Ayr Campus, University of the West of Scotland

This document contains a Building Performance Evaluation report from the £8 million Building Performance Evaluation research programme funded by the Department of Business Innovation and Skills between 2010 and 2015. The report was originally published by InnovateUK and made available for public use via the building data exchange website hosted by InnovateUK until 2019. This website is now hosting the BPE reports as a research archive. As such, no support or further information on the reports are available from the host. However, further information may be available from the original project evaluator using the link below.

Innovate UK project number	450089
Project lead and author	BRE Scotland
Report date	2014
InnovateUK Evaluator	Unknown (Contact www.bpe-specialists.org.uk)

Building sector	**Location**	**Form of contract**	**Opened**
Higher education	Ayr	Design and build	x
Floor area (GIA)	**Storeys**	**EPC / DEC**	**BREEAM rating**
17,835 m^2	3	B / N/A	Excellent

Purpose of evaluation

The BPE project examined the performance of the building and its systems and services over a period of two years, through periods of high and low occupancy and varying seasonal changes. Energy data was interrogated to understand the consumption and demands in different areas of the building and to determine if operational efficiencies are being accrued, in line with the design team forecasts and client aspirations.

Design energy assessment	**In-use energy assessment**	**Electrical sub-meter breakdown**
No	Yes (over GIA)	Yes

Electricity: 106.8 kWh/m² per annum, thermal (gas) 230.2 kWh/m² per annum. Biofuel boilers were originally specified by the project services engineers to satisfy the heating and hot water demand for the Ayr Campus development, while aiming to mitigate the overall carbon impact of the building when in-use. The biofuel boilers did not operate as efficiently or effectively as the University had initially believed they would. During the first year of occupation, as a result of the on-going maintenance and performance issues that had been incurred, the University made the decision to operate their 'back-up' gas boilers as a more reliable option to satisfy their heating and hot water demand.

Occupant survey	**Survey sample**	**Response rate**
BUS, paper-based, staff and students	162	N/A

The survey showed indicated that the majority of scores fell within an acceptable range. The results also show that temperatures in the summer were considered by users as being 'too hot' and that temperatures in the summer were varying during the day rather than being stable. **Note: Some BUS results were shown in non-standard and inappropriate formats. Survey responses are only suitable for display in histograms in order to show response numbers or percentages, not response distributions. The survey also mixed results from permanent users with those from transient users, which is also non-standard data-handling.**

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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

The University of the West of Scotland (UWS) has successfully secured funds from the Technology Strategy Board (TSB) to deliver a Building Performance Evaluation (BPE) on their new Ayr Campus. UWS share the Ayr Campus with Scotland's Rural College (SRUC). The BPE project will be delivered over a period of two years and will consider the functional, technical and environmental performance of the building as well as obtaining in-depth feedback from the building occupants and assessing how far the building is meeting their needs and operating as expected.

The BPE project will examine the performance of the building and its systems and services over a period of two years, through periods of high and low occupancy and varying seasonal changes. Energy data capture will be collated during this period and will be interrogated to understand the consumption and demands in different areas of the building and to determine if operational efficiencies are being accrued, in line with the design team forecasts and client aspirations.

BRE consultants have an in-depth understanding of the building, having previously adopted the role as sustainability advisors and supporting the client and project team in realising their ambitious BREEAM Excellent rating. Having this knowledge along with a broad experience of carrying out post occupancy evaluation projects enabled BRE to develop a rapid, structured process. Activities undertaken as part of the evaluation process included:

Project initiation:

- A site visit and kick-off meeting between TSB representatives, BRE and UWS to introduce the project and gain background knowledge on the Ayr Campus development;
- Preparation and agreement of the monitoring and reporting plan for the BPE project;
- Review of existing sub-metering capability, identifying additional areas where sub-metering would be required in order to support TSB's TM22 energy monitoring requirements;
- Technical inspection / survey of the Ayr Campus building services and LZC technologies; and
- Delivery of 'Summer period' occupant consultation workshops to introduce the BPE project and obtain initial user feedback.

Internal monitoring and on-site testing:

- Calibration of all additional sub-meters and upgraded Automated Meter Reading (AMR) system to support user interface and enable energy monitoring;
- Set-up of data collection tags (temperature, humidity and air quality) to monitor the building's internal environment;
- Thermal Imaging to help identify any performance issues with the building fabric or services;
- In-situ U-value testing to monitor the rate of heat transfer via the external wall construction;
- Air tightness testing to examine and compare the results at the post occupancy stage with those achieved at the building handover stage;

- Internal environment scientific spot checks around the campus (temperature, humidity, air quality, sound, lighting levels) to help develop a better understanding of the building performance in relation to user comfort and wellbeing;
- Continuous internal environment monitoring of selected areas (temperature, humidity and air quality) to assess the impact of varying occupant and seasonal changes; and
- In-depth analysis of internal environmental conditions in the selected areas (recorded at 5 minute intervals for temperature and relative humidity and 3 times per hour for carbon dioxide levels) as identified by the building users.

Occupant consultation:

- An initial occupant workshop session to obtain feedback on the user experience;
- A structured Building User Survey to help assess building performance from the user perspective;
- Informal interview sessions with building users during site visits;
- A final occupant workshop session to obtain further user feedback and to discuss some of the evaluation findings; and
- A review of the Building User Guide to ensure that current and future building users have access to information that enables them to interact with and operate the use the building effectively and efficiently.

Energy monitoring:

- Collection and analysis of energy data from the Automated Meter Reading monitoring system;
- Building survey to collect data to populate the ‘in-use’ section of TM22;
- Continuous energy use data monitored, downloaded and transferred into CIBSE TM22; and
- In-depth energy consumption analysis, including further development of the CIBSE TM22 tool.

Review of building services performance:

- Building survey to inspect operations, programming and control of building services;
- Review of available documentation e.g. as built drawings, manufacturer guidance, O&M details etc.;
- Timetable analysis against the operation of air handling units to map supply with demand;
- The Building Management System functionality review (access, control, programming etc.); and
- Detailed discussion sessions in relation to the operation, control and performance of the lighting software, heating and ventilation systems with the estates team.

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

The new UWS Ayr Campus building, designed by an international architectural practice RMJM, is hoped to provide state-of-the-art facilities for the University and their project partners, the Scottish Rural College (SRUC) and includes suites, studios and laboratories for performance, music, broadcasting, education and healthcare. The new 17,835 m2 building has been developed around an ambitious brief which considered sustainability at the heart of it. The new campus can accommodate up to 4,000 students and 270 staff members.

The installation of biofuel boilers, energy efficient systems and significantly improved building fabric performance levels (up to 30% improvements above building regulation requirements at the time) should enable the University to achieve a significant reduction over building regulations in relation to the building's CO_2 emission levels.

Figure 1 – Main entrance

The architect's design was inspired by the building's 6ha site in a woodland setting and is focused around a series of external 'garden classrooms' which flow into the new three storey building to create an entrance courtyard, a central atrium and a more private library courtyard space. The building takes the form of a rectangular shape, which floats above the landscape offering spectacular views in a truly unique setting. It also boasts a SUDS pond to attenuate surface water run-off and provide a new habitat for local flora and fauna. The campus was delivered by developer Lend Lease, ACTS partnership services engineers and Woolgar Hunter structural engineers.

The building has successfully achieved an ambitious BREEAM Excellent rating at Post Construction Review certification. The ambitious BREEAM certification illustrates that out of the eight environmental categories that were considered, full percentage scores were awarded to the Management and Water categories. In order to achieve this ambitious score, the client and project team worked together to ensure that the construction stage was managed in a way that was sensitive and considerate to the site surroundings. This involved appointing a dedicated site ecology champion and adopting a number of protection measures for the existing ecological features and habitats on and close to the site as well as considering the efficient use of resources and implementing pollution prevention measures. The design of the building and choice of materials was heavily influenced by a fabric first approach. High levels of insulation and materials with U-value performance that were significantly above minimum building regulation compliance were specified for use. The design also incorporated passive design features such as free cooling strategies and the successful exploitation of natural light throughout the building. The incorporation of biofuel boilers sought to reduce the carbon impact of the building in-use and aimed to assist the Campus in achieving its Carbon Management Plan targets. The installation of a 'state of the art' lighting system aimed to provide the University with flexible control options and reduce the overall electricity consumption by incorporation of daylight and movement sensors. In terms of water, consumption is minimised through the specification of more efficient fixtures and fittings extensive sub-metering allows the Campus to monitor and target reduction in high-use areas and a dedicated leak detection system was specified to alert building users to any significant drop in pressure within the building or the site boundary. Walking and cycling routes have been significantly enhanced for users, in terms of safety and accessibility and the Campus is now well connected to the public transport hubs within the Town Centre.

Figure 2 – Atrium Space

3 Review of building services and energy systems.

The aim of this section is to provide an overview of what building services operate at the campus and gain an understanding of what contributes to the overall energy consumption of the building.

3.1 Heating

Building services and supporting equipment for the campus's heating include;

- Gas fired boilers
- Biofuel boilers
- Oil tank and pump
- Pumps
- Pressurisation unit
- Radiators
- Underfloor heating
- Trench heating
- Boiler flue
- Herz valves
- Dirt separator
- Energy mater stations

A dedicated plant room stores all of the above building services on site on the lower level of the University building. The plant room is spacious and well laid out, providing a good level of access for maintenance and operations. The area also benefits from opening externally into the Campus' dedicated service yard, allowing ease of access for delivery and other vehicles.

Biofuel boilers were originally specified by the project services engineers to satisfy the heating and hot water demand for the Ayr Campus development, whilst also helping to mitigate the overall carbon impact of the building when in-use. Unfortunately the biofuel boilers did not operate as efficiently or effectively as UWS initially believed that they would. The University Estates team encountered a number of challenges in relation to maintenance and performance of the boilers, largely as a result of sourcing the correct biofuel mix for the boilers. The University explored alternative options such as alternative feeds and boiler conversions; however no suitable alternative has been identified. During the first year of occupation, as a result of the on-going maintenance and performance issues that had been incurred, the University made the decision to operate their 'back-up' gas boilers as a more reliable option to satisfy their heating and hot water demand. This option has proved to be a more reliable solution for the University and there have also been significant financial savings for the University in opting to utilise the gas boilers as the main fuel source for heating and hot water as the costs for the gas supply were around a third of what was spent on the biofuel costs for this building. The downside to this decision was that the University were no longer benefiting from a low / zero carbon technology. This was disappointing for the University as previously this has been a key design feature for the new build campus.

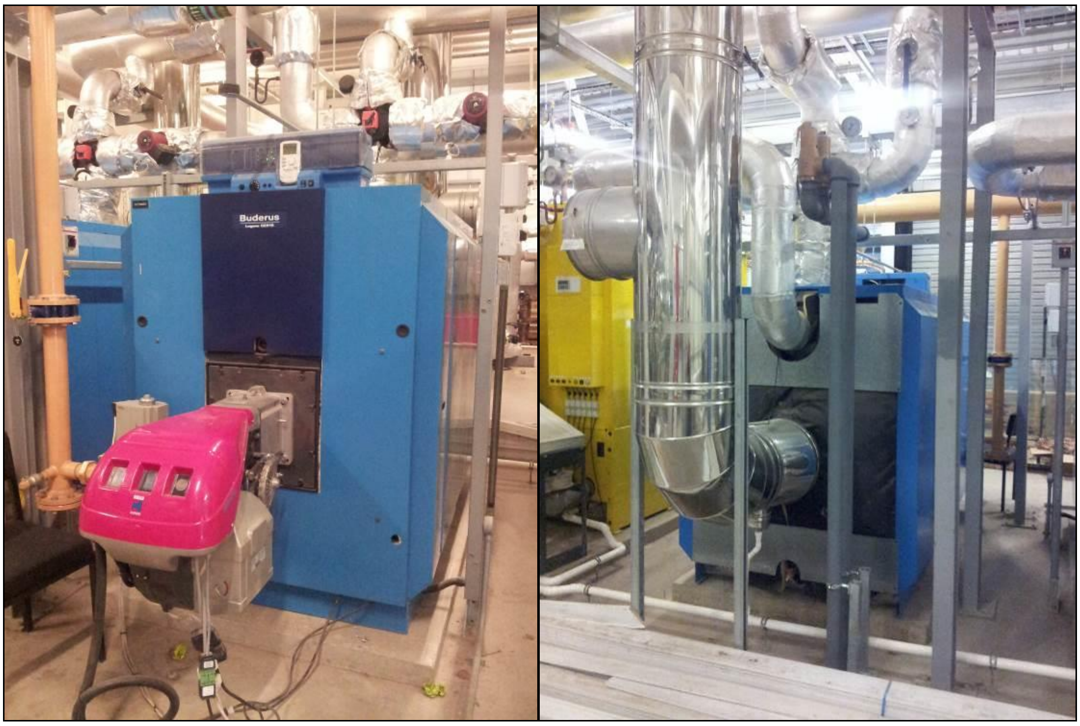

Figure 3 – Buderus Gas boiler

Figure 4 – Atlantic biofuel boilers

Figure 5 – Flamco Pressurisation unit

At present, the University of the West of Scotland’s largest contributor to their overall carbon emissions is from their gas boilers, which are presently satisfying all of the Campus heating and hot water requirement. Therefore, as part of this building performance evaluation process, attention should be paid to the use of these boilers and the systems and services that provide heat to the building. A multi-boiler system provides heat to Ayr Campus building via;

- Variable air volume units (VAVs) - type of heating, ventilating, and/or air-conditioning (HVAC) system;
- Fan control units (FCUs) - devices consisting of a heating or cooling coil and a fan;
- Under-floor serving the gym and some circulation and social areas;
- Trench heating around the perimeter of a number of classrooms;
- Radiators in the circulation and office areas.

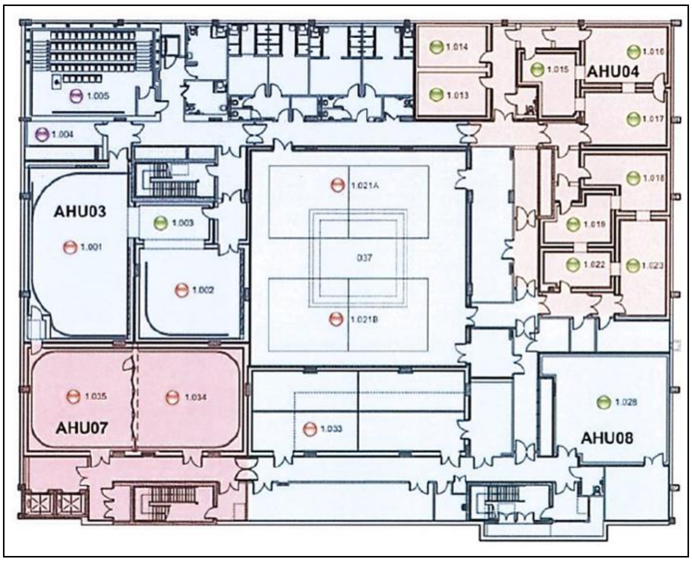

Figure 6 - Basement heating options

Figure 6 illustrates the heating / cooling systems servicing the basement level. The VAV unit, marked in purple, services the lecture theatre. Green indicates FCUs or a combination of both VAVs and FCUs, which service the smaller rooms. The underfloor heating system, marked in red, services the gymnasium and drama studios. Other 'red' areas indicate the trench heating on the upper levels, primarily around the classroom perimeters and within the library area.

Figure 7 – Examples of heating provision; a radiator in the basement's corridor and trench heater in the library

The complexity of the campus and lack of sub-metered information in relation to gas consumption for specific areas has made it difficult to analyse the actual consumption and operation of the heating systems servicing the different areas of the Campus. It is highly recommended for the UWS staff to review how the heating is controlled. Despite having limited access to information, it is likely that gas consumption could be reduced by appropriate maintenance, monitoring and efficient control.

3.2 Cooling

Building services and equipment responsible for cooling at the UWS include;

- Chillers and dry air cooler
- Chilled water buffer vessel
- Chilled beams
- Air conditioning
- Pumps
- Pressurisation unit
- Trace heating
- Deaerator and dirt separator

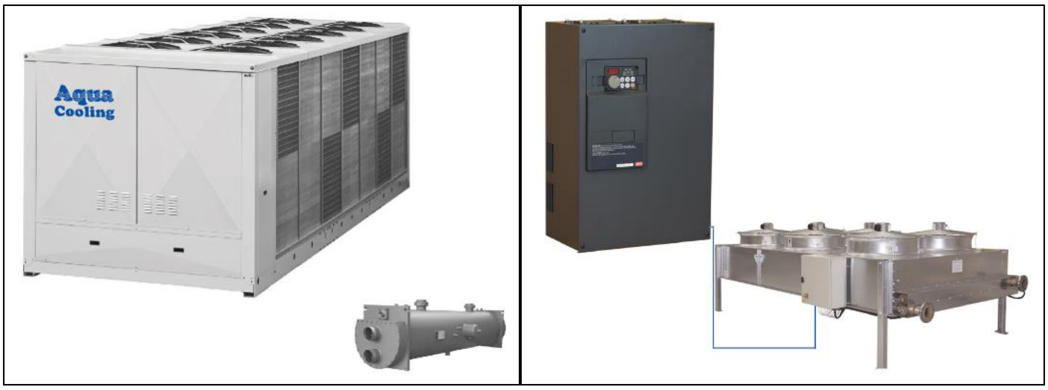

Figure 8 – Air Cooled Liquid Chiller and Air Blast Cooler Inverter Control

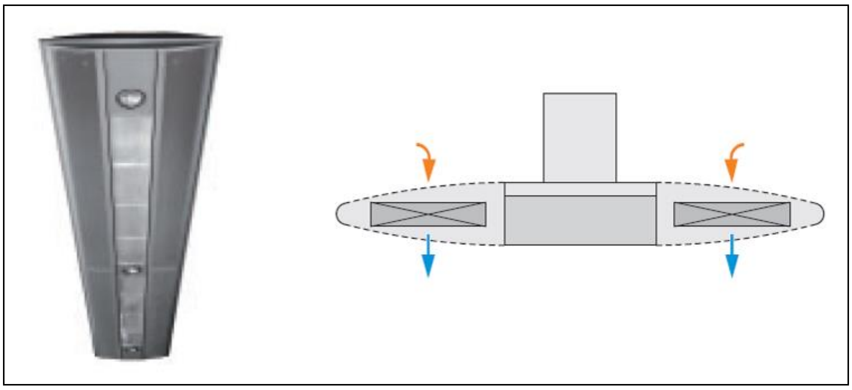

Figure 9 - TROX Technic Multi Service Chilled Beam

Figure 10 – Level 3 cooling options

Figure 10 illustrates heating/cooling systems. As before purple indicates areas serviced by VAVs and green refers to FCUs, or a combination of VAVs and FCUs. A difference here is that many areas (labs and computer rooms in particular) are cooled by chilled beams (blue dots).

3.3 Ventilation

Ventilation services and equipment at the campus include;

- Air handling units
- Air handling unit control valves
- Fan coil units
- Extract fans
- Grilles
- Variable air volume and constant volume devices
- Attenuators/silencers

Figure 11 – Diffusers variety (from top left, clockwise); Ceiling, Ceiling Swirl, Displacement, Staircase swirl

Figure 12 – Movable floor diffusers in the library

3.4 Air handling units

There are 13 air handling units operating within the campus. Their arrangement and the zones in which they operate is illustrated in Appendix **Error! Reference source not found.**. Figure 13 indicates the roof top plant and the location of the air handling units.

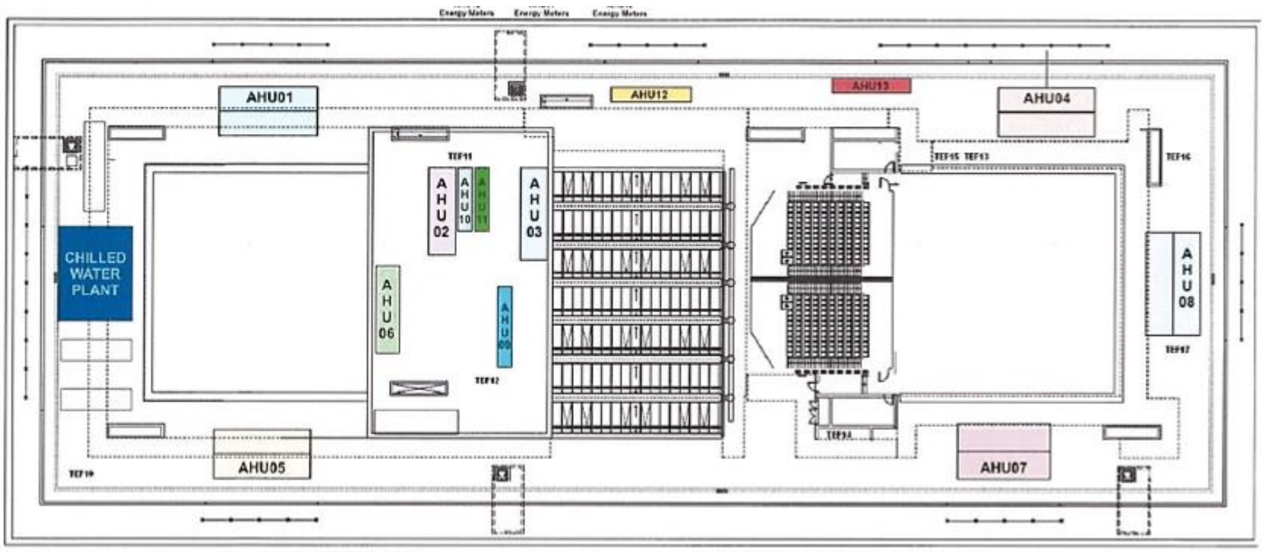

Figure 13 – Roof top plant

A number of AHUs are assigned to specific room functions and these include;

- AHU 6 – library
- AHU 2 – library and part of the atrium space
- AHU 9 – lecture theatre 2
- AHU 13 – lecture theatre 1
- AHU 10 – kitchen
- AHU 11 – kitchen and student union
- AHU 12 – student union

The remaining AHUs service areas with a mix of different functions; classrooms, studios, labs and meeting rooms. Additionally these units also serve offices, toilets, storage spaces and corridors.

The breakdown below illustrates the main room types serviced by the remaining AHUs.

- AHU 1 - Offices, classrooms, workshops, computing labs
- AHU 3 - TV studios, lecture theatre, computing labs
- AHU 4 - Music studios, classrooms, labs
- AHU 5 - Radio studios, art rooms, mac suite, classrooms
- AHU 7 - Performance studios, cyber café, pc suite, classrooms

- AHU 8 - Gymnasium, music teaching, classrooms, labs

In addition to the UWS activities, the building also accommodates the Scotland's Rural College (SRUC). SRUC is located over two levels, level 2 and level 3 and is served by the AHU 4 and AHU 8.

Details of the operating hours of the air handling units and how those operating hours can be reduced, based on a timetable analysis, are described in Section **Error! Reference source not found.** in this report.

Figure 14 – Images of roof top plant; air ducts, an air handling unit and water pipes

3.3 Small power, ICT and lighting

Lighting, ICT and small power equipment, particularly in the offices, the library and computer labs, greatly contribute to the overall energy consumption. The campus makes significant use of IT equipment such as computers, monitors, printers and faxes. Additionally, the campus accommodates specialised lighting and sound equipment for drama and TV classes (all listed within the TM22).

