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

(Appendix 6)

78, Grove Road, Hounslow, London

Analysis of Monitored Data

A Deep Retrofit Using Certified Passivhaus Components and Methods

March 2012

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Contents

1: Introduction

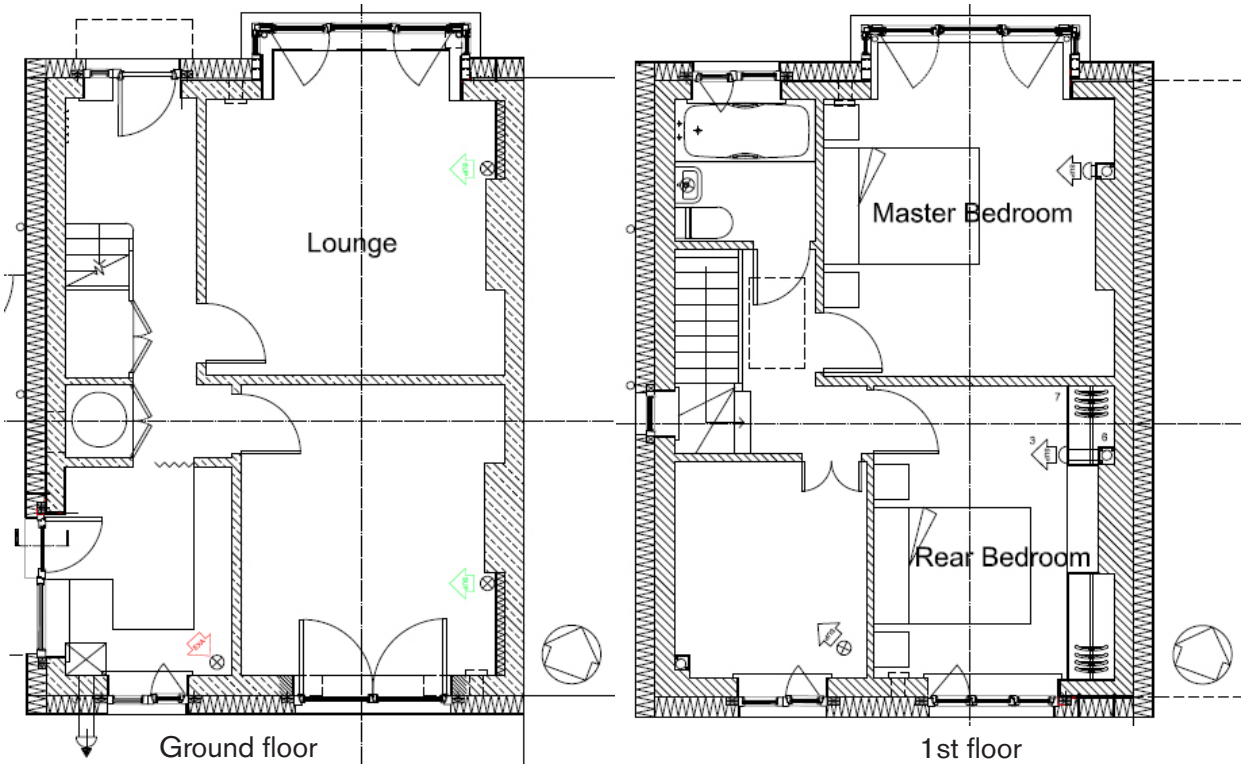
Funded by the Technology Strategy Board's 'Retrofit for the Future' programme, this house in Grove Road, Hounslow, London, although not meeting Passivhaus or Enerphit certifiable standards, has been retrofitted by experienced passivhaus architects using a fabric-first approach, and some passivhaus components.

The retrofit started in February 2011 and finished in July 2011. As a result of this deep retrofit the energy efficiency of the house and the comfort of the occupants have been greatly improved. To monitor the effect of the retrofit several parameters were metered. Analysis in this report is for the period from the 16th Aug 2011 until19 Feb 2012 thus it covers the period after the retrofit, including some summer months and the first winter post-retrofit. The 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 (living room, master bedroom, rear bedroom)
- relative humidity [%]: external, internal (living room, master bedroom, rear bedroom)
- solar insolation [W/m^2}
- energy [kWh]:
  - electricity,
  - heating, hot water and cooking (gas consumption in m^3 converted into kWh),
  - heat produced by the solar thermal panels (not included in this report),
  - used by auxiliary components of solar thermal panels (not inc. in this report).
- gas [m^3]

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



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 to show diurnal changes in temperatures and relative humidity. All the graphs for the whole analysed period are collated in the Appendix that follows this report.

Relative humidity is closely related to temperature. Generally, the higher the external temperature the lower the external and internal relative humidity. If the air inside the house is heated then this also reduces the relative humidity, as shown by the graphs depicting the data collected during the winter. The relationship between humidity and comfort is reviewed in section 2.2.

It was found that after the retrofit, external conditions have only a small effect on the internal temperatures of the house. The graphs show that the temperature in the lounge, master bedroom and rear bedroom stays between 20 and 25 degrees during the periods monitored (see also 2.2 Comfort Charts: Temperature) and are relatively unaffected by the daily peaks and troughs of the external summer or winter temperatures.

In the colder conditions the temperatures vary more than in the summer which is caused by the occupants changing the set temperature for the heating to save energy at night.

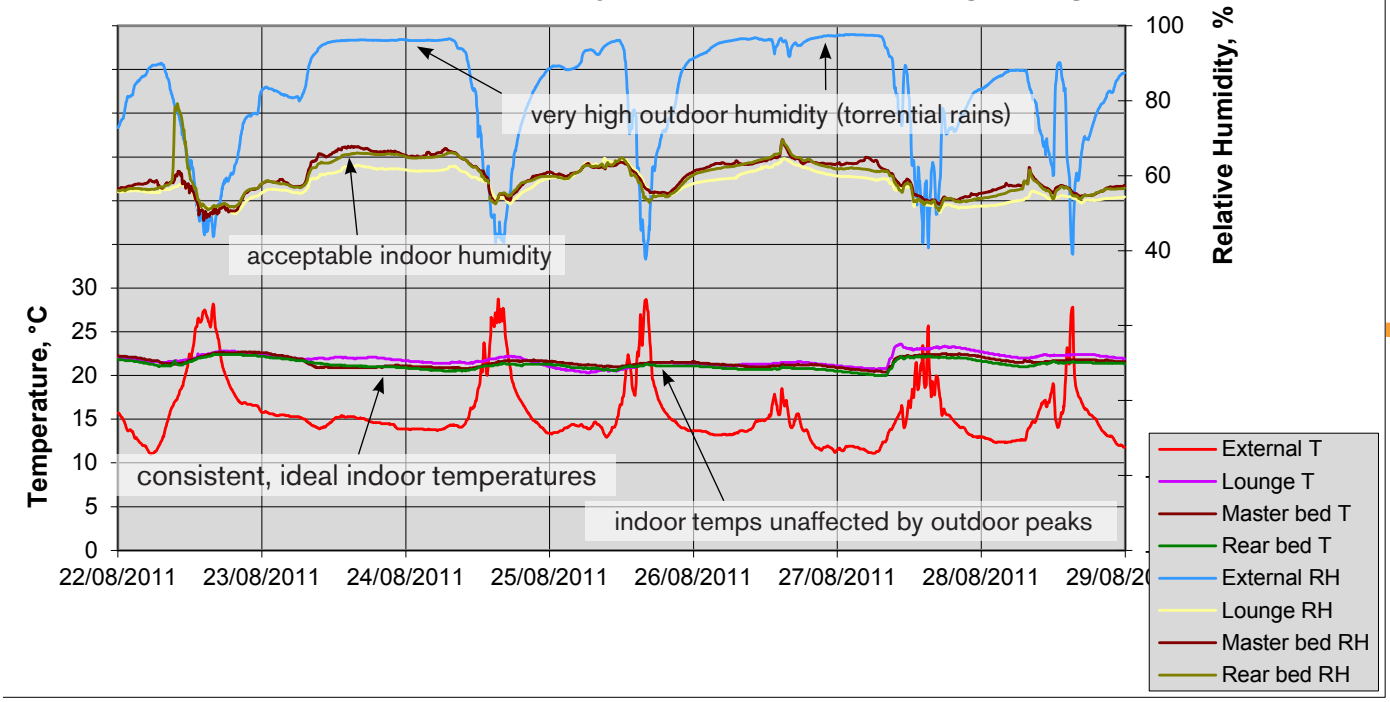
The increase or decrease of the indoor relative humidity, together with the CO_2 concentration has been used as good marker of the occupancy of the house.

As expected in houses with good thermal inertia, the temperature after reaching its set point changes only very slowly if the set point is lowered. This can be seen during the night when the set point is reduced. The temperature and relative humidity trends for all three monitored rooms are very similar which means that changes in external conditions have an insignificant effect on the interior conditions.

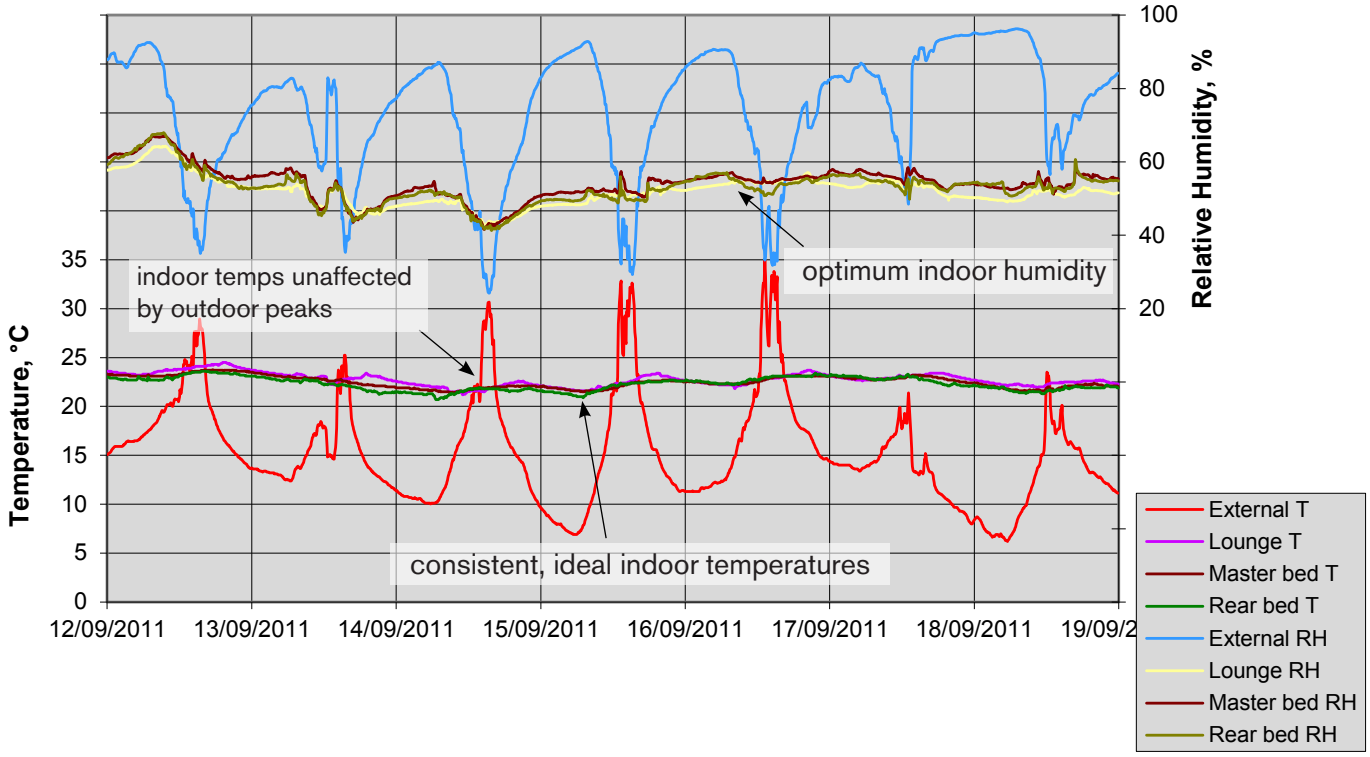
Some of the graphs show high false external temperatures at midday on sunny days which is caused by exposure of the sensor to direct sunlight. The casing warms up and the sensor's outdoor temperature is overstated.

In the monitored house the indoor comfort conditions change very slowly, as determined by the temperature and relative humidity, indicating a steady and comfortable indoor microclimate.

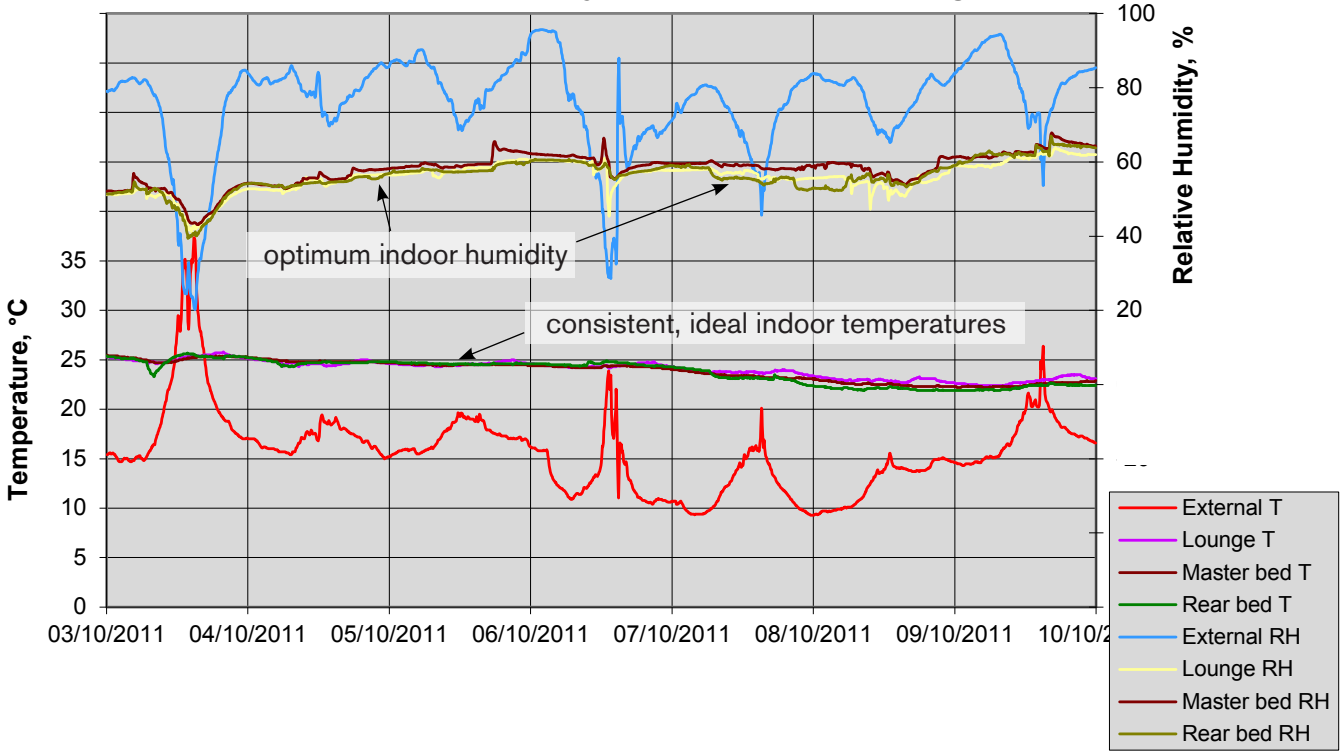
Temperature and Relative Humidity for the week commencing 22 Aug 2011



