Angmering Community Centre

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Innovate UK project number	450048
Project lead and author	Low Carbon Building Group, Oxford Brookes University
Report date	2015
InnovateUK Evaluator	Unknown (Contact www.bpe-specialists.org.uk)

Building sector	Location	Form of contract	Opened
Community Centre	Angmering	Traditional	2010

Floor area	Storeys	EPC / DEC	BREEAM rating
563 m^2	Single	A (24) / N/A	N/A

Purpose of evaluation

The key objectives of the research were to analyse and report on the actual in-use measurements and changes over time of the variables (including energy use) in the Community Centre to represent its occupied performance, to analyse and report on the occupant response and satisfaction, and to triangulate between data for internal and external environmental conditions, energy and water use, and occupant perceptions. project evaluated the performance of the building's ground-source heating system. Two heat pumps provided all space heating and domestic hot water. PV of 10.2 kWp supplemented the mains supply.

Design energy assessment	In-use energy assessment	Electrical sub-meter breakdown
No	Yes	Yes

Electricity consumption: 49.1 kWh/m² per annum. Fossil fuel equivalent energy consumption: 141.5 kWh/m² per annum, 25% lower than the contemporaneous CIBSE *TM46* benchmark . The PVs generated 6,675 kWh (19% of the total operational requirement). The building's three sub-meters had not been commissioned properly as they were displaying negative values. This was due to the polarity of the meters being setup incorrectly. Data from the re-commissioned meters were compared against end-use data collected from a bottom-up on-site energy audit, which included an audit of the appliances and an estimation of usage profiles.

Occupant survey	Survey sample	Response rate
BUS, for transient users	33	Not applicable

The transient version of the BUS questionnaire was used, given that Angmering Community Centre is primarily used by visitors. Semi-structured interviews were also conducted with occupants. Walkthroughs were conducted in order to further investigate any underlying issues with regards to the building's performance and overall user experience. Occupants involved in light and sedentary activities were satisfied with the temperatures in the building. Occupants involved in more intensive activities found the spaces quite warm and prefered to open the windows, even during winter, to cool themselves down.

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About this document:

This report, together with any associated files and appendices, has been submitted by the lead organisation named on the cover page under contract from the Technology Strategy Board as part of the Building Performance Evaluation (BPE) competition. Any views or opinions expressed by the organisation or any individual within this report are the views and opinions of that organisation or individual and do not necessarily reflect the views or opinions of the Technology Strategy Board.

This report template has been used by BPE teams to draw together the findings of the entire BPE process and to record findings and conclusions, as specified in the Building Performance Evaluation - Guidance for Project Execution (for domestic buildings) and the Building Performance Evaluation - Technical Guidance (for non-domestic buildings). It was designed to assist in prompting the project team to cover certain minimum specific aspects of the reporting process. Where further details were recorded in other reports it was expected these would be referred to in this document and included as appendices.

The reader should note that to in order to avoid issues relating to privacy and commercial sensitivity, some appendix documents are excluded from this public report.

Contents

1 Introduction and overview

This report outlines the findings of the Technology Strategy Board (TSB) funded Phase 2 building performance evaluation (BPE) project, that was designed to evaluate the in-use condition of the Angmering Community Centre.

This detailed in-use BPE study of a Community Centre will contribute towards the wider evidence-base for understanding the real energy consumption in civic (public) buildings, given the fact that about 18% of the UK's CO_2 emissions comes from energy use in public and commercial buildings.

The key objectives of the Phase 2 research programme are:

- Analyse and report on the actual in-use measurements and changes over time of the variables (including energy use) in the Community Centre to represent its occupied performance.
- Analyse and report on the occupant response and satisfaction.
- Analysis to be grounded in triangulation of internal (and external) environmental conditions, energy and water use and occupant response.

The overall objective of the project is to improve and optimise energy performance by reducing the gap between the designed and actual performance, using feedback from the assessment of overall energy consumption, demand profiles, in-use monitoring of the thermal environment, and occupant surveys.

Angmering Community Centre (ACC) is a one storey community centre in the Angmering Parish of the Arun district of West Sussex County Council. The total area of the site is just under 0.2 hectares and the gross external area of the centre is 563 m^2. It is a timber frame building with a multi-purpose hall, two meeting/activity rooms and a central display and refreshment area. Its construction was completed in September 2009 and it has been in full occupation since May 2010.

The building has achieved an Energy Performance Certificate rating of 'A'.

1.1 Building services and energy systems

The Centre has been designed to have an exceptionally low heat demand; it is double glazed and has high levels of insulation throughout. The design incorporates a significant degree of natural light into all rooms except the Central Refreshment & Display Area.

Ground source heat pumps provide all the space and hot water heating needed for the Centre. There is no other back up heat source. An additional electrical heating element is included in each heat pump to deal with exceptionally cold weather. The Centre also generates its own electricity by means of an array of 60 Photovoltaic panels on its roof which are capable of providing 10.2kWpwith an estimated annual yield of 8200 kWh.

The ventilation strategy is a combination of natural ventilation and mechanical extract for the toilets and kitchen. The lighting consists of a combination of fluorescent tube and compact fluorescent lamps with a mix of manual switches and PIR controls (only in toilets).

The energy monitoring in Angmering Community Centre has proven to be a challenging and complicated task because of a lack of documentation and proper commissioning of the sub-metering system of the building. Additional sub-metering arrangements were made in order to conduct a full energy audit of the building.

1.2 Occupant survey

The BUS questionnaire method was used to map the reactions of transient users in Angmering Community Centre. For almost the first time, a transient version of the BUS questionnaire was implemented, given that Angmering Community Centre is primarily used by transient users. In addition to the BUS survey, semi-structured interviews with occupants and walkthroughs took place in October 2013, in order to further investigate any underlying issues with regards to the building's performance and overall user experience.

Overall, the BUS survey and interviews with occupants reveal a positive opinion towards Angmering Community Centre, with the quality of light, design and image being the most appreciated elements. Respondents generally feel that the facilities provided meet their needs well. Temperatures are generally regarded as comfortable and air quality is regarded as satisfactory.

Whilst occupants involved in light and sedentary activities are satisfied with the temperatures in the building, occupants involved in more intensive activities find the spaces quite warm and prefer to open the windows, even during winter, to cool themselves down. This could result in energy wastage in the winter season. Zoning would promote better control over the temperatures in each space and could improve the performance of the building. External shading and night-time ventilation would also help in preventing overheating.

The caretaker controls the heating system and one set temperature (19^{o}C) is used for the whole building. Occupants, despite not being able to control heating, feel they have good control over their environment because they can open the windows which are effective and easy to operate.

1.3 Aftercare operation, management and maintenance

The handover documentation was reviewed and interviews with management were carried out in order to identify the arrangements that were made for the seasonal commissioning, aftercare and maintenance of the building.

A maintenance contract exists for the GSHP but not for all the building operations and systems. Items that fall under the care of the Parish Council have maintenance contracts (eg. Fire and security) and a budget is being set aside for ongoing maintenance of the building.

No handover training was provided through a building and system induction tour. Furthermore, a list of legally required documents were found to be missing: the building logbook, the electrical commissioning documents, metering and sub-metering schematic/plan, Heat Pump Water and electrical circuit diagram which includes details of pipe sizes and power data. According to management, the lack of proper electrical installation drawings creates problems in maintenance and repairs.

There is no help desk or building log book which is contrary to Part L (2006) of the Building Regulations under which the Community Centre was built. In cases of breakdown, manufacturers are contacted directly by the building manager, and the response rate was reported to be good.

1.4 Energy use

Analysis of monitoring data on energy use has shown that the building is performing well. The annual CO_2 emissions (March 2013 – March 2014) figure of 27 $kgCO_2$ /m^2 is 47% better (lower) than the raw CIBSE TM46[1] benchmark of 51.1 $kgCO_2$ /m^2. The annual fossil fuel equivalent energy consumption in the Centre is 141.5 kWh/m^2/annum and is 25% lower than the Raw TM46 benchmark of 190 kWh/m^2/annum. The total annual electricity consumption during the monitoring period is 34,306 kWh of which 6,675 kWh (19%) was generated by the PVs and used on-site. The total PV generation from March 2013 to March 2014 is 28% higher than the PV specification estimate of 8,160 kWh/annum. ACC performs better than the 'Good practice' benchmark using 38% less electricity even though it is electrically heated.

Space heating and hot water account for 45% of the total electricity use, lighting accounts for 41% of the total, ICT equipment for 4.9% of the total and small power for only 1% of the total electricity used in the building (Table 10). Electricity consumption peaks during winter months, which is expected since the Ground Source Heat Pumps are also at their peak performance. There is a very strong correlation between weekly heating demand and heating degree days indicating that the GSHPs and the building are performing well. The coefficient of performance (COP) for both heat pumps was calculated at 3.68. It should be noted that according to the specifications of the heat pumps the COP is 4.4/3.3.

1.5 Technical Issues

The review of controls showed that most controls installed in the Centre are intuitive and easy to use. Light switches and electrical window controls are easy to operate. The Velux window controls and the kitchen hatch control that were originally installed were complex and have already been replaced with simpler controls that are well-labelled and effective. However, this has been at additional costs to the centre. The designers should consider installing simpler, intuitive controls from the outset in future. The heating and hot water controls are not very intuitive and the caretaker is the only one who has received training on how to operate them. It is therefore recommended that other members of the management team familiarise themselves with the controls of the GSHPs.

A site survey was conducted in order to identify any energy wastage that takes place in the building. The survey showed that occupants generally take care in ensuring lights and appliances are off when not used. In some cases, however, the blinds are kept closed by the users and artificial lighting is used instead. The survey also revealed that the overhead projector and remote control screen are permanently switched on due to the sockets being inaccessible. In addition to this, the lights in the Entrance Hall are on at all times when the centre is occupied due to the fact that there is no natural light entering this space. Such issues increase electricity use and therefore undermine the performance of the Centre.

[1] TM46 energy benchmark indicates the typical energy performance for similar buildings of this type.

2 Details of the building, its design and delivery

2.1 Background to the case study building

Angmering Community Centre is a one storey community centre in the Angmering Parish of the Arun district of West Sussex County Council. The building is leased to the Charity, Angmering Community Centre Association, which manages the building. Its construction was completed in September 2009 and it has been in full occupation since May 2010.

2.1.1 Location

The scheme is located in Foxwood Avenue, Angmering, West Sussex. It is in the centre of the community and is easily accessible on foot and by car. However, there is no frequent bus route connecting the Community Centre with the surrounding areas. The site has designated cycle ways which connect to a wider network of routes. Taking into consideration GEN12 and Appendix 2 in Arun District Council's Local Plan the maximum parking standards for this building based on a maximum of 200 users was calculated at 25 spaces. The case park of the Community Centre has spaces for 23 cars, 2 disabled user bays, 1 delivery bay, 2 motorbike bays and baby buggy storage. In addition to the community centre car park there are 4 public parking bays accessed from Foxwood Avenue.

The Community Centre is surrounded by playing fields and recreation areas and the nearest property is over 38m away from the building (Figure 1). Effort was put into the design to make the Centre an attractive focal point to the village green with low impact on the surrounding area.

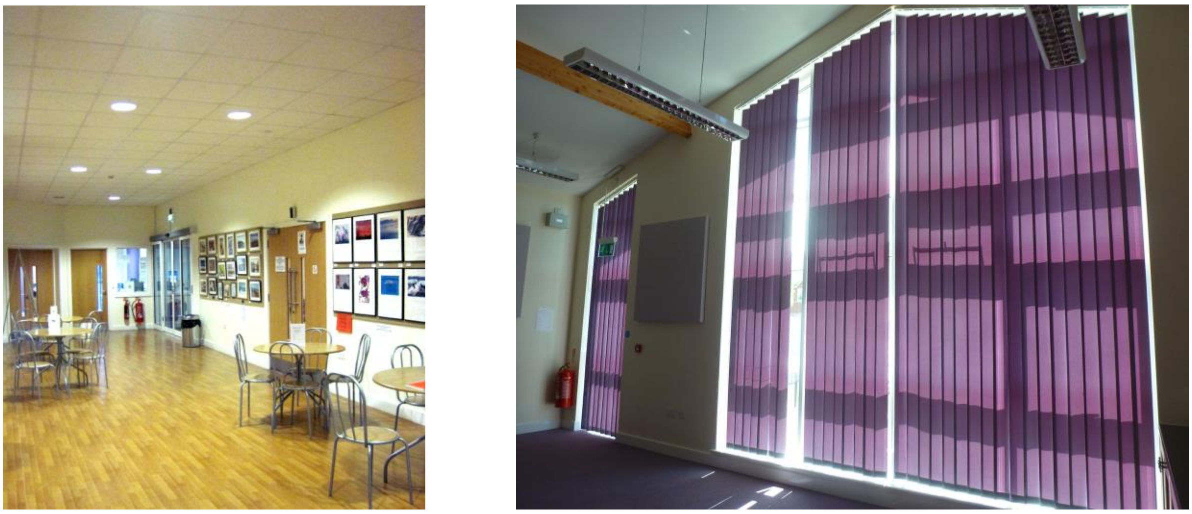
Figure 1Aerial view of site

2.1.2 Design and Layout

The total area of the site is just under 0.2 Hectares and the gross external area of the centre is 563 m^2. It is a single storey timber frame building that consists of a large Main Hall which can seat 200 people and has a semi-sprung wood block floor, two Meeting/Activity Rooms (one carpeted, one with vinyl floor covering), a central Display and Refreshment area and a fully equipped stainless steel semi-commercial kitchen (Figures 2-5).

Figure 2 External view of the Angmering Community Centre Front

Figure 3 Main Hall. Size and layout of the space allows for various activities to take place, ranging from dance classes to film screenings.



a) **b)**

Figure 4 (a) Entrance Hall, (b) Parish room

Entrance Hall
Main Hall
Kitchen
Meeting Room
Parish Room

Figure 5 Angmering Community Centre plan

2.1.3 Occupancy schedules

The building is occupied from Monday to Sunday from 9am to 10pm. There are no out of hours activities. There is one member of staff managing the building during occupancy hours. Approximately 50-80 people visit the building on a daily basis. Occupancy varies depending on the activities taking place in the Main Hall and meeting rooms. The Community Centre is available for children's activity classes, indoor sport activities, short mat bowls, choir classes, dance and aerobics classes, painting classes, cooking classes, computer classes and church activities. It also provides essential meeting and function rooms for the local Parish Council and other organisations.

2.1.4 Sustainability features

The building has achieved an A rating Energy Performance Certificate (EPC) and was designed to have an exceptionally low heat demand. The design incorporates a significant degree of natural light into all rooms except the Entrance Hall (Central Refreshment & Display Area).

Ground Source Heating is installed in the building and is connected to an under floor heating system. There are two heat pumps that provide all the space heating and hot water needed in the Centre. There is no other back up heat source.

The Centre also generates its own electricity by means of an array of 60 Photovoltaic panels on its south facing pitched roof which are capable of providing 10.2 kW peak with an estimated annual yield of 8200 kWh. Any excess power generated is fed back to the grid. At times of high demand backup is required from the mains supply.

The external finish takes its cues from the surrounding properties which are a mix of brick and flint walls. It is a brick cavity construction with timber frame and concrete tile roof. The building fabric has been designed to U-values of < 0.2 W/m^{2}K for the roof and floor and < 0.23 W/m^{2}K for the walls. The windows are uPVC coloured frames with 24mm thick hermetically sealed double glazed units and have a U-value of < 1.96 W/m^{2}K.

Table 1 Design characteristics of the case study building including external and internal views.

Case study design characteristics	
Location	Foxwood Avenue, Angmering, Littlehampton, West Sussex, BN16 4FU, UK
Building type	Community centre, 562.25 m^2
Main construction elements	• Walls: Masonry with flint panel appearance. Facing brick outer-leaf (Bexhill Red) - 110 Cavity including 60 Kingspan Thermo Wall TW50 Insulation (Design U-value 0.23 W/m^{2}K) • Roof: Entrance lobby- Flat roof construction Elastomeric felt roofing (3-layer) Rigid foam insulation boards. W arm roof design with a pitch of 72 degrees interlocked with concrete tiles (Design U-value 0.20 W/m^{2}K) Type 2- Timber framed Pitched Roof- (Design U-value 0.2 W/m^{2}K) • Windows: Thermally broken aluminium argon filled frames. 28mm Sealed Double glazing units, comprising 6mm LAM and 4mm toughened, filled with Argon (Design U-value 1.2 W/m^{2}K) • Floor: Tarmac top floor bonded with sand/cement screed (U-value 0.2 W/m^{2}K)
Air tightness	5.77 m^3/(h.m^2) when pressure tested at 50 Pascal (22.09.2009)
Sustainability rating	EPC rating A (28.09.2010) Ref: 0663-3091-0712-0900-7525
Date of completion	29 September 2009

2.2 Review of arrangements for managing delivery of design intent

The ACC was a 'Design and build' project where the architects were given a specific design brief from the contractors in order to produce the relevant drawings for construction. The main decisions concerning the design and arrangement of spaces, required facilities, construction elements and systems applied to the ACC were agreed through a series of consultation meetings between the Parish Council and contractors. A subcommittee of the Parish Council (owners of the building) consisting of three Councillors was set up and they met with the project managers (Hamsons), the builders (Catchpoles) with input from the electrical engineers (A.J. Taylor) and other subcontractors. The Charity and Management Committee would receive copies of the minutes and would respond if they felt strongly about something but did not participate in the meetings directly.

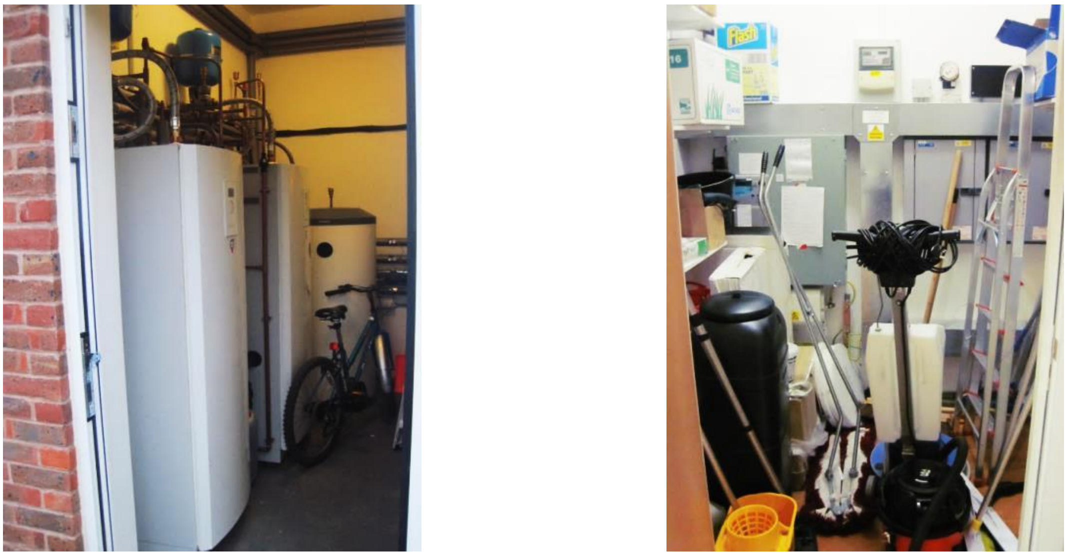
A meeting with all parties was made on site to decide the colour of the bricks and the roof tiles in order to blend in with the houses of the surroundings. In the later stages the Charity and Management Committee were consulted about the colour of flooring and paintwork and toilet doors and tiles.

The Charity undertook a door-to-door survey during the design stage to identify potential uses/activities, popular times of day and information on ages and demographics. The findings never reached the design team in order to have an effect on the design intent but were mainly used to identify future uses. Whilst the survey was undertaken after the briefing and initial design meetings, it was felt it could have been useful to the design team. However, a lack of communication between Council and Charity seems to have negated the potential of this.

During the design process the heating strategy was changed from gas boiler with radiators to GSHPs with underfloor heating. This change was a result of ACCA's effort to provide the community with a low-carbon building. Changes on the initial drawings (e.g. plant room size) due to GSHP and PV installation were effectively addressed.

The fragmented communication between the Parish council and contractors, and the ACC Trustees and Management committee resulted in a series of future usability issues:

- The request of the Trustees to have the two meeting rooms next to one another so that there could be a sliding partition between them – allowing one larger "mini-hall" at times- was not taken into account. Unfortunately, this has proved to have been an important element since the size of the main hall is too large for certain sport and leisure activities while the meeting rooms are too small for them (Figure 5). This has resulted in the meeting rooms being less popular to hire out than they could potentially be.
- The plant room was initially designed to be accessed only from outdoors. After the Committee of Trustee's insistence for access to the fuse boxes from inside the building these were placed in the Caretaker's store. However, a knock-on effect of this was to reduce the size of the dedicated space for cleaning products and equipment (Figure 6) and created an accessibility issue (the fuses were placed at the back of the room, thus all cleaning equipment is in front of them).
- After the building was handed over it was found that the actual size of the toilets exceeds legal requirements and space could have been added to other rooms (meeting rooms or storage space).
- The response of the Parish council was that most of the changes were not delivered because of cost issues.



a) b)

Figure 6 (a) Plant room, (b) Cleaner's storage room. The addition of the electric meters and fuse boxes in the cleaners' store led into lack of a dedicated cleaning storage space and created access issues to the room.

2.3 Conclusions and key findings

- Angmering Community Centre is a one storey community centre in the Angmering Parish of the Arun district of West Sussex County Council. The building is leased to the Charity, Angmering Community Centre Association, which manages the building.

- The building is occupied from Monday to Sunday from 9am to 10pm. Approximately 50 people visit the building on a daily basis. Occupancy varies depending on the activities taking place in the Main Hall and meeting rooms.

- The building has achieved an A rating Energy Performance Certificate (EPC).

- Meetings were organised by Angmering Parish Council (owner) with Project managers (Hamson), architects (Felce and Guy) and builders (Catchpole) with input from electrical contractors (AJ Taylor) and other subcontractors. The building manager and maintenance staff were not a part of the briefing and building procurement process.

- Fragmented communication between user and owner; ACCA- the Charity and future building management committee- did not participate to the meetings arranged during design and construction stage. Meeting minutes were provided in order to make any comments on design. The Charity and Management Committee of ACC were consulted mainly for aesthetic and decorative issues rather that practical.

- Changes on the initial drawings (e.g. plant room size) due to GSHP and PV installation were effectively addressed.

- Request from ACCA for meeting rooms next to each other divided by sliding partition allowing space flexibility were ignored.

- The Parish council suggested that some of the changes were not delivered because of cost and planning issues. The need for effective communication was also highlighted.

- The addition of the electric meters and fuse boxes in the cleaners' store led to the lack of a dedicated cleaning storage space and created access issues to the room.

3 Review of building services and energy systems

3.1 Building services

This section includes a basic review of the building services and energy related systems. Figure 7 below demonstrates the energy profile of Angmering Community Centre.

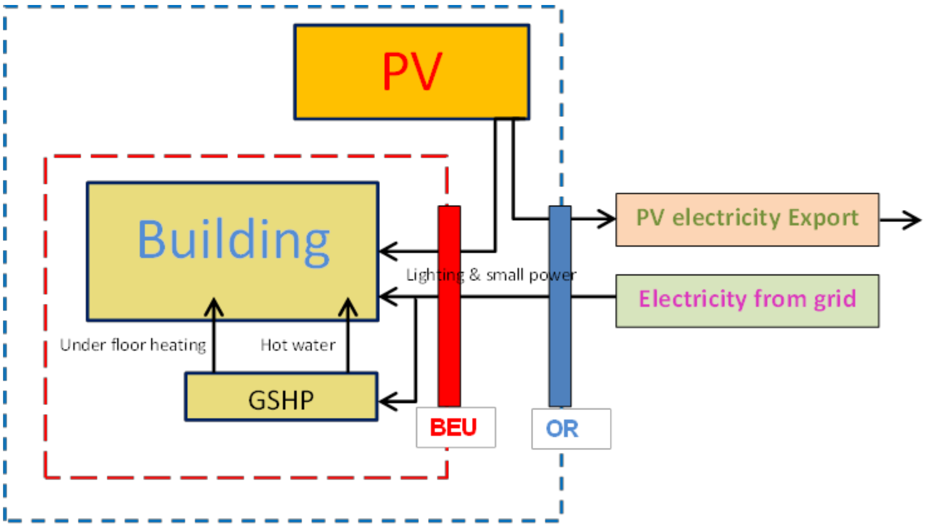


Figure 7 Energy profile of ACC (BEU=Building Energy Use; OR=Operational Rating)

3.1.1 Electricity systems

Electricity is supplied from a three phase electrical feed and consumption is recorded through the electricity meter in the cleaner's storage room (Figure 8). There are three sub meters on the side of the main distribution board meter that, according to the electrical contractors (AJ Taylors), include the buildings' small power, the lighting circuits and the electrical requirements of the GSHP and underfloor heating (Figure 9). These sub-meters do not hold historical data.

The Centre generates its own electricity by means of an array of 60 **photovoltaic panels** on its roof which are capable of providing 10.2 kW peak with an estimated annual yield of 8200 kWh. Any excess power generated is fed back to the grid via an import/export meter installed by SWALEC. At times of high demand backup is required from the mains supply. The electricity generated from the PV panels is metered through a generation meter located in the cleaner's storage room (Figure 10). The panel controls are located in the externally accessible plant room. The solar PV meter does not store data; however, there is a display unit in the Display and Refreshment area that shows current usage, total generation to date and CO_2 saved (Figure 11). Feed-in tariff income from the PVs has helped the running costs of the building. According to the Chairman of Parish Council the PVs are doing very well in balancing the electricity demand of the GSHP.

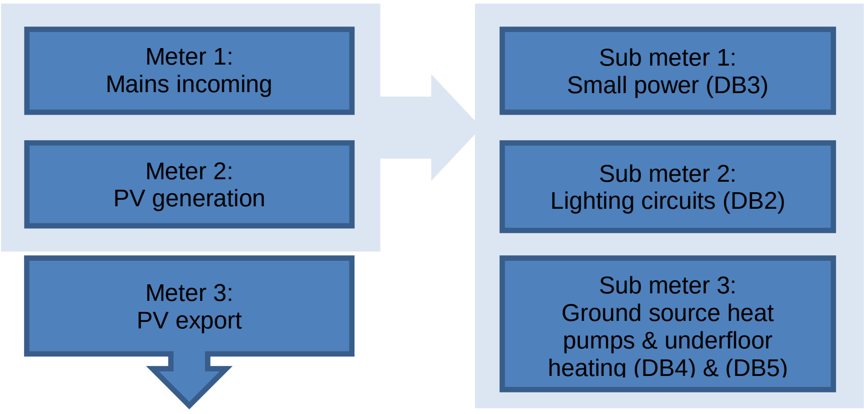
Figure 8 Electricity meter

Figure 9 Sub-meters

Figure 10 PV generation meter

Figure 11 PV display panel

The following diagram demonstrates the original physical metering schematic for the building.



3.1.2 Heating and hot water system

Heating in the building is provided by two Thermia Diplomat Ground Source Heat Pumps connected to an underfloor heating system. The ground loops are in 4x200 m horizontal trenches. The heat pumps are located in the plant room and provide all the space and water heating needed for the Centre. There is no other back up heat source. An additional electrical heating element is included in each heat pump to deal with exceptionally cold weather.

3.1.3 Water service

A mains water service enters the building within the cleaner's store room and runs throughout the building to serve the kitchen and toilets (Figure 12). The water meter is located outside the building but within the property boundary and is accessible only by the water company. The exact position of the water meter is unknown.

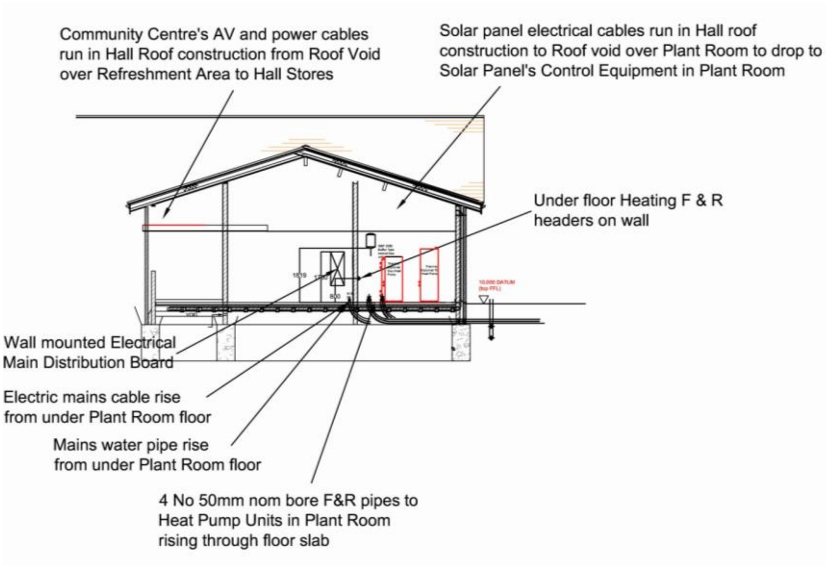


Figure 12 Draft M&E plant room equipment section drawing.

3.1.4 Ventilation systems

HVAC is a combination of wet mechanical heating, natural ventilation and mechanical extract for the toilets and kitchen. Natural ventilation controls are a mix of electrically opened high level windows and roof lights in the main hall and manual openings in the meeting rooms, office and main hall. The main hall high level windows are operated by a single switch and the roof lights are controlled by a separate control.

3.1.5 Lighting systems

The lighting consists of a combination of fluorescent tube and compact fluorescent lamps with a mix of manual switches and PIR (presence detectors) controls. The PIR's are restricted to the toilets.

All spaces have good daylight levels apart from the Entrance Hall/Display and Refreshment Area, which does not have any windows for direct light or ventilation. Artificial lighting needs to be on at all times during opening hours in this space (Figure 13).

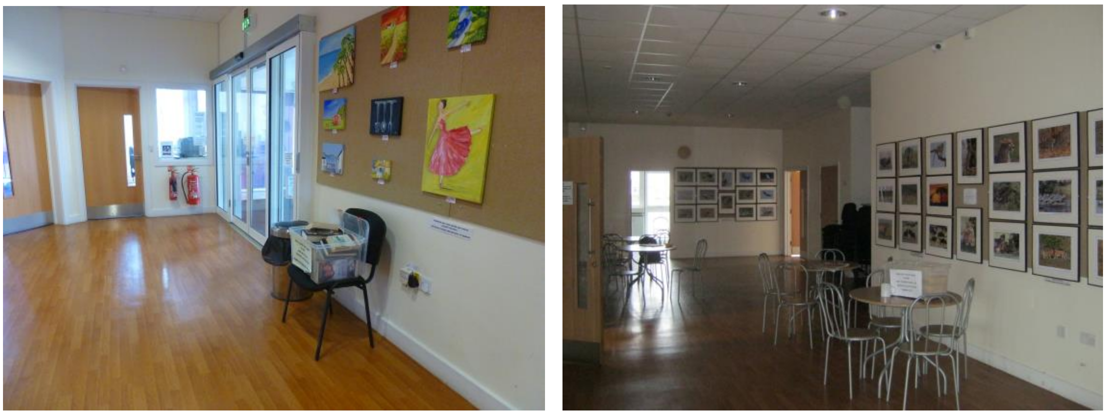


Figure 13 Entrance hall with and without artificial lights on.

Table 2 Systems and services

Case study systems and services	
Space heating system	Provided by 2x Ground Source Heat Pumps (Thermia Diplomat maximum output of 16.61 kWth) in ground loops of 4 x 200m horizontal trenches with electric element as back-up feeding underfloor heating
Space cooling	No cooling system currently installed
Hot water system	Provided by a Ground Source Heat Pump with electric element as back-up
Renewables	60 Photovoltaic panels on the roof which are capable of providing 10.2 kWp with an estimated annual yield of 8200 kWh
Ventilation strategy	Natural; manually openable windows with trickle vents; and roof lights with electrically operated controls including rain sensor override.

3.2 Review of existing installed meters and sub-metering arrangements

The energy monitoring in Angmering Community Centre has proven to be a challenging and complicated task because of a lack of documentation and proper commissioning of the sub-metering system of the building.

Drawings with the metering and sub-metering arrangements were missing from the handover documents and O&M manuals provided to the management team, including electrical and mechanical specification documents and as-built drawings. A building logbook does not exist and the building manager did not have any plans available. The research team were unable to find any copies of these documents.

The positions of the original meters and sub-meters were located during a walkthrough. However, it is unclear from the documentation available what the three existing sub-meters are measuring. After close inspection it was discovered that the three sub meters had not been commissioned properly as they were displaying negative values. This was due to the polarity of the meters being setup incorrectly. Having contacted the electrical contractors (AJ Taylors), they proved to be completely unaware of the problem as they had not addressed the sub-meters in question during the hand over.

As a result of the BPE study the issue was addressed. Additional sub-metering arrangements were made in order to conduct a full energy audit of the building as none of the existing meters and sub-meters could store data.

3.2.1 Monitoring equipment installation

Two Hager meters were fitted by the BPE team to the grid electricity feed and the PV export respectively (Figure 14). These were then connected to a web portal through a Modbus connection in order to provide 5 minute energy data from the meters. The electricity consumption of the two GSHP of the building is being monitored in the same way through two Hager meters connected to the web portal (Figure 14).