Figure 15 below illustrates typical energy uses against 10 categories for 4 different office types from the Energy Consumption Guide 19 (ECON19) – Energy use in offices. Although it refers to office type buildings, it does help to provide a good indication of what equipment has the largest influence on the overall energy consumption.

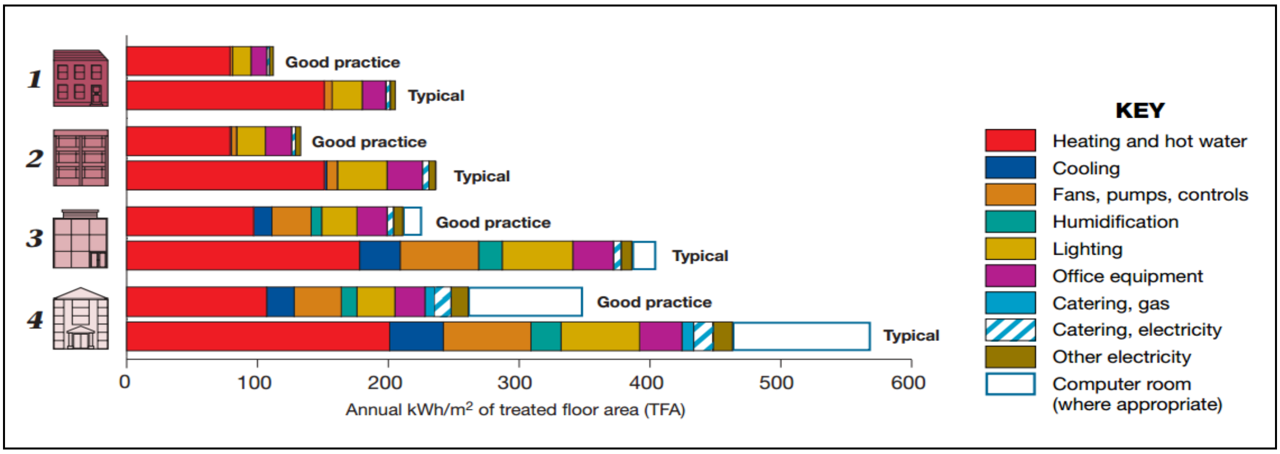

Figure 15 – Energy use indices (EUIs) for good practice and typical examples of four office types (ECON19 – Energy Consumption Guide 19, Energy use in offices)

In terms of lighting, the university invested in an intelligent lighting subsystem manufactured by Phillips, which can be controlled wirelessly by software called DALI (Digital Addressable Lighting Interface). This is an international standard lighting control system which provides a single interface for all light sources and lighting controls. The system should benefit the Campus Estates team in the following ways:

- Undertaking simple modifications e.g. change of use not requiring any rewiring;
- Status reporting of lamps and ballasts;
- Lower maintenance costs; and
- Increased Operational efficiencies and savings e.g. dimming and control settings.

End users should benefit in the following ways:

- Customised lighting preferences;
- Improved comfort levels (lighting adjusted to appropriate/ desired levels);
- Individual area control; and
- Easy modification (requested via Estates).

Details of the system and lighting controls are included in Section 0. Figure 16 provides examples of light fitting types that have been installed across the Campus.

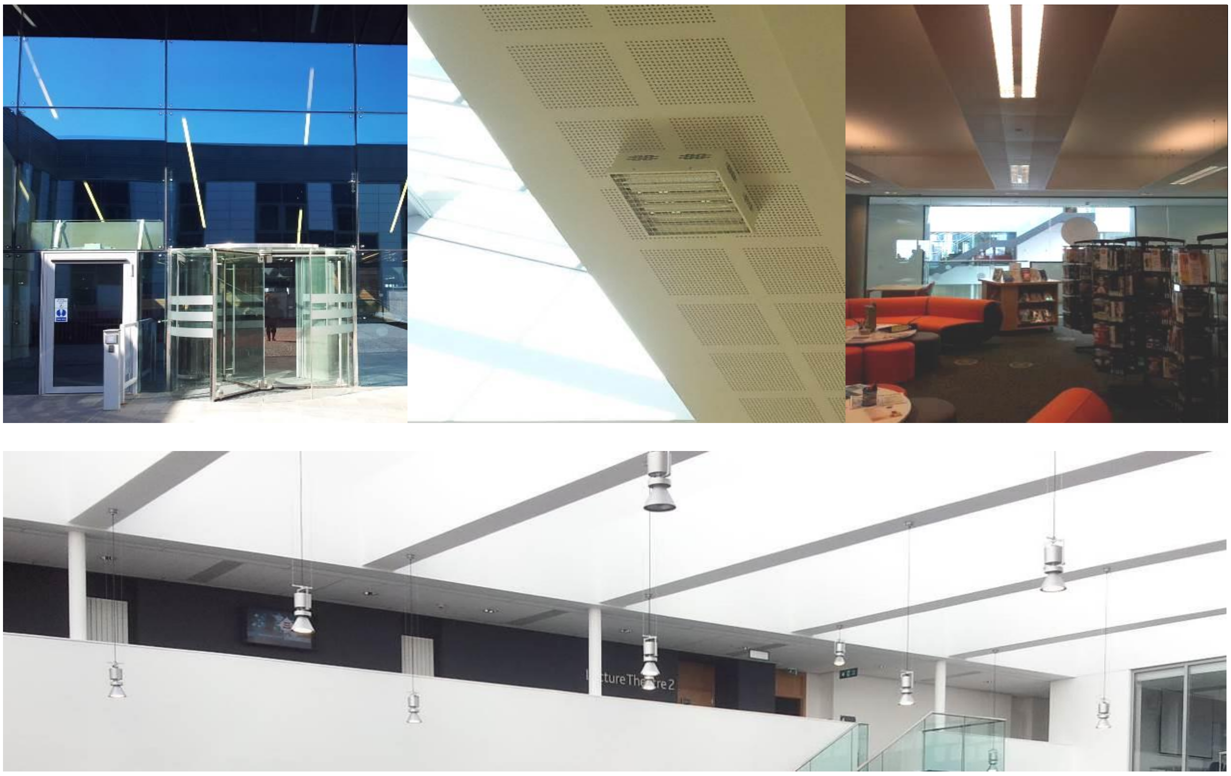

Figure 16 – Variety of different light fittings in the reception area, gymnasium, library and atrium

Illustrated fittings include;

- Trimmed recessed luminaires in the reception area, with a sleek, modern design;
- Fully boxed recessed luminaires in the gymnasium, designed to provide even light distributions and reduced level of glare particularly important with sport activities;
- Suspended fittings with integrated acoustic panels in the library; and
- Die cast aluminium and thermo plastic material sleek pendant fittings in the atrium.

Small power items and other specialised equipment that is present on the Campus will greatly contribute to the overall electricity consumption. Therefore, ensuring that office equipment is controlled and operated efficiently e.g. not operating when unnecessary or powered on when not in use is important and can help to accrue operational savings for the Campus. Computers, monitors and other small powered equipment that is in operation can also contribute to secondary heating gains, hence causing a risk of overheating in naturally ventilated spaces or a greater cooling load requirement in air-conditioned areas. In order to help avoid this and to reduce the requirement for cooling, care should be taken to ensure that all of these electrical items are powered off when not in use.

Figure 17 – Small power equipment in the lecture theatre

Figure 18 – Specialised lighting in the performance studio

3.4 Conclusions and key findings for this section

This section of the report provides an overview of building services that are present at the UWS Ayr Campus which all contribute to overall energy consumption at the campus. Later chapters within this report contain more detailed information in relation to;

- The users' perception of these services and the effect of their operation on the occupants' comfort;
- Illustrations of building management system used to set up and control numerous equipment;
- An intelligent lighting and sensors system;
- Overall energy consumption and recommendations on how to reduce this figure; and
- How the operation of building services, in addition to building fabric, affect the internal environment.

4 Occupants' surveys and Building User Guide

This section of the report examines the building users experience and how they interact with and how satisfied they are with their building. From preliminary understanding of the users' experience, to a structured questionnaire, to walkthrough surveys and discussions with staff and students, BRE collated an in-depth analysis of how far the building satisfies users' needs and whether it provides the optimum learning and working environment for the variety of end users.

Figure 19 – River side view

4.1 Initial occupant consultation

In order to obtain feedback in relation to end user experience, BRE facilitated occupant consultation workshops with a variety of end user groups. These sessions were attended by a cross-section of building users; including first to fourth year UWS and SRUC students studying a variety of subjects at different levels and also UWS and SRUC staff including lecturers, administrators, support staff, technicians and estates staff from the estates department. The purposes of the workshops were to evaluate how well the completed building had been designed and constructed to meet the needs of the end user. BRE provided the attendees with a questionnaire containing short, non-technical statements looking at the functionality, build quality and impact of a building.

The group discussed each of these topics in turn in order to assess the user's perception of the building.

- **Functionality** looks at the way the building is designed to be useful.
- **Build Quality** looks at the materials and the different systems and conditions inside the building.
- **Impact** refers to a building's effects on the local community and environment.

Details of those discussions are described in the following sections of this report.

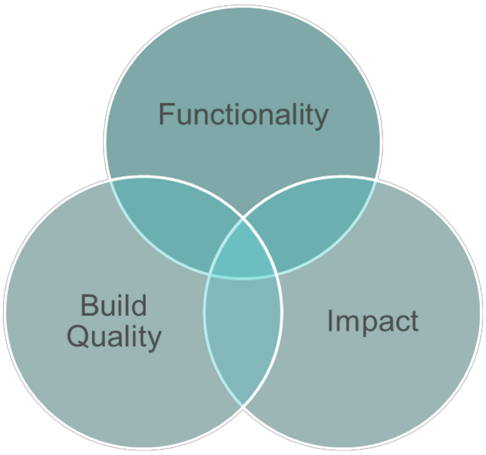

Figure 20 – Initial occupant consultation – discussion topics

Functionality

Functionality is concerned with the arrangement, quantity and interrelationship of spaces and how the building is designed to be useful.

'Functionality' focussed discussion on three key areas:

- Access;
- Space; and
- Uses.

Access
Access is concerned with how easy it is for all people to get to and from and around the building.

When commenting on the external area of the building, building users agreed that the external areas have been significantly enhanced for walking and cycling compared to what was there previously. The riverside walkway has been enhanced and is now landscaped and well lit and offers access for building users, linking them to the town centre. Building users did report that they feel that the access routes from some of the car parking areas to the building could be enhanced by an additional pathway, as at present, pedestrians are adopting the shortest route which entails either walking over flower beds or going through the car park vehicle entrance barrier.

The University has a dedicated travel information point located close to the main entrance to the building which provides users and visitors with information on a range of travel options. Building users commented that public transport links from the town centre are adequate and the enhanced walking and cycling routes connect well with the train station and other key amenities. The University has installed priority car parking spaces, which are close to the building's main entrance, for car those who share and actively promote the car share initiative as a more sustainable travel option. However, despite the significant external areas dedicated to staff and student car parking, occupants also reported that they would welcome additional car parking space on the campus to meet the demands of staff and students. A number of building users who commute by car aim to park as close as possible to the building entrance resulting in the parking spaces closest to the building being in high demand and there appears to be a perception that when the closest car parks are full that there is a lack of parking, which can lead to overspill into residential areas. The University has advised that there is sufficient parking available in car parks 3 and 4 and that this could be further promoted to staff and students.

Further reporting on the external area, users commented that they enjoyed the external enhancements and that they look forward to making best use of these throughout the academic year. Users did confirm that they would welcome additional external path lighting to allow them to make better use of the external walkways in the evening, particularly when accessing the train station and they also suggested that the river path surface should be more even to allow users with mobility challenges to also enjoy and make better use of the enhanced external areas. It is noted that some of the area by the river is out with the confines of the site and control of the University and therefore some external consultation may be required. Staff also reported that they would welcome more direct access from the building to the riverside; particularly during periods of good weather when they could enjoy external seating areas. There was also reported interest in the 'Secret Garden' and occupants are keen to learn how and when they can gain access to this new external enhancement.

When feeding back their thoughts on the inside of the building, users commented that wheelchair access has been greatly improved in the new building as there are now four dedicated passenger lifts that provide access to all levels and wheelchair or physically impaired users do not experience restricted access between floors as they did in their old building. On discussing the layout of the building and ease of access throughout, the majority of staff and students agreed that the circulation space is plentiful and the layout of areas and services is complimentary. Despite users agreeing that access has greatly improved, there are some issues that users highlighted during the occupant consultation workshop where they felt that further improvements could be made. This included making improvements to the internal floor numbering system as at present users reported that this can be confusing due to different formats of numbering and unclear ordering of numbers and signage being small and signage positioned too high above ground level in some cases.

It is acknowledged that the University did prepare mock signs during the construction phase to allow the signage and numbering to be tested with both staff and students, unfortunately, however, users are reporting that they do feel signage is confusing. Senior University staff have stressed the importance of designing a signage scheme that is weighted heavily towards function rather than aesthetic.

Staff from the labs expressed that their access route from the main entrance using the lifts was only possible via the open plan seating and server area where food is served and consumed. Some staff felt uncomfortable with this when they are carrying lab samples through this area. To help rectify this issue the Estates and Buildings team has informed the lab staff that access through the 'Goods In' entrance doors adjacent to their labs could be arranged with advanced warning.

Space

Space is about the size and interrelationship of the buildings or component spaces.

When discussing space, building users reported that there was a good variety of space in the new building and that they enjoyed the mix of social, study, teaching and informal learning spaces that were available. It was reported that the informal canteen and social seating areas, the library area and study rooms, the student union and the flexible teaching spaces are well utilised by occupants.

Both staff and students reported that they would welcome more locker and storage space, particularly for those studying courses that require students to have access to equipment or a change of sports kit etc. Students expressed frustration over what they considered an inconvenience at having to carry all of their clothing and equipment from class to class on a daily basis and that they would welcome the option to store it on site. Staff reported that storage space has been limited and that generally they are lacking dedicated space for their books and printed materials. They also reported that most storage cupboards are locked and believed to be underused. Staff commented that management of storage space and space utilisation generally in the building could be monitored more closely and improved.

Some SRUC building users did express that they were unhappy with the space in the SRUC video conference facility. They explained that they felt the space here was inadequate due the shape of the room and the layout of the screens (one on each wall), and that the layout would be enhanced if the screens were on the same wall allowing ease of visibility. Users also commented that more space was needed for lab based projects in addition to analytical equipment in this area.

SRUC building users also reported that some rooms can at times appear to be too small for teaching comfortably (the allocated number of students) and that the flexibility of space can often be a problem. During the early design stages both College and University representatives worked together with the project delivery team to determine how much space would be required for each person / area. However, the building users have reported that they feel that these ‘space norms’ are not always the best measurement, and that the space planning measurement of 2.5 meters squared per person does not always work for small (<40 person) teaching rooms as circulation space and disability access can eat into the space available for desks. Flexibility of the teaching space in SRUC teaching rooms was reported as an issue particularly when staff wish to deliver group working exercises with the students. Many of the teaching spaces have been reported to be set-out in ‘school-like’ rows of desks which some staff do not believe are conducive to an effective learning and teaching environment. Users would at times welcome an alternative set-up; where desks and chairs are grouped into smaller sections and spread across the floor space. Students also commented that the smart boards are often too low for those at the back of the room to comfortably view the full board, and although adjustable, users are unable to adjust them to a higher height due to the arrangement of the lighting and chilled beams which prevent the boards from adjusting to higher heights.

Building users discussed the provision of space in different areas of the building. On discussing the student union, students reported that during break and event times, the demand for this space is high and that the overall space is too small for the size of the student population (particularly after the merger) and that they would welcome additional space in this area to comfortably host social events for all users.

Students discussing social space and the space available to them between classes reported that there was poor availability of (non-food) seating areas and suggested that possible future space for seats and couches could be created in the larger open corridors, the 4th floor was suggested as a suitable location. Students also reported that corridors (especially those within close proximity to the lecture theatres) can become choked between classes and during peak periods and that better timetabling could potentially help to alleviate this.

SRUC Sports students discussed both the spaces available for sports and the facilities available to them. These students reported that they feel that there should be more sports facilities available for use as the current provision is reported to struggle to accommodate the 3 sports degrees on offer. These students further reported that the gymnasium is very small and that the facilities are insufficient; and that sports pitches, a gym and changing facilities would be welcomed, particularly when SRUC has two football, one rugby and one hockey teams.

Both SRUC and UWS students would welcome the idea of sharing sports equipment and facilities. Students are looking to engage more with each other on a social level and would welcome opportunities that encourage this.

Uses

Use is concerned with how well the building caters for the functions it may accommodate originally and in the future.

When discussing the various uses of the building and how it accommodates differing functions, students had many positive comments to feed back. It was reported that the break-out rooms are ‘fantastic’ during high stress periods and that they provide a location for relaxation and quiet study. Users also commented that the rooms with flexible partitions were very good for accommodating larger groups, and that the building overall caters ‘brilliantly’ to IT access and study; and that there are laptop connection facilities in the library and AV facilities throughout. Students appreciated the possibility to utilise IT at short notice due to wide access throughout building, and that they can step into most rooms and find IT equipment available. Students also reported that the canteen is excellent and well laid out, and is useful also for group study and collaboration as well as eating, socialising and holding meetings.

The level of natural light in the building and the splendid views out, particularly to the riverside, were something that the occupants remarked on positively. However, occupants at the consultation workshops did report various issues with the lighting. The University corridors and teaching areas have occupancy sensors that are activated by movement. However, staff explained that the corridor lights can often all switch off when occupancy use is low after 5pm. During the darker winter months, staff reported that this can make the corridors very dark and they do not feel as safe during these periods when they are unable to trigger the occupancy detection sensors and are then standing in dark corridors to lock classrooms. The lighting system that is in place at the UWS Ayr Campus does offer users the capability of programming the lighting times and adjusting the setting for the control preferences to help rectify these issues.

Occupants also reported that the lights continue to not operate as they should in Room GT 1 and reported that they fade out after a matter of minutes. They also reported that the switches for lights in Room GT 3 are not in the best condition as a result of wear and tear. Staff explained that the reduced lighting levels in some classrooms can make it difficult to undertake desk based activity as there is no individual desk lamps in these areas and that the level of artificial light is considered by some to be too low to perform these activities comfortably. The lighting system has the capability of being adjusted for these rooms and can specify higher levels of artificial lighting to help accommodate end user requirements. This would be more efficient and most likely more comfortable for the end user than making use of individual desk lamps.

Further issues regarding the current and future use of the building included concern over the length of time it has taken to repair the ventilation system serving the toilet areas and there were also a few user complaints regarding the unpleasant smells in this area. Water efficient fixtures and fittings have been specified for use in the building, however building users reported that the wash hand basin taps in the toilet areas stay on for much longer than required.. The sanitary fittings within the bathroom areas have been fitted with flow restrictors that are also adjustable and can be set to reduce the length of time that water runs from the wash hand basin taps to accommodate user needs. The general feeling from the user group was that the building was wearing well initially and that it does still very much resemble a new build. On future use, some staff reported that they feel the fittings and furnishings may not last very well if they are not adequately maintained and raised concern about the wear of certain areas over a long period such as the white internal walls and desks marking easily.

Build Quality

Build Quality stems from how well the building is constructed: its structure, fabric, finishes and fittings, its engineering systems, the co-ordination of all these and how well they perform.

Build Quality has 2 areas:

- **Performance; and**
- **E**ngineering.

Performance

Performance is concerned with the building's mechanical, environmental and safety systems.

Building occupants reported that they were impressed with the overall aesthetics of the building. However, many users also expressed their concern in relation to on-going issues that they reported to experience with regards to the heating and ventilation and many present at the workshop also reported their dissatisfaction over being unable to open windows. Users expressed a preference for being able to open windows in classrooms and offices so to have control over ventilation and temperature.

Some users reported that a lack of ventilation has caused some staff to have headaches and feel tired later in the afternoon and that they would describe some areas as unpleasant, including the lecture theatres and small staff office rooms. This was reported as a result of a lack of provision of comfort cooling or ventilation in these areas. The users explained that this has been communicated to the relevant helpdesk. The Campus does benefit from a Building Energy Management System (BEMS) which controls the services at a central level for a number of occupied areas, including the lecture theatre. Therefore, it is possible for the Estates team to adjust the building services for the lecture theatre areas to accommodate end user requirements.

Users provided examples of the areas in which they found problems with the building services, and explained that ventilation is a problematic issue in the lab area; however when staff attempt to open the internal door to promote the circulation of air, noise pollution can become an issue for other users. With a number of burners and many bodies in this space, it has been described as being an unpleasant environment especially when windows cannot be opened. Users explained that rooms without opening windows can be described as stuffy, particularly on the south side of the building. Room GT 3.055 was also mentioned as a room users found unpleasant due to the cold draughts blowing up through the floor vents. Room 2.078; the Bioscience lab was also reported to have temperature issues when in use with business literature.

In general, users reported that they felt the heating systems did not perform as required throughout the building and that there is a variance between the north and south of the building and that this is not accounted for. The building services which supply heat, cooling and ventilation to all of these teaching areas can be adjusted through the Campus BEMS to help to accommodate end user requirements and to also help create more comfortable internal environments.

Engineering

Engineering looks at the quality of the building's components.

Building User Guides (BUG) have been produced and are made available through the building's intranet. BUGs should be non-technical guides that aim to help end users understand their building, the design, the services and the level of control available to allow them to use the building in the most efficient and effective way possible, thus helping to create pleasant internal environments. Unfortunately, most of the building users who attended the focus group sessions did not know where to locate these guides and did not have a full understanding the operational characteristics of the systems and services that are present. Users at the sessions explained that they feel there is a general lack of knowledge over the systems in place and that they are unsure what is individually controlled and what is centrally controlled. Many of the users reported that they were unable to operate the lighting and heating systems and commented that they would welcome training on the use of these systems and the building, especially since the building has now been occupied for some time and all users are still not confident on how best to operate the some of the systems within the building which is having an impact on their internal comfort levels. As such, users would welcome further education on this as they felt that little initial user induction was provided. Focus groups attendees reported that awareness of and the provision of information about building engineering and building sustainability credentials could be improved. Staff had a general knowledge of BREEAM and the ambitious rating that was secured for this building, however, users did comment that more could be done to raise awareness and support for some of the sustainability features and resource efficiency initiatives that are in place and that also commented that if they had further details on some of these then they could be better communicated to visitors, community partners and new students.

Impact

Impact refers to a building's effects on the local community and environment.

Impact has 4 areas:

- **Urban and Social Integration;**
- **Internal Environment;**
- **Form and Materials; and**
- **Character** and Innovation.

Urban and Social Integration

Urban and Social integration is concerned with the integration of the building into the local neighbourhood and the relationship of the building with its surroundings

On discussion about the relationship of the building with its surroundings users reported that they felt the building was well placed and designed in a way that was sympathetic to the external environment. They felt overall that the building contributes to the surrounding areas; however, appreciation of this has been limited due to the problem of parking overflow into the neighbouring residential area. The awareness and benefits of the more sustainable travel options that are supported and encouraged could be raised. For example, users the dedicated travel plan, the provision for journey share etc.

Building users would welcome further community interaction and suggested that perhaps open days for locals would help as this could increase the use of the facility by local groups. Building users indicated that they had little idea how the local neighbourhood felt about the new building and that by opening the doors to the coffee shop from the riverside, this could encourage interaction with the local neighbourhood as the perception is that local people may be keen to use this facility.

