Sustainable Construction Academy

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Innovate UK project number	450062
Project lead and author	Low Carbon Building Group, Oxford Brookes University for the Institute for Sustainability
Report date	2015
InnovateUK Evaluator	Unknown (Contact via www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Education	Dartford	Unknown	2011
Floor area (GIA)	**Storeys**	**EPC / DEC**	**BREEAM rating**
2916 m^2	2	A (9) / N/A	Outstanding

Purpose of evaluation

The Sustainable Construction (SusCon) Academy was built as an exemplar facility to inspire and educate trainees in the construction industry. The report covers the scope of the BPE study: details of the building, services and energy systems (biomass boiler with gas back-up), building handover, aftercare operation, management and maintenance, building user survey and interviews, energy and environmental monitoring analysis, and key messages and wider lessons.

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

Electricity consumption: 33.7 kWh/m^2 per annum, thermal (gas) consumption: 90.6 kWh/m^2 per annum. Carbon dioxide emissions were nearly four times worse than the predicted regulated emissions, at 9.4 kgCO_2/m^2 per annum. Due to a commissioning fault the biomass boiler was shutting down when the temperature in the buffer vessel was dropping below a certain level, in turn causing the gas boiler to work for a long period. Serious issues arose due to the lack of knowledge in how to operate and maintain the biomass boiler. The FM was not trained in biomass boiler operation and maintenance. There were 18 sub-meters, but the sub-meters were not connected to the BMS as originally designed.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based	27 of 35	77%

The overview of BUS survey responses revealed that users are especially satisfied by the design and appearance of the building and the suitability of facilities in satisfying their needs. All but one of the building's 'overall categories' of the BUS survey factors scored higher than scale midpoints and benchmarks, including overall comfort, and air quality in both winter and summer.

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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.

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Contents

1 Introduction and overview

Technology Strategy Board guidance on section requirements:	This section of the report should be an introduction to the scope of the BPE and will include a summary of the key facts, figures and findings. Only the basic facts etc should be included here – most detailed information will be contained in the body of this report and stored in other documents/data storage areas.

1.1 Introduction and scope

With the built environment responsible for almost half of the UK's carbon emissions and with a stock turnover of just 1%, it is clear that the quality of both new buildings and the upgrade of our existing buildings play a key role in the UK's success of achieving its 2050 carbon reduction targets. However, many buildings fail to meet expectations, and there has been a lack of activity in build-performance studies to understand how and why this gap exists. The Institute for Sustainability and Oxford Brookes University recognise the fundamental importance of Building Performance Evaluation (BPE) in understanding how energy is used in buildings and we very much welcome the initiative by Innovate UK (formerly TSB) to support the promotion of BPE to clients and building owners, via the BPE study.

The Sustainable Construction (SusCon) Academy was built as an exemplar facility to inspire and educate trainees in the construction industry. It was designed to be an educational environment as well as a case study for sustainable construction in which all elements of the building and its services provide a real world living laboratory. Subjecting the SusCon Academy to a BPE study fits completely with the overall ambition of the Academy and the Institute welcomes the opportunity to understand where and how the energy systems and use may be improved.

This report summarises the findings from the two-year phase 2 building performance evaluation (BPE) of the SusCon Academy. This report covers the scope of the BPE study: details of the building, services and energy systems; building handover, aftercare operation, management and maintenance; building user survey (BUS) and interviews and energy and environmental monitoring analysis; key messages and wider lessons.

The two storey SusCon Academy (figure 1.1) is operated by North West Kent (NWK) College as a teaching facility for Sustainable Construction Techniques to support an exemplar 'Green Skills' training programme which is being provided by North West Kent College in Dartford. The building is owned by Dartford Council and leased to NWK College. The purpose of the design is to form a key part of the curriculum serving as an example of current best practice in sustainable development and as an inspiration to the users of the building, wider industry and community.

Figure 1.1 SusCon Academy front entry (left) and south east façade (right)

Address:	Brunel Way, Dartford, DA1 5FW
UPRN number	522252280000
EPC RRN	9582-3027-0292-0200-8501
Recommendation Report RRN:	0850-0249-8229-5002

1.2 Project team

Table 1.1 The project team consisted of:

Institute for Sustainability (IfS)	Terry McGivern Julian Boss	IfS was the project lead
Low Carbon Building Group of the Oxford Institute for Sustainable Development at Oxford Brookes University (OBU)	Prof Rajat Gupta Matt Gregg Magdalini Makrodimitri	OBU was the academic subcontractor to IfS. OBU undertook testing, survey work, environmental and energy monitoring, and analysis and report writing.
North West Kent College (SusCon)	Christina Blanco Craig Norman	The SusCon team provided access to the building, information on daily use and arranged meetings and workshops for the project team
Dartford Borough Council		Owners of the building and site

1.3 Key facts, figures and findings

The building was designed to be an exemplar in sustainability and to act as a live teaching tool for students and visitors to the Academy. Unfortunately, the building itself is not being used effectively as the live teaching tool, as was intended. In reality, there is much to be done in linking operations of the building to informing and teaching. The building is overall favourable to occupants and visitors, it achieved the targeted air tightness, and is considered by management to be low maintenance.

Some issues hinder the in-use operations from meeting as designed specifications and performance, i.e. the biomass boiler (designed to be the primary heat source) has been decommissioned due to complexity and cost and the sub-metering of electricity consumption is still incomplete three-and a half years after completion. Lack of sub-meter data has restricted the BPE team from comprehensive TM22 assessment and will limit future load isolation analysis for the building. Energy waste is commonly found throughout the building, as examples: computers are left on in computer labs, lights are left on in rooms and difficult for visitors to operate and heating is left on in unoccupied rooms.

Though the building is relatively low in energy consumption (considering benchmarks), supplied (actual) CO_2 emissions rate is found to be nearly four times worse than the predicted regulated emissions from the building, which were 9.4kgCO_2/m^2/year, despite the fact that the building is reported to have been under-used. Table 1.2 details the most recent annual energy and CO_2 emissions figures for the building.

Table 1.2 Energy and carbon dioxide performance for 12 months from 1 October 2013

Unit values	Energy supplied (kWh/m^2 GIA)		Carbon dioxide emissions (kg CO_2/m^2 GIA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied	90.6	33.7	17.6	18.5	36.1
Combined benchmark	167.6	44.9	32.5	24.7	57.2

According to the BUS survey users are especially satisfied by the design and appearance of the building and the suitability of facilities in satisfying their needs which are the three areas of survey that received the highest rating. Overall comfort is rated positively (and scored significantly better than the benchmark) but when queried about specific comfort points, issues like too cold and too hot were found to occur within seasons.

Overall the air quality in both winter and summer is rated significantly better than the BUS benchmark, as confirmed by the CO_2 level readings (441-1178 ppm) taken on the day of the survey. This would suggest that the natural ventilation strategy of the building is likely to be effective. There is little confidence over control for the occupants, e.g., due to limited opening distance, it is doubtful the manual windows in meeting, teaching and offices would give the occupant a feeling of control over ventilation or cooling their space.

Overall, though the building is not used to full capacity or as designed in a number of respects, there are a number of lessons to be learned from the evaluation of SusCon. As examples, the BPE study resulted in revealing the incomplete sub-metering, many areas of small power, lighting and heating consumption can be reduced around the building and the BPE study revealed ways in which the building can be utilised efficiently in the future and brought up to the standard of an exemplar academy in sustainability as it was intended. Details on these suggestions are explained in this report.

2 Details of the building, its design, and its delivery

Technology Strategy Board guidance on section requirements:	This section of the report should provide comments on the design intent (conclusions of the design review), information provided and the product delivered (including references to drawings, specifications, commissioning records, log book and building user guide). This section should summarise the building type, form, daylighting strategy, main structure/ materials, surrounding environment and orientation, how the building is accessed i.e. transport links, cycling facilities, etc – where possible these descriptions should be copied over (screen grabs - with captions) from other BPE documents such as the PVQ. This section should also outline the construction and construction management processes adopted, construction phase influences i.e. builder went out of business, form of contract issues i.e. novation of design team, programme issues etc. If a Soft Landings process was adopted this could be referenced here but the phases during which it was adopted would be recorded in detail elsewhere. If a Soft Landings process was adopted this can be referenced here but the phases during which it was adopted would be recorded in detail elsewhere in this report and in the template *TSB BPE Non Dom Soft Landings report.doc*.

2.1 Summary of spaces

The external area of the building is about 6226 square metres while the internal area is 2916 square metres (GIA). The primary uses in the building are offices and teaching rooms. Extra-ordinary uses in the building include the workshop areas where electrical tools can be used to work with construction materials and an in-house catering service for meetings and conferences.

Table 2.1 Five typological divisions of the spaces in the building

	Area 1	**Area 2**	**Area 3**	**Area 4**	**Area 5**
Description of use	Workshop areas	Teaching spaces	Kitchen / café area	Offices	Circulation and auxiliary spaces
General type	Workshop	University campus	Restaurant	General Office	Public buildings with light usage
Specific type	Workshop	Classroom	Cafe	Offices	Circulation
Gross internal area (m^2)	584.5	563	156	153.2	1155.3

Figure 2.1 Ground floor and first floor plans with spaces identified

2.2 Design details summary

Key stakeholders in the project were: Dartford Borough Council (Owner); Stephen George & Partners LLP (Architects); WinVic Construction Ltd (Contractors); Prologis Development Ltd (project managers); North West Kent College and SusCon (Tenant and Facility Managers). The building was developed through extensive stakeholder consultation and the design process considered sustainability through a four stage process:

1. The building was designed to operate passively with minimal energy requirement and low reliance on fossil fuels. Construction materials have been selected based on; embodied carbon profile; thermal efficiency; thermal mass. Design maximises use of natural light. Cooling was designed out through solar shading, natural ventilation and thermal performance measures.

2. Specified energy efficient lighting, e.g. high efficiency fluorescent (T5 or T8) with movement and daylighting sensing and small detection zones.

3. Installing LZC solutions appropriate to the buildings use: biomass boiler to provide heat; 30kWp of PV on SE facing roof.

4. Measure, reduce and offset embodied carbon. Predicted regulated emissions from the building are 9.4 $kgCO_2/m^2/year$. This represents an annual saving of $55tCO_2$ (70%) compared to a Building Regulation Compliant benchmark and $124tCO_2$ (84%) compared to an existing building (pre-1995). This target aligned the project with the UK Government 2050 target of an 80% reduction in national CO_2 emissions compared with 1990 levels:

a. BREEAM Outstanding rating

b. EPC rating of A (9) / As designed A (10)

c. TER = 25.7 $kgCO_2/m^2/yr$ BER = 9.4 $kgCO_2/m^2/yr$

To communicate these concepts, the building was designed to provide high-visibility of sustainability and showcase this for students, visitors, as wells as the wider industry and community, as an exemplar low-energy building.

Table 2.2 Design details of the SusCon building

Building type	Teaching facility; divided into five use categories for benchmarking in TM22: Workshop, teaching, café, offices, circulation/ exhibition area
Occupancy	Since handover in March 2011 occupancy has been lower than designed occupancy. Use of teaching and workshop space is highly variable; as the building is a training academy most users are transient. During initial occupancy there were approximately 20 full-time members of staff and an average between 20-60 visitors on a daily basis. This number was reduced after summer 2013: staff reduced to 14 with a small visitor reduction. An occupancy increase is expected to gradually occur beginning August 2014. Core operational hours are from 9:00 – 17:15 Monday – Friday. The hours and days are however flexible and events can be held on weekends.
Environment and orientation	Built on edge of new development north of Dartford centre. Access to walking/ cycling path. Built along edge overlooking the A206, a heavily travelled bypass for Dartford. The building was oriented to maximise daylight, winter solar access and prevailing winds (for summer ventilation) in the offices, meeting rooms, and teaching rooms. The offices, teaching rooms and PV on the roof have a south east orientation.
Main construction elements	Construction materials were selected based on embodied carbon profile, thermal efficiency and thermal mass. **Structure:** The building uses three different structural techniques: the workshops have a steel frame, the atrium a wooden frame and the teaching spaces a concrete frame. Materials and components have been selected based on their embodied energy profile and their contribution to the overall environmental performance of the development. **Walls:** Diffutherm construction system. System for light steel buildings externally finished with render. Wood fibre boards over the outside of the frame in a continuous, external insulation layer; externally mineral based thin render system is applied directly to the wood fibre boards; airtightness layer on the inside of the frame; Sheep's Wool Insulation. Proposed area-weighted U-value: 0.18 $W/m^2.K$ **Block Wall**: Minimum of 80% recycled aggregate; 20% of natural materials; Replace 20% ordinary Portland Cement (OPC) content with GGBS; certified by the BRE Environmental Profiling Scheme. **Roof:** Timber frame; European White Wood Spruce from FSC certified source; glued laminated timber (glulam); The main roof of the building faces south-east, which make the area ideal for active solar technology installation and research purposes related to testing the performance of different types of PV technologies. Proposed area-weighted U-value: 0.18 $W/m^2.K$ **Windows:** External glazing; FSC sourced timber internally; anodised Aluminium internally; Internal Windows; double glazed FSC timber. Proposed area-weighted U-value: 1.8 $W/m^2.K$ **Doors:** Glazed pedestrian entry doors and large garage doors for vehicle access to workshops Proposed area-weighted U-value: 1.8 glazed and 0.4 $W/m^2.K$ garage doors **Floors:** Underfloor Heating in Atrium area

	Proposed area-weighted U-value: 0.2 W/m^2.K **Internal Finishes:** Recycled Carpet (offices, teaching and meeting rooms); Recycled ceramic tiles (entrance-reception); Marmoleum (Atrium)
Air tightness	Target air permeability: 7 m3/(h.m2) at 50 Pascal Actual air permeability: 7.08 m3/(h.m2) at 50 Pascal (08.03.2011)
Passive strategies	The design maximises use of natural ventilation, thermal mass, and daylight with external shading to reduce summer solar gain.
Transportation	Most visitors drive and park in the SusCon car park. The facility is accessible from the A206. **Public transport:** A bus service every 10 minutes links the site to Dartford and Ebbs fleet international (20 minutes to St Pancras) and it is directly connected to the extensive, local traffic free cycle network. For convenience however, most visitors and regular occupants drive to the site. Cycle parking is also located in front of the building.
Impact intent	BREAM and EPC certificates are displayed in public and the methodologies employed to meet these achievements will be shared with SusCon students and other interested parties to inform and advance sustainability across the building/property industry.

2.3 Construction and handover

A site progress meeting on 30 September 2010 took place on site. In addition a site visit by the TSB evaluator and Prologis Project Manager took place during BPE project phase 1 (construction stage). The observations during the aforementioned meetings coupled with project documentation (contractor's proposals, specification, energy performance calculations; details of energy sub-metering and the proposed ventilation strategy); a pre-visit questionnaire completed by Prologis and the initial project proposal, informed the TSB evaluator's key findings and recommendations at that stage:

- The building incorporates 18 energy sub-meters that were about to be connected to a web-enabled BMS system at that stage. It was recommended that a metering strategy should be developed before commissioning of the meters to provide guidance on data management and utilisation for teaching purposes and reporting performance. *It appears that this delay (and lack of follow up) led to the sub-meters not being connected until discovered and requested by the BPE team. No information is available on whether the sub-meters were not connected because the metering strategy was / was not developed. A recommendation like this should have follow-up to ensure that the appropriate actions are taken in a timely manner.*

- Recommendation: SusCon should identify a member of staff to act as the occupier's main point of contact for the commissioning and handover process, learn how the building should operate and issues to be resolved. This person should be enthusiastic about the aspirations for the building's sustainability performance. Ideally the same person will keep this role after occupation and will champion all measures which help to ensure the design intent is achieved in practice. This will require a good knowledge of all plant and equipment and their controls and the metering and monitoring systems. The person should also be good at motivating their colleagues and other occupants to use the building economically, encouraging the applicable parties to correct any defects, etc. promptly, setting energy use targets and reporting to senior management on performance regularly, and generally ensuring that by the end of the first year of occupation the building is working smoothly and efficiently. The BPE project should provide the resources for this work to be done.

- Recommendation: a metering strategy should describe how the meter data available from the BMS will be processed into actionable information for those responsible for delivering energy efficient performance.

    - *None of the parties involved were able to act fully on the above recommendations, but the reasons for this are entangled with the fact that the use of the building did not turn out as expected.*

- Further recommendations were related to building construction with regards to airtightness strategy in order to identify the intended air sealing barrier for the whole envelope and inform the construction of wall/roof interface accordingly. *It is likely this helped SusCon meet the designed airtightness target.*

- Daylighting control was reviewed and suggested SusCon review the need for blinds in workshops in order to avoid glare or excessive lighting levels during day or summer evenings.

- Following a review of the Information and Communication Technology (ICT) systems, suggestions were made towards increasing their energy efficiency, including Energy Star Accredited server facilities and controls for mechanical cooling (in server room), Multi-function Devices (printers and copiers) and small power saving settings (PCs).

- Finally the proposal (during design stage) for solar thermal panels was dropped due to the capital cost, uncertainty surrounding the renewable heat incentive and the potential for conflict with the biomass boiler.

The design team visited the building during construction (every two weeks) and there were regular updates of the building thermal models.

SusCon was handed over to the occupants on 14 March 2011. After handover a few complications were revealed and quickly resolved: a leakage in the atrium roof and installation problem with the rainwater harvester. Issues with other systems (discovered later) are outlined in Section 3. Snagging works were re-inspected as scheduled on 30 March 2011 and after that two meetings (every six months) in September 2011 and January 2012 took place to review the progress with building defects, such as the leaking roof above Atrium due to driving rain.

According to the handover review, consensus among stakeholders reveals that the building was delivered on time despite the short time-frame. It was considered an exceptional building that was delivered on time at reasonable cost. Furthermore, collaboration between all key stakeholders was considered excellent throughout the project implementation. More details on the handover are covered Section 5.

2.4 Conclusions and key findings

- **Overall aesthetic:** Overall occupants are satisfied with the design of the building and suitability of facilities. The overview of BUS responses reveals that users are especially satisfied by the design and appearance of the building and the suitability of facilities in satisfying their needs. Only a small number of respondents disliked the design of the building; points of disagreement were around choice of materials, particularly concrete.

- **Impact:** Although through design and construction, the building could be praised for exemplifying the didactic nature of the design in using a variety of structural systems, according to occupant interviews, there has not been ownership in active advertising of the achievements or details of SusCon outside of displayed certificates post-construction. Originally, the building was to have a real-time digital energy generation screen which provides feedback to building users about the total energy consumption and generation by solar PV; this does not exist. Simply put, the building itself is not being used effectively as the live teaching tool, as was intended. In reality, there is much to be done in linking operations of the building to informing and teaching.

- SusCon is considered by the FM to be a building that requires low maintenance compared to other NWK College's buildings.
- Construction of the air tightness barrier (on the inside of the framing) was successful; actual air permeability was extremely close to as-designed target.
- Soft landing or equivalent not contractually a part of the project. O&M manual and building user guide considered to be too technical, overwhelming and not user friendly.
- Issues were found with BMS and sub-metering arrangement – more details in section 3.

3 Review of building services and energy systems.

Technology Strategy Board guidance on section requirements:	This section should provide a basic review of the building services and energy related systems. This should include any non-services loads – which would therefore provide a comprehensive review of all energy consuming equipment serving the building or its processes. The key here is to enable the reader to understand the basic approach to conditioning spaces, ventilation strategies, basic explanation of control systems, lighting, metering, special systems etc. Avoid detailed explanations of systems and their precise routines etc., which will be captured elsewhere. The review of these systems is central to understanding why the building consumes energy, how often and when.

3.1 Building services and energy systems summary

Table 3.1 Building services, energy systems, and passive design elements aimed at reducing energy use

Space heating and hot water system	**Biomass boiler** (Gilles Biomass heating, pellets energy density: 4.9 kWh/kg) originally **designed as primary (base load) system** to provide heating water to serve a variable temperature circuit to the heat emitters and a constant temperature circuit to the hot water cylinder and the underfloor heating. **Gas fired boiler** (Remeca gas 310 Eco: high efficiency condensing boiler with low NOx emission, heat outputs: 51 – 573 kW) **designed as backup system** when the buffer vessel drops below 65°C and for extreme weather conditions. Provision has been made for the addition of a further gas fired standby boiler in the future. The atrium is heated 24 hours every day by an underfloor heating system. The Café area is heated by two concealed ceiling mounted horizontal fan convectors which are controlled by remote thermostats together with a low water temperature cut off thermostat. The remaining rooms are heated by wall mounted radiators. Apart from the underfloor heating, the heating schedule is from 7:05 – 17:05. **Biomass boiler problems:** • Due to a commissioning fault the biomass boiler was shutting down when the temperature in buffer vessel was dropping below a certain level in turn causing the gas boiler to work for a long period. The problem was resolved by installing an assist control to balance the system. • Though the above problem was resolved, the assistant FM felt that the gas boiler was operating for longer periods than it is supposed to and therefore the temperature set points for both biomass and gas boilers would need to be reviewed (February 2013). • Serious issues partially arose due to the lack of knowledge in how to operate and maintain the biomass boiler, e.g. FM not trained on operation and maintenance. • Operation of the Biomass boiler was discontinued April-May 2013 due to continual faults and fuel costs deemed too expensive. • The biomass boiler is an important icon for the project's sustainability objectives and overall performance in reduced emissions.
Space cooling/ ventilation strategy	Mechanical Cooling is only provided for the server room / Mechanical ventilation in toilet rooms; Cooling is designed out for the rest of the building through solar shading, natural ventilation (manually operable windows and motor driven louvers) and thermal (e.g. mass) performance measures. Natural ventilation is assisted by passive stack in the atrium.
Renewables	29.68 kWp solar PV panels (106 panels) on south east face of roof.
Water systems	**Rainwater harvesting** system collects rainwater run-off from the roof and then stores it for WC flushing. The design intent was to reduce water supply costs and surface water runoff. Like the biomass boiler, the rainwater harvesting system is considered among occupants as an

	element of sustainable credentials. There is a missed opportunity by placing the rainwater harvesting system and display in the workshop store instead of a public space. The purpose of the display is to be exhibited publically to make occupants aware of the use of the system and amount of rainwater harvested and potable water saved.
Lighting	**Interior lighting:** High efficiency fluorescent (T5 and T8): entrance lobby, atrium and corridors on time schedules with daylight sensing override; occupancy sensors in most rooms with dimmable controls and automatic daylight dimming controls **Exterior lighting** is set on a timer with daylight sensor overrides.