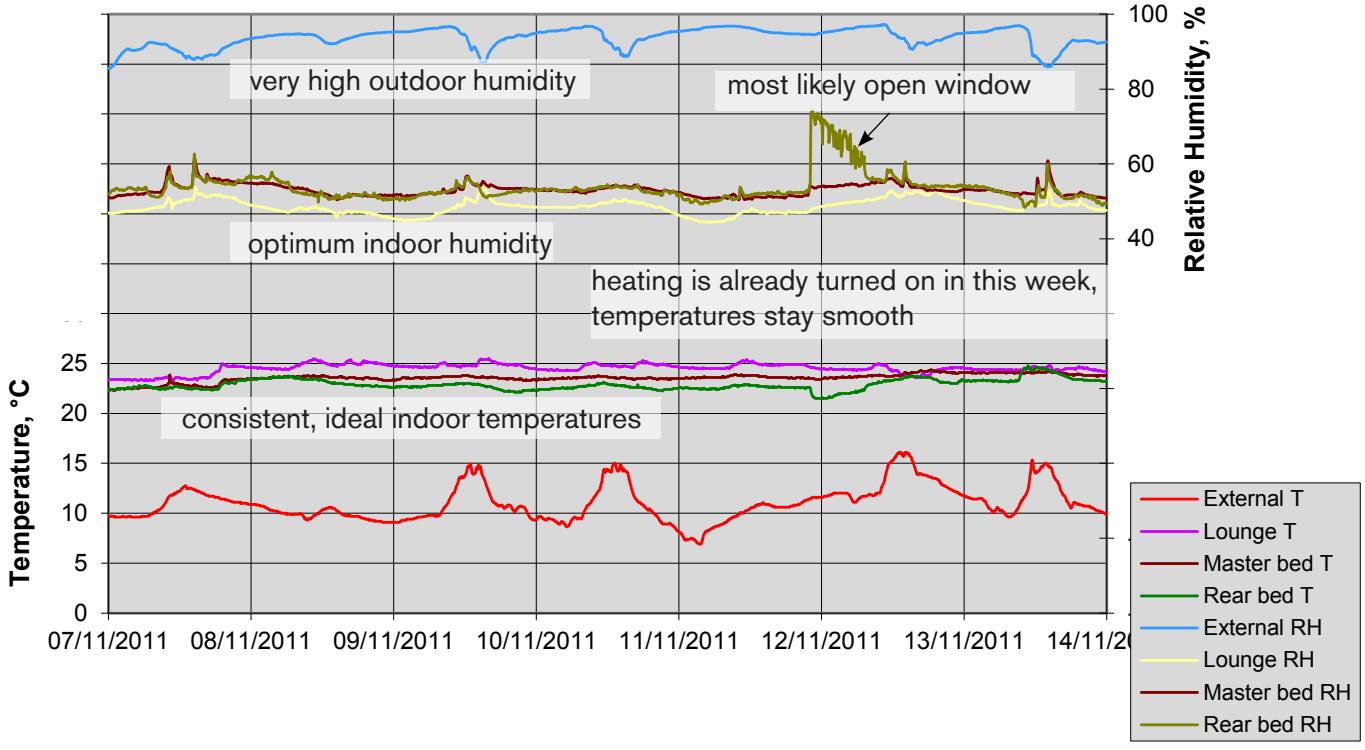
Temperature and Relative Humidity for the week commencing 12 Sep 2011



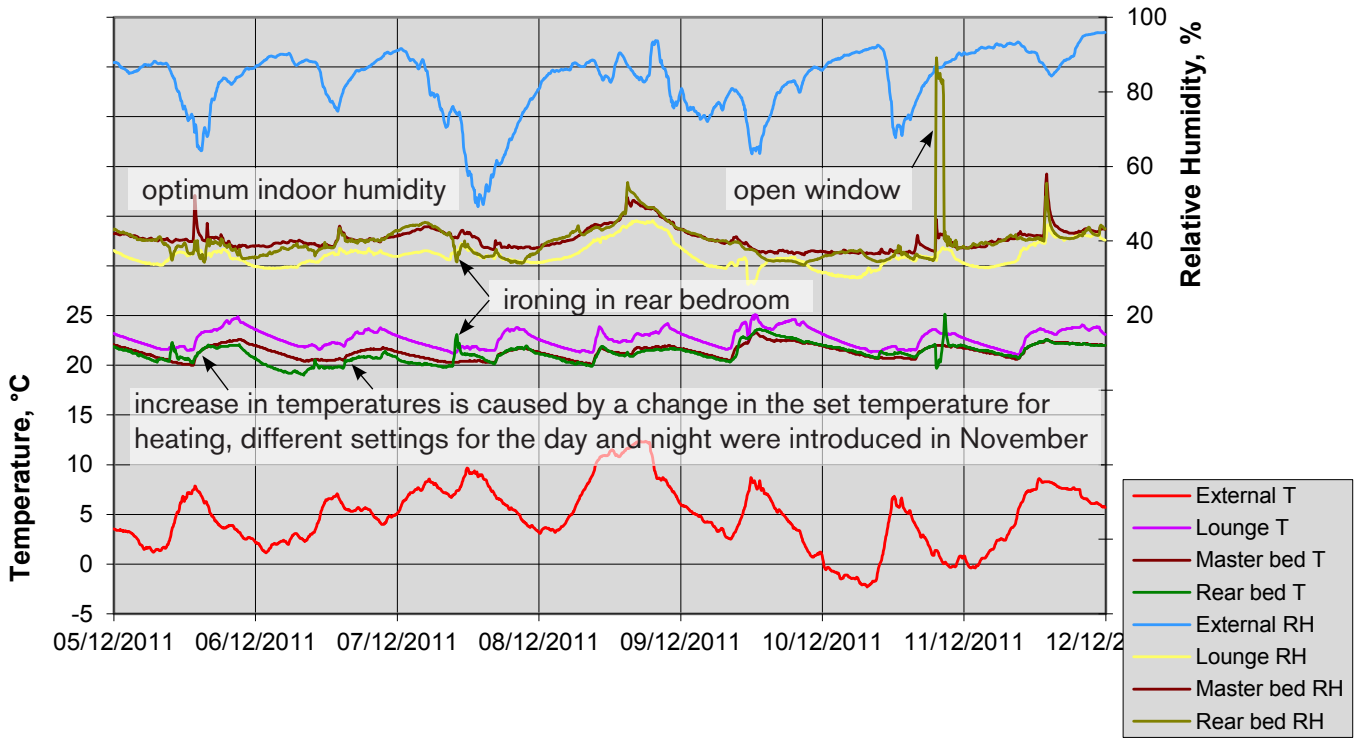
Temperature and Relative Humidity for the week commencing 03 Oct 2011



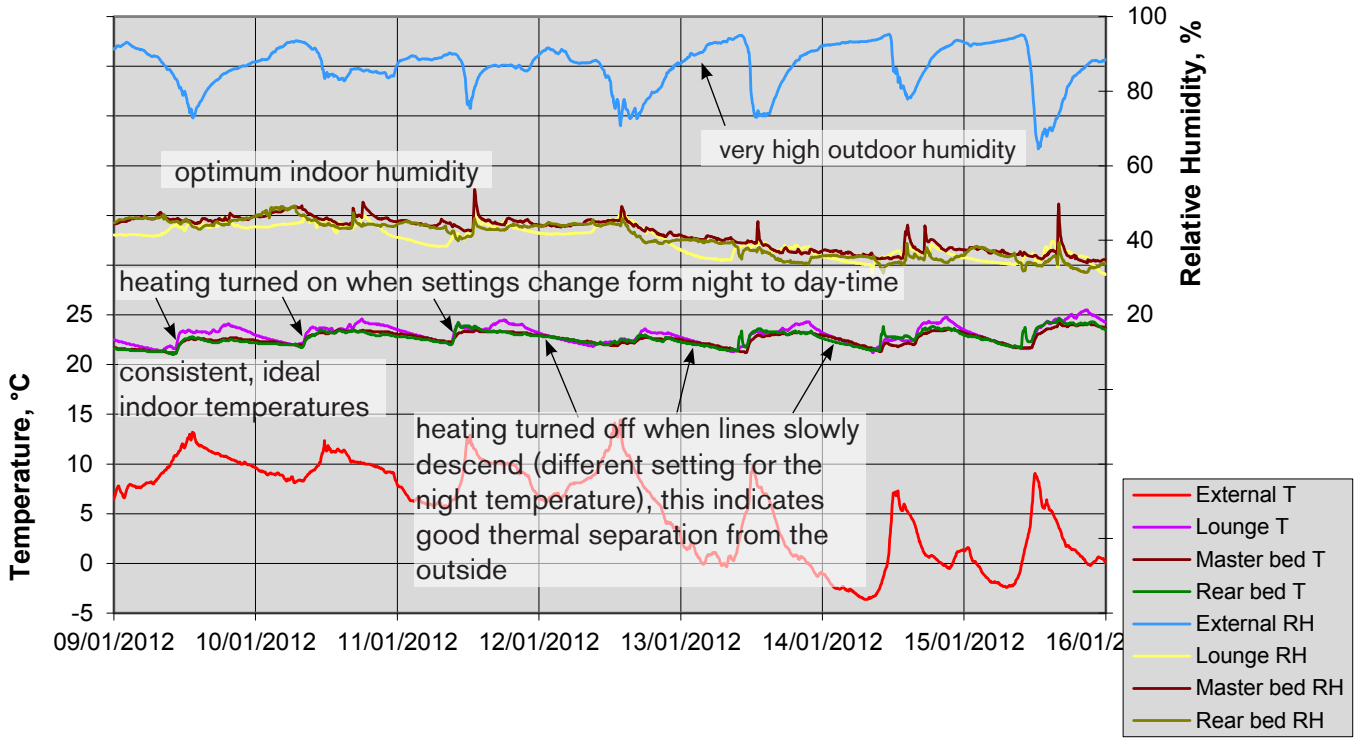
Temperature and Relative Humidity for the week commencing 07 Nov 2011



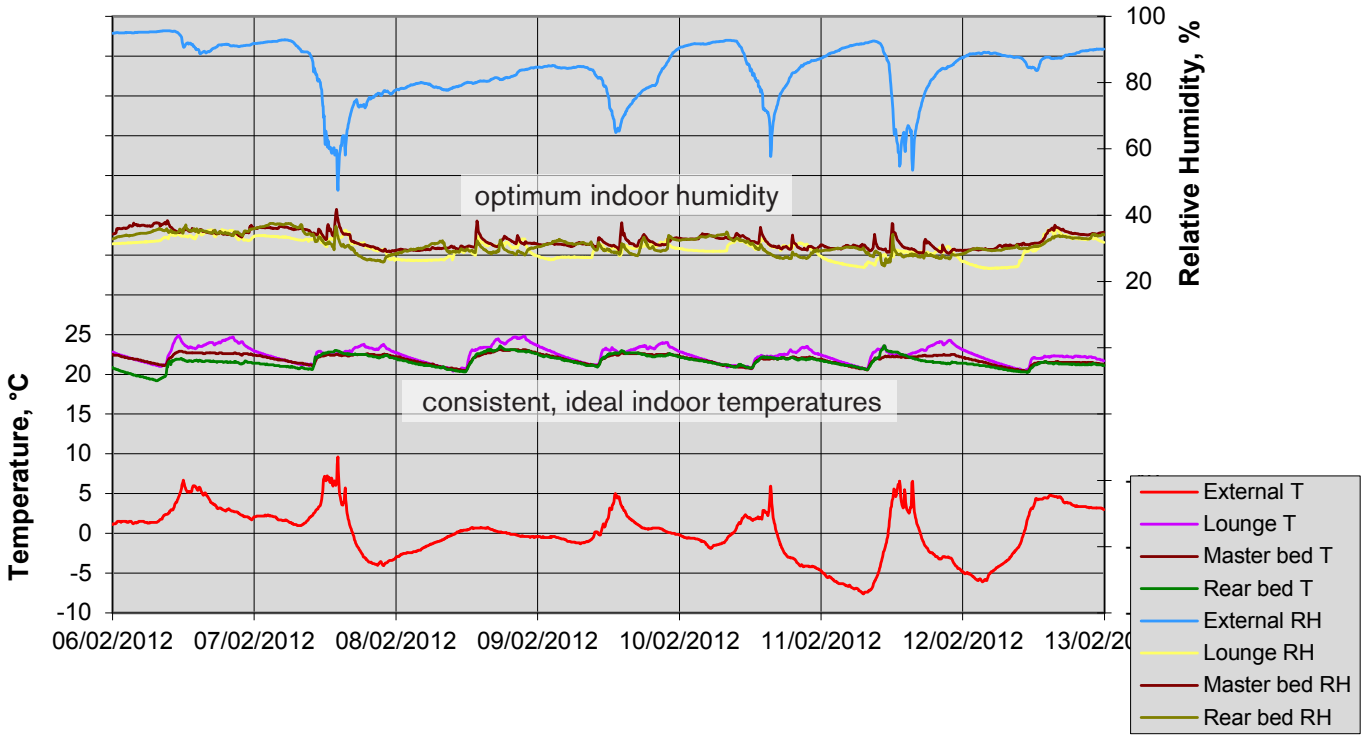
Temperature and Relative Humidity for the week commencing 05 Dec 2011