Internal Environment

Internal Environment is concerned with the quality inside the building's envelope. The quantitative aspects of some of these elements are dealt with under Performance.

Building users confirmed that overall they believed the building has been finished to a high standard. Some users, however, did express concern in relation to the cleanliness of the facilities that experience a high volume of users. An example of this was the toilet facilities located close to the reception, where users expressed concern that these presented an unfairly negative impression for visitors.

Some focus group participants reported that the white walls have become dirty very quickly in some areas and that the internal staircases look unfinished. The users were not aware that the exposed concrete staircases are a design feature and that the large, exposed thermal mass helps to regulate internal temperatures within the building. Some students also reported that they felt the building lacked some character and that they felt colour would make the internal building 'happier'. Students suggested that their own work could be used in displays to help build character and decorate the white walls.

Form and Materials

Form and materials is concerned with the building's physical composition, scale and configuration within its boundaries.

Building users reported that they found the external aesthetics of the building inspiring and that they believed the materials and finishings were of a high standard. Users did express their desire to utilise all areas of the Campus and explained that they were disappointed that they cannot gain as much access to the riverfront from the coffee area or to the Secret Garden as they would like. These areas are viewed as desirable by users and the group would like to encourage the University to make these areas more accessible to users throughout the year.

Building users commented that many new users do take some time to familiarise themselves with the new Campus and the building layout as many of the corridors do look the same and that it can be difficult to navigate using the room numbering system. Users reported that additional signage may help to assist visitors and new students who visit the building for the first time.

Building users also commented that they generally felt the quality of the building, design, furnishings and overall make-up of the building is of an excellent standard and that the modern design is inspiring. Users also reported that they liked the library, and that the 'nice open space allows for fresh, creative thinking'. However they there was comment in relation to the poor acoustic performance of the partitioned rooms, despite offering a good level of flexibility in terms of available floor space.

Character and Innovation

Character and innovation is concerned with what people think of the overall building.

Focus group participants reported that they found the building to be modern and clean. Some users reported that they felt the building had great character and a positive reputation and would recommend (and have recommended) to prospective students and community partners. Other students did express that they would welcome the opportunity to personalise some areas, e.g. display student work on some of the white corridor walls.

Towards the end of the occupant workshop building occupants were asked about their general opinions of the building and how the new campus compared to the previous building they studied in.

Users commented that they very much enjoyed the abundance of natural daylight within the building and the natural setting of the Campus and found that the facilities accommodate the needs of most students. Many found the building a welcoming, open, clean space and others commented on the impressive design, character, facilities, interior and exterior, management of building and ease of use, improved I.T. provision and the shared space, teaching facilities and break-out spaces. As already mentioned, many building users experienced issues with the heating and ventilation in a number of areas and also expressed a desire to be able to open the windows, however in general users reported that they were satisfied with the new building.

Users did comment that they would welcome more interaction and integration between SRUC and UWS students. Some SRUC students felt as though there was a lack of SRUC image within the building and that they would welcome discussions between the College and University regarding further shared facilities and methods for enhancing social integration between the two groups.

The majority of users reported their preference for their new building over their previous academic building, overall with many positive comments including:

- Far superior and more impressive;

- A real improvement in the teaching resources;
- There is no comparison. This building is fit for purpose;
- Night and day;
- New building is much better;
- No comparison – the old building was falling down;
- Wheelchair access is much better and there are now two lifts;
- Brighter, more modern, cleaner and better learning environment. Space provisions are vastly improved at new campus compared to previous campus;
- Overall, virtually every aspect of the new building is vastly superior to former building, and is absolutely brilliant to work and study in;
- IT facilities, teaching, shared study and private spaces are greatly improved, appearances (internal and external) are vastly improved. Catering is much improved, library is larger with greater facilities (for study and group work and meetings); and
- New building has better facilities.

4.2 BUS Survey

Carrying out a structured survey was the second stage in the consultation process. The set of pre-determined questions within the Building User Survey were distributed to staff and students provided some addition to the initial user consultation exercise. The adopted methodology and survey results are described in the following sections.

Methodology

In order to investigate if users' needs are met, BRE was required, as part of this exercise, to measure occupant satisfaction using the BUS approach, developed by an independent party and managed by ARUP. The BUS (Building Use Studies) methodology uses a structured questionnaire which was designed to try and extract as much information as possible from as few questions as possible. Respondents rate various aspects of performance on a scale of 1-7 and can also provide comments so both quantitative and qualitative feedback. Over 45 key variables are evaluated covering aspects such as thermal comfort, ventilation, indoor air quality, lighting, personal control, noise, space, design, image and needs.

The BUS format and content is fixed, which was challenging for some Ayr Campus users when completing the BUS as a number of the questions were difficult to relate to a mixed-use Campus such as this one. In order to support students and staff when completing the BUS, BRE staff made themselves available at the Ayr Campus to help explain the BUS questions and how best to respond to these.

When analysing the results it is important to remember that the BUS compares a number of different buildings with different functions, uses and facilities and that a direct comparison cannot always be made with user feedback from the Ayr Campus with that of a similar building.

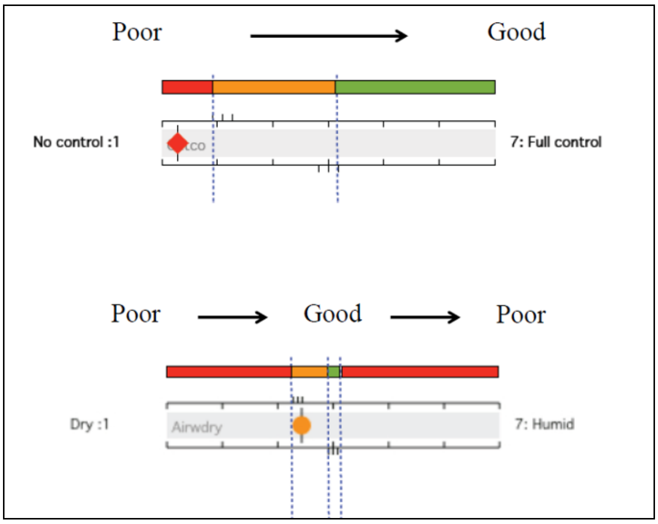

Figure 21 – BUS survey questions scales

The BUS requires users to complete it by hand. BRE staff visited the UWS Ayr Campus in November 2012 and distributed the BUS to as many occupants as was physically possible on the day. As a result 162 responses were collected from both staff and students. As is shown in Figure 21 the BUS has two types of questions. The BUS captures and reports responses on a sliding scale from 1 to 7, representing a ‘poor’ or ‘good’ response. This is demonstrated in Figure 21. Either the best possible conditions can be represented with a score of 7 or 1 – the highest or lowest score, or 4 - an ideal mid-point. For instance, an ideal score for the overall comfort within the building would be represented as 7. On the other hand, for the summer air in terms of relative humidity, the best score would be represented as 4 as neither, indicating that the conditions are neither too dry nor too humid, which is beneficial for the occupants. However, benchmark scores are also taken into consideration to allow a comparison against any other buildings that have previously been surveyed. It means that an acceptable score range might not necessarily fall between the scale midpoint, and it can be extended including the benchmark’s upper or lower limits, this is shown in Figure 22.

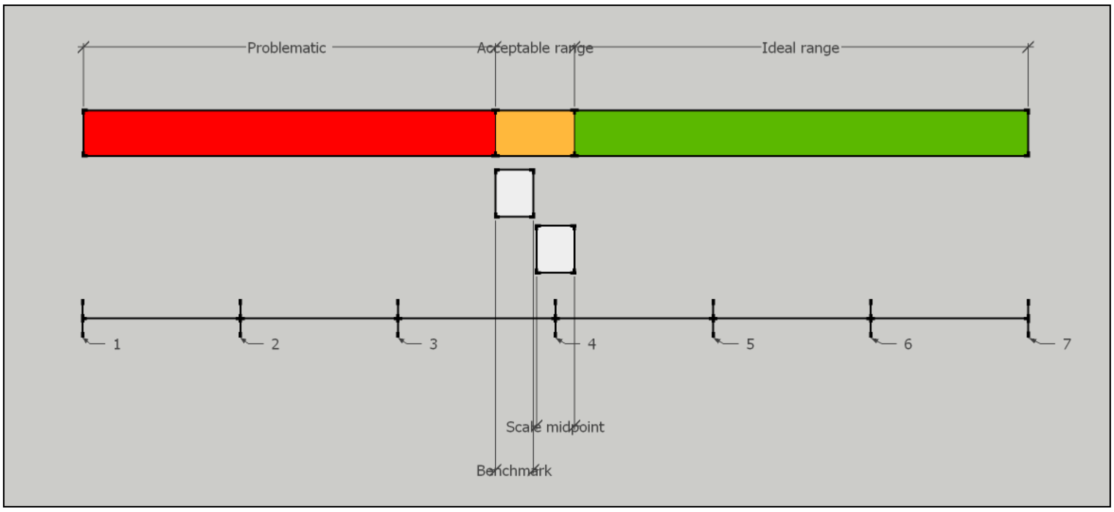

Figure 22 – A sample scale range

A colour key is used to identify the results of the BUS. This is described as follows:

- Better than acceptable or ideal (green);
- Acceptable (amber); and
- May need attention (red).

Results

The results of the survey can be grouped into seven main categories; temperature, air, lighting, noise, control, design and needs and facilities management (Figure 23). This section of the report focuses on overall finding from the survey. Exact scoring, benchmarks and scale midpoints are included in Appendix **Error! Reference source not found.**.

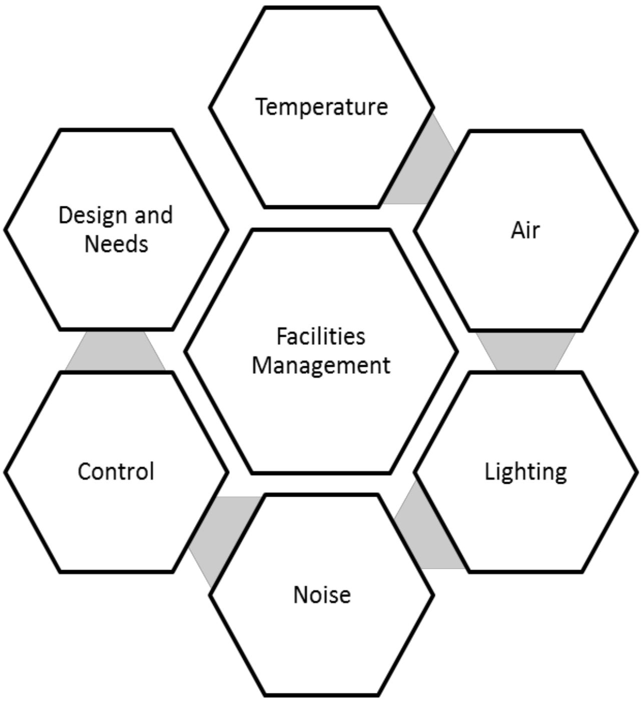

Figure 23 – BUS Survey - Categories

Figures 24, 24 and 26 summarise responses for each of these categories, highlighting the ideal scores, the low scores and the high scores from the BUS.

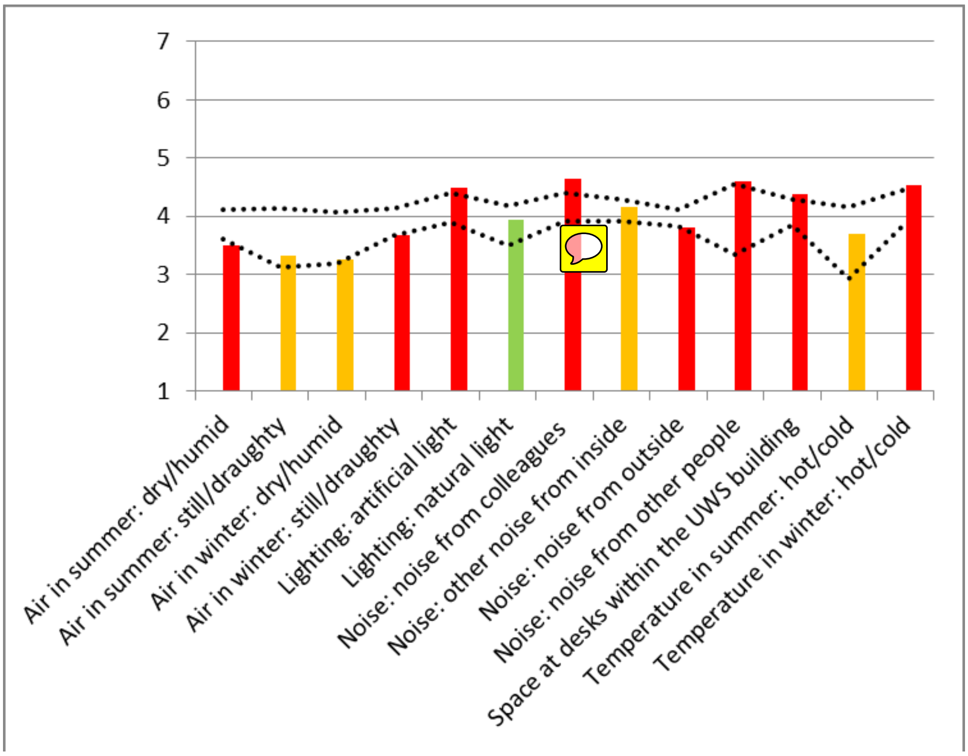

Figure 24 - BUS results – mid scale score (4) being ideal
(Dotted lines indicate ideal or acceptable results range)

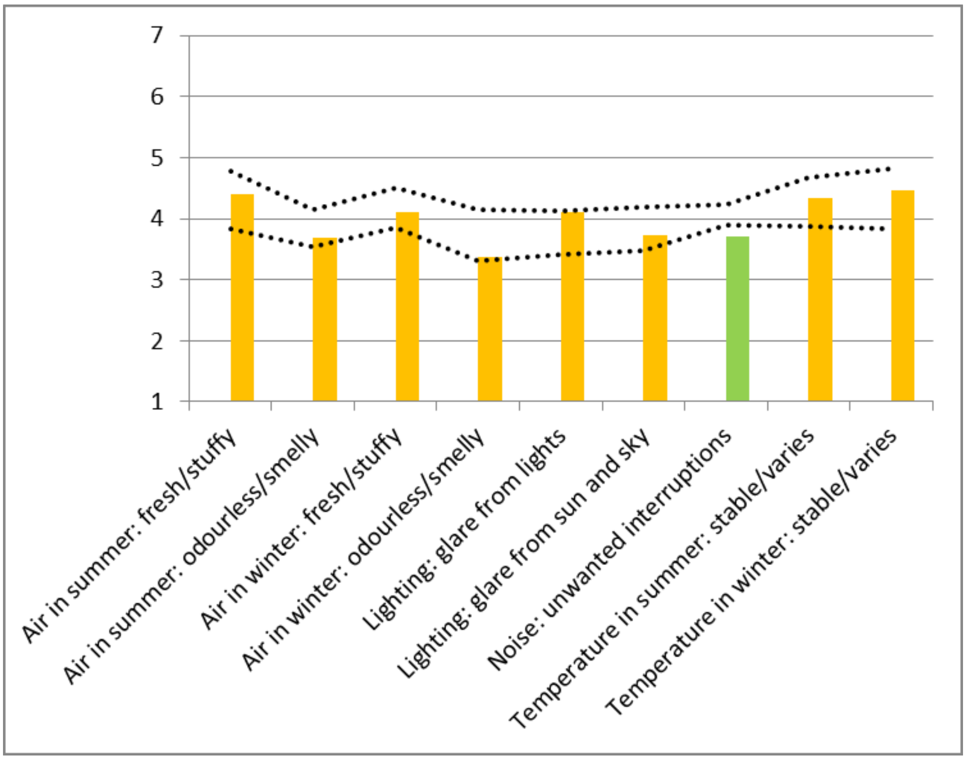

Figure 25 - BUS results – low score (1) being ideal
(Dotted lines indicate acceptable results range, values below the lower line would be ideal)

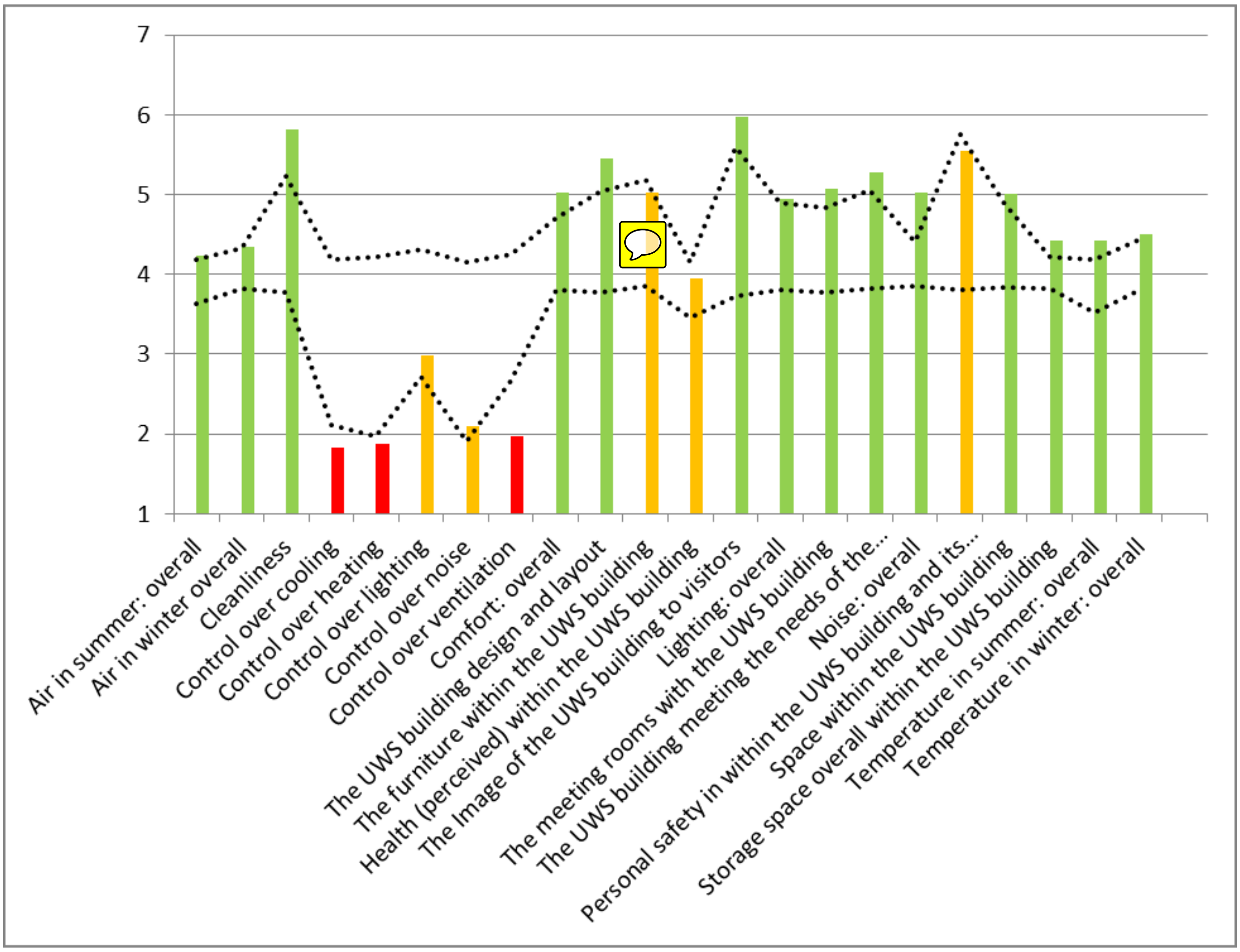

Figure 26 - BUS results - high score (7) being ideal
(Dotted lines indicate acceptable results range, values above the top are ideal)

Temperature

Temperatures within the campus were considered and scored separately for summer and winter periods. The BUS results confirm that the majority of scores fall within and acceptable range (amber).

Numerical results suggest that temperatures in the summer are considered by users as being too hot rather than too cold and that temperatures in the summer are also considered as varying during the day rather than being stable. The score falls into the acceptable range and does not suggest a problem; however there is scope for improvement.

For winter temperatures the Ayr Campus building recorded a score which was just outwith what the BUS considers to be an acceptable limit. The results suggest that cold temperatures can be unpleasant for the occupants. As was noted during summer periods, occupants perceive variations in temperature; however the results do not suggest a major problem.

The BUS results for this category do not indicate any major issues, however there is room for improvement, especially in terms of the cold temperatures occupants reportedly experience during winter. However, overall scores for both, summer and winter temperatures were positive. Both received a 'green' score which suggests overall comfortable temperature conditions in general. This is summarised in figures 27 and 28.

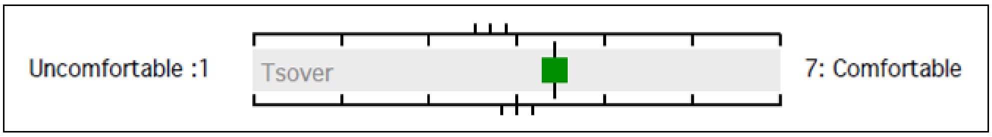

Figure 27 - Summer temperature overall (BUS survey)

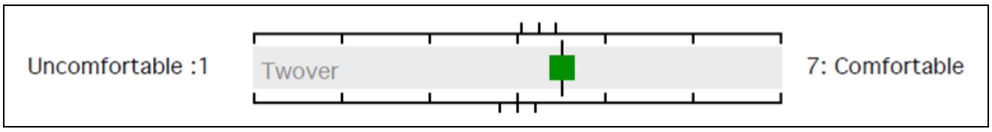

Figure 28 - Winter temperature overall (BUS survey)

Please refer to section 8 Internal Environment to view findings of the internal temperature monitoring. BRE undertook additional internal environment monitoring as part of this project within a few selected spaces of the Ayr Campus building.

Air

Similarly to temperature, internal air conditions within the Campus were considered and scored separately for the winter and summer periods and the following characteristics were investigated;

- Dry / humid;
- Fresh / stuffy;
- Odourless / smelly; and
- Still / draughty.

The results of the BUS confirm that the building's air is viewed as being dry rather than humid during the summer months. It is also viewed as stuffy rather that fresh. The score falls within an acceptable range thus it does not suggest a problem. In terms of odours, summer air within the campus is perceived as odourless and the score falls within an acceptable range. And finally, summer air is reported as still rather than draughty, with an acceptable score. This is largely as a result of the design and layout of the building e.g. no openable windows in many teaching spaces.

Although, there is some room for improvement, especially in terms of air being dry, the overall score for air quality during summer is very positive having a 'green' score as is shown in figure 29.

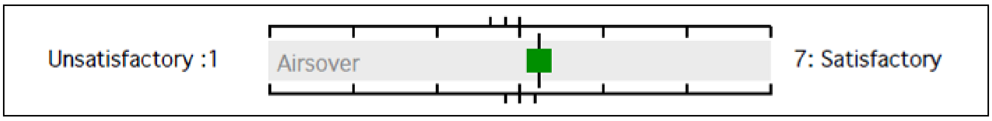

Figure 29 – Summer air quality overall (BUS survey)

In the winter internal air falls into an acceptable range in terms of any odours, humidity levels and freshness. Winter air is perceived as still rather than draughtily and although it falls slightly out of the acceptable range it does not suggest any major problem. As with summer air, the overall score for winter months suggest comfortable conditions as is summarised in figure 30.