Figure 2.1 illustrates the designed energy profile of SusCon.

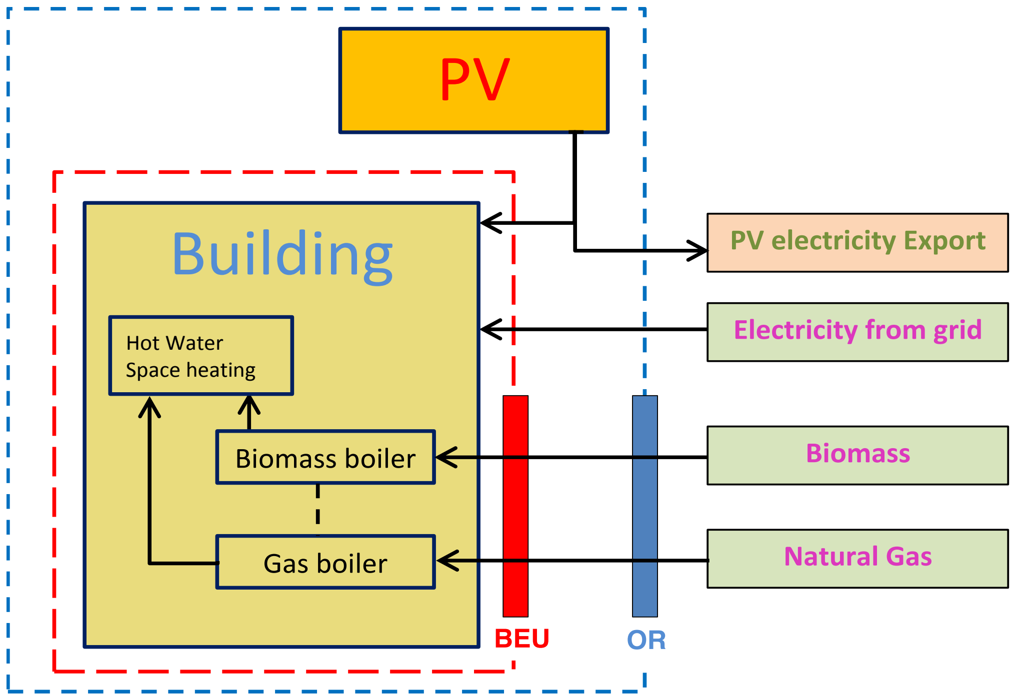


Figure 2.1 Energy profile of SusCon Academy (BEU= Building Energy Use, OR= Operational Rating)

3.2 Review of installed meters and sub-metering arrangements

The SusCon building uses electricity for lighting, small power and other building operations. Electricity is supplied by mains electricity and photovoltaic electricity. Mains electricity and PV consumption is monitored by the BMS. The total onsite PV electricity generation is metered by one of 18 sub-meters located on the top floor plant room.

There are 18 sub-meters in the top floor plant room. The sub-meters were not connected to the BMS as originally designed. In January 2013 the BPE team discovered that the BMS did not capture all required data, therefore BSRIA was commissioned to install pulse meters to seven of the sub-meters so that the data could be monitored (though still not connected to the BMS). Finally after months of attempts, the BPE team arranged for the contractor to connect all sub-meters to the BMS. The job was performed on 30 May but was incomplete (e.g. ground floor light and power not connected). Table 3.2 list the sub-meters, connectivity and data availability.

Table 3.2 List of sub-meters and relevant dates

Sub-meter	Date connected to BMS	Start date of data availability
Server room light and power	30 May 2014	22 February 2013 (BSRIA)
PV power (total on-site generation)	30 May 2014	22 February 2013 (BSRIA)
External lighting power 1 (DBXL1)	30 May 2014	22 February 2013 (BSRIA)
External lighting power 2 (DBXL2)	30 May 2014	22 February 2013 (BSRIA)
Plant room motor control	30 May 2014	22 February 2013 (BSRIA)
Kitchen light and power	30 May 2014	22 February 2013 (BSRIA)
Lift power	30 May 2014	30 May 2014
Workshop store light (DBL1)	30 May 2014	30 May 2014
Workshop store power (DBP1)	30 May 2014	30 May 2014
Ground floor light (DBL2)	Not connected	-
Ground floor power (DBP2)	Not connected	-
First floor light (DBL3)	30 May 2014	30 May 2014
First floor power (DBP3)	30 May 2014	30 May 2014
Roof plant light (DBL4)	30 May 2014	30 May 2014
Roof plant power (DBP4)	30 May 2014	30 May 2014
Integral surge suppression equipment	Not connected	-
Integral power factor connection equipment	Not connected	-
Fire alarm panel	Not connected	-

Due to a lack of sub-meter data monitoring, the sub-areas of energy use within the building cannot be completely analysed such as interior lighting and small power. To add to the list of elements un-monitored, the rainwater harvesting power consumption is also not monitored, e.g. pumps, water collected, water saved. The original design intent was to have it monitored by the BMS.

In addition to mains electricity and PV consumption, SusCon's BMS records natural gas consumption, gas boiler energy output, biomass boiler energy output, hot water primary heating energy, water usage and temperatures for the atrium and corridors. The BPE team has remote access to the BMS system under the permission of the FM.

The BPE team also commissioned BSRIA to install additional environmental monitoring equipment to record temperature, relative humidity and CO_2 levels in certain areas of the SusCon building, a signal booster and a Wi-Fi hub to allow access to environmental monitoring and sub-metering data through the OBU web portal. Table 3.3 lists all variables monitored and date of useful data.

Table 3.3 list of energy and environmental variables monitored in SusCon

Energy consumption/generation	Date*	Environmental variables	Date*
Mains electricity kWh (BMS)	Oct 2011	Temperature (Café, office, teaching room, Workshop 1, and Workshop 2) °C (PT)	Mar 2013
PV consumption kWh (BMS)	Nov 2012	Temperature (Office, teaching room, Workshop 1, and Workshop 2) °C (BMS)	July 2012

Biomass boiler energy meter MWh (BMS)	Mar 2012	Relative humidity (Café, office, teaching room, Workshop 1, and Workshop 2) % (PT)	Mar 2013
Mains gas m^3 (BMS)	July 2012	CO_2 (Café, office, teaching room, and Workshop 1) ppm (PT)	Mar 2013
Gas boiler energy meter MWh (BMS)	Mar 2012	Pyro W/m^2 (PT)	Mar 2013
HWS cylinder primary heating energy meter MWh (BMS)	Nov 2012	Office windows (x4) opened/closed (PT)	Mar 2013
Server room light and power kWh (PT)	Mar 2012	External temperature °C; external RH % (PT)	-
PV total generation kWh (PT)	Mar 2012	External temperature °C (BMS)	July 2012
External lighting power 1 kWh (PT)	Mar 2012	Atrium temperature °C (BMS)	July 2012
External lighting power 2 kWh (PT)	Mar 2012	Underfloor heating flow temperature °C (BMS)	July 2012
Plant room motor control (PT)	Mar 2012	First floor corridor temperature °C (BMS)	July 2012
Kitchen light and power kWh (PT)	Mar 2012	High level windows (x12) (BMS)	July 2012
Lift power kWh (PT)	-	Incoming cold water m^3 (BMS)	July 2012
* First date of complete and usable data BMS = building management system; note: large gap in all BMS data from 11 June – 19 July 2013 PT = pulse transmitters			

3.2.1 Ideal metering strategy

SusCon's metering requirements were considered early on in the design process, whilst the supply and distribution network was being designed (new buildings: Part L2A compliance). However there are several design intents as far as the metering strategy is concerned that were not finally met. One of these is the fact that the sub-meters are not connected to the BMS system and data are not available from other meters as listed above. Furthermore, using CIBSE's TM39:2009 as guidance for the ideal monitoring strategy, the listed observations below reveal weaknesses of the existing metering strategy and potential improvements:

- SusCon's metering strategy lies on the "acceptable" – average – level of non-domestic buildings' metering pyramid. The main meters and sub-meters record, display and transmit either through the BMS system or the OBU web portal real time data. Therefore, the energy consumption of the building can only be obtained by calculating the difference between energy readings. According to CIBSE's TM39:2009 guidance document for building energy metering, this type of data does not allow occupants to reflect on past energy use.

Improvements that could be made to SusCon's metering strategy are as follows:

- Apart from the imported energy already being monitored by the BMS system, PV electricity export should also be monitored.

- Additional sub-metering data should be obtained for future management. Lack of sub-meter data has restricted the BPE team from comprehensive TM22 assessment.

- Check the metric values associated with the transmitted data through BMS and web portal. Heat meters (for example) are logged in MWh, thus limiting detailed analysis.

3.3 Conclusions and key findings

- Due to ongoing issues and inability to repair the biomass boiler along with the cost of the pellets, the biomass boiler has not been used since May 2013, although it was intended to be the primary source of heating. *There should be follow up with the design team to potentially resolve this issue. If there is a defect in the product itself, it should be brought to the notice of the manufacturer.*
- Early integration and training for the FM with regard to the biomass and BMS would have been beneficial as many issues were missed due to not knowing the systems.
- The gas fired boiler is now being used as the primary and single thermal energy source for the building. This has led to an increase in annual CO_2 emissions (See section 6 for energy and CO_2 implications).
- None of the 18 sub-meters were connected to the BMS system despite this being part of the design intent. This is likely to be because of an apparent lack of communication, co-ordination and follow-up between the installer of BMS, installer of the sub-meters the design team and other stakeholders. This reveals the communication gap that can occur between ‘different’ trades during construction and commissioning of buildings.
- Currently even though some sub-meters were recently connected to the BMS, end-use profiling will still be challenging as not all sub-meters are connected.
- There is much to be done in linking operations of the building to informing and teaching. This is seen through the examples of the BMS system and the rainwater harvesting system.
  - The BMS system is not user friendly and reporting is not intuitive. As explained in the review of controls report, ease of use (downloading data) and degree of fine control (defining periods of data for download) are very poor, slow and extremely frustrating. There is little control over the time period range for which you can download at a time even when specifying exactly what you want. It is not suitable as a teaching tool.
  - A user guide for the BMS would be beneficial.
  - The rainwater harvesting system is not located in public view so that visitors can acknowledge the existence of the system or view water savings attributed to the system.

4 Key findings from occupant survey

Technology Strategy Board guidance on section requirements:	This section should reveal the main findings learnt from the BPE process and in particular with cross-reference to the BUS surveys, semi-structured interviews and walkthrough surveys. This section should draw on the BPE team's forensic investigations to reveal the root causes and effects which are leading to certain results in the BUS survey; why are occupants uncomfortable; why isn't there adequate daylighting etc. Graphs, images and data could be included in this section where it supports the background to developing a view of causes and effects.

The SusCon building occupant survey took place on 22nd and 23rd May 2013, using BUS questionnaires and interviews. The BUS questionnaires were distributed to regular occupiers of the building on the morning of 22nd May (10:00am). The survey participants filled in the questionnaires and returned them by the end of the day (5:00pm). A total of 27 responses out of 35 distributed questionnaires were obtained (response rate: 77%).

The interviews with occupants and facilities managers took place on 22nd and 23rd May 2013. The following users were interviewed in depth:

1. Facilities Manager
2. Assistant Facilities Manager
3. Occupant 1 - member of staff (reception) – working in the building for one year
4. Occupant 2 - member of staff (catering) – working in the building over one year
5. Occupant 3 – working in SusCon (client) – working in the building for two years
6. Occupant 4 - tutoring National Construction Academy's (NCA) seminars in SusCon (Health and safety supervisor) – using the building for two years

The following sub-sections triangulate the findings from the questionnaire, interviews and environmental analysis to determine the root causes for specific findings and where, if possible, energy consumption is impacted and what could be done to improve energy consumption.

4.1 The building overall

The overall results (figure 4.1) of the BUS survey reveal a positive perception of the building facilities and overall environmental conditions of the SusCon Academy.

- The overview of BUS survey responses reveal that users are especially satisfied by the design and appearance of the building and the suitability of facilities in satisfying their needs which are the three areas of survey that received the highest rating.
- All but one of the building's 'overall categories' of the BUS survey factors scored higher than the benchmarks.
- Overall, health perception is the only factor that scored relatively lower than the other factors.
- Among the 27 respondents to the BUS it was found that overall comfort was rated positively, with the building scoring significantly better than the benchmark. Only two respondents had neutral responses and all others rated the building above neutral.

- Overall the air quality in both winter and summer is rated significantly better than the BUS benchmark, as confirmed by the CO_2 level readings (441-1178 ppm) taken on the day of the survey. This would suggest that the natural ventilation strategy of the building is likely to be effective.

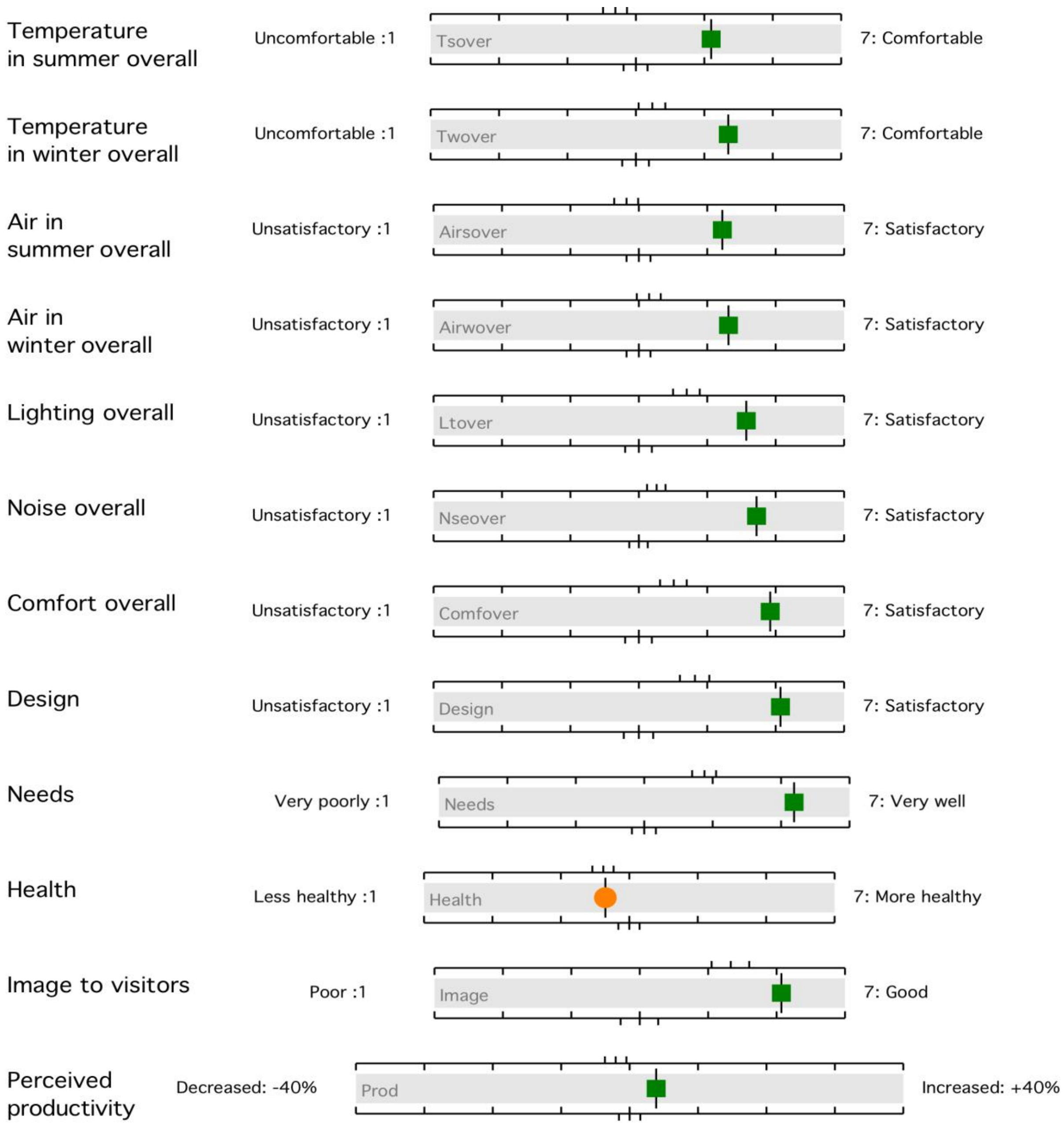


Figure 4.1 Overall building results

4.2 Seasonal thermal comfort

The ‘overall’ summer and winter temperatures are perceived to be ‘comfortable’ and better than the benchmark. However when investigated deeper with directed questions toward too hot, too cold, etc., the responses are less desirable. Figure 4.2 illustrates the findings from the BUS questionnaire regarding seasonal temperature. The following sub-sections look at these results in depth.

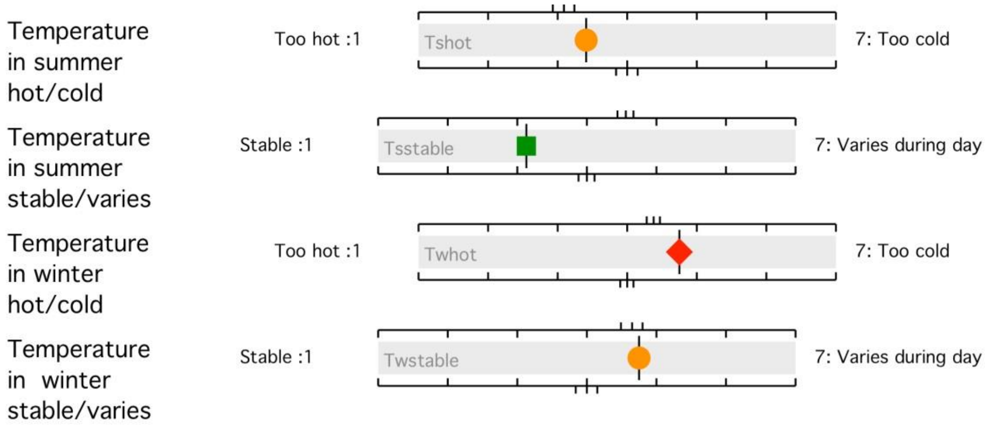


Figure 4.2 BUS responses: temperature in winter and summer

4.2.1 Temperature stability

According to the BUS, temperatures in winter are perceived to vary (no different from the benchmark) while summer temperatures appear to be more stable (better than the benchmark). To investigate temperature stability, figures 4.3 & 4.4 illustrate the degrees of variation from each day's temperature mode for a selected span of days representing both summer and winter (occupied hours only). Notably between the two graphs, summer temperatures are far less stable than winter temperatures; not in agreement with BUS results. The same results are seen in the ground floor teaching room but to a slightly lesser degree.