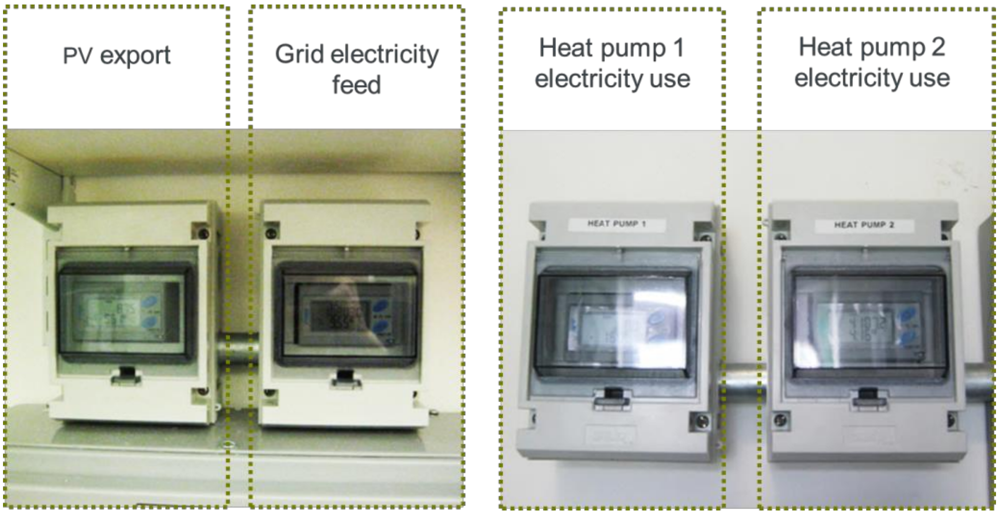


Figure 14 Hager meters installed by the BPE team

The three original sub meters after being re-commissioned by the BPE team were connected to an online database (**http://obu.global-net.eu**) via a wireless data-hub also providing 5 minute data.

In order to monitor the performance of the heat pump four heat flux meters were installed by the BPE team (Figure 15). The separation of the energy generated and used within the two heat pumps within the building is being monitored providing data regarding the energy demand for hot water and space heating. To achieve this, heat flux meters measuring both the flow rate and the temperature differences within the flow and return pipe work enable the CoP (Co-efficient of Performance) and an understanding of electricity used vs the energy provided to the building in the form of heating and hot water to be established. Two heat fluxes have been installed on each of the ground loops monitoring the geothermal energy produced by each loop. In addition to this, a heat flux has been installed in order to monitor the energy output for hot water. Another heat flux was installed monitoring the energy used for space heating. The data are being recorded at 5 minute intervals and stored in the online database (**http://obu.global-net.eu**).

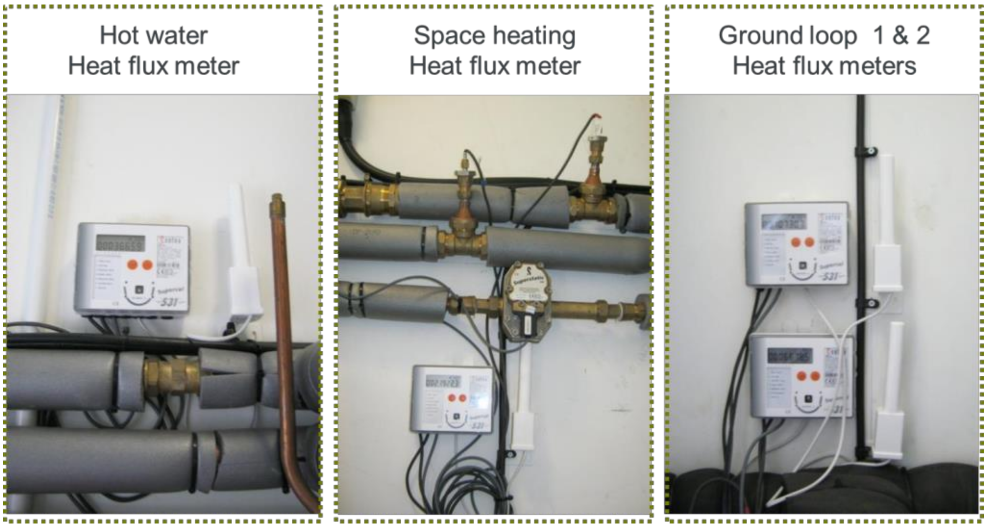


Figure 15 Four heat flux meters were installed by the BPE team in order to monitor the energy generated and used by the two heat pumps. These data regarding the energy demand for hot water and space heating

Figure 16 outlines the locations of the installed heat flux meters.

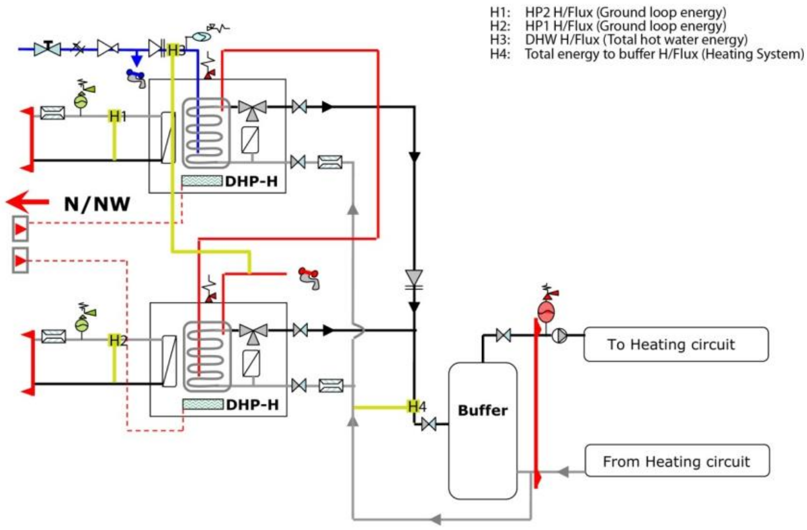


Figure 16 Heat pump diagram and location of heat flux meters

Table 3 shows a list of the metering and sub-metering arrangements made and the dates that reliable data started coming in.

Table 3 Additional sub-metering installed by the BPE team

Equipment	Monitoring	Data since	Online
PV meter	PV generation	07/11/12	http://obu.global-net.eu/login
Sub-meter 1	Lighting	21/02/13	http://obu.global-net.eu/login
Sub-meter 2	Small power	21/02/13	http://obu.global-net.eu/login
Sub-meter 3	Heat pumps & Main Hall	21/02/13	http://obu.global-net.eu/login

	small power		
Heat flux meter	Ground loop1	07/11/12	http://obu.global-net.eu/login
Heat flux meter	Ground loop 2	07/11/12	http://obu.global-net.eu/login
Heat flux meter	Hot water	07/11/12	http://obu.global-net.eu/login
Heat flux meter	Space heating	07/11/12	http://obu.global-net.eu/login
Hager meter	Grid electricity feed	06/03/13	http://www.m-2-m.com/M2M/
Hager meter	PV export	06/03/13	http://www.m-2-m.com/M2M/
Hager meter	HP1 electricity use	06/03/13	http://www.m-2-m.com/M2M/
Hager meter	HP2 electricity use	06/03/13	http://www.m-2-m.com/M2M/

According to the Pre-Visit Questionnaire[2] of the building the three sub-meters installed by AJ Taylors are providing energy data on a) the buildings' small power; b) the lighting circuits, c) the electrical requirements of the GSHP and the Main Hall small power (Figure 17). However, data reconciliation that was done after the review of the sub-metering system and the installation of additional sub-metering showed that there is a residual amount of energy that is not being measured by the three sub-meters. That energy accounts for about 500-900kWh/month and follows a daily profile similar to that of lighting. TM22 analysis also points to the fact that this residual amount is lighting.

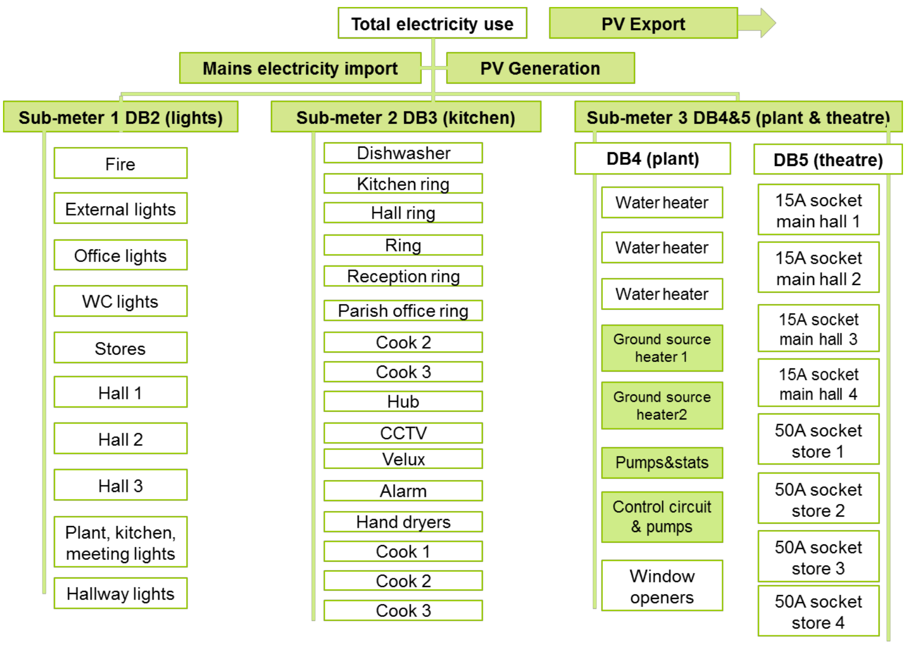


Figure 17 Existing electrical schematic and areas monitored. Original sub-metering arrangement

[2] Pre-Visit Questionnaire is a tool used by the TSB appointed evaluator to assess the energy performance of the Angmering Community Centre building. It collects information on metering and sub-metering along with details on building area, occupancy and pattern of usage of the building.

3.3 Conclusions and key findings

- Heating and hot water in the building is provided by two Ground Source Heat Pumps connected to an underfloor heating system.
- PV panels installed in the building are capable of providing 10.2 kW peak with an estimated annual yield of 8200 kWh. Any excess power generated is fed back to the grid.
- The building is naturally ventilated. Mechanical extract is only found in toilets.
- Drawings with the metering and sub-metering arrangements were missing from the handover documents left on-site including electrical and mechanical specification documents and as-built drawings. As such, their assumed positions were located during a walkthrough within the building.
- The existing meters and sub-meters do not hold any historical data and additional arrangements had to be made to monitor energy use.
- The three sub-meters in the cleaner's store room were found to display inaccurate values as their cabling was not correct. The electrical contractors (AJ Taylors) were unaware of the problem.
- The PV generation and export are being monitored as well as the grid electricity import. The electricity consumption of each of the two GSHPs is also being monitored.
- Heat flux meters were installed to monitor the geothermal energy going in the GSHPs and to monitor energy output for space heating and hot water.
- Sub-metering data reconciliation showed that there is a residual amount of energy that is not being measured by the sub-meters. This amount is attributed to lighting.

4 Key findings from occupants survey

This section cross-relates the findings from the BUS survey, semi-structured interviews with occupants, interviews and walkthrough with management, spot check and recording measurements and the review of performance and usability of controls, and reveals the main findings learnt from the BPE process and the fore mentioned activities. It draws on the BPE team's forensic investigations to reveal the root causes and effects which lead to certain results in the BUS survey.

The BUS questionnaire method was used to map the reactions of transient users in Angmering Community Centre, Angmering. For almost the first time, the transient version of the BUS questionnaire (as shown in Appendix 10.3) was implemented in a BPE project, given that Angmering Community Centre is primarily used by transient users all the time. The BUS Transient user questionnaire is much shorter that the domestic and non-domestic versions and includes variables such as: building design, needs, image, comfort, temperature and air quality, noise, lighting, health and productivity.

In this BPE project, in order to get as many responses as possible over a given period, the BUS Transient user questionnaires were distributed to the community users and also left (with instructions) at the main reception of the Community Centre on 7th May 2013 to 30th July 2013. The users were encouraged by the building management to complete the questionnaires during this period. The completed questionnaires were collected on 30 July 2013. A total of 33 responses were obtained. The raw data from the BUS analysis were submitted in two separate reports. This section is a summary of the findings.

The purpose of the BUS transient user questionnaire survey is to understand how well the Community Centre meets the users' needs and the perceived level of comfort within the centre. The questionnaire prompted users to comment on the building's image and overall design, the air temperature and quality, noise and lighting of the building and their journey times and modes of travel to the building. Their responses included ratings in terms of satisfaction and additional comments, where needed. The survey also collected comments made by the respondents under each of the categories.

The questionnaire variables are compared with their respective scales midpoint and BUS benchmarks to provide a slider showing the mean score across the 33 responses using green/amber/red lights depending on where it sits within the upper and lower limits of the scale midpoint and benchmark. As there are no transient benchmarks currently available, the results have been benchmarked against the UK 2011 non-domestic benchmark. On this basis comparison against the benchmark should be treated with extreme caution. We have avoided comparing results with the benchmark for this reason.

In addition to the BUS survey, semi-structured interviews with occupants and walkthroughs took place in October 2013, in order to further investigate any underlying issues with regards to the building's performance and overall user experience. Four users were interviewed: the administrator, a cooking class teacher, a Zumba class teacher and a children's activities class teacher.

Furthermore, interviews with four members of the management team and owners were conducted in May and June 2013. Their views and comments have been cross-related with findings from the BUS survey and occupant interviews.

4.1 The building overall

Overall, the BUS survey and interviews with occupants reveal a positive opinion towards Angmering Community Centre, with the quality of light, design and image being the most appreciated elements. Respondents generally feel that the facilities provided meet their needs well. Temperatures are generally regarded as quite comfortable and air quality is regarded as satisfactory (Figure 18). Comments received were very positive overall. Some of the interviewees pointed out that additional storage space would be useful.

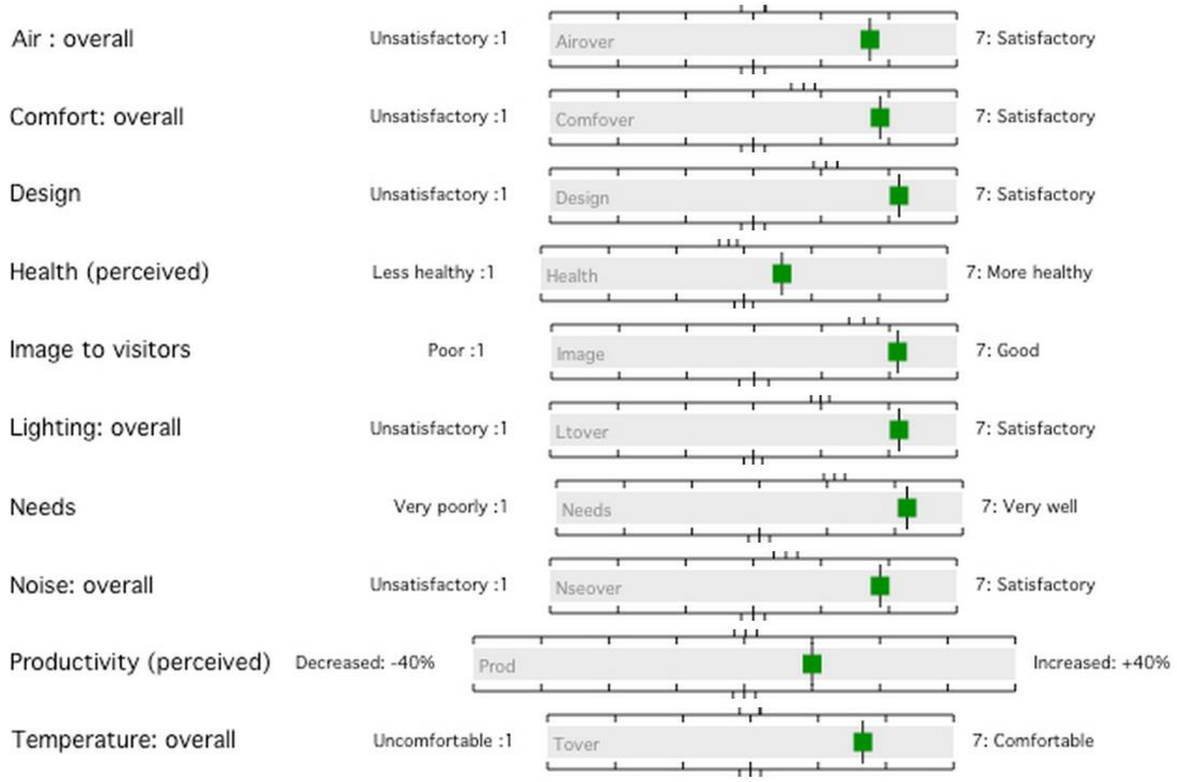
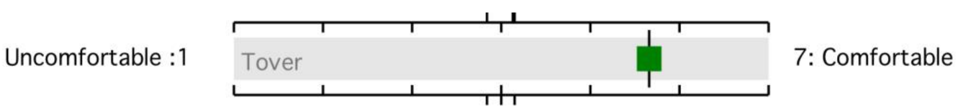


Figure 18 The building overall

4.2 Air temperature and quality

The BUS questionnaires revealed that the overall temperature is perceived as comfortable, with 39% of the respondents being fully comfortable (Figure 19). Building management also reported that the building remained pleasantly warm throughout the winter. Comments collected through the BUS survey point out that the building can get too hot in both summer and winter. This is also reflected in the monitoring data as shown in Figure 20 below.



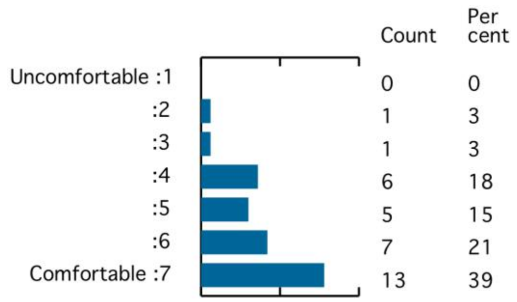


Figure 19 Temperature overall, slider and histogram

As shown in Figure 20 internal temperatures during the monitoring period remain mostly within the band of 20-24°C. The entrance hall shows higher temperatures and some instances of overheating during the winter months, suggesting that less heating is needed in this space. Overheating is observed during the summer months (June-July), especially in the south-facing Parish room indicating that measures might need to be taken to prevent the building from overheating. According to management, there are no plans to install a cooling mechanism. The Centre would benefit from the installation of external shading in the south facades and night-time ventilation.

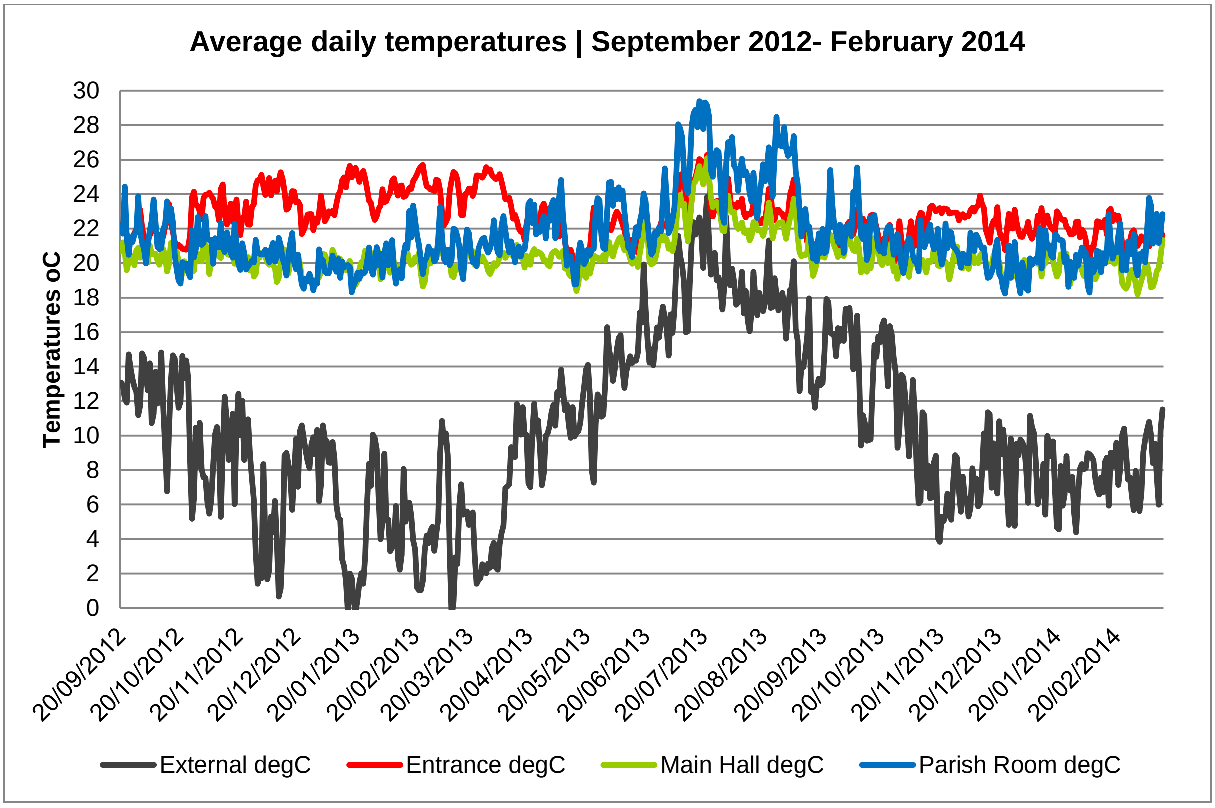


Figure 20 Average daily temperatures (September 2012 – February 2014)

In the occupant interviews none of the interviewees reported any instances of overheating. However, cross-relation of the occupants' responses revealed that occupants involved in light and sedentary activities are satisfied with the temperatures in the building, whereas occupants involved in more intensive activities (dancing, zumba etc.) find the spaces warm and open the windows as well as using portable fans to cool themselves down.

The interviewees are satisfied with the quality of air and ventilation in the building. The BUS questionnaires revealed that air quality is perceived as satisfactory with 33% of the respondents being fully satisfied (Figure 21). Participants pointed out that the air can get dry during the winter when internal temperatures are high. This was also observed in the environmental monitoring data on relative humidity levels (Figure 22).

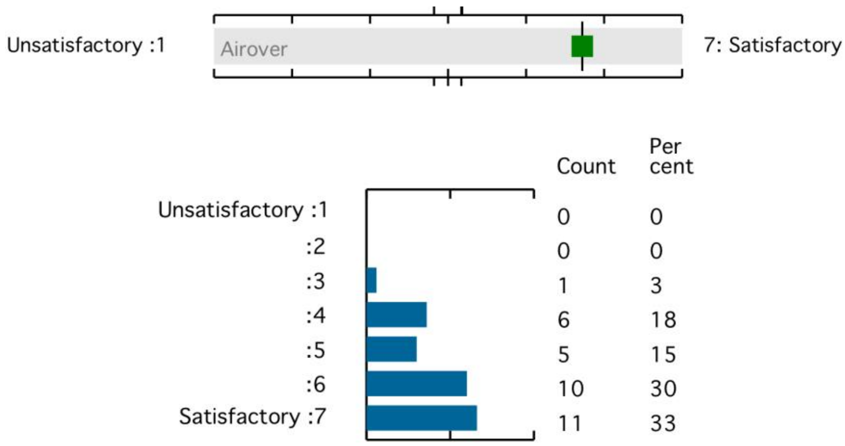


Figure 21 Air quality, slider and histogram

Figure 22 shows that RH levels in the Main Hall and Parish room remain within the CIBSE recommended range of 40-70%. The RH in the Entrance Hall is significantly lower; falling under 40% from December to April, possibly due to a lack of sufficient ventilation and high temperatures in the space.

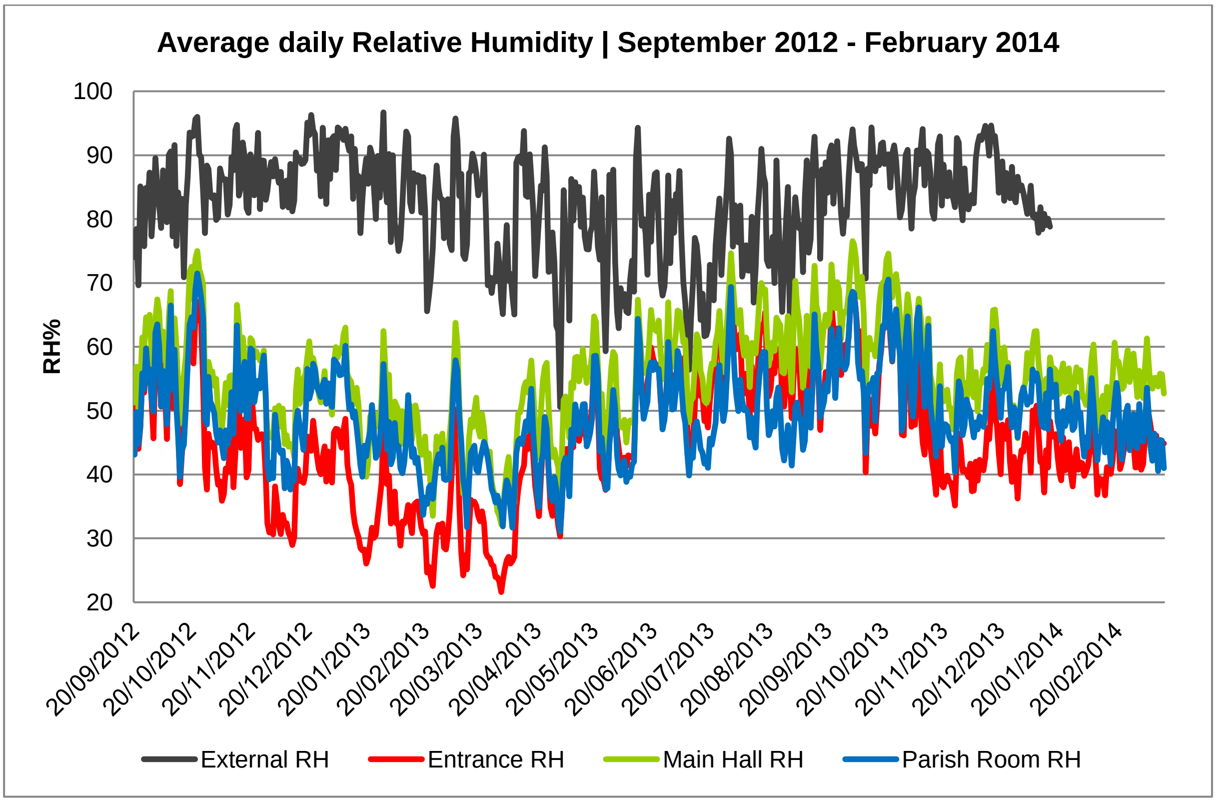


Figure 22 Average daily Relative humidity (September 2012-February 2014)

4.3 Lighting

The analysis of the BUS questionnaires showed that lighting is one of the most appreciated elements of the building; with 48% of the respondents being fully satisfied (Figure 23). The interviewees are also satisfied with the quality of light.

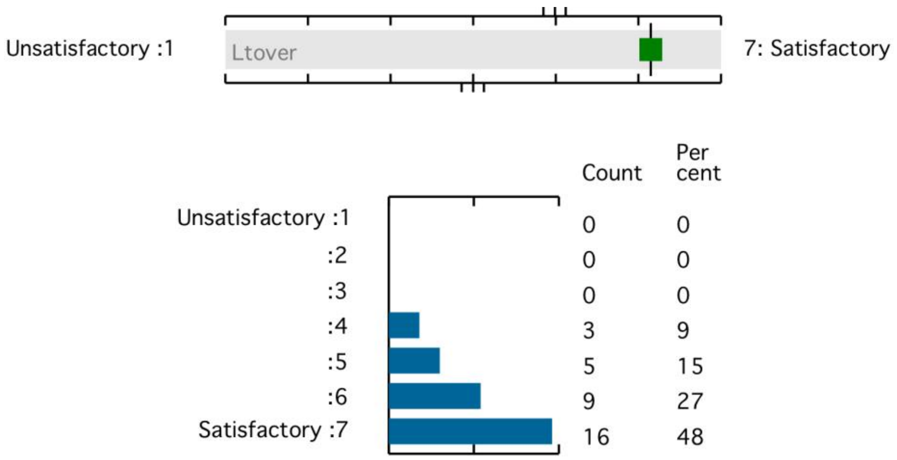


Figure 23 Lighting, slider and histogram

Furthermore, the building management reported that they are generally satisfied with lighting controls, but are not so satisfied with the Entrance Hall/Display and Refreshment Area lighting (which is always on) and external lighting.

According to the management, the lack of external lighting at the back of the building has resulted in some of the windows being vandalised. Also, the pillar lights originally installed were vandalised and had to be replaced with lights sunk in the ground. An external PIR detector would be useful for protecting the rear windows from vandalism, without excessive energy use.

Regarding the Entrance Hall/Display and Refreshment Area, due to its very low daylight levels the lights need to be switched on constantly during occupancy hours increasing electricity consumption and resulting in the low life span of light bulbs, that need to be changed regularly at the expense of ACC Charity. Management is considering the possibility of replacing the existing lights with LED ones to reduce the electricity use. The Chairman of the Parish Council, who was involved in the design process, pointed out that they never considered natural light in the Entrance Hall.

Spot measurements taken on 3 May 2012 showed that, in general, the daylight levels in all the spaces that were measured were adequate but supplementary artificial lighting is needed depending on the nature of the activity undertaken within the space (meeting, sport activity, etc.) (Figures 24, 25). Wide variations in light levels between the areas closest to windows and the interior areas in the same room were observed. The main hall was adequately lit on its southern side with some darker areas identified in the middle and eastern side of the room, indicating the need of artificial lighting if uniform lighting levels were to be achieved.

Although some areas do not seem to need artificial lighting, members of staff mentioned that the building users express a feeling of gloominess when the artificial lights are turned off.

Figure 24 Daylight factor analysis of the building's main spaces.

a) **b)**

Figure 25 (a) While the Main Hall is in use the artificial lighting is always on to support the activities. (b) The lights in the Entrance Hall are on during the whole day due to the lack of natural lighting sources.

4.4 Control

Interviews and walkthroughs with the management team revealed that they were not very familiar with the GSHP and its controls. The part time caretaker is responsible for operating the GSHP controls, and is the only person who has received training from the GSHP installer on how to operate the controls.

Both building management and owner are happy with the existing controls and believe they are conveniently located. However, the Velux windows and kitchen hatch controls originally installed had to be changed by the management as they were unnecessarily complicated. The new controls are simple to use and effective but the additional cost to change them could have been avoided through better specification. Full control of the kitchen hatch can now only be accessed by an engineer and not the general public – thus safeguarding the settings.

Management believes that occupants have good control over their environment as they can easily open the windows. However, users are advised by management not to use individual room thermostats in the meeting rooms because there have been cases where users turned off the heating completely and then, due to the heating system, it took many hours to bring the temperature back up to comfortable levels (Figure 26). According to the Chairman of the Parish Council (Building owner) who was the head of the client team during the design phase, '*it is best to make things as automated as possible in a community centre building and give users simple controls'.*

Occupants also pointed out in the BUS questionnaire that a more flexible thermostat control is needed in order to provide more heat in spaces with sedentary activities and less heat in spaces with more lively activities. The review of performance and usability of control also revealed that a tighter control of internal temperatures for different activities and spaces would help in increasing comfort levels and reducing energy consumption. Management is considering zoning the heating system in order to improve energy consumption and comfort within the different areas of the building.

The ACCA management also reported that before anyone starts hiring the premises they are taken on a tour of the building and shown how to operate the controls and where they are situated. In the same way a plan of the building is given to them showing all fire exits and fire equipment positions. Management added that for most hirers there is someone in attendance during their time at the Centre – an administrator during the day and a caretaker in the evenings, so someone is always available to help.

Interviews with occupants revealed that they find all the controls easy, accessible and effective. Furthermore, occupants feel they have good control over their environment because they can open the windows. Occupants also find labelling around the building and on controls to be helpful (Figure 27).

Figure 26 The lack of a centralised Building Management System (BMS) where room temperatures could be controlled leads the users to experiment with the individual thermostats.

Figure 27 Notes are indicating the proper use of lights and windows are placed in the community spaces.

4.5 Noise

Acoustics are an important attribute of community centre buildings due to their multi-purpose space use. Yet acoustics in most cases do not receive the same level of design attention as thermal, ventilation and other architectural and engineering considerations (Salter et al. 2003).

In the case of the ACC, it is believed that an acoustic consultant was not used in the initial design stages, nor at specification. A number of issues relating to acoustics and noise were found in the first months of the ACC opening to the public; external noise restrictions from the building's residential location limited the use of the natural ventilation strategy during the first months of use; and a poor acoustic performance of the Main Hall and Meeting Room 1 was also documented in the early stages of the public opening of the building as the reflecting sound was too loud and there were reverberation issues due to the hard materials used and the lack of sound absorbing panels. The problem affected the usability of the spaces as they could not be used for film projections, music performances or talks.

A simple acoustic test was undertaken in the hall by the project managers approximately 6 months after the centre was opened to the public and it was agreed that the contractor would pay for additional acoustic material on the east end wall of the hall. However, this was still found unsatisfactory to a number of users, particularly dance groups. In March 2011, the Parish Council agreed to undertake professional acoustic testing. The resultant report is held with the Parish Council and it proved a need to reduce echo and reverberation in the hall (Appendix).

The works undertaken included fixing acoustic panels to both walls and ceilings as shown in Figure 28. Whilst the estimated costs were between £9-13,000, the actual cost was £8,255. This was paid for by the Parish Council who owns the building.

Following on from a successful resolution of the acoustic issues in the hall (Film shows started again in December 2011), the Trustees then paid for acoustic wall panels (Figure 28) to be installed in Meeting Room 1, at a cost to the Charity of £1,767 ex. VAT.

a) b)

Figure 28 (a) Acoustic panels placed on the ceiling of the main hall. (b) Acoustic panels placed on the walls of the Meeting Room 1.