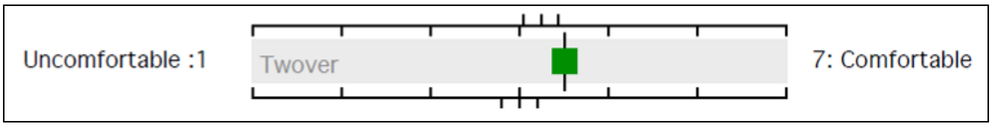

Figure 30 - Winter air quality overall (BUS survey)

Lighting

Lighting at the Ayr Campus was scored taking into consideration;

- Artificial light;
- Natural light;
- Glare from lights; and
- Glare from sun and sky.

Figure 31 – Naturally lit gymnasium in the basement

The building's artificial lighting is viewed by BUS respondents as being too much rather than too little, although it does not fall within the area of ideal or acceptable, the score does not suggest a major problem. Natural light entering the building received a positive score falling into an ideal range. It means that the occupants feel that the amount of natural light is neither too low nor too high. In terms of glare from; artificial lights, the sun and the sky the scores fell within an acceptable range. Although there is room for improvement, especially with the use of artificial lights, lighting overall received a very positive feedback with a high level of users' satisfaction as shown in figure 32.

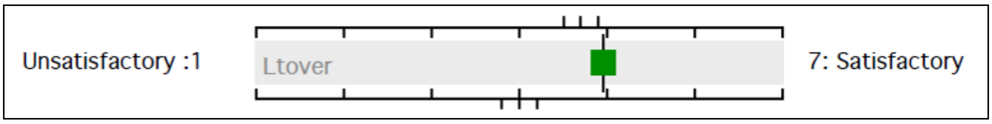

Figure 32 – Lighting overall (BUS survey)

For additional guidance and results of the lighting level 'spot check' tests that were completed at the Campus please refer to sections 0 Lighting levels and 0

8.2 Spot Checks of this report.

Noise

Noise levels within the Campus were scored against the following;

- From colleagues;
- From inside;
- From outside;
- From other people; and
- Unwanted interruptions.

Figure 33 – Wall mounted acoustic panels in the performance studio

An ideal score was awarded to the 'unwanted interruptions' category, which means that the occupants did not complain about disturbances, such as maintenance work which would distract them from everyday tasks. However most of the results, illustrated in Figure 24, show that noise from various sources fell below the acceptable level. Noise from colleagues, other people or from outside was viewed as unacceptable. From the additional consultation workshops, user feedback would suggest that those responses could potentially be

from staff members who are not yet accustomed to working in open-plan offices or from students studying in the library during exam periods. Perhaps, due to warmer temperatures and doors being opened to corridors, noise from other occupants passing through the building could also be a source of disturbance. Any other internal sounds, such as operating plant or systems within the building, were not seen as a problem. Despite some negative responses, overall noise levels at UWS were marked as ideal as shown in figure 34.

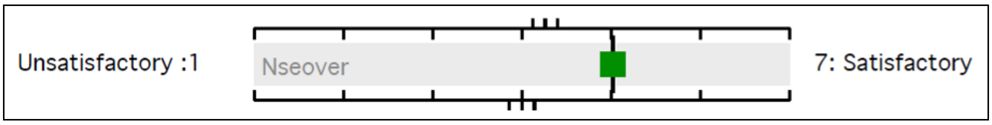

Figure 34 - Noise overall (BUS survey)

In addition to these BUS findings, BRE carried out on-site sound level tests to identify any potential problems with the building which would lead to unnecessary sound transmittance. Please refer to sections 0 Table 16 – Comparative Light Levels

Noise levels and 0

8.2 Spot Checks of this report to examine these results.

Control

Building users gave feedback in regards to control over building services;

- Cooling;
- Heating;
- Lighting;
- Noise; and
- Ventilation.

As demonstrated in Figure 26, it is clear that there is limited end user involvement in controlling how this building operates;

- Control over cooling, heating and ventilation are seen as unacceptable; and
- Control over lighting and noise are seen as acceptable.

Two gas boilers, a number of chilled beams and thirteen air handling units help to service and provide heating, cooling and ventilation to this building. A variety of radiators and an under-floor heating system help to provide heat to the building. As a result, those services influence internal temperatures, relative humidity and air quality. A perceived lack of control over the internal environment from the user perspective appears to be an issue. In addition to negative comments regarding temperatures being too high or too low and still or dry air within the building, some occupants also complained about not being able to open the windows. They believe that by having this flexibility it could improve their working environment. In contrast, other building users, including administration office staff for instance, were satisfied with their office environment. Section 8

Internal Environment of this report contains an analysis of the internal environment readings and does not suggest that there are any major problems in the intensively monitored areas of the building.

Occupant' control over noise and lighting was seen as acceptable. Users would appear to appreciate that individual behaviour and management of spaces can help to ensure that there are no adverse issues in relation to internal noise pollution. Noticeably, an intelligent sensor controlled lighting system is in place and helps to ensure that the artificial lights in the building are only powered on when needed. Occupants do feel that they are able to control the lights at a reasonable level, despite having some complaints in relation to the settings of the lighting system and sensor controls.

To manage issues relating to buildings services' control and to ensure that occupants understands the level of control that they can exercise, it is recommended That UWS delivers information sessions for both staff and student to receive training to help raise their awareness in relation to local level control and to understand what influence they can have and also what central level control is in place. A number of matters in relation to the building design, services and controls could be discussed, such as:

- Design, layout and servicing which all help to understand the reasoning behind not having openable windows in all areas;
- Temperature settings adjustable to users' needs e.g. the use of TRVs on radiators, the zoning and control mechanism for the delivery of heat etc. The function of the daylight and movement sensors explained and the benefits of these.
- 'Out of hours' energy savings and how to help accrue these.

Please note that the estates team should be supported first to ensure appropriate and accurate information is delivered to the building users.

Design and needs

The BUS survey results confirmed that the users provided very positive feedback on the building in relation to the design and how the building meets users' needs, as figures 35 and 36 demonstrate. Many users commented that they enjoyed the clean, spacious and modern design and feel that their working environment is very pleasant. A variety of spaces, from quiet study to lobby seating areas, to modern labs appear to satisfy users' expectations. The introduction of open plan offices and bright open spaces with 'beautiful views' increased peoples' wellbeing. The building was reported to meet users' needs in terms of rooms spaces, access, safety and new facilities such as a room booking system and interactive 'smart boards'. Additionally, respondents were particularly pleased with The Campus staff who were described as friendly and helpful.

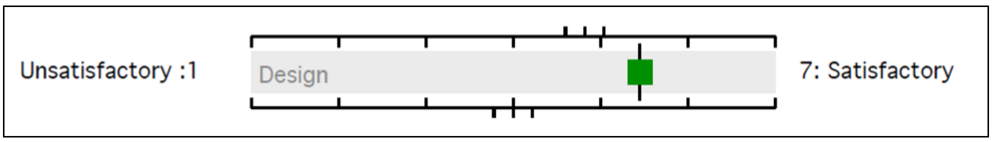

Figure 35 – Building design (BUS survey)

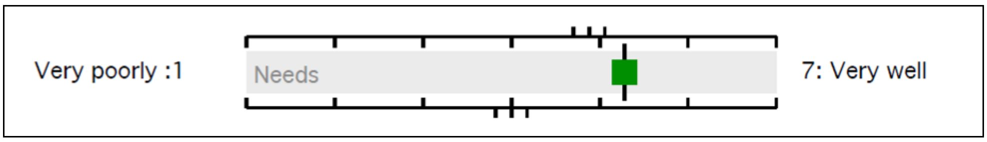

Figure 36 – Building users' needs met (BUS survey)

Facilities management

Finally, the BUS survey asked users to comment on the buildings' facilities management and included matters such as;

- Cleaning;
- Furniture;
- Health (perceived);
- Image to visitors;

- Meeting rooms: overall;
- Productivity (perceived);
- Space in the building;
- Space at desk;
- Storage space: overall; and
- Do facilities meet needs?

The majority of responses received were positive responses. This is demonstrated in figures 37 to 42 and Appendix **Error! Reference source not found.** contains additional comments from the **Error! Reference source not found.**.

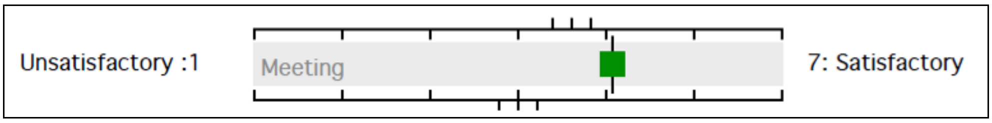

Figure 37 – Meeting rooms overall (BUS survey)

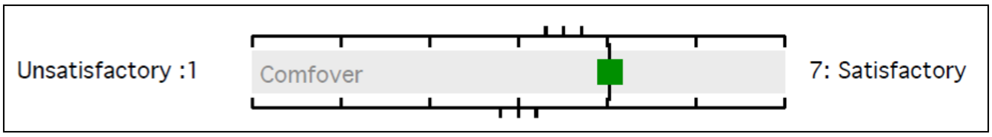

Figure 38 – Comfort overall (BUS survey)

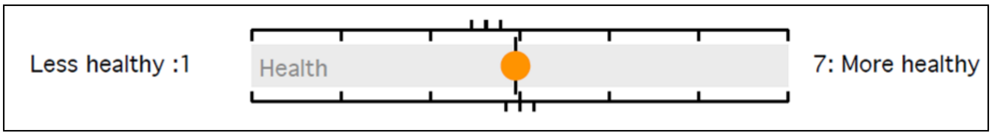

Figure 39 – Perceived health (BUS survey)

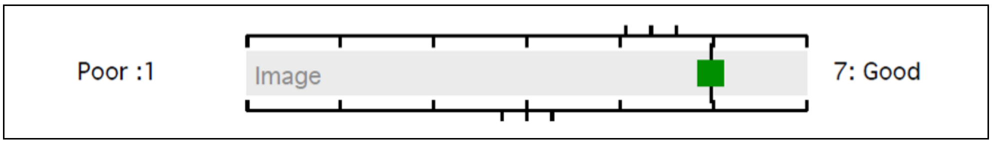

Figure 40 – Image to visitors (BUS survey)

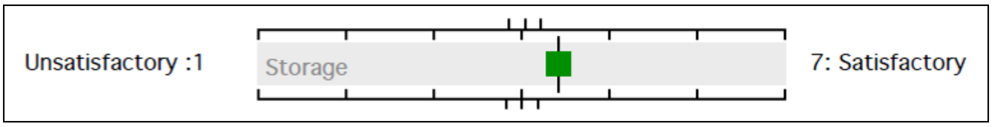

Figure 41 – Space overall (BUS survey)

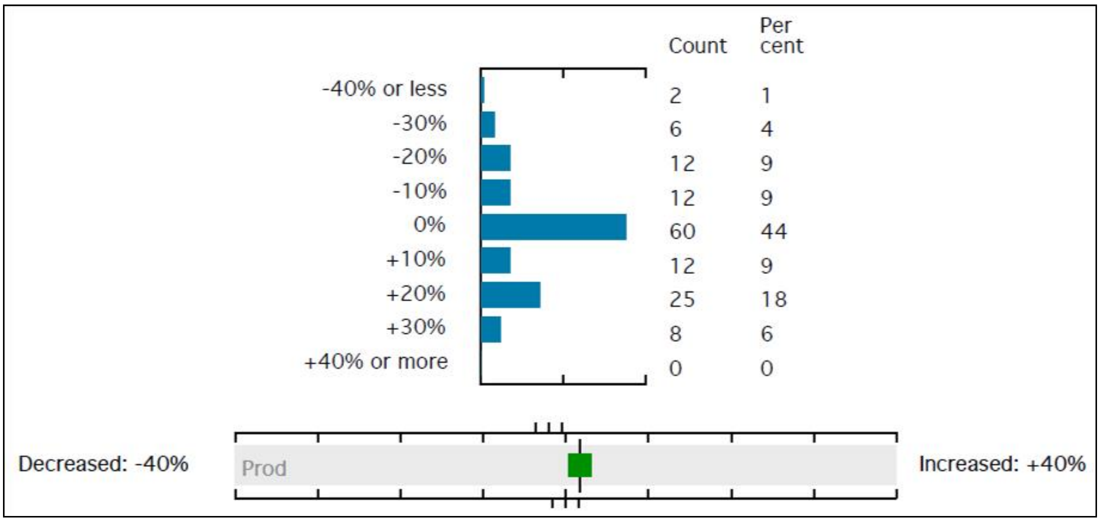

Figure 42 – Perceived productivity (BUS survey)

To summarise the overall feedback in relation to air quality, lighting and noise levels, design and needs and facilities management was positive. Temperatures during summer and winter periods could be improved, especially in terms of being too cold in the winter and too hot in the summer within the campus. A lack of control over building services raised the most concerns from the BUS respondents.

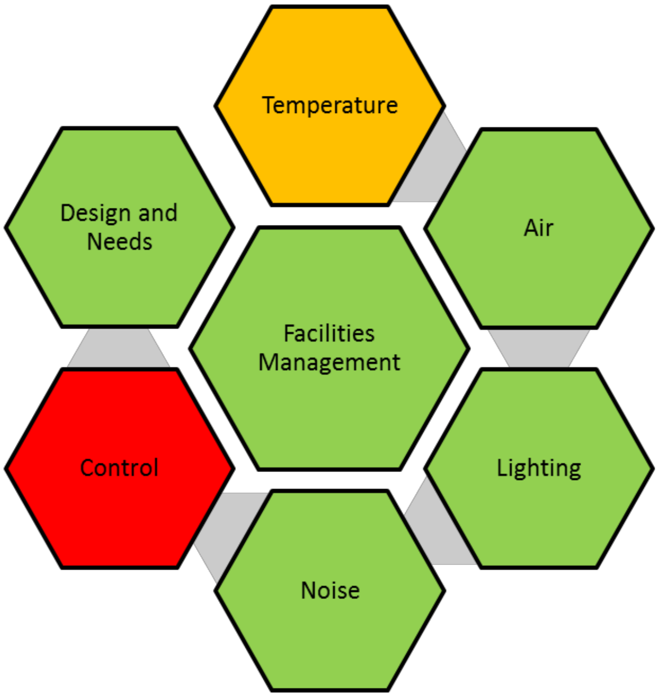

Figure 43 – BUS Survey – Overall Results

4.3 Final occupant consultation

Towards the end of the project, in June 2014, BRE carried out a final occupant consultation workshop with staff members. The aims of this session were to;

- Share and review the initial feedback from building users & the BUS survey;
- Share the results from the internal monitoring / fabric testing with users;
- Summarise how the building users now feel about the building design and its operation; and
- Review whether occupants' needs have been met and if users feel comfortable in the campus.

Staff who attended the sessions represented a number of areas including members of the estates team, administration and library staff as well as the sports staff. Attendees represented both the UWS and SRUC. The meeting was organised around four discussion topics, providing a two-sided analysis of the building itself and the occupants using the space. This is demonstrated in figure 44.

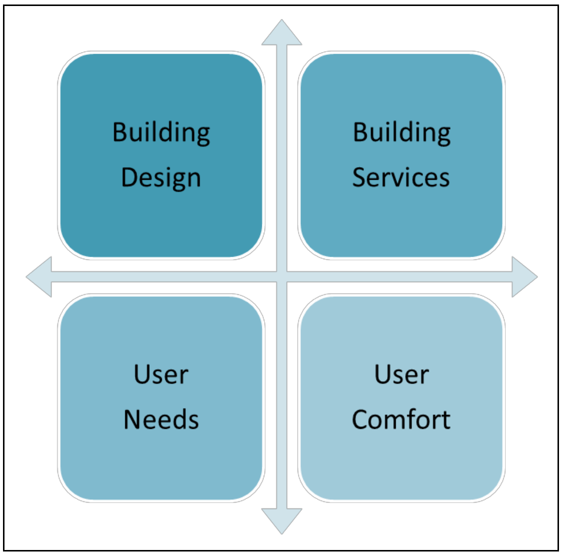

Figure 44 – Discussion topics at occupant consultation session

Building design

Throughout the design stage of the project there was good relations and collaboration between the design team and the client. Building users were involved in consultation sessions where they could express their thoughts in relation to functional and aesthetical requirements of the new campus.

During the final consultation workshop, facilitated by BRE, there was an opportunity for occupants to evaluate how successfully the outcomes of the design stage consultation had been implemented within the final design and to collect final feedback from the users on the design and layout of the campus form an operational perspective.

Staff explained their involvement in design decisions making process and provided examples of their participation in the design of the atrium space and the library. Originally, a circular staircase was designed to be a feature element of the atrium. However, users explained that they had felt that this element would not be very practical and they believed that straight flight stairs would be more convenient to use and by having them located to the perimeter of the atrium would create more usable space. This feedback was reflected in the final design.

Users expressed that they were very pleased with a final result and believe that they have gained a better utilised social space, which was a very important feature for them. Staff working in the library area also mentioned that changes had been made to the initial design of the library counter. As a result of feedback the staff now believe that they have a desk and area that is more fit for purpose. Additionally, other users made suggestions that they preferred cellular type offices rather than larger open plan areas. This was successfully implemented into the campus' layout. A series of small spaces around a courtyard on all levels can be viewed on the floor plans in Appendix **Error! Reference source not found.** of this report.

✓ Very clean & modern	× 'Asylum' appearance, plain
✓ Handy layout	× Too big
✓ Lots of seating	× Toilets should be more central and better signposted
✓ Excellent size	× No lockers
✓ Open plan offices	× Revolving doors
✓ Work laboratories	× Poor external lighting (safety)
✓ Good image to visitors	× Traffic, public transport & parking
✓ Classrooms too small	× Access
✓ Pleasant site	

Figure 45 – Building Design – discussion topic 1

In terms of the existing facility staff agreed with positive comments summarised in Figure 45. They confirmed that the overall space and layout provide a very pleasant working environment and were satisfied with the modern, clean design, the sites' surroundings and how well the building fits into the environment. The library area spread over three levels is seen as particularly successful. It is visible from the entrance foyer, which staff reported is a large improvement in comparison to the old campus. Currently students are intuitively led into the study space, which provides various areas, from discussions spaces, to quiet study areas, to separate rooms for group work. Overall, the staff reported that they feel that they have gained an impressive facility which helped in raising their profile. The building has been described by users as a striking landmark and is reportedly attracting a number of visitors who have an enjoyable experience. During the final consultation workshop discussions staff agreed that the University would benefit from utilising the campus better. Staff commented that the facility could be advertised to accommodate local events, which would attract interest from the local community and could also generate some income which staff felt could be used to assist with on-going maintenance requirements.

Some of the less positive feedback from the BUS survey was also discussed. Some of this feedback, such as a revolving door entry system was challenged during the discussion. Although having a revolving door entry system might be viewed by some as inconvenient to use, the group did agree that the design does help to provide much needed protection from any drafts which would otherwise enter the foyer and the atrium space. Lowering the internal temperature and would create an uncomfortable working environment for reception staff. Moreover, this system contributes to energy savings – one of the top priorities of the University's sustainability agenda. Other issues including toilets signage or insufficient external lighting are already being addressed by the University. Staff who were present during the final consultation session disagreed that there were issues with access, public transport or parking and explained that all of these have been significantly enhanced when compared to the old Campus.

Finally, flexibility and spaces that are fit for purpose were discussed as desirable characteristic. Areas such as classrooms and the library should be adaptable for a change of use or some modifications. Staff felt that the size and layout of most teaching rooms offered a good degree of flexibility, however the low level floor vents were perceived as a restriction in some rooms as staff felt that these dictated the furniture arrangement. During this session it was pointed out by the Estates team that it is feasible to move and relocate the floor vents, which would help to resolve any functionality issues in this respect.

The gymnasium generally received positive feedback, particularly in relation to the level of natural daylight entering the space. However, sport tutors explained that they were disappointed with the shape of the gym area which they described would have been better if it was more rectangular in shape rather than square as this would have been more appropriate for team activities, such as football, tennis, and so on. The possibility of having shared external facilities was discussed (as part of a separate education development) and this was received very positively by all.

Building services

✓ Acceptable glare levels from lights and outside	× Too cold
✓ Natural light	× Too hot
	× Stuffy
	× Draughts
	× Not operable windows
	× Automatic lighting controls not working (timing, dimming)
	× Lighting – too bight / too dark

Figure 46 – Building Services – discussion topic 2

After discussing the design, layout and functionality of the campus, the session then focused on user perception in relation to the building's operation. When discussing natural lighting , staff agreed that they enjoyed good levels of natural lighting levels throughout the building which reduced the need or demand for artificial lighting. They also confirmed that they were not aware of any issues in relation to glare. Staff, however, did agree that many users complain about comfort in relation to internal temperature levels, drafts and the operation of the artificial lights. Detailed within section 0 and Appendix **Error! Reference source not found.** of this report, is a record of a mix of views form building occupants in relation to temperature and air quality within the campus. However, staff who attended this final consultation session did confirm that they found most areas within the building comfortable. BRE's internal environment monitoring confirmed that temperature levels are higher at times than the recommended maximum comfort level of 21°C in some areas, staff were pleased with their working conditions. Additionally, the estates team confirmed that the temperatures can be adjusted in most areas using the BEMS to suit the users' preferences for each zone within the campus.

Air quality was raised as a concern by some users who responded to the BUS survey. However, BRE's closely monitored a selection of teaching, office and library spaces over a period of time and none of the results suggested that there was reason for concern when examining relative humidity and CO_2 levels (please refer to section 8 Internal Environment for further details). From the 'spot check' readings that were collected around the campus, the results confirmed that the air quality in the smaller, cellular staff office accommodation was of the poorest quality, yet these areas did benefit form control at a local level via openable windows and vents. The survey and consultation feedback suggested that occupants in these small office rooms are not opening their vents and windows to adequately promote fresh air exchange, as a result of wishing to maintain higher internal temperatures and are therefore reducing the quality of their internal air as a result. In mechanically ventilated spaces where there is a lack of openable windows, intuitively occupants believe that their air quality has decreased as a result of a perceived lack of control. BRE did not record anything in relation to air quality levels that would suggest any concern; however this could be possible if the ventilation system was not properly programmed to accommodate air exchanges that are suitable for the number of occupants and different activities in different areas of the building. Thus, it is recommended to review these settings and the review the zoning strategy with the occupant numbers and end use for each area. It would be advised to check that the ventilation system has been adjusted appropriately and is not set to the original default settings (that may not have been changed since the building's handover).

The reception area and the gymnasium are serviced by the buildings underfloor heating system. No negative feedback has been received in relation to the reception area, users of this space are happy with their environment. However, for those who make use of the gym area the most common feedback was that there is a lack of local control over the temperature in this space and that the underfloor heating system is not responsive enough for users. The evening fitness classes were given as an example of when the gym area is reported to be uncomfortable due to a lack of cooling and ventilation. This suggests that the building services' programming and settings should be reviewed and adjusted, with a particular attention to timetables to ensure that areas are serviced during times when they are occupied.

