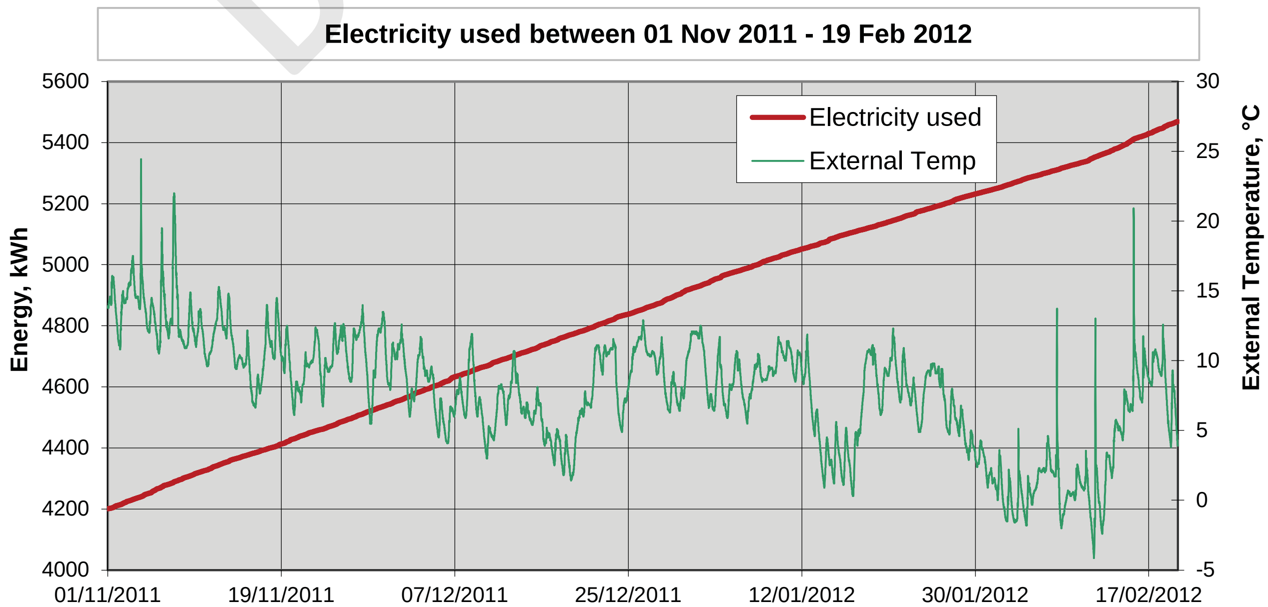


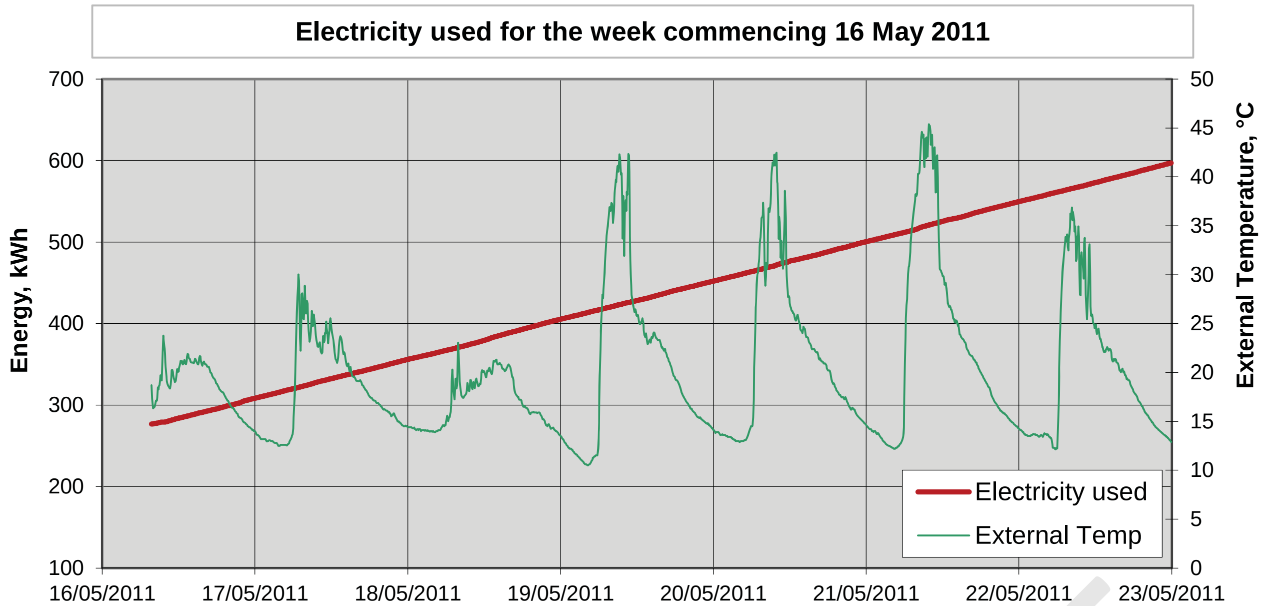
2: Analysis and Graphs

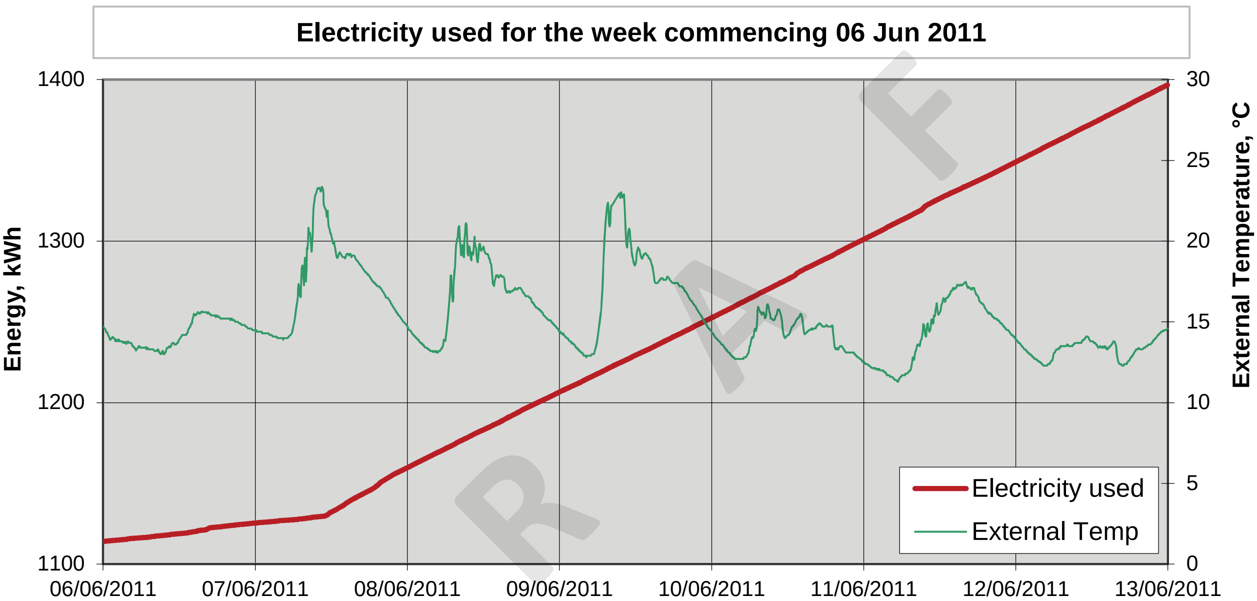
2.4: Electricity usage

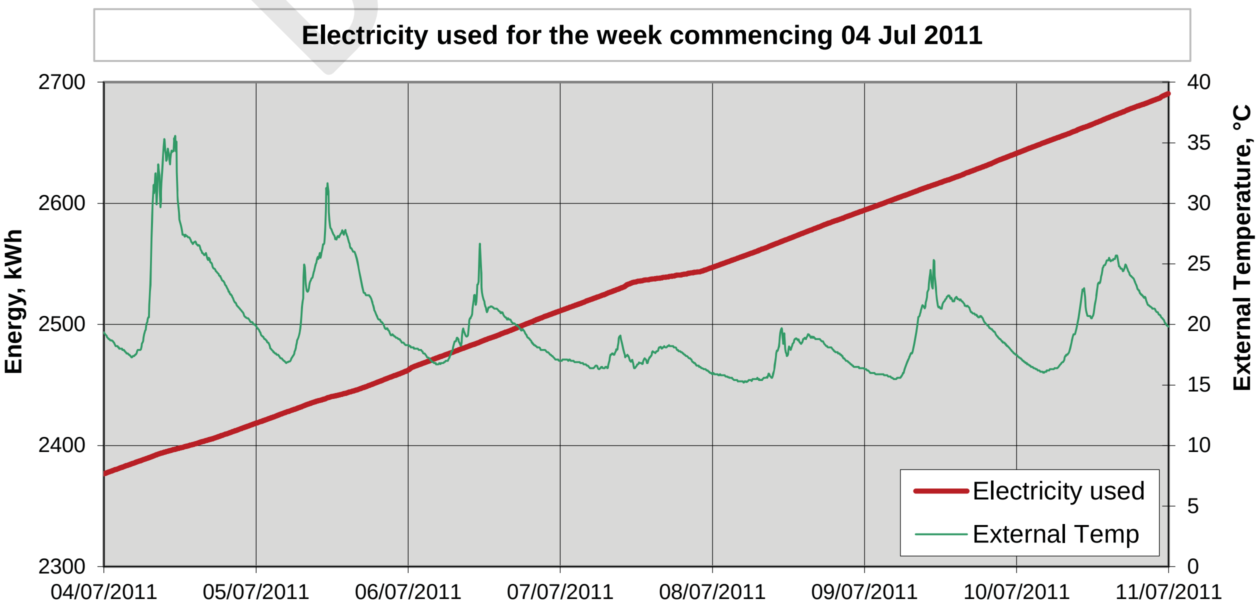
Monitoring data indicates that electricity use significantly decreased on the 19th July which is attributable to the end of the retrofit works. Before and after that change it was very consistent with only small diurnal fluctuations for most of the time.