The BUS questionnaires showed that noise overall is rated favourably, with 42% of the respondents being fully satisfied with it (Figure 29). Participants pointed out that the acoustic panels installed by the ACCA were performing well but also that noise from the Main Hall and Entrance Hall can be heard in the other rooms on occasions. No external noise issues were reported. The interviewees were also satisfied with the acoustics of the building.

Figure 29 Noise, slider and histogram

Management also reported that they are satisfied with the acoustics of the building. They pointed out that an acoustics survey was performed and acoustic panels were added on the walls and on the ceiling thus addressing the problem of reverberation.

It was noted that during the planning application and submission, there were objections to the ACC, and in particular the potential use of the hall for music, dance and film activities that may cause external noise issues to the nearby residents. A planning condition stated that a scheme to ensure provisions were specified ‘to control the noise emanating from the building’ was required. A noise control device has also been fitted in the ACC to ensure noise levels do not go above recommended levels. It has been noted in a conversation with the building manager that no complaints regarding noise from neighbouring houses have been received since the building opened, even when dance and music events have taken place in the evening.

4.6 Health and productivity

4.6.1 Health (perceived)

The majority of the respondents (63%) feel the Centre has not had any effect on their health (Figure 30). This is possibly because of the transient nature of the community users.

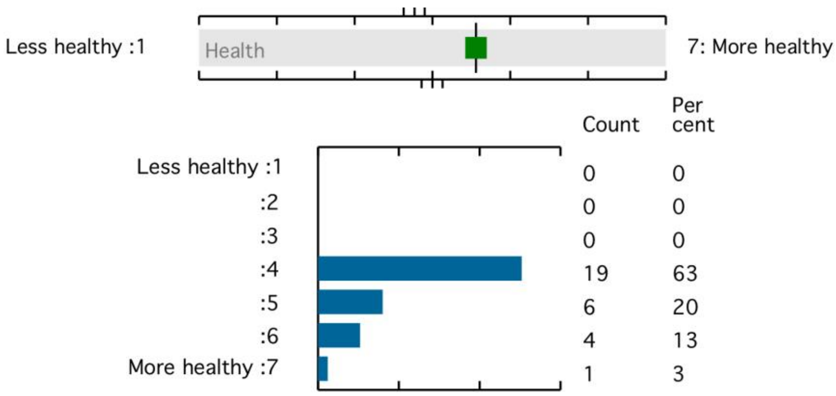


Figure 30 Health (perceived), slider and histogram

4.6.2 Productivity (perceived)

Most of the respondents (37%) feel the Centre has not had any effect on their productivity (Figure 31). Again this might be because of the transient nature of the users and the fact that productivity tends to be more of a concern in office-type buildings.

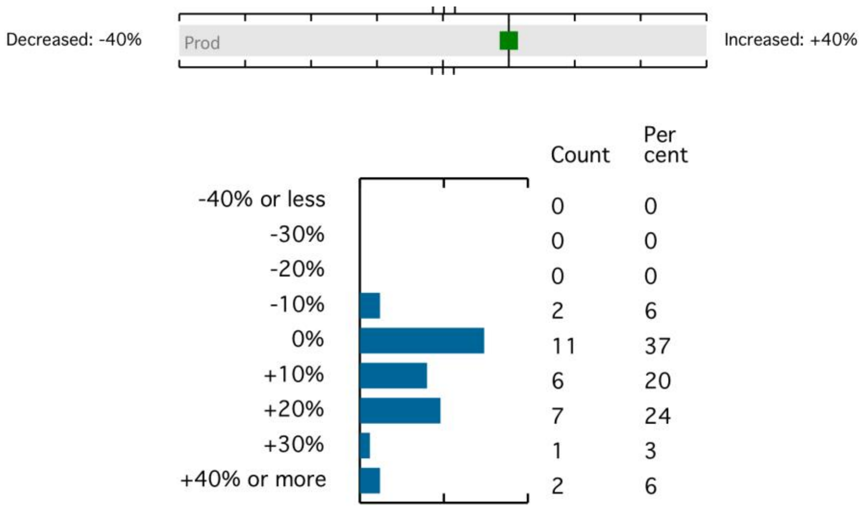


Figure 31 Productivity (perceived), slider and histogram

4.7 Travel to the building

The majority of the respondents drive to the Centre, either on their own (55%) or share (17%). However, 24% prefer to walk (Figure 32). Users point out that a more regular bus line is needed and that parking space is limited when the Centre is fully occupied. The management team and Parish Council have taken action to extend the parking space.

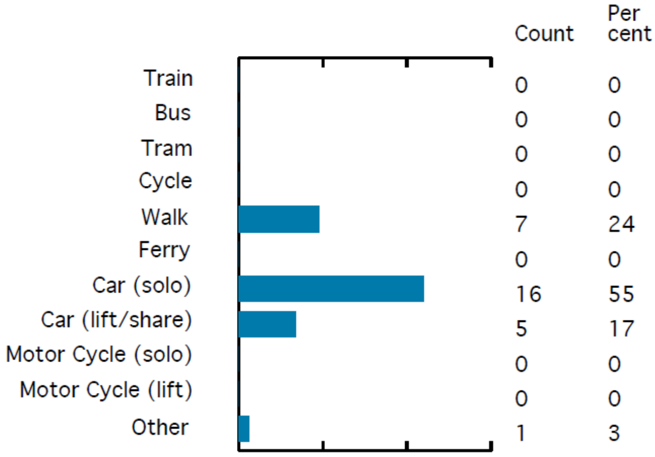


Figure 32 Travel to the building histogram

4.8 Conclusions and key findings

Findings from the occupants interviews are in accordance with the results from the BUS questionnaires and coincide with some of the responses received during the interviews with management. In both the interviews and the BUS survey, occupants have a positive opinion about the Community Centre and feel that their needs are met well. Additionally, the limited parking space issue came up in both the interviews and the wider survey. Key findings are the following:

- Occupants are satisfied with the building spaces, layout and facilities provided. The centre is good at accommodating their needs.
- Almost all the (n = 33) respondents feel that their needs are met well rating this parameter highly. In fact 51% of the users are fully satisfied that their needs are met fully. This serves as a confirmation of the dedication of the Chairman of the trustees of Angmering Community Centre Association.
- The spaces are appropriate for their daily use and function well. Some occupants point out that additional storage space would be useful.
- Most of the respondents rate the building design favourably with 48% finding the appearance 'satisfactory'.
- The image that the building presents as a whole is rated positively by all the respondents. 51% of the respondents believe the image is good.
- The respondents were generally positive about overall comfort with 36% being fully satisfied.
- Temperatures are generally regarded as quite comfortable. 39% of the respondents are fully comfortable.
- Occupants are satisfied with finishes, both internal and external.
- Occupants involved in light and sedentary activities are satisfied with the temperatures in the building, whereas occupants involved in more intensive activities find the spaces quite warm and prefer to open the windows, even during winter, to cool themselves down. This could result

in energy wastage in the winter season. The centre could encourage alternative ways of making the spaces that host intense activities more comfortable (e.g. fans) and in order to reduce heat loss and achieve lower energy use.

- No instances of overheating were reported (although instances of high temperatures were found through the monitoring of the internal temperatures).

- More effective management of internal temperatures for different activities and spaces would help in increasing comfort levels and reducing energy consumption. This issue was picked up by the management team who are considering zoning the heating system to reduce energy consumption.

- Air quality is regarded as satisfactory; with 33% of the respondents being fully satisfied.

- Lighting is one of the most appreciated elements of the building by all respondents; with 48% of the respondents being fully satisfied.

- All interviewees are satisfied with the quality of air and ventilation in the building.

- Noise overall is rated favourably with 42% of the respondents being fully satisfied with noise levels. Acoustics were reported to be good.

- During the design stage the issue of acoustics did not receive significant design attention although it was important for the future use of the building. The poor sound performance in the main hall and meeting room was identified and resolved after the opening of the building – the Hall at the expense of the Council (owner) and the Meeting Room at the expense of the Charity (user).

- Occupants find all controls easy, accessible and effective. It should be noted that controls of the velux windows and kitchen hatch had to be changed by ACCC early on in the life of the building, as the original controls were not intuitive and user friendly. The additional cost to change them could have been avoided through better specification at the design stage.

- The occupants have no control over heating. The caretaker controls the heating system and one set temperature is used for the whole building. In a public building that hosts such a variety of activities it is recommended that the management team is in full control of heating and that the heating system is zoned. Occupants, however, feel they have good control over their environment because they can open the windows which are effective and easy to operate.

- Most of the respondents (72%) drive to the Centre either solo or through car shares and only 24% prefer to walk. More walking or cycling could be encouraged. Lack of parking space is considered to be a problem. Action has been taken to expand the parking space.

5 Details of aftercare, operation, maintenance and management

The handover documentation was reviewed and interviews with management were carried out in order to identify the arrangements that were made for the seasonal commissioning, aftercare and maintenance of the building.

The purpose of a building handover is to enable building and facilities managers (FMs) to understand, manage and operate their building effectively from its initial operational phase. This should result in lower running costs and reduced CO_2 emissions and also contribute to the improvement of the occupant's comfort, satisfaction and productivity.

A building handover should involve:

- Support in the first weeks of occupation from the building design and contractors team.
- Demonstration of operation and maintenance of controls and technologies for the building users (windows, taps, heat controls, check meters, etc.).
- Technical guidance to the FM and building manager in a clear, simple manner.
- Provision of handover documentation (Logbook, O&M manuals, User guides for Occupants and management).
- Arrangements for aftercare, operation management and maintenance.

In order to identify the effectiveness of the handover process in Angmering Community Centre (ACC):

- The existing handover documentation was carefully reviewed.
- A questionnaire was distributed among the different parties involved in the design, construction and maintenance of the building.
- A handover workshop was organised where all the previous parties met and discussed the identified issues.

The interviews with management were conducted at the Angmering Community Centre on 9 May 2013 and on 30 July 2013. Four interviews were conducted:

- Chairman of the Trustees of the ACC Charity, Mrs Val Jerram who manages the day-to-day running of the Community centre and Angmering Community Centre Association (ACCA).

- Mr Bryan McCants, member of the Trustees, who has been involved in the progress of this building from September 2011.

- Mr Steve Mountain, Chairman of the Parish Council who has been involved in the progress of this building since its conception.

- Caretaker of the building.

5.1 Review of arrangements for seasonal commissioning, aftercare, maintenance

A questionnaire was circulated among the different parties involved in the design and construction phase of the building and the handover documentation was reviewed on site in order to identify the arrangements that were made for the seasonal commissioning, aftercare and maintenance of the building. According to the Soft Landings approach (UBT, 2009), during the initial aftercare period the main intention is to familiarise the building occupiers and facilities management with the features of their building features and its operation. The main actions required to ensure this would be:

- Support in the first weeks of occupation from the design team and contractor/subcontractors
- Setup home for resident on site attendance
- Monitoring, review, fine-tuning &feedback

In the case of ACC, the standard snagging and defect period of one year was undertaken. The contractors, builders and system installers were often approached by the ACC Charity directly to help with technical and operational issues, as well as general snagging details. However, after this, the Charity felt a lack of support as they still required advice after the one year period.

A maintenance contract exists only for the security alarm, CCTV, fire alarm and fire extinguishers, which are the responsibility of the Parish Council. The GSHP units have an annual maintenance service, which proved beneficial as unknown fungus growths were found during the routine check, and required dealing with. Most other equipment does not have formal maintenance contracts, instead they are reliant on warranties and the ACC Charity undertaking general annual maintenance. The Parish is establishing a property maintenance budget of £10,000/year to ensure costs for general upkeep of the building and services are met.

The design and build contractors (Catchpole) were bought out by another firm a few months after the completion of the building limiting the option of aftercare from their side. It was also found that the maintenance folders were not complete at handover, and still have some items missing.

In order to evaluate the handover procedure, Soft Landings framework was used as a benchmark of best practice methodology despite the fact that the ACC was not meant to comply with Soft Landings. According to the Soft Landings approach, the initial aftercare checklist covers the initial period of occupation, typically four to six weeks after handover. In the suggested action checklist ACC did not comply with any of the steps.

Table 4 Soft Landings stage 4: Initial aftercare.

Stage 4 checklist: Aftercare	
A1. Resident on-site attendance of design and building team representative (4-6 weeks after move-in)	X
A2. Availability of well-located workstation for the aftercare team provided by the occupier	X
A3. Introductory guidance for the building users (at least two meetings). Introduction of aftercare team, key building operation information, introduction of occupant's guide, questions.	X
A4. Technical guidance to the FM	X
A5. Communications e.g. operational issues progress feedback via a newsletter, website, intranet, etc.	X
A6. Walkabouts, informal roaming and observation, spot checks	X

5.2 Handover process reviewed: familiarisation and training of occupants & management maintenance

The building handover took place in September 2009, with the keys being handed to the Parish Council. A tour of the building took place, with demonstrations of the intruder and fire alarms being undertaken. Other smaller demonstrations of items such as the dishwasher were also given, but the facilities manager was not present (he had not yet been appointed). No handover training was provided through a building and system induction tour. The building manager contacted the contractors and system subcontractors directly for help and information or to arrange individual training on the systems use (e.g. Heat Pumps).

The handover documentation included an Electrical Operation and Maintenance Manual, PV and Heat Pumps system manuals and equipment specification documents but has been found to be very technical and negatively impacted the efficient use of installed components such as the Velux windows due to occupants not being able to understand how to use them.

The Building Logbook and User guides for occupants and management were never delivered, which is contrary to Part L (2006) of the Building Regulations under which it was built. The building did achieve Building Control sign-off however.

Table 5 Handover checklist

Handover checklist (Source: Peter Tse, BSRIA, 2012)	
Tailor a move-in support plan with the client from the start – including a programme of induction sessions	x
Arrange strands of training (three are recommended)	x
Consider techniques: Soft Landings Residency, Walkthroughs, Photo survey, discussions with occupants, discussion with site manager, hindsight review, energy logging and Energy workshops.	x
Involve caretakers and facilities teams in the planning to clarify roles and responsibilities.	x
At the inductions, plan for: Distributing keys to the end users Discussing teething issues to expect, such as settling cracks, stiff doors	✓
Provide simple non-technical user guide (~four A4's – the more concise, the better)	x
Provide a simple cleaners guide (one or two A4’s)	x
Demonstration of operation and maintenance of controls and technologies (windows, taps, heat controls, check meters, etc.)	✓
Provide guides as hard copies and electronically	✓
Develop a Welcome Letter to aid staff in taking ownership of the building and explain normal teething issues before inductions begins	x

5.3 Evaluation of handover data: log book, O&M manuals, user guides for occupants

The handover documentation available on site (Figure 33) included:

- Operation and Maintenance Manual (AJ Taylors – Electrical contractors ltd)
- Photovoltaic system manual (Southern Solar – PV suppliers)
- Heat Pumps system manual (Source- Ground source heat pump installers)
- Building manual in two parts (Hamsons – Project management and M&E design). Technical information on Mechanical Services (Part 1), Building Fabric (Part 2) and all the construction drawings.

A number of legally required documents were missing, including: the building logbook, the electrical commissioning documents, metering and sub-metering schematic/plan, Heat Pump Water and electrical circuit diagram which includes details of pipe sizes and power data. The building management has reported that lack of proper electrical drawings, including electrical and mechanical specification documents and as-built drawings creates serious problems for carrying out maintenance and repairs. As an example, management reported that *'when the electrical windows had broken down the technician could not find the fuse and was not able to repair them immediately'*.

Table 6 Handover documentation checklist

Handover documentation checklist	**Available on site (✓)**
Legal contract	x
Drawings (incomplete)	✓
System Specifications	✓
Commissioning records (incomplete)	✓
Log book	x
Strategy for energy and metering	x
Building User guide	x
White goods' manuals guarantees	✓

Figure 33 The handover documentation that was available on site.

Table 7 Handover evaluation list

Handover evaluation list (poor-average-good-excellent)	
Clarity of objectives and explanation	Poor
Dissemination techniques (slide presentation, printed leaflets, User Guide)	Poor
User Engagement (Participation, expressed views and queries)	Poor

Operation and Maintenance Manual (AJ Taylors – Electrical contractors)

The O&M manual was compiled by the electrical contractors, AJ Taylors. They describe the operation and maintenance requirements for the electrical services supplied, installed, set to work, tested and commissioned by AJ Taylor Electrical Contractors Ltd. It is recommended that this manual is reviewed on a 12 monthly basis as a part of the maintenance program, but it is unknown if this has been undertaken or not. It is also to remain on site, in both digital and hard copy.

Upon inspection, the manual was found in a broken folder, with Section 9 (test certificates and distribution schedules) incomplete. In addition to this, not all of the electrical drawings had been updated to 'as built' status.

Table 8 Operation and Maintenance Manual content list

1. Introduction
2. Contract Information
3. Description of the electrical devices
4. Manufacturers information
5. Product Information (lighting, AV devices, distribution boards, wiring and cables, etc.)

6. Recommended spares (only for lamps)
7. Maintenance, recommendations and fault finding
8. Health and Safety
9. Test certificates and distribution schedules (only for alarms) missing
10. Record drawings

5.4 Conclusions and key findings

5.4.1 Key findings from review of handover and documentation

- The standard snagging and defect period of one year was undertaken.
- Items that fall under the care of the Parish Council have maintenance contracts (eg. Fire and security) and a budget is being set aside for ongoing maintenance of the building.
- The GSHP units have an annual maintenance service. Most other equipment does not have formal maintenance contracts, instead reliant on warranties and the Charity undertaking general annual maintenance.
- The design and build contractors (Catchpole) were bought out by another firm a few months after the completion of the building limiting the option of aftercare from their side.
- ACC handover process did not comply with any of the Soft Landings suggested aftercare actions indicating an inadequate handover.
- The building handover took place in September 2009, with the keys being handed to the Parish Council. A tour of the building took place, with demonstrations of the intruder and fire alarms being undertaken. Other smaller demonstrations of items such as the dishwasher were also given, but the facilities manager was not present (he had not yet been appointed).
- No handover training was provided through a building and system induction tour.
- The building manager contacted the contractors and system subcontractors directly for help and information and to arrange individual training on the systems use (e.g. Heat Pumps).
- The handover documentation included an Electrical Operation and Maintenance Manual, PV and Heat Pumps system manuals and equipment specification documents but has been found to be very technical and reduced the efficient use of installed components such as the Velux windows due to occupants not being able to understand how to use them.
- The Building Logbook and User guides for occupants and management were never delivered, which is contrary to Part L (2006) of the Building Regulations under which it was built. The building did achieve Building Control sign-off however.
- A list of legally required documents were found missing. Those were: the building logbook, the electrical commissioning documents, metering and sub-metering schematic/plan, Heat Pump Water and electrical circuit diagram which includes details of pipe sizes and power data.
- Section 9 of the O&M manual was incomplete with electric installation certificates missing.

5.4.2 Key findings from structured interviews with management

- The building has matched the expectations of the management team and they believe it is performing well. Management is satisfied with the energy performance of the building.
- The caretaker is responsible for the maintenance of the building.
- Management is very conscious at reducing equipment electricity consumption by switching off all appliances that are not being used.
- Maintenance contracts exist for the GSHP and fire and security alarms but not for all the building operations and systems.
- Automatic sliding doors are considered by the management team as problematic and obsolete and they are not covered by a maintenance contract.
- External lighting is insufficient at the back of the building. All lights in the parking area had to be changed from pillars to ground sunken due to repetitive vandalism. Change could have been avoided if different lights had been specified from the designers.
- There is no help desk or building log book which is contrary to Part L (2006) of the Building Regulations under which the Community Centre was built. This was first observed by the project team during the review of the handover process.
- Issues are first reported to the member of staff and the ACCA chairman.
- In cases of breakdown manufacturers are contacted directly by the building manager. Response rate was reported to be good.
- Lack of proper electrical installation drawings creates problems in maintenance and repairs.
- There were a few issues with the security system and the insurance given by the original supplier that resulted in having the sensors replaced.
- According to the Chairman of the Parish Council, having the sustainable systems has helped the general image of the building and along with the whole design.
- The building needs to be completely asset registered and organised and a proper long term plan needs to be developed with regards to asset replacement. According to the Chairman of the Parish Council this is likely to happen in the next 12 months.
- The principle of low carbon strategies was adopted within 16 months of the discussions on the project starting. Some re-engineering had to be done from the original drawings to take up these strategies.

6 Energy use by source

6.1 CIBSE TM22 _Simple assessment

The Energy Performance of Buildings Directive (EPBD) required a range of building energy labelling measures to be implemented in the UK. A TM22 assessment can produce a rapid initial estimate of the breakdown of energy use and associated CO_2 emissions based on metered energy use and sub-metering data. For the TM22 assessment of this building, metered energy use from March 2013 to March 2014 (1 year) is used.

Community centres do not have a standard TM46 building benchmark as they often vary drastically in use and occupancy etc. Therefore the TM46 building benchmark of 'schools and seasonal use buildings' was used in preference to 'light use public building' or other such benchmark for the ACC. This was due to the fact that the centre is known to experience similar usage patterns to that of a school; activities increasing and decreasing in line with the school year. The definition also noted it was suitable for community centres, and included additional areas such as a restaurant and basic office equipment that the 'light use public building' does not allow for. Comparison with the TM46 benchmark is slightly complicated as the benchmark is not developed for electrically heated buildings and considers fossil fuel as the primary heating source.

The annual CO_2 emissions figure of 27 $kgCO_2/m^2$ is 47% better (lower) than the raw CIBSE TM46[3] benchmark[4] of 51.1 $kgCO_2/m^2$ (Figure 35). The annual fossil fuel equivalent energy consumption in ACC is 61 kWh/m^2/annum and is much lower than the Raw TM46 benchmark of 190 kWh/m^2/annum (Figure 36). Grid electricity import is 49.1 kWh/m^2/annum (Figure 34).The annual fossil fuel equivalent CO_2 emissions are 33.5 $kgCO_2/m^2$/annum, which is 19.4% higher than the actual CO_2 emissions of the building (Figure 37).

The total annual electricity consumption was 34,306 kWh of which 6,675 kWh (19%) was generated by the PVs and used on-site (Table 9). The total PV generation for the year was 10,442kWh, with 3,767kWh being exported to the grid. The actual PV generation from March 2013 to March 2014 is 28% higher than the PV specification estimate of 8,160 kWh/annum.

Table 9 Building energy efficiency

BUILDING ENERGY EFFICIENCY

Absolute values	**Fossil Fuel Equivalent Energy supplied (kWh)**		**Fossil Fuel Equivalent Carbon dioxide emissions (kg CO_2)**		
	Fuel/thermal	**Electricity**	**Fuel/thermal**	**Electricity**	**TOTAL**

[3] TM46 describes the statutory building energy benchmarks prepared to complement the Operational Rating procedure developed by the Department for Communities and Local Government (CLG) for Display Energy Certificates for use in England, Wales and Northern Ireland under the Energy Performance of Buildings (England and Wales) Regulations 2007. There are 29 benchmark categories each of them representing a major functional group of buildings, so the benchmarks provide an indication of how a building is performing in relation to the wider group. Angmering Community Centre was categorised as a school or seasonal public building with normal occupancy.

[4] The "raw" TM46 benchmark values for a particular benchmark category are therefore based on relatively 'energy-lean', tightly run buildings located in the average UK (excluding Scotland) climate (2,021 degree days). (CIBSE review of energy benchmarks for display energy certificates, May 2011).

Supplied less separables	0	27,631	0	15,197	15,197
Renewables (used on site)	0	6,675	0	3,671	3,671
Renewables (exported)	0	-3,767	0	-2,072	-2,072
Exported CHP	0		0		

Unit values	**Fossil fuel equivalent energy (kWh/m^2TADA)**		**Fossil fuel equivalent CO_2 ($kg\ CO_2/m^2$ TADA)**		
	Fuel/thermal	**Electricity**	**Fuel/thermal**	**Electricity**	**TOTAL**
Supplied less separables	0.0	49.1	0.0	27.0	27.0
Renewables (used on site)	0.0	11.9	0.0	6.5	6.5
Renewables (exported)	0.0	-6.7	0.0	-3.7	-3.7
Exported CHP	0.0		0.0		
Raw TM46	150.0	40.0	29.1	22.0	51.1
User Specified	0.0	0.0	0.0	0.0	0.0
Benchmark from DEC	0.0	0.0	0.0	0.0	0.0

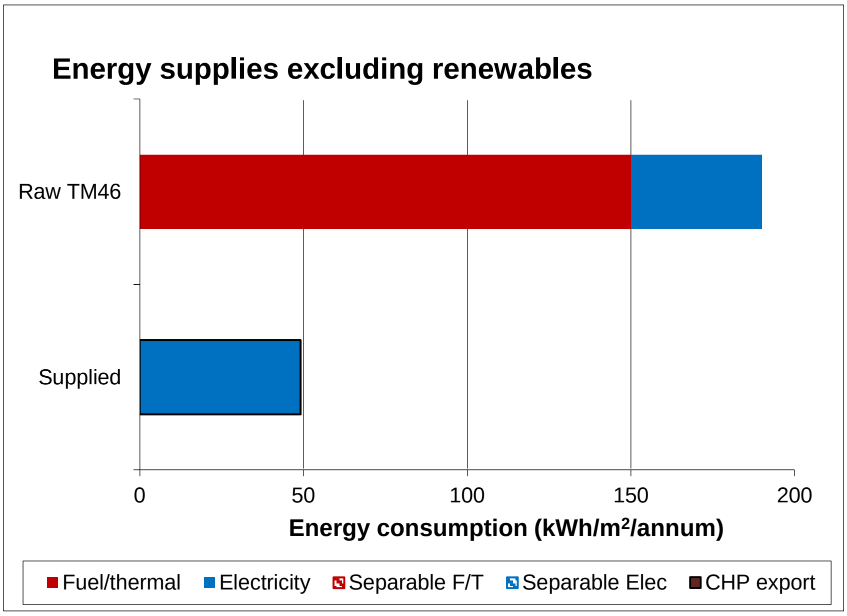


Figure 34 Annual energy use excluding PV generated electricity (March 2013 – March 2014).

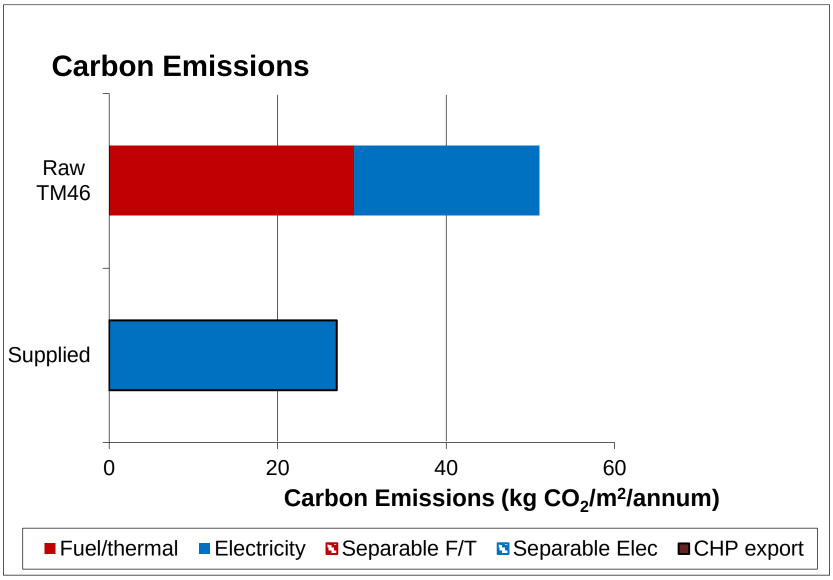


Figure 35 Annual carbon emissions (March 2013 – March 2014).

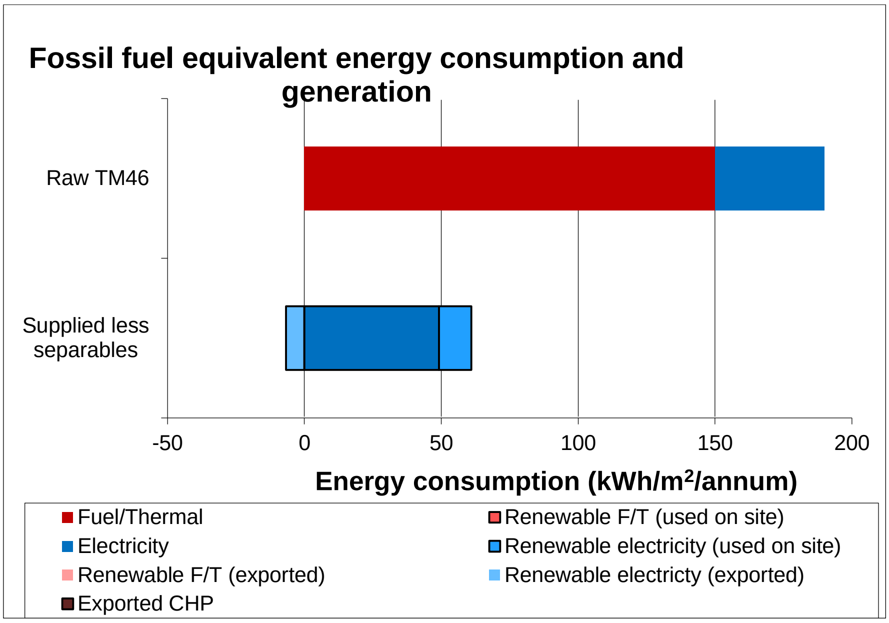


Figure 36a Fossil fuel equivalent energy consumption and generation (March 2013 – March 2014).

The actual energy use (grid and PV generated electricity) of Angmering Community Centre is 5% lower than the estimated annual energy use (from BRUKL) including appliances, heating and hot water, lighting and auxiliary end-uses. (Figure 36b).

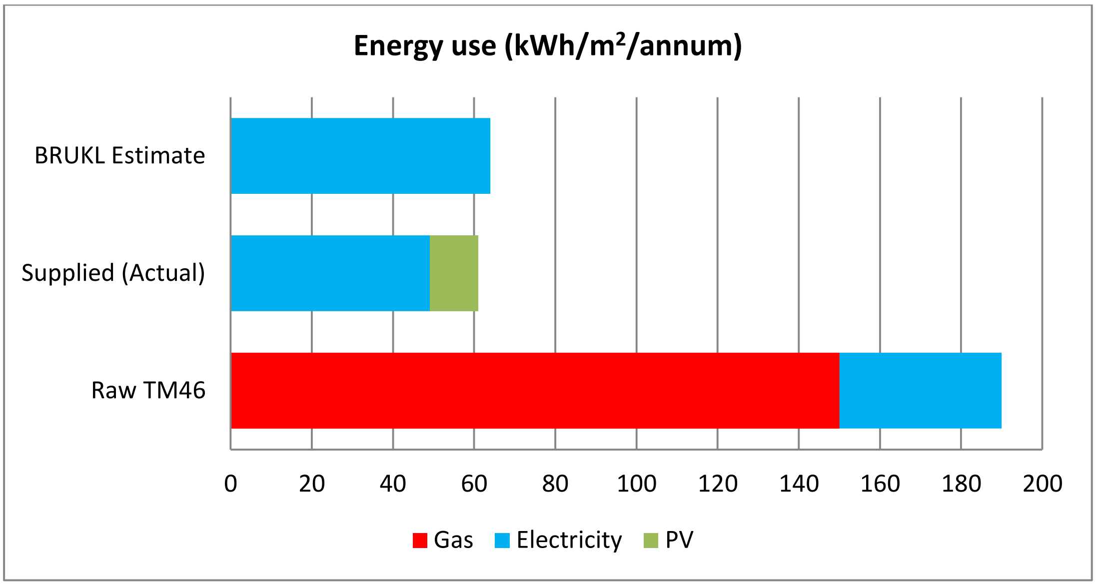


Figure 37b Annual energy use, actual and BRUKL estimate

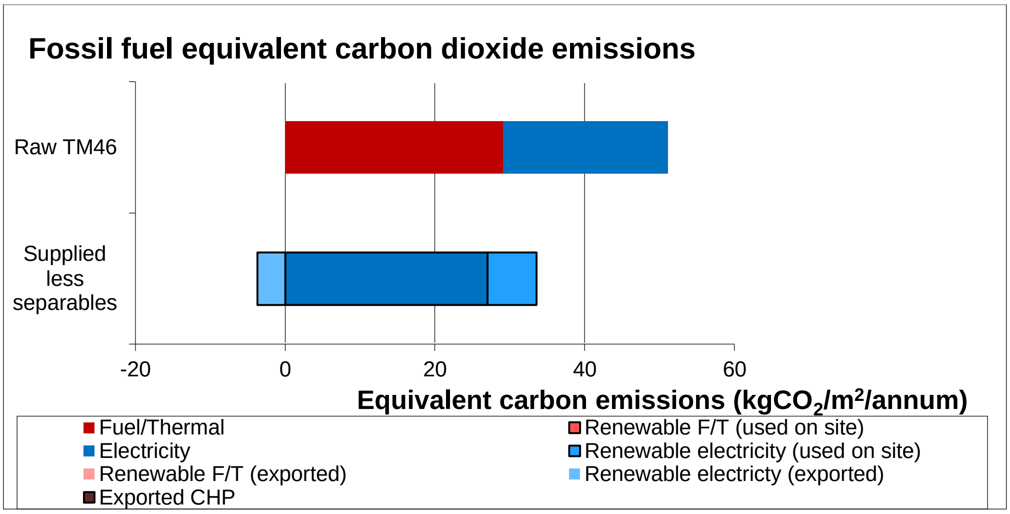


Figure 38a Fossil fuel equivalent carbon dioxide emissions (March 2013 – March 2014).