The level of user control and the operation of the artificial lighting was reported as a concern. Some users complained about a lack of control, dimming not working properly or not being satisfied with the timings that have been programmed for the lighting occupancy detection sensors. Staff present at the consultation workshop confirmed that the artificial lighting control system was complex and difficult to understand and operate efficiently. This feedback was also echoed through the occupant feedback that was collected from the BUS survey. The Estates team suggested that various lighting settings can be individually changed to accommodate user preference. While this is possible, it should be noted that this would be a time consuming exercise. It is recommended that a structured approach and procedure is adopted to help examine what the operational requirements for each of the different areas within the building and to adjust lighting levels and control settings according to planned activities and timetabling to accommodate these.

Current and future maintenance requirements were also raised during the discussion session. It was estimated that some plant and services equipment would be required to be replaced within the next ten to–fifteen years. At present, the Estates team confirmed that there is a significant amount of funding being allocated to on-going maintenance and general upkeep; however they are not aware of any longer-term plan to ensure that there will be adequate provision of funds for future replacement items that have will require significant capital expenditure. Examples of current, significant maintenance expenditure includes external fees being paid to specialist lighting engineers to cover everything from light bulb changes to software programming updates. The University also incurs significant costs in relation to the hire of specialist equipment which is required to access high-level glazing and lighting systems within the atrium space, for general maintenance and cleaning purposes. It is recommended that a detailed maintenance plan is developed to allow all of the required maintenance, along with any future replacement costs, to be identified and adequately planned for. It would also be beneficial for the University to consider maintenance and replacement requirements for the building envelope, internal finishes and external spaces.

User needs and comfort

The BUS results indicated that occupants believed that the new Campus meets the majority of their needs. Occupants reported that they were pleased with their new working environment and pleasant soundings. The BUS survey results revealed many positive comments in relation to staff who are considered by students to be very helpful and friendly. Attendees of the consultation workshops confirmed that staff members had received an award for an excellent customer service.

✓ Good facilities
✓ Great building
✓ Effective security
✓ Space
✓ Friendly staff
✓ Booking system
✓ Classroom space
✓ Work space just right

× Furniture
  × uncomfortable / poor quality / chairs don't fit under the desks
× Meeting rooms
  × small / no privacy / limited availability
× Crowded stairs
× IT equipment
  × computers availability / performance
× No gym facilities
× Storage / lockers
× Small desks

Figure 47 – User Needs – discussion topic 3

There were also some aspects where attendees felt that there was room for improvement, such as the provision of more storage space for staff and students. Occupants also agreed that the provision of IT facilities had greatly improved, however they did comment that they believed that there was still room for improvement here in relation to access and performance (e.g. connectivity and speed). Staff and students were also of the opinion that there could be more extracurricular activities for all to enjoy. Many expressed a desire for an accessible gym facility that could be utilised by all users during their free time.

User comfort was discussed as a combination of the following;

- Daylighting;
- View out;
- Air quality;
- Thermal comfort;
- Aesthetics; and
- Comfortable furniture.

These topics have been described previously and although the views were mixed for some aspects, building users are reported to feel comfortable in their new campus overall.

✓ Daylight
✓ External view

× Poor air circulation

Figure 48 – User Comfort – discussion topic 4

4.4 Building User Guide review

A non-technical Building User Guide (BUG), which is usually developed by the design team and issued to occupants prior to the building handover stage, can be effectively used to explain what systems and features are present in a new building. The key benefit of this information source is to provide guidance, in non-technical terms, on the level of control an individual has within the building. This is often viewed as an invaluable source of knowledge for building occupants.

UWS benefits from having two separate BUGs, one for general building users and one for the Estates team. The BUGs are available in an electronic format and are accessible to users via the Campus extranet.

This section of the report investigates the guide that has been prepared for the Estates team, who have a greater responsibility in terms of building operation and controls. Thus this guide should provide more detailed and complex information than the everyday user guide.

BUG Content

The aim of the Building User Guide is to ensure the appropriate provision of guidance for the non-technical building user, so that they can access, understand and operate the building efficiently and in a manner which compliments the original design intent.

The guide should provide information relevant to UWS Ayr campus's staff, students, the Estates team, as well as visitors.

The content of the guide will be specific to the building type, however it would typically include information on the following:

- Overview of the building and its environmental strategy e.g. energy/water/waste efficiency policy/strategy and how users should engage with/deliver the policy/strategy.
- Building services overview and access to controls (where to find them, what they control, how to operate effectively and efficiently etc.).
- Pre-arrival information for visitors e.g. access and security procedures/provisions.
- Provision of and access to shared facilities.
- Safety and emergency information/instructions.
- Building related operational procedures specific to building type/operation e.g. labs.
- Building related incident reporting/feedback arrangements.
- Building related training information/links.
- Provision of and access to transport facilities e.g. public transport, cyclist facilities, pedestrian routes etc.
- Provision of and access to local amenities.
- Re-fit, refurbishment and maintenance arrangements/considerations.
- Links, references and relevant contact details.

Figure 49 – Sheltered, accessible cycling facilities

Review of Current UWS BUG Content

Overview of the building and its environmental strategy

This section should contain as a minimum the following:

- The function of the University campus;
- The key innovative and low impact features of the University Campus; and
- The BREEAM score that the campus has achieved'.
- All of the key operational features of the building should be outlined here i.e. its heating, lighting, water, and waste strategies
- 'Do's' and 'don'ts' in relation to the users helping the Campus to deliver on its environmental strategies.

The guide provides the following:

- A description of the layout and function of the building.
- Its carbon reduction targets for the forthcoming year.
- A guide into the campus' innovative carbon reducing products i.e. heating, ventilation and cooling systems.
- Overview of the waste processes.
- Water saving devices, the water monitoring scheme.
- A website link for information on UWS' sustainability initiatives.
- Waste strategy – including the campuses composting facilities.

Possible additional information for inclusion into the guide:

- Provision of a floor plan.
- The key innovative and low impact features of the campus.
- Simple ‘do’ and ‘don’t’ instructions - e.g. don’t open the windows when the radiator TRVs are turned high and are also delivering heat to the space etc.
- Short list of the campus’ sustainability initiatives.
- How the sustainability targets are going to be met, and who is responsible for implementing and managing the strategy.
- Contact details for the campus sustainability champion.
- Guidance on all controllable features and restrictions for the building users and Facilities Management. Each relevant part of the section should be clearly marked for the appropriate users group(s).

Building services overview and access to controls

Guidance should be provided for the control of the temperature/ventilation. Information contained here should include the following:

- Map location of the appropriate controls and zones that they control.
- Information on how to operate the controls effectively and efficiently.
- ‘Do’s’ and ‘Don’ts’ in relation to building users achieving the energy strategy.
- This guidance should encompass visitors and UWS Staff.

The guide does provide the following:

- Information on the various technologies that are currently in use.

Possible additional information for inclusion into the guide:

- Maps of the campus that include the location of the technologies and controls.
- More detailed information on how the controls should be operated (for Estates team in particular).
- Attachment / web link to the Operation & Maintenance Manual (OMM) – referred to several times.
- Further explanation of ‘Natural Ventilation’, ‘Displacement Ventilation’, ‘CO_2 sensors’ and ‘Active Chill Beams’ to allow users to identify which of these is in operation and to allow them to identify what level of control they have over each internal environment.

- Restrictions and limits on building controls. Can all building users adapt the internal environment as per their requirements? (I.e. temperature, air quality etc.)
- Location of the disabled WC and instructions detailing how to operate the controls efficiently i.e. emergency controls/flushing etc.
- Allocation of all required maintenance tasks to appropriate, responsible person to ensure that these are completed e.g. register and allocation of ‘oil bund empty’ task, to ensure it is completed.
- Contact details of the Building Management System (BMS) manager.
- This section should also include guidance for the Estates team and should include the following;
- Maintenance / replacement guidance.

Pre-arrival information for visitors

This section should contain guidance on the following as a minimum:

- Transport: Directions to and from the campus, the parking provided and public transport strategy.
- Access: any issues and the sign in procedure.
- Facilities: toilets and showers etc.

The guide does provide the following:

- The location of pathways into the campus.
- Information on car parking and cycling rack locations.
- Information on first aid facilities, toilets and showers.

Possible additional information for inclusion into the guide:

- Mapping – routes how to the site from existing public transport hubs train / bus etc.
- Access: Information should be provided detailing procedures for ‘in hours’ and ‘out of hours’ operation, sign in procedure and times of restricted access.
- Ease of access instructions for disabled building users e.g. ramps / disabled toilets / manoeuvrability.
- Details of building procedures that are on-going – safety briefing (fire drills / emergency exits / sustainability initiatives etc.)
- Sign posting to emergency procedures and contact details in case of fire / accident.

Provision and Access to Shared Facilities

It would be beneficial for all potential users if the guide provided more detailed information on the provision of and access to shared facilities. Possible additional information for inclusion into the guide includes:

- The opening and closing times of the shared facilities.
- Details of any requirements for users to complete any required authorisation forms to ensure management procedures and any health and safety requirements are managed and addressed.
- Clear signing and of restricted areas, taking into account the deaf and visually impaired.
- Mapping illustrating restricted areas.

Safety and emergency information / instructions

It is recommended that, as a minimum, guidance should be provided on the following as a minimum:

- Emergency procedures: what to do and where to assemble in case of an emergency or accident.
- Details on when the emergency alarms are scheduled for testing.

The guide does provide the following:

- The assembly evacuation procedure.
- Phone number for first aider.
- Room number for first aid room.
- Places where staff will be located upon exit.
- Highlight the provision and awareness of an evacuation lift.
- Location of fire hydrants and extinguishers.

Possible additional information for inclusion into the guide:

- Mapping of fire exits / routes / refuge areas / evacuation lifts.
- Details of schedule fire drills.
- Information on the operation of evacuation lifts and details of the person who is responsible for the operation of these.
- Contact details of a fire warden.
- Details of first aiders in each department.

Building related incident reporting/feedback arrangements

This section should provide the following as a minimum:

- Building related incidents in accordance with legislation: Under the Reporting of Injuries, Diseases & Dangerous Occurrences Regulations 1995, it is imperative that the Campus staff must keep records of any building related incident and follow up with appropriate action where required.

The guide does provide the following:

- A procedure for documenting accidents, who to report to and what must be recorded.
- Details of when and how an accident report must be completed.

Possible additional information for inclusion into the guide:

- Phone number for the emergency services: 999/112.
- Report major incidents to the police.

Building related training information/links

This section should provide the following as a minimum:

- Available training, trainer details and training schedules.
- Building / facilities management training, trainer details and schedules.

The guide does provide the following:

- The document explains that 'training should be given on the controls of all the systems and reading of all the meters'.

Possible additional information for inclusion into the guide:

- Details of the trainer / training organisation.
- Who is required to undertake training.
- How often the training should be undertaken.

Provision of and access to transport facilities

Guidance should be provided on the following as a minimum:

- Car parking/motorbike facilities including any dedicated provision for disabled users.

- Cyclist facilities including showers and lockers etc.
- Public transport links.
- Local Taxi contact numbers.
- Any special transport amenities e.g. electric car.

The guide does provide the following:

- Describes the access routes to the Campus with reference to road names.
- Explains that there are bus services in the local area.
- Provides information on the parking facilities at the Campus.
- Information on cycle storage within the Campus.

Possible additional information for inclusion into the guide:

- Local Taxi contact numbers.
- Mapping of the local area depicting the Campus and the local public transport routes / nodes and access to the facilities.
- Signposting to showering / changing facilities.

Provision of and access to local amenities

Guidance should be provided on the relevant services that are required by each user group.

The guide does provide some information in relation to local amenities.

Possible additional information for inclusion into the guide:

- Map and Information to the nearest local amenities mosgt likely to be accessed by users e.g. shopping centre and sports centre.

Re-fit, refurbishment and maintenance arrangements/considerations

Guidance should be provided on the following as a minimum:

- Building services / fabric maintenance and replacement.
- Considerations for re-fitting / refurbishment of the development: This can include all the services location and important structural features such as load bearing walls along with points of access.

The current guide states the following:

- It highlights that when rearranging furniture and /or partitions occupants must also consider the health and fire safety impacts and requirements.

Possible additional information for inclusion into the guide:

- Information relating to longer-term service replacement / maintenance requirements.
- Life Cycle Cost analysis results.
- A Maintenance Plan - This should include information on acoustics and day-lighting requirements etc. and also ensure that any new construction materials are responsibility sourced and any new services and equipment are energy efficient.

Links, references and relevant contact details

The guide does provided contact details for the Contractor, Project Manager, Architect, Services Engineer, Structural Engineer, Transport Engineer, CDM Co-ordinator, Landscape Architect, Fire Engineer, Access Consultants, Acoustic Consultant, Space Planning Consultants, Ecologist, as well as emergency contact details.

It also contains useful links to organisations such as The Carbon Trust and BRE.

Possible additional information for inclusion into the guide could include:

- West Coast Controls – If problems arise with the 'Night-time Cooling Strategy & Thermal Mass Storage'.
- Phillips Dynalite lighting.
- Manufacturers of building services.
- Receptionist contact details.
- University Switchboard.

Summary of Building User Guide

To maximise the benefits of the Building User Guide for the UWS Ayr Campus, the document should be updated to support the building users. This will ensure that occupants are provided with appropriate information to responsibly manage the efficient operation of the building and its performance during its lifecycle.

A new guide should be enhanced with the information provided in this section, particularly with regards to;

- Building services overview and access to controls;
- Building related training information, and;

- Re-fit, refurbishment and maintenance arrangements / considerations.

This will enable the Estates team to be adequately supported which in turn will help them to achieve the energy performance targets that they have committed to. It would also be advisable to produce a short information page for building users, tailored for each different space, providing an overview of the systems, controls and guidance on operation for each space. This would be easier for users to access, review and digest.

4.5 Conclusions and key findings for this section

This section provides in-depth information on what the building occupants have fed back about their Campus and how well they believe the building meets their requirements;

- Overall the building occupants agreed that the new facility has significantly enhanced the learning experience for staff and students, particularly compared with their old Campus. Users agree that the overall site has been greatly enhanced. Access through the green woodland has been significantly improved and is now a safer connection from the Campus to the Town Centre. User's appreciated urban and social integration of the new facility and felt that close contact with the surrounding environment improved their overall wellbeing. Vehicle and cycle parking facilities have been enhanced to help meet users' needs;
- Occupants were generally pleased with the variety of spaces that are now available and the abundance of natural light and scenic views out that the building now enjoys. Sport facilities are also highly valued by users, however users would welcome more shared use and enhanced outdoor facilities for both UWS and SRUC students;
- Functionality of the building has gained positive user feedback in terms of the provision and variety of space, general access to IT equipment (especially in the library) and the sizeable, naturally lit canteen. However, some users expressed concern about the quality of some of the furniture and the time that is taken to carry out minor repair work and commented that attention should be paid to these issues in order to continue to maintain the Campus to a high standard.
- Users view build quality as exceptional and believe that the new facility represent a modern, state of the art facility. However, perception about the building performance is more negative. This is an area that could be improved by ensuring that there is better control and programming of building services which should help create more comfortable internal environments.

The campus overall provides a flexible space, which can be used not only for varied learning facilities, but it also adds value to the local community with its modern design and many opportunities for the use of space. Occupant consultation sessions and BUS results confirm that the Campus, overall, is successful in meeting the end user needs and that occupants are proud of their building.

- Some questionnaire results suggested that users were not pleased with the perceived lack of control in the building, with many referencing the lack of openable windows, which they believed influenced a level of fresh air in the building.
- The most negative user feedback was in relation to the building services as it is clear that some operational settings could be improved. Additionally, a lack of understanding of how the building operates from the occupant perspective appears to be contributing to some of the negative feedback. It would be beneficial for all for the end users to be receiving more detailed information in relation to the building design and operation of services.

Occupant's dissatisfaction in relation to the operation and control over heating, cooling, lighting and ventilation should be tackled. The following activities are recommended;

- Provide in-depth training for the Estates team to allow them to efficiently and effectively manage and programme the building services and enable them to make adjustments as required to account for occupancy changes, functional changes and seasonal changes;
- Review building the current building services settings in order to help improve the functional performance and operational efficiency (e.g. the time settings and proximity detection of the lighting sensors and the dimming control functions, the air handling units programmed hours of operation and whether these correspond to timetabling);
- Enhance the existing Building User Guide according to the recommendations highlighted within this report for future dissemination. This will help to provide the foundation for any awareness sessions that may be delivered for staff and students;
- Provide end user awareness session for building occupants (operation and control of building services, building design and use of materials, energy efficiency and carbon emission reduction);
- Further promote and advertise the use of the shared facilities within the Campus to the community and surrounding areas to help ensure this is viewed as a valuable rental space (e.g. to host community events, employer or industry engagement sessions); and
- Work towards developing a Maintenance Plan for at least 25 years, making use of the current Operation & Maintenance Manuals (O&M) as a reference point.

5 Details of aftercare, operation, maintenance & management

5.1 Monitoring, metering and operation

UWS are committed to ensuring that energy and water data for Ayr Campus is monitored, captured and reported in accordance with the CIBSE TM22 guidance. UWS has an extensive sub-metering and monitoring system which allows the University to monitor and target consumption levels within different areas of the building. High use areas have their own sub-metering to allow usage to be monitored closely. UWS aim to optimise efficiencies by examining user behaviour and system performance and compare performance with others in their sector.

The sub-meters are pulsed output meters that link back to the Building Management System (BMS). The BMS allows energy and water use to be monitored as well as providing options to control the heating system.

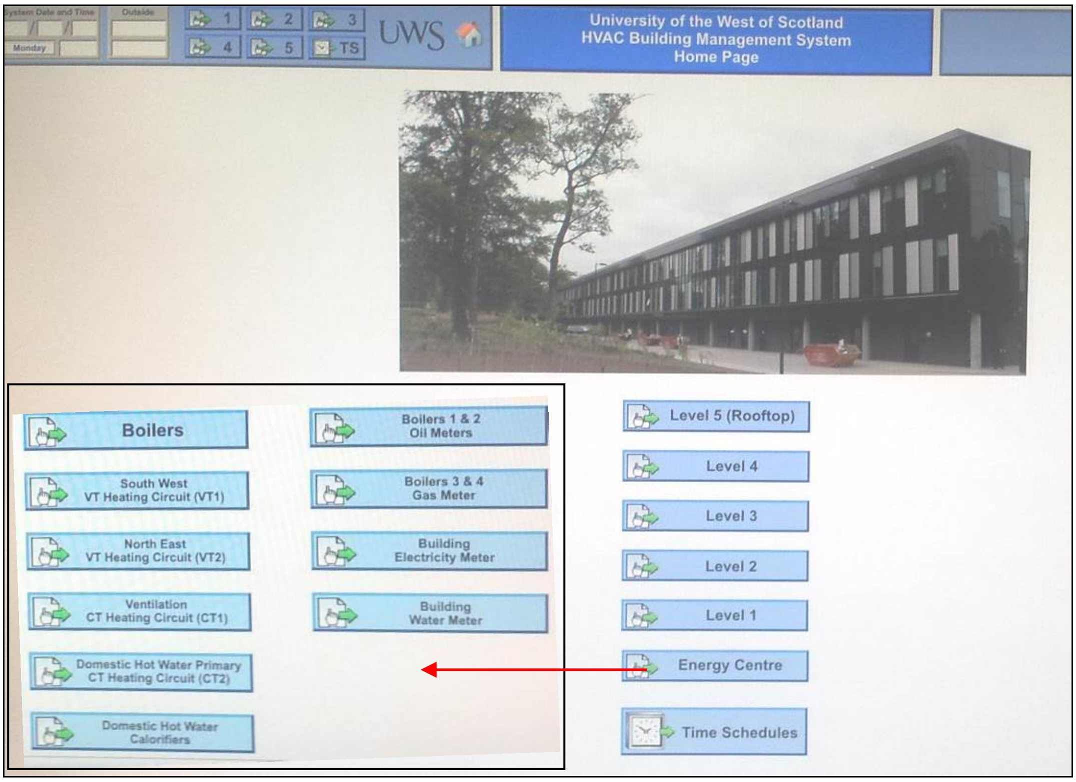

Figure 50 – BMS; Main menu

Figure 50 illustrates the main page of the UWS BMS system, though which the estates team can wirelessly control and set up the services. The ‘Energy Centre’ tab links to the operation of boilers and pumps, contains schematic of heating circuits and provides the user with an option to view meter readings (with the exception of the electricity meters which are connected to different software). Time schedules of air handling units are easily accessible from the main page and five indicative tabs which reference different areas of the building provide users with direct links to the controls for the heating equipment for all spaces. Figures 50 to 55 show sample views of the BMS parameters for each the services operation highlighting how each can be viewed or modified. For instance it is possible to change the set point temperature and time schedule for the operation of underfloor heating in the cyber café (Figure 53). Gas and water consumption can be also viewed via the BMS (

Figure 55).