Temperature and Relative Humidity for the week commencing 09 Jan 2012



Temperature and Relative Humidity for the week commencing 06 Feb 2012



2: Analysis and Graphs

2.2: Comfort Charts

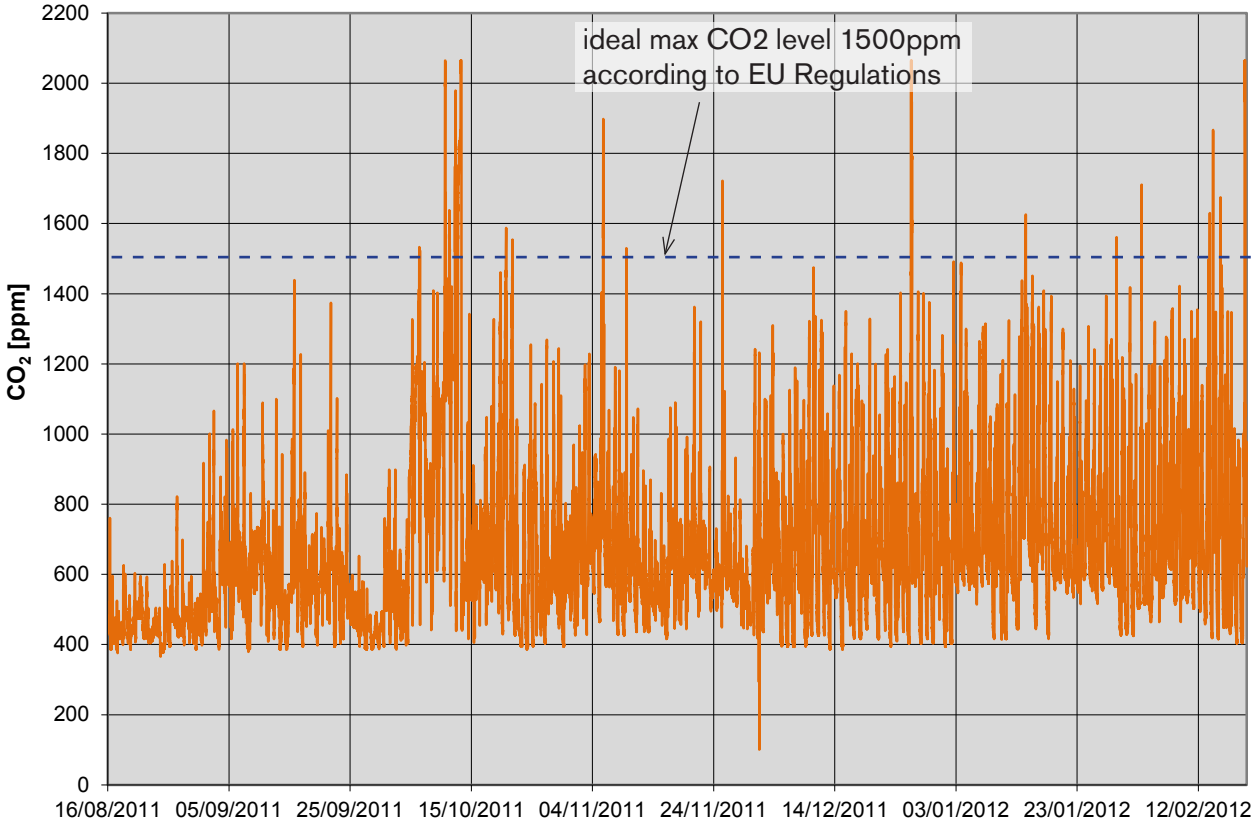
2.2.1: CO_2

Human comfort depends on thermal comfort and air quality. Thermal comfort is very personal to the 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 in a given temperature and relative humidity (see 2.2.3 Temperature vs Relative Humidity). Another factor is the quality of air which except for VOCs (volatile organic compounds) is determined by the level of carbon dioxide in the air.

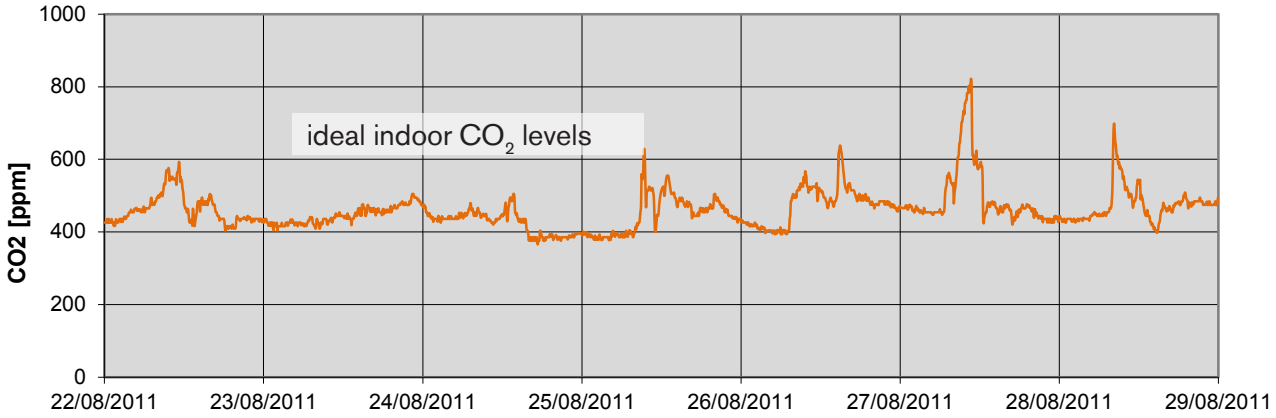
The CO_2 levels in the monitored house are most of the time kept at a very low level, much below the EU Regulations level of an ideal maximum concentration of1500ppm. As seen on the graph for the whole analysed period, the measured CO_2 levels only briefly exceeded 1500ppm a few times over the course of half a year.

Consistently low levels of CO2 in the indoor air indicate extremely good indoor air quality. This proves the effectiveness of the heat recovery ventilation system installed in the house.

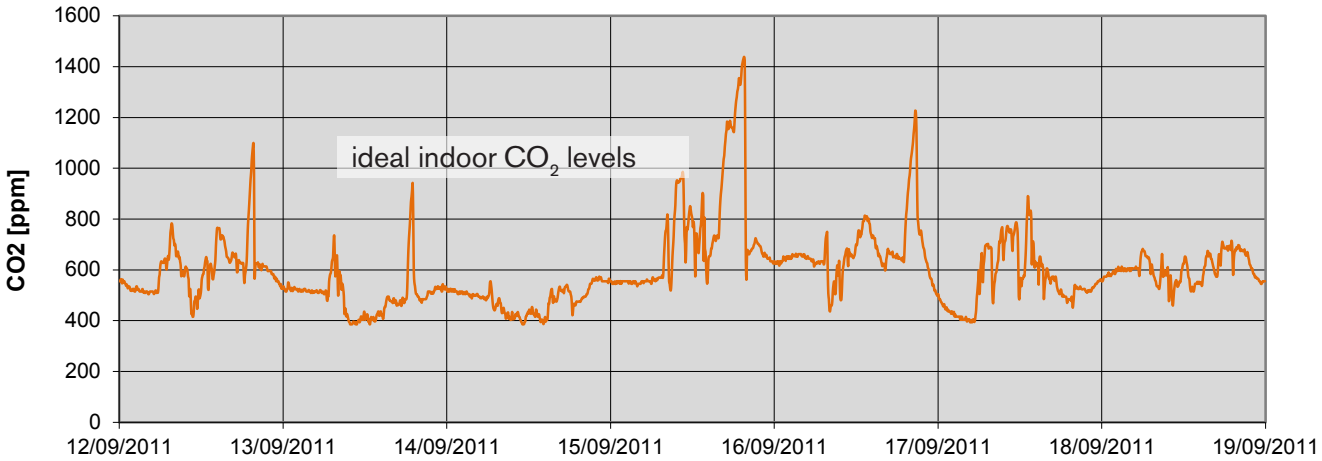
CO_2 concentration measured in Lounge between 16 Aug 2011 - 19 Feb 2012



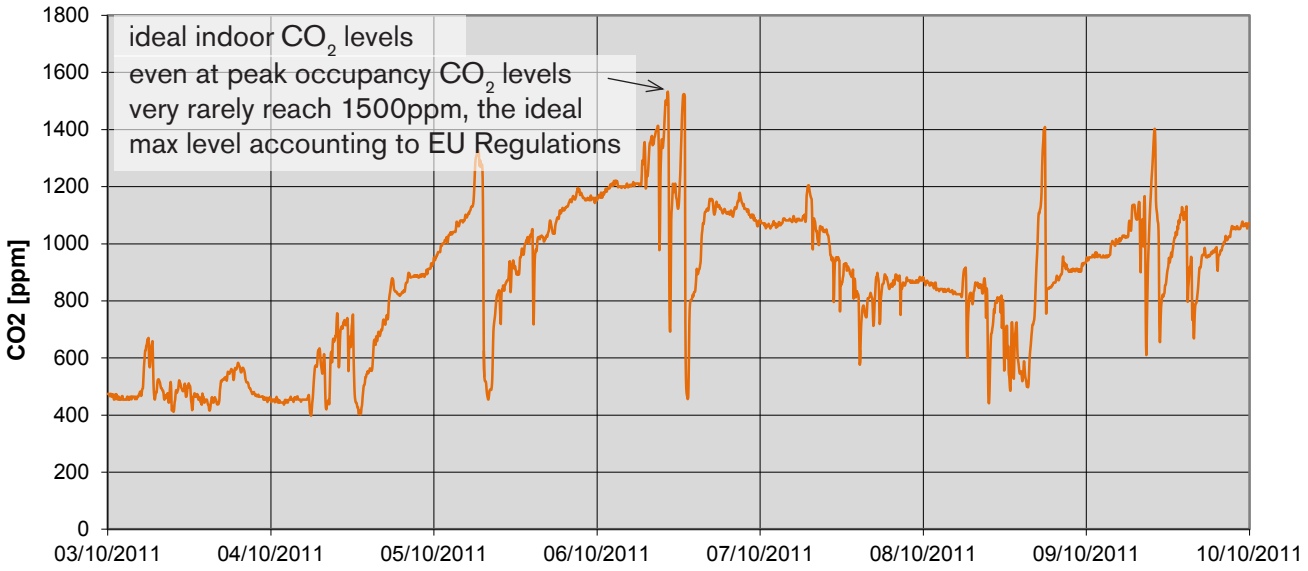
CO_2 concentration for the week commencing 22 Aug 2011



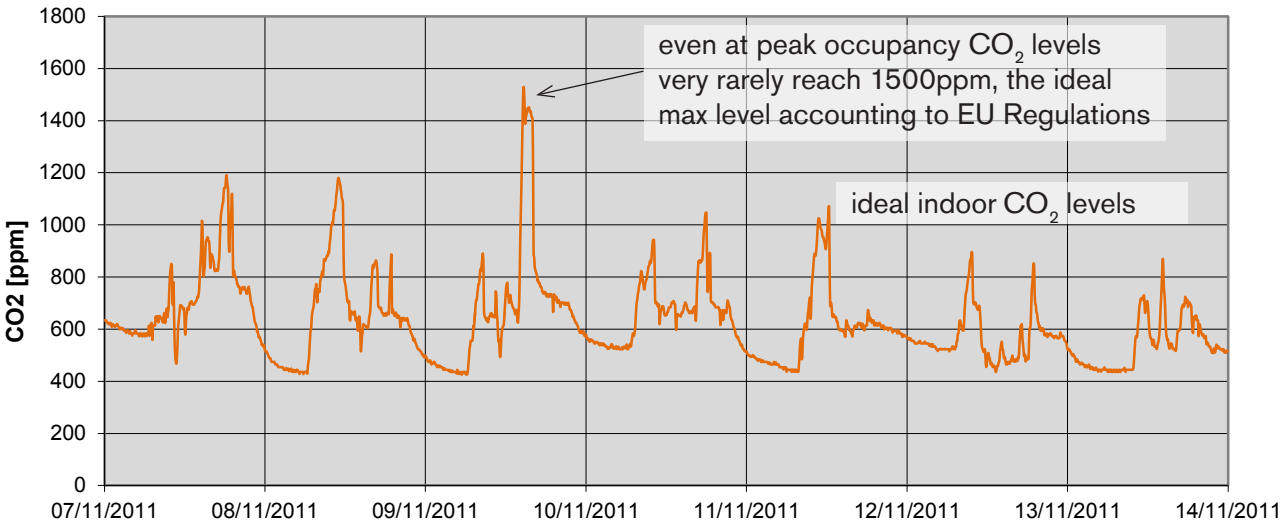
CO_2 concentration for the week commencing 12 Sep 2011



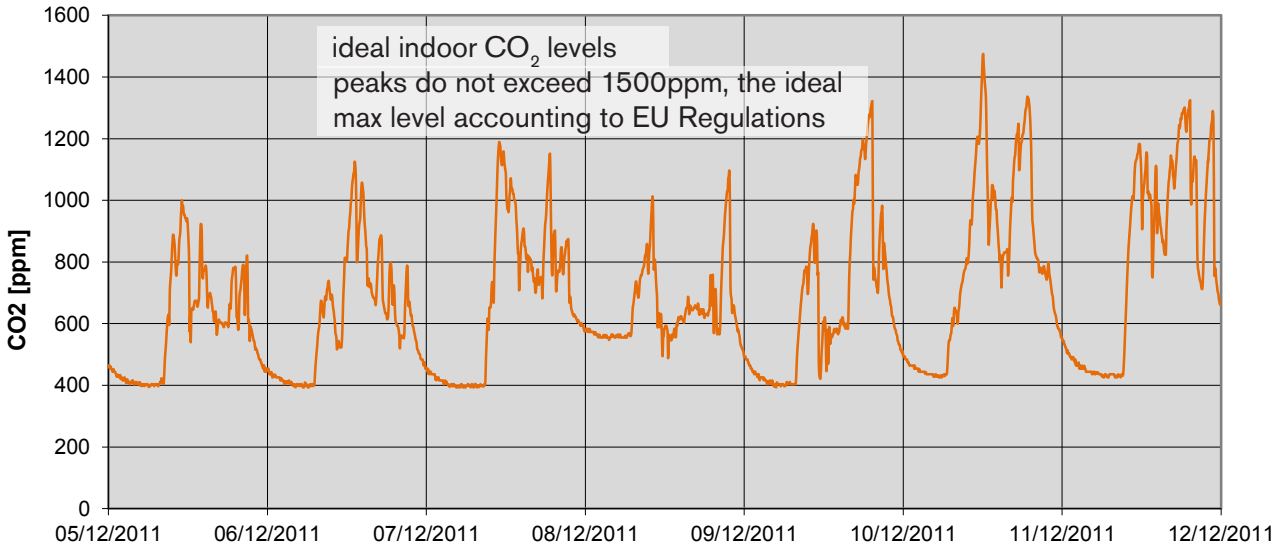
CO_2 concentration for the week commencing 03 Oct 2011