The carbon footprint from actual energy use of Angmering Community Centre is 25 $kgCO_2/m^2$/annum while the estimated Building Emissions Rate (from BRUKL) is 12.4 $kgCO_2$ /m^2, which is almost 50% lower than the actual emissions for 2013 (Figure 37b). It should be noted that BRUKL does not count all end uses of energy especially catering energy use or electricity used by plug loads.

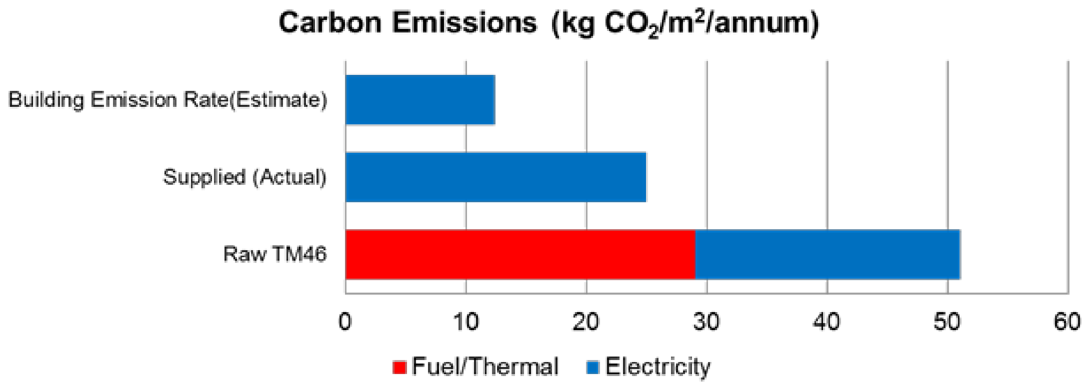


Figure 37b Annual carbon emissions, actual and BER estimate

6.2 CIBSE TM22 _ Sub-meter assessment and analysis

Metered data were compared against end use data collected from a bottom-up on-site energy audit, which included an audit of the appliances and an estimation of usage profiles. This comparison allows for reconciliation of energy use on a sub-meter by sub-meter basis and allows for detailed analysis of the building energy use.

Annual electrical energy use (including heating and hot water) is 34% higher than the Raw TM46 benchmark. Comparison with the benchmark can be misleading as the benchmark is not developed for electrically heated buildings as is the case of ACC (Figure 38).

Space heating and hot water account for 54% of the total electricity use, lighting accounts for 38.7% of the total, ICT equipment for 4.9% of the total and small power only for 1% of the total electricity used in the building (Table 10).

Table 10 Energy demand by end use

	Heat demand (kWh/m2/year)	Electricity demand (kWh/m2/year)		
System	**In-Use (kWh/m2/year)**	**In-use electricity (kWh/m2/year)**	**In-use electricity (kWh/year)**	**In-use % of total**
Space Heating	0.0	27.3	15,374	45.0%
Hot water	0.0	0.2	130	0.4%
Cooled Storage	0.0	1.6	920	2.7%
Controls	0.0	3.7	2,059	6.0%
Lighting (Internal)	0.0	21.3	11,996	35.1%
Lighting (External)	0.0	2.2	1,231	3.6%
Small Power	0.0	0.6	339	1.0%
ICT Equipment	0.0	3.0	1,684	4.9%
Catering - Central	0.0	0.7	404	1.2%
Total	**0.0**	**60.7**	**34,136**	100.0%
Metered building energy use	0.0	61.0	34,305	
Variance TM22 versus metered total	0.0	-0.3	-169	
Variance TM22 versus metered total	#DIV/0!	0%	0%	

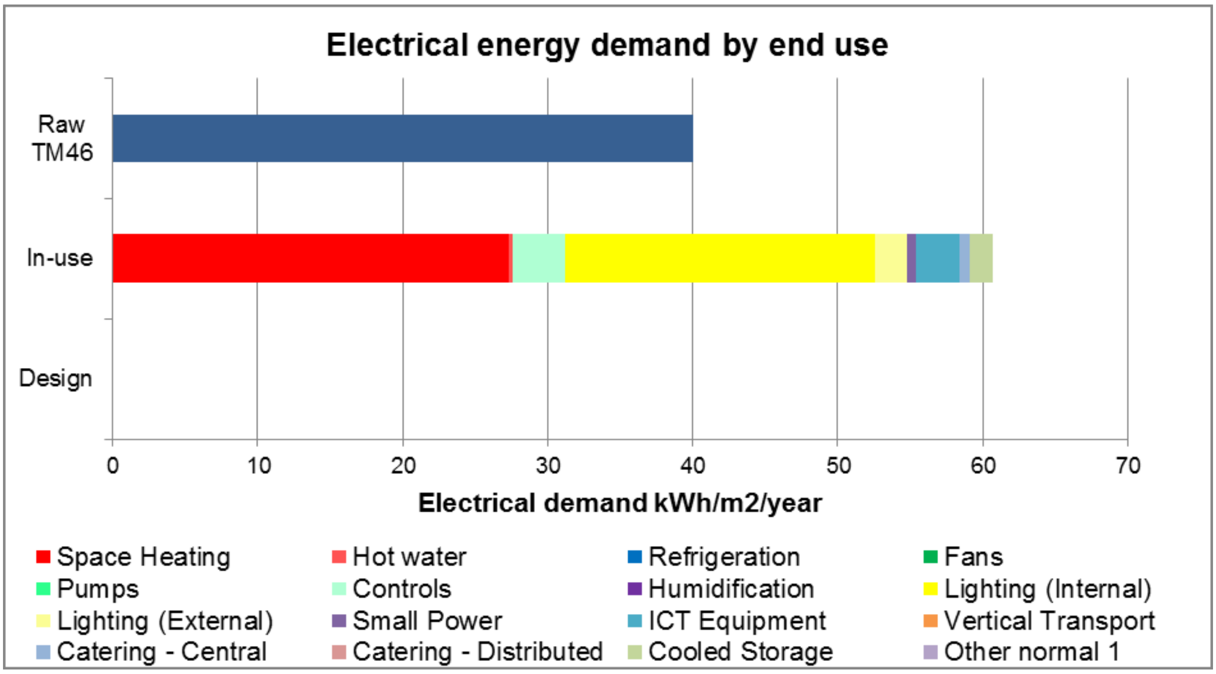


Figure 39 Electrical energy demand by end use

Grid equivalent electrical carbon emissions by end use are shown in Figure 39. It should be noted that these figures represent grid equivalent and that the actual emissions are lower since PV generated electricity is used in the building.

Table 11 Carbon emissions by end use

	Fuel /Thermal (kg
System	**In-use Fuel/Therma emissio**
Space Heating	
Hot water	
Refrigeration	
Cooled storage	
Lighting (Internal)	
Lighting (External)	
Small Power	
ICT Equipment	
Catering - Central	
Total	

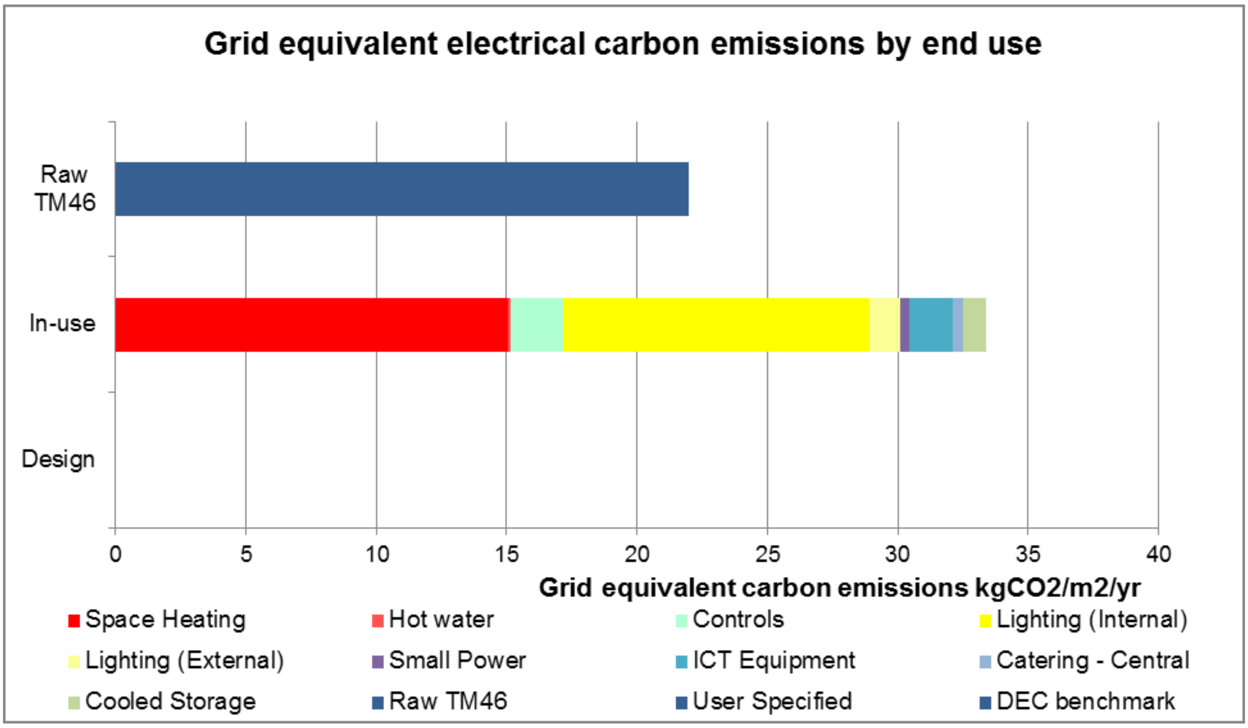


Figure 40 Grid equivalent electrical carbon emissions by end use

A comparison between the actual and the estimated (from BRUKL) electricity use of end-uses shows that the building is performing similarly to its design target (Figure 39b). Actual heating energy use is 48% higher than the design estimate, but electricity use of equipment is actually 69% lower than the estimate.

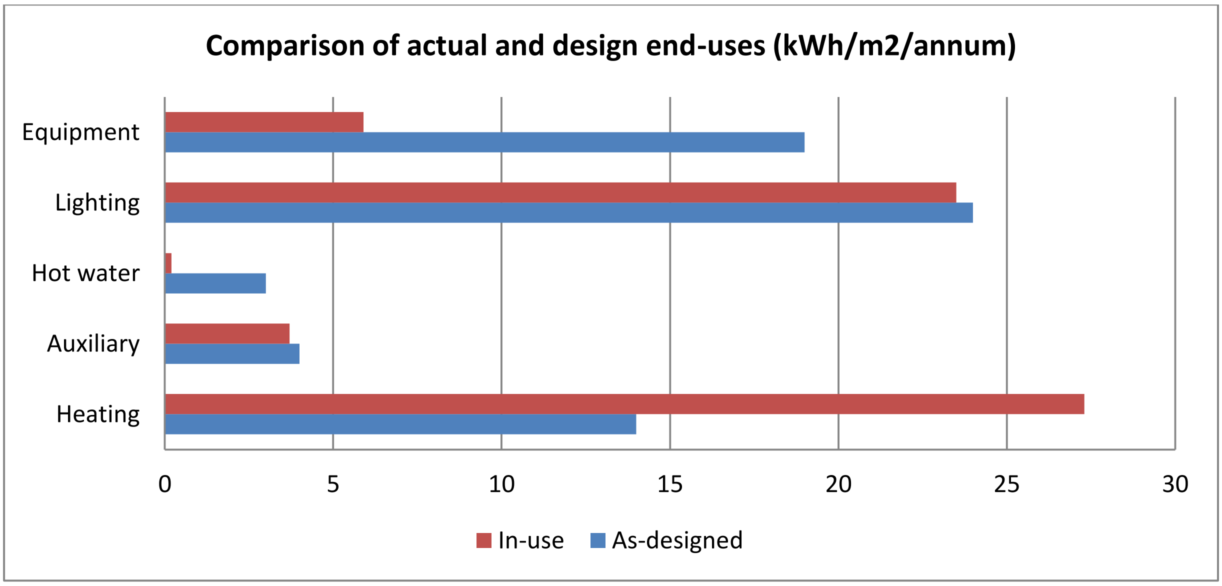


Figure 39b41 Comparison of actual and as-designed (from BRUKL) electricity use (kWh/m^2/annum).

6.3 Comparison with other buildings

Comparison is also made with buildings of similar uses; Angmering Community Centre uses far less energy than most (all except Mayville/Mildmay Community Centre). The annual energy use of the other buildings ranges between 104kWh/m2/annum in the College Lake Centre to 442 kWh/m^2/annum in Donnington Community Centre (Figure 40). Data for Angmering Community Centre, Mayville/Mildmay Community Centre and College Lake Visitor Centre were collected between 2012-2013, whereas the other community centres were studied between 2006-2007. With the exceptions of Angmering Community Centre, Mayville/Mildmay Community Centre and College Lake Visitor Centre, nearly all of the other buildings do not perform well as compared to even typical benchmarks. These are largely community centre buildings which are found to have a poor fabric performance in terms of heat loss, lack of insulation in the walls, and leaky fabric. Angmering Community Centre is performing better than the CIBSE Guide F-Good practice benchmark as a result of the good performance of the GSHPs, relatively low thermostat settings and good management.

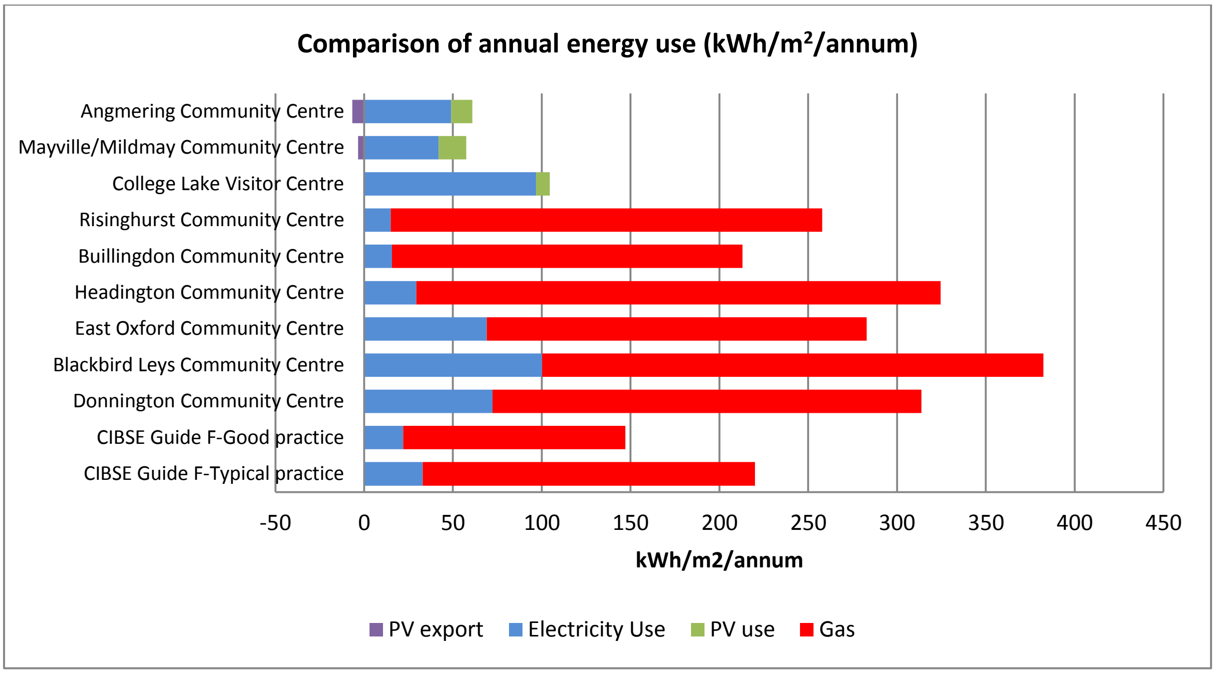


Figure 42 Comparison of annual electricity and gas consumption (kWh/m^2/annum).

6.4 Analysis of energy demand

From March 2013 to March 2014 the grid electricity import was 27,603kWh (Figure 42). From the PV generated electricity, 6,673 kWh was used in the Centre and 3,767 kWh was exported. Compared with figures from 2011 shows that electricity consumption in Angmering Community Centre has risen (Figure 43). This rise can be explained by the increase in occupancy as the Centre has become more popular during the last two years and is now used by more people and for longer hours. PV generation has not changed during this two year period but PV export has decreased, indicating that more PV generated electricity is now being consumed in the building.

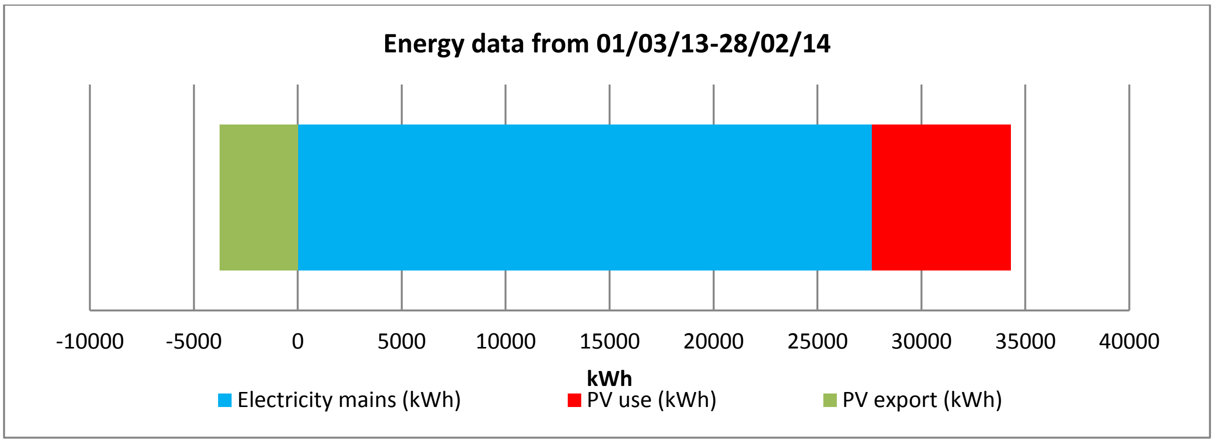


Figure 43 Annual energy use and PV export (March 2013 – March 2014)

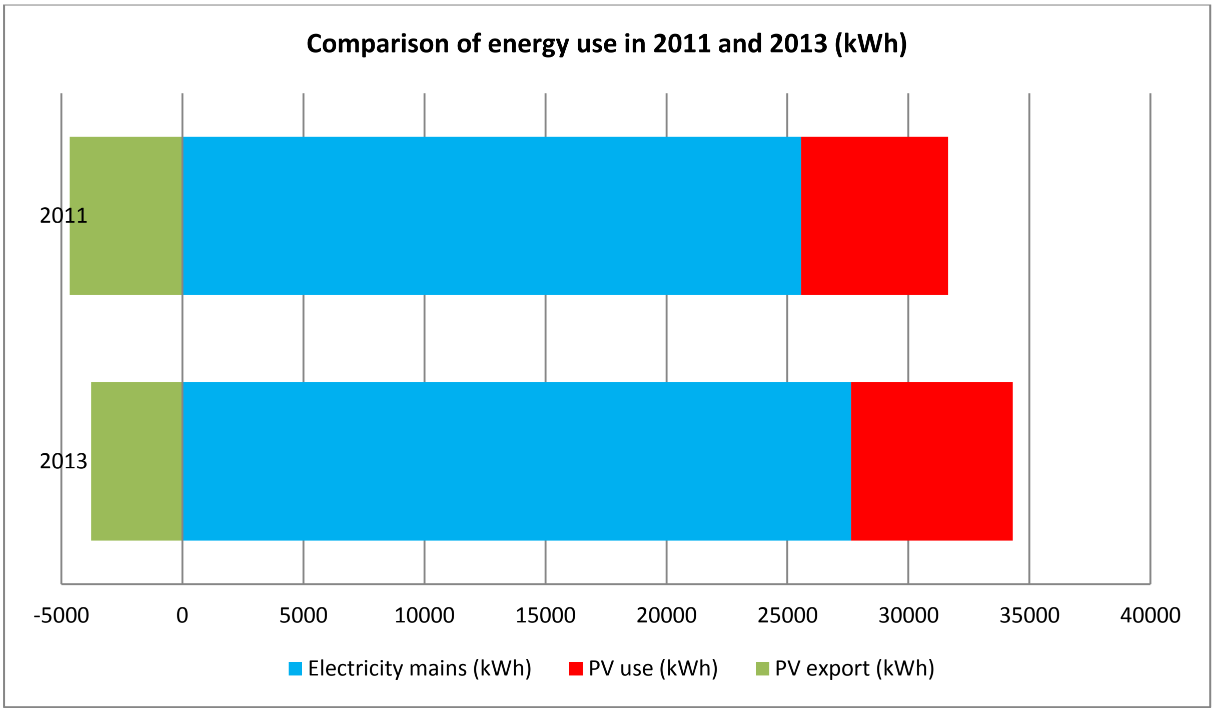


Figure 44 Comparison of annual energy use and PV export in 2011 (Jan-Dec 2011) and 2013 (Mar 2013-Feb 2014).

On a monthly basis, grid electricity import drops from 4,000 kWh in March 2013 to 700kWh in July 2013 (Figure 44). PV generated electricity used in the Centre ranges between 25-750 kWh/month. During this period PV generated electricity exported back to the grid gradually rises from nearly 0 kWh in March 2013 to 800 kWh in July 2013.

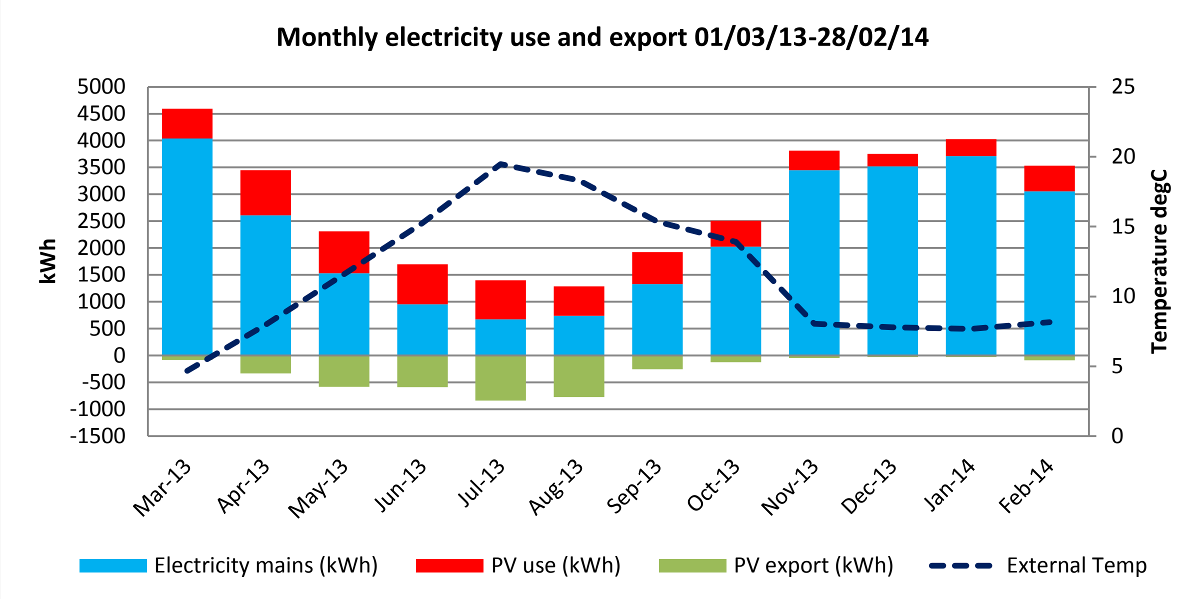


Figure 45 Monthly electricity use and export (March 2013 – March 2014)

Monthly electricity sub-metering is shown in Figure 45. Electricity used by the heat pumps drops from 3,000kWh in March to 250kWh in July. Electricity used by the kitchen appliances remains steady (200kWh/month). Electricity used for lighting ranges between 500-650 kWh/month from March to June and then drops to 100kWh/month from July onwards. As shown in Figure 45, the largest amount of electricity is used for space heating (and hot water). The heating thermostat is always set at 19°C leading to continuous heating during winter. In an attempt to decrease the heating demand, the management lowered the thermostat temperature settings from 19°C to 18°C for a week but had to turn it up again following complaints by users who found the spaces to be 'too cold'. Furthermore, intermittent heating has proven unsuccessful due to the slow responsiveness of the heating system. In order to decrease the heating demand it is suggested that spaces are individually zoned thus allowing for better control.

A residual amount of 500-1,200 kWh per month indicates that not all electricity use is monitored. This amount is attributed to lighting (shown in TM22 analysis). From August 2013 onwards, there appears to be a decrease in lighting use and a simultaneous increase of the amount of electricity not included in the sub-metering. The BPE team has investigated this but were unable to identify the source of the issue. Despite this, however, there is potential to decrease electricity use for lighting through the use of LED high efficiency lamps. The ACCA have considered that option but are struggling to get the funds to buy the new lighting fittings. This cost could have been avoided if LED lamps had been originally specified.

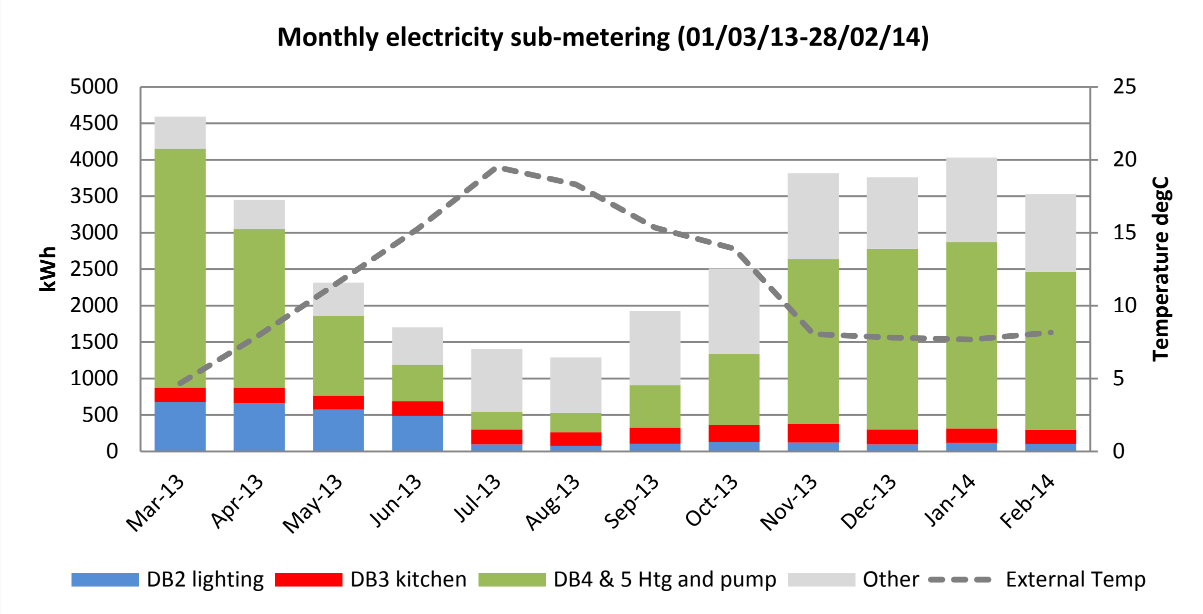


Figure 46 Monthly electricity sub-metering (March 2013 – March 2014)

The hourly profile of grid electricity and PV generated electricity is shown in Figure 46. Average hourly grid electricity import ranges between 2.5-4.5kWh. Grid electricity import drops during the day when PV generated electricity is being used and peaks around 19:00. PV generated electricity use peaks at midday reaching 2.5kWh at 11:00. Baseline consumption is around 3kWh/hour.

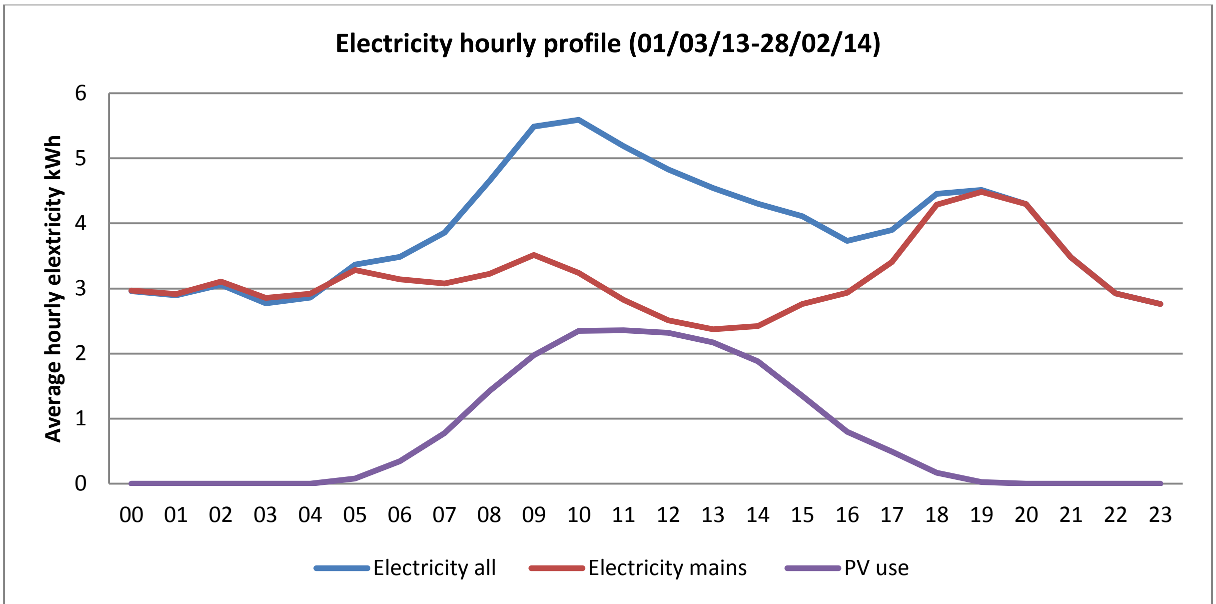


Figure 47 Grid and PV generated electricity hourly profile (March 2013 – March 2014).

The hourly profile of electricity sub-metering is shown in Figure 47. Electricity used by the heat pumps gradually drops during the day, as occupancy in the Centre rises, and starts rising again after 17:00 to reach its peak in the early morning. This indicates that the heating in the Centre is left on during the night. Electricity used for lighting starts rising at 6:00 and is kept quite steady until 20:00 when the Centre closes at night. Electricity use for lighting shows little variance as most spaces are continuously occupied and the Entrance Hall lights are turned on throughout the day. External lighting does not seem to be included on the DB2 lighting board since the load at night is very low. External lighting is controlled by a time clock. Due to the lack of electrical schematics, it can only be assumed that external lighting is not included in the sub-metering and is part of the residual amount of electricity ('Other').

Electricity used in the kitchen is low throughout the day, peaking at 11:00. The trend of the 'Other' electricity is similar to that of lighting indicating that part of the lighting energy consumption was not included in the original sub-metering arrangements.

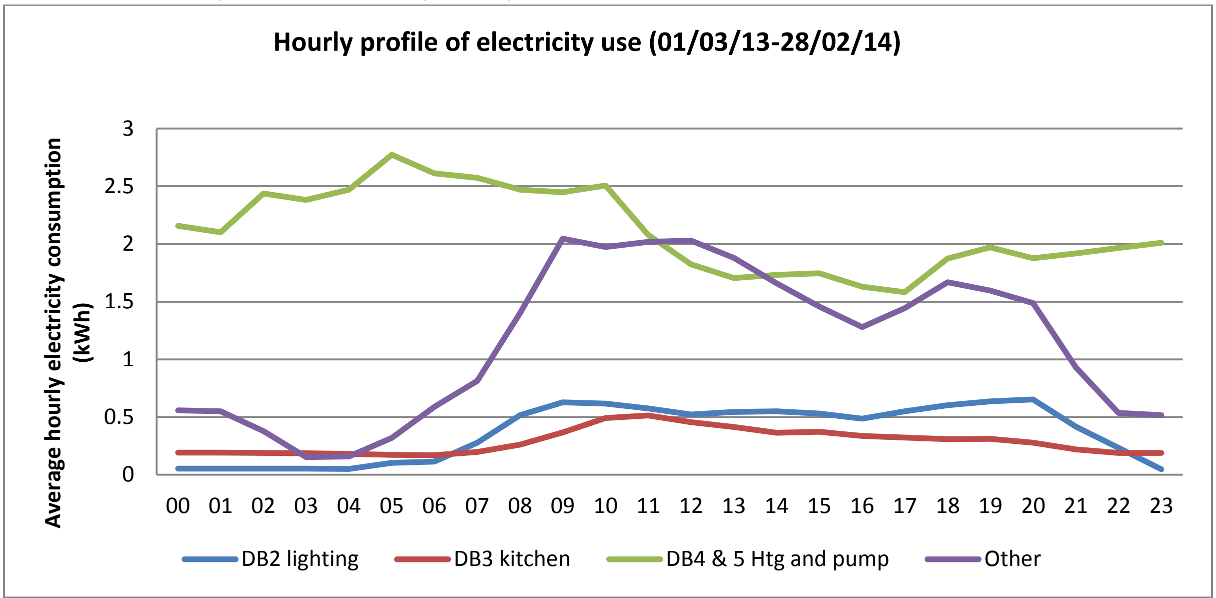


Figure 48 Hourly profile of electricity sub-metering (March 2013 – March 2014).

Figure 48 shows the monthly energy output from the GSHPs. Hot water energy ranges from 600-1,900 kWh/month, while space heating energy varies greatly according to external temperatures.