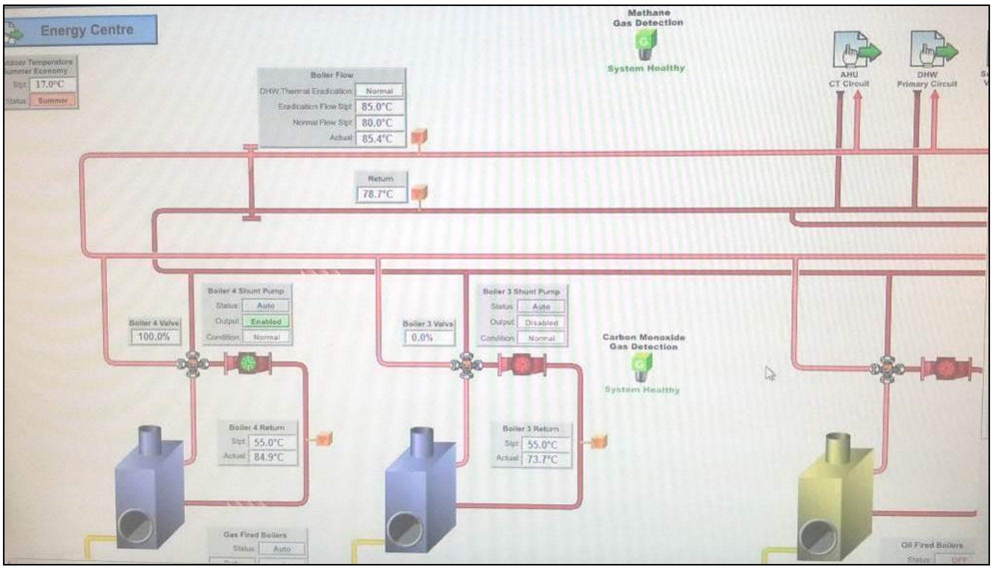

Figure 51- BMS; Gas and Biofuel boilers

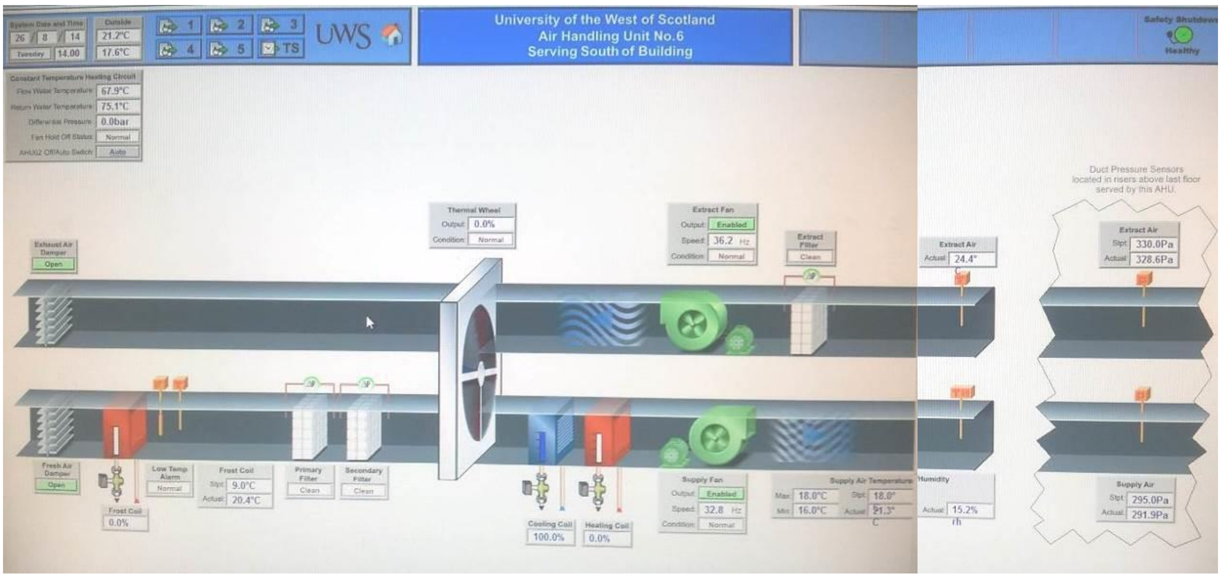

Figure 52 – BMS; Air Handling Unit 6

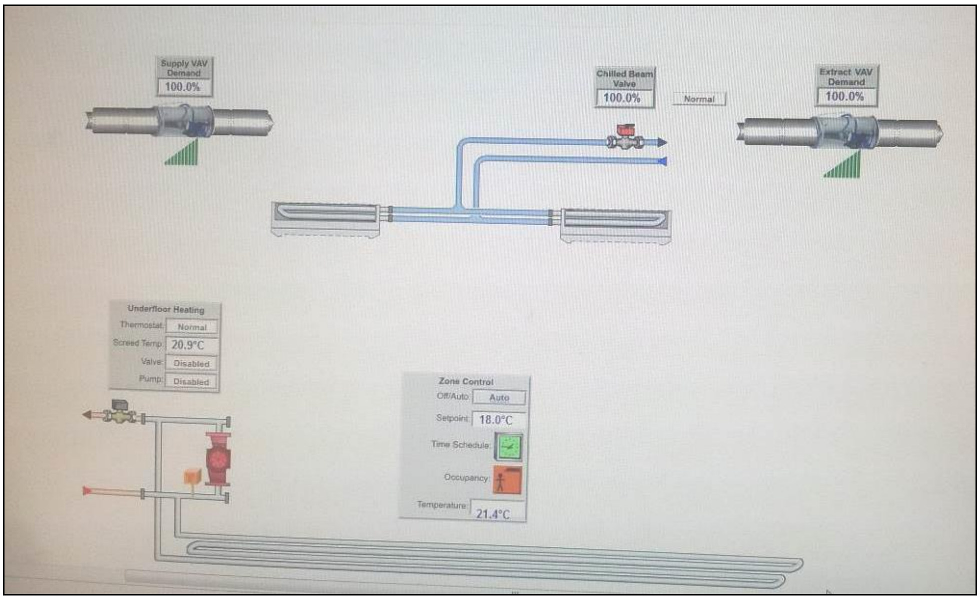

Figure 53 – BMS; underfloor heating in the cyber cafe (room 2.093)

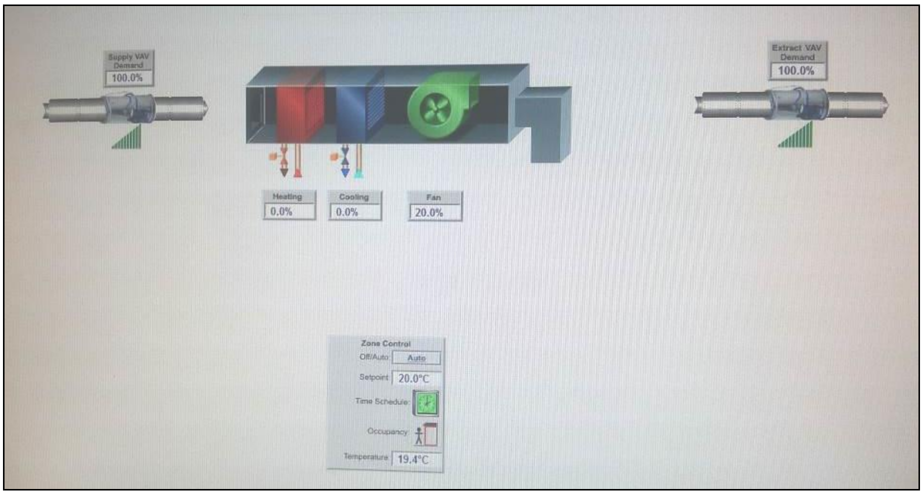

Figure 54 – BMS; Variable Air volume system / Fan Coil Unit in the TV control room (1.003) in the basement

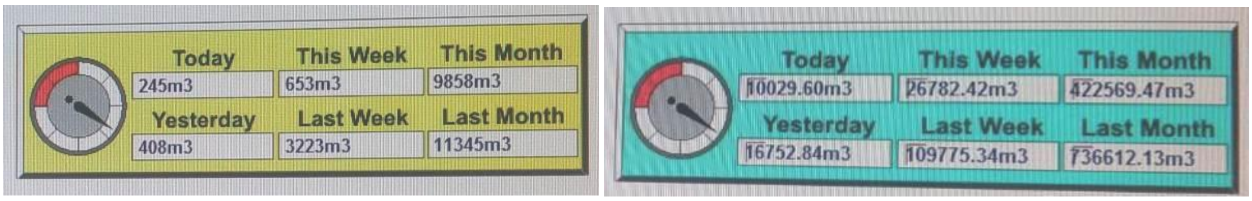

Figure 55 - BMS; Gas and water consumption

5.2 Collection of energy data

To assist with the collect of electricity readings from all sub-meters present throughout the Campus, UWS made the decision to invest in an upgraded Automatic Meter Reading (AMR) system that would allow them ease of access to these readings in a more user friendly format and that would also enable them to benefit more from their BMS. The AMR system has also helped to assist in the data capture requirement for this project. During the initial stages of this BPE project, the new AMR system was commissioned and all meters were calibrated.

The AMR system, called METERology, is capable of backdating and interpreting all of the sub-metered data and has helped to provide clear and valuable outputs.

Energy consumption within the UWS Ayr Campus is monitored via 58 meters and sub-meters. All readings can be viewed through the AMR web application. Figure 56 illustrates a sample screen view of the system.

Figure 56 - Remote energy monitoring for the Campus

The application has a number of functions enabling energy usage analysis. The functionality of the METERology system includes;

- Profile Pages (Daily Profile, Weekly Profile, Custom Period Profile);
- Analysis Pages (Pareto, Pie Chart, Base Load, 12 Month Rolling Average);
- Summary Pages (Current Day, Current Week, Selected Meter); and
- Comparison Pages (Daily Comparison, Weekly Comparison).

To view examples of different output options of the AMR system please refer to Appendices **Error! Reference source not found.** and **Error! Reference source not found.**.

BRE was tasked to collect energy consumption data throughout the duration of the project. An in-depth analysis has been carried out based on METERology readings through CIBSE TM22 tool (refer to section 6) for the full year, from January till December 2013. Appendix **Error! Reference source not found.** contains all available overall monthly energy consumption figures up to date for the duration of the project. Note that they are also presented in a graph form with an additional function of being compared against other years (Appendix **Error! Reference source not found.**). To represent the significance of separate energy uses of each sub-meter campus graphs based on July 2012 consumption have been include in Appendix **Error! Reference source not found.**.

5.3 Lighting controls

Artificial lighting within the building accounts for a significant percentage of the total electricity usage for the Campus. Artificial lighting can consume much more electricity than often required in spaces where manual lighting control is the only means of operation. However, the University has invested in a modern lighting control system to help to ensure that they use their artificial lighting efficiently and in return accrue operational energy savings. A Phillips Dynalite lighting system is arranged in six networks across the Campus. Each network can be managed separately by the Estates team through a DALI control interface. As previously described, the DALI allows for single lights to be switched on or off wirelessly. Timing of daylight and movement sensors can also be easily adjusted to meet user needs, as well as individual lux levels for each of the light fittings.

The Estates team have the ability to adjust the lighting sensors via the lighting software packages. Some sensor lighting controls have been adjusted as a result of user feedback. It was confirmed during the consultation session that some occupancy detection sensors power the artificial lighting off after a period of five minutes without activity. There are some areas where some staff members have made requests the Estates team to have these sensors adjust to a period of two hours. The reason for this is to avoid the artificial lighting from powering off when longer periods of desk based activity is being undertaken, where movement is less and the artificial lighting is automatically powering off. Understandably, if staff and students remain still while working at their desk for long periods of time, it can become distracting when the artificial lights continue to power off frequently. On the other hand, having a lit room for two hours after the last person leaves this space does not agree with energy saving aspirations of the University. Therefore, it is recommended that the sensor range is examined and that the range is adjusted to account for a larger area, covering the areas where occupants are seated so to allow the sensor to detect small movements and to avoid the artificial lighting system from powering off when it is required.

Although a ‘state of the art’ lighting system is in operation and various settings can be modified, during site visits some operational problems were noted. This included some artificial lighting being on within some classroom areas and a number of artificial lights noted to be left on in areas where natural light could have been sufficient, for instance in the corridors around the atrium space and in the seated café areas. Through interviews with staff, BRE also identified that there have been a number of on-going issues with the lighting control systems in the lecture theatres and that the complexity and commissioning of these systems has been a challenging issue for the University.

This might suggest that this type of lighting system, with so many functions, provides more possibilities and is more complex than is required for the Campus. Furthermore, the lack of training and control over the system,

from both the Estates and end user side, has resulted in some occupants struggling to efficiently operate the system.

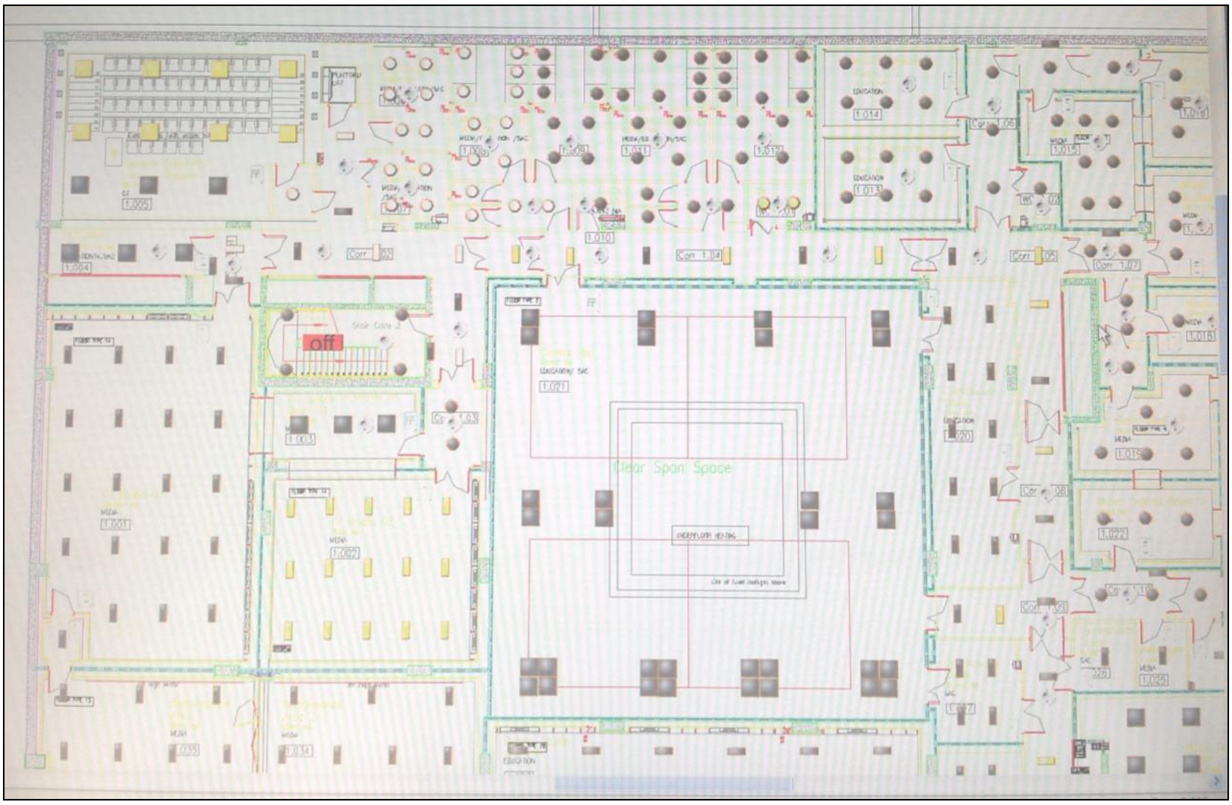

Figure 57 – DALI; Basement lighting
(Note, the lights are on in the lecture theatre and the TV studio)

Figure 58 - DALI; Basement lighting network

5.4 Maintenance

Maintenance issues were raised during the final discussion session with the estates team, these included;

- It was estimated that some new services equipment maybe required to be replaced within a period of ten to fifteen years, which is expected to incur significant capital expenditure;
- Current repairs, part replacement and general maintenance are largely contracted out via external contractors which impacts heavily on the maintenance budget for the Ayr Campus building e.g. light bulb replacements or glazing cleaning in the atrium area that requires specialist equipment to work at height;
- Any issues that the Estates team experience as a result of interacting with the building's building services and monitoring software are currently being resolved by external specialist contractors which often incurs high fees for UWS; and
- There is no long-term maintenance plan in place and there is concern over a lack of available or planned funding to cover the costs of any future repairs, replacements and system or service upgrades that will be required.

Developing a long term, comprehensive maintenance plan can help to ensure that the value of the asset is protected and operational efficiencies and performance is realised. Advantages as a result of implementing this plan could include;

- Required maintenance is identified;
- Any additional spend can be planned for in advance;
- The Campus can be organised, managed and maintained in a systematic way;
- Building services can be closely monitored and maintained to ensure that they are being operated efficiently;
- The standard and presentation of the Campus can be adequately maintained; and
- Subjective decision making and emergency corrective maintenance can be minimised.

The UWS Ayr Campus Estates team are not aware of any existing maintenance plan that was prepared for the Campus at building handover stage. This plan is not believed to exist, however it is noted that the Ayr Campus Estate team has changed a number of times since initial building handover and this is a valuable document that may not have been passed over or communicated to new members of the Estates team during periods of staff handover. Having the plan is key to avoiding any extensive and/or avoidable damage to the building, the fabric or equipment and it will also help prepare users and allow them to plan for any major capital expenditure costs. Furthermore, when buildings are not properly or adequately maintained and services, systems or fabric is perhaps unnoticeably neglected, this can in some cases lead to additional fire and safety hazards, which could result in building owners being found legally liable for any injuries.

Ref	Building element	Maintenance task	Responsibility	Frequency	Annual cost £	J	F	M	A	M	J	J	A	S	O	N	D
1.1	Roofs																
1.1.1	Roof areas generally	Inspect roof areas from the ground and accessible high points and report any loss or damage to the roof coverings.	unskilled/ voluntary	i. after stormy weather ii. annually	–			✓									
1.1.2	Slate and tile roofs and vertical cladding	Inspect for cracked, displaced and broken slates and tiles. Replace to match.	contractor	twice per year	£					✓						✓	
1.1.3	Sheet metal roofs and cladding	Inspect condition of panels, joints and clips. Make temporary repairs to cracks and splits.	contractor	twice per year	£					✓						✓	
1.1.4	Ridge tiles	Inspect bedding and jointing between ridge tiles. Re-bed and repoint as necessary.	contractor	annually	£					✓							
1.1.5	Lead weatherings and flashings	Inspect condition of lead flashings and weatherings. Make minor repairs (e.g. dress back clips, make good mortar fillets).	contractor	annually	£					✓							
1.1.6	Asphalt roofs	Inspect condition of flat areas and upstands. Make temporary repairs to splits and holes.	contractor	twice per year	£					✓						✓	

Figure 59 – A Maintenance Plan extract (from 'Grants for Historic Buildings, Monuments and Designed Landscapes - Maintenance Plans, English Heritage, 2004)

It is recommended that as a minimum, a maintenance plan for UWS should cover the following:

- Building services (including boilers replacement);
- Building envelope (e.g. cladding repairs and required maintenance);
- Finishes (e.g. walls repainting); and
- External spaces (e.g. landscaping, paving relaying).

A maintenance plan will help to describe the total package of all maintenance requirements required to provide adequate care for the building, its systems and services. A maintenance checklist should list all preventive or predictive tasks (typically derived through some form of analysis e.g. Estates team referring to O&M manuals). A checklist can help to influence a 'schedule of work' for the UWS Ayr Campus Estates staff, which can act as a reference document for them on a day-to-day basis. This should help to assist in the monitoring and reporting of the overall maintenance and performance of the Campus. Figure 59 is an example of how the plan could be structured and the approach that could be taken for this building. It is crucial to ensure appropriate aftercare is provided to also help avoid any unnecessary spending.

5.5 Conclusions and key findings for this section

Metering and control

In summary, the University has functional management and monitoring equipment in place;

- The BMS allows the user to make adjustment to the operation of the buildings services that are responsible for delivering heating, cooling and ventilation. For instance, during this research project the operating hours of some of the air handlings units were adjusted to match the operating and occupancy requirements, thus ensuring large areas of the building were not being serviced when they were not in use (this was being managed and altered remotely from the UWS Paisley Campus);

- The AMR allows a user-friendly navigation between energy consumption data for all sub-meters installed; and
- The DALI interface provides the Estates team with the capability to wirelessly control of all of the artificial light fittings within the Campus.

It is recommended for UWS to provide adequate time and resources to support the Estates in receiving adequate training on the operation and programming of these systems and services and a period of time to allow them to familiarise themselves with the user software, ensuring that all programmes are managed, adjusted and utilised to their optimum operational efficiencies. This would be particularly beneficial for the Ayr Campus staff to allow them to manage seasonal and occupancy changes in an efficient way.

Lighting

It is recommended to provide a programme of training for the;

- Estates team to allow them to fully benefit from the lighting system's control system and to understand how to manage and maintain this system; and
- Building users, to provide them with a better understanding of what control is available at a local and central level and what can be modified to help satisfy their needs.

Maintenance

Furthermore, it is highly recommended to produce a maintenance plan for at least 25 years of the building's life, investigating secure funding options for any repairs or replacements required, covering

- Building services (including boilers replacement);
- Building envelope (e.g. cladding repairs and required maintenance);
- Finishes (e.g. walls repainting); and
- External spaces (e.g. landscaping, paving relaying).

6 Energy use by source

6.1 A summary of annual energy consumption

Energy Benchmarks		**Illustrative CO_2 benchmarks calculated from the energy benchmarks***		
Electricity typical benchmark (kWh/m^2)	Fossil-thermal typical benchmark (kWh/m^2)	Illustrative electricity typical benchmark ($kgCO_2/m^2$)	Illustrative fossil fuel typical benchmark ($kgCO_2/m^2$)	Illustrative total typical benchmark ($kgCO_2/m^2$)
80	240	44.0	45.6	89.6

*CO_2 emission factors used: electricity: 0.550 $kgCO_2/kWh$, fossil – fuel: 0.190 $kgCO_2/kWh$

Table 1 – TM46 benchmarks for a University Campus

Energy consumption (2013)		**Actual CO_2 emissions***		
Electricity consumption (kWh/m^2)	Natural Gas consumption (kWh/m^2)	Electricity carbon emissions ($kgCO_2/m^2$)	Gas carbon emissions ($kgCO_2/m^2$)	Total carbon emissions ($kgCO_2/m^2$)
106.8	230.2	55.43	49.72	105.15

*CO_2 emission factors used: electricity: 0.519 $kgCO_2/kWh$, natural gas: 0.216 $kgCO_2/kWh$, (SAP 2012, Table 12)

Table 2 – UWS Ayr Campus actual energy consumption and carbon emissions 2013

Energy source	**Total consumption** (kWh)	**Total CO_2 emissions** ($kgCO_2$)	**Unit price** (p/kWh)	**Total cost** (£)
2013 readings				
Electricity	1904359	988362.32	13.19	251184.95
Gas	4105896	886873.54	3.48	142885.18
Historical data (2011/12)				
Rapeseed oil*	1958559	162560.40	9.78**	191607.23

*Originally biofuel boilers were used (gas boilers are currently in operation)
** Vegetable oil carbon emissions factor: 0.083 $kgCO_2$ per kWh (Table 12 in SAP 2012)
***Unit price factor is calculated from the actual consumption and the cost (otherwise unit price factor for a vegetable oil - 7.64 from Table 12 in SAP 2012 would have been used)

Table 3 – UWS Ayr Campus energy costs calculations

Clearly, actual energy consumption is higher than what would be defined as ‘typical’ for this building type. The actual electricity consumption is more than 30%higher than the TM22 benchmark. Due to the monitoring and observational activity that has taken place and that is been documented within the report, this is not unexpected. Carbon Buzz confirms that generally there are notable differences in terms of the overall design versus actual carbon emissions for this type of exercise.

Unlike electricity use, actual gas consumption is slightly lower than the fossil-thermal typical benchmark (4% lower).

As a result, the overall carbon emissions for the campus during 2013 were 105.15 kgCO2/m². This figure is 17% higher than the benchmark largely due to the relatively high electricity consumption.

Carbon emissions and costs were calculated for rapeseed oil used as heating fuel in 2011/12 period in order to compare those against gas consumption. Switching to gas reduced the cost by 34%, but increased carbon emissions by approximately 80%. Details of the calculations are included on Table 3.

Figure 60 illustrates data collected by Carbon Buzz relating to a University type building.