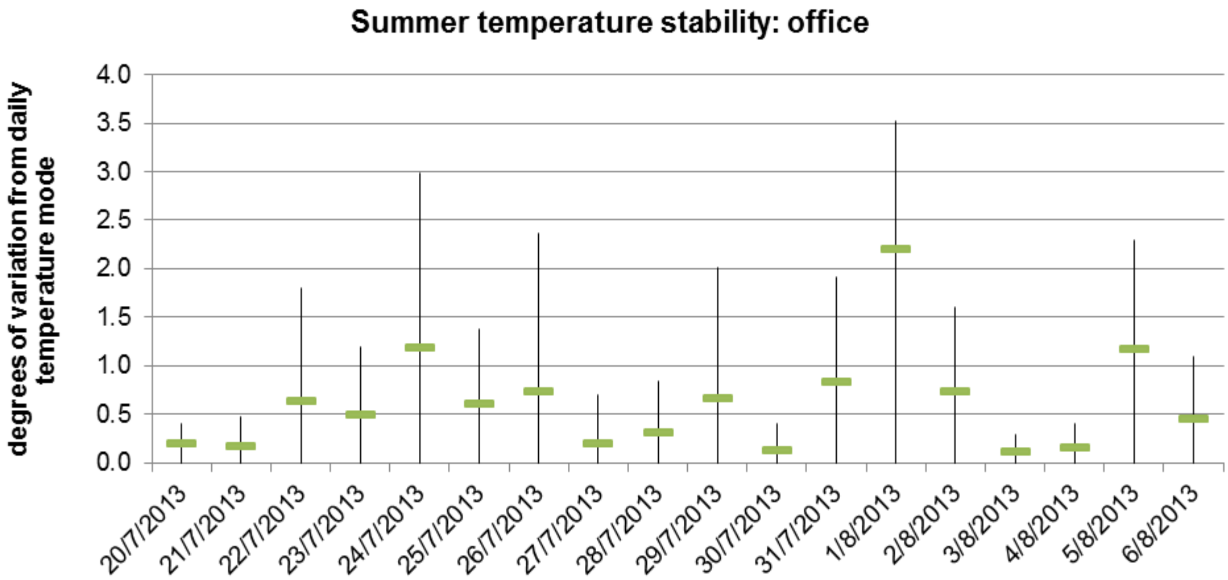


Figure 4.3 Summer temperature stability

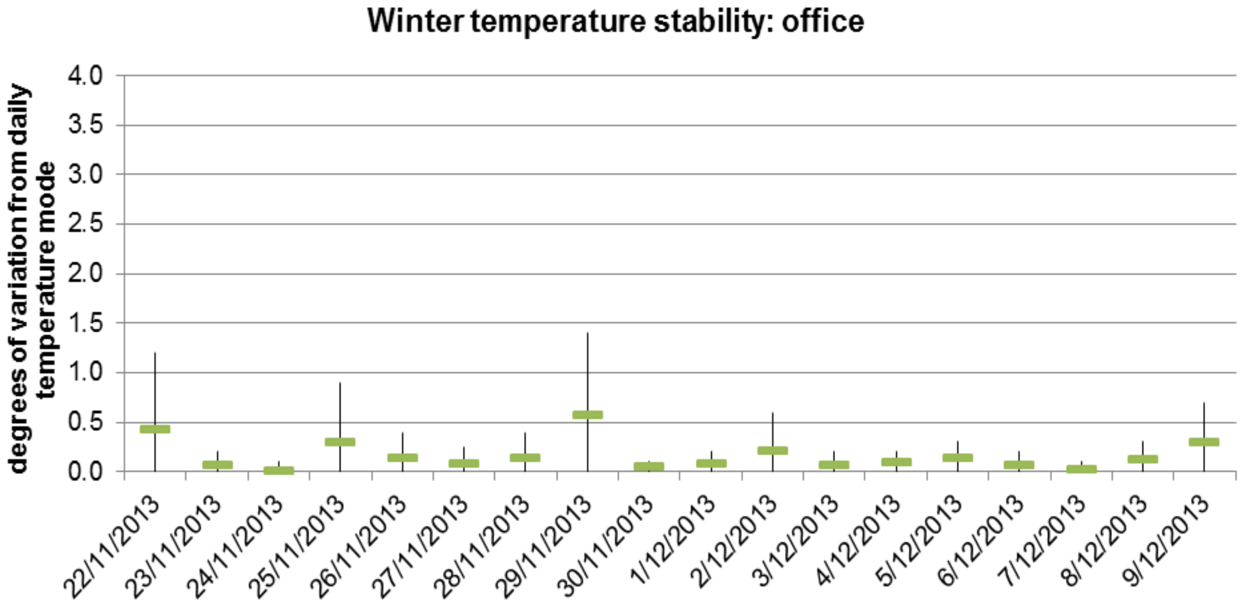


Figure 4.4 Winter temperature stability

One office occupant interviewed suggested that heating within the office is uneven; 'one side is boiling hot and the other is freezing'. This has resulted in occupants (number unknown) using portable heaters. This experience is likely to lead to a perception of temperature variation. Particularly in the SusCon office, the room is large in depth. The 'freezing' side could be the area on the far end from the radiators and the 'boiling' side could be next to the radiators. Alternatively, on one side of the external wall the radiator could be off and the other side of the external wall, the radiator could be on (scenario found in a similar sized meeting room). To add to this the external ventilation panels could be contributing to draughts. The occupants should not have heating control issues in these rooms as the radiators are fitted with TRVs and are easily adjusted.

This sense of variability in winter temperatures over summer temperatures perhaps also comes from the larger difference in winter temperatures between spaces within the building from room to room. As is seen in figures 4.5 & 4.6, winter temperatures (figure 4.6) vary prominently from room to room as opposed to summer temperatures (figure 4.5). This variation in winter can be attributed to the different location and types of heating sources within rooms and within the building, whereas in the summer, the building is free-running and the ambient temperature appears to be better evenly maintained by the thermal mass. *This trend can also be seen in all other temperature graphs presented in other sections.*

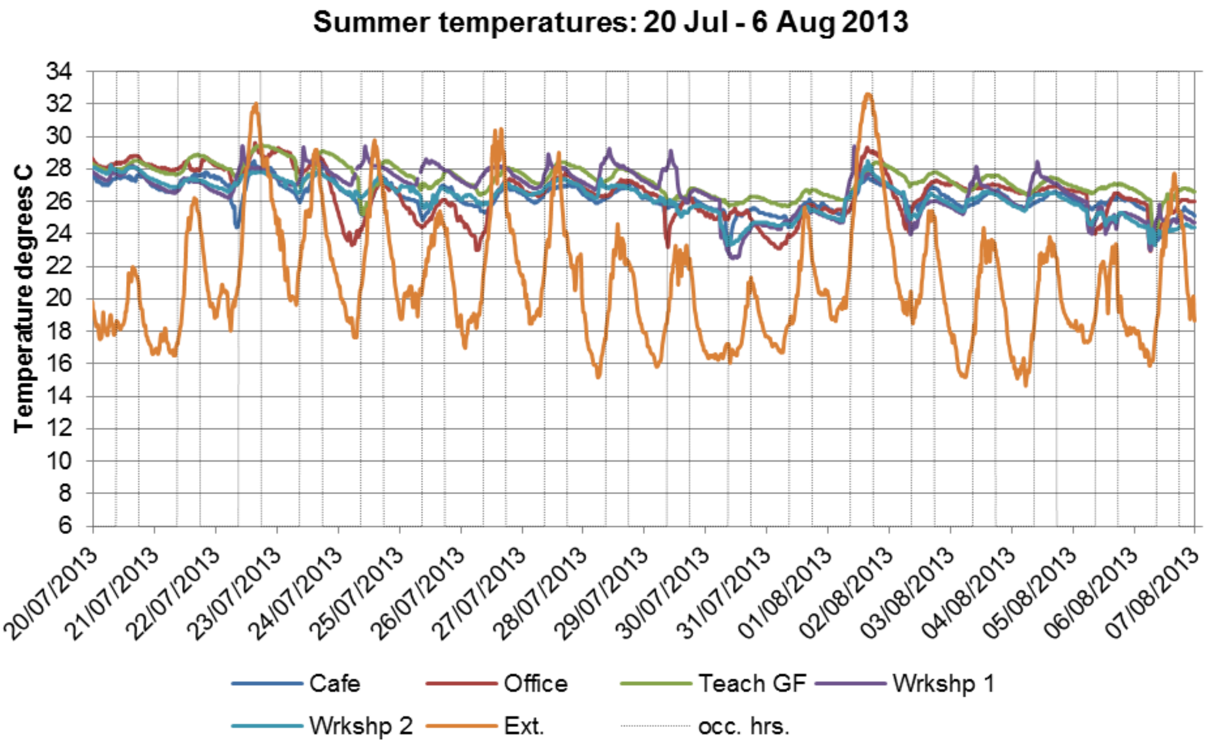


Figure 4.5 Summer temperatures

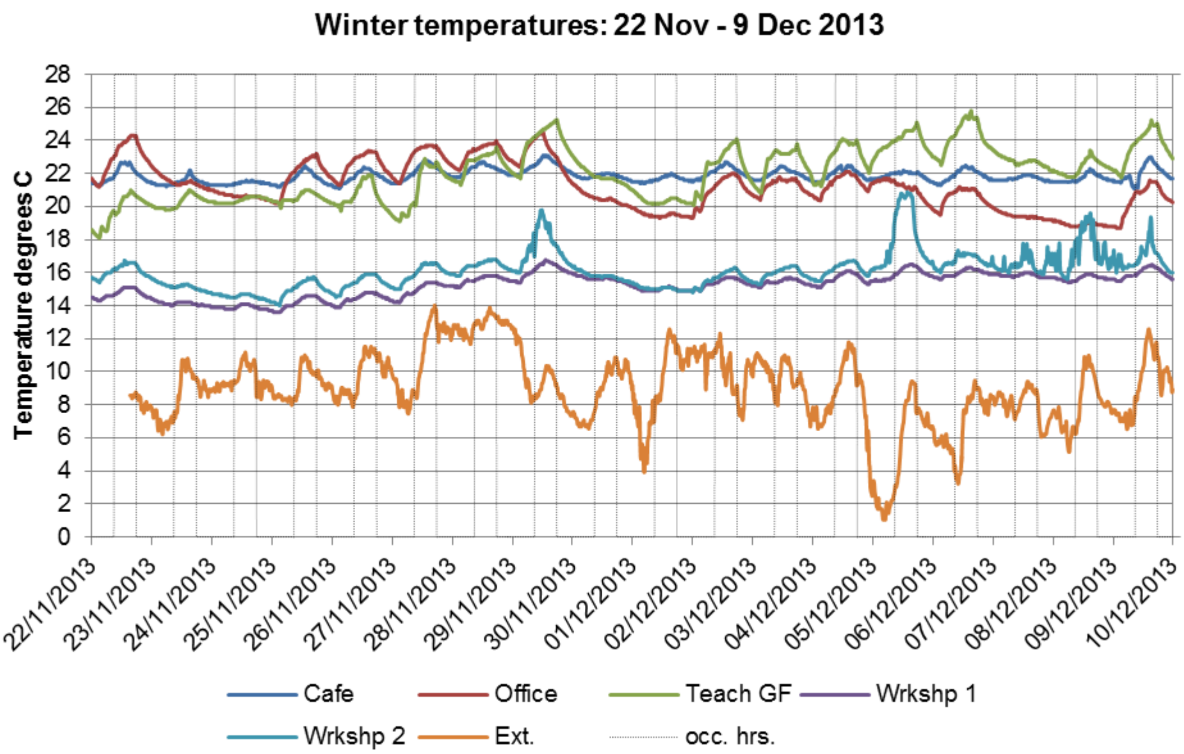


Figure 4.6 Winter temperatures

4.2.2 Seasonal temperature extremes

According to the BUS, summer temperatures are perceived to be **warm** (**no different** from the benchmark). Winter temperatures are perceived to be **cold** and **worse** than the benchmark. This is surprising given that the building is highly insulated and designed for passive solar gain.

The workshops are kept cooler than the rest of the building due to intermittent and/or active-participatory use. It is possible that some respondents were thermally experiencing these rooms (figure 4.6).

Table 4.1 summarises the occupied hours for which specific spaces are within or outside of CIBSE operative temperature ranges. *Note: 'occupied hours' are strictly hours of occupation during working days.*

- The café is most successfully kept at operative temperature for both seasons. 15% of occupied hours are over-heated in the winter.
- One third of the office's winter temperatures are below the recommended operative temperature; this would likely contribute to a 'too cold' vote on the BUS and further comments in occupant interviews suggesting that heating may not be sufficient at times in the office. The office is also slightly over-heated in the winter and is experiencing summer overheating. BUS votes indicate 'too warm' in summer and an office occupant interview says some use portable fans.
- Teaching room 5 (ground floor), a space not used every day, should be of concern considering that it is being over-heated 85% of the time. According to CIBSE standards, the teaching room's operational temperature could be reduced, thereby saving heating energy; the heating regime of the teaching spaces should be reviewed for potential energy reduction especially considering the intermittent use of the spaces. Though the teaching room is also experiencing summer overheating, it is also potentially the most comfortable among the three in the summer with 56% of hours at or below the recommended operative temperature.

Table 4.1 Occupied hours at the recommended operative temperatures for the café, office, and teaching room

	Winter			Summer		
	Café (21-23°C)	**Office (21-23°C)**	**Teaching (19-21°C)**	**Café (25°C)**	**Office (25°C)**	**Teaching (25°C)**
Overheating (1% annual occ. hrs. over operative temp. of 28°C)	-	-	-	-	**2.1%**	**1.5%**
Percentage of hours **above** operative temps.	15.2%	14.6%	84.9%	51.7%	65.6%	44.2%
Percentage of hours **within** operative temps.	82.1%	51.5%	9.3%	34.2%	30.4%	25.4%
Percentage of hours **below** operative temps.	2.7%	33.9%	5.8%	14.1%	4%	30.4%

4.2.3 Summer overheating

Table 4.1 indicates overheating in the main SusCon office according to CIBSE Guide A (2007) (still relevant when the building was built and for most of the analysis). The SusCon office was however not occupied halfway through the latter part of the analysis. Another office, occupied throughout the entire BPE study also experienced overheating to a lesser degree (1% of annual occupied hours over 28°C). However when applying the adaptive comfort method (CIBSE TM52, 2013), no overheating is found (figure 4.7).

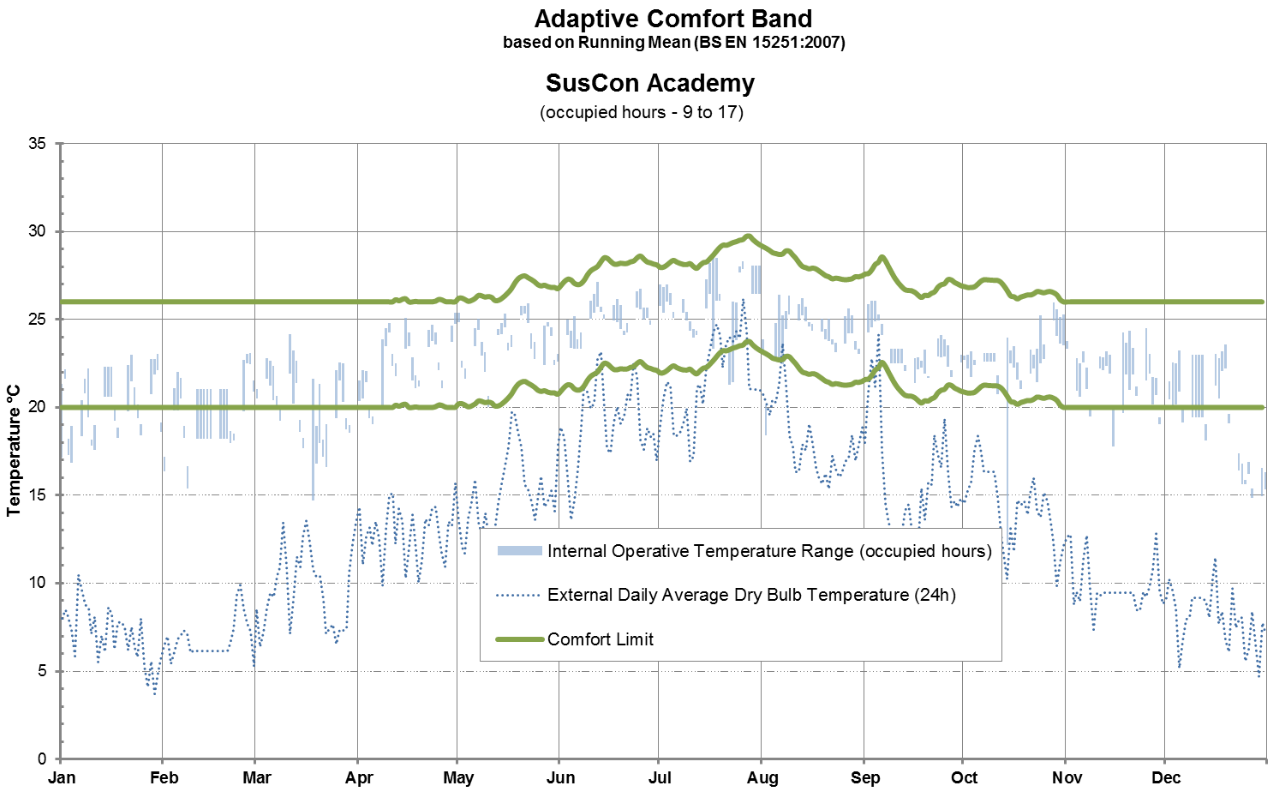


Figure 4.7 Adaptive comfort analysis for an office from September 2013 – September 2014.

4.3 Air quality

Figure 4.8 illustrates the findings from the BUS questionnaire regarding seasonal air quality.

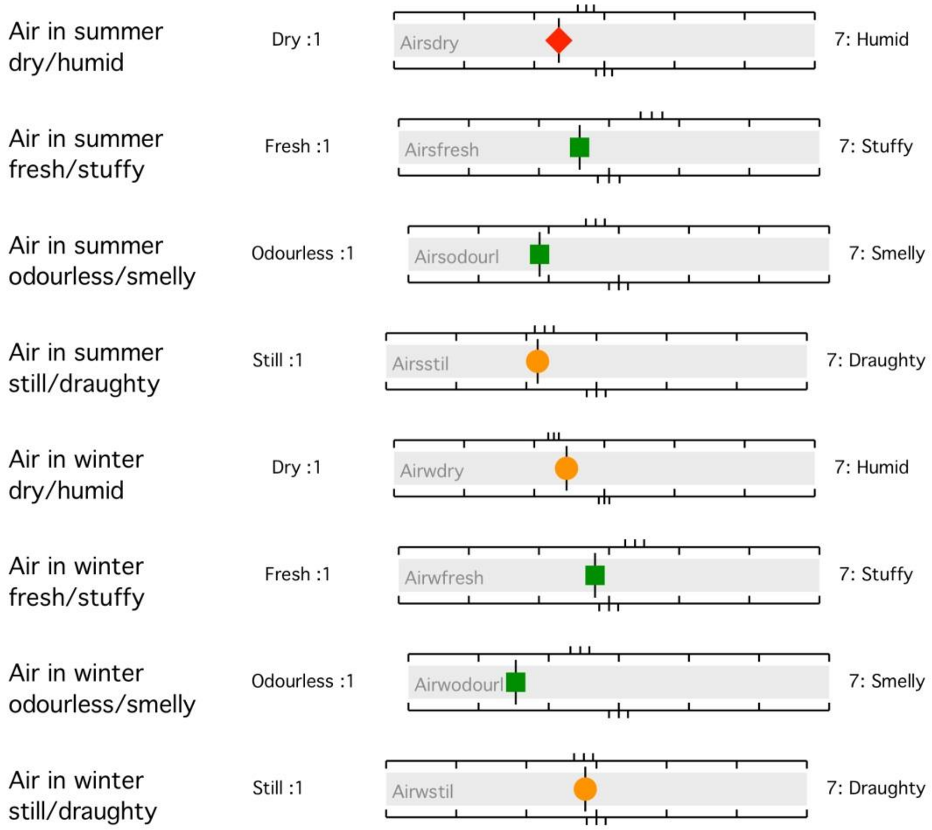


Figure 4.8 BUS responses: air quality in winter and summer

4.3.1 Ventilation effectiveness

Spot checks were performed with a portable anemometer at SusCon early June 2013. Two measurements were taken in each space. All rooms lie slightly below the lowest level of recommended value for comfortable conditions (0.5m/s) when louvers are open and windows are closed.

- Only the meeting room appeared to have air velocity within the comfort range with windows closed. This is likely to be due to the shallow depth of the room in combination with the stack effect from the atrium windows.
- Due to the large sliding doors in the café, the air flow in the café is the greatest; when extra ventilation is required the large windows of the café are opened to allow extra air into the building.
- Environmental review in the office (where window opening is monitored) shows that when CO_2 concentrations are isolated to occupied hours when the windows are closed only, the concentrations are as follows:

CO_2 concentrations in the office during occupied hours with windows closed		
Maximum: 799.6 ppm	**Average:** 431.1 ppm	**Minimum:** 341.2 ppm

According to the BUS, air in both winter and summer is perceived as fresh and odourless; scoring significantly better than the BUS benchmark. Figure 4.9 illustrates the CO_2 concentration for occupied hours in the café, office and teaching room over the winter and summer months. The graphs indicate that CO_2 levels are kept reasonably low corresponding with the 'fresh' air votes in the BUS, demonstrating that the natural ventilation strategy is effective in providing fresh air to the building in most spaces. In the teaching room however, there are obvious peaks of CO_2 concentrations over 1000ppm when the teaching rooms are densely occupied. It is likely that concentrations below 500 in the teaching rooms indicate no occupancy.

- Summer ventilation is highly effective at keeping CO_2 concentrations below 500ppm for over 90% of occupied hours in all spaces.
- The teaching room (ground floor) has had the most hours of concentrations above 1000ppm. This is expected considering the potential high occupancy of teaching rooms and the transient nature of the occupants (visitors). Visitors are less likely to know or attempt to open windows for ventilation when only present for short periods and when unfamiliar with their surroundings. According to occupant interviews, a regular user of the teaching room states that, in their opinion, there has not been a need to control the local environment, therefore these is a lack of knowledge in how to do so. To add to this figure 4.10 gives the details of the natural ventilation override control. As is suggested the natural ventilation override switch is poorly labelled and is confusing for visitors (often mistaken for a light switch). If there are complaints of stuffiness and stale air in the teaching rooms, signage and labelling on the natural ventilation override switch could be improved.
    - Different expectations of occupants may create issues with natural ventilation controls; e.g. when occupants choose to override BMS settings via the manual switches. According to interview comments, the control of vents could be more flexible; occupants can use the switch to close them, but cannot open them again, unless they are automatically triggered again or manually opened via the BMS.