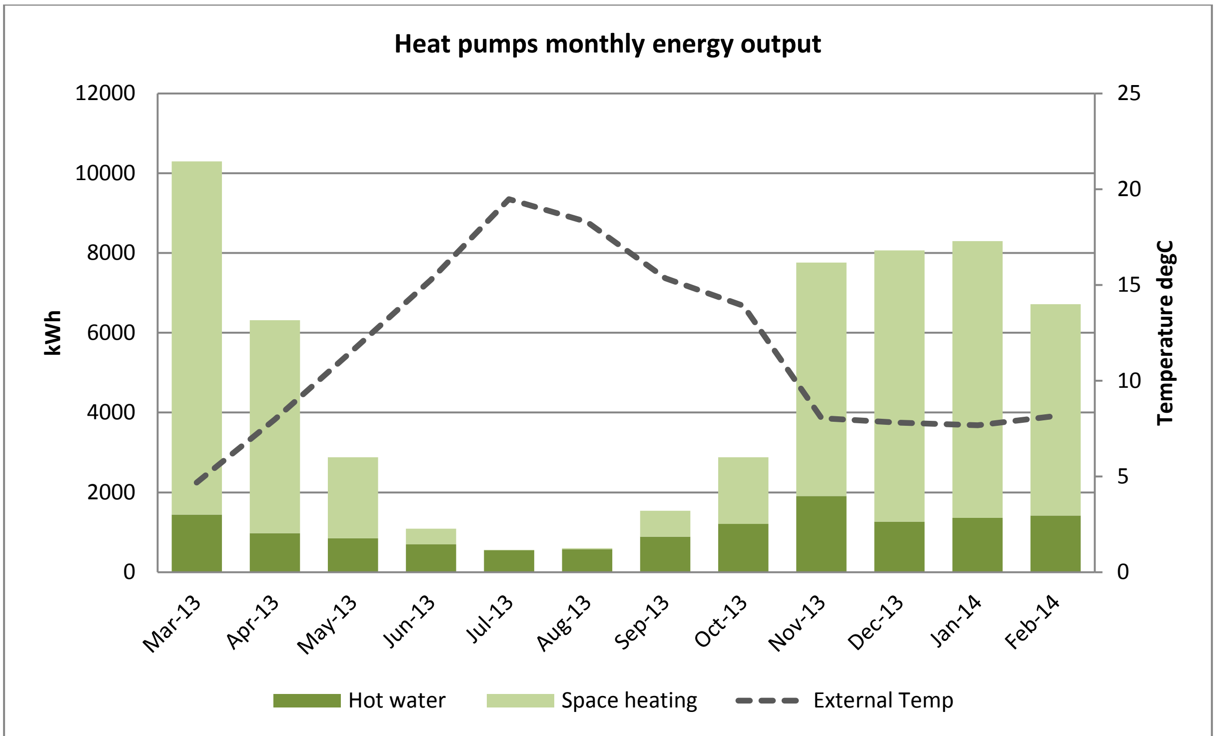
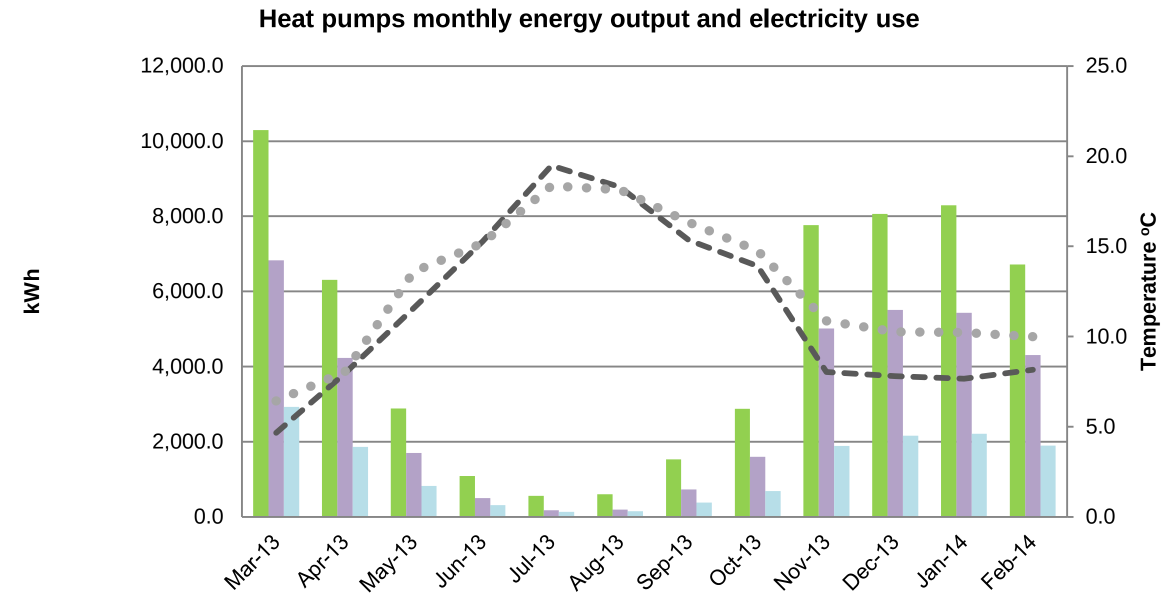


Figure 49 Monthly heat pump output

The seasonal performance factor (SPF) of both heat pumps was calculated at 3.7 by comparing the total annual energy output of the heat pumps with their annual electricity use. The monthly coefficient of performance (COP) varies on a monthly basis ranging between 3.5 to 4.1, depending on the heat demand. This indicates that the GSHPs are performing well as the expected COP of the heat pumps the COP is around 3.3-4.4. Ground temperature varies from 8-10°C during winter to 15-18°C during summer (Figure 49).

As shown in Figure 49 the heating energy closely follows external temperature. From March to July energy demand for space heating and hot water gradually drops from 9,000kWh to 500kWh. Energy from the two ground loops gradually drops from 6,000kWh in March to 170 kWh in July. Electricity use of the heat pumps drops from 2,500kWh in March to 100kWh in July.



	Mar-13	Apr-13	May-13	Jun-13	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14
Hot water+Space heating	10,297.9	6,313.1	2,882.4	1,087.8	559.9	603.2	1,535.9	2,879.3	7,762.1	8,061.7	8,294.9	6,719.9
Energy from ground loops	6,825.5	4,233.4	1,699.3	501.8	175.4	197.8	728.6	1,597.0	5,013.1	5,511.8	5,429.1	4,308.8
HPumps electricity use	2,927.8	1,867.0	828.4	313.1	139.9	156.7	379.4	688.1	1,892.9	2,162.7	2,214.3	1,894.3
External Temp	4.7	8.0	11.6	15.3	19.5	18.3	15.4	13.9	8.0	7.8	7.7	8.2
Ground Temp	6.42	8.04	13.60	15.18	18.34	18.14	16.32	14.75	10.87	10.27	10.23	9.99

Hot water+Space heating   Energy from ground loops   HPumps electricity use
External Temp   Ground Temp

Figure 50 Monthly heat pump performance (March 2013 – March 2014)

6.5 Conclusions and key findings

- The annual CO_2 emissions figure of 27 $kgCO_2/m^2$ is 47% better (lower) than the raw CIBSE TM46 benchmark of 51.1 $kgCO_2/m^2$. The annual fossil fuel equivalent energy consumption in ACC is 61 kWh/m^2/annum and is much lower than the Raw TM46 benchmark of 190 kWh/m^2/annum. These results indicate that the building is performing much better than the benchmark and that energy is used efficiently.

- Electricity generated by the PV panels offsets 19% of the fossil fuel equivalent carbon emissions of the building.

- The total annual electricity consumption was 34,306 kWh of which 6,675 kWh (19%) was generated by the PVs and used on-site. The total PV generation for the year was 10,442kWh, with 3,767kWh being exported to the grid. The actual PV generation from March 2013 to March 2014 is 28% higher than the PV specification estimate of 8,160 kWh/annum.

- Annual electrical energy use (including heating and hot water) is 34% higher than the Raw TM46 benchmark. Comparison with the benchmark can be misleading as the benchmark is not developed for electrically heated buildings as is the case of the ACC.

- Space heating and hot water account for 54% of the total electricity use, lighting accounts for 38.7% of the total, ICT equipment for 4.9% of the total and small power only for 1% of the total electricity used in the building.

- Electricity consumption peaks during winter months which is expected as the Ground Source Heat Pumps are also at their peak capacity. The consumption rate gradually falls towards the summer due to the reduction in need for lighting and heating during the warmer, lighter, summer months.

- Electricity demand is higher during the day. High electricity consumption during the night hours during the winter period indicates that the heating is left on even during the night when the building is unoccupied.

- From March 2013 to March 2014 grid electricity import is 27,603kWh. From the PV generated electricity 6,673 kWh/annum was used in the Centre and 3,767 kWh/annum were exported.

- Electricity used by the heat pumps drops from 3,000kWh in March to 250kWh in July. Electricity used by the kitchen appliances remains steady (200kWh/month). Electricity used for lighting ranges between 500-650kWh/month from March to June and then drops to 100kWh/month from July onwards. A residual amount of 500-1200kWh/month indicates not all electricity use is monitored. This amount is attributed to lighting (shown in TM22 analysis).

- Average hourly grid electricity import ranges between 2.5-4.5kWh. Grid electricity import drops during the day when PV generated electricity is being used and peaks around 19:00. PV generated electricity use peaks at midday reaching 2.5kWh at 11:00. Baseline consumption is around 3kWh/hour.

- There is a very strong correlation between weekly heating demand and heating degree days indicating that the GSHPs and the building are performing well. The coefficient of performance for both heat pumps was calculated at 3.68. It should be noted that according to the specifications of the heat pumps the COP is 4.4/3.3.

7 Technical issues

7.1 Review of performance and usability of systems and controls

A survey of the controls was conducted on May 2013. Most of the controls were found easy and intuitive to use and conveniently located. Some of the controls (Velux windows, Kitchen hatch) originally installed in the building were complicated to use and the building management had to change them for more user-friendly ones. As in all public buildings, the controls specified in the design phase should be clear and intuitive to use. Users should be given the opportunity to control their environment but without being able to change basic settings such as thermostats. Care should be taken so that the management has overall control of the building in terms of thermostat settings and energy use.

7.1.1 Heating and hot water controls

- The usability of heating and hot water control of the GSHP is not intuitive and needs instructions on how to use it properly (Figure 50). The GSHP controls are located on the GSHP and are accessible from outside the building, in the plant room. The part time caretaker is responsible for operating the GSHP and is the only one who has received training on how to operate the GSHP and understands the system. During the handover review, the Heat Pump system manual that was provided to the management as part of the handover documentation was found to be very technical. It would be recommended that the other members of staff, Chairman and members of the Trustees responsible for the operation of the building also receive training on how to operate the GSHP and that a more easy to use manual is provided by the installer.

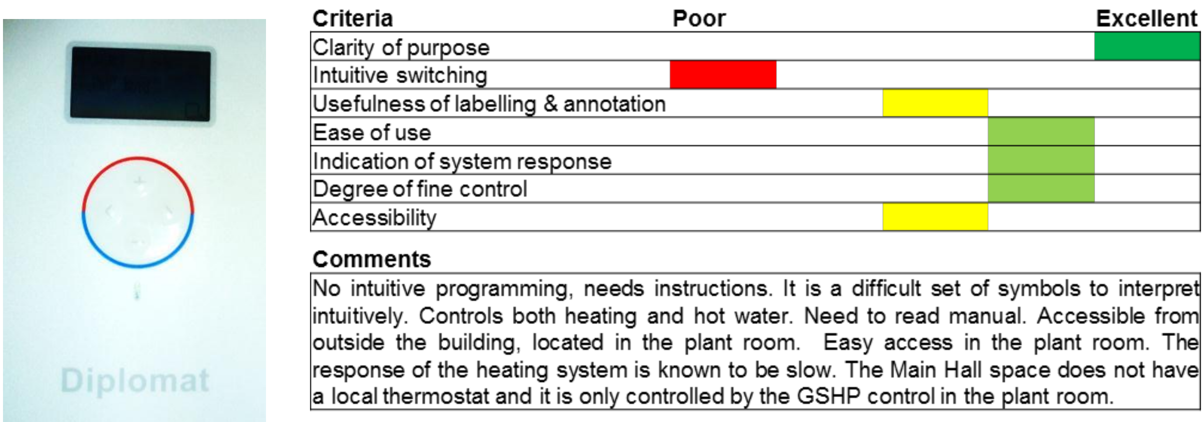


Figure 51 Evaluation of heat pump control

- The degree of fine control offered by the controls of the GSHP is good but the building is not fully zoned so one temperature setting applies for all spaces, apart from the meeting rooms that feature individual room thermostats. This results in some spaces having higher temperatures than others and in some cases overheating due to internal or solar gains. It would be recommended that the building is properly zoned and thermostats are kept at lower temperatures in the Parish room, the Entrance Hall and the Main Hall. The Main Hall space does not have a local thermostat and it is only controlled by the GSHP control in the plant room.

- Tighter control of required internal temperatures for different activities and spaces would help in increasing comfort levels and reducing energy consumption.

- The response of the heating system is known to be slow, which is inherent with a thermally massive underfloor heating system. This has an effect on the way occupants can control space temperature as most of them are not familiar with this sort of system and underfloor heating.

- The individual room thermostats in the meeting rooms are easy and intuitive to use but users are advised by management not to use them. There have been cases where users turned off the heating completely and it then took many hours to bring the temperature back up to comfort levels. It is recommended that the heating system is zoned and that only management able to control the individual room temperatures based on the activities taking place in that space.

7.1.2 Electrical equipment controls

- Light switches and control panel are intuitive to use and have good labelling and annotation. PIR sensors could be installed in Meeting rooms and the Main Hall in order to improve energy saving.

- PV inverters are well labelled and accessible from outside the building, in the plant room.

- Light switches are easy and intuitive to use. They are conveniently located in most cases, with the exception of the disabled toilet and the Parish room.

- Entrance Hall lights have to be turned on throughout the day as there is no daylight in the space. Design interventions are necessary to provide natural daylight in the Entrance Hall. This could be achieved by adding roof lights or daylight tubes.

- The Main Hall lights offer a good level of fine control but it is not obvious to users that they are dimmable. Also, there is no indication of which switch controls which row of lights therefore users need to experiment. Labelling of these switches would help to communicate this information to users.

- PIR sensors need to be installed in the disabled toilet to facilitate users. The existing switch is located outside the bathroom and makes it difficult for disabled people to switch on/off when entering and leaving the bathroom. As a result the lights are usually left switched on.

- Kitchen switches and fuses are all well labelled.

- Fire and security alarm are easily accessible and well labelled. However, management does not know how to reset the fire alarm and technicians need to be called in each time the system is set off. It is recommended that management receives training on how to operate this system and that an easy to understand guide is provided to them by the security team.

- After the control of the kitchen hatch was changed it is easy to use and intuitive (Figure 51). Good labelling and annotation has been added by management. Occupants reported that the previous control was very complicated to use. The new control for the kitchen hatch is still linked to the fire alarm and is set to come down automatically during a fire. The full controls can now only be accessed by an engineer and not the general public – thus safeguarding the settings.

a) b)

Figure 52 (a) Old kitchen hatch control. The fire blind mechanism instructions reveal the complicated control interface design of the appliance. To open the curtain you have to press the 'down' arrow while to close it the 'up'. (b) New kitchen hatch control

7.1.3 Kitchen appliances

- Kitchen appliances labelling is clear and the use is easy and intuitive. Good indication of system response and good level of fine control.

7.1.4 Water services controls

- Bathroom taps well labelled and easy to use. Push system is good for water management purposes. Kitchen taps well labelled and offering good level of fine control.

7.1.5 Doors and windows

- Windows and doors purpose is clear. Windows are intuitive to open and offer security.

- Top windows are difficult to reach and operate. Motors were added to the top windows of the Main Hall which allows users to open them by operating a switch.

- Electrical windows control interface is intuitive to use and well labelled (Figure 52).

Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching					■
Usefulness of labelling & annotation					■
Ease of use					■
Indication of system response	■				
Degree of fine control				■	
Accessibility			■		

Comments

Control not clearly visible, located behind drapes. Intuitive switching and easy to use. Not clear view to the windows from the location of the control. Very good labelling indicating its purpose and how to operate

Figure 53 Evaluation of electrical window controls

- Velux windows control is simple and good labelling has been added by management to explain how it should be used (Figure 53). Controls were recently changed because the originally installed controls were complex and not intuitive to use. Occupants reported that the previous controls were very complicated to use and that they operated with a remote control. The remote controls were problematic: when occupants were operating the velux windows in one room, the velux windows in other rooms would also be affected.

Criteria	Poor				Excellent
Clarity of purpose		■			
Intuitive switching		■			
Usefulness of labelling & annotation					■
Ease of use				■	
Indication of system response		■			
Degree of fine control					■
Accessibility					■

Comments

Useful labelling added by management indicating how to operate the control. Inscription 'Velux' indicating their use. Indication of response by windows moving. Easily accessible next to door. Occupants reported that the previous controls were very complicated to use and that they operated with a remote control. The remote controls were problematic: when occupants were operating the velux windows in one room, the velux windows in other rooms would also be affected.

Figure 54 Evaluation of velux window controls

- The control of the automatic sliding doors is well labelled and easy to use.

- The ventilation strategy relies on stack and cross ventilation. It is important that management takes care in ventilating each space as appropriate before and after its use, to ensure good indoor air quality.

7.1.6 Shading devices

- Blinds offer a good degree of fine control. They are easy to use but difficult to open fully. Management has reported that they often break and need to be repaired (Figure 54).

- Despite the blinds however the Parish room and the Main Hall experience overheating due to solar gains. The risk of overheating should have been thoroughly investigated at the design stage. It is recommended that external shading is added to the south facing glazing areas.

Criteria	Poor				Excellent
Clarity of purpose					■
Intuitive switching			■		
Usefulness of labelling & annotation	■				
Ease of use				■	
Indication of system response					■
Degree of fine control				■	
Accessibility					■

Comments

Easy to rotate by pulling studded rope. Not easy to fully open. Users reported that blinds snap easily. Two ropes to control each set of blinds. Not clear which set of ropes rotates or opens the blinds. Users need to experiment.

Figure 55 Evaluation of blinds

7.2 Site survey to identify energy wastage

A site survey was undertaken to review any areas of potential energy wastage. The occupants are not involved in energy management but appear aware of their energy use and take great care in ensuring lights and electrical appliances are switched off when no one is in the room. The administrator takes care to switch off any appliances that are not being used, ensuring that lights are off and windows are closed when the spaces are unoccupied. However, a few areas of energy wastage were identified.

Key findings include:

- The overhead projector and remote control screen in the Main Hall were left permanently switched on at the socket and there was a double socket above the screen, both of which were switched on. This is a result of the location of the sockets which are hard to reach (Figures 55, 56).

- There is only one switch for all the lights of the Entrance Hall providing occupants with little control over the lighting levels of the space. This results in some energy wastage as all of the lights are turned on throughout the whole day.

- No PIR sensors exist in the disabled WC. The location of the switch makes it hard to operate, affecting accessibility and resulting in the light being left on after use. The building manager had to put a note on the wall in order to remind people to turn off the light (Figure 57).

- In some cases the blinds are kept closed by the users and artificial lighting is used which may be leading to energy wastage.

The kitchen is mainly used for making tea and coffee and is used for cooking only a few hours per week during cooking lessons.

Figure 56 The overhead projector in the main hall

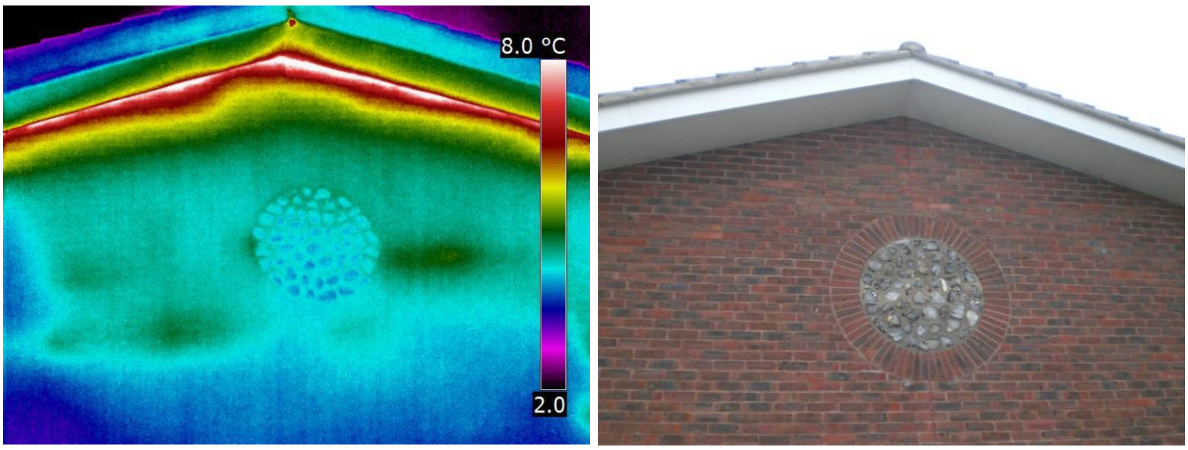
Figure 57 The screen in the Main Hall and the double socket are always switched on

Figure 58 Notes were put by the management to remind people to switch off the lights.

7.3 Thermographic survey

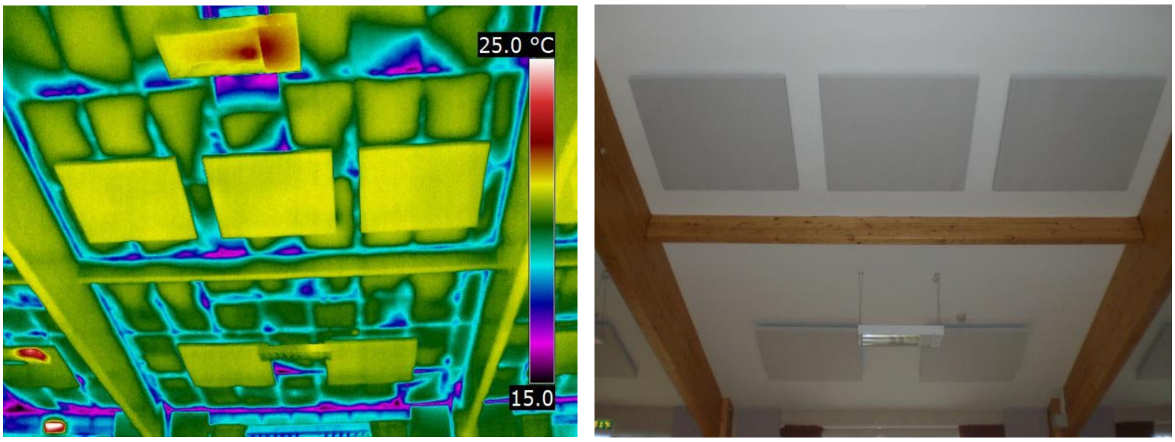
A thermographic survey was conducted on 20 February 2013 (Appendix 10.5). A series of thermograms were taken showing the various elevations of the building and for the purposes of this survey, images were primarily taken of the external walls and internal surface that exhibited any thermal anomalies.

The thermograms show a limited number of thermal anomalies. In general terms the external anomalies identified could be considered to be a result of the construction process (Figure 58). Cold areas are evident on the ceiling skim finish / plasterboard layer in all spaces (Figures 59, 60).



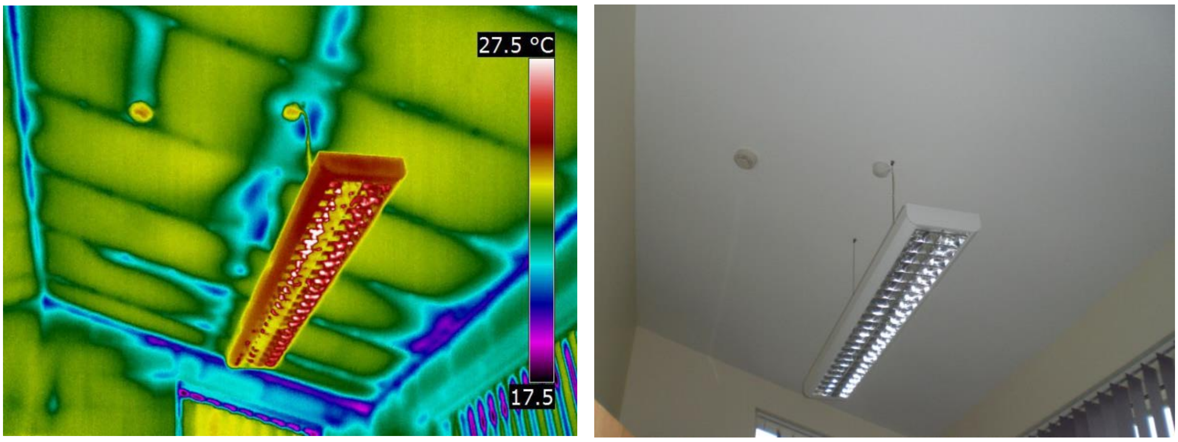
a) b)

Figure 59 (a) West pitch roof soffit thermogram. Note: Thermal abnormality is likely to be due to air leakage from the building. (b) West pitch roof soffit digital photograph.



a) b)

Figure 60 (a) Main hall ceiling (centre) thermogram. Note: Cold areas are evident on the ceiling skim finish / plasterboard layer. The cause of this is likely to be behind these construction elements from cold air leakage between the edges of the structurally insulated panels (sip's) as they are probably not well butted together. Furthermore in some areas there may also be a space between the plasterboard and the adjacent sip which is creating cold voids. Similar thermal phenomena were also found in the Parish Room and the Office ceilings. Confirmation of this may be possible if access into one of these areas can be obtained via a suitably located electrical fitting and a fiberscope. (b) Main hall ceiling (centre) digital photograph



a) b)

Figure 61 (a) Office ceiling thermograph. (as previous image). (b) Office ceiling digital photograph

7.4 Conclusions and key findings

7.4.1 Key findings from review of controls

- Usability of heating and hot water control of the GSHP is not intuitive and instructions are required to use it properly. The part time caretaker is the only one who received training on how to operate the GSHP and understands the system.
- Light switches and control panel are intuitive to use and have good labelling and annotation.
- Fire and security alarm are easily accessible and well labelled. However, management does not know how to reset the fire alarm and technicians need to be called in each time the system is set off.
- Kitchen appliances labelling is clear and use is easy and intuitive. Good indication of system response and good level of fine control.

- Bathroom taps are well labelled and easy to use. Kitchen taps are well labelled and offering good level of fine control.
- Windows and doors purpose is clear. Windows are intuitive to open and offer security.
- Top windows are very difficult to reach and operate as users have to stretch to reach the handle. Motors were added to the top windows of the Main Hall which allows users to open them by operating a switch.
- Electrical windows control interface is intuitive to use and well labelled.
- Velux windows and kitchen hatch controls that were originally installed were perceived to be complex and have already been replaced with simpler controls that are well-labelled and effective.

7.4.2 Key findings from site survey

- The occupants appear aware of their energy use and take great care in ensuring lights and electrical appliances are switched off at the socket when no one is in the room.
- The overhead projector and remote control screen in the Main Hall were left permanently switched on at the socket and there was a double socket above the screen, both of which were switched on. This is a result of the location of the sockets which are hard to reach.
- There is only one switch for all the lights of the Entrance Hall providing occupants with little control over the lighting levels of the space. This results in some energy wastage as all of the lights are turned on throughout the whole day.

7.4.3 Key findings from thermographic survey

- The thermograms show a limited number of thermal anomalies.
- The external anomalies identified could be considered to be as a result of the build process.
- The internal thermal anomaly of the roof structure however could be seen as significant due to the scale of the phenomena throughout the building.
- Physical investigation of the areas identified would be recommended to confirm the cause of the cold areas.

8 Key messages for the client, owner and occupier

8.1 Key findings

Table 12 below presents a summary of the key findings associated with the BPE study elements.

Table 12 Key findings across BPE study elements

BPE Study Elements	Findings	Key messages
Review of handover and commissioning	• Building manager excluded from design meetings and planning. • No systematic induction or training provided in the use of building equipment and systems. • No documentation, logbook or electrical circuit's drawings available. • Sub-meters not commissioned properly. • Additional sub-metering installed: 4 Hager meters, 4 Heat flux meters	• Lack of proper training, handover process and user guide results in the management not being familiar with the GSHP controls. • Lack of proper documentation, drawings and logbook creates problems in maintenance and repairs. • Lack of proper commissioning of the sub-metering arrangements delayed the collection of accurate sub-metering data.
Occupant satisfaction survey using BUS questionnaires	• The overall picture of the survey revealed a positive opinion towards the Community Centre. • Respondents feel their needs are met well and were generally positive about overall comfort. • Temperatures and air quality are generally regarded as satisfactory. • Occupants involved in light and sedentary activities are satisfied with the temperatures in the building, whereas occupants involved in more intensive activities find the spaces quite warm and prefer to open the windows to cool themselves down. Lack of parking space is considered to be a problem. • Acoustics were reported to be good.	• The occupant satisfaction survey and interviews with management showed that both users and owners are very satisfied with the building (appearance, spaces, layout) and find that it suits their needs well. • High temperatures recorded in some of the spaces during summer and comments received through the BUS questionnaires indicate that measures need to be taken to prevent overheating (external shading, night ventilation) • High temperatures recorded during winter and interviews with management indicate that tighter control of internal temperatures for different activities and spaces would help in increasing comfort levels and reducing energy consumption. Management is considering zoning the heating system.

	• Occupants, however, feel they have good control over their environment	
Operation, maintenance and management	• The building has matched the expectations of the management team and they believe it is performing well. • Maintenance contract exist for the GSHP and fire and security alarms but not for all the building operations and systems. • There is no help desk or building log book which is contrary to Part L (2006) of the Building Regulations under which the Community Centre was built.	• The low carbon strategies were not adopted at the beginning of the project, resulting in some re-engineering. This might have resulted in the lack of proper zoning of the heating system.
Analysis of actual energy performance	• Total emissions (25 $kgCO_2$ $/m^2$) are 50% better (lower) than raw CIBSE TM46 benchmark (51.1 $kgCO_2$ $/m^2$). • Grid electricity import is 49.1 $kWh/m^2/annum$ • About 19% of the total building electricity consumption was generated by the PVs. • Space heating and hot water account for 45% of the total electricity use, lighting accounts for 41% of the total, ICT equipment for 4.9% of the total and small power only for 1% of the total electricity used in the building • Annual grid equivalent electrical carbon emissions in ACC are 39% lower than 'Good practice' and 65% lower than 'Typical'. • Very strong correlation between weekly heating demand and heating degree days indicating that the GSHPs and the building are performing well. The coefficient of performance for both heat pumps was calculated at 3.68.	• Interviews with management, analysis of the actual performance and in use energy monitoring indicates that the building is performing well in terms of energy consumption. FITs payments reduce the running costs of the building.
Review of	• The controls are simple to use	• Lack of consistent design of the systems and controls that were going to be installed in the building originally, resulted in some controls not being simple and intuitive to use and having to be replaced by the management.

performance and usability of controls	and effective. Occupants and management are satisfied with them. • Velux windows and kitchen hatch originally installed controls had to be changed by the management as they were unnecessarily complicated.	
Energy wastage	• Management is very conscious at reducing equipment electricity consumption by switching off all appliances that are not being used. • Due to the very low daylight levels in the entrance hall the lights need to be switched on at all times increasing electricity consumption.	• Natural daylight in the Entrance Hall was not part of the brief during the design stage, resulting in problematic lighting of the space and high electricity consumption.
Thermal imaging	• Cold areas identified on the ceiling skim finish / plasterboard layer.	

8.2 Suggestions for improvement

Good standards of design, generous spaces, quality of lighting and acoustics are appreciated by the users, as reflected in the positive image perceived of the community centre and the fact that the centre meets its user's needs well. Clearly these aspects need to be maintained or even improved upon, for future civic buildings. However, other areas could be improved.

Suggestions for improvement are categorised as no, low, medium and high costs measures. Some of the strategies are included as reference for future projects. The study has shown that extra costs for remedial works and corrections could have been avoided if some of the strategies had been implemented from the beginning.

8.2.1 No cost measures

- Ensure a successful transition from design to in-use, in future projects:
  - Better briefing (more in-depth and contextual to end user)
  - More integrated consultation from the briefing period through to the construction phase
  - 'Keeping things simple' was key to ensuring end-users can understand the building, its controls and subsequently their interactions with it.
  - Clear definition of responsibilities and roles of people involved to reduce potential personality conflicts and create more cohesive framework for the project.
- Lack of proper documentation (for example 'as built' electrical installation drawings) creates problems in maintenance and repairs. It is strongly recommended that the building management is provided with detailed electrical installation drawings from the project managers (Hansom). This has also been raised with the building owner (Angmering Parish Council).
- There is no help desk or building log book available, which is contrary to Part L (2006) of the Building Regulations under which the Community Centre was built. These should be provided by the project manager/builder.

- Make more use of the passive ventilation strategies provided. Consider night time ventilation during summer. This will make the spaces more comfortable and possibly, eliminate the perceived need for having air-conditioning.
- Heat pump controls are not intuitive to use. It is recommended an easy to use manual is provided which enables the building management team to operate the heat pump effectively.
- Some of the controls (Velux windows, Kitchen hatch) originally installed in the building were complicated to use and the building management had to change them for more user-friendly ones. It is recommended that in all public buildings, controls specified in the design phase are clear and intuitive to use. Users should be given the opportunity to control their local environment but without being able to change basic settings. Care should be taken so that the management has the overall control of the building, without the users overriding it.
- The external lighting and light fitting specifications should be reviewed at the design phase so that the lights installed are more robust against vandalism.
- The Community Centre could benefit from more frequent bus connections and less people would have to use their cars to get to the Centre. Walking and cycling to, and from, the Community Centre should be encouraged by the building management. This will also reduce the need to increase parking spaces.