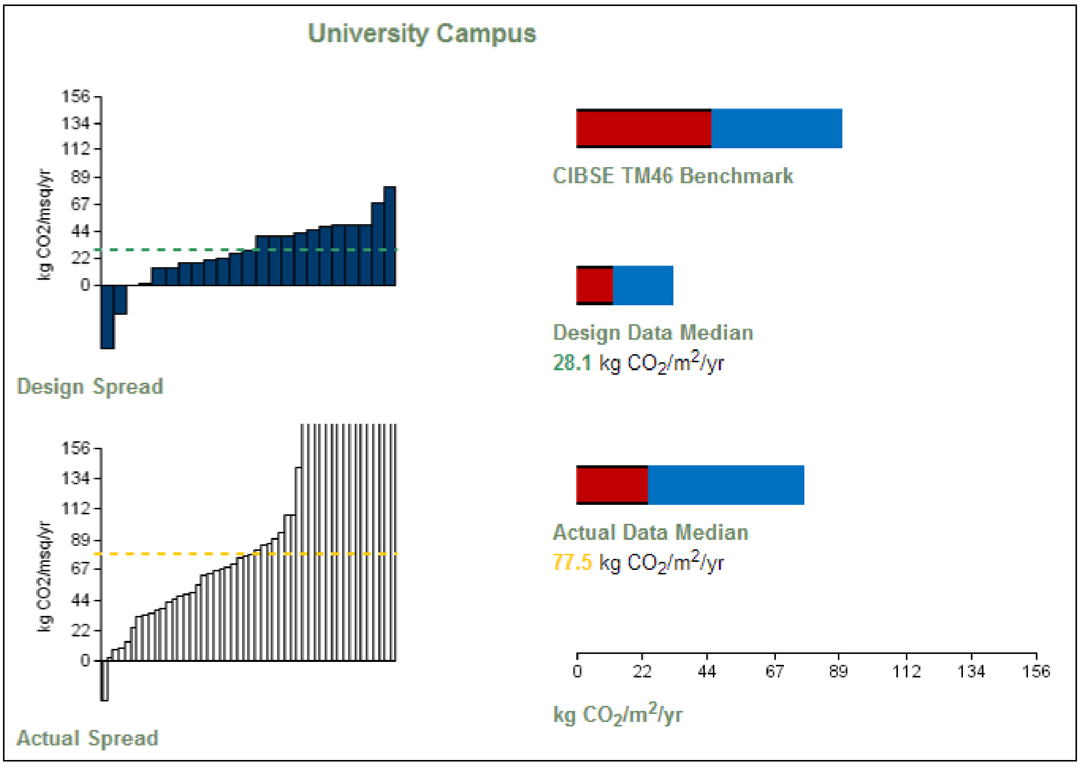

Figure 60 – A University Campus building performance monitoring by Carbon Buzz

6.2 Gas consumption

Reading Date	Month	Consumption
01-Jan-13		532136.1 kWh
01-Feb-13	January	442366.5 kWh
01-Mar-13	February	498429.5 kWh
01-Apr-13	March	378552.7 kWh
30-Apr-13	April	251412.2 kWh
30-May-13	May	121904.0 kWh
02-Jul-13	June	156847.7 kWh
01-Aug-13	July	143859.7 kWh
02-Sep-13	August	188357.4 kWh
30-Sep-13	September	243006.6 kWh
04-Nov-13	October	324099.7 kWh
02-Dec-13	November	283453.7 kWh
06-Jan-14	December	541470.2 kWh

Table 4 – 2013 Gas Meter Readings for Ayr Campus

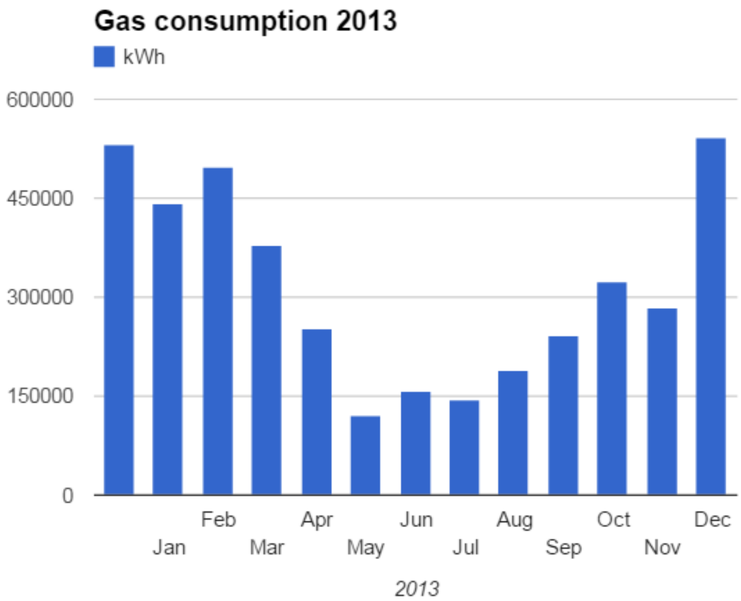

Figure 61 – Gas consumption readings 2013

6.3 Electricity consumption

A comparison exercise between what is recognised as a TM46 benchmark versus the TM22 predicted and Ayr Campus actual electricity consumption figures is illustrated in Figure 62. This shows variances in carbon emissions and the annual electricity cost for each of the three different values.

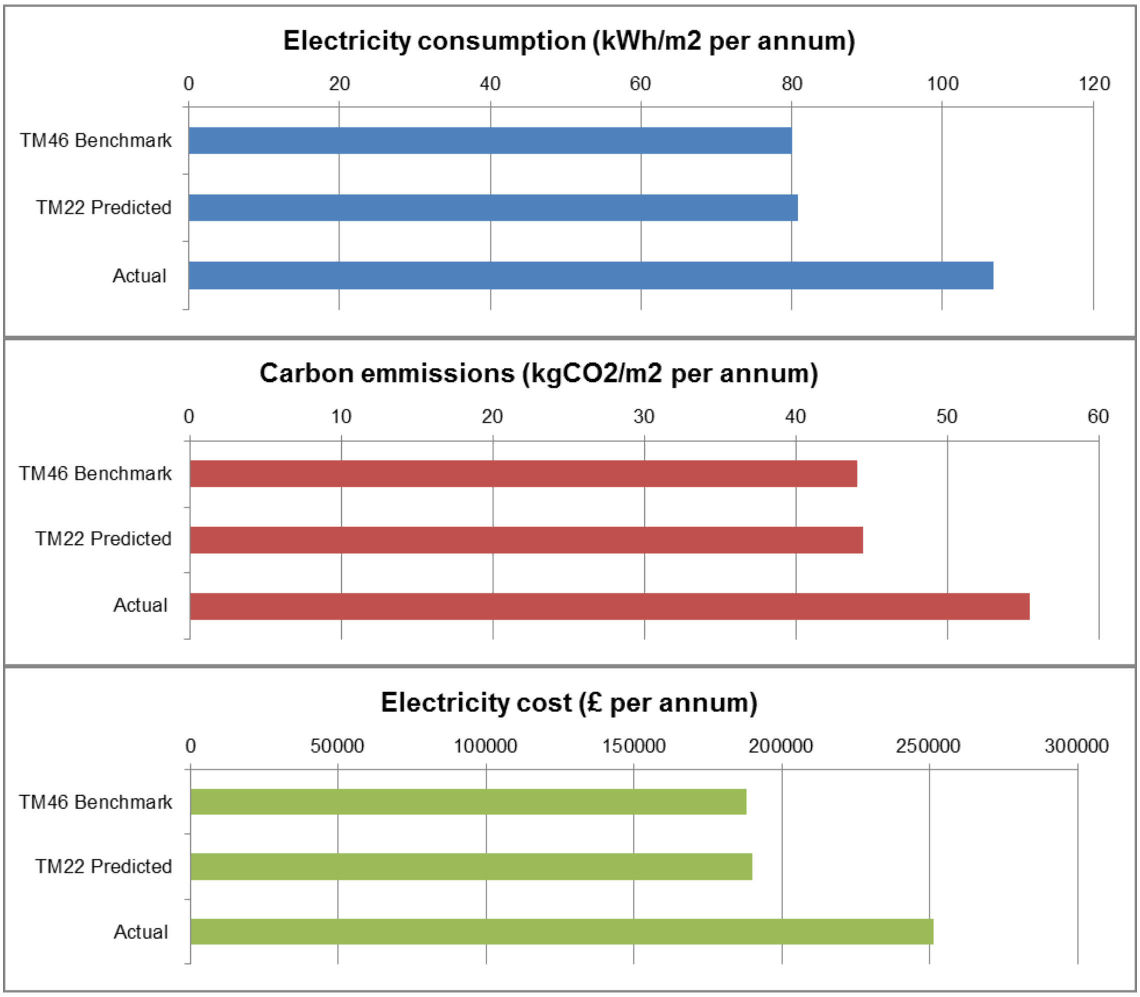

Figure 62 – Electricity consumption, carbon emissions and costs (2013)

As stated previously, a referenced TM46 benchmark for electricity consumption in a typical university building has been confirmed as 80kWh/m^2/year. Figure 62 confirms that the actual consumption for Ayr Campus is, as predicted, slightly higher than this figure at 106.78 kWh/m^2/ (more than 30% higher than the referenced benchmark). A figure of 80.8kWh/m^2/year, representing the TM22 predicted energy consumption, is much closer to the benchmark level. However, it should be noted that not all operating equipment may be accounted for or recognised within the TM22 tool and that various assumptions were also required to be made in relation to the building, equipment and use and the output of TM22 unfortunately does not account for this.

Error! Reference source not found. and Figure 63 illustrate a predicted division of electricity use among ten TM22 categories: Space heating (only a small fraction for boilers operation), Fans, Pumps, Controls, Internal Lighting, External Lighting, Small power, ICT Equipment, Central Catering, and Distributed Catering.

Similarly, **Error! Reference source not found.** and Figure 64 refer to the categories defined by Carbon Buzz; Heating and HW, Fans, Pumps and Controls, Lighting and Other electricity.

Considering both Figure 63 and Figure 64, it is clear that the Ayr Campus' highest contributors to carbon emissions, from the electrical consuming items, are fans. Comments relating to power consumption of fans and other equipment are described in section below.

System	In-use electricity (kWh/m²/year)	In-use electricity (kWh/year)	In-use % of total	In-Use Full load W/m2	System hours/year	Utilisation
Space Heating	0.1	2,520	0.2%	0.1	1,355	15.5%
Fans	31.9	568,528	39.5%	7.2	4,429	50.6%
Pumps	3.8	68,078	4.7%	1.5	2,503	28.6%
Controls	0.1	1,435	0.1%	0.0	8,760	100.0%
Lighting (Internal)	6.7	119,471	8.3%	7.5	892	10.2%
Lighting (External)	0.4	6,287	0.4%	0.1	2,816	32.1%
Small Power	5.9	105,958	7.4%	6.6	894	10.2%
ICT Equipment	8.2	146,036	10.1%	3.8	2,140	24.4%
Catering - Central	20.4	363,053	25.2%	11.5	1,773	20.2%
Catering - Distributed	3.0	53,128	3.7%	1.8	1,618	18.5%
User 1	0.4	6,630	0.5%	0.8	443	5.1%
Total	**80.8**	**1,441,124**	100.0%	**41.1**		
Metered building energy use	106.8	1,904,359				
Variance TM22 versus metered total	-26.0	-463,235				
Variance TM22 versus metered total	-24%	-24%				

Table 5 – Predicted Electricity Energy Demand (kWh/m²/year) – TM22 categories

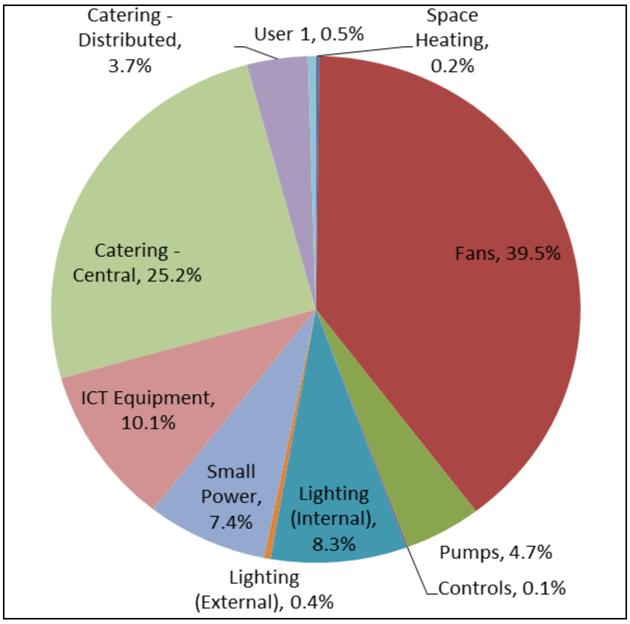

Figure 63 - Electricity Energy Demand - TM22 categories

System		Predicted In-use electricity (kWh/m²/year)	Actual In-use Electricity (kWh/m²/year)	Predicted In-use electricity grid equivalent emissions (kgCO2/m2/year)	Actual In-use electricity grid equivalent emissions (kgCO2/m2/year)
Heating & HW		0.1		0.1	
Fans	AHUs	31.9	20.84	17.5	10.82
	Other fans				
Pumps & Controls		3.9		2.1	
Lighting		6.7	16.34 - 22.4	3.7	8.48 – 11.62
Other electricity	ICT and small power	38.2	23.9 - 30	21.0	12.4 – 15.0
	Other (e.i. catering)				
Total		**80.8**	**106.8**	**44.4**	**55.4**

Table 6 – Predicted vs. Actual Electricity Energy Demand (kWh/m²/year) and Carbon Emissions ($kgCO_2/m_2/year$) – Carbon Buzz categories

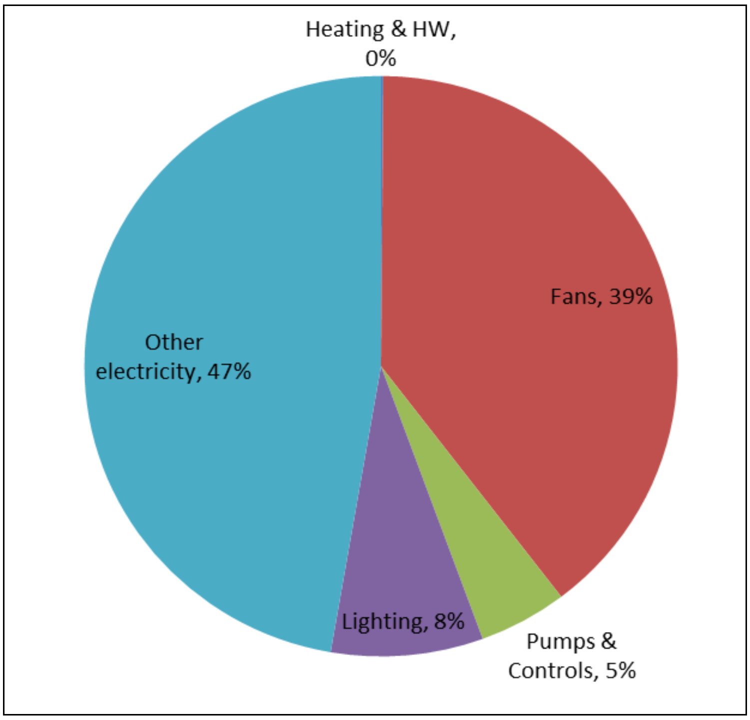

Figure 64 - Electricity Energy Demand - Carbon Buzz categories (based on predicted consumption).

Fans, Pumps & Controls

There are 13 air handling units servicing the campus building (all listed in Section 3.4), which highly contribute to power consumption of fans, pumps and controls group of services and equipment. Thus, it is highly recommended to focus on reducing power consumption of those units.

A later section of this report - 6.5 describes in detail the operational settings of air handling units. It points out that the units' operating hours are much higher than required. Refer to this section for details of occupancy versus operating hours analysis for AHU 13, AHU 9 and AHU3.

As an example of what financial and carbon emissions savings could be made, one air handling unit (no13) was selected for the analysis.

AHU 13 serves lecture theatre 1. A difference between its operating hours and hours during which the room is in use is illustrated in Figure 65 Figure 80. The diagram shows that this lecture theatre was only required to be in-use between 9 am and 5 or 6 pm during the week. The only late night classes were organised for a Thursday night (until 9pm) during Trimester 2. It is clear that those operating hours are much lower than the default university time clock - 6.30 am to 10.30 pm.

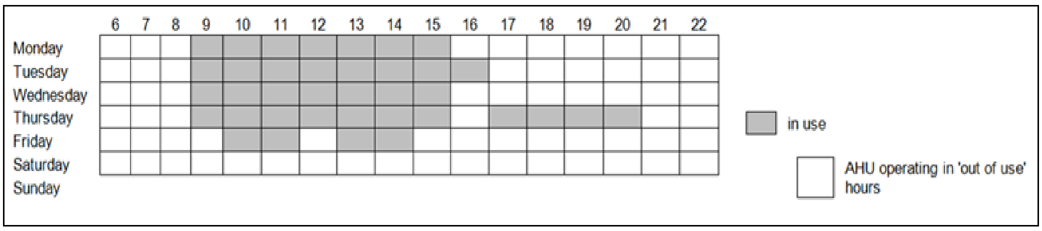

Figure 65 – Actual vs. potential in-use hours of AHU 13 during Trimester 2 (Lecture theatre 1)

In addition to this diagram, graphs below provide an illustrative representation of those differences. Both graphs show average load by a weekday. The first graph is based on actual meter readings (January till July 2013). In addition to differences in consumption by a different day of the week, it shows that there is some electricity supply requires for 'base load' conditions.

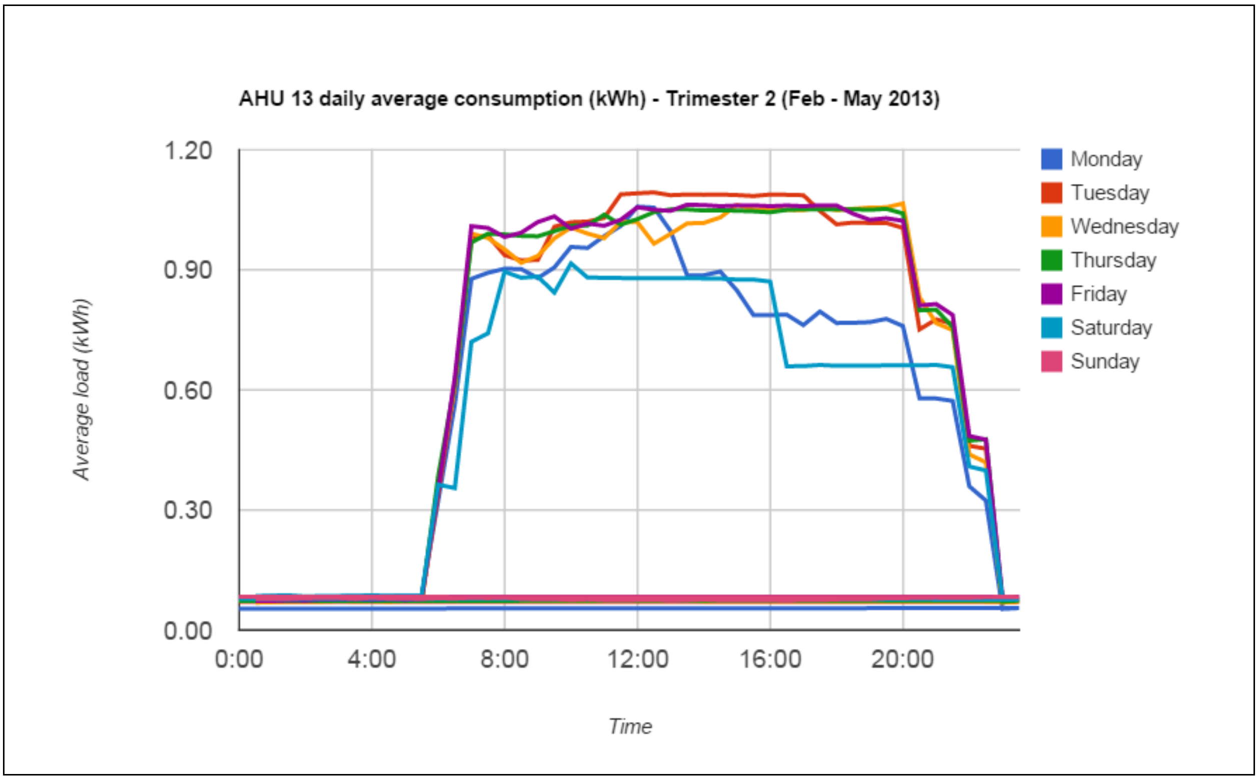

Figure 66 - AHU 13 – Actual Average daily electricity consumption (kWh) during Trimester 2 (Feb- Mar 2013)

The second graph illstrates potencial consumption for each day of the week based on the timetable analysis and excludes the 'base load'.

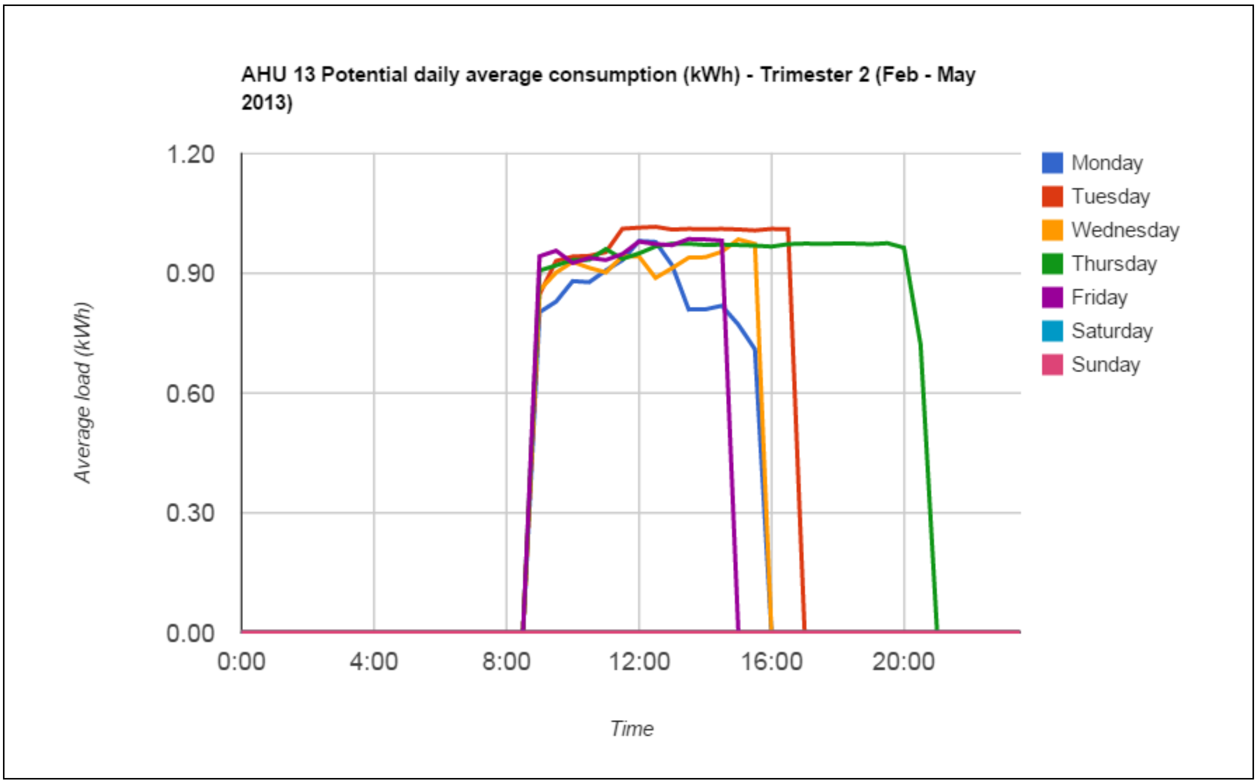

Figure 67 - AHU 13 – Potential average daily electricity consumption (kWh) during Trimester 2 (Feb- Mar 2013)

By comparing data on which the two graphs were based, the potencial consumption and carbon savings were calculated. A summary of those calculations are included in Table 7.

As it can be seen in the table, revising the operation of air handling unit 13 could provide financial savings of nearly £200 per trimester for this lecture theatre. By carrying out a rough calculation and assuming that the whole building would benefit from such savings in AHUs' operation, the savings could reach approximately £70000 per annum (this is based on the lecture theatre taking about 1% of the total floor area of the campus).