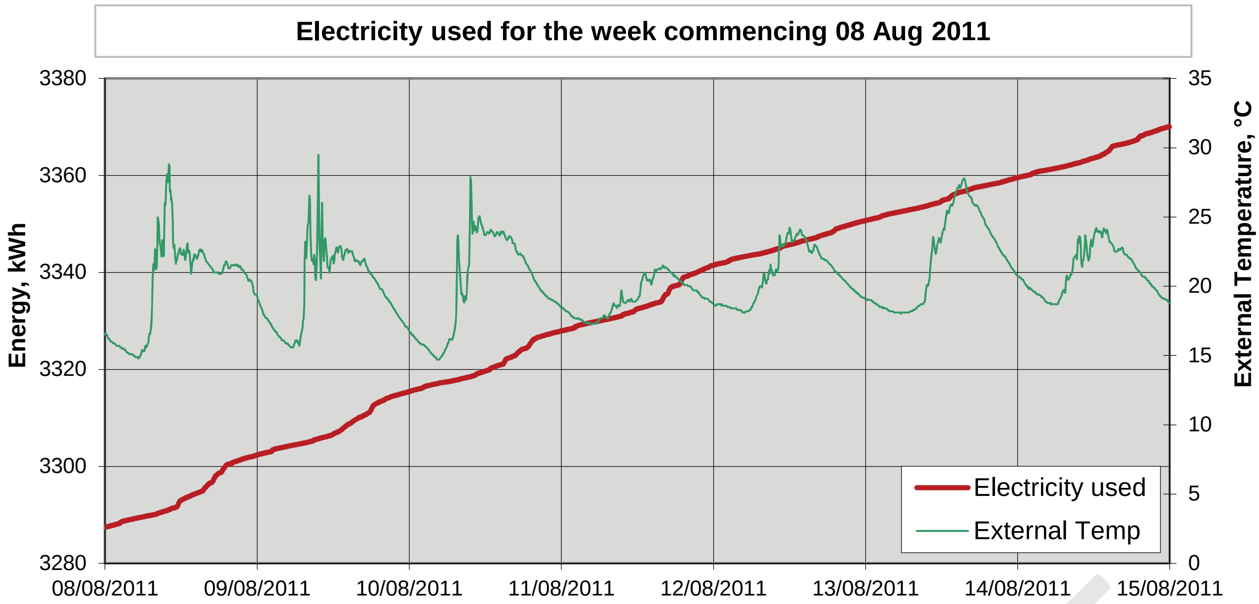




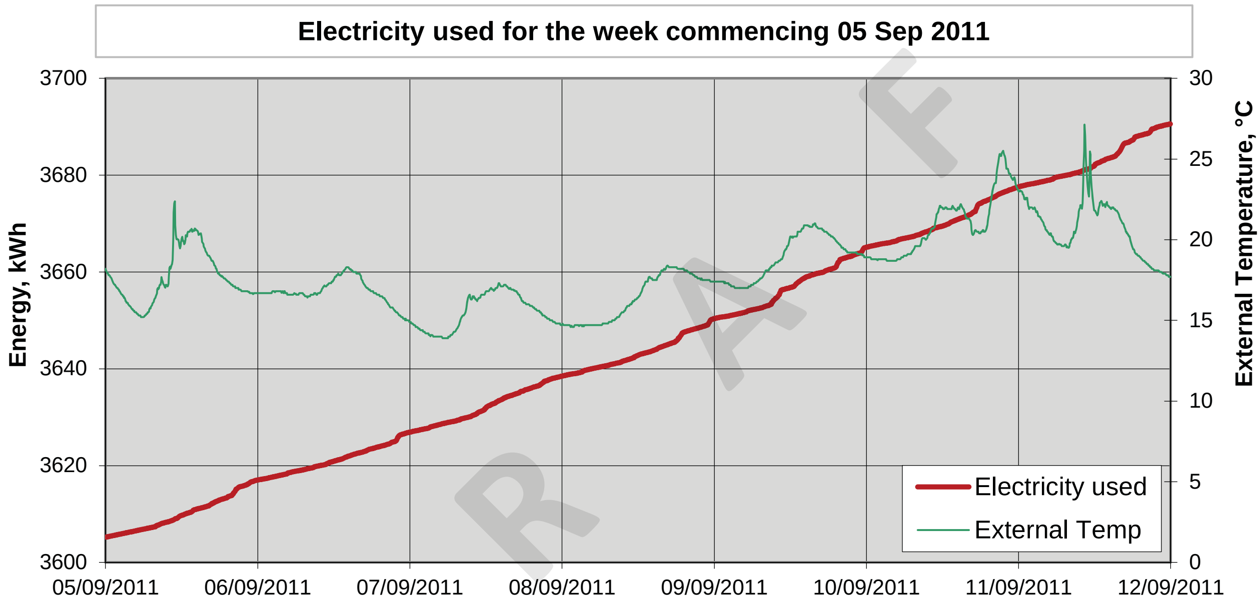

Electricity used for the week commencing 16 May 2011
Energy, kWh
700
600
500
400
300
200
100
External Temperature, °C
50
45
40
35
30
25
20
15
10
5
0
16/05/2011
17/05/2011
18/05/2011
19/05/2011
20/05/2011
21/05/2011
22/05/2011
23/05/2011
Electricity used
External Temp