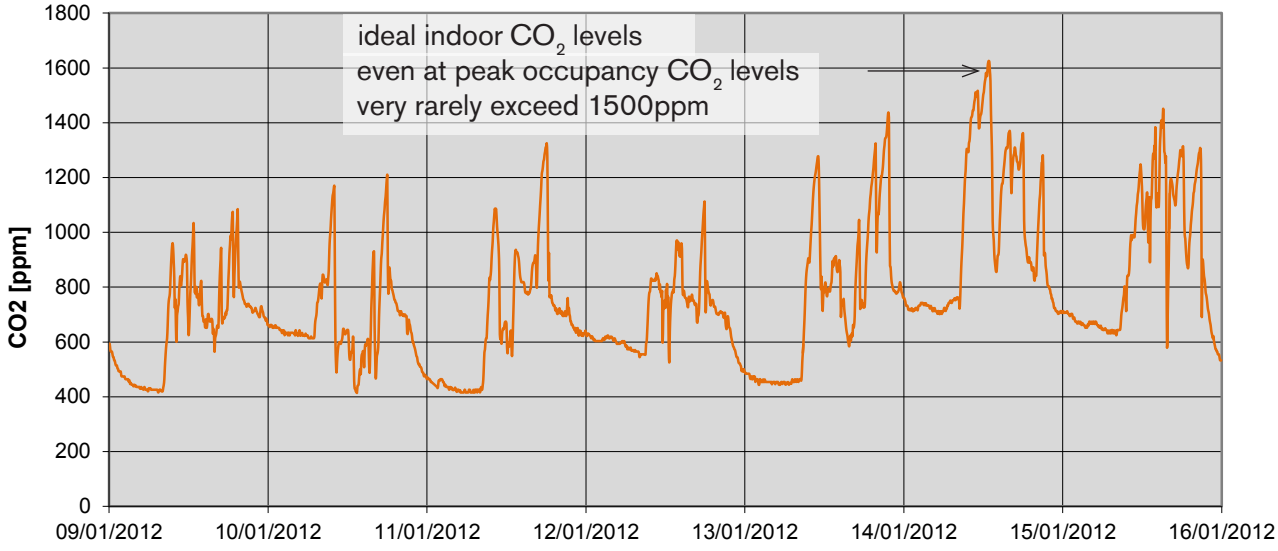
CO_2 concentration for the week commencing 07 Nov 2011

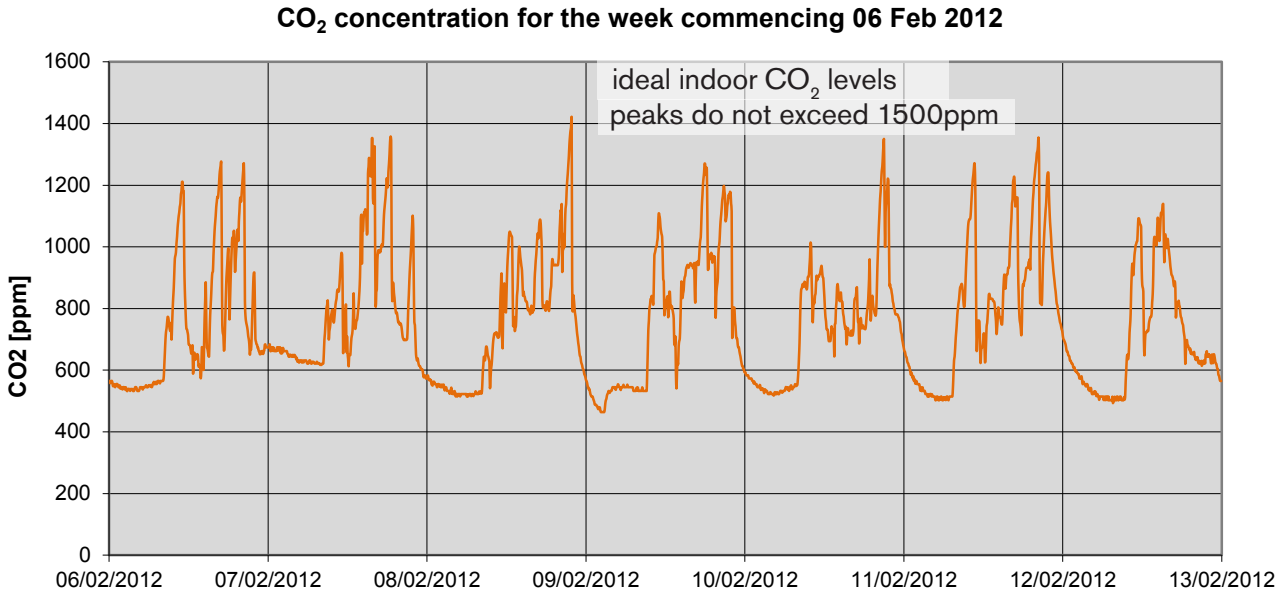


CO_2 concentration for the week commencing 05 Dec 2011



CO_2 concentration for the week commencing 09 Jan 2012





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2: Analysis and Graphs

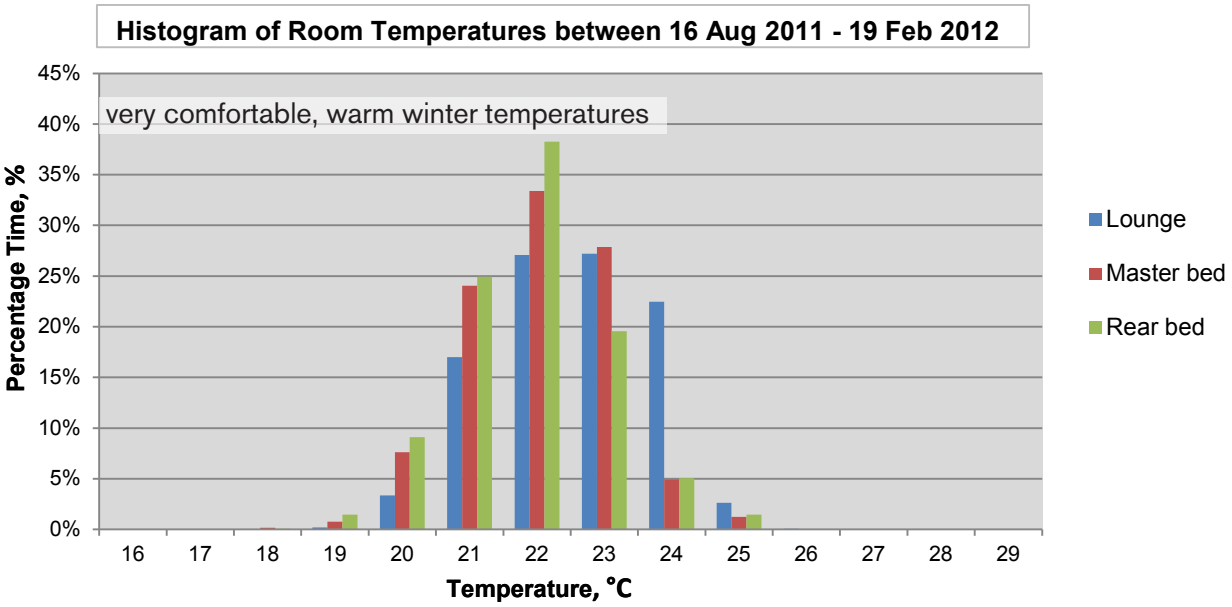
2.2: Comfort Charts

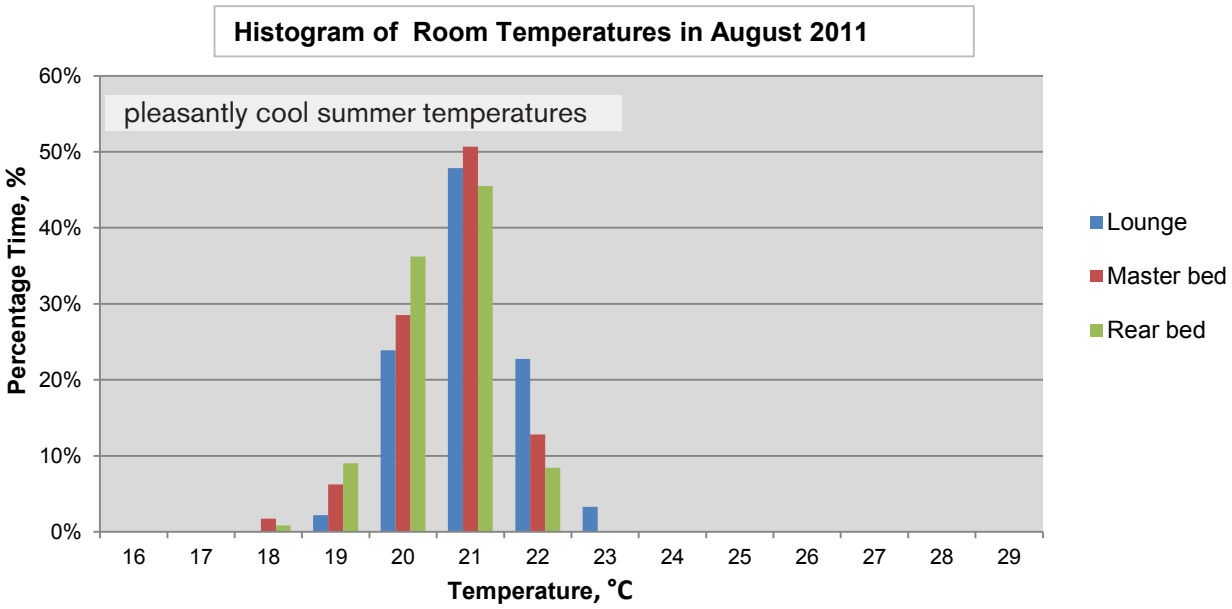
2.2.2: Indoor Temperatures Occurrence

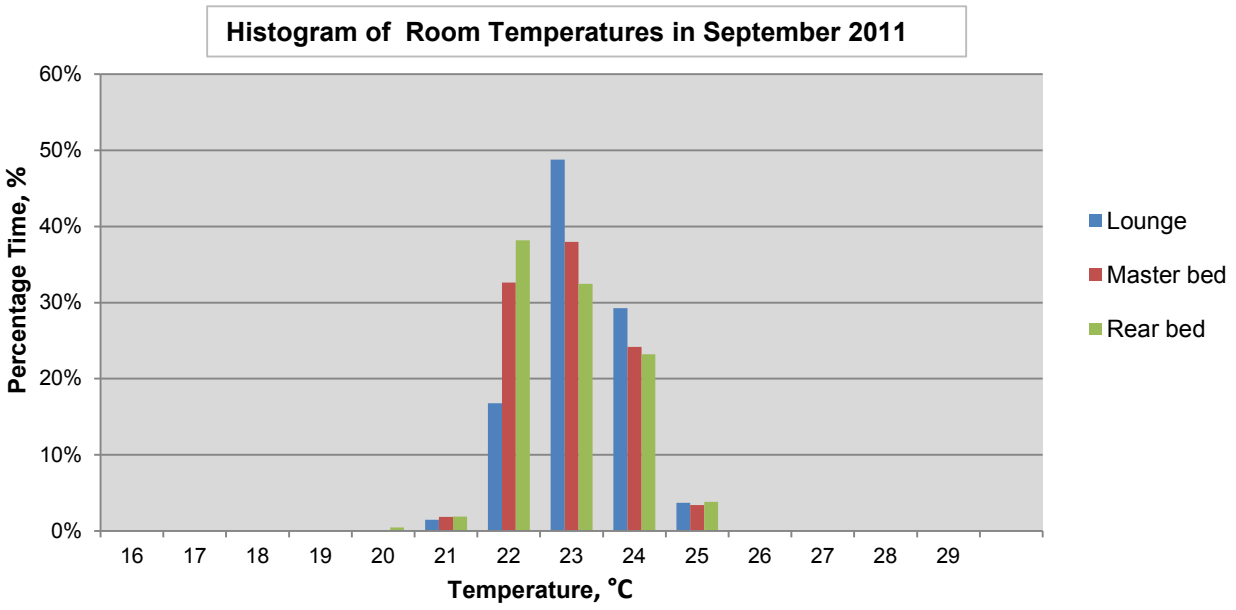
The histograms below depict temperatures measured in the monitored rooms after the retrofit. As can be observed the temperatures are kept most of the time between 20 and 25 degrees with the most predominant temperature being 22 degrees.

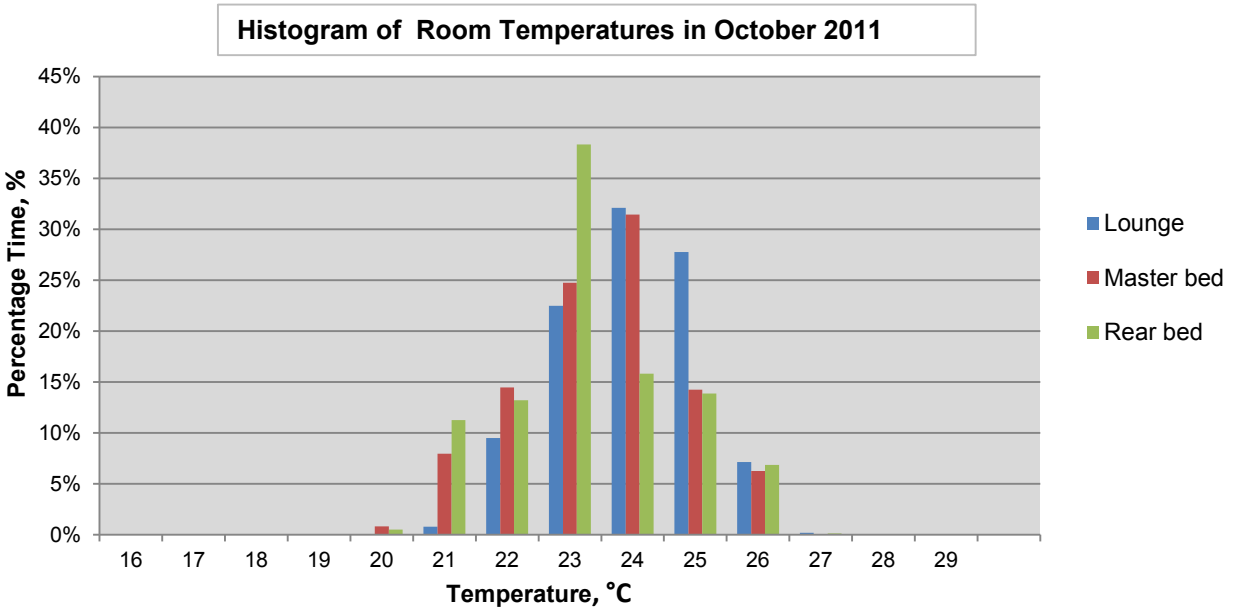
The temperature in the living room was kept slightly higher than in the master and rear bedrooms. Temperatures below 20 degrees were measured only in August when heating was not yet required and the house was naturally ventilated.