8.2.2 Low cost measures

- Lack of an adequate (concise, graphic and easy-to-understand) user guide has led to issues with the use, operation and maintenance of the energy systems by the building management. Design teams should ensure that a user guide for public buildings is made available just before handover.
- The BPE study helped to reveal and re-commission the three sub-meters (which were recording negative values) for an extra cost. For effective energy management of low energy buildings, it is vital that adequate commissioning checks of sub-meters and energy systems are made mandatory especially for public buildings where budgets for re-commissioning are minimal.
- External lighting design needs to be reviewed as it is inadequate in the rear of the building. An external PIR detector linked to external light would be useful for protecting the rear windows from vandalism without excessive energy use.
- PIR sensors could be installed in the main hall and meeting rooms to improve energy savings. PIR sensors also need to be installed in the disabled toilet.
- The awareness of hirers/users on energy consumption was reported to be good. Easy-to-understand information leaflets and tours of the building systems could help new users get engaged further with energy management and energy reduction.

8.2.3 Medium cost measures

- The Centre accommodates various activities and needs to provide the users with enough adaptive opportunities to make themselves comfortable. Ceiling fans in the Main Hall could be used during more intensive activities to increase air movement in the space and make occupants more comfortable without compromising the temperatures in the space for other uses.
- Consider adding external solar shading to the south facing facades which includes the meeting room and the Main Hall, to prevent any overheating.
- Design interventions are necessary to provide natural daylight and fresh air in the Entrance Hall which is currently not daylit. This could be achieved by retrofitting sun pipes with some capital investment.
- Consider the addition of sound absorbers in the communal meeting area to prevent noise from being transmitted to the meeting rooms and Main Hall.

8.2.4 High cost measures

- It is recommended that the heating system is fully zoned and that the management team is able to control the individual room temperatures based on the activities taking place in that space. The caretaker or administrator should be in charge of controlling the room thermostats.

9 Wider lessons

The BPE study of a civic building such as Angmering Community Centre has provided important lessons for the industry, clients, developers, building operators and the supply chain. The BPE study has revealed several issues regarding commissioning, handover and logbooks, management and maintenance.

The BPE study of Angmering Community Centre has helped to widen the understanding of real energy consumption in community buildings. The study has helped to generally raise awareness of energy performance of buildings and the impact of a good energy champion. It has discovered the lack of metering associated with heat pumps, subsequently installed input/outputs meters and verified the performance of these systems. All this has added to the capabilities of the building management team, and helped to fine-tune the building performance; an initial aim of the BPE study.

Wider lessons learnt from the study are as follows:

- Documentation of design intent and 'as built' information should be enforced for effective management of the building during operation phase. Commissioning records of services and systems should be used to check the performance of heating and ventilation systems.
- Ensure technicians are knowledgeable about the process and documentation is thorough and complete.
- Sub-metering arrangements should be carefully designed (according to end use and zones); installed as designed; commissioned; calibrated and reconciled.
- Ensure there is reconciliation of outputs from meters and sub-meters after handover to correct problems quickly.
- Communication and involvement of all parties involved in the design and construction process (including building owner, operator and suppliers) through all stages is essential.
- As much as possible, involve the FM team right from the inception and briefing stage of a building project so that expectations can be managed and appropriate services and systems can be designed and specified for a particular building type.
- Soft Landings based approach is highly recommended to ensure that design teams remain engaged with the project post-handover and during the in-use stages.
- Tried and tested low/zero carbon technologies should be specified, with an understanding of their maintenance regimes, operation and control.
- Joints, junctions and thresholds should be carefully designed and constructed to avoid 'weak links' in the building fabric.
- Weaknesses in thermal performance of building fabric can be identified using a combination of thermal imaging and air-tightness testing especially for early detection of problems. There is also

a growing recognition in the industry to develop shared resource of robust construction details for different types of building systems.

- Aftercare matters in delivering good performance. Maintenance regime of heating and ventilation system should be clarified at the installation and commissioning stage so that the perception of 'fit and forget' does not exist. If necessary, maintenance (service) contracts should be set up for unfamiliar low carbon systems such as GSHPs and PV panels.

- Accurate 'as-built' models (required under Building Regulations) should become mandatory and enforced rigorously. This could ensure that SAP/SBEM worksheets and drawings are updated to record design and/or procurement changes that could affect energy use.

- Design teams should ensure that easy-to-understand user guides for public buildings are made available just before handover operation for management teams and occupants, offering clear guidance on the daily and seasonal operation of systems and controls.

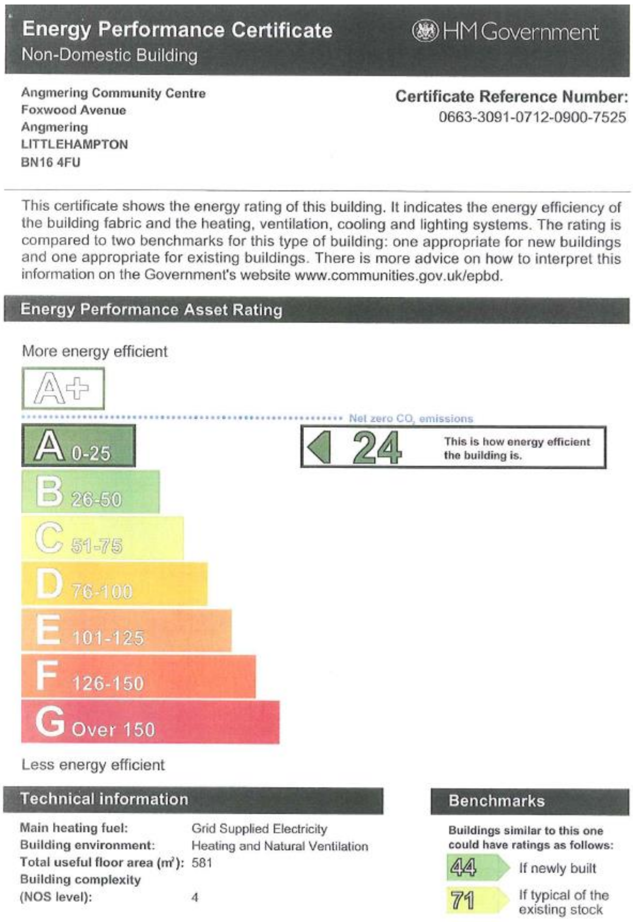
- Occupants and FM team of the buildings also need to be trained through graduated and extended handover which involves FM team and users trying out systems and controls in the presence of architects and specialist contractors (of BMS, low carbon technologies).

- Balance between automation and occupant control is needed. Control interfaces need to be intuitive, labelled and properly designed, and installed in an accessible location that encourages occupants to interact with their environment in an adaptive and positive manner.

- BPE studies not only help in understanding the reasons behind the energy performance gap, but also uncover faults with services and systems, that would otherwise go unnoticed and transform into bigger issues at a later stage requiring expensive and possibly disruptive remedial works.

10 Appendices

10.1 Energy Performance Certificate



Energy Performance Certificate
Non-Domestic Building
HM Government

Angmering Community Centre
Foxwood Avenue
Angmering
LITTLEHAMPTON
BN16 4FU

Certificate Reference Number:
0663-3091-0712-0900-7525

This certificate shows the energy rating of this building. It indicates the energy efficiency of the building fabric and the heating, ventilation, cooling and lighting systems. The rating is compared to two benchmarks for this type of building: one appropriate for new buildings and one appropriate for existing buildings. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Asset Rating

More energy efficient

A+

Net zero CO_2 emissions

A 0-25
B 26-50
C 51-75
D 76-100
E 101-125
F 126-150
G Over 150

24 This is how energy efficient the building is.

Less energy efficient

Technical information

Main heating fuel:	Grid Supplied Electricity
Building environment:	Heating and Natural Ventilation
Total useful floor area (m^2):	581
Building complexity (NOS level):	4

Benchmarks

Buildings similar to this one could have ratings as follows:

44 If newly built
71 If typical of the existing stock

10.2 Air tightness test

DRAFT

AIR TIGHTNESS TESTING RESULTS

ob No: 25362A

Project Name: ANGMERING COMMUNITY CENTRE

Location: ANGMERING

Test Date: 22 SEPT 09

Based upon information available at the time of testing

Target of: 10 $m^3h^{-1}m^{-2}$ at 50 Pa Permeability / Leakage

The building achieved 5.77 $m^3h^{-1}m^{-2}$ at 50 Pa Permeability / Leakage

The envelope area used were 1581.9 m2

A full report will be issued on completion of our Quality Assurance programme and verification of the Areas used. The Report will be emailed in PDF format, additional Hard Copies are available on request.

Test Engineer ....
Signed

Test Engineer K BERCHER
Print

Dated: 22 SEPT 09

10.3 BUS transient questionnaire

Building Evaluation

The results from this survey will be used to help improve the design and planning of future buildings. All information will be treated as confidential by the indepenedent survey team. Survey reports will use summaries of information and not reveal the identities of individuals.

Please fill in as many questions as you can. Write any further comments in the spaces provided or on a separate sheet.
Thank you for your help

Queries:
If you have any queries please contact Rajat Gupta:
e-mail: rgupta@brookes.ac.uk

Background

Is this your first visit to this building? *Please tick* Yes [1] [2] No

If you have visited before, how often do you visit this building? *Please tick*
Frequently (More than once a week) [1] [2] Quite Frequently (At least once in two weeks)
Less Frequently [3] [4] Other (Please comment)

How long is a typical visit to this building? *Hours per visit*

Comments

Other Please tell us about any other aspects of this building you like or dislike.

Comments

The building overall

Building design All things considered, how do you rate the building design *Please tick*
Unsatisfactory [1] [2] [3] [4] [5] [6] [7] Satisfactory → *Comments about design*

Needs Overall, do the facilities meet your needs? *Please tick*
Unsatisfactory [1] [2] [3] [4] [5] [6] [7] Satisfactory → *Comments about needs*

Image How do you rate the image that the building presents as a whole? *Please tick*
Poor [1] [2] [3] [4] [5] [6] [7] Good → *Comments about image*

Comfort This section asks how comfortable you find the building.
How would you describe typical conditions in the building?

Temperature *Please tick each scale*
Uncomfortable [1] [2] [3] [4] [5] [6] [7] Comfortable
Too hot [1] [2] [3] [4] [5] [6] [7] Too cold → *Comments about temperature*

Air *Please tick*
Unsatisfactory overall [1] [2] [3] [4] [5] [6] [7] Satisfactory overall → *Comments about air*

Overall comfort All things considered, how do you rate the overall comfort of the building environment? *Please tick*
Unsatisfactory [1] [2] [3] [4] [5] [6] [7] Satisfactory → *Comments about comfort*

Noise How would you describe noise in the building? *Please tick*
Noise overall Unsatisfactory [1] [2] [3] [4] [5] [6] [7] Satisfactory → *Comments about noise and its sources*

Lighting How would you describe the quality of the lighting in the building? *Please tick your rating on each scale*
Lighting overall Unsatisfactory [1] [2] [3] [4] [5] [6] [7] Satisfactory → *Comments about lighting*

Health Do you feel less or more healthy when you are in the building? *Please tick*
Less healthy [1] [2] [3] [4] [5] [6] [7] More healthy → *Comments about health*

Productivity Please estimate how you think your productivity is increased or decreased by the environmental conditions in the building? → *Comments about productivity*

By 'environmental conditions' we mean the combined effect of the previous topics covered in the questionnaire e.g. temperature, noise etc. taken as a whole.

Please tick one point on the scale

Productivity Decreased by ...	- 40% or less	-30%	-20%	-10%	0	+10%	+20%	+30%	+40% or more	Productivity Increased by ...
	1	2	3	4	5	6	7	8	9	

Travel to the building

Please estimate your journey times ...

Journey to building		Time Hours : minutes	Journey home		Time Hours : minutes
Best case	Journey to building		Best case	Journey home	
Normal	Journey to building		Normal	Journey home	
Worst case	Journey to building		Worst case	Journey home	

Post or zip code What is your home post or zip code (or the place where you normally start and end your journey if not home) ...? *Postcode*

Mode of travel

For your *journey to the building only*, how do you normally travel...?

	Please tick those which apply	*Main mode Please tick one*
Walk	1	1
Cycle	1	2
Bus	1	1
Train	1	1
Car (as driver)	1	1
Car (lift or car share passenger)	1	1
Motor cycle (solo)	1	1
Motor cycle (as passenger)	1	1
Tram / Trolleybus	1	1
Ferry	1	1
Other (please specify)	1	1

← *Main mode means the journey mode by which you travel the longest distance.*

Please specify if Other

Have you any comments or observations on your journeys to the building and home...? *Comments on journeys to and from the building*

10.4 Spot checks and recording measurements

The Spot checks activity took place during a weekday in early May (03.05.2012)consisting of temperature (ºC), relative humidity (%), illuminance (lux) and noise levels (dB) spot measurements. In each area the spot checks were taken close to the position of the existing monitoring equipment. Table 13 gives general guidance and recommendations according to CIBSE Environmental Design Guide A on suitable winter and summer temperature ranges (together with maintained illuminance and noise ratings) for a range of room types in multi-purpose halls and office buildings to be used as a reference to the following study.

Table 13 Recommended comfort criteria for specific applications. Source: CIBSE Guide A, 2009

Building/ Room type	Winter operative temperature range (°C)	Summer operative temperature range (°C)	Maintained illuminance (lux)	Noise ratings (dB)
Multi-purpose halls			300	
Offices:				
Executive	21-23	22-24	300-500	30
General	21-23	22-24	300-500	35
Open-plan	21-23	22-24	300-500	35

10.4.1 Temperature

There is no statutory limit to the upper temperature in multipurpose halls. The Workplace (Health, Safety and Welfare) Regulations 1992 (Statutory Instrument 1992 No, 3004) require only that: 'During working hours, the temperature in all workplaces inside a building shall be reasonable.' Section 1 (Environmental criteria for design) of CIBSE Guide A: Environmental design, suggests for offices that the temperature range for comfort should be 21-23ºC in winter and 22-24 ºC in summer. The latter range applies to air conditioned buildings. Higher temperatures may be acceptable in non- conditioned buildings air.

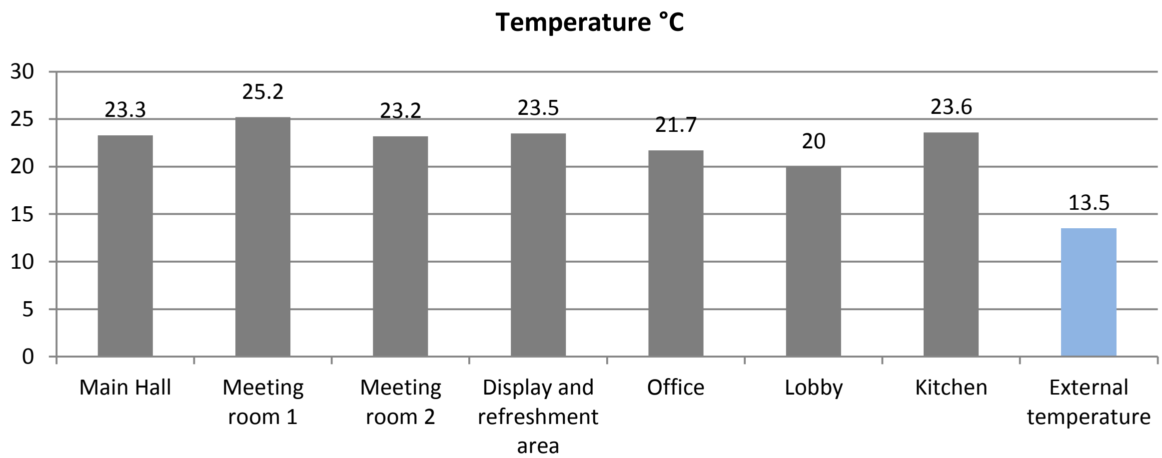


Figure 62 Temperature values in various spaces of the community centre during the spot check

Key Findings
The majority of the spaces were found to have a temperature within the comfort range of 22-24 ºC while the external temperature was 13.5 degrees.
It was noticed that in the meeting room 1 the temperature slightly exceeded the 25 ºC possibly because of the solar gains and the fact that the room was occupied before the measurement was taken. The combination of the high daylight factor, temperature and low RH values indicate that the room has lots of thermal gains due to its south orientation and number of openings. The proper use of blinds and the opening of windows is important to avoid overheating and air dryness.

10.4.2 Relative Humidity (RH%)

Humidity in the range 40–70 % RH is generally acceptable (CIBSE, 2009). If possible, at the design temperatures normally appropriate to sedentary occupancy, the room humidity should be above 40% RH. Lower humidity is often acceptable for short periods. Humidity of 30% RH or below may be acceptable but precautions should be taken to limit the generation of dust and airborne irritants and to prevent static discharge from occupants.

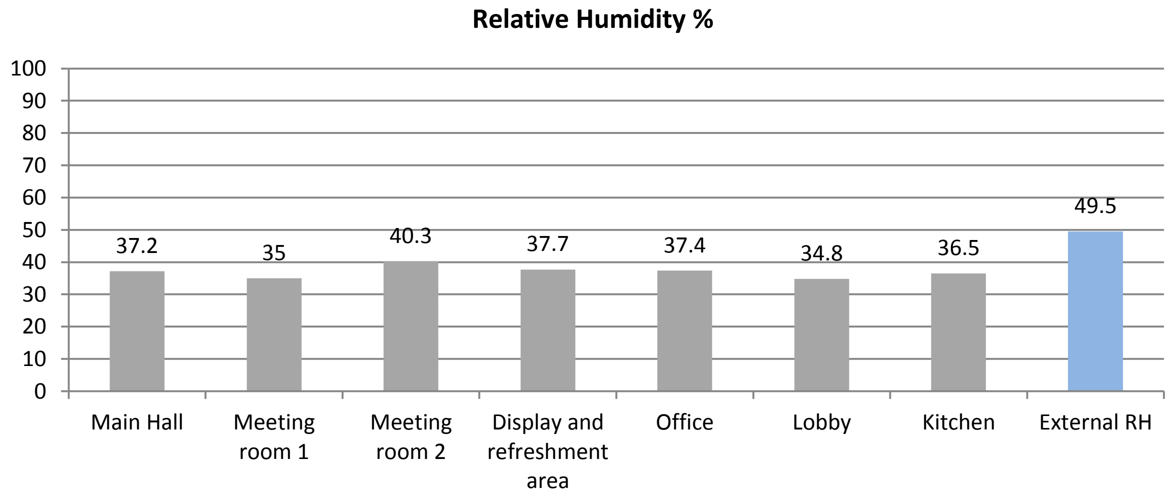


Figure 63 Relative humidity values in various spaces of the community centre during the first spot check visit.

Key Findings
Humidity levels for most of the spaces were fluctuating between 35 % and 40.3 % slightly below the external rate that was 49.5%. The range is considered slightly low and periodic natural ventilation is recommended.
The lowest value was detected on the meeting room 1 where it had a value of 35% in comparison with the 40.3 % of the meeting room 2 possibly due the fact that the space was occupied before the measurement was taken and not properly ventilated afterwards.

10.4.3 Daylight survey

During the visit, the day remained overcast and the outdoor light levels varied between 20,000 lux at 12:00 to 10,000 lux at 14:00. Most rooms were not in use except from the meeting room 1 and the office, artificial lights were switched off and blinds were open.

The lux levels were measured based on a grid of 2x2 m for three key spaces, the main hall and the two meeting rooms. Daylight factor is the ratio, in percentage, of a work plane illuminance (at a given

point) to the outdoor illuminance on a horizontal plane evaluated under cloudy sky conditions only (no direct solar beam).
The daylight factor is defined as: DF= (Ei/Eo) x 100%
Ei = illuminance due to daylight at a point on the indoor's working plane
Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky

Table 14 Analysis of Daylight Factor (DF) levels (DETR, 1998).

DF<2%	2%<DF<5%	DF≥5%
– room looks gloomy under daylight alone – full electric lighting often needed during daytime – electric lighting dominates daytime appearance	– windows give a predominantly daylit appearance but supplementary electric lighting needed – usually the optimum range of daylighting	– the room is strongly daylit – daytime electric lighting rarely needed – major thermal problems from large windows'

The CIBSE Code for Lighting recommends a maintained illuminance of 500 lux for library reading rooms and general offices (e.g. writing, typing, reading, data processing, etc.) and for work stations and conference/meetings rooms. Where the main task is less demanding, e.g. filing, lending and reference areas a lower level of 300 lux is recommended.

Figure 64 Daylight factor analysis of the building's main spaces.

In general, the lighting levels within all the three spaces were found to be adequate but supplementary artificial lighting is needed depending on the nature of the activity undertaken within the space (meeting, sport activity, etc.). Meeting room 1 was found strongly daylit while the main hall and the meeting room 2 had parts were the light levels were particularly low. Wide variations in light levels between the areas closest to windows and the interior areas in the same room were observed. Although some areas do not need the artificial lighting, members of staff mentioned that the building users express a feeling of gloom when the artificial lights are turned off.

Key Findings
Meeting room 1 was the found to be strongly daylit having the higher and most consistent lighting levels reaching a DF of 10%. The main hall was adequately light on its southern side with some darker areas identified in the middle and eastern side of the room indicating the need of artificial lighting if uniform lighting levels were to be achieved. The meeting room 2 had a daylight factor between 2 and 8 % suggesting the need of artificial lighting if higher lighting levels are required by the activity that is taking place in the room.

10.1 Analysis of the actual performance (January 2011 – February 2012)

Total annual electricity consumption in Angmering Community Centre in 2011 is 31,635 kWh while grid electricity use is 25,558 kWh (January-December 2011). Total PV generation is 10,735 kWh and electricity exported is 4,658 kWh (January-December 2011). Electricity consumption peaks during winter months (5767 kWh in February 2012), which is expected since the Ground Source Heat Pumps are also at their peak capacity. The consumption rate gradually falls towards the summer. Interestingly there is a significant dip in electricity consumption in August which is due to a reduction in usage and occupancy (Figure 64). Electricity demand is higher during the day. High electricity consumption during the night hours during the winter period indicates that the heating is left on even during the night when the building is unoccupied. After a discussion with the building manager we were informed that during the winter the heating is left on constantly, including night hours and when the building is not occupied, and that the thermostat is always set at 19^{o}C. Intermittent heating had been tested in the past but is not a viable solution for this building due to the slow responsiveness of the underfloor heating system. Further attempts to reduce the temperature setting of the thermostat at 18oC were also unsuccessful as the occupants complained of the building being 'too cold', especially when engaged in sedentary activities.

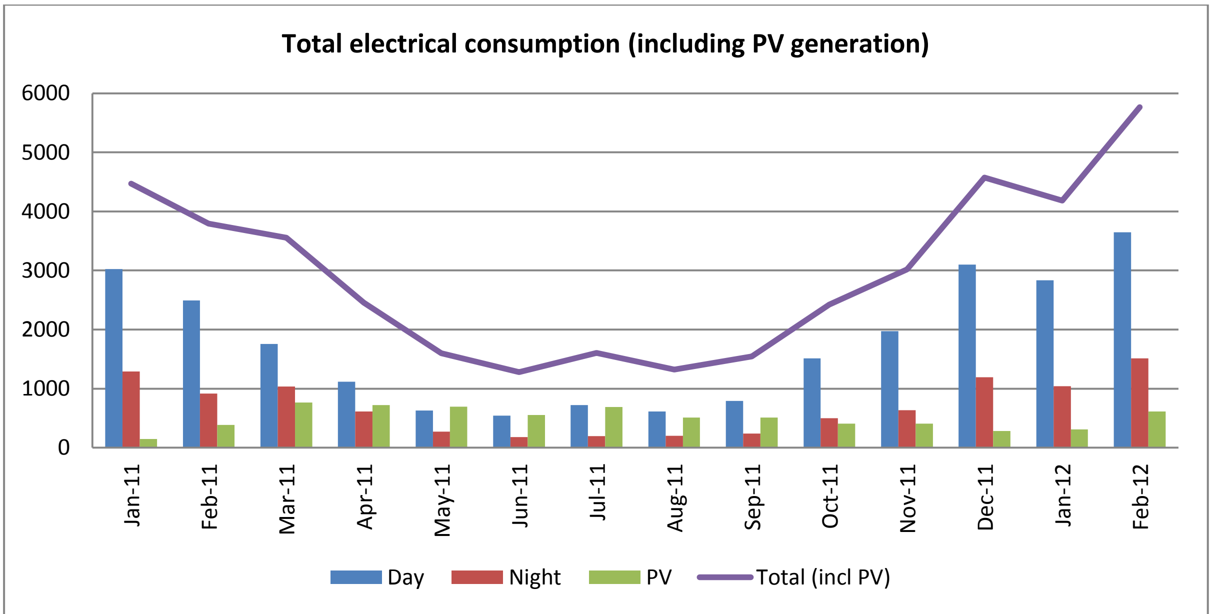


Figure 65 Total electricity consumption (kWh) for the period between January 2011 and February 2012. It includes the monthly total electricity consumption, including the electricity used that was produced by the solar PV panels. Generation tariff 0.314 p/kWh, export tariff 0.03 p/kWh.

The cost follows the consumption trend and peaks during winter months with its highest value being £490.65 in February 2012 (Figure 65).

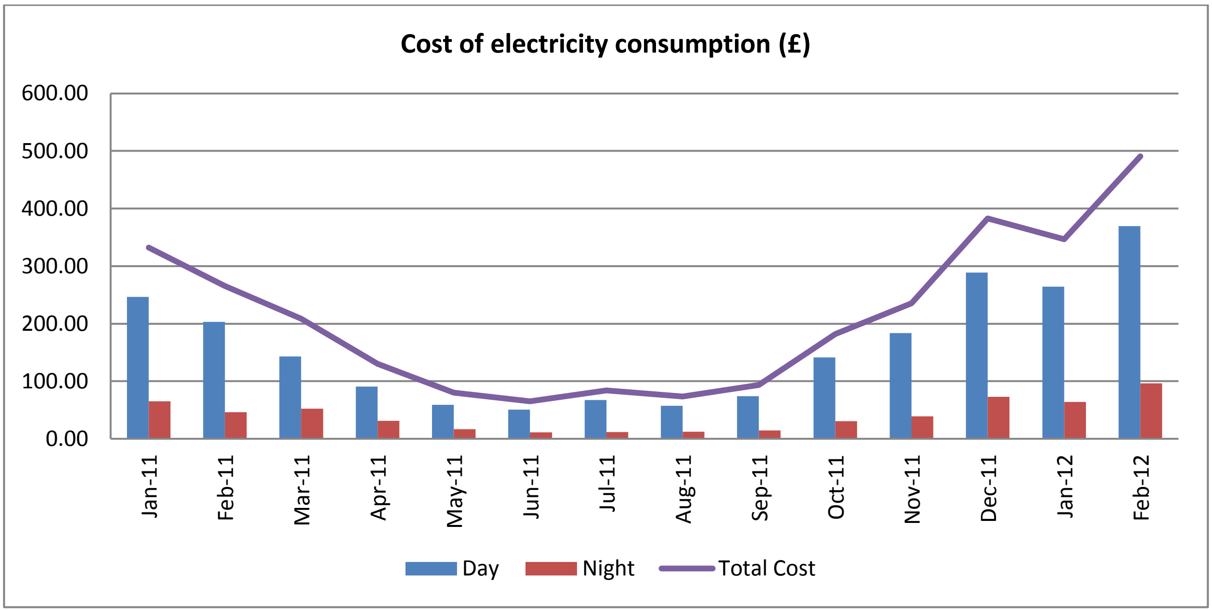


Figure 66 Total electricity cost (£) for the period between January 2011 and February 2012.

PV electricity generation peaks during July reaching 1600 kWh. The PV electricity export to the grid during this month reaches 900kWh. The lowest values of PV generation are recorded during the winter months reaching 20kWh during January and December (Figure 66). The data shows that during the winter or 'cooler' months, the PV generated electricity is used within the building, rather than being exported to the grid. This is due to the lower electricity generation figures during winter months. This is unlike the months from April to September, where the consumption and export rates are almost equal. Low export rates during winter indicate that the PV generated electricity matches the electricity profile of the building.

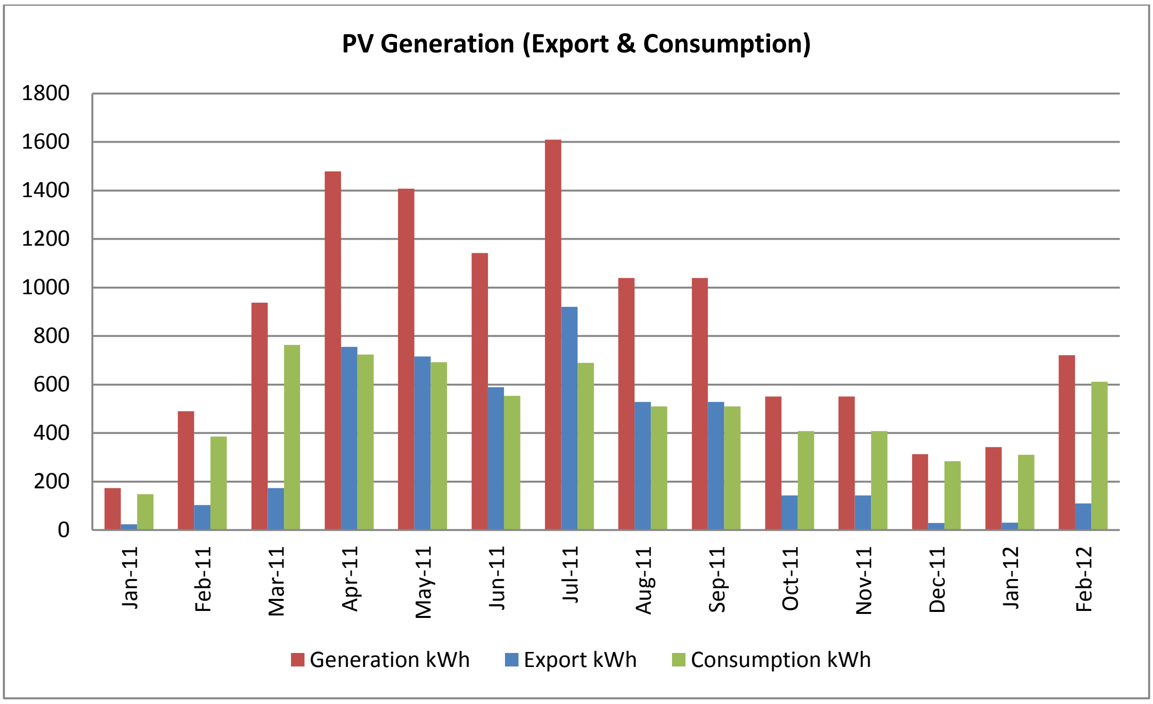


Figure 67 PV electricity generation, consumption and export values for the period between January 2011 and February 2012.

Figure 67 shows there is a very strong correlation between weekly heating demand and heating degree days. The weekly energy consumption of heating fuel increases along with the heating degree days but remains low when no heating is required following the heating degree days, indicating that the GSHPs and the building are performing well.

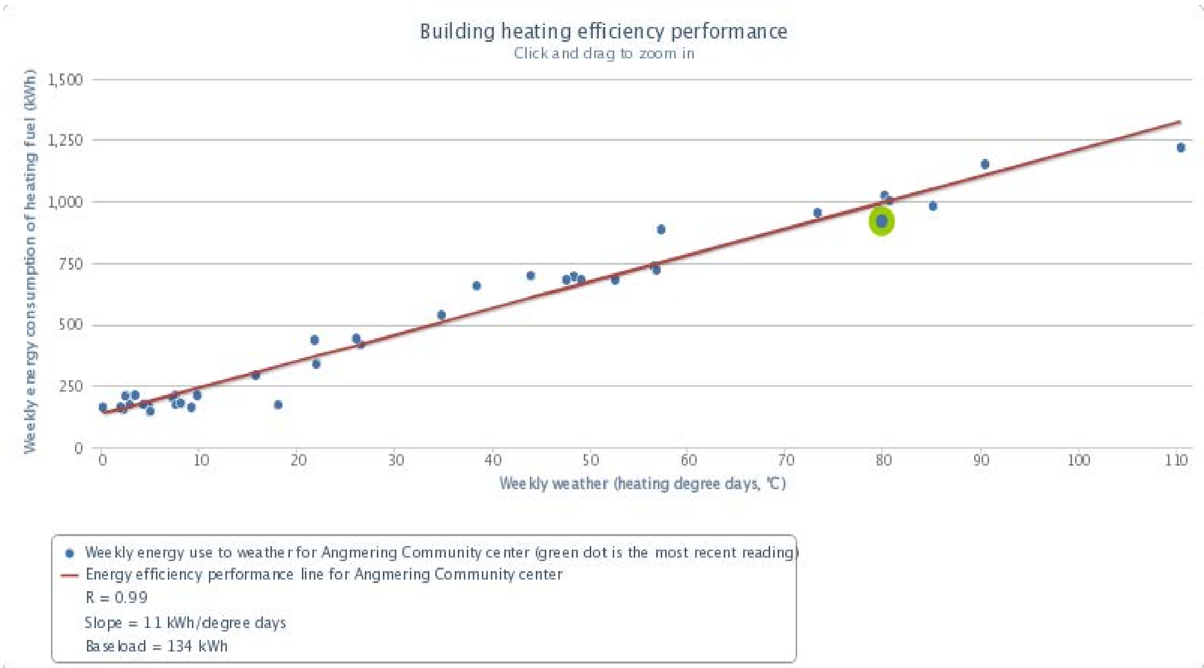


Figure 68 Building heating efficiency performance

10.2 Installation of monitoring equipment

The monitoring equipment was installed by BSRIA in August 2011. Its main purpose was to monitor the environmental conditions in several building spaces providing 5 minute Temperature, Relative Humidity and CO_2 data through dataloggers.
All the data are collected and transmitted via a wireless data-hub to an online database in the form of CSV files and are accessible through the following link **http://obu.global-net.eu**
The spaces being monitored are the Main Hall, the Entrance Hall and the Parish room. The external temperature and relative humidity are also being monitored. The main hub is placed in the Plant room.