Electricity used for the week commencing 06 Jun 2011
Energy, kWh
1400
1300
1200
1100
External Temperature, °C
30
25
20
15
10
5
0
06/06/2011
07/06/2011
08/06/2011
09/06/2011
10/06/2011
11/06/2011
12/06/2011
13/06/2011
Electricity used
External Temp

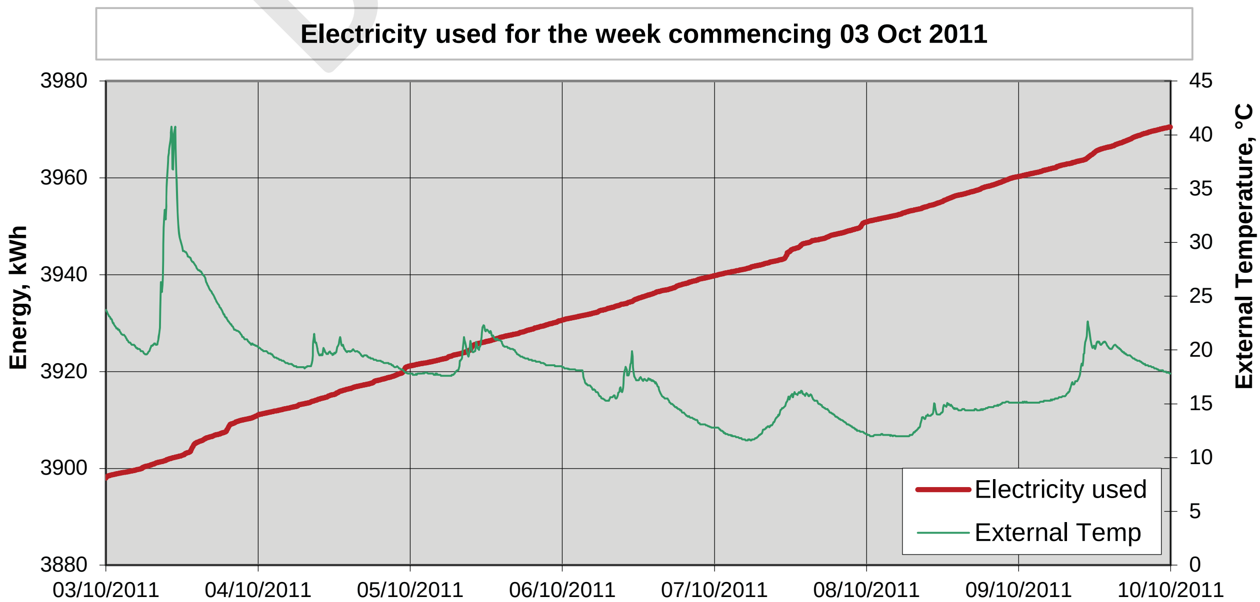

Electricity used for the week commencing 04 Jul 2011
Energy, kWh
2700
2600
2500
2400
2300
External Temperature, °C
40
35
30
25
20
15
10
5
0
04/07/2011
05/07/2011
06/07/2011
07/07/2011
08/07/2011
09/07/2011
10/07/2011
11/07/2011
Electricity used
External Temp



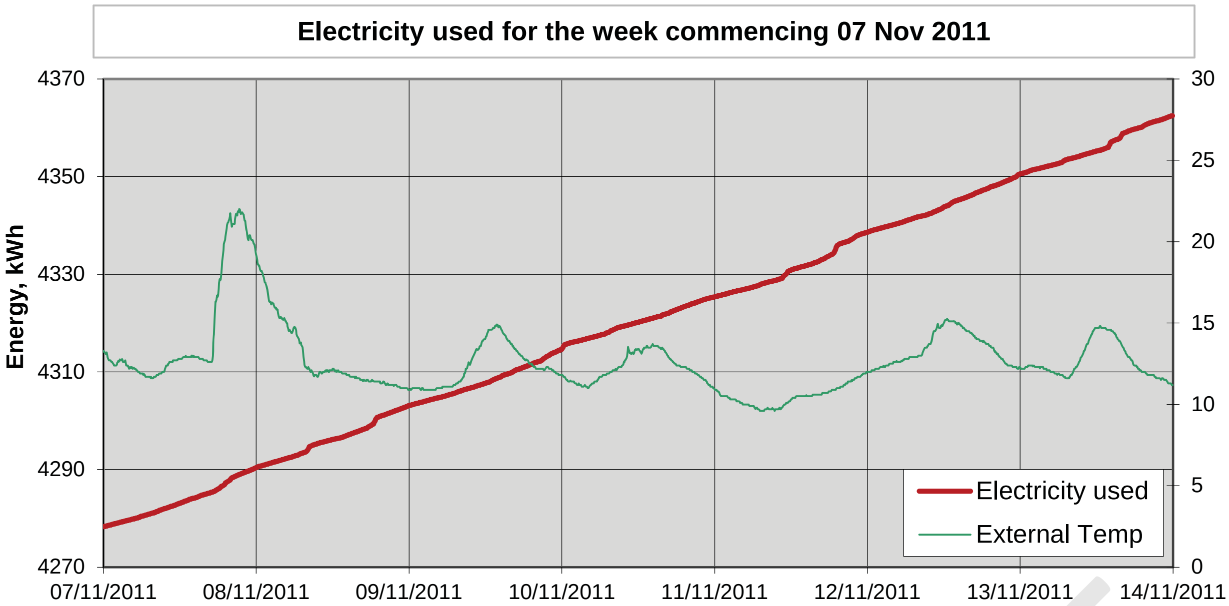
Electricity used for the week commencing 08 Aug 2011
Energy, kWh
External Temperature, °C
3380
3360
3340
3320
3300
3280
35
30
25
20
15
10
5
0
08/08/2011
09/08/2011
10/08/2011
11/08/2011
12/08/2011
13/08/2011
14/08/2011
15/08/2011
Electricity used
External Temp