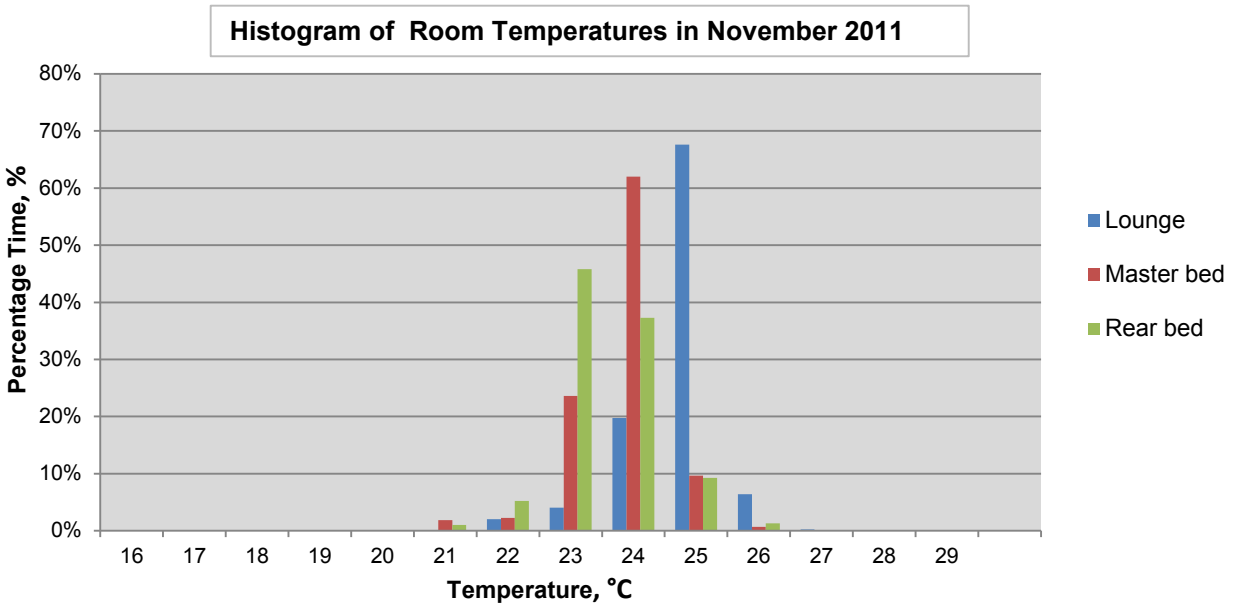
We can conclude that this super-insulated house provides excellent year-round comfort conditions; slightly cooler in summer and warmer in winter.

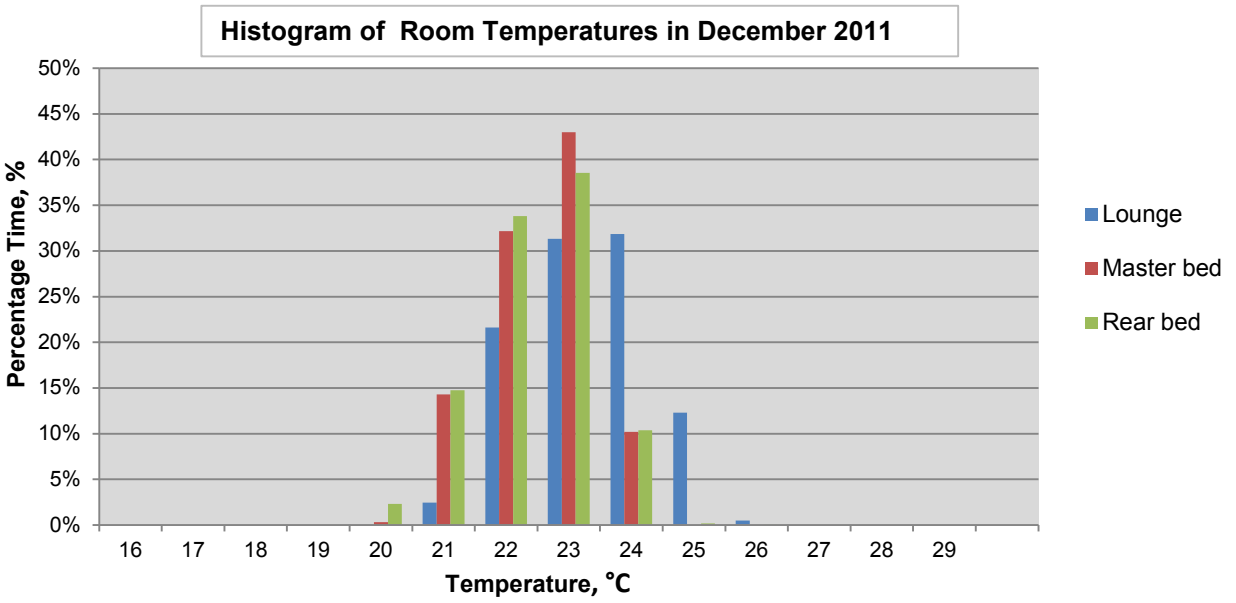


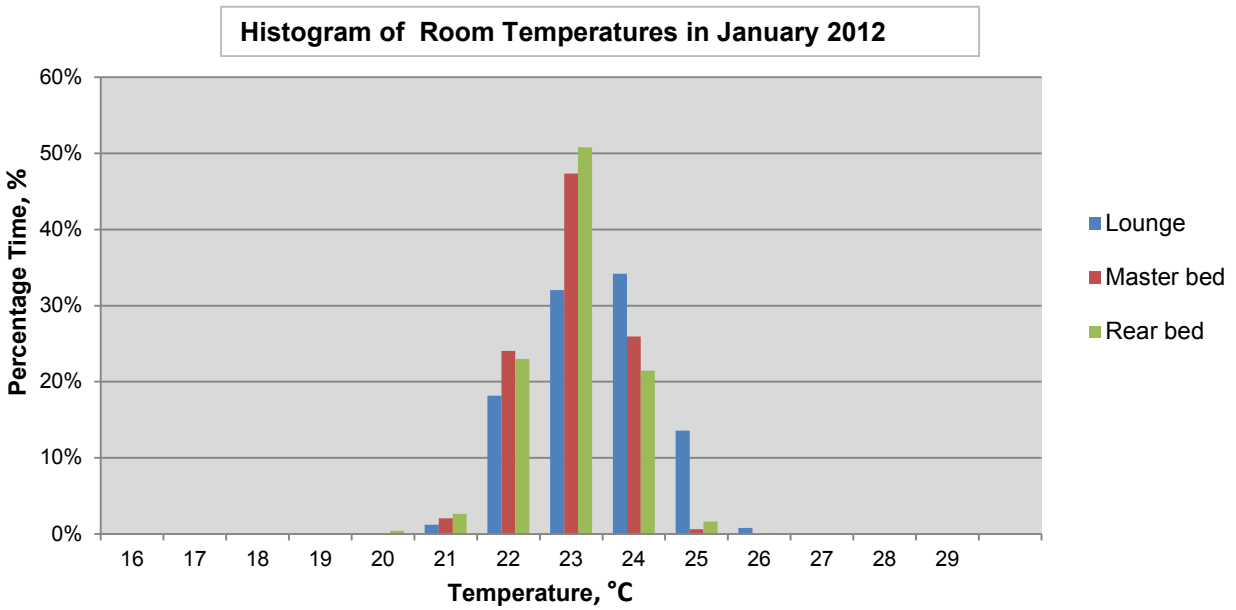


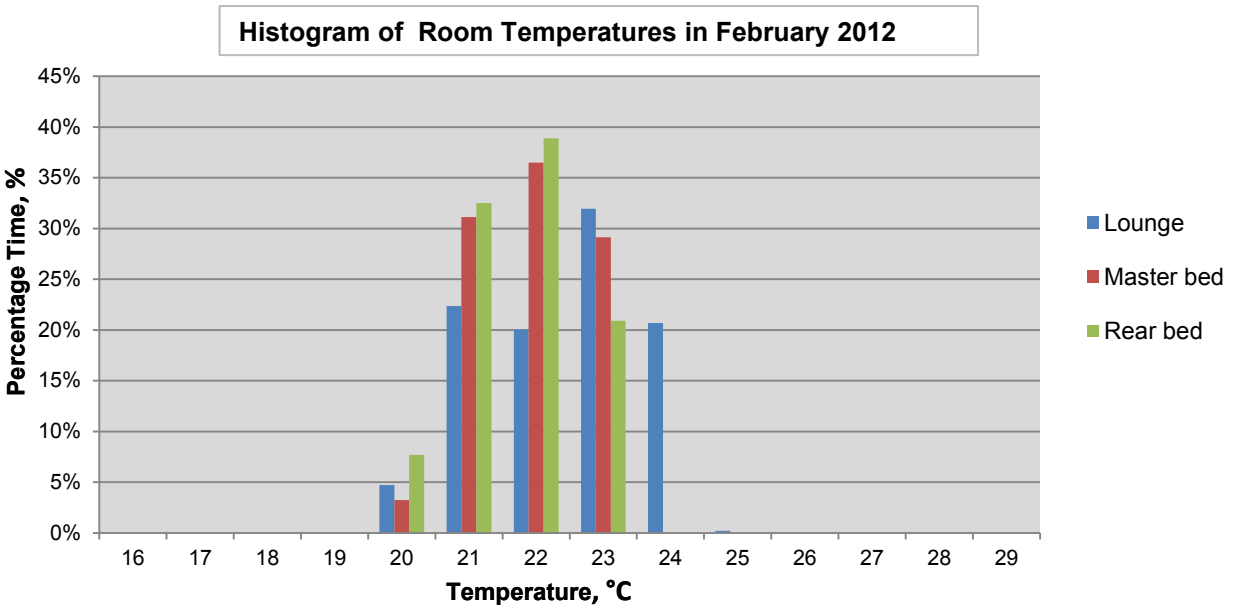












2: Analysis and Graphs

2.2: Comfort Charts

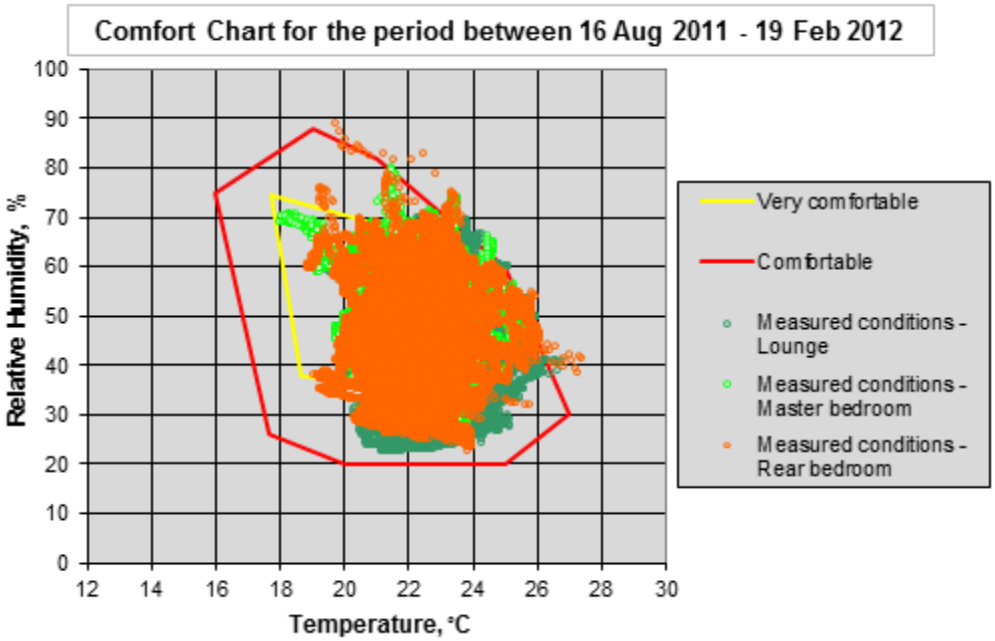
2.2.3: Thermal Comfort

Comfort defined by temperature and relative humidity is crucial for wellbeing. The conditions in which an individual feels best are very personal, however, generalisations can be made. The graphs below show the measured indoor conditions and the standard parameters for comfortable and very comfortable conditions. The comfort outlines have been taken from the following website: http://ecologic-architecture.org/main/index.php?id=48&L=1

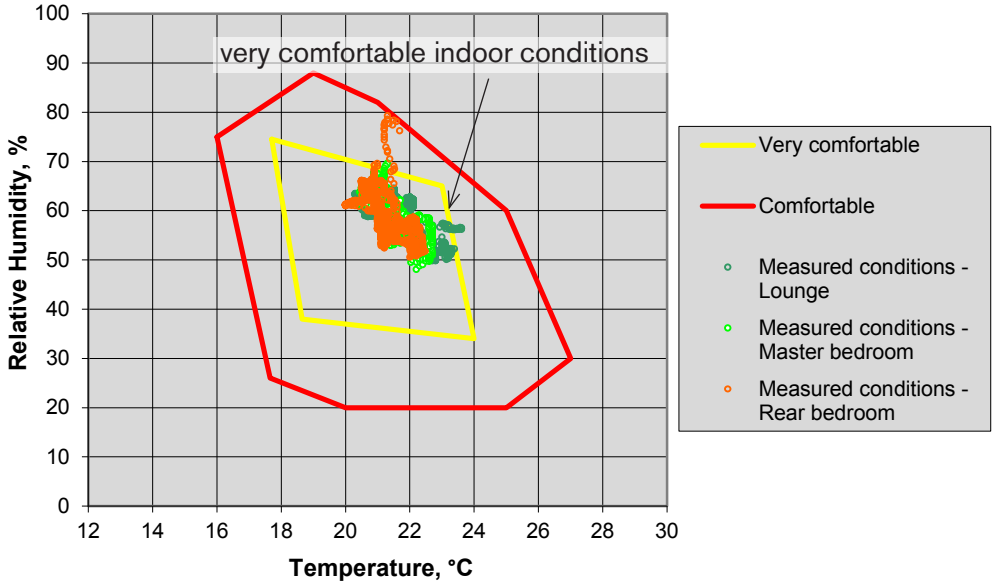
In the colder season the graphs show reduced indoor humidity because the heat recovery ventilation system carries away the moist indoor air which has increased humidity from the occupants, and replaces it with drier air from outside (warmed by the stale air by means of the ventilation heat exchanger). Nevertheless, even in the coldest days the measured drier conditions stayed almost entirely within the outline for comfortable conditions.

The elderly occupants prefer higher temperatures which sometimes resulted in crossing the outlines slightly. Because it was for such a short time probably it was not noticeable.

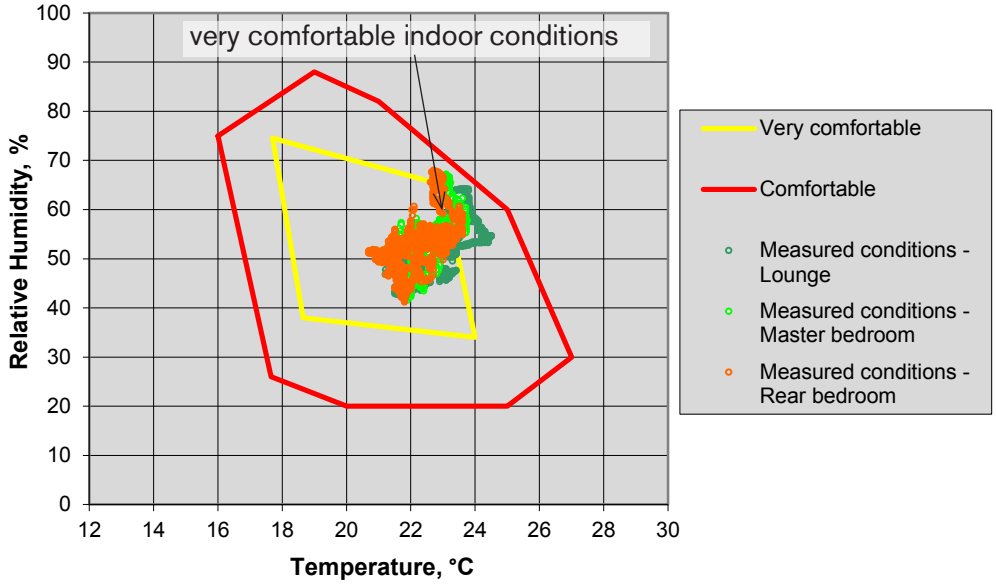
The graphs show that the measured conditions are very comfortable irrespective of outdoor weather conditions; remaining almost entirely within the parameter for ideal comfort conditions.