Table 15: Monitoring equipment

Monitoring Equipment Description	Quantity	Project activity
Internal temperature/humidity wireless transmitters	3	Monitoring of internal environmental conditions
External temperature/humidity transmitter	1	Monitoring of external environmental conditions
Internal CO_2 transmitter (powered via PSU/3 pin 230V socket)	3	
Wi5 Data hub GPRS (WiFi) enabled for collection of 5 minute data and	1	Data acquisition

Figure 69: Left: The Wi5 data hub, the Internal Temperature/Humidity and CO_2 transmitters and the external temperature/humidity transmitter. Right: The data hub is placed is the plant room.

1 Main Hall
2 Display and refreshment area
3 Kitchen
4 Activities room 1
5 Activities room 2

Monitored space
Sensor position (Internal Temp, RH)
Sensor position (CO2)
External Temp/RH transmitter position
Data collection Hub

Figure 70 Location of monitoring equipment on plan

Figure 71: Temperature, humidity and CO_2 transmitters placed in key areas of the building.

10.3 Environmental conditions

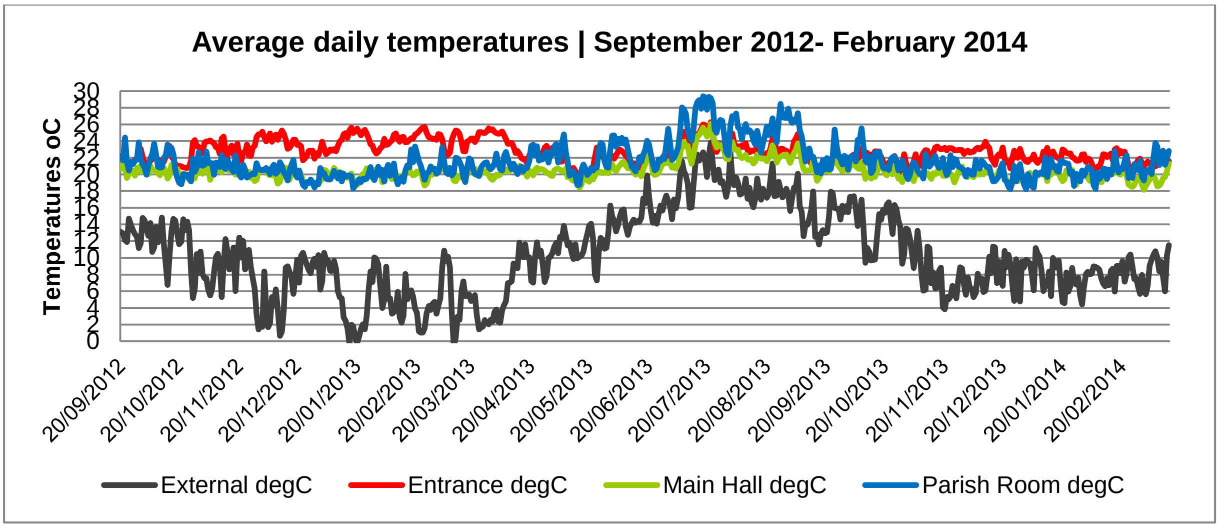


Figure 72 Average daily temperatures (September 2012 – February 2014)

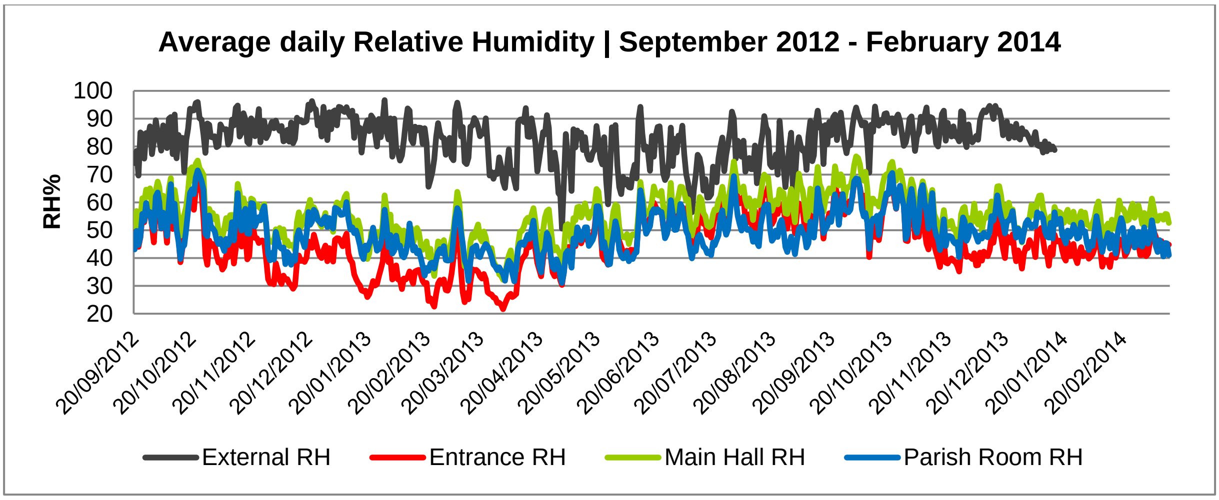


Figure 73 Average daily relative humidity (September 2012 – February 2014)

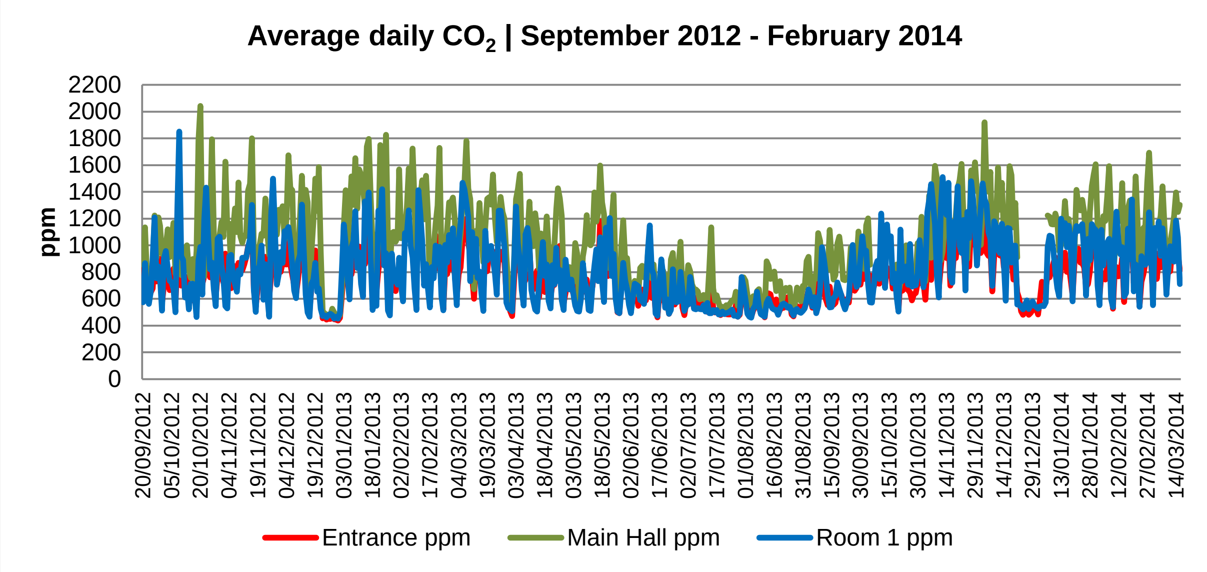


Figure 74 Average daily CO_2 (September 2012 – February 2014)