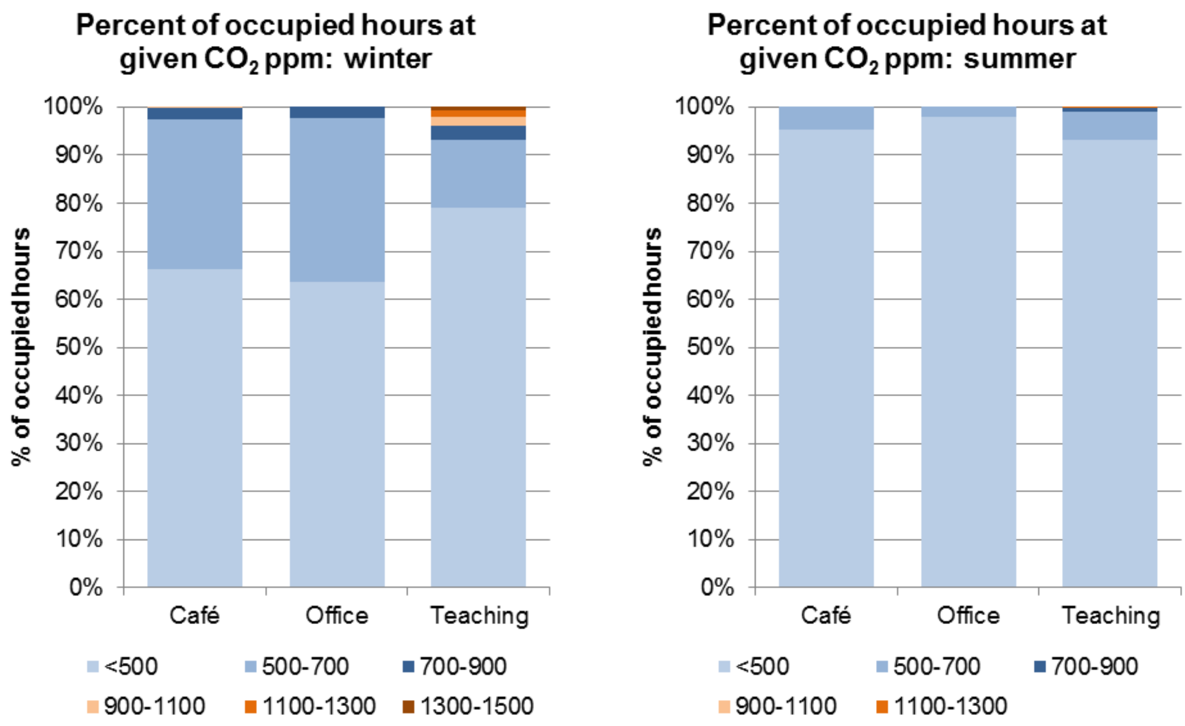


Figure 4.9 percent of occupied hours at a given CO_2 concentration range in winter and summer

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

The motor driven louvers (at floor level) are automated to open and provide natural ventilation if the room temperature exceeds 23 degrees C or the CO_2 sensor detects high levels of CO_2. Alternatively, the louvers are manually controlled by a simple on/off switch in the room. This ‘natural vent override’ switch is labelled; therefore clarity of purpose is moderate. There is no flow control. The ventilators are either in opened or closed position.

Figure 4.10 Control review for natural ventilation override

4.3.2 Relative humidity

BUS respondents consider the air to be dry in both seasons; in summer this result classifies the building as worse than the BUS benchmark. As would be expected, on the day of survey, RH levels were low, 36% in the office (too dry) and 45% (acceptably low). Figure 4.11 illustrates the relative humidity for occupied hours in the café, office and teaching room over the winter and summer. The graphs indicate:

- Though the BUS respondents said the building was equally dry in both seasons, it appears that the winter RH is generally lower (much drier) than summer.
- The summer RH, for the majority of occupied hours, is within the recommended operative range 40-70%. Whereas, here the summer RH appears to be acceptable, it is important to note that the BUS responses were collected before the summer of 2013 and were collected on a day with low RH readings after the winter was fresh on the minds of the respondents.
- Higher (satisfactory) RH levels in summer are further attributed to the ventilation strategy.

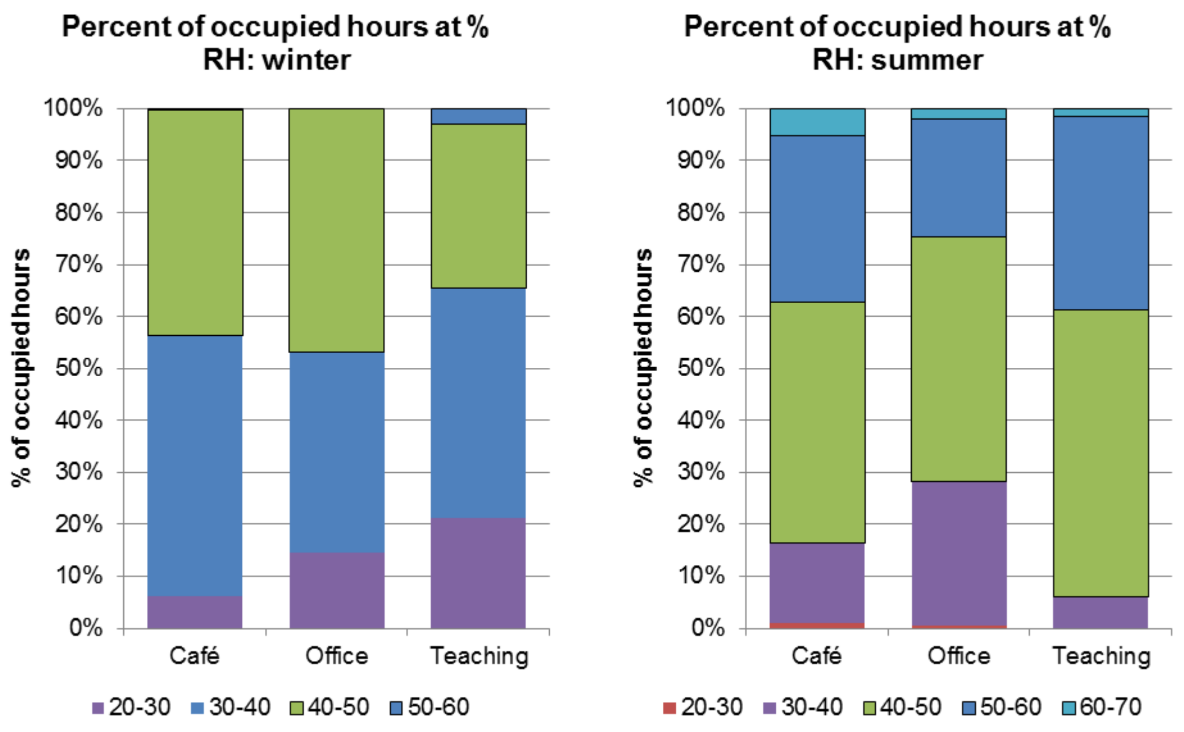


Figure 4.11 percent of occupied hours at a given relative humidity range in winter and summer. *Note: black borders indicate recommended operative RH percentages.*

The same can be seen in the monthly maximum, minimum and average RH per month (figure 4.12). The average relative humidity for the office and teaching room are within the recommended range for the months of June – October and potentially unacceptable for a majority of the time in February – April.

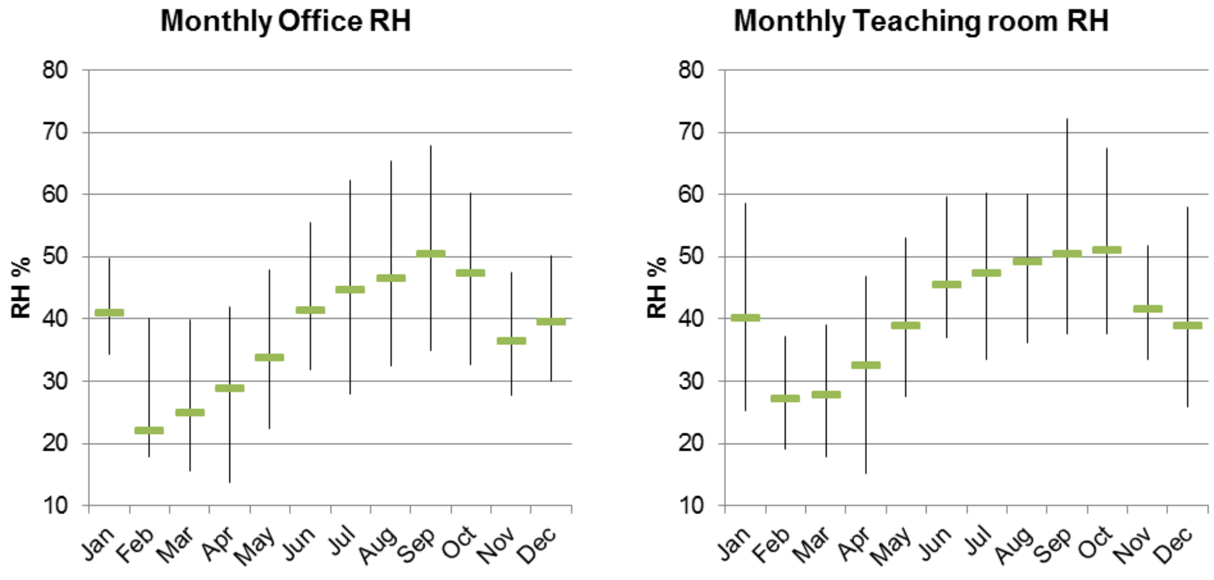


Figure 4.12 monthly RH for the office and teaching room. *Note: January and February data are incomplete for a majority of the month.*

4.4 Lighting

The analysis of the BUS questionnaires showed that lighting is one of the most appreciated sensory elements of the building. The interviewees are also satisfied with the quality of light.

Figures 4.15 and 4.16 present the calculated daylight factors for SusCon's internal spaces.

- Teaching spaces appear to have insufficient levels of natural light.
- Offices, meeting room, 1-1 meeting rooms and café area are within the optimum range of daylighting.
- These spaces together with the kitchen are located in the southwest part of the building which is found to obtain higher light levels during afternoon hours and therefore possess higher levels of daylight. Though this is the case, electric lighting also remains on during most of the time to accommodate occupants' requirements.
- The two workshop areas have the highest daylight factor values. Both areas consist of large glazing areas that provide spaces with large amounts of daylight. Glare is not reportedly an issue in these spaces (figure 4.13).
- Finally, adequate daylight is provided to the atrium area where reception and the entrance hall are located. The upright artificial lighting luminaires are controlled by daylighting sensors and are rarely switched on during daytime (figure 4.14).
- Daylight analysis and occupant opinion confirm that the teaching rooms are not provided with adequate daylight levels whether overcast or sunny, making electrical lighting necessary during occupancy periods.
- Reception and circulation corridors benefit from daylight through atrium windows and main and rear entrance areas on the ground floor.
- High daylight factors of above 15% have been identified close to the main entrance area which is not shaded by external louvers.

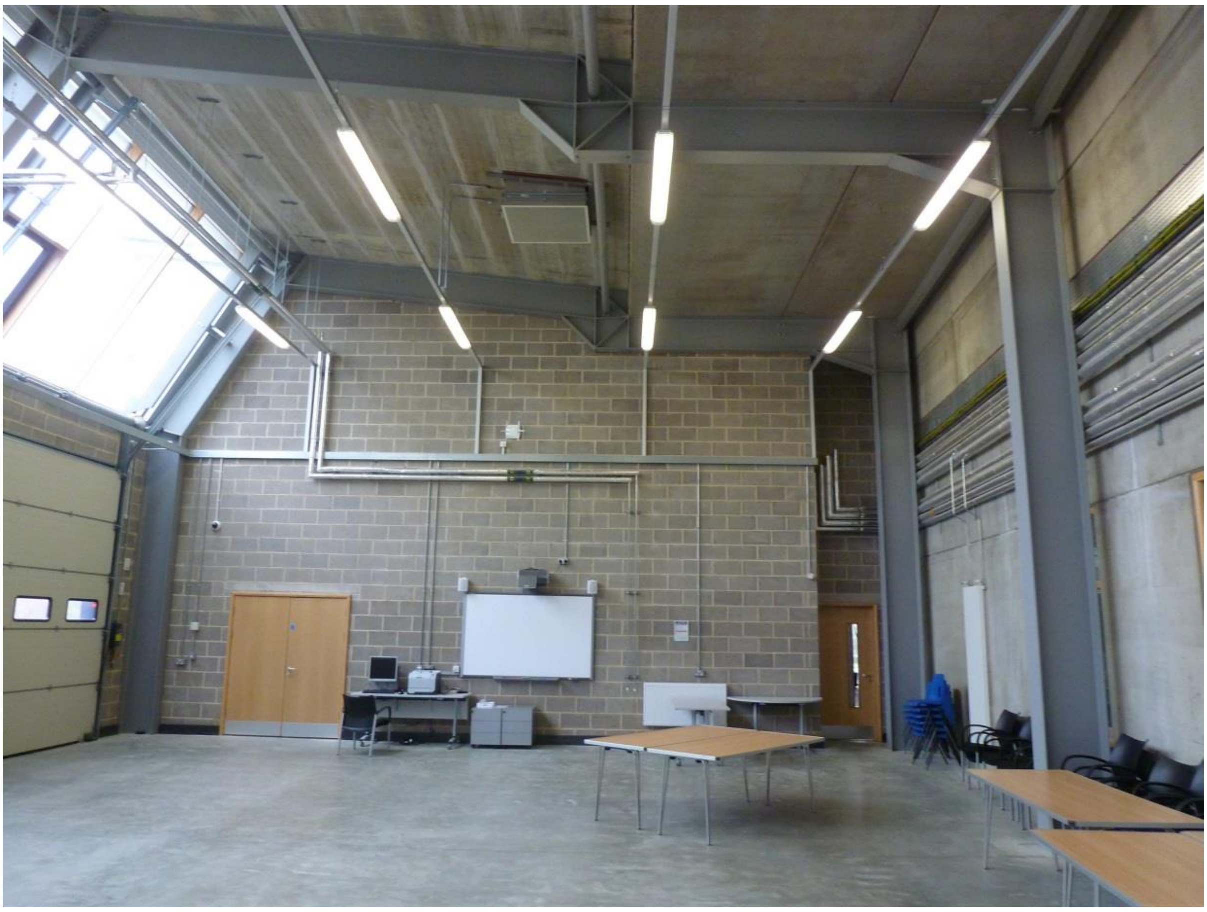


Figure 4.11 Workshop (northwest corner)

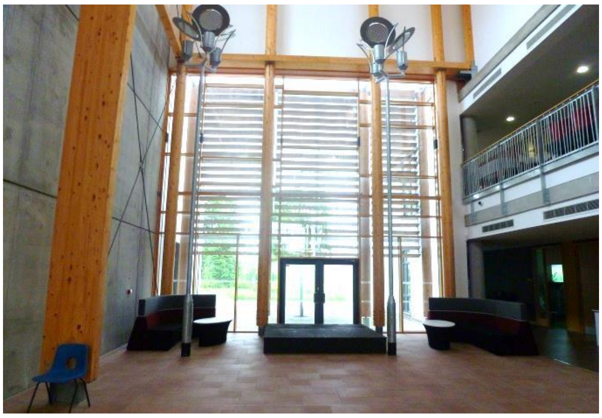


Figure 4.12 Left: Atrium/reception area | Right: Upright luminaires in the reception area and atrium windows.

Figure 4.15 Ground floor daylight factor plan

Figure 4.16 First floor daylight factor plan

4.5 Perception of control

Figure 4.17 illustrates the findings from the BUS questionnaire regarding perception of control. Overall there is little sense of control for the occupants over the local work environment which is no different from the BUS benchmark apart from control over lighting which is also worse than the BUS benchmark.

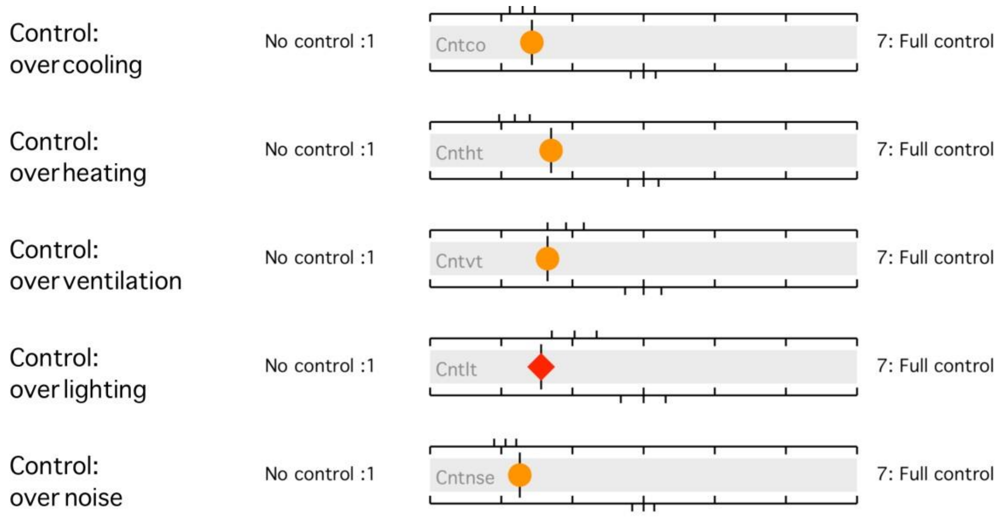


Figure 4.17 BUS responses: control

- Locally, heating is controlled through the individual radiator valves in all SusCon spaces, apart from the atrium where underfloor heating is installed. Though this would appear to provide sufficient control, interviews indicate otherwise; there are only two radiators on either side of the office; 'as a result one side is boiling hot and the other is freezing.' Therefore some occupants use portable heaters, although they are aware that it will increase the energy consumption for the building.

- Control over lighting is rated low because lighting is generally operated through a remote control available to SusCon staff and occupants only upon request. Easier access to the remote control for lighting and guidance on using it could enable occupants to have an enhanced level of control.

- Occupants are very unhappy with outside road noise and suggest that it hinders their willingness to use the windows for additional ventilation and heat release in summer. The same office occupant interviewed, suggested that the window is often 'kept closed' due to road noise. Window monitoring suggests that the office windows are used but possibly not as much as occupants would prefer, e.g. three windows in the office are open at least 30% of occupied hours in July where the average internal temperature was almost 27°C (maximum just below 30°C).

4.5.1 Control over ventilation and cooling

For cooling and ventilation, the occupants must open windows or override the motor driven louvers which allow natural ventilation when specific internal variables are reached. Though windows are considered to be easy to open, there are significant complaints coming through both the BUS and interviews with regard to road noise (from the A206 – as seen through the window in figure 4.18) hindering use of the windows. This issue is likely to make occupants feel like they are less in control of their environment. To add to this, it is possible that the small degree to which the windows can be opened would give the occupant a sense of less control. The windows in figure 4.18 are open to the maximum allowable degree.

Doors to rooms are often left open for cross flow ventilation. There were no complaints of noise outside rooms (from within the building) which would hinder the use of doors in this way.

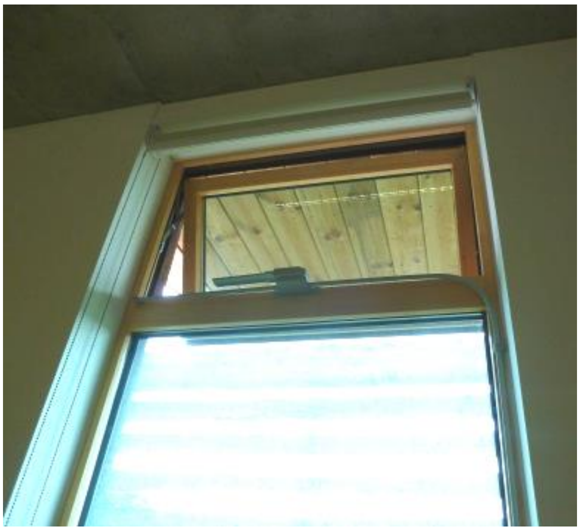


Figure 4.18 office windows in open position: left image: lower window, right image: upper window

Figure 4.19 shows the location of the monitored windows in the office on the first floor.

Figure 4.19 Monitored windows in the first floor office

Figures 4.20 and 4.21 illustrate office and external temperatures with window opening times during July 2013. The two weeks are *Sunday – Saturday 14-20th July 2013* and *Sunday – Saturday 21-27th July 2013*. These weeks were selected to show the conditions around the July 2013 'hot and dry spell' experienced in the south east of England. In addition, 22nd July 2013 was the date on which the highest office temperature (29.6°C) was the recorded for the year. For the same period, figures 4.22 and 4.23 illustrate the CO_2 concentration and RH. *Note: the centre windows are grouped because during the graphed periods they are all opened together when opened. The left window is the only window which is operated differently.*

- The building could benefit from night ventilation in the summer months: over the 18th and 19th of July all four windows are left open overnight, this allows the morning of the 19th to begin at a lower temperature and rise slower throughout the day (figure 4.20). More effectively, the three centre windows are left open from the 23rd – morning of the 26th July. This allowed the office temperature to drop to 23°C the night of the 23rd and kept the daily maximum 2°C lower than the typical of 29°C even while the daily maximum external temperature for the 24th peaked above 29°C (figure 4.21).

- Unlike temperature, CO_2 concentration is kept reasonably low during this period even over the days when the windows are closed.

- BUS responses rated spaces as dry in the summer; opening windows appear to help increase RH.