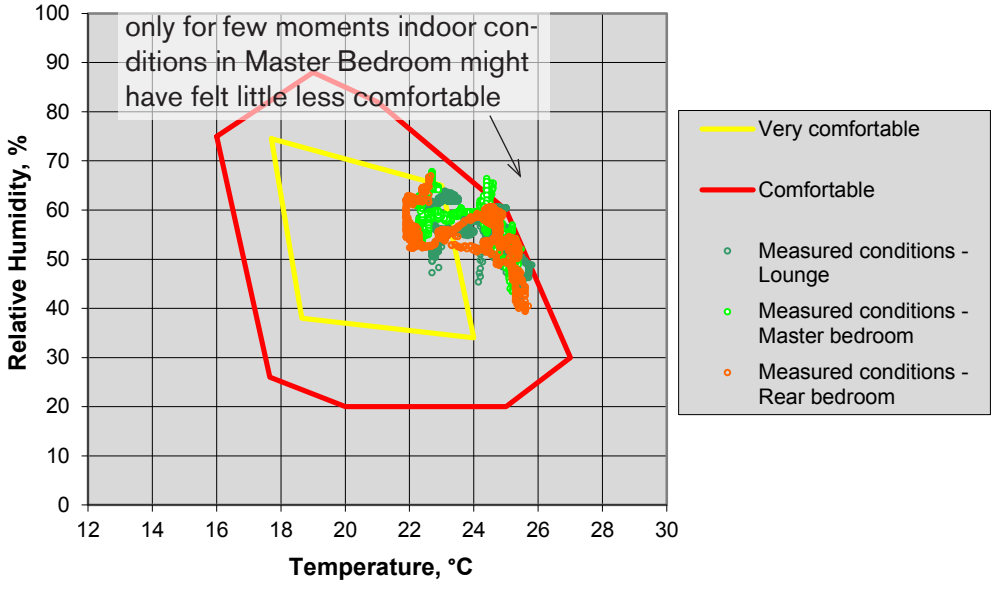
Comfort Chart for the week commencing 22 Aug 2011



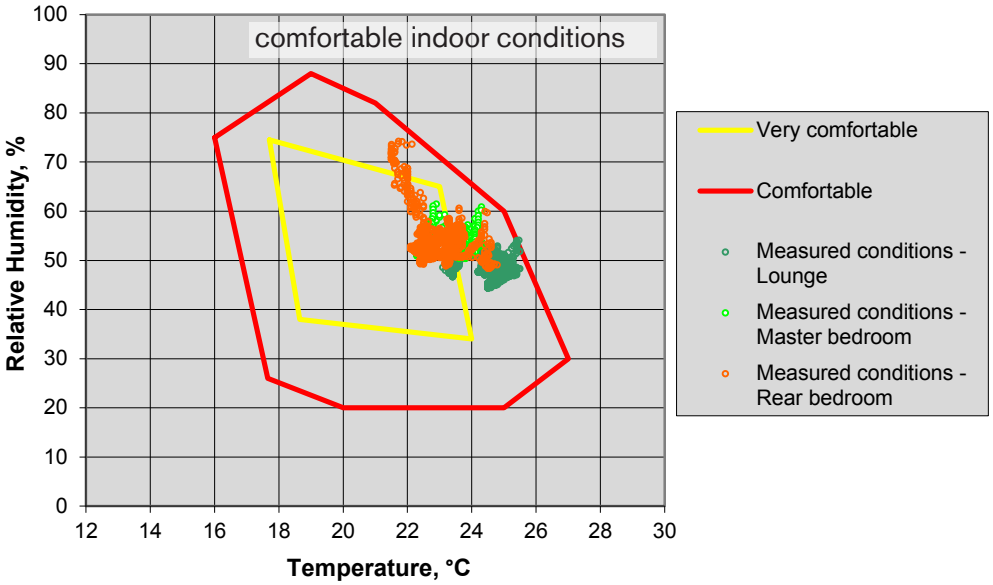
Comfort Chart for the week commencing 12 Sep 2011



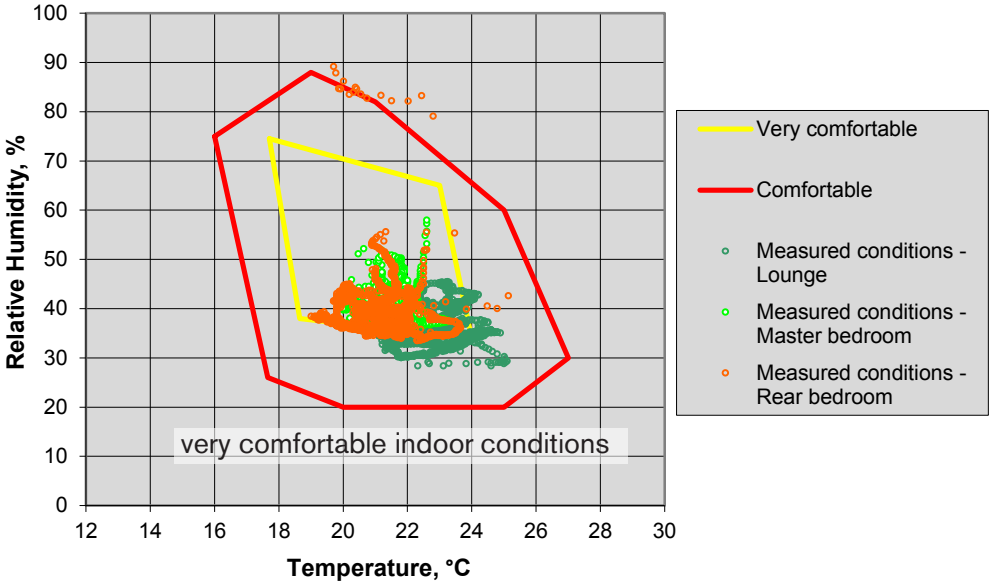
Comfort Chart for the week commencing 03 Oct 2011



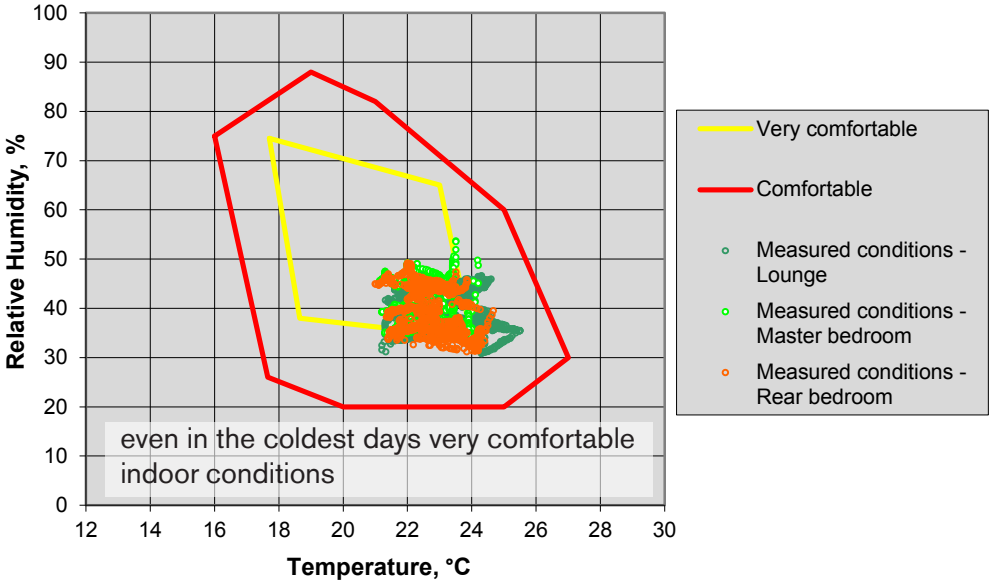
Comfort Chart for the week commencing 07 Nov 2011