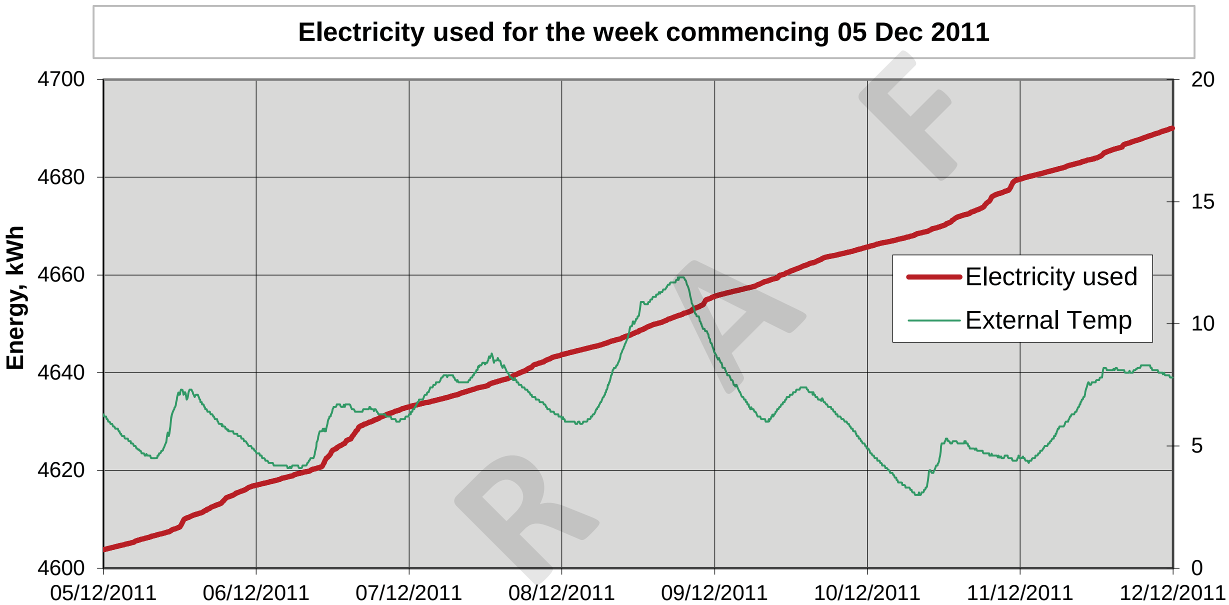


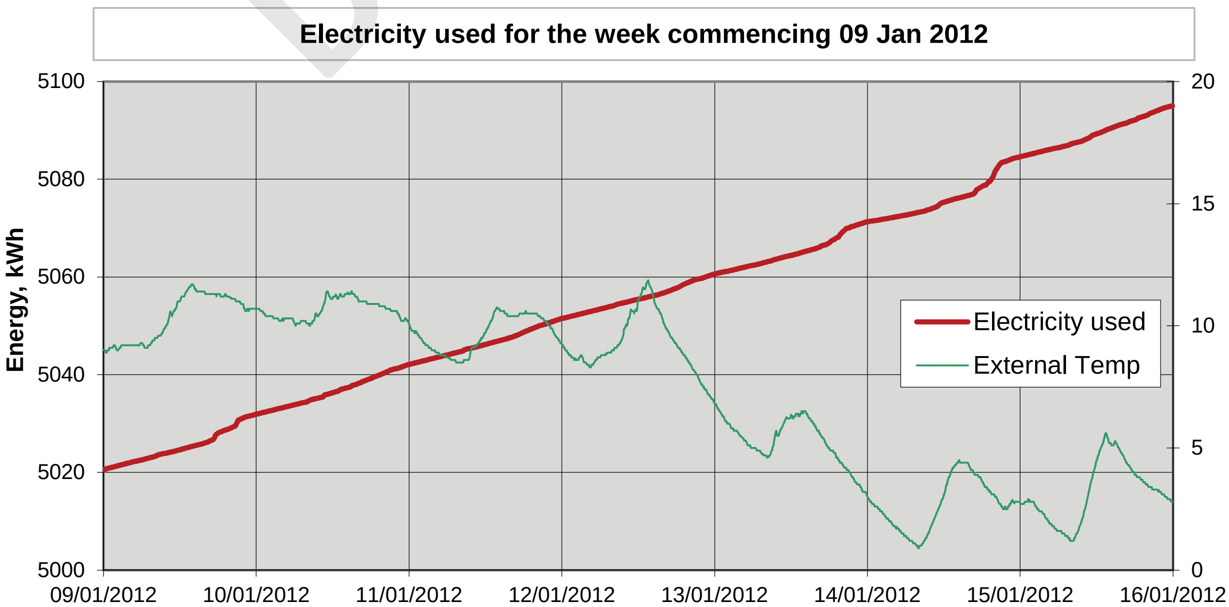
Electricity used for the week commencing 05 Sep 2011
Energy, kWh
External Temperature, °C
3700
3680
3660
3640
3620
3600
30
25
20
15
10
5
0
05/09/2011
06/09/2011
07/09/2011
08/09/2011
09/09/2011
10/09/2011
11/09/2011
12/09/2011
Electricity used
External Temp