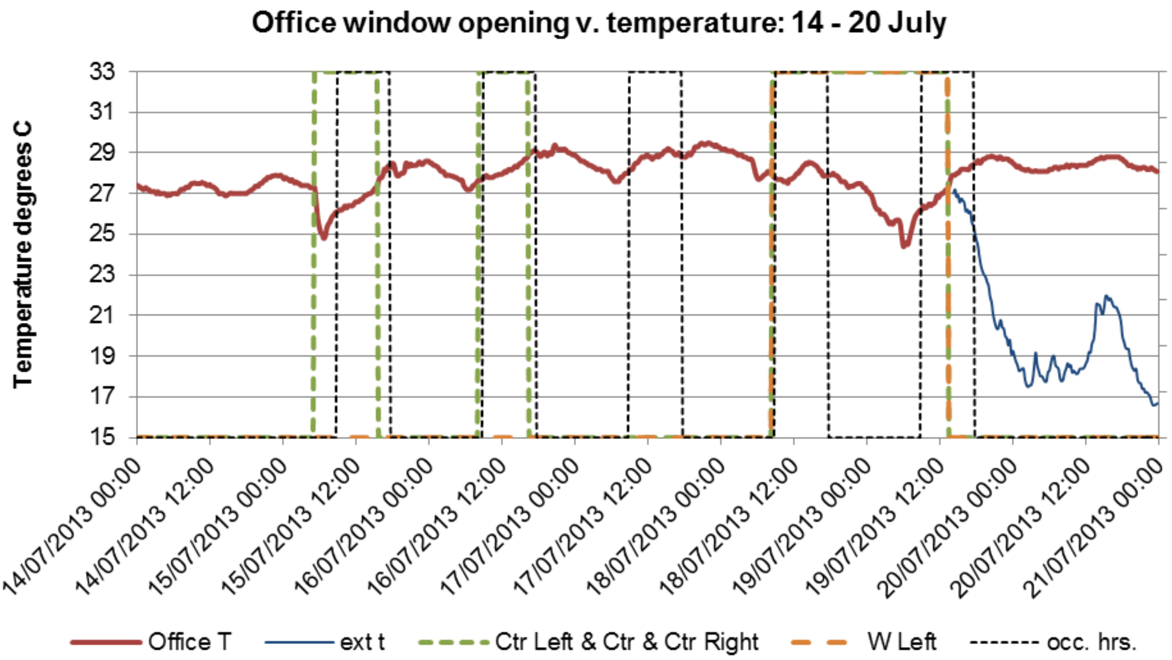


Figure 4.20 Office window and temperatures 14-20 July 2013. *Note: exterior temperature data is unavailable for a large part of the graph.*

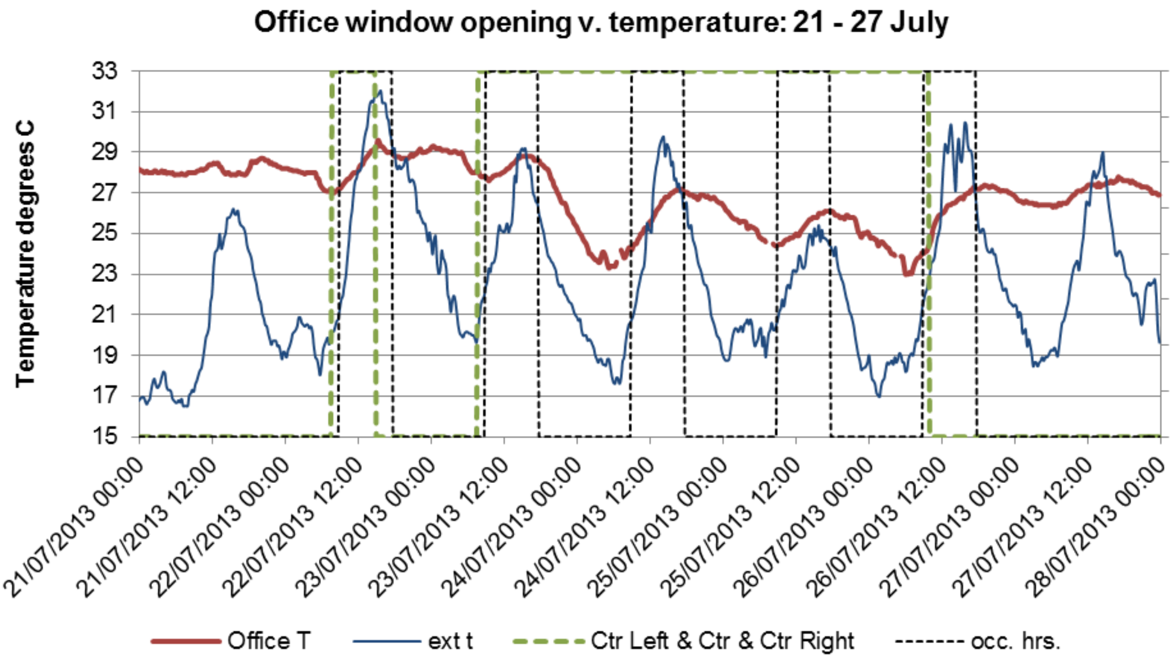


Figure 4.21 Office window and temperatures 21-27 July 2013

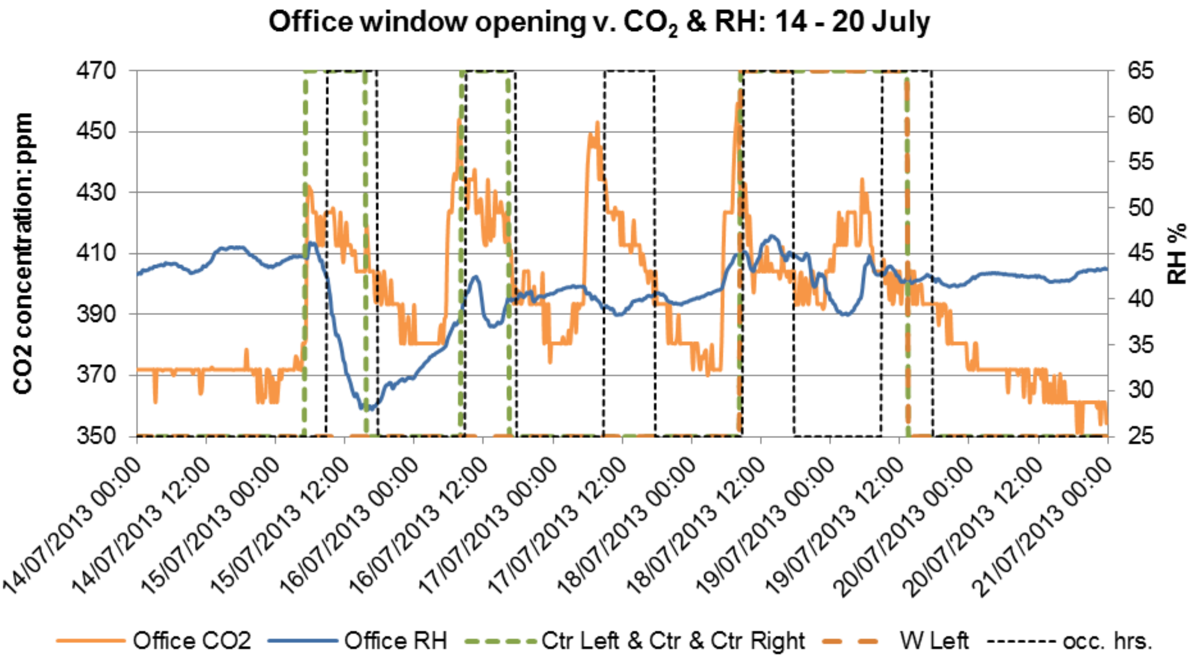


Figure 4.22 Office window, CO_2 and RH 14-20 July 2013

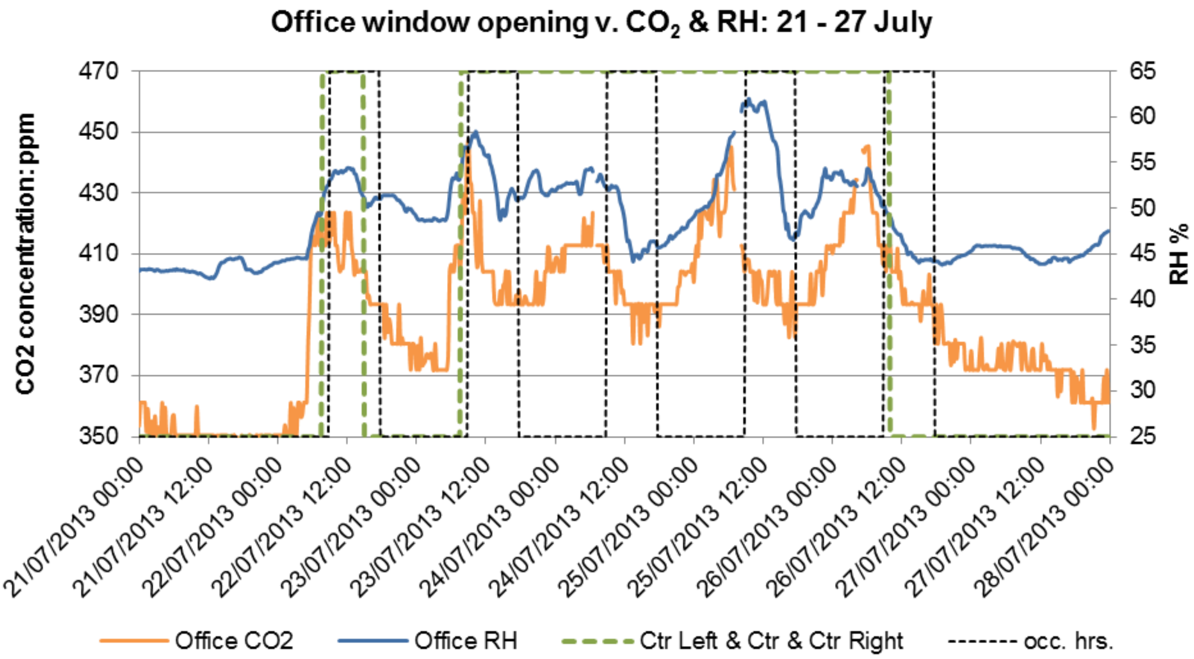


Figure 4.23 Office window, CO_2 and RH 21-27 July 2013

4.6 Underfloor heating

According to the interviews with occupants and management, the underfloor heating was a point of concern for potential energy reduction. From the interviews:

- The underfloor heating is considered to be inefficient because it heats up a large space that is almost always empty (the atrium/corridors).
- Atrium (underfloor) heating runs 24hrs/day and the assistant FM suggests this should not be happening. This is a potential area to reduce energy use.
- The atrium is heated on the weekends, stopping this practice could reduce heating energy use.
- The mean winter temperature (24 hours/day) in the atrium is 23°C. This is between 2-4°C above the CIBSE recommended operative temperature for like spaces. This operative temperature could be reduced during occupied hours and especially outside of occupied hours.
- Interview with occupants indicate that the receptionist finds the underfloor heating to be too hot in the winter and that the receptionist must wear sandals for comfort.

4.7 Conclusions and key findings for this section

- Overall comfort is rated positively but when queried about specific comfort points, issues like too cold and too hot were found to occur within seasons.
- The temperatures in each space are more stable in the winter than the summer as would be expected in a well-insulated free running building with thermal mass; however, the occupant perspective suggested the opposite.

- Winter temperatures were perceived as cold, this was found to be true in the office for one-third of all occupied hours in the winter.
- Summer temperatures were perceived as slightly warmer than mid-scale; two-thirds of the summer occupied hours in the office were above the CIBSE recommended operative temperature. Depending on standard used, there is some marginal overheating in the summer.
- Occupant complaints and the use of portable heaters for personal comfort indicate a possible inefficiency in the heating system design, timing and location of radiators (or workspaces).
- Though air velocity in the majority of internal spaces is lower than the required values for comfortable conditions even when the mechanical louvers are open and natural ventilation through opened atrium windows is activated both BUS and environmental analysis revealed the air to be fresh, signifying a well designed and implemented natural ventilation strategy for the building (as far as providing positive air quality).
- The spaces are too dry from November – May, essentially when the building is heated.
- There is little confidence over control for the occupants, e.g., due to limited opening distance, it is doubtful the manual windows in meeting, teaching and offices would give the occupant a feeling of control over ventilation or cooling their space.
- A considerable percentage (26%) of respondents frequently request changes in heating, lighting, ventilation and overall indoor conditions. Speed of response is rated favourably and significantly better than the benchmark. This affirms the vital role played by the building management team.
- Although occupants find indoor air to be fresh and odourless in summer and winter, the fact that external noise is an issue and deters occupants in opening windows, this could affect the indoor air quality in the future.
- Introduction of night-time ventilation to cool the building in summer would be effective in reducing daytime temperature peaks as has been demonstrated through environmental analysis.
- Natural ventilation appears to be insufficient in maintaining CIBSE recommended relative humidity levels in the winter, where over 50% of measured winter RH levels were below the recommended low of 40%. BUS responses also indicate the winter is dry.

5 Details of aftercare, operation, maintenance & management

Technology Strategy Board guidance on section requirements:	This section should provide a summary of building operation, maintenance and management – particularly in relation to energy efficiency, metering strategy, reliability, building operations, the approach to maintenance i.e. proactive or reactive, and building management issues. This section should also include some discussion of the aftercare plans and issues arising from operation and management processes. Avoid long schedules of maintenance processes and try to keep to areas relevant to energy and comfort i.e. avoid minor issues of cleaning routines unless they are affecting energy/comfort.

5.1 Handover and aftercare

Following the handover in March 2011, practical completion documentation and support included those listed in table 5.1, M&E and BMS training, seasonal commissioning dates agreed. The following list indicates the documents available on site for handover.

Handover documentation checklist	Available on site (✓)
• Legal contract	x
• Architectural – Operation & Maintenance manuals	✓
• Civil & Structural – Operation & Maintenance manuals	✓
• Building Services – Operation & Maintenance manuals	✓
• Health and Safety file	✓
• System Specifications	✓
• Commissioning records	✓
• Log book	✓
• Strategy for energy and metering	x
• Building User guide	✓
• Building manual	✓
• Energy assessment documents	✓

Table 5.1 Documents provided after completion and comments regarding effectiveness

Practical completion documentation provided at handover	
O&M manuals (architectural, civil & structural, building services, mechanical & electrical)	The operation and maintenance (O&M) manual and building user guide were designed as reference documents for the facility managers and building users, since controls of the building and its facilities will be displayed to wider audience for teaching purposes. Maintenance checklists exist in O&M manuals. However ‘word of mouth’ is often used as more ‘convenient and quicker’ approach of addressing any defects. O&M considered to be too technical, overwhelming and not user friendly.
Commissioning records (e.g. BMS commissioning certificate); Systems and BMS training schedule	BMS/ sub-meter commissioning fault (sub-meters not connected to BMS) not caught until initial walkthrough with BPE team (January 2013). Additional training on BMS would benefit facilities manager (FM) Due to poor user interface design and operation, a building management system (BMS) user guide may be compiled for reference as training may be not feasible on a regular basis.

Log book	NWK College estate has a system in place for logging activities and use of the SusCon building logbook would be a duplication of effort. For this reason, the building logbook is used only for significant actions.
Building user guide	Produced according to BREEAM best practice guidelines covering: Building Services, Emergency Information, Energy & Environmental Strategy, information on Water Use, Transport Facilities, Materials & Waste Policy, Re-fit/ Rearrangement Considerations, Reporting Provision and Training. Building user guide considered to be too technical, overwhelming and not user friendly.
Other documents: Key schedule; Arranged security; Arranged insurance; Building Control completion certificate; As built EPC certificate; Deloitte LCA report; Planet Positive Certification; Lift manual; Lighting protection certificate; Air Leakage test report; Health and Safety file; Planning Permission in Health and Safety file	

Though the design team conducted regular visits (every two weeks) to the building during construction of the building and its initial period of occupation, the Soft Landings approach was not specifically adopted for the building. In addition, Basic M&E systems and BMS training session were carried out within a couple of weeks after occupancy.

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 building features and its operation. The main actions required to ensure this include:

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

It is likely that taking an approach like that of Soft Landings would have resolved at an early stage the issues with the biomass boiler and the sub-meters. This is especially true where only after the BPE team visited the building for the first time it was revealed that the sub-meters and rainwater harvesting system were not connected to the BMS.

5.2 O&M guidance and requirements

Maintenance is required to be implemented as detailed within the maintenance section and manufacturer's literature inserted in the O&M manual.

- Maintenance contract recommendations are included in the M&E Health & Safety files.
- The O&M manual covers operation and maintenance requirements for the electrical and mechanical services, e.g., general maintenance guidance, personnel requirements, safety, facility examination and maintenance and maintenance plan of mechanical services is available in the mechanical services O&M manual.
- The O&M manuals suggest that maintenance should be undertaken on certain dates and any activities should be recorded in the building's logbook. A maintenance and system work/failure template was also provided in appendix D of the building logbook.

5.3 Seasonal commissioning

According to key stakeholders, the seasonal commissioning is managed by the SusCon team. All seasonal commissioning has been pre-arranged and the SusCon's FM team has been co-ordinating the implementation of works according to the given schedule after communication with the sub-contractors.

5.4 In practice

The SusCon team follows the maintenance schedule set by the NWK College's estate, according to which the maintenance checks tend to be more frequent than the ones required by the O&M manual.

- Some of these activities are recorded in the building logbook and others are recorded directly to NWK College's diaries according to the college estate's requirements.
- Maintenance checklists exist in O&M manuals; however according to the FM, "word of mouth" is often used as more convenient and quicker approach of addressing any defects. *This would suggest a reactive approach is taken with regard to operation and maintenance.*
- According to building management interviews there was expressed concern over the 24-hour heating of the atrium but no evidence of action taken to manage or alter this potential opportunity for energy reduction in the building.
- A considerable percentage (26%) of BUS respondents frequently request changes in heating, lighting, ventilation and overall indoor conditions. Speed of response is rated favourably and significant better than the benchmark. This affirms the effectiveness in the building management team's response strategy.

5.5 Conclusions and key findings for this section

- Overall, aftercare, maintenance, operation and management have not lived up to expectations partly because the use of the building did not turn out as expected.
- According to the handover assessment from March 2013, the seasonal commissioning and maintenance of the building runs smoothly under the management team.
- Since SusCon is part of the NWK College's estate management, most of maintenance activities are required to be recorded in the college's archives. According to the management team it would be a duplication of effort to copy those entries in the building logbook.
- Defects are reported directly to the FM team via personal communication.
- According to the FM, the O&M manuals are found to be very helpful in the everyday operation of the building.
- It is likely that following the Soft Landings approach, particularly including onsite support and review of systems, would have caught and led to the revision in the commissioning faults.
- As the building management expressed concern over excessive energy use in the atrium, there appears to be either an issue with knowledge on how to investigate the issue, motivation, or permission to change energy and heating schedules.

- Building occupants are satisfied with the speed of response with regard to requests for indoor environment changes or repairs.

6 Energy use by source

Technology Strategy Board guidance on section requirements:	This section provides a summary breakdown of where the energy is being consumed, based around the outputs of the TM22 analysis process. This breakdown will include all renewables and the resulting CO_2 emissions. The section should provide a review of any differences between intended performance (e.g. log book and EPC), initial performance in-use, and longer-term performance (e.g. after fine-tuning and DEC – provide rating here). A commentary should be included on the approach to air leakage tests (details recorded elsewhere) and how the findings may be affecting overall results. If interventions or adjustments were made during the BPE process itself (part of TM22 (process), these should be explained here and any savings (or increases) highlighted. The results should be compared with other buildings from within the BPE programme and from the wider benchmark database of CarbonBuzz.

6.1 Simple assessment (TM22 benchmarking and analysis)

The following simple assessment from TM22 benchmarking and analysis covers the period from 1st October 2013 to 1st October 2014. This section assesses energy use in the building after the occupancy change and biomass boiler decommissioning which were both complete by summer 2013. Some brief comparisons will be made to earlier assessments, i.e. before the occupancy change. Refer to the interim report for detailed assessment of this prior period.

A majority of the energy supplied (and carbon dioxide emissions) in the SusCon Academy is from mains gas. Gas supplied to the building for the 12 months to 1st October 2014 was 236,607 kWh per annum which equates to carbon dioxide emissions of 45,902 $kgCO_2$ per annum (at the default carbon factor for natural gas of 0.194). This equates to 90.6 kWh/m^2/year. *Comparing the 2012-2013 consumption to 2013-2014 consumption for the same period there has been a reduction of 20,847 kWh in heating fuel consumption.*

Grid electricity consumption for the 12 months to 1st October 2014 was 87,932 kWh per annum which equates to carbon dioxide emissions of 48,363 $kgCO_2$ per annum (at the default carbon factor for electricity of 0.55). This equates to 33.7 kWh/m^2/year *Comparing the 2012-2013 consumption to 2013-2014 consumption for the same period there has been a reduction of 30,510 kWh in grid electricity consumption.*

The photovoltaic electricity generated on site has been metered at 34,326 kWh per annum for the 12 months to 1st October 2014, of which 28,758 kWh was used on site, and 5,567 kWh was exported to the grid. *There is suspicion that the photovoltaic generated and used on site figures are incorrect. It is presumed that these values are overestimated by a factor of 1.4. This presumption is based on the estimated annual generation of 25,422 kWh as estimated from the size of the PV: 29.68 kWp. This report, however, is using the metered data which is available.*

The following Key Performance Indicators (KPI) provide the total conventional energy supplies that would have been required if on-site renewables were not present:

- Total electricity: 116,690 kWh p.a. | 44.7 kWh/m^2 | 64,180 $kgCO_2$ (carbon factor 0.55)
- Total natural gas: 236,607 kWh p.a. | 90.6 kWh/m^2 | 45,902 $kgCO_2$ (carbon factor 0.194)

SusCon's annual (supplied) energy consumption and carbon dioxide emissions are shown in table 6.1.

Table 6.1 Energy and carbon dioxide performance for 12 months from 1 October 2013

Unit values	Energy supplied (kWh/m^2 GIA)		Carbon dioxide emissions (kg CO_2/m^2 GIA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied	90.6	33.7	17.6	18.5	36.1
Combined benchmark	167.6	44.9	32.5	24.7	57.2

Figures 6.1 and 6.2 graph the grid energy supplied to the building during the annual period of assessment.