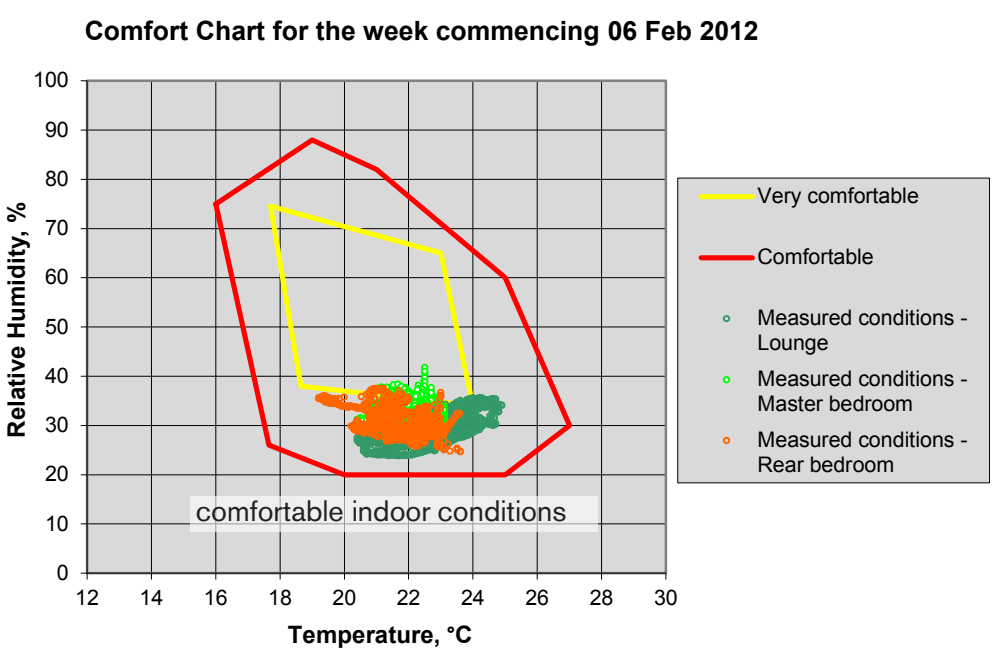


Comfort Chart for the week commencing 05 Dec 2011



Comfort Chart for the week commencing 09 Jan 2012



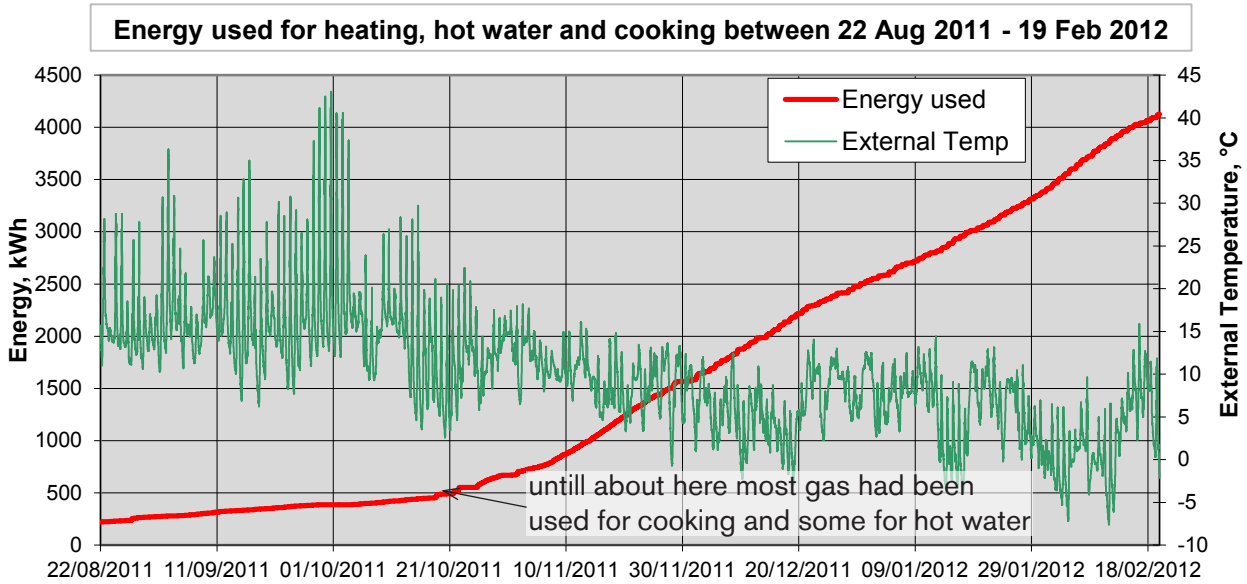


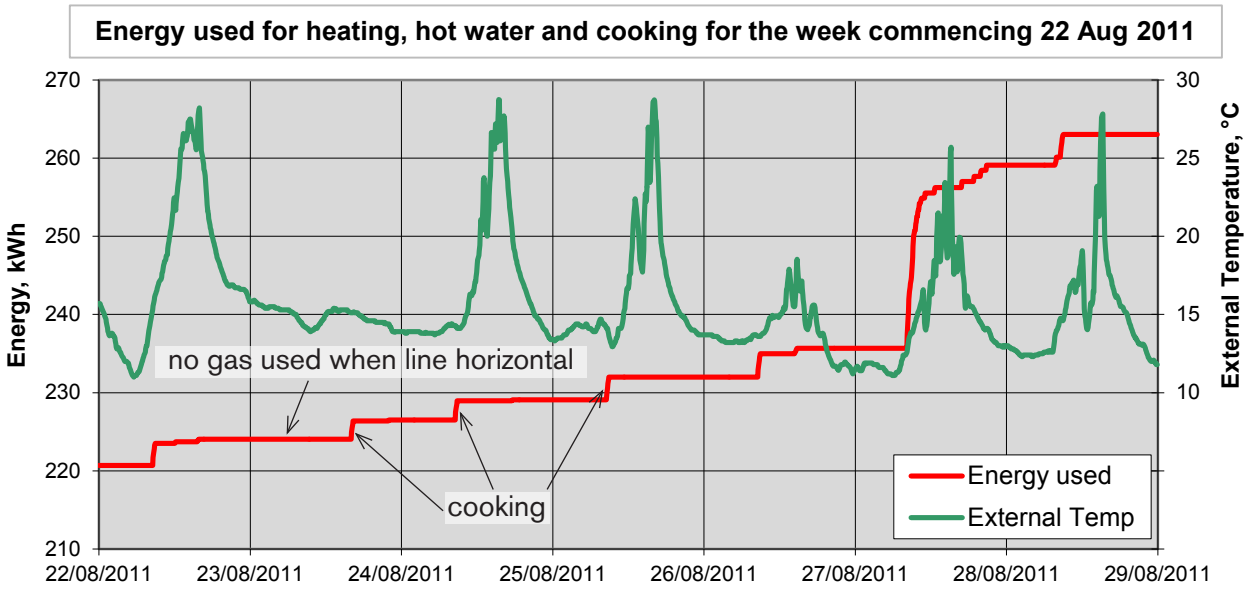
2: Analysis and Graphs

2.3: Energy for Heating, Hot Water and Cooking

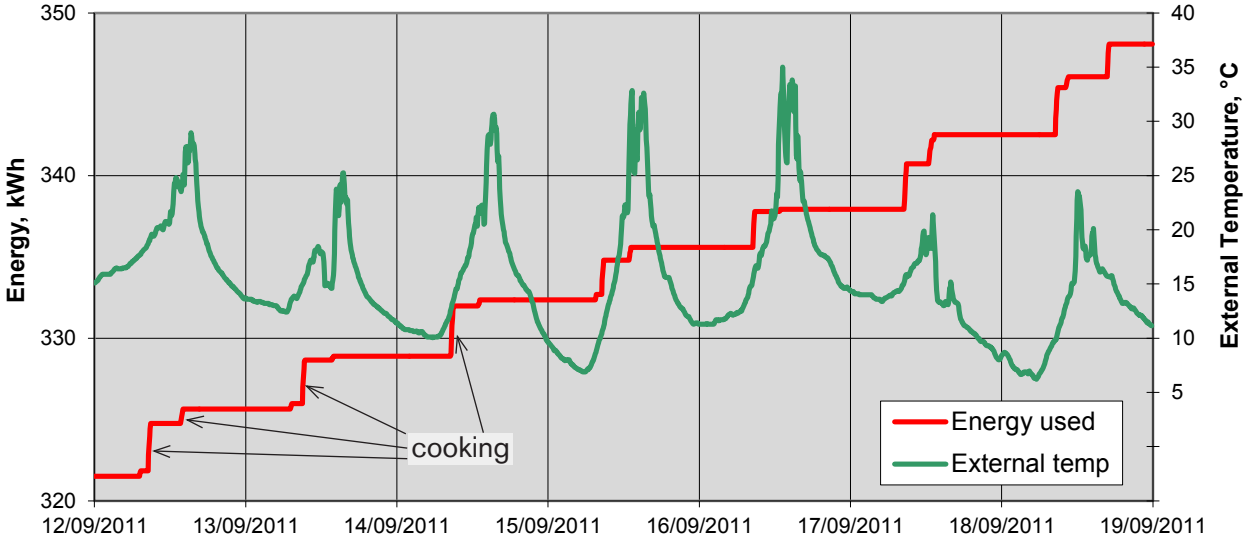
In the retrofitted house, gas is used to top up indoor temperatures, top up the solar-heated hot water and for cooking. In the graphs below the usage for cooking is easily determinable before the heating has been turned on. When heating is turned on the usage for cooking is still just discernible.

Some of the gas use on the graphs is attributable to hot water needs. However, it is highly probable that in the summer most of the hot water needs are met by the solar thermal panels installed on the roof. In the winter months, when some space heating is required, the hot water demands are masked by the heating demands.

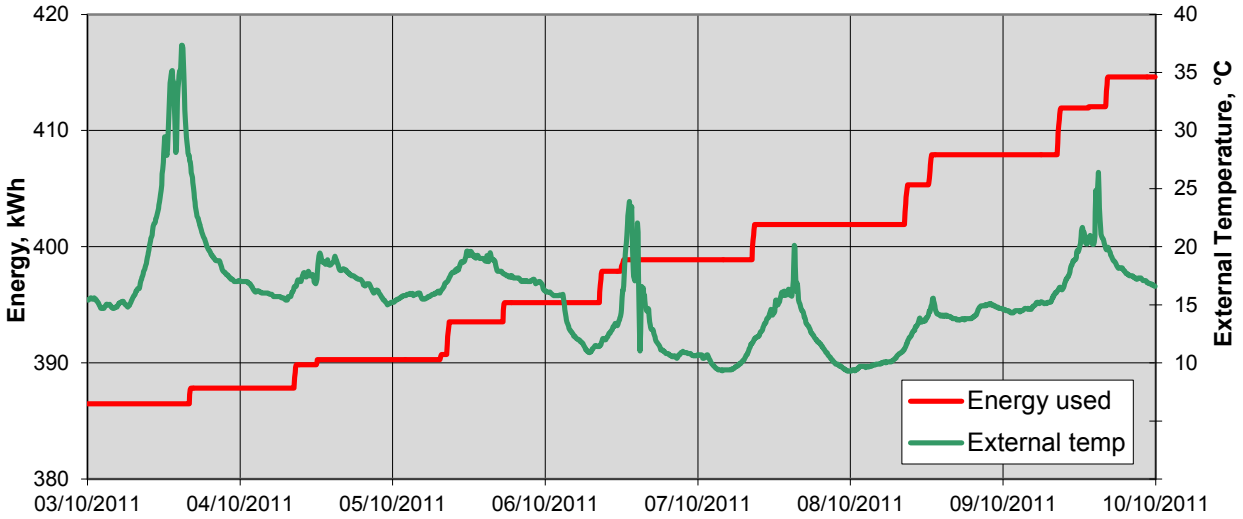




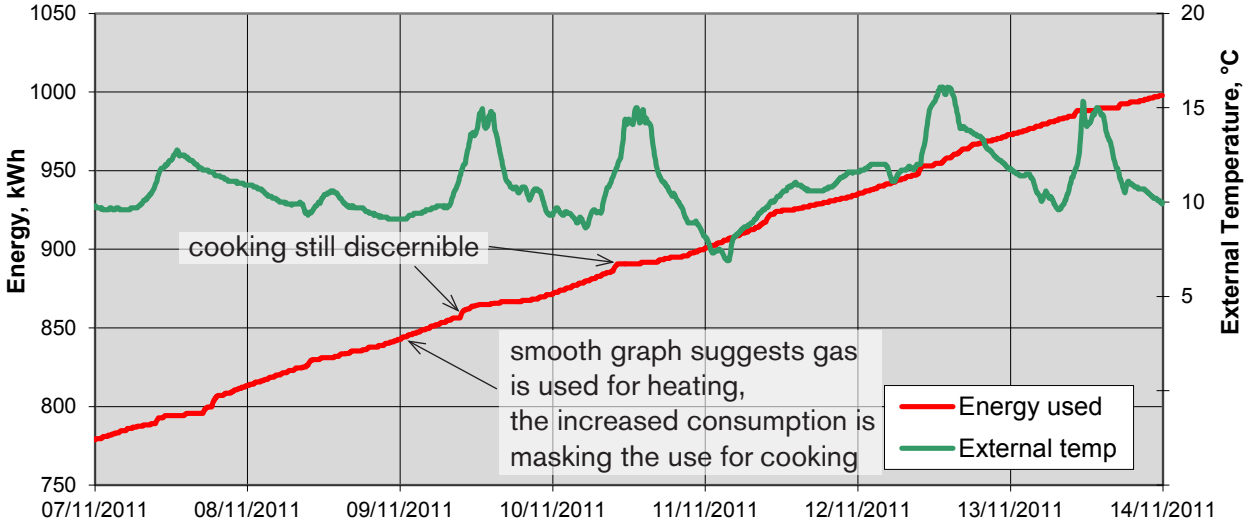
Energy used for heating, hot water and cooking for the week commencing 12 Sep 2011



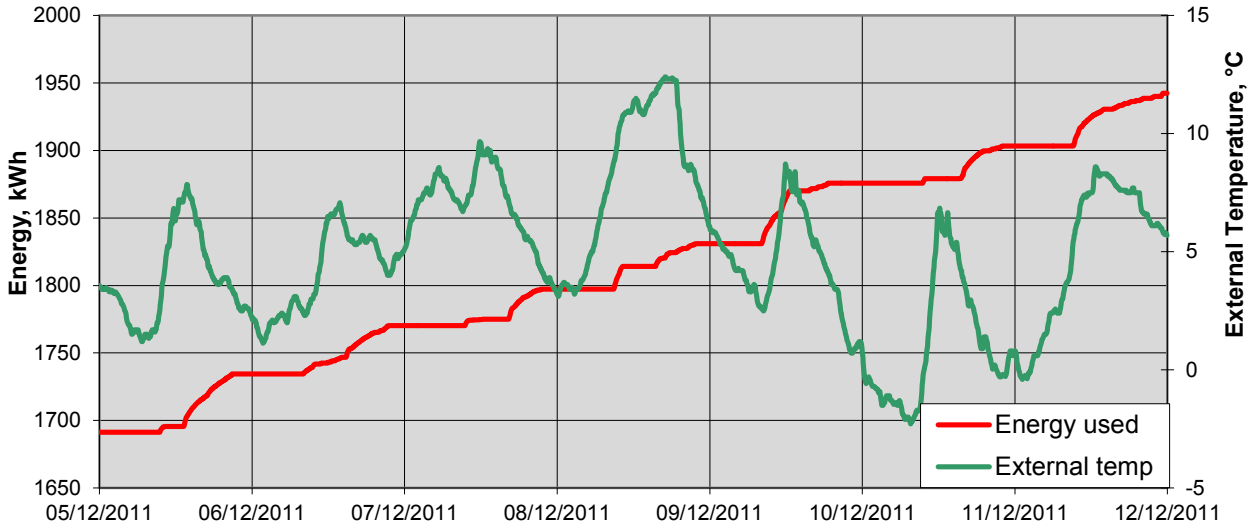
Energy used for heating, hot water and cooking for the week commencing 03 Oct 2011



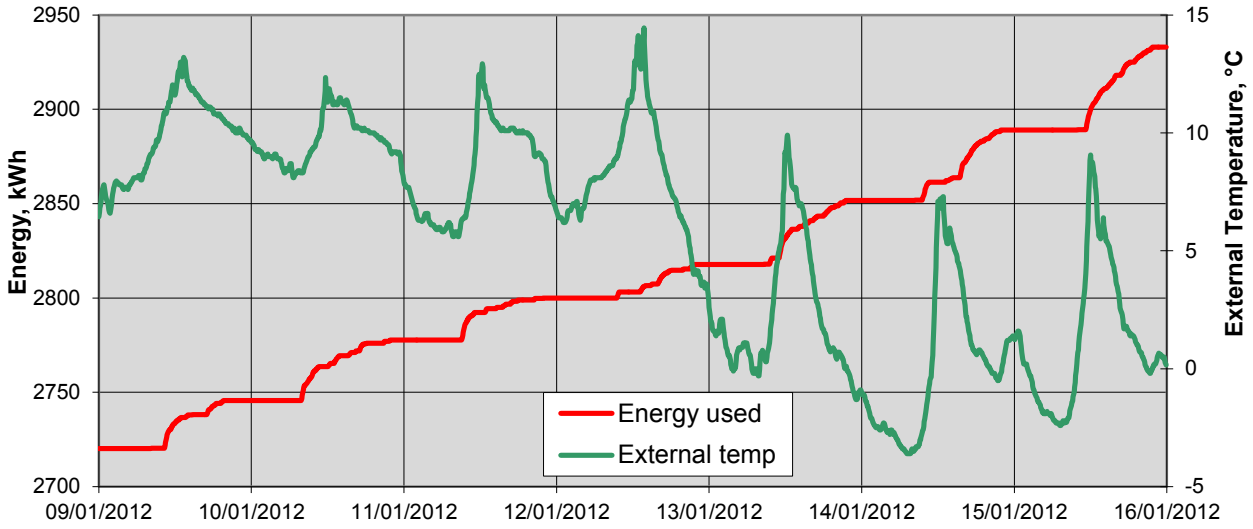
Energy used for heating, hot water and cooking for the week commencing 07 Nov 2011



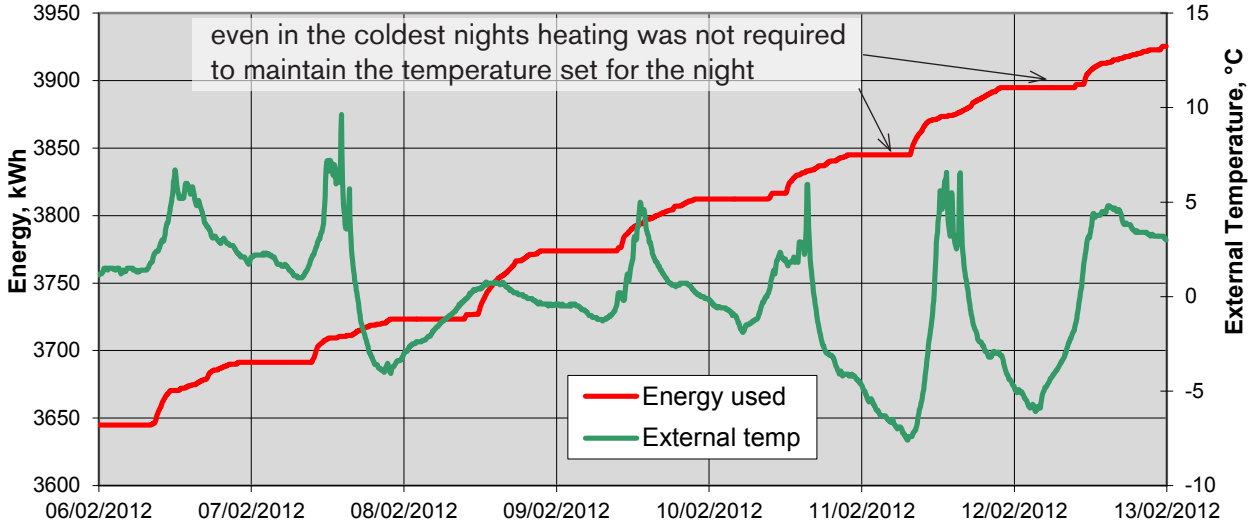
Energy used for heating, hot water and cooking for the week commencing 05 Dec 2011



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



Energy used for heating, hot water and cooking for the week commencing 06 Feb 2012



2: Analysis and Graphs

2.3: Energy for Heating, Hot Water and Cooking

2.3.1: Pre and Post Retrofit Gas Usage

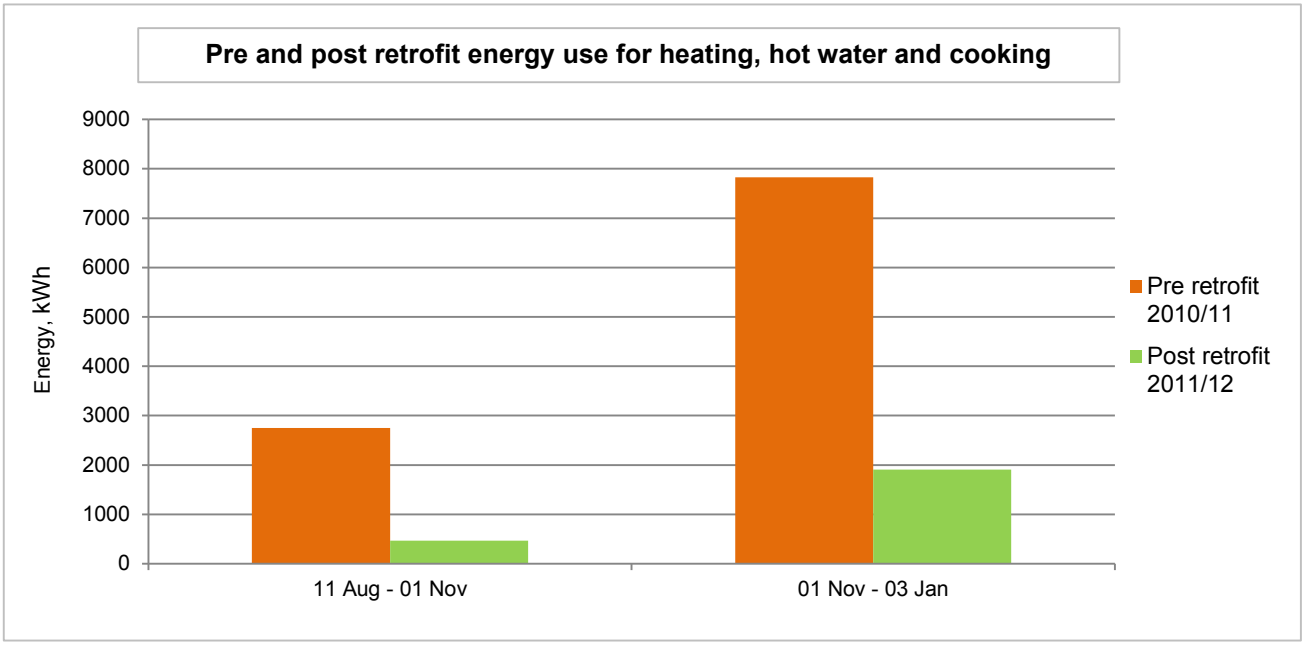
The retrofit started on the 7th Feb 2010 and finished on the 30th Jul 2011. This analysis is for the period between the 16th Aug 2011 till 19th Feb 2012.