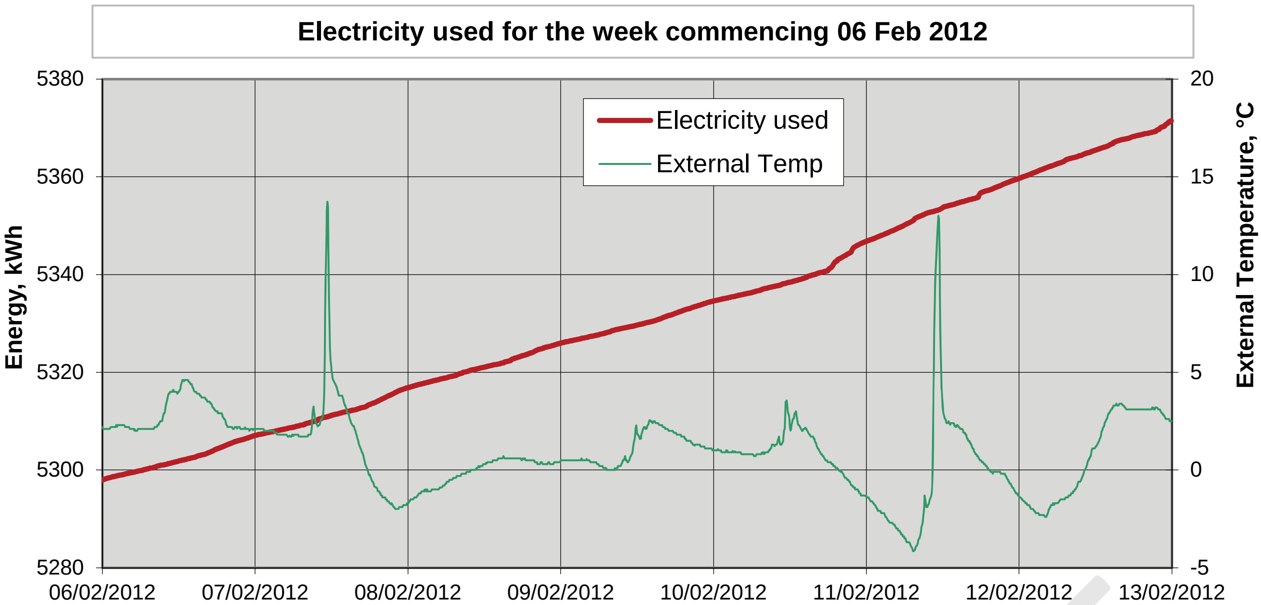


Electricity used for the week commencing 03 Oct 2011
Energy, kWh
External Temperature, °C
3980
3960
3940
3920
3900
3880
45
40
35
30
25
20
15
10
5
0
03/10/2011
04/10/2011
05/10/2011
06/10/2011
07/10/2011
08/10/2011
09/10/2011
10/10/2011
Electricity used
External Temp


Electricity used for the week commencing 07 Nov 2011
Energy, kWh
External Temperature, °C
4370
4350
4330
4310
4290
4270
30
25
20
15
10
5
0
07/11/2011
08/11/2011
09/11/2011
10/11/2011
11/11/2011
12/11/2011
13/11/2011
14/11/2011
Electricity used
External Temp


Electricity used for the week commencing 05 Dec 2011
Energy, kWh
External Temperature, °C
4700
4680
4660
4640
4620
4600
20
15
10
5
0
05/12/2011
06/12/2011
07/12/2011
08/12/2011
09/12/2011
10/12/2011
11/12/2011
12/12/2011
Electricity used
External Temp


Electricity used for the week commencing 09 Jan 2012
Energy, kWh
External Temperature, °C
5100
5080
5060
5040
5020
5000
20
15
10
5
0
09/01/2012
10/01/2012
11/01/2012
12/01/2012
13/01/2012
14/01/2012
15/01/2012
16/01/2012
Electricity used
External Temp



Electricity used for the week commencing 06 Feb 2012
Electricity used
External Temp
Energy, kWh
External Temperature, °C
5380
5360
5340
5320
5300
5280
20
15
10
5
0
-5
06/02/2012
07/02/2012
08/02/2012
09/02/2012
10/02/2012
11/02/2012
12/02/2012
13/02/2012