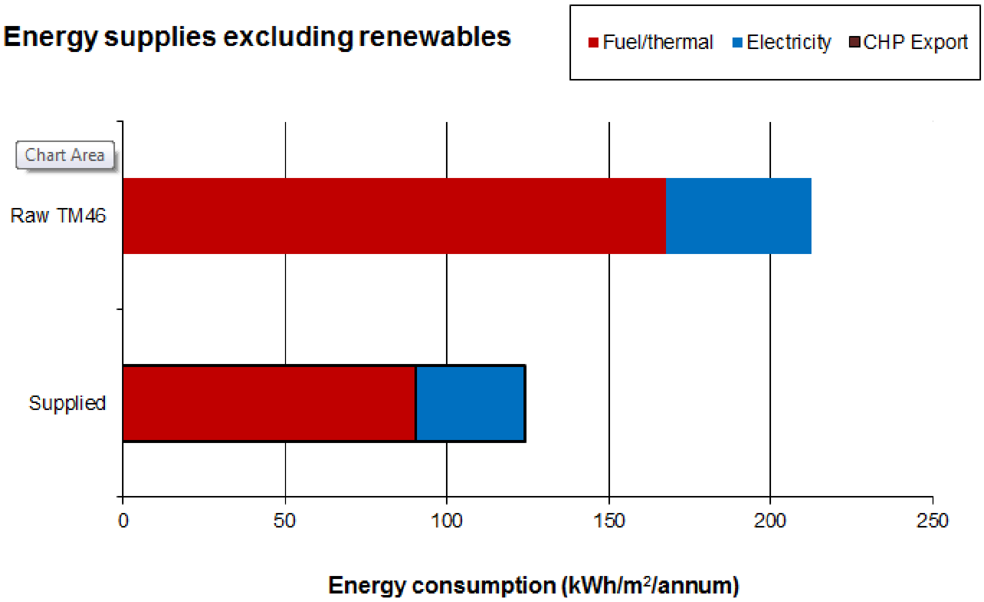
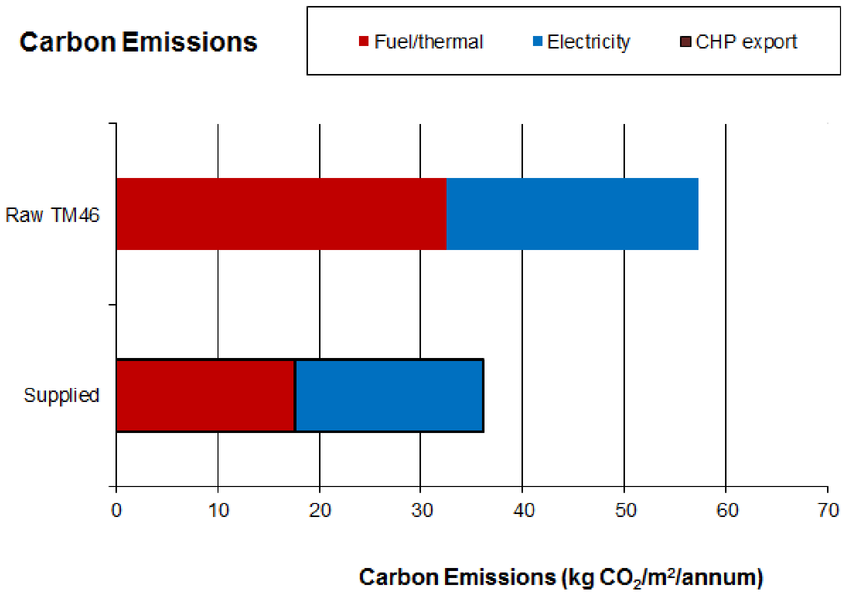


Figure 6.1 Energy supplied excluding renewables (i.e. PV)



CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Natural gas	0.194
Other delivered heati	0.025
Renewable electricity	0

Benchmark CO_2 factors:	kg CO_2 /kWh
Electricity (grid)	0.55
Gas	0.194

Figure 6.2 Carbon emissions

Supplied energy use and resultant CO_2 emissions are lower than the TM46 benchmark. Natural gas supplied is far lower than the benchmark as compared to the difference in electricity supplied; electricity supplied is extremely close but still below the benchmark. Overall the SusCon Academy is supplied energy that equates to 63% of the CO_2 emissions of the TM46 benchmark. SusCon's annual energy consumption and carbon dioxide emissions are shown in table 6.2.

Table 6.2 Energy and carbon dioxide performance for 12 months from 1 September 2013

Unit values	Fossil fuel equivalent energy (kWh/m^2TADA)		Fossil fuel equivalent CO2 (kg CO_2/m^2 TADA)		
	Fuel/thermal	Electricity	Fuel/thermal	Electricity	TOTAL
Supplied less separables	90.9	19.6	17.6	10.8	28.4
Renewables (used on site)	0.0	11.1	0.0	6.1	6.1
Renewables (exported)	0.0	-2.1	0.0	-1.2	-1.2
Exported CHP	0.0		0.0		
Combined benchmark	167.3	44.7	32.5	24.6	57.1

Figures 6.3 and 6.4 graph the complete operational energy picture for the annual period of assessment.

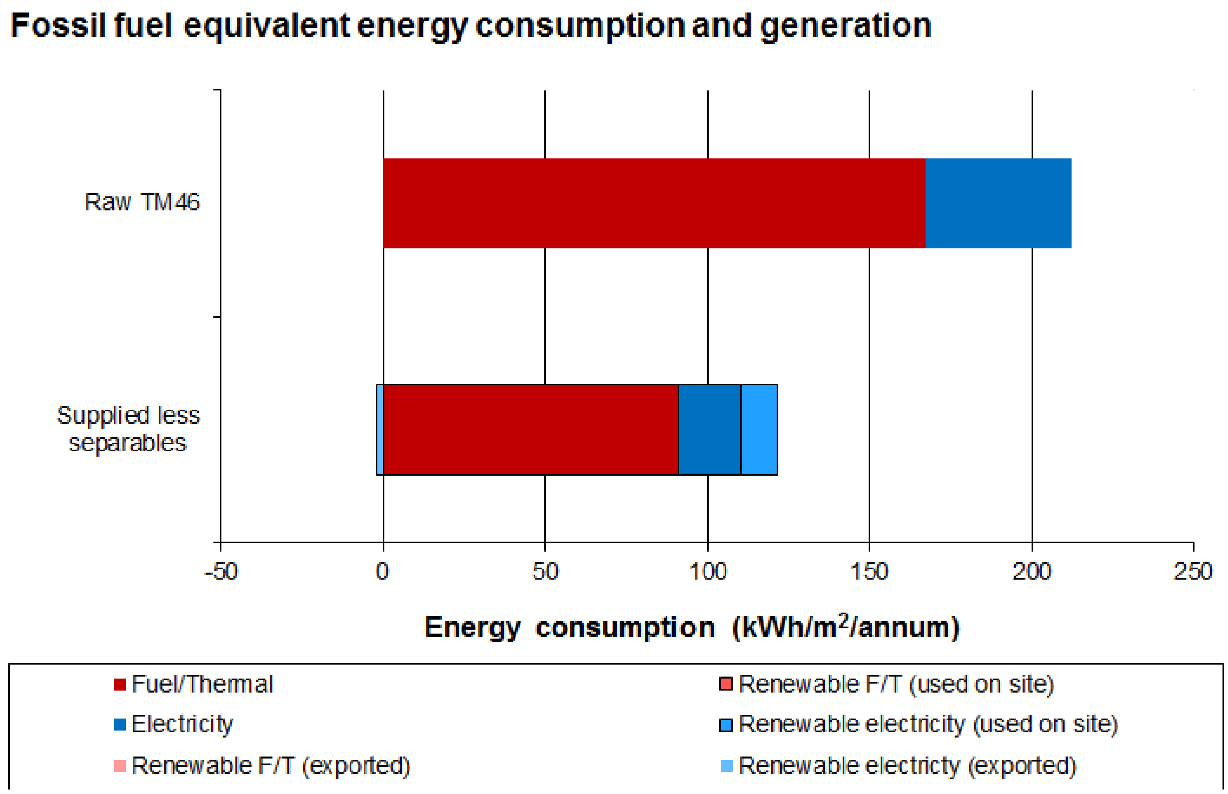
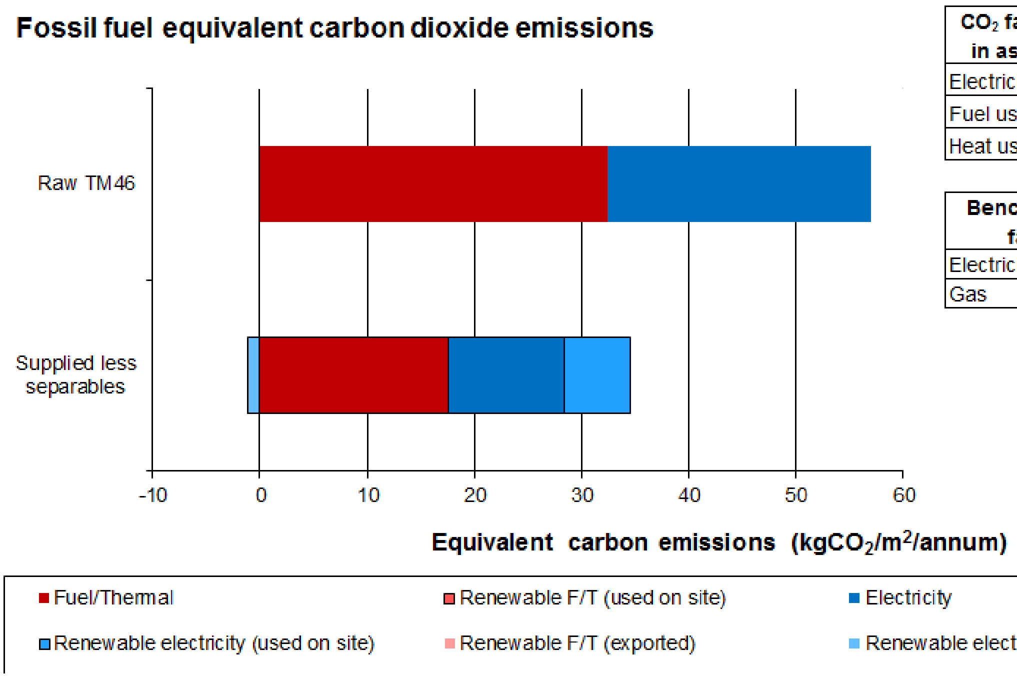


Figure 6.3 Energy supplied excluding renewables



CO_2 factors used in assessment:	kg CO_2 /kWh
Electricity (grid)	0.55
Fuel use	0.194
Heat use	0.243

Benchmark CO_2 factors:	kg CO_2 /kWh
Electricity (grid)	0.55
Gas	0.194

Figure 6.4 Carbon emissions

Predicted regulated emissions from the building were 9.4kgCO_2/m^2/year. This represents an annual saving of 55tCO_2 (70%) compared to a Building Regulation Compliant benchmark and 124tCO_2 (84%) compared to an existing building (pre 1995). This aligned the project with the UK Government 2050 target of an 80% reduction in national CO_2 emissions compared with 1990 levels. However, the supplied (actual) CO_2 emissions rate is found to be nearly four times worse (table 6.3) than the building emissions rate (BER) (design aspiration) despite the fact that the building is reported to have been under-used. To be considered:

1. BERs do not include all the end uses of energy and
2. SusCon is classified as 100% ‘further education university building’ which is different from reality.

Table 6.3 Supplied emissions rate and design emissions

	kgCO_2/m^2/yr
Actual carbon dioxide emissions rate (October 2013 - 2014)	**36.1**
Building CO_2 emissions rate (BRUKL document)	**9.4**

- An obvious ‘reality gap’ or performance gap would come from the designed intent to allow the biomass boiler to act as the primary heat source and the gas boiler to act as back up. As a theoretical example, if the biomass boiler were responsible for 80% of the thermal energy for the year of analysis (October 2013 - 2014), the total supplied emission rate would be 23.8 kgCO_2/m^2/yr. As electricity alone is 18.5 kgCO_2/m^2/yr, the boiler change does not explain the entire gap.
- Further to comments made by the assistant facilities manager in the interviews, it is possible that the under floor heating system is running far longer than necessary (Section 4.6).
- Meeting and teaching rooms are heated when unused for entire days (Section 7.1).
- Equipment and lights are left on for long periods when not used (Section 7.1).

6.1.1 In-use assessment

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. Table 6.4 lists system and end use estimates. Refrigeration and internal lighting are estimated to be the largest electricity consumers on site. Figure 6.5 graphically presents the same.

Table 6.4 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	74.1	0.0	0	0.0%
Hot water	1.3	0.0	0	0.0%
Refrigeration	0.0	9.3	24,178	20.6%
Fans		0.3	657	0.6%
Controls	0.0	4.1	10,679	9.1%
Lighting (Internal)	0.0	15.5	40,389	34.5%
Lighting (External)	0.0	4.6	12,023	10.3%
Small Power	0.0	3.9	10,119	8.6%
ICT Equipment	0.0	5.0	13,140	11.2%
Vertical transport	0.0	0.0	27	0.0%
Catering - Central	0.0	0.9	2,345	2.0%
Catering - Distributed		1.4	3,612	3.1%
Total	**75.5**	**44.9**	**117,169**	100.0%
Metered building energy use	75.5	44.7	116,690	
Variance TM22 versus metered total	0.0	0.2	479	
Variance TM22 versus metered total	0%	0%	0%	

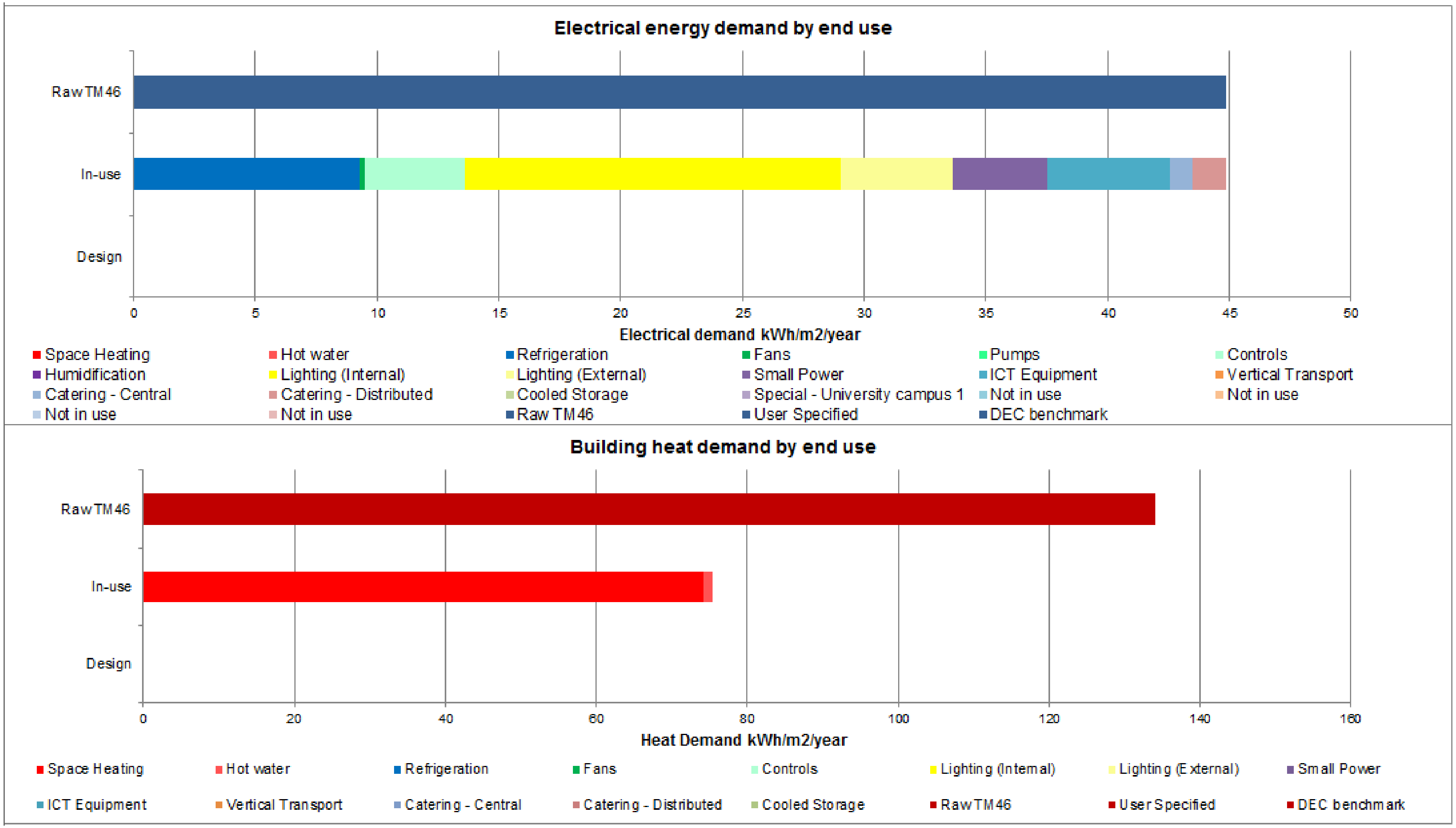


Figure 6.5 Electrical and heat energy demand by end use.

6.2 Benchmarking

Figures 6.6 and 6.7 illustrate the SusCon building against standard TM22 benchmarks and other relevant university buildings on Carbonbuzz. Data from July 2012 – July 2013 is used for SusCon to represent the building when it was most occupied during the study (even during this period the building is considered to be under-utilised).

- SusCon heating fuel demand in kWh/m^2/yr is above ISO 12 ECON 19 Good Practice.
- Overall whole building CO_2 emissions for SusCon is better than all benchmarks including three Carbonbuzz sampled university buildings.

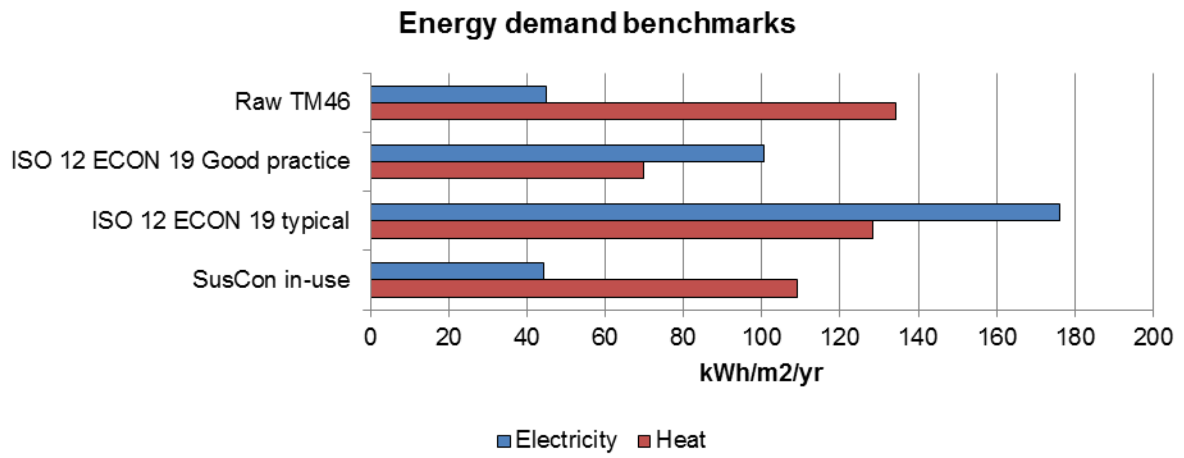


Figure 6.6 Energy demand benchmarks. *Note: ISO 12 ECON benchmarks are for type 2 office.*

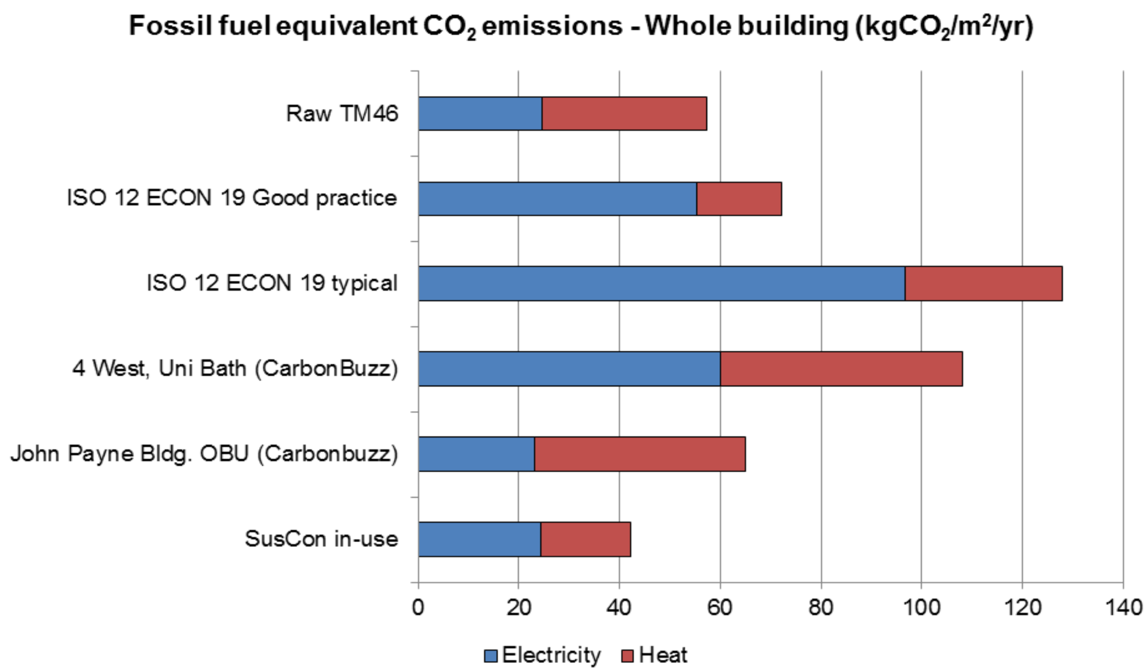


Figure 6.7 Whole building CO_2 emissions benchmarks. *Note: ISO 12 ECON benchmarks are for type 2 office.*

6.3 Conclusions and key findings for this section

The SusCon building's 2013-2014 emissions (36.1kgCO_2/m^2/yr) are lower than the raw CIBSE TM46 benchmark but almost **four times** the predicted regulated emissions according to the BRUKL document. Though the BER does not include unregulated end use, this is much higher than would be expected, particularly considering the building is under-occupied and underused.