The pre-retrofit figures include figures for the period when the retrofit was still ongoing and are based on the utility bills. The post-retrofit figures are based on the readings taken remotely every 5 minutes. This makes comparison of the gas usage limited to the dates of the bills provided by the residents. Moreover the timelines of the retrofit and the analysis makes comprehensive comparison even more difficult. All the above is the reason why a similar electricity usage comparison for the analysed period could not be carried out yet.

The graph below depicts pre and post retrofit energy uses for heating, hot water 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 the 11 Aug and 01 Nov the post retrofit energy use was 17% of the pre retrofit use. In that period the post retrofit figure was interpolated to match up with the date when the analysis begun. In the period between the 01 Nov and 03 Jan the post retrofit energy use was 24% of the pre retrofit use. This included a period of a month where the living room recorded steady 25 degrees., day and night. After the residents understood the controls better, 25 degrees was maintained during the day, and a nightime setback was adopted.

Early indications are that gas savings are between 76% and 83% which is impressive - especially when the residents tell us that the house is much warmer in winter and much more comfortable than before it was retrofitted.

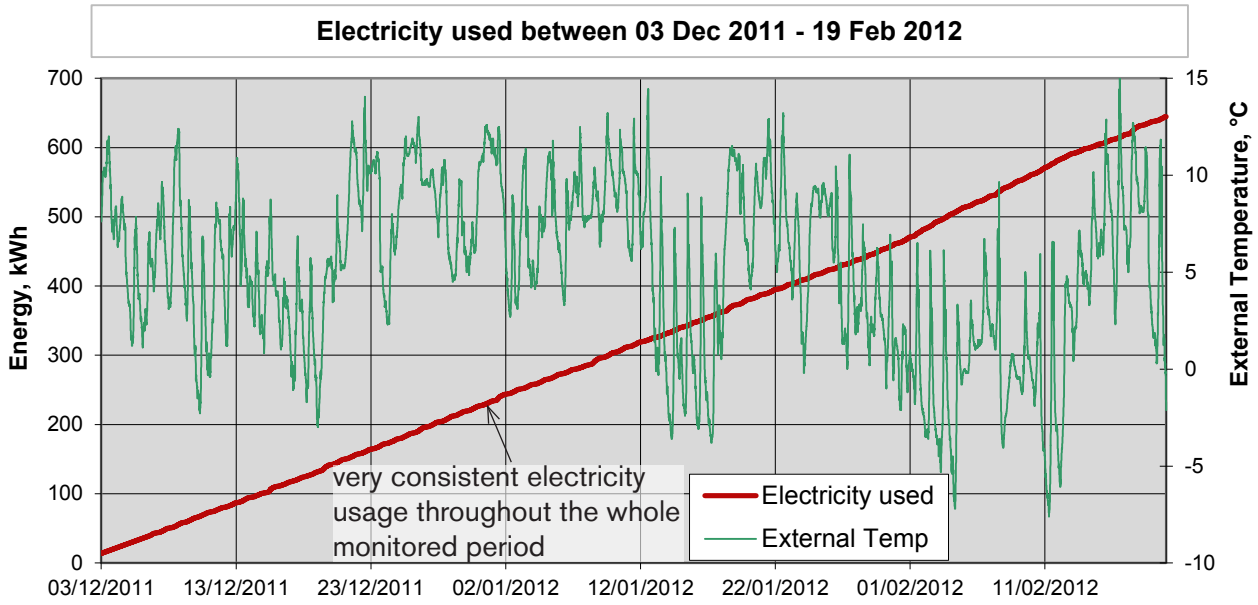


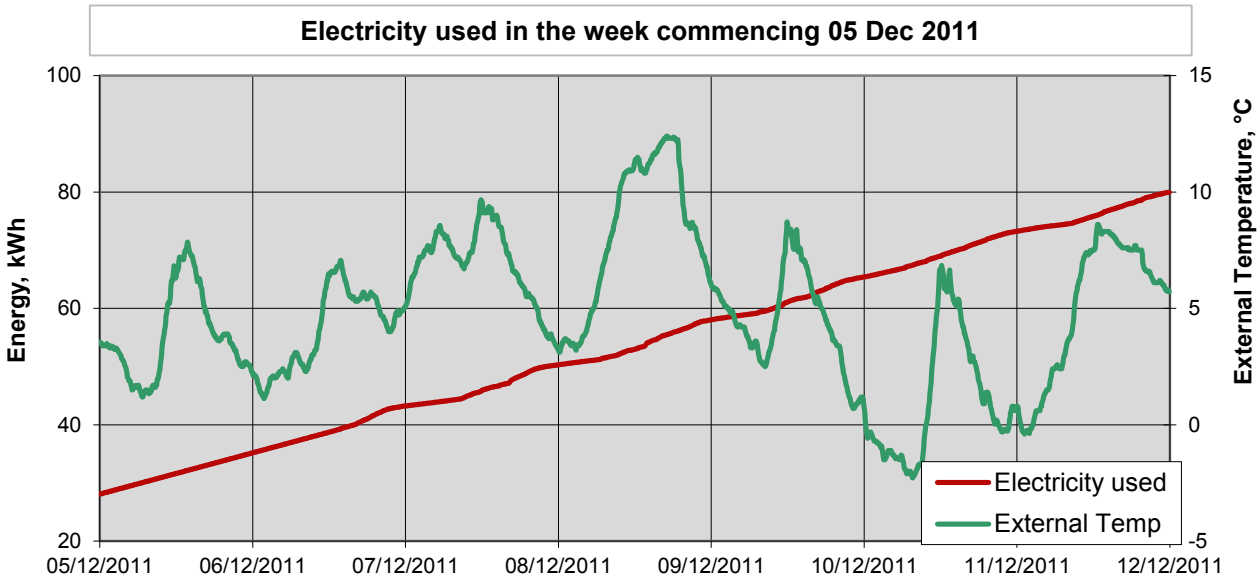
2: Analysis and Graphs

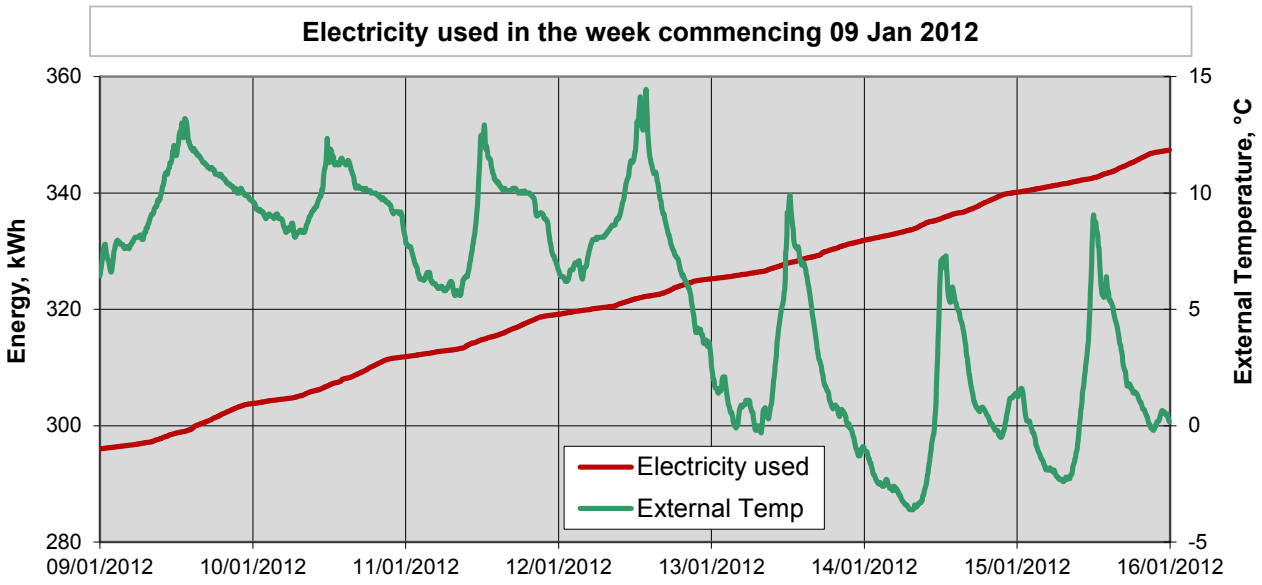
2.4: Electricity consumption

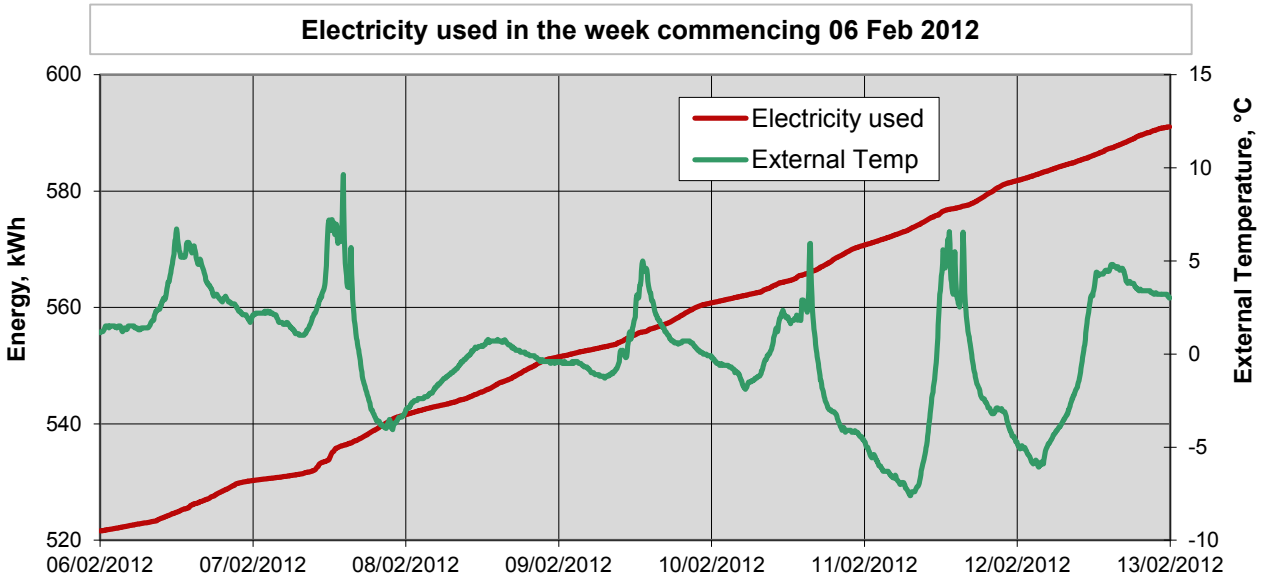
Monitoring of electricity usage started on 3rd Dec 2011. Throughout the period that has been monitored, the electricity usage was very consistent.

Because the length of the day did not change much during the monitored period, it is difficult to state how natural light affects electricity consumption.









bere:architects

3: Conclusions

This report presents graphs and analysis of indoor and outdoor conditions as well as energy used in the house at 78 Grove Road, Hounslow which was retrofitted with certified Passivhaus components and methods. The retrofit started on the 7th February 2010 and finished on the 30th July 2011. The monitored parameters are temperature, relative humidity, CO_2 levels, and gas and electricity usages.The analysis is for the period of time from the 16th Aug 2011 until the 19th Feb 2012.

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:
Indoor temperatures and relative humidity were found to remain at ideal levels no matter what the outdoor conditions. In the summer and autumn the temperatures in the monitored rooms remained very consistent. Opening a window or cooking the main daily meal at lunchtime caused some rapid, short changes in the indoor temperatures. After such an event the temperatures quickly returned to equilibrium or to the set point. In November, a few weeks after turning the heating on, the day and night-time temperature settings on the thermostat began to be set to different values. The result was high daytime set temperatures (up to 25 degrees), mainly during the afternoon and evenings, and a temperature setback to achieve energy savings overnight. Even with the heating switched off at night, the lowest winter night-time indoor temperatures still remained above 20 degrees.

Comfort:
The comfort charts for the CO_2 concentrations show that most of the time air quality remained better than the ideal maximum concentration of 1500ppm according to the EU Regulations. CO2 levels rose above this only a few times, very briefly, during the whole analysed period. The results prove the effectiveness of the heat recovery ventilation system used in the house.

Gas consumption:
The retrofit aimed at reducing energy loss through the building envelope and through draughts, as well as aiming to improve the comfort of the occupants. As the result, gas usage was significantly reduced, by up to 83%, at the same time as room temperatures were improved.

The comparison in this report is based on the utility bills for the pre retrofit usages and on the readings taken remotely every 5 minutes for the post retrofit usage. Some of the bills are based on the estimates, therefore this may result in some inaccuracy. Moreover, every year is different with variations in the seasons' lengths, temperatures, rainfall and solar insolation. Although the energy usage comparison in this analysis might be very accurate, a comparison for a few years after and before the retrofit would show more comprehensive results.

Electricity consumption:
The dates when the bill readings were taken do not match up with the timelines of the analysis, therefore no electricity usage comparison is presented in this report.