2: Analysis and Graphs

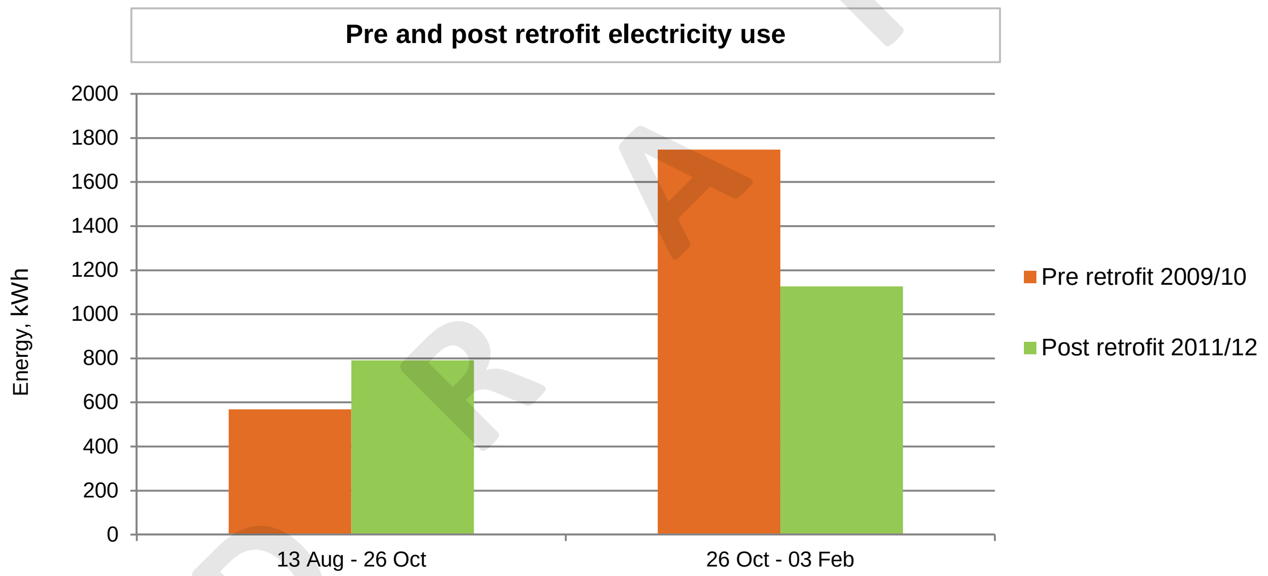
2.4: Electricity Usage

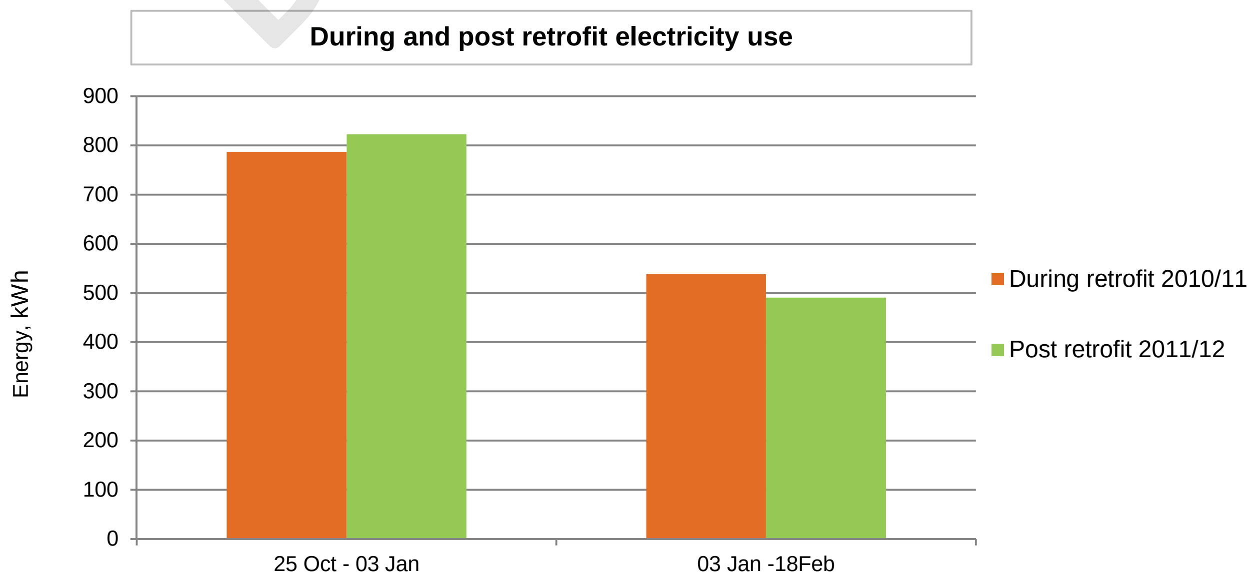
2.4.1: Pre and Post Retrofit Usage

The retrofit started on the 18th October 2010 and finished on the 12th July 2011. This analysis is for the period between the 16 May 2011 and 19 February 2012.

As described in Section 2.3.1 Pre and Post Retrofit Gas Energy Usage the comprehensive comparison of electricity usage is limited by the dates when the bill readings were taken and by the time lines of the retrofit and the analysis.

The following graphs indicate that the post retrofit electricity usage for the whole analysed period is lower than the pre retrofit usage. Electricity consumption during and after the retrofit are very similar. However, in some other periods that are not presented on the graphs, electricity consumption was much greater during than the pre and post retrofit, which is justified by the nature of some of the works undertaken.