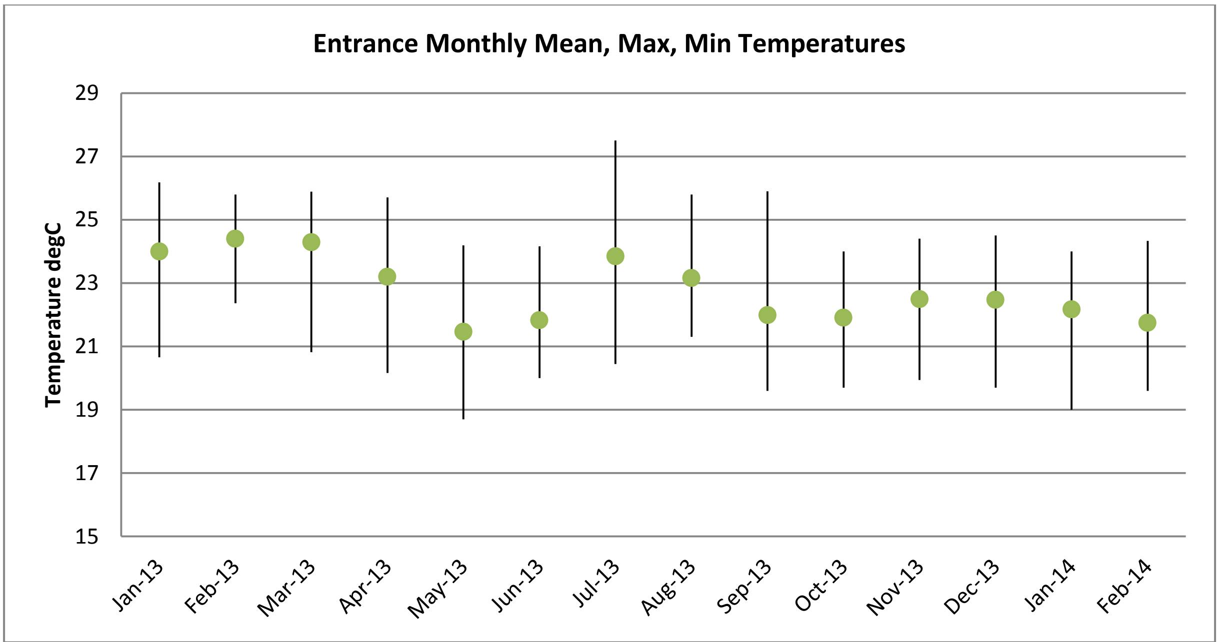


Figure 75 Entrance Hall: monthly mean, max, min temperatures

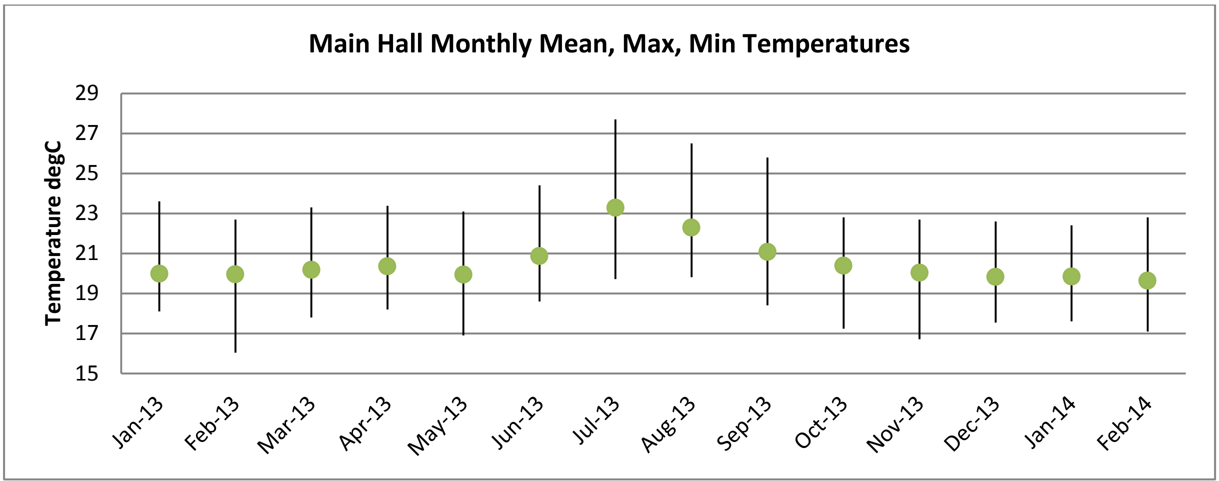


Figure 76 Main Hall: monthly mean, max, min temperatures

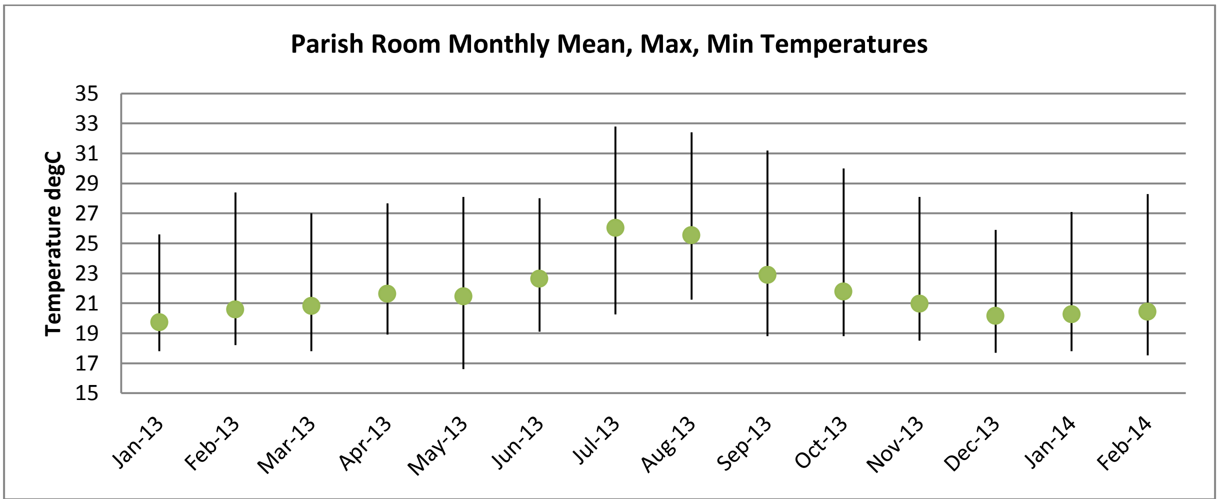


Figure 77 Parish room: monthly mean, max, min temperatures

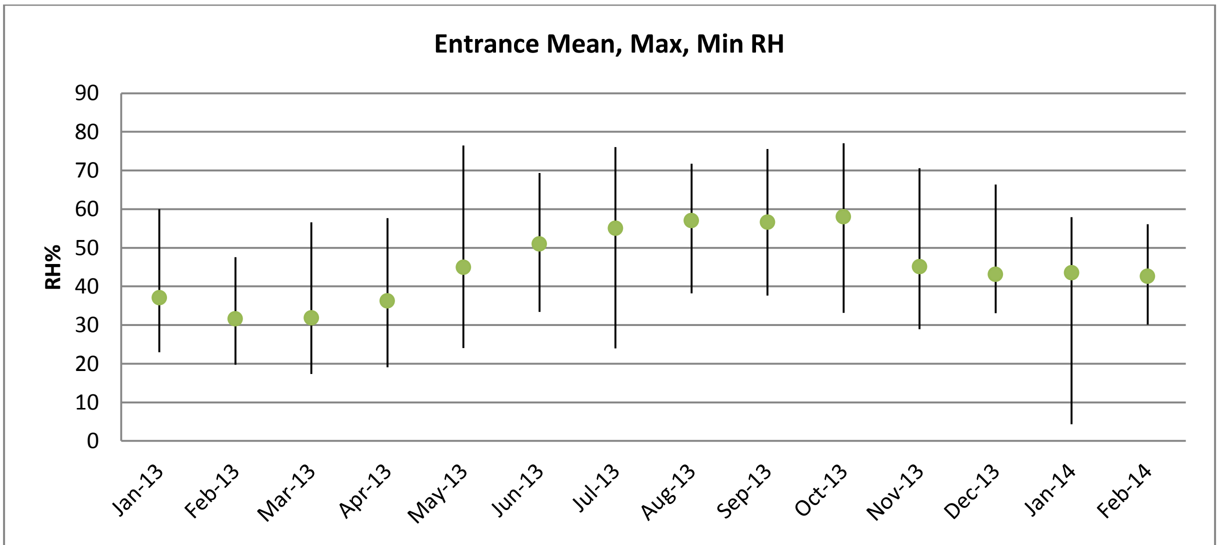


Figure 78 Entrance Hall: monthly mean, max, min relative humidity

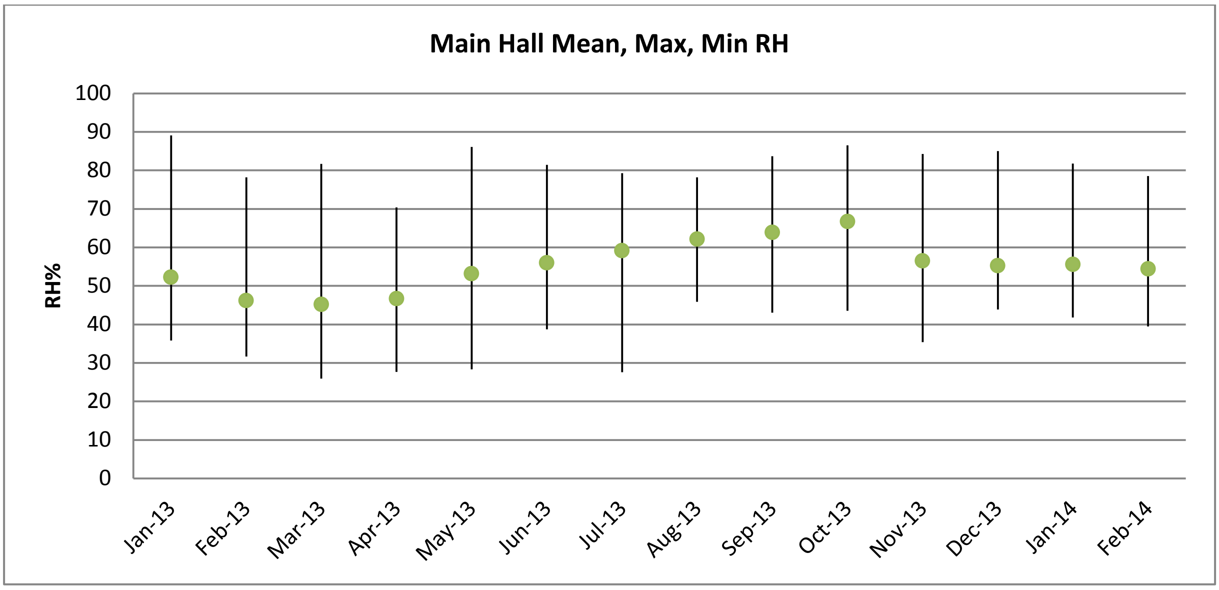


Figure 79 Main Hall: monthly mean, max, min relative humidity

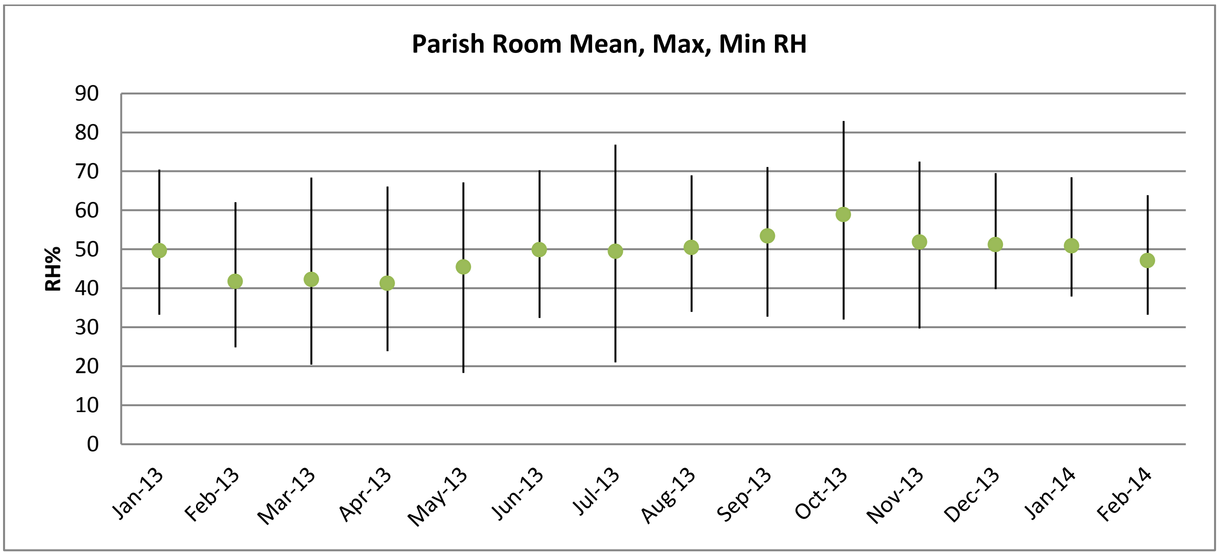


Figure 80 Parish room: monthly mean, max, min relative humidity

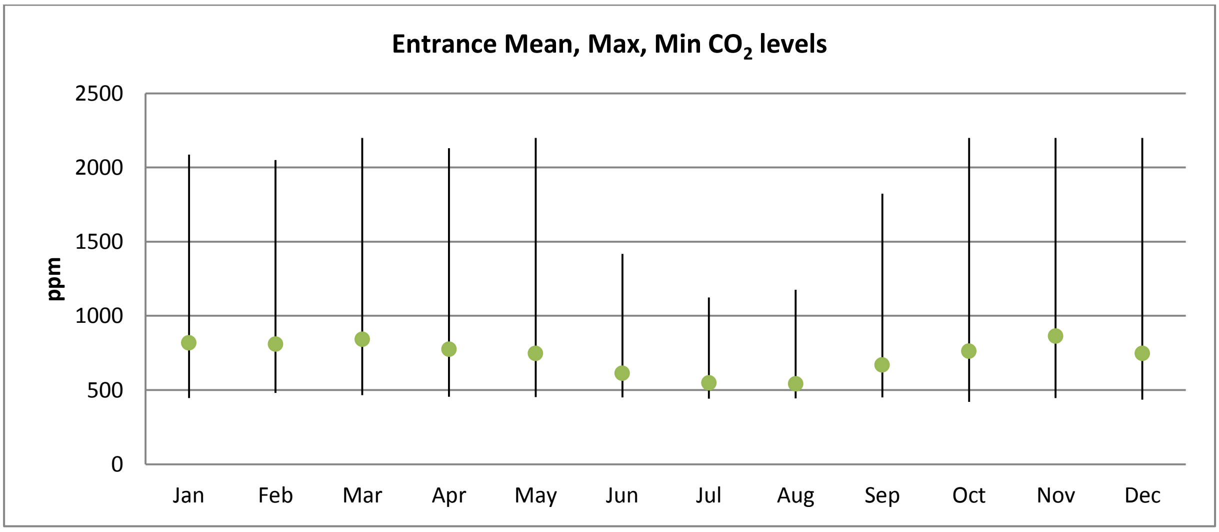


Figure 81 Entrance Hall: Monthly mean, max, min CO_2 levels

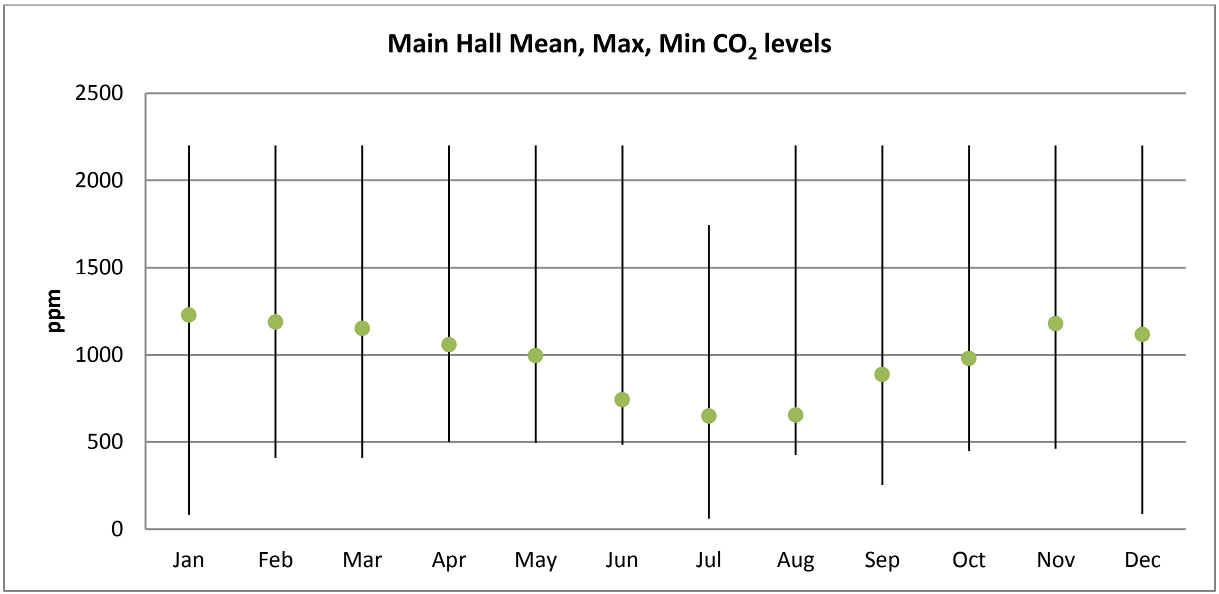


Figure 82 Main Hall: Monthly mean, max, min CO_2 levels

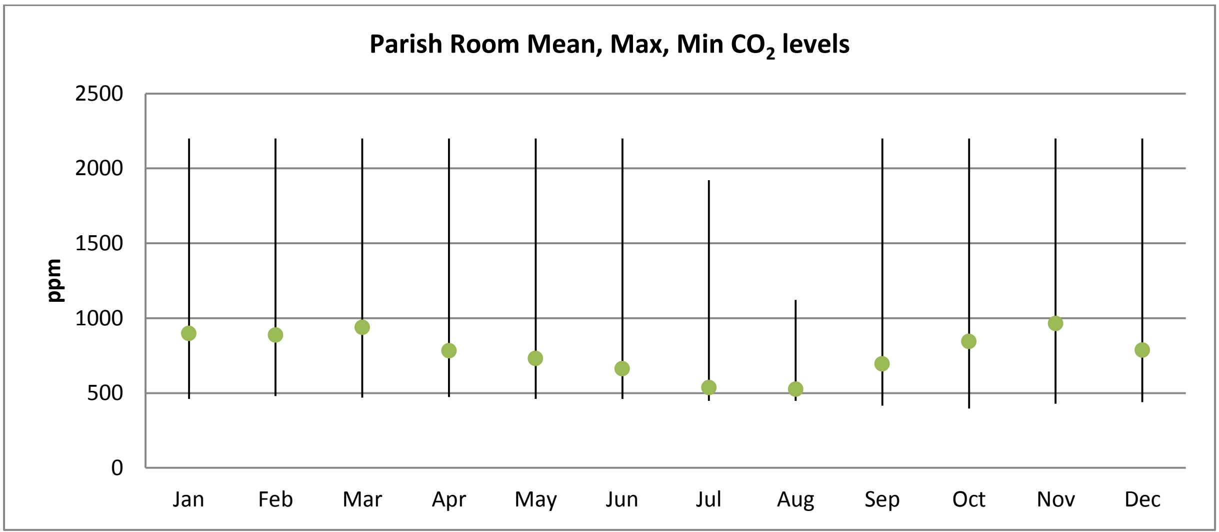


Figure 83 Parish room: Monthly mean, max, min CO_2 levels

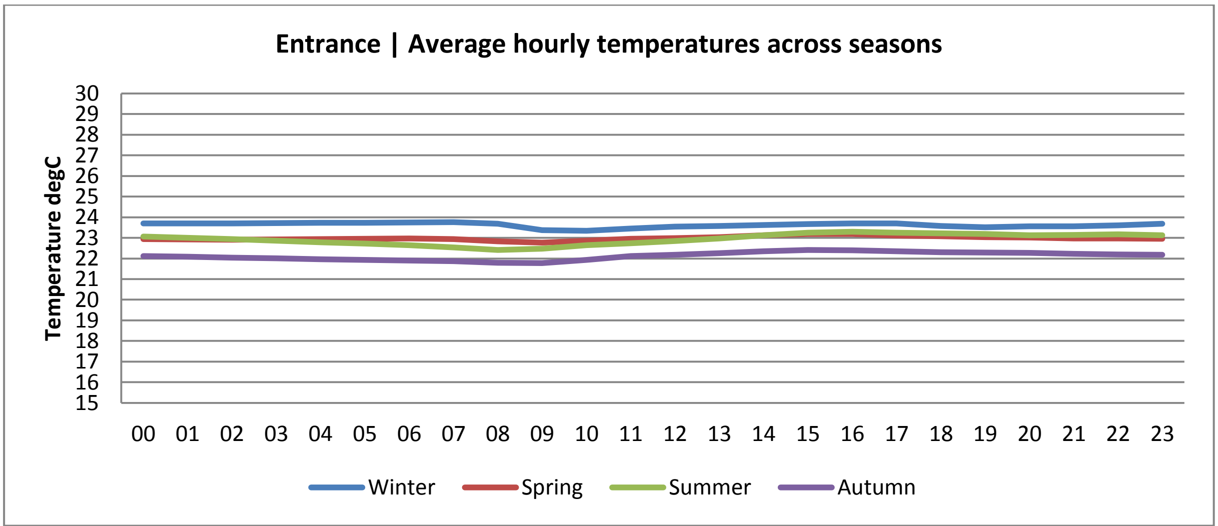


Figure 84 Entrance Hall: average hourly temperatures across seasons

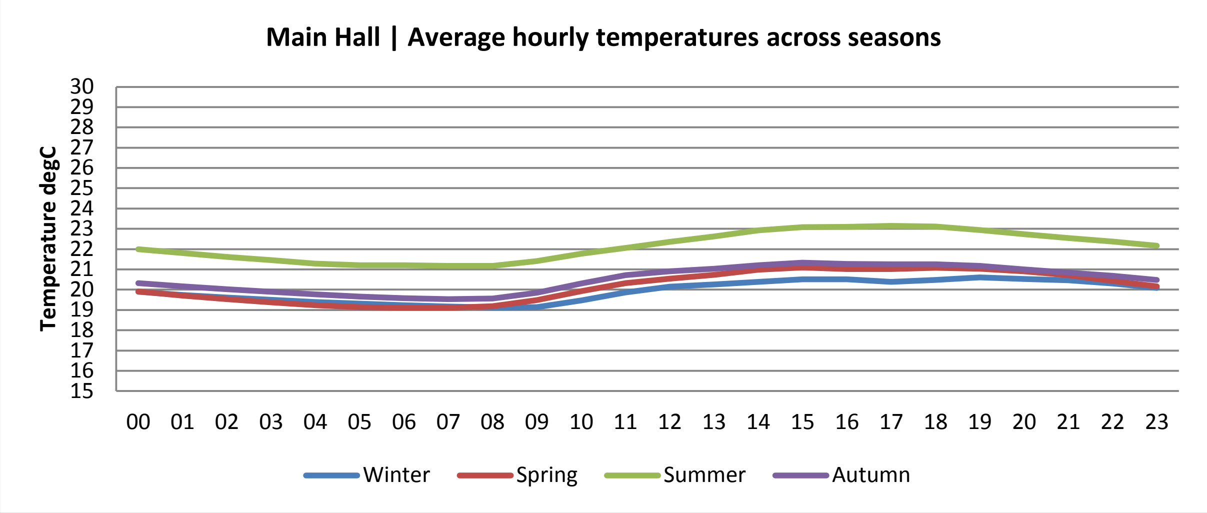


Figure 85 Main Hall: average hourly temperatures across seasons

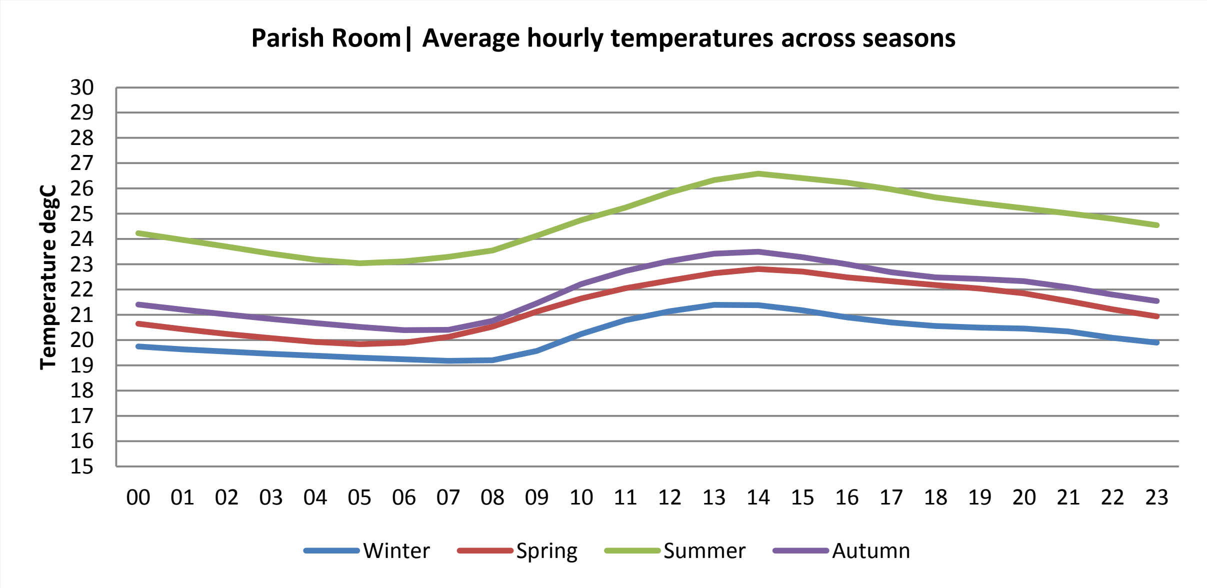


Figure 86 Parish room: average hourly temperatures across seasons

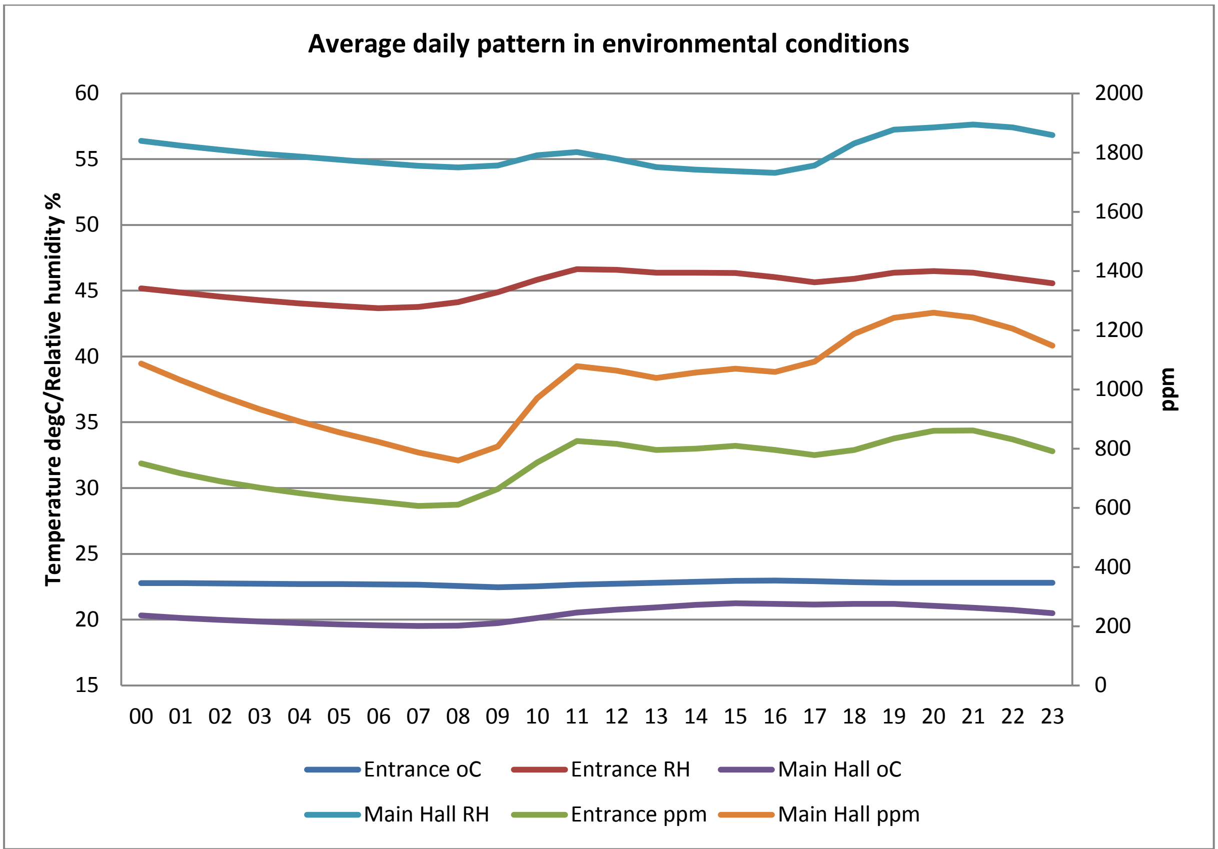


Figure 87 Average daily pattern in environmental conditions

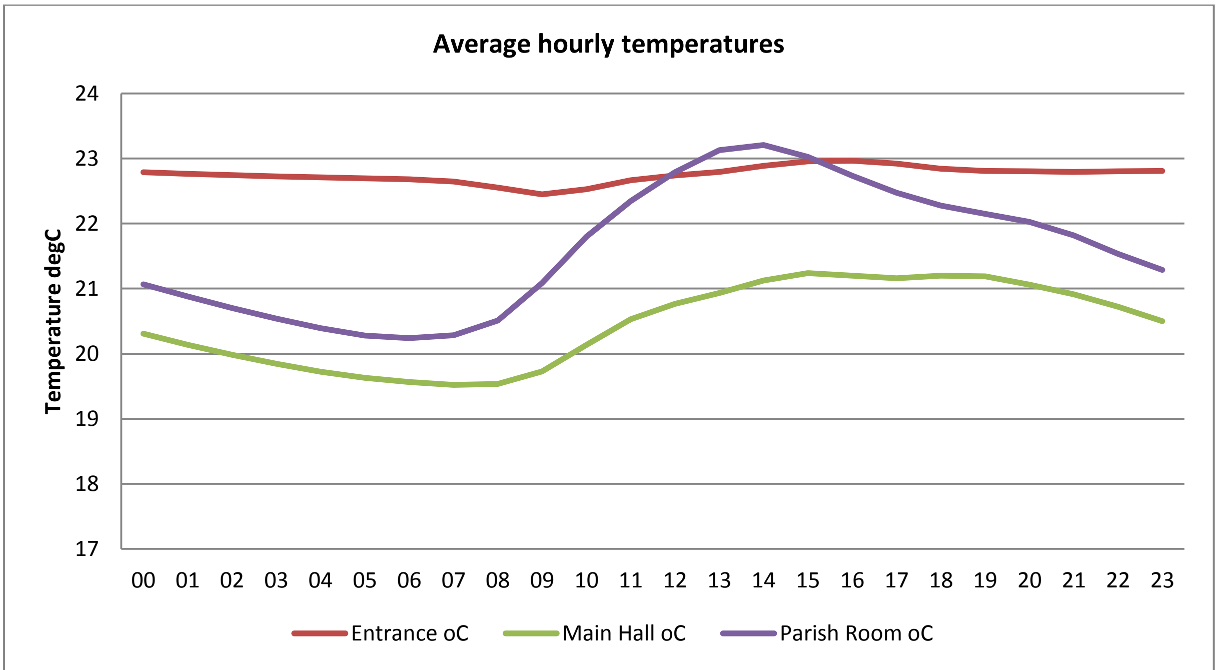


Figure 88 Average hourly temperatures in different spaces

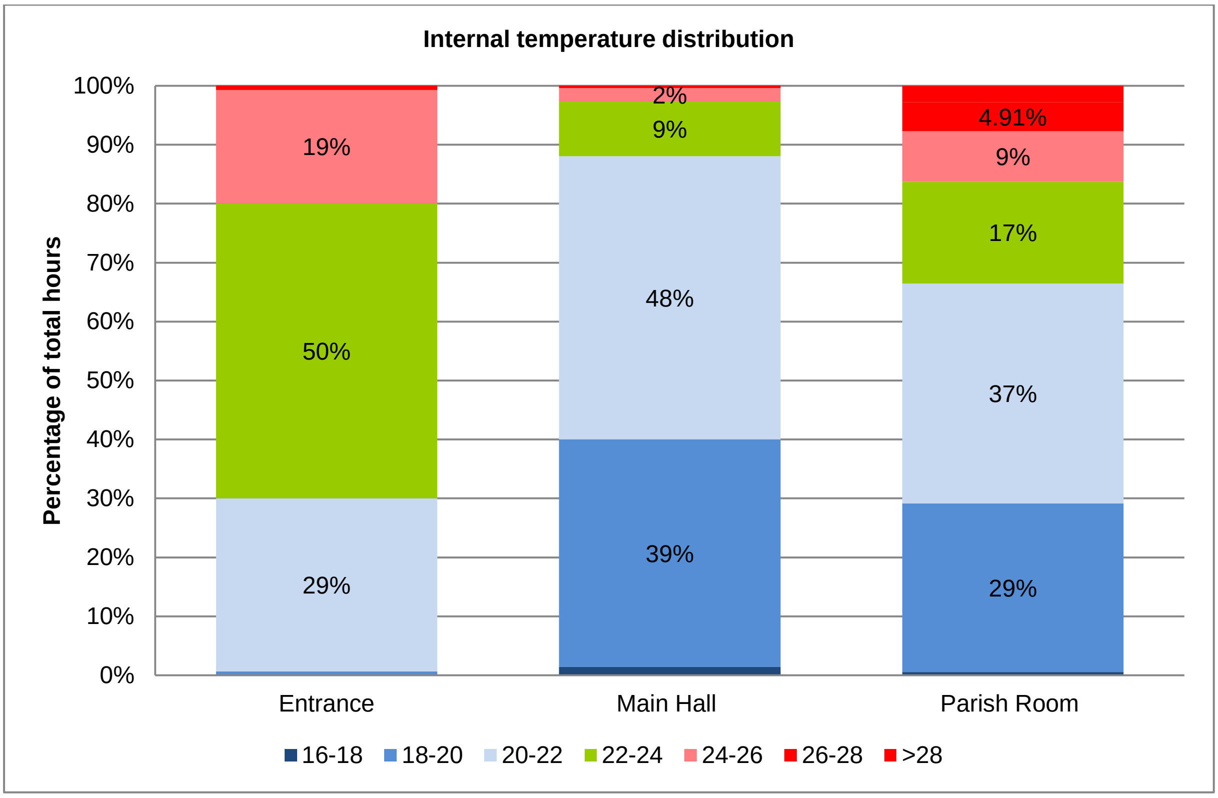


Figure 89 Internal temperature distribution

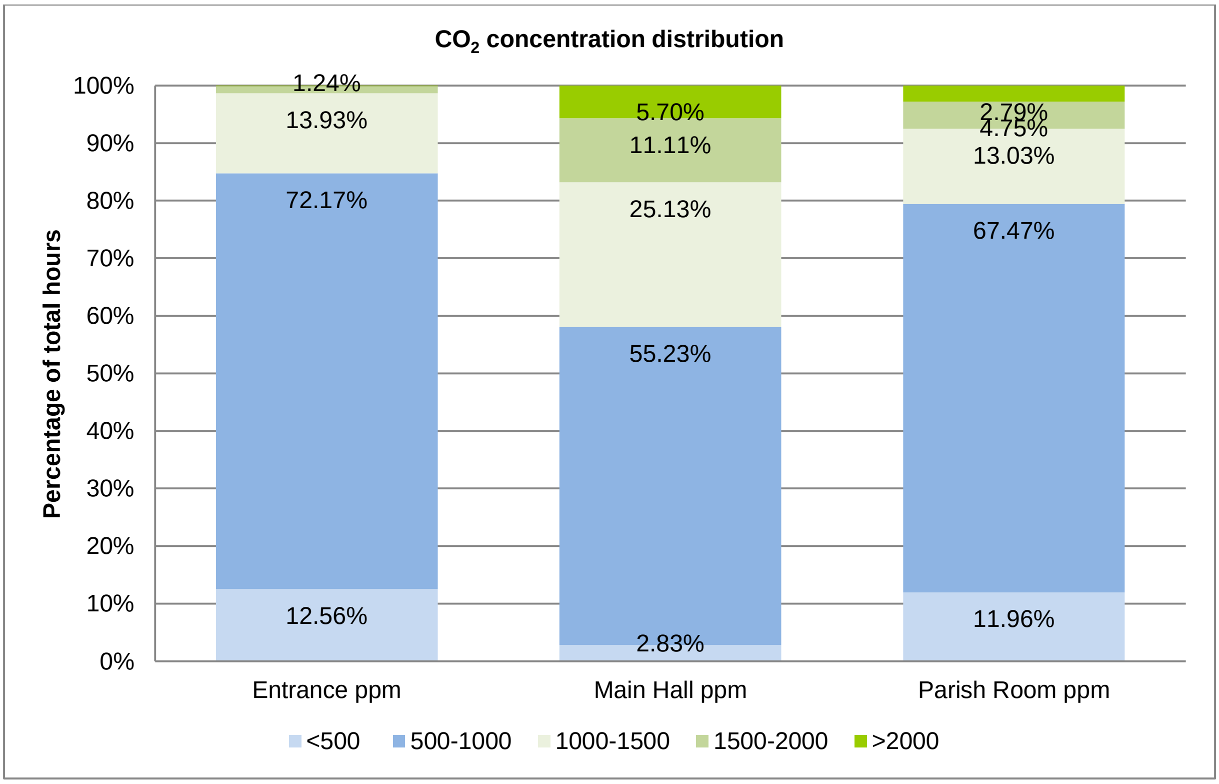


Figure 90 CO_2 concentration distribution

Temperature and humidity levels (Winter) (January 2013)

Internal temperature fluctuates between 19 and 25°C while external lies between 0 and 9 °C. The internal temperature of the Entrance hall remains steadier throughout the week fluctuating between 23 and 25 °C remaining above the comfort levels (CIBSE Guide A). The temperature in the Main Hall fluctuates between 19 and 22 °C following the room occupancy. The highest temperatures are recorded in the parish room during the afternoon. The pattern is different between weekdays and weekends indicating that the Main Hall and the parish room are less occupied during the weekend. It is noticeable that the whole building is heated throughout the week and during the night.

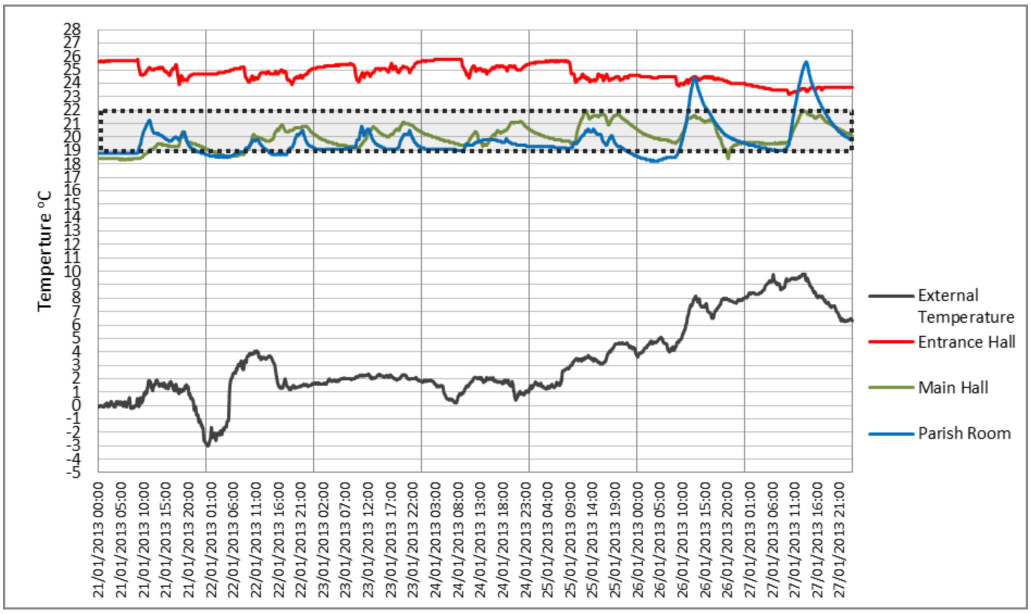


Figure 91: Temperature graph of typical winter week (21/01/13-27/01/13)

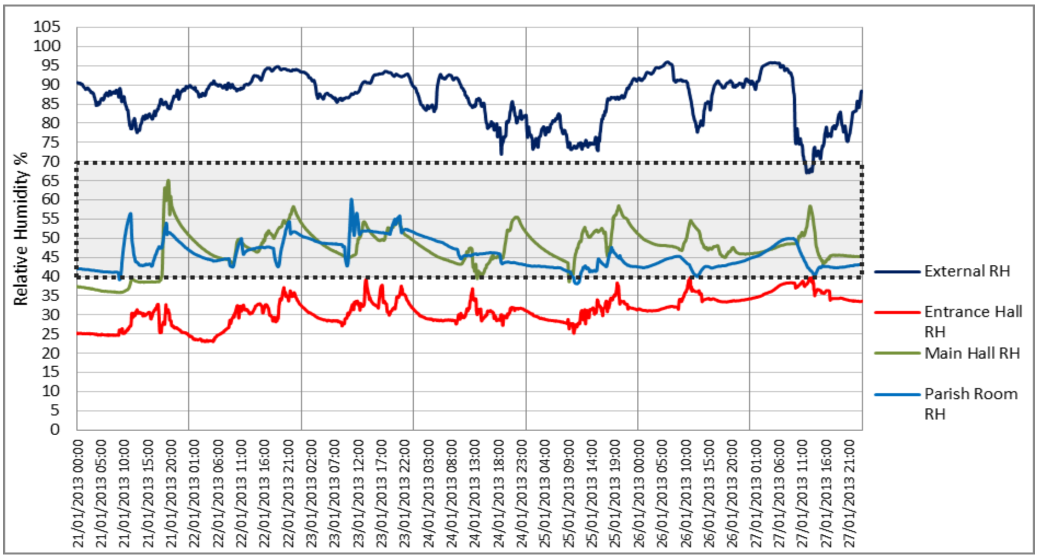


Figure 92: Relative Humidity levels during a typical winter week (21/01/13-27/01/13)

Relative humidity fluctuates between 25 and 55 %. Humidity in the range of 40-70% is generally acceptable (CIBSE Guide A) but in the case of cold weather values under 40% are also considered up to standard. The lowest values are noticed in the Entrance Hall reaching 25% in the early morning of 22 January while the external Relative Humidity was 90%. The space temperature during that time was 23oC while the external temperature was 4oC. The relative humidity in the Main hall and parish room fluctuate between 40 and 55%.

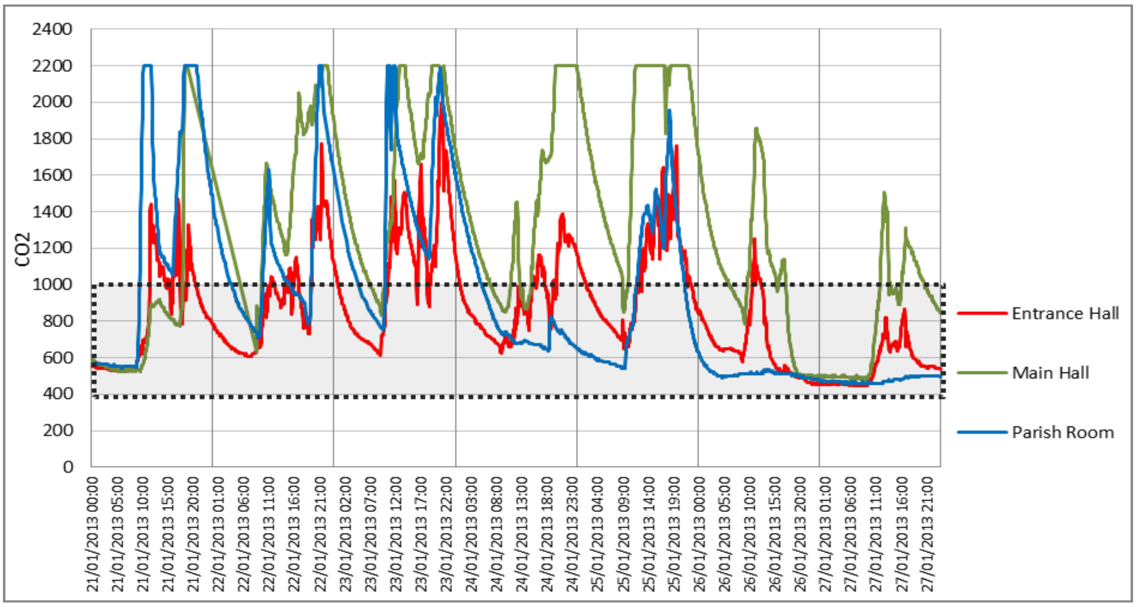


Figure 93 CO_2 levels during a typical winter week

The CO_2 levels range from 500 to 2200 ppm rising high above the ASHRAE benchmark. The highest peaks are recorded during hours of high occupancy during the afternoon in the Main hall and the parish room. CO_2 readings between 1000 and 2000 ppm are generally related to perceptions of poor air quality and stuffiness and are suggesting inadequate ventilation.

10.4 Study of external acoustics and its effects on internal comfort

Acoustics are an important attribute of community centre buildings due to their multi-purpose space use. Yet acoustics in most cases do not receive the same level of design attention as thermal, ventilation and other architectural and engineering considerations (Salter et al. 2003).

In the case of the ACC, it is believed that an acoustic consultant was not used in the initial design stages, nor at specification. A number of issues relating to acoustics and noise were found in the first months of the ACC opening to the public; external noise restrictions from the building's residential location limited the use of the natural ventilation strategy during the first months of use; and a poor acoustical performance of the Main Hall and Meeting Room 1 was also documented in the early stages of the public opening of the building as the reflecting sound was too loud and there were reverberation issues due to the hard materials used and the lack of sound absorbing panels. The problem affected the usability of the spaces as they could not be used for film projections, music performances or talks.

A simple acoustic test was undertaken in the hall by the project managers approximately 6 months after the centre was opened to the public and it was agreed that the contractor would pay for additional acoustic material on the east end wall of the hall. However, this was still found unsatisfactory to a number of users, particularly dance groups. In March 2011, the Parish Council agreed to undertake professional acoustic testing. The resultant report is held with the Parish Council and it proved a need to reduce echo and reverberation in the hall (Appendix).

The report used BB93 for acoustic design in schools and BS 8233 guidance to establish required reverberation times. The reverberation tests undertaken showed that without additional acoustic works, the T_{mt} (mid-frequency reverberation time) was 2.20 seconds, and the reverberation time, T, was 2.41 seconds. The report outlined proposals that would ensure T_{mt} was reduced to 1.00 seconds, and T was reduced to 1.07 seconds, in line with both BB93 and BS 8233. The works undertaken included fixing acoustic panels to both walls and ceilings as shown in Figure 93. Whilst the estimated costs were between £9-13,000, the actual cost was £8,255. This was paid for by the Parish Council who owns the building.

Following on from a successful resolution of the acoustic issues in the hall (Films Shows started again in December 2011), the Trustees then paid for acoustic wall panels (Figure 93) to be installed in Meeting Room 1, at a cost to the Charity of £1,767 ex. VAT.

a)

b)

Figure 94 (a) Acoustic panels placed on the ceiling of the main hall. (b) Acoustic panels placed on the walls of the Meeting Room 1.

Table 16 gives general guidance and recommendations according to CIBSE Environmental Design Guide A (CIBSE, 2006) on acceptable noise ratings (NR) for a range of room types that are used as references in this study. The additional column contains the approximate dB levels that are roughly equivalent to the noise rating given. As explained in the CIBSE guide, the relationship between NR and dBA is not constant.

In addition to the table, the CIBSE guide states that in terms of an office, conversation can be carried out in reasonable comfort if the ambient level is below 60dBA. According to Planning Policy guidance, there is no recent major U.K.-based research from which to take figures for road or rail traffic. The acceptable noise levels for planning permission are based on guidance provided by the World Health Organisation (World Health Organisation, 1980) that "general daytime outdoor noise levels of less than 55 dB (A) are desirable to prevent any significant community annoyance".

It was noted that during the planning application and submission, there were objections to the ACC, and in particular the potential use of the hall for music, dance and film activities that may cause external noise issues to the nearby residents. A planning condition stated that a scheme to ensure provisions were specified ‘to control the noise emanating from the building’ was required. Whilst the authors have not seen this scheme, it is known that the materials chosen for the construction of the external fabric of the building such as external masonry walls, and double glazed windows prevent any excessive noise from impacting on the neighbouring residential area. A noise control device has also been fitted in the ACC to ensure noise levels do not go above recommended levels. It has been noted in a conversation with the building manager that no complaints regarding noise from neighbouring houses have been received since the building opened, even when dance and music events have taken place in the evening. There is, however, conflict between the natural ventilation system and the noise constraints, which are simply dealt with by the occupants on an ad hoc basis. Further physical measurement of this issue has not been investigated within this report.

In terms of monitoring the internal acoustics, the building was visited twice during the year, once in May and once in August. The occupancy of the centre is dependent on the number of hirers, and many are ‘term time’ only. Therefore, one visit was scheduled during term time (May), and the other during the holiday period (August). As the level of occupancy was higher during May, outside noise and traffic could be expected to be higher.

Within each room, measurements (in decibels, dBA) were taken to assess the noise levels over a period of one minute. It must be noted that a number of practical issues limit the accuracy of acoustic spot checks, such as time it takes to get from inside to outside; and the impact of sporadic mobile elements such as cars and people on the noise levels. In order to improve results, a longitudinal survey of acoustic levels over a set period of time would potentially give a better overview of any acoustic issues.

In both May and August, noise levels in occupied spaces (office and display area) were above the recommended standards for offices and circulation spaces. However, it must be noted that while the spot measurements were taken, the windows were open and external noise from the parking area adjacent will have had an impact on the readings. The level of external noise during the first visit was 80.9 dB, 26 dB higher than the recommended value of 55 dB indicating that the parking space outside the building can affect noise quality in the interior when the windows are open.

Table 16 Recommended comfort criteria for specific applications. Source: CIBSE Guide A, 2006

Building/room type	Noise Rating (NR)	dBA (approximate equivalent)
General building areas:		
Corridors	40	46
Entrance halls/lobbies	35–40	41-46
Kitchens (commercial)	40–45	46-51
Toilets	35–45	41-51
Waiting areas/rooms	30–35	36-41
Offices:		
General	35	41
Open–plan	35	41
Places of public assembly:		
Circulation spaces	40	46
Foyers	40	46
Halls (sports & exhibition)	40	46

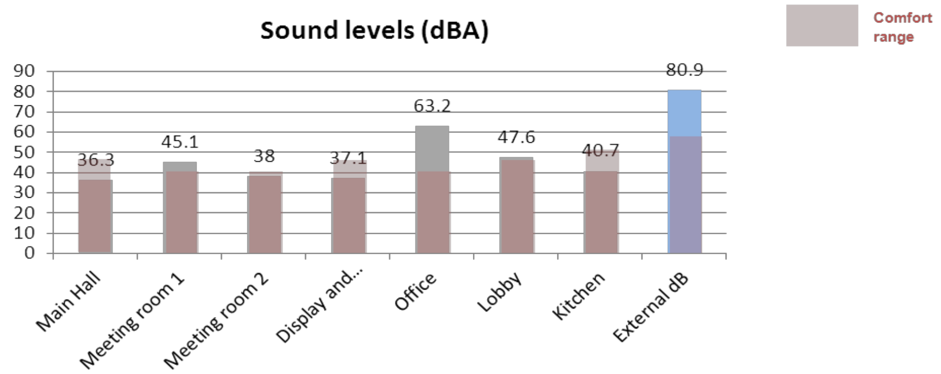


Figure 95 Noise level values in various spaces of the community centre during the first spot check visit (03.05.2012).

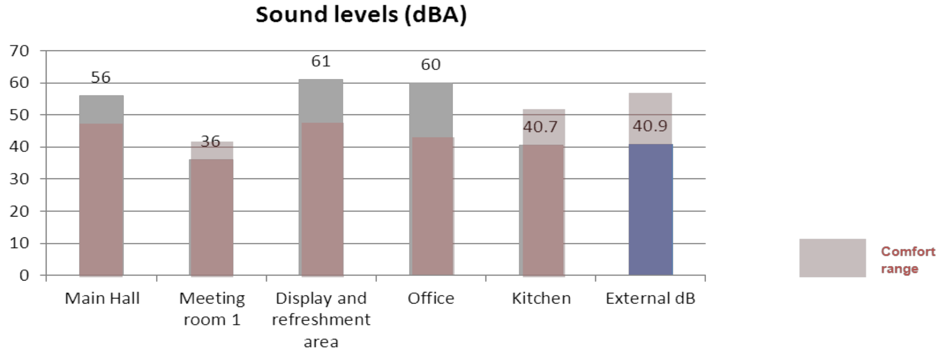


Figure 96 Noise level values in various spaces of the community centre during the second spot check visit (21.08.2012).

Key findings
• During the design stage the issue of acoustics did not receive significant design attention although it was important for the future use of the building. The poor sound performance in the main hall and meeting room was identified and resolved after the opening of the building – the Hall at the expense of the Council (owner) and the Meeting Room at the expense of the Charity (user).
• The higher dB levels in the building interior were recorded in the office and display and refreshment areas were the values were almost double than the recommended limits. It must be noted that the while the spot measurements were taken the windows were open and external noise from the parking area may affected the readings.
• The level of external noise during the first visit was 80.9 dB, 26 dB higher than the recommended value of 55 dB indicating that the parking space outside the building can affect noise quality in the interior when the windows are open for natural ventilation needs.
• A comparison between the original acoustic testing results and the spot check measurements is not possible as the full report, including a description of the tests undertaken is not available to the evaluators. However, extracts proved useful to understanding the modelled impact of the acoustic treatments proposed. Spot measurements also have limitations in assessing the reverberation time, and thus an accurate comparison between results was not possible to achieve for this study. Despite this, there is qualitative evidence that suggests the acoustic works undertaken have substantially improved the acoustic performance of the hall.

10.5 Thermographic survey

A thermographic survey was conducted on 20th February 2013. The conditions during the time of the survey are included in Table 17. In accordance with the TSB requirements all thermographic images are in the full colour rainbow-hi pallet, and the work was undertaken whist the properties were occupied.

A series of thermograms were taken showing the various elevations of the building and for the purposes of this survey, images were primarily taken of the external walls and internal surface that exhibited any thermal anomalies. The environmental conditions and building fabric properties were entered into the thermal imaging reporting software and the relevant corrections made.

Table 17 Conditions during thermographic survey

Parameter	Measurement
Internal Temperature	19.5^{0}C – Main Hall 25.0_{o}C – Entrance 21.5_{o}C – Hall 1
External Temperature	3.5^{0}C to 4.5^{0}C
Wind speed	Nil
Precipitation	Nil

The thermograms show a limited number of thermal anomalies, and more detail are supplied against each image. In general terms the external anomalies identified could be considered to be as a result of the build process, and in overall terms have little significance in regards to heat loss from the building. The internal thermal anomaly of the roof structure however could be seen as significant due to the scale of the phenomena throughout the building, and some further physical investigation of the areas identified would be recommended to confirm the cause of the cold areas.

11 References

BRE, 1985. BRE Digest 272: Lighting Controls and Daylight Use.

CIBSE, 1994. *Code for Interior Lighting*, Chartered Institute of Building Services Engineers.

DETR 1998. Desktop guide to daylighting -for architects. Good Practice Guide 245, DETR Energy efficiency best practice programme publications
CIBSE, 2006. *'Environmental Design, Guide A*',

World Health Organisation. 1980, *Environmental Health Criteria 12 - Noise.*

Escuyer, S. & Fontoynont, M., 2001. Lighting controls: a field study of office workers' reactions. *Lighting Research and Technology*, 33(2), pp.77 -94.

Leaman, A. & Bordass, B., 2001. Assessing building performance in use 4: the Probe occupant surveys and their implications. Building Research and Information 29(2), pp.129-143.

Loe, D. & Mansfield, K., 1998. *Daylighting Design in Architecture: Making the Most of a Natural Resource*, BRESCU on behalf of BRE.

Moore, T., Carter, D. & Slater, A., 2002a. A field study of occupant controlled lighting in offices. *Lighting Research and Technology*, 34(3), pp.191 -202.

Roche, L., Dewey, E. & Littlefair, P., 2000. Occupant reactions to daylight in offices. *Lighting Research and Technology*, 32(3), pp.119 -126.

Ruffles, P., 2005. Lighting Guide 7: Office Lighting.

Salter C., Powell K., Begault D. and Alavarado R., 2003. *Case studies of a method for predicting speech privacy in the contemporary workplace*, Center For The Built Environment, UC Berkeley,

Slater, A., Bordass, W.T. & Heasman, TA, 1996. People and Lighting Controls, BRE Information Paper 6/96. Available at: about:home [Accessed May 30, 2011].

Tregenza, P.R. et al., 1974. Consistency and variation in preferences for office lighting. *Lighting Research and Technology*, 6(4), pp.205 -211.

Veitch, J. et al., 2008. Lighting appraisal, weel-being and performance in open-plan offices: A linked mechanisms approach. Lighting Research and Technology, 40(2), pp.133-151.

CIBSE, 2006. *'Environmental Design, Guide A*', CIBSE publications, Norfolk
Custom Audio Designs, 2011. *Angmering Community Centre Acoustic Report*, Custom Audio Designs, pp. 7-12.

World Health Organisation (WHO), 1980. *Environmental Health Criteria 12 – Noise,* [online], available: **http://www.inchem.org/documents/ehc/ehc/ehc012.htm**

Escuyer, S. & Fontoynont, M., 2001. *Lighting controls: a field study of office workers' reactions.* Lighting Research and Technology, 33(2), pp.77 -94.

Leaman, A. & Bordass, B., 2001. *Assessing building performance in use 4: the Probe occupant surveys and their implications*. Building Research and Information 29(2), pp.129-143.
Salter C., Powell K., Begault D. and Alavarado R., 2003. *Case studies of a method for predicting speech privacy in the contemporary workplace*, Center For The Built Environment, UC Berkeley

Phil Jones Building Energy solutions (2003), GPG348, Good Practice Guide, Building log books – a user's guide, Action Energy, Queen's Printer and Controller of HMSO
Usable Buildings Trust (UBT) (2009) *The Softlandings Framework, for better briefing, design, handover and building performance in-use,* BSRIA [online], available: http://www.bsria.co.uk/download/soft-landings-framework.pdf