- Though the biomass boiler, a key element in the sustainable appearance of the project, has been decommissioned, using it as designed would not be sufficient in closing the gap. Based on 2013 - 2014 consumption, if the biomass boiler were responsible for 80% of heating energy, emissions would only be reduced by 12.3 kgCO_2/m^2/yr. In addition to this reduction, a larger reduction than this in electricity consumption would be required to meet the predicted emissions.
- From October 2013 – 2014, heating fuel consumption was fairly well correlated to weather and was cumulatively in line with HDD.
- Electricity generated by the PV panels offsets 14% of the fossil fuel equivalent carbon emissions of the building.
- A much larger reduction would need to take place in the area of electricity use. Unfortunately due to a lack of sub-metering data, areas of large electricity users cannot be isolated.
- The as-built air permeability was almost exactly the same as the as-designed air permeability. The as-built air permeability (7.08m^3/(h.m^2) at 50Pa) is better than the building regulations target (10m^3/(h.m^2) at 50Pa). Obviously the air permeability could be better but there were no expectations beyond this performance in the BER.

Potential areas of reduction:

- Electricity use from electrical lighting could be reduced in meeting rooms and teaching spaces by installing occupancy sensors or through better management of lighting controls in these rooms (some occupants suggest that the lighting is left on in unoccupied rooms).
- The workshops were designed with large high windows which allow for substantial levels of daylight. Electricity use from lighting could be reduced by installing daylight sensors.
- Heating consumption could be reduced in the atrium. The temperature could be reduced overall and the heating schedule could be shortened.
- Further heating could be reduced during the winter particularly as temperatures remain above the CIBSE recommended operational temperature in some spaces.
- Heating in meeting and teaching rooms should be managed carefully as heating is often left on in unused rooms for long periods.

7 Technical Issues

Technology Strategy Board guidance on section requirements:	This section should review the underlying issues relating to the performance of the building and its systems. What are the technical issues that are leading to efficiency results achieved to date? Are the automated or manual controls effective, and do the users get the best from them? Are there design related technical issues which either need correcting/modifying or have been improved during the BPE process? Did the commissioning process actually setup the systems correctly and, if not, what is this leading to?

7.1 Controls and energy waste

Highlights of the in-use performance and usability of controls are summarised in this section to identify underlying technical issues that contribute to measured performance. Furthermore, energy wastage is identified where controls or systems are found to be misused. For detailed photographic and graphic survey of each control refer to Q6, evidence 3, Review of controls report.

Heating and hot water (thermal energy) controls

- The biomass boiler is conveniently located next to the biofuel storage. The boiler has intuitive switching but the control is complex and the facilities management team prefers to let it be programmed and operated by experts. Faults occurred quite often as the biomass boiler needed frequent maintenance which could not be performed internally. Due to ongoing issues, cost concerns and inability to repair the biomass boiler, its use has been decommissioned from May 2013. *The biomass boiler disuse contributes to higher CO_2 emissions than predicted – significant contributor to the performance gap.*

- The backup gas boiler was not designed as the primary heating source though it was designed to take up the load if needed. The boiler and the heat pump controls all have poor identifiers and guidance on use.

- For in-location control of heating, the radiator valves provide a good level of control and are intuitive, accessible and easy to use. The room thermostats on the other hand are confusing as they provide no indication of purpose, control or responsiveness. Regardless, BUS responses indicate occupants feel they have a poor level of control over heating. *Radiators were found to be left on the highest setting in meeting/teaching rooms that were not occupied or booked during the entire day of site visits.*

Ventilation and openings

- Manual windows only open to a maximum of 6-8 inches (figure 7.1). There is no degree of fine control and it is doubtful that the windows provide the occupants with an adequate sense of control over ventilation.

Figure 7.1 operable window – limited opening distance

- The motor driven louvers (at floor level) are automated to open and provide natural ventilation if the room temperature exceeds 23°C or the CO_2 sensor detects high levels of CO_2. Alternatively, the louvers are manually controlled by a simple on/off switch in the room (manual close only). This 'natural vent override' switch is labelled; therefore clarity of purpose is moderate. There is no flow control. The ventilators are either in opened or closed position. *Confusion over the appearance of the louver switches leads to accidental manual operation of the louver in an attempt to turn on or off lighting in meeting and teaching rooms. The result can lead to inadequate ventilation.*

- Interviews with management revealed that the vents in the atrium do not have rain sensors and that if it is exceptionally windy and rainy, rain can enter the building and the BMS settings must be adjusted to close the vents.

Lighting and small power loads

- Internal lights are not labelled and often not controlled without a remote control. External lights are, on the other hand, clearly labelled and operable from an accessible location. In addition to this the external lights are on timers with daylight sensor override, requiring no further control of the external lights on a daily basis. *Fine-tuning of the settings for external lighting for further energy savings is possible.*

- Suspended ceiling luminaires in teaching rooms, offices and meeting room areas are switched on and off via remote controls available to the facilities manager and reception staff. Although teaching and meeting rooms are not occupied during the whole day, lights remain switched on. *Setting lighting in teaching and meeting rooms on occupancy sensors would save electrical energy. Otherwise having on-site staff manage lighting control will also reduce waste.*

- Suspended ceiling luminaires in workshop areas are switched on and off via remote controls available to the facilities manager and reception staff. The lighting is also on occupancy sensor. The workshops receive a large amount of daylight given the large high windows (figure 7.2). To add to this, when weather permits, the garage doors could be opened to allow more daylight into the space further negating the need for electrical lighting. *Setting lighting in workshop areas on daylight sensors could help reduce the use of electrical lighting in workshops.*

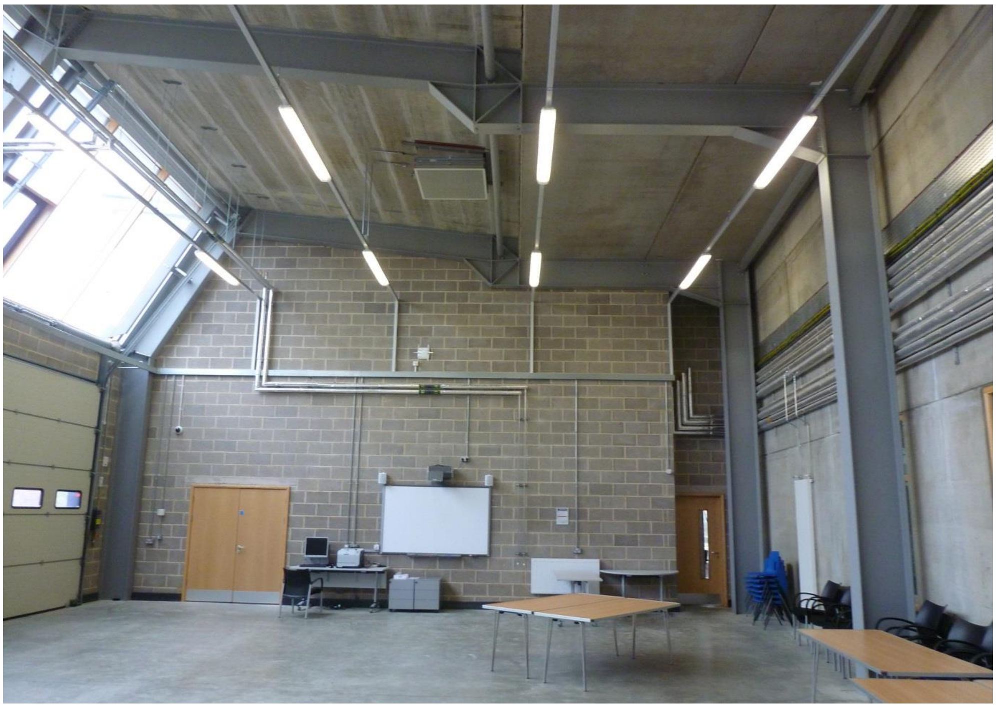


Figure 7.2 ground floor workshop

- In the first floor kitchenette, the lights were found to be left on although next to the light switch there is a sign that says: "HELP CONSERVE ENERGY Turn off lights when leaving." (figure 7.3) *An occupancy sensor would likely reduce consumption in the kitchenette.*

Figure 7.3 kitchenette conservation sign

- In most meeting/teaching rooms (including the workshops) equipment was found to be left on, including computers, projection system (one instance) and audio systems. In almost every room all equipment is left on standby (at least); wall switches were in the *on* position. Figure 7.4 shows the projection system is on standby in the workshop though not used the day of the visit.

Figure 7.4 ground floor workshop projection board on standby

Other findings:

– In the Hawthorne room (ground floor computer lab) three of the 16 computers and the audio system were left on. According to the room booking schedule, this room has not been occupied (officially) since November 2013 and was not scheduled for use through to the end of March 2014. *Estimated to be 698kWh energy wastage over the unoccupied period.*

– In the White Siris room (first floor computer lab) all of the 17 computers were left on. According to the room booking schedule, this room has not been occupied (officially) since November 2013 and was not scheduled for use through to the end of March 2014. *Estimated to be 3,917kWh (standby) energy wastage over the unoccupied period.*

– Mini-refrigerator in the SusCon office was left plugged in and on though the office (and the fridge) are empty and have been since end of summer 2013. *Estimated to be 323kWh energy wastage over the unoccupied period of the office.*

– Atrium lights on when daylight is sufficient for the space (figure 7.5). *500W per post x 10 posts.*

– Television on in atrium – questionable use of energy even if the atrium space was heavily occupied which it is often not (figure 7.6).

Figure 7.5 & 7.6 Atrium lighting and atrium television

Building management system (BMS) and sub-meters

- The BMS trend logging facility appears at first as a normal computer and is in an accessible location; it is however not expected that anyone not introduced to the BMS would need to find and use the BMS. Labelling and basic navigation within the BMS software is OK. Ease of use (downloading data) and degree of fine control (defining periods of data for download) are very poor, slow and frustrating.
- The sub-meters are poorly labelled. The sub-meters were not originally connected to be logged by the BMS although this connection was intended in design. *Without complete sub-metering it is unlikely that the performance of SusCon can be sufficiently optimised or assessed for large energy users.*

Water controls

- The rainwater harvesting system is located in the workshop store. The system and controls are located in a relatively open area with easy access. However, the rainwater harvesting display is not in a public space where it is intended. The rainwater harvesting display is located with the rainwater harvesting system in the store between the two workshops on the ground floor (figure 7.7). This is currently out of view for occupants, where the purpose of the display is to educate and raise awareness. Furthermore, for the reason that the display is out of public sight, the display is not updated to indicate the correct values, i.e. the daily use value matches the total all time value (figure 7.8). Because the display is not being used as per its purpose it is wasting energy (however small that may be).

Figure 7.7 & 7.8 rainwater harvesting system and display located in the ground floor workshop store.

7.2 Thermography

A thermographic survey was undertaken early evening on 20th March 2014. Refer to Appendix D for locations of images in plan and environmental conditions during the survey. Figures 7.9 – 7.13 outline the main anomalies uncovered.

Figure 7.9 Interior of southwest facing external wall in the Walnut room (directly above Catalpa). Image shows heat loss through natural ventilation louver (behind the radiator); ~5°C difference between the point below the radiator (Sp1) and a point on the adjoining wall (Sp2). It is unclear whether the vent was open or closed; however, other radiators in the unoccupied room were on maximum setting, resulting in waste of heat.

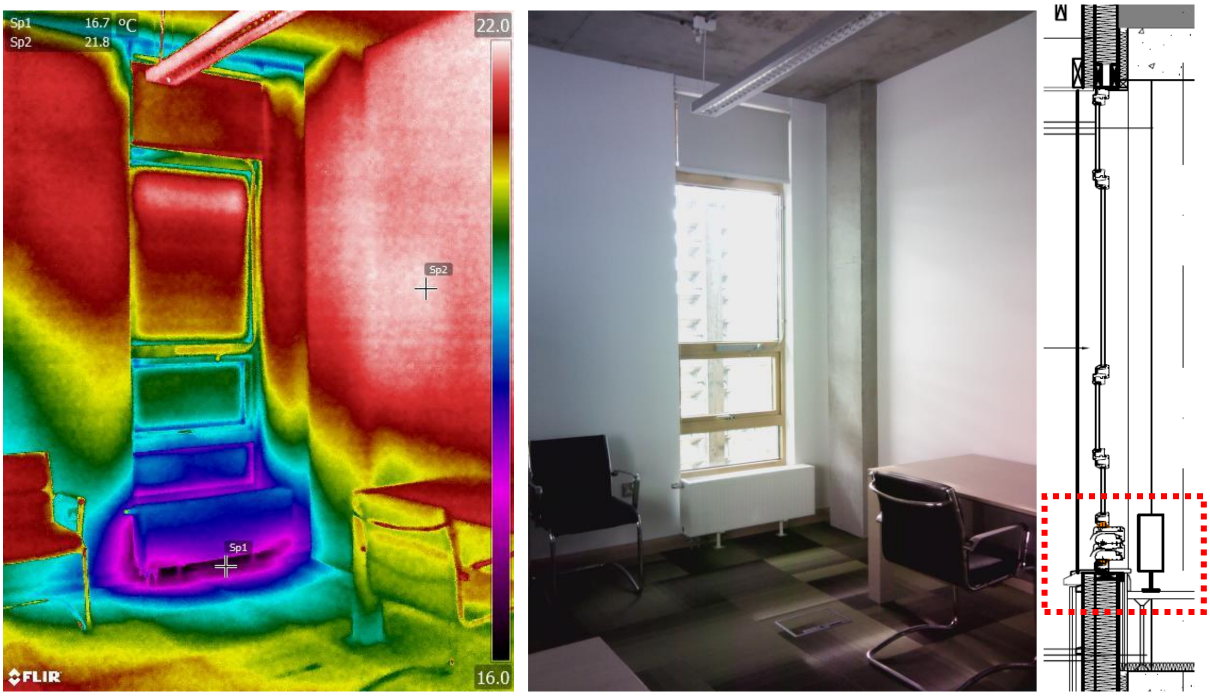


Figure 7.10 Interior of southwest facing external wall in the Catalpa room (directly below the Walnut room). Thermal abnormality where the exposed concrete wall and ceiling meets the wall plaster on the interior of the external wall; ~4°C difference between the lowest point on the adjoining concrete wall (Sp2) and highest point toward the interior of the room (Sp1).

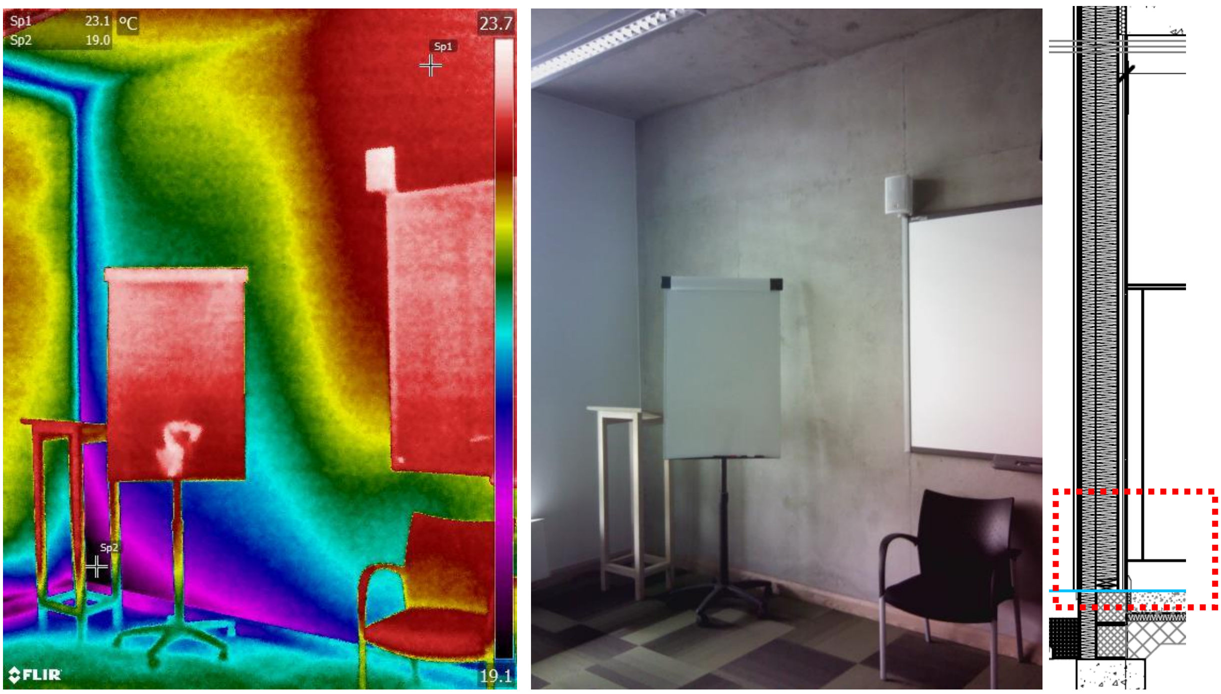


Figure 7.11 Entry façade of SusCon (northwest facing). Signs of potential heat loss under the overhang of the gable and the corner of the building where the atrium space meets the corridor on the second floor; ~3-4°C difference between these hot spots (Sp1) and a point further down the wall (Sp2).

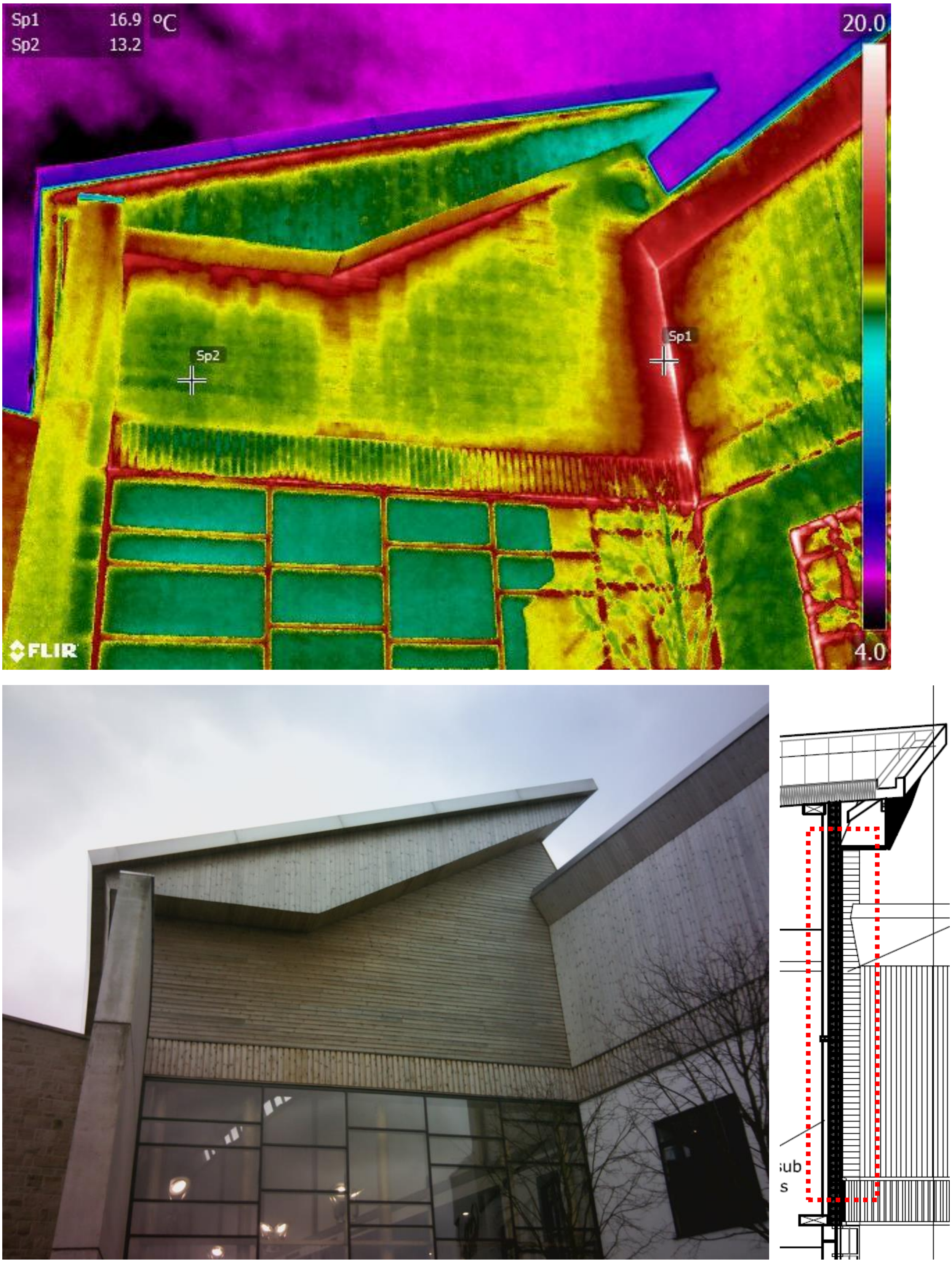


Figure 7.12 West facing corner outside the Linden Room (right of the stairs). Signs of potential heat loss under the overhang of the gable and above the windows; ~2°C difference between these hot spots (Sp2 and Sp3) and a point further down the wall (Sp1).