3: Conclusions

This report presents graphs and analysis of indoor and outdoor conditions as well as energy used in the house in 3 Passfield Drive, East London which was retrofitted with certified Passivhaus components and methods. The monitored parameters are temperature, relative humidity, CO_2 level, and gas and electricity consumption. The analysis is for the period of time from the 16th May 2011 until the 19th February 2012. The retrofit started on the 18th October 2010 and finished on the 12th July 2011.

Section 2.1 shows indoor and outdoor temperatures and relative humidity, section 2.2 comfort charts, section 2.3 energy used for heating, hot water and cooking and section 2.4 electricity usage.

Indoor temperatures and relative humidity:

Internal temperature fluctuations during summer were reasonably low for a non-conditioned building. However, there is certain degree of overheating which probably partially occurs when spaces are not occupied and thus internal conditions are not controlled. External conditions caused higher variations of relative humidity levels. However, they remained within the optimal range most of the time. High relative humidity levels in the lounge were often caused by cooking in the kitchen.

During the coldest part of the winter the thermostat settings were increased during short periods of day, especially in the mornings. These changes can be seen as peaks in the temperatures for all three monitored rooms. The length of time it took for temperatures to reduce to the earlier settings indicates good thermal separation of the house from the outside.

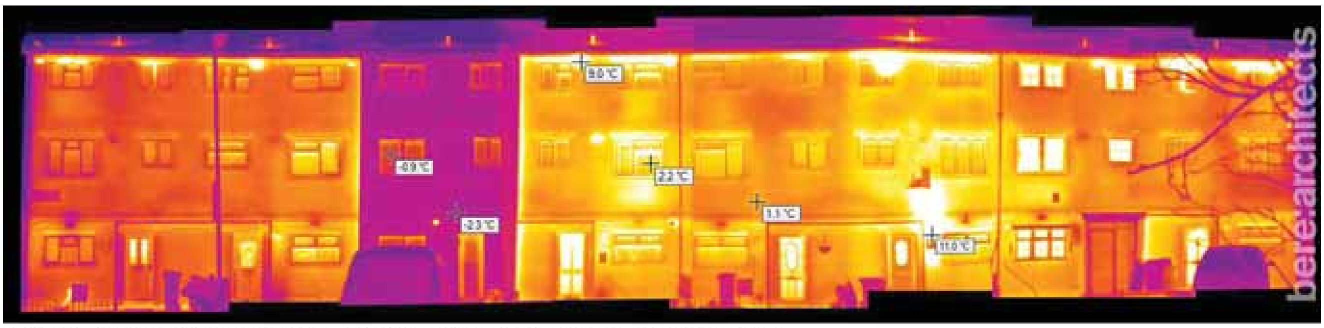


Image reference: (369pd) Passfield Drive bere:architects towards Passivhaus retrofit

Thermal image showing Passfield Drive after retrofit, and adjacent buildings

Comfort:

Indoor thermal conditions were within the comfort zone most of the time. However, some overheating is noticeable during summer due to elevated external temperatures and solar heat gains. Further reduction of thermal comfort when the indoor temperatures were relatively high was sometimes also contributed by increased internal relative humidity due to moisture generating activities in the house (e.g. cooking). During winter internal conditions were optimal almost all time.

The quality of air is another factor important both for health and comfort of the occupants. CO_2 levels were optimal most of the time, according to EU regulations criteria. Optimal for optimal indoor quality was exceeded only sometimes during peak occupancy. These elevated levels might also be partially caused by gas cooking.

An occupant survey could be a good way to validate the results of the thermal comfort analysis. Based on such feedback it could also be established whether occupants are using all available controls related to indoor environment adjustment and energy consumption (such as different settings for the boiler and mechanical ventilation depending on outdoor conditions) in the optimal way which was explained in detail at the handover process at the beginning of their occupancy. Such occupant awareness already proved to be important. Shortly after moving in occupants were complaining about stuffiness in the kitchen. After inspection was carried out it was discovered that extract filter was clogged much faster than usual due intensive use of oil for cooking and consequent accumulation of grease. Occupants were shown how to easily clean the filters and were instructed to do so more often.

Gas usage:

The retrofit aimed at reducing heat loss through the building envelope and air infiltration, and consequently improving comfort of the occupants. As a result of the retrofit the gas consumption significantly reduced. The post retrofit gas usage is approximately one third of the usages in the winter during and before the retrofit. Moreover, the internal temperatures in the monitored rooms were kept on a relatively high levels. Presuming that they were greater than before the retrofit the comfort of the occupants must have improved as well.

Electricity usage:

On average the post retrofit electricity consumption is slightly lower than the pre retrofit usage. It needs to be noted that the mechanical ventilation system installed uses electricity to drive the fan which makes the post retrofit performance even better.

The comparison is based on the utility bills for the pre and during the retrofit consumption and on the readings taken remotely every 5 minutes for the post retrofit usage. Some of the bills are based on the estimates, which may result in inaccuracy. Moreover, annual variations in the seasons' lengths, temperatures, rainfall and solar insolation pose limitations for the comparative analysis of pre and post retrofit performance. Consequently, comparison for a few years after and before the retrofit would give more comprehensive results and result in more reliable conclusions.