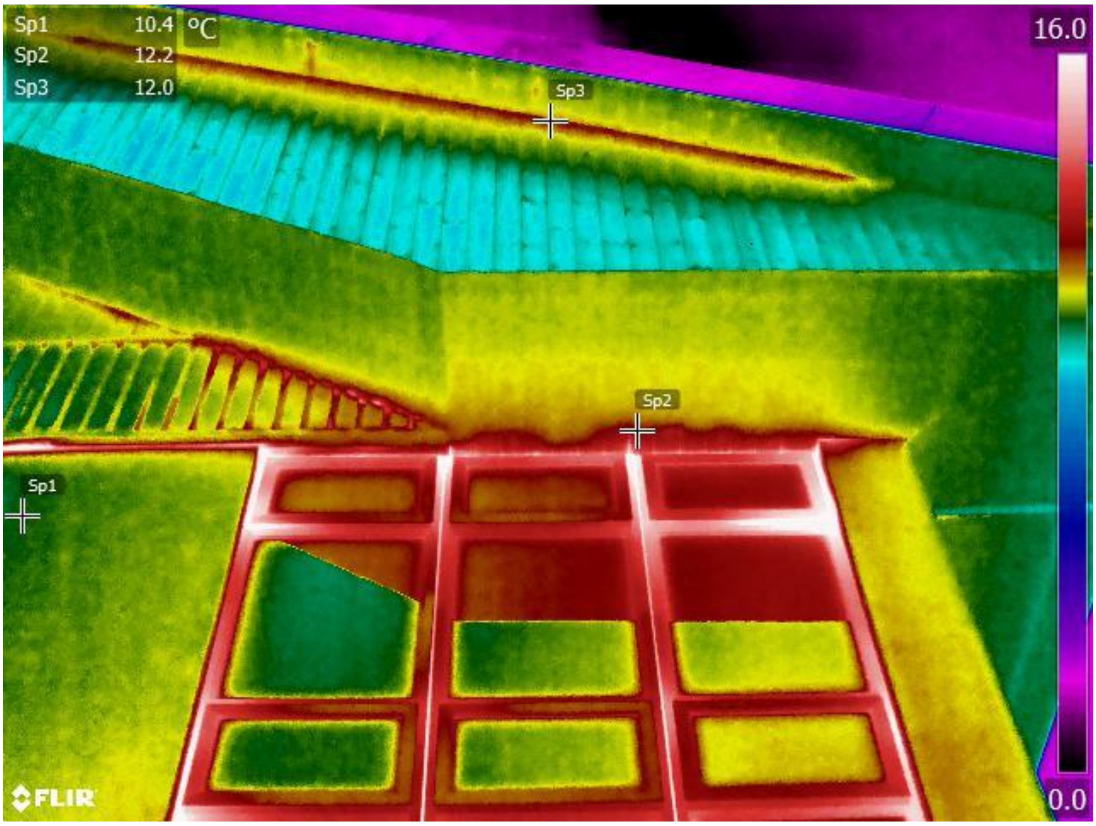
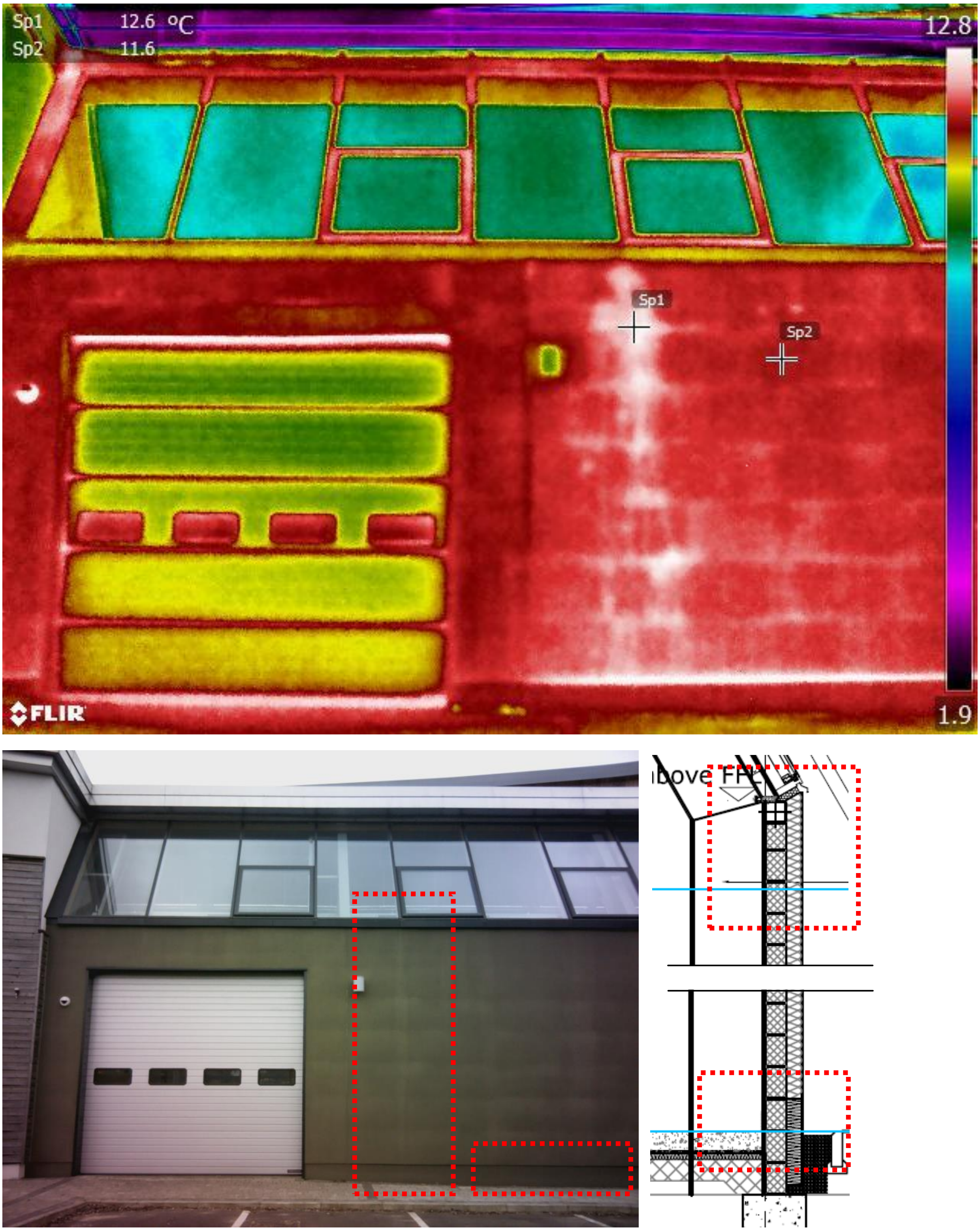


Figure 7.13 Northeast facing (rear façade) of the SusCon building; located outside the Firethorn Workshop (Workshop 1). Signs of heat loss under and above the garage door and signs of heat loss where the external insulation material type changes just above the ground. Thermal abnormality where it looks as though there is water damage in the block wall, between the block wall and the external insulation or within the external insulation; however resulting in only 1°C difference between the water damaged area (Sp1) and a point further down the wall (Sp2).



7.3 Commissioning and technical issues

The primary commissioning errors and technical issues are found in the biomass boiler and the sub-metering. Refer to table 3.1 for faults with the biomass boiler and Section 3.2 for faults with the sub-metering.

7.4 Conclusions and key findings for this section

- Appropriate design discussion with stakeholders, commissioning, aftercare, and operational training for the biomass boiler could have possibly helped avoid the problems and eventual disuse of the system.
- Reception, using the meeting schedule, could turn on and off lights and radiators in meeting and teaching rooms before and after meetings to accommodate visitors while managing energy consumption.
- Review the scheduling for the White Siris and Hawthorn rooms (computer labs); coordinate when to turn on and off computers so that computers are not left on for periods of non-occupancy.
- Kitchenette lighting energy waste could be reduced with occupancy sensors; the turn off light signage does not appear to be sufficient.
- Lights and radiator energy waste is prevalent in meeting rooms, workshops and teaching rooms.
- Computers are found to be left on in computer labs long after the rooms have officially been occupied.
- The rainwater harvesting display is NOT in a public space where it is intended. *There is no educational benefit to this system in its current location. As an exemplar building of sustainable construction the rainwater harvesting system display and potentially the system itself would have been ideally located in a public place.*

8 Key messages and recommendations for the client, owner and occupier

Technology Strategy Board guidance on section requirements:	This section should investigate the main findings and draw out the key messages for communication to the client/developer, the building owner, the operator and the occupier. There may also be messages for designers and supply chain members to improve their future approaches to this kind of building. Drawing from the findings of the rest of the report, specifically required are: a summary of points raised in discussion with team members; recommendations for improving performance, with expected results or actual results where these have already been implemented; a summary of lessons learned: things to do, things to avoid, and things requiring further attention; a summary of comments made in discussions and what these could be indicating. Try to use layman's terms where possible so that the messages are understood correctly and so more likely to be acted upon.

8.1 Public presence

In general the building was designed to serve as a teaching facility on sustainable construction; a live teaching tool. In reality, from a visitor's point of view, there is much to be done in linking operations of the building to informing and teaching.

Similar to an exhibition like forum in the building (e.g. with public display screens with presence sensors), there should be open information on the type of systems in the building, how the building operates and day-day performance of the building (including energy use metrics, carbon metrics, comfort metrics and benchmarks). To maximise dissemination: 1. Sub-meters need to be linked to the BMS or logged in a way to show where and how energy is used in and by the building. 2. Publically acknowledge in a way visitors will see the use of the rainwater harvesting system and the performance (e.g. water saved) of the system. 3. Do the same as above with the PV system.

8.2 Building and energy management

Issues found in this report will persist without responsive action and further investigation.

Assign a willing and knowledgeable individual to direct efficient use and maximise the sustainable features of the building, continually guiding it in the direction of as-designed (or close to it as possible) performance. This person will act as the sustainability champion and work alongside the FM to manage efficient operations. As mentioned in Section 2, the TSB evaluator anticipated there might be issues with implementing the low energy aspirations for the building and the paramount need to have in place a "sustainability champion".

Operation and Maintenance (O&M) manuals and building user guide considered to be too technical, overwhelming and not user friendly. This limitation likely leads to mismanagement of energy consuming equipment, inability to maintain equipment correctly, etc.

Develop technically detailed but user friendly O&M / building user guide (including a user guide for the BMS) which will ensure efficient use of equipment to minimise energy used by the building, well informed maintenance of equipment and building elements, and well-timed and appropriately performed seasonal commissioning. These tools are essential for current and future facility *managers. A user friendly manual / user guide will also be useful for visiting students or trainees as the building is intended to be an exemplar teaching tool for sustainable construction.*

Some sub-meters are still not connected to the BMS and cannot be read on site (though there was an attempt to have all sub-meters connected to the BMS in May 2014, the task was incompletely carried out). Ultimately the current sub-metering arrangement is/ has been ineffective for complete energy management.

The remaining sub-meters should be connected to the BMS for future evaluation and management of energy consumption by building management, training visitors and students.

8.3 Thermal comfort and energy consumption

Occupants find internal temperatures to be uncomfortable at times and do not feel there is sufficient control over thermal comfort in both heating and cooling seasons. The root causes range from difficulty in managing localised temperature with radiators and the location of office, meeting and teaching spaces on the side of the building facing the motorway (limiting ventilation). A knock-on effect is realised through occupants using personal portable heating and cooling devices.

Facility management, as a solution, should review the heating and ventilation schedule and settings, and review personal control issues and localised management with permanent occupants. Demonstration of SusCon's facilities and controls to occupants would enhance the occupants' appreciation of the sustainable nature of the building; occupants could gain an understanding of how to control their own environment and how to achieve thermal comfort without using extra energy consuming equipment, e.g. portable fans. If a solution cannot be found it is possible that personal heating and cooling devices may need to be used to meet the needs of the occupants.

In regard to summertime thermal comfort there are incidences of borderline overheating and summertime discomfort resulting in use of personal fans by some occupants.

Introduction of night-time ventilation to cool the building in summer would be effective in reducing daytime temperature peaks as has been demonstrated through environmental analysis. Night ventilation is secure but ventilation via only the mechanised route is insufficient in bringing down summer temperatures. Through environmental analysis, when additional windows were opened in the 'SusCon office' overnight there was an observed reduction in daytime temperature peaks.

During site visits radiators are found to be left on full in meeting/ teaching rooms which were not scheduled to be used on that day. This indicates both a limitation in management of localised heating and the inability to communicate the importance of this management to users.

There are two potential solutions: 1. Involve reception in this localised management, e.g., first thing in the morning, turn on radiators at TRV in rooms that are to be occupied that day (and turn off at end of day or ideally after the meeting or use) or, 2. retrofit radiators with 'smart' radiator valves which allow scheduling. These can be installed over existing TRVs.

The reception space (atrium) is considered to be too hot in winter. Findings from analysis of the atrium temperatures when the underfloor heating is used suggest the maintained temperature is too high. Anecdotally, the receptionist must wear sandals in winter because the floor is too hot. In addition, the atrium is heated 24/7; the need for continual heating is questioned by both BPE team and users.

Facility management to revaluate the temperature and heating schedule for the atrium. As thermal management in the space depends on the large areas of thermal mass, there may need to be *prolonged tests to find the ideal heating schedule, e.g. explore the impact of excluding weekend heating.*

8.4 Other energy consumption

The occupants and BPE team have observed lights left on in unoccupied rooms. As an example, visitors are unable to turn off lights without the hand-held remote lighting control. Often in the attempt to turn off the lights, the ventilation override is switched because it appears to look like a light switch (and is the only switch on the wall next to the door.)

For meeting and teaching rooms, as with managing heating by room scheduling, the receptionist could do the same with lighting. A more costly solution would involve installing typical light switches in the rooms for visitors. The kitchenette would benefit from occupancy sensor. The workshops are on occupancy sensors, however, additional daylight sensors coupled with occupancy could further reduce lighting consumption.

Equipment is found to be left on or on standby for long periods in rooms that are not used.

Again, like above, equipment and computers in computer labs should be checked regularly to ensure there is no energy waste.

Exterior lighting is required for site security and is on daylight sensors coupled with timers. The exterior lighting is observed to come on at 2:00 am.

To reduce the time lights need to stay on during dark hours, movement sensors could alleviate security concerns. These movement sensors would most likely be most beneficial along the perimeter of the gate. To add to this, LED luminaires should be used to reduce electricity consumption further.

9 Wider lessons

TSB Guidance on Section Requirements:	This section should summarise the wider lessons for the industry, clients/developers, building operators/managers and the supply chain. These lessons need to be disseminated through trade bodies, professional Institutions, representation on standards bodies, best practice clubs etc. As well as recommendations on what should be done, this section should also reveal what not to do on similar projects. As far as possible these lessons should be put in layman's terms to ensure effective communication with a broad industry audience.

It is now widely acknowledged in the construction sector that buildings often do not perform as well in reality as their design calculations predict. However, the performance gap is also a consequence of weaknesses across the entire build process, from initial design to construction and beyond to operation and maintenance. In recent years the gap may have widened, partly due to more stringent regulatory CO_2 targets, which have lead design teams to specify innovative low carbon systems which are increasingly complex and have less robust in-use testing. Public and private clients alike have recognised this shortfall in predicted and actual performance and have begun to stipulate operational performance targets within new-build contracts; the industry must therefore act to solve underperformance where it is apparent or prepare to face the financial consequences.

The performance gap can be due to a combination of issues, such as:

- Technical shortfalls in building construction, systems and strategies.
- Performance predictions which fail to account for certain end-uses of energy, such as IT, plug loads and small appliances, and extended hours of occupation.
- Users and managers misunderstanding design and performance features, and operating them inefficiently.
- Unforeseen changes in the buildings use, between the design and handover of the building, meaning that performance simulations used to inform design decisions no longer reflect the actual use of the building.

BPE can help to identify and address the performance gap in the various stages of a buildings lifecycle to aid in maximising efficiency, reducing operating costs and improving the overall performance of a building. Depending on the stage in the building lifecycle that BPE is undertaken and for what purposes, there are various techniques which are appropriate to gaining useful feedback. To contribute to wider learning and progression, the SusCon BPE's wider lessons for industry, clients and developers and building operators are summarised in the following pages:

Wider lessons	Industry	Clients and developers	Building operators
Design: Get to know the site personally, e.g. visit the site, including the smells and sounds. Investigate how nearby road noise, for example, can impact occupant satisfaction and willingness to ventilate (with unintended knock-on effects leading to discomfort and increased energy consumption). The fact that windows cannot be opened for fresh air due to external noise potentially affecting the natural ventilation strategy, implies that location of the building on site, appropriate landscaping measures and internal space planning such as siting of office spaces, should be carefully considered at the design stage.	✓		
Design and construction: Involve as many stakeholders as possible in as many meetings as possible to protect the future in-use life of the building and expected performance. In the example of the SusCon Academy, the biomass boiler was designed as a system responsible for a large reduction of carbon emissions. A biomass boiler is a relatively unknown system. More effort should have been placed in protecting the efficient and long-term use of the system. This is done by: • ensuring the client has staff on hand who can use and maintain or will be trained on the use and maintenance of the system • this staff or FM should be part of the early discussion and should be present during commissioning • all benefits and costs should be known up front and discussed thoroughly with the client • when problems arise they can be dealt with quickly and if commissioning agents or suppliers need to be involved, there is no confusion regarding responsibility	✓	✓	✓ (request to be involved)
Design and construction: Communication and involvement of all parties involved in the design and construction process (including client and suppliers) through all stages is essential. This includes documentation and agreement for all changes to be shared for successful future development. (Issues involving the occupant such as systems control comprehension and storage dissatisfaction are lessons learned post-occupation. It is imperative that these problems are recognised, enter the feedback loop and are resolved in future development.).	✓	✓	
Design: Consider the usability of all control interfaces; discuss the interface design with manufacturers and provide feedback on controls.	✓		

Wider lessons	Industry	Clients and developers	Building operators
Construction: The installation and commissioning process for services (e.g. low carbon systems) is critical; ensure technicians are knowledgeable about the process and documentation is thorough. Provide on-site training at all levels to ensure appropriate fitting of materials and equipment.	✓	✓	
Design – Aftercare / Performance evaluation: Informing performance gap research and improved future performance of designs, the design team should follow-up, assessing year-one and year-two energy consumption and re-model predicted consumption to evaluate where possible modelling mistakes were made.	✓		
Construction / Commissioning – Aftercare: Reconciliation and calibration of sub-meters with BMS should have been checked during handover and early occupancy. With regard to wider-lessons, there was a lack of follow-up after construction and commissioning which did not catch or require the sub-meters to be connected to the BMS – something to plan for and diligently observe in future commissioning of new buildings. Specifically, without an active BPE study of the project this problem potentially would have not been discovered or rectified – this demonstrates the importance of BPE or similar in evaluating all phases from briefing to in-use.	✓	✓	✓
All stages: Design, the procurement process and cost of biomass boiler pellets (as an example), and the route and method of storage and supply to the boiler need to be detailed and discussed with facility management and owner in the early stages. In addition, with all relatively unknown technology, extra care should be taken to ensure proper commissioning, training and aftercare.	✓	✓	✓
Handover: Develop technically detailed but user friendly O&M / building user guide (including a user guide for the BMS) which will ensure efficient use of equipment to minimise energy used by the building, well informed maintenance of equipment and building elements, and well-timed and appropriately performed seasonal commissioning. These tools are essential for current and future facility managers.	✓		
Handover: Trial building user guide design with laypeople to ensure it is not overly technical (though it should remain technically relevant) and user friendly.	✓		

<table>
<tr><th>Wider lessons</th><th>Industry</th><th>Clients and developers</th><th>Building operators</th></tr>
<tr><td>All stages: The Soft Landings approach is highly recommended. Beneficial actions include:
At design development stage, review design targets, usability and manageability – involving future building manager(s). Confirm roles and responsibilities of all stakeholders.
Before handover, include FM staff and contractors in reviews.
During the first few weeks of occupation there should be support from the design and construction team. Demonstration of operation and maintenance of controls and technologies for the building users. Technical guidance to the FM and building manager in a clear, simple manner.
Final stage involves 1-3 years of aftercare, monitoring, review, fine-tuning and feedback.</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>All stages: The clients should take the lead on initiating and ensuring communication between all stakeholders; ensure all are following building procurement plan, e.g. Soft Landings.</td><td></td><td>✓</td><td></td></tr>
<tr><td>All stages: Ensure capability and experience of all stakeholders involved, involve building management early and train accordingly. Bringing the FM on early in the project, involving in meetings and providing appropriate training helps to ensure smooth running of the building and avoids issues such as that with the biomass boiler and the sub-meter (lack of) commissioning.</td><td></td><td>✓</td><td>✓</td></tr>
<tr><td>In-use: Coordinate training and continued education for support staff after occupation.</td><td></td><td>✓</td><td></td></tr>
<tr><td>Early occupation / In-use: Review building occupancy and use to ensure the building is being used as planned and designed; as with SusCon underuse of the building is resulting in a performance gap and large amounts of energy waste (low energy use in the case of underuse does not mean the building is performing well).</td><td></td><td>✓</td><td>✓</td></tr>
<tr><td>Aftercare / In-use: Provide hands on training of occupants and staff for equipment and controls preferably after commissioning has been satisfactorily completed and the occupants have had time to settle in and develop personal queries around the operation of the building</td><td></td><td>✓</td><td>✓</td></tr>
<tr><td>In-use: Reach out and provide an atmosphere of openness where occupants can discuss concerns regarding their environment and control. When a building operator is willing to work with clients to find the most comfortable condition for the majority, use of additional personal heating and cooling equipment can be reduced.</td><td></td><td>✓</td><td>✓</td></tr>
</table>