Please note that the calculations were based on meter readings from the first half of 2013. During the second part of the year the estates team have changed working hours of all air handling units. It means that noticeable savings should be seen in the second part of 2013. This calculation however should encourage the estates team to pay a particular attention to the units' operation.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Totals
Total daily electricity consumption (kWh)	28.03	33.18	32.65	33.14	33.40	26.48	3.75	
Variance between actual and potential consumption (kWh)	14.85	16.34	18.50	9.21	20.72	25.12	2.55	
Potential daily percentage savings	53%	49%	57%	28%	62%	95%	68%	
Daily electricity cost (£)*	3.68	4.36	4.28	4.35	4.39	3.47	0.49	25.02
Potential savings (£) per 13 teaching weeks (Trimester 2)	25.36	30.01	29.45	29.98	30.21	23.86	3.39	**£172.27**
Potential carbon savings per 13 teaching weeks per m2 (Trimester 2)								**1.4 kg CO2**

* 13.14 p/kWh
** 0.519 kgCO2/kWh/y (divided by 4to achieve a result for the 13 weeks savings)

Table 7 – Actual daily electricity consumption and potential savings for AHU 13 (calculations based on Trimester 2 period – 13 weeks)

ECON19

The End Use categories are compared against benchmarks which are set in the Energy Consumption Guide 19 – Energy in Offices (ECON19). Although the publication refers to office building type, four different types of offices were taken into consideration to enable accurate comparisons.

Table 8 summarises ‘typical’ and ‘good practice’ figures for the office type 4 (the closest in terms of building specification) and compares them against the university’s electricity consumption figures for the 2013. Please note that the actual electricity figures are shown in the table for Air Handling Units, Lighting, Small Power and ICT Equipment. Predicted electricity demand figures illustrate potential fraction of power consumption by end use and provide an overview of consumption figures where the actual consumption could not be calculated (based on sub-meters data).

	ECON19 – Office type 4 (kWh/m2/year)		UWS – predicted electricity demand (kWh/m2/year)	UWS – actual electricity demand (kWh/m2/year)
	Good practice	Typical		
Fans, Pumps & Controls	36	67	35.8	20.84 (Air Handling Units)
Lighting	29	60	7.1	16.34 - 22.4
Small Power & ICT Equipment	23	32	14.1	23.9 - 30
Catering	13	15	23.4	
Computer room (where appropriate)	87	105		

Table 8 – ECON19, Office type 4 benchmarks against Predicted Electricity Energy Demand at UWS

Lighting

The actual lighting load for the campus is within a range of 16.34 - 22.4/m^2 (Table 8). It is lower than both ‘good practice’ and ‘typical’ benchmarks in ECON19.
To view the actual consumption figures taken from all sub-meters connected to lighting refer to Table 9. Please note that two sub - meters (E14 and E16) provide readings which also include other equipment. Taking this into consideration and analysing two different sums; lighting only meters and all meters, results in a range where the actual lighting power consumption falls into. In comparison to ECON benchmarks for lighting in the ‘type 4 office’ the use of electric lighting within the campus is below the good practice (29 kWh/m^2/year). This confirms that having an intelligent lighting control system along with efficient fittings in place is beneficial for the University.

Although the overall power consumption for the lighting is relatively low, it is suggested that additional savings could be made. 45% of the total consumption is outside the core hours. This could suggest that some lights are left on in unoccupied areas when not necessary.

Sub-meter	Reference	Description	HH total kWh	M-F 9.00 _ 18.00	M-F non-core hours	Sat - Sun
E8	E011	Basement Lighting	41,490	25,183	12,284	4,023
E14*	E039	En Cent Lighting POwer	2,029	702	922	404
E16*	E006	Kitchen Power Lighting	106,636	36,362	49,769	20,505
E17	E029	Library Lighting	39,660	17,132	16,686	5,841
E21	E014	Riser1 1st flr lighting	27,749	9,995	13,428	4,325
E23	E010	Riser1 Grnd flr lighitng	15,085	3,979	7,643	3,464
E25	E028	Riser1 2nf flr lighting	15,272	5,581	7,865	1,825
E27	E016	Riser2 1st flr lighting	11,388	4,366	5,339	1,683
E29	E008	Riser2 Grnd flr lighting	20,905	7,318	9,673	3,914
E31	E026	Riser 2 2nd flr lighting	14,481	5,344	6,898	2,240
E33	E018	Riser 3 1st flr lighting	9,090	3,757	4,509	823
E35	E003	Riser3 Grnd flr lighting	11,996	4,653	5,750	1,593
E37	E024	Riser3 2nd flr lighting	9,308	3,366	4,494	1,447
E39	E020	Riser4 1st flr lighting	36,367	12,992	16,777	6,599
E41	E005	Riser 4 Grnd flr lighting	12,419	4,563	5,814	2,042
E43	E022	Riser 4 2nd flr lighting	26,246	9,366	12,648	4,232
All sub-meters demand (kWh/m²/year)			22.4	8.67	10.12	3.64
Lighting only sub-meters demand (kWh/m²/year)			16.34	6.59	7.28	2.47
All sub-meters			100%	39%	45%	16%
Lighting only sub-meters			100%	40%	45%	15%

*sub meters for lighting and power

Table 9 – Actual lighting electricity demand (2013)

Small Power and ICT Equipment

Table 11 summarises all sub-meter readings which would contain power consumption of small power and ICT equipment. Additionally, sub-meter E9 - basement power covers special equipment used in arts and sound studios. Note that E14 and E16 cover some lighting. As previously, two different were calculated; power (exc. lighting) only meters and all meters (inc. E14 and E16). As a result a range where the actual small power and ICT consumption falls into is between 23.9 and 30 kWh/m²/year.

In comparison to benchmarks stated in ECON19 electricity consumption of small power and ICT equipment would fit between 'typical' (32 kWh/m²/year) and 'good practice' (23 kWh/m²/year) benchmarks.

There are a number of rooms with a higher electricity demand, such as art and sound studios or computer rooms. According to ECON19 an electricity demand for a computer room would be between 87 and 105 kWh/m²/year. If those rooms were separately metered, then the electricity demand for the remaining rooms would be closer to the 'good practice' benchmark.

Sub-meter	Reference	Description	HH total kWh	M-F 9.00 _ 18.00	M-F non-core hours	Sat - Sun
E9	E012	Basement Power	12,230	5,899	4,741	1,590
E14*	E039	En Cent Lighting POwer	2,029	702	922	404
E16*	E006	Kitchen Power Lighting	106,636	36,362	49,769	20,505
E18	E001	Library Power	17,264	5,682	7,636	3,947
E20	E041	Panel Board LG2P	50,833	13,158	24,922	12,753
E22	E013	Riser1 1st flr power	40,683	13,487	18,330	8,866
E24	E009	Riseer1 Grnd flr power	9,318	2,580	4,203	2,535
E26	E027	Riser 1 2nd flr power	14,641	4,396	6,637	3,608
E28	E015	Riser2 1st flr power	25,839	7,639	11,710	6,490
E30	E007	Riser2 Grnd fl power	38,027	10,862	17,150	10,016
E32	E025	riser2 2nd flr power	13,687	4,223	6,186	3,277
E34	E017	Riser3 1st flr power	14,996	4,796	6,698	3,503
E36	E002	Riser3 Grnd flr power	20,739	6,227	9,429	5,083
E38	E023	Riser3 2nd flr power	47,224	13,518	21,214	12,493
E40	E019	Riser 4 1st flr power	52,665	16,130	23,841	12,693
E42	E004	Riser 4 Grnd flr power	31,994	9,269	14,356	8,369
E44	E021	Riser 4 2nd flr power	36,848	10,983	16,747	9,118
All sub-meters demand (kWh/m²/year)			30	9.3	13.71	7.02
Power only sub-meters demand (kWh/m²/year)			23.94	7.22	10.87	5.85
All sub-meters			100%	41%	61%	31%
Power only sub-meters			100%	44%	66%	36%

Table 10 - Actual small power and ICT electricity demand (2013)

Catering

At the UWS catering facilities are covered by the kitchen, student union and the canteen. The actual electricity consumption was only possible to determine in the kitchen area. Other catering related spaces are metered along with other non-catering equipment across the campus. Hence, the predicted electricity consumption for catering overall (23.4 kWh/m²/year) is used here for the comparison. This figure is higher than a typical benchmark for a selected office type (15 kWh/m²/year). That would be expected for a University building with more catering facilities than in an office building.
As an example Table 11 illustrates the actual power and lighting consumption in the kitchen during the 2013. A large fraction of power consumption in the kitchen is outside the core hours. Understandably the white goods such as fridges and freezers operate continuously. However, it is recommended to review if there are any kitchen appliances which could be switched off when the room in not in operation. The appliances would include kettles, microwaves, food processors, etc.

Sub-meter	Reference	Description	HH total kWh	M-F 9.00 _ 18.00	M-F non-core hours	Sat - Sun
E16	E006	Kitchen Power Lighting	106,636	36,362	49,769	20,505
Kitchen sub-meter demand (kWh/m²/year)			5.98	2.04	2.79	1.15
			100%	34%	47%	19%

Table 11 - Actual lighting and power electricity demand in the kitchen (2013)

6.4 Energy consumption review using the TM22 Tool

To review the energy consumption of the campus, BRE was required to carry out the energy assessment using the CIBSE TM22 tool as part of a mandatory requirement for this BPE study. The tool can be used to analyse the energy performance of a building at design stage, operation stage or for a combination of both. BPE requires that the operational analysis, is used to reconcile the performance of the building when occupied with metered data from the building's meters and sub-meters.

Firstly, the readings from all of the Ayr Campus sub-meters had to be arranged in an order that was recognised by the TM22 tool and some sub-meter data also had to be combined. The CIBSE TM22 tool allows for the input of energy data for up to 50 sub-meters. As the Ayr Campus has a total of 58 sub-meters, BRE were advised to combine the readings on some of these to enable all data to be captured within the tool. A list of this arrangement is included in Appendix **Error! Reference source not found.**.

Half hourly version of the TM22

As part of the TM22 exercise, data input was required for a half hourly (HH) version of TM22 (HH TM22) where a detailed half hourly data was available for all meters. By using this part of the tool a breakdown of energy use could be identified, for core and non-core hours. It is claimed to offer a greater resolution of the estimated versus metered reconciliation in the subsequent TM22 analysis.

This section of the report focuses on the initial process of the tool completion and data included in Figure **Error! Reference source not found.** represents average daily energy consumption for some of the air handling units, illustrating results from the half hourly analysis. Despite providing a description only for some of the sub-metres this provides a clear analysis of how half hourly TM22 data can be used for an analysis of energy consumption of any selected sub-meter.

In order to complete the HH TM22 tool the following tasks were undertaken;

- All meter readings edited to align with the tool's format

- Combining some of the sub-metered data to allow data to be represented on the 50 available input tabs
- Data review for each output graph

Furthermore, initial average energy usage pattern graphs did not represent valuable results.

Figure 68 shows the output graph for Air Handling Unit 7 (AHU 7). It is noted that there is one figure significantly larger than the remaining figures which is believed to be an anomaly. Removing this anomaly provided much clearer results, which can be seen in a graph shown in Figure 69.

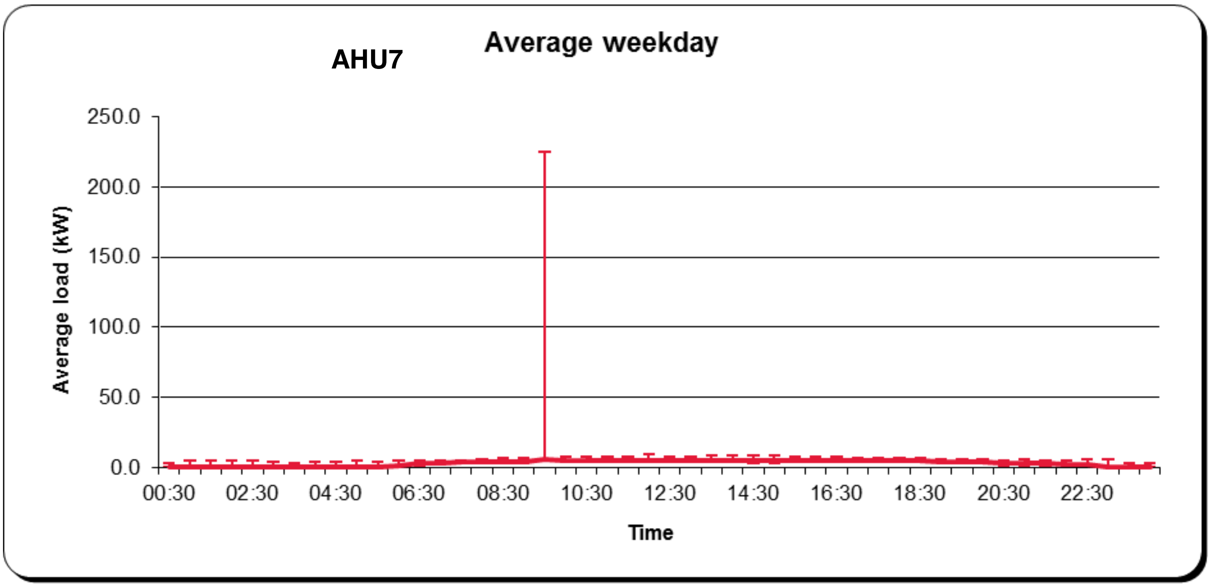

Figure 68 - Average weekday energy use for AHU7 during monitored period

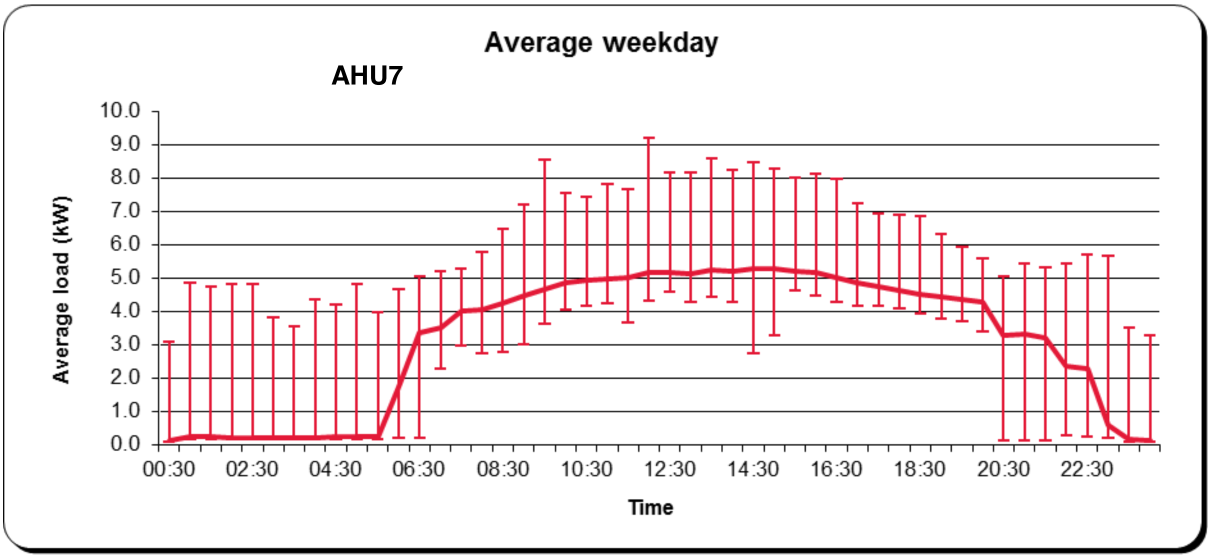

Figure 69 - Average weekday energy use for AHU7 during monitored period after revision

Those meter readings could be caused by the BMS' dysfunction. The system didn't record readings for a period of time and the large figure would represent a sum of the missing values. To reduce the impact of this system error, the figure was divided by the number of preceding time steps. This sequence of proceedings was applied to each sub-meter to provide more appropriate outputs.

Completion of the TM22 'in-use' analysis

The full version of the tool was a next step in energy consumption analysis. The purpose of completing it is to compare actual vs. predicted energy consumption by each sub-meter. To complete the 'in-use' analysis following tasks were required;

- Building survey – collection of specification and number every equipment type, building services and lighting
- Arranging equipment into relevant zones matching the sub-meters already included in the half hourly TM22
- Reviewing mechanical drawings to ensure the arrangement aligns with each zone
- Reviewing all available documentation (drawings, specifications, manufactures' data etc.)
- Reviewing the BMS – Air handling units arrangement and operation, energy centre equipment,

For each item of equipment the following information was required;

- Sub meter reference
- Number of items of each piece of equipment
- End use category (internal lighting, ICT, heating, etc.)
- Nameplate rating, kW
- Electrical load factor
- Usage profile
- Usage factor
- Seasonal usage factor

Different usage profiles were assigned to equipment, lighting and services within each space in the campus. They are included in Appendix **Error! Reference source not found.** to illustrate different operating hours. Load factors definitions are listed below.

Electrical load factor

The electrical load factor is the factor for typical (full load) power consumption compared to the rated watts. CIBSE recommends that, in accordance with 'Energy Consumption Guide 35', typical electrical loads are as follows; direct electrical heaters, tungsten lamps – 100%, fluorescent lamps – 125%, pumps and fans – 80% (variable speed pumps and fans 70%), desktop equipment – 30%.

Usage factor

The usage factor is the percentage of the profile time that the equipment is operating. For example, the usage factor for lighting in open plan offices with normal manual controls (poorly arranged and labelled) can be 100% or more. The UWS lighting is aimed to be regulated by both movement and day lighting sensors. This should reduce this figure greatly.

'Energy consumption guide 19 – Energy use in offices' states that a typical lighting usage factor for naturally ventilated cellular offices is 60% and for air-conditioned office building – 85%. This shows a significant difference. Therefore, it can be a challenge to precisely estimate usage factors for all spaces within the university campus.

Seasonal usage factor

Seasonal usage factors define the relative usage of each item across three seasons (winter, spring/autumn, and summer). Therefore, predicted seasonal usage for lights and boilers would be the lowest during summer.

However, the use of small power equipment would still be relatively high in the summer, as many classrooms are still in operation.

In summary, many assumptions have been made to complete the analysis. These include;

- Load factors for all lighting is assumed to be 100%;
- Usage factors and seasonal factors are fairly generic; 0, 25, 50, 75, 100%; and
- Classrooms are assumed to be used for 75% of the operating hours.

If necessary these figures can be adjusted, however this would be a very time intensive process. UWS campus accommodates a variety of spaces over 4 levels with a total floor area of approximately 18,000 m^2. Energy readings for separate sub-meters can be a helpful tool to provide patterns on how certain equipment operates. Nevertheless, most of the sub-meters are linked to electrical equipment by zones. For instance, a quarter of the ground floor's lighting belongs to one sub-meter. This arrangement makes it difficult to analyse energy consumption for a specific office or a classroom. The library is the only separately identified space which has designated meters recording electricity consumption for lighting and small power.

Summary of TM22 outputs

In summary the outputs in a graph form illustrate predicted in-use electricity demand (kWh/m2/year) for the UWS Ayr campus. The figures below were taken from the full version of the TM22 tool. As it is visible in Figure 70 the predicted demand is over 80 kWh/m^2/year. However, the actual electricity demand for the campus was 106.8 kWh/m^2/year in 2013. The actual building performance and separate end uses are described in a previous section 6.3.

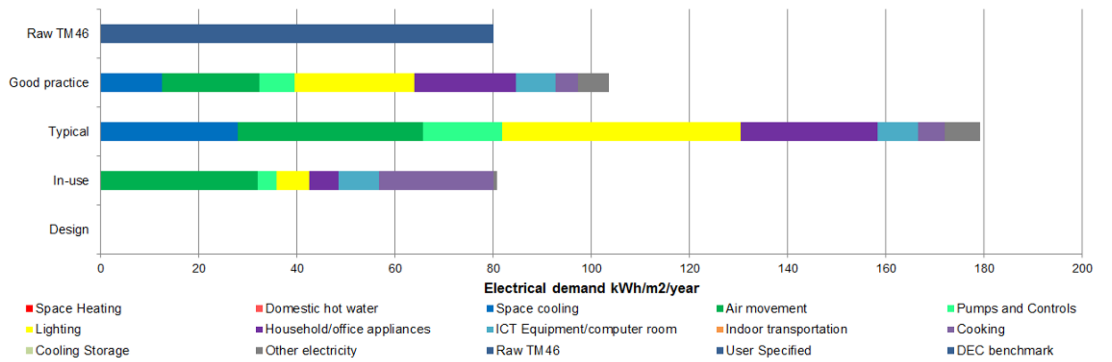

Figure 70 – Electrical energy demand by end use against 12 ISO12 and ECON19 categories

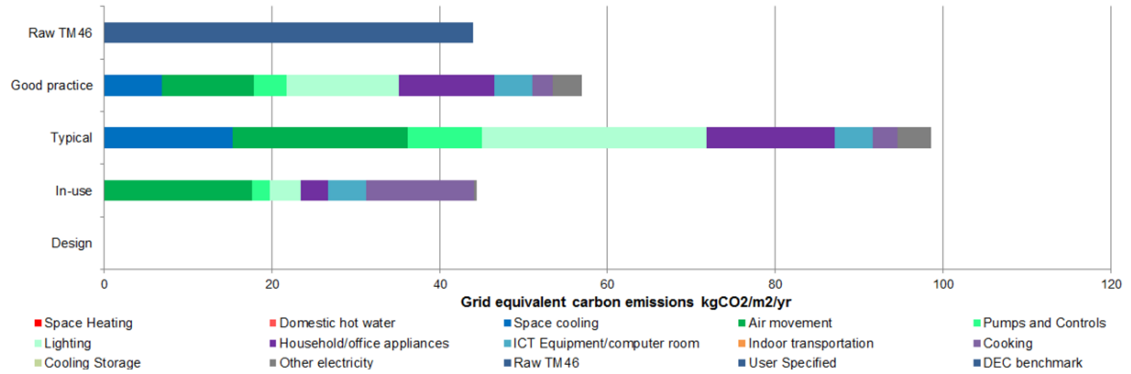

Figure 71 - Grid equivalent electrical carbon emissions by end use against 12 ISO12 and ECON19 categories

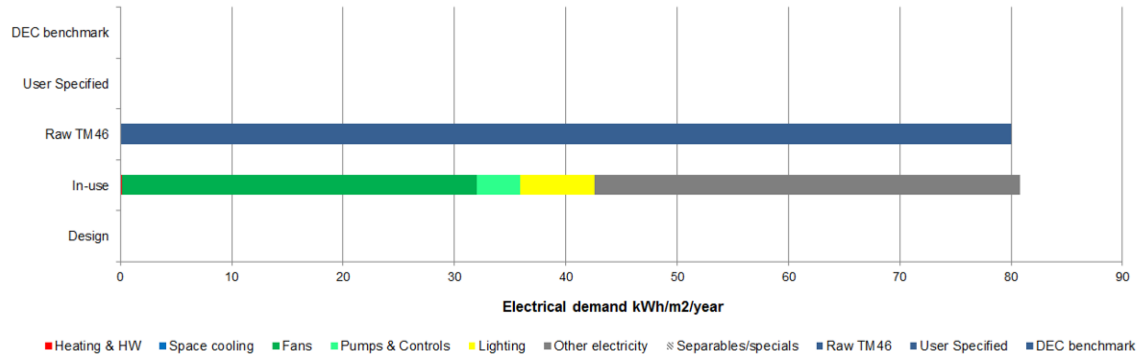

Figure 72 - Electrical energy demand by end use against 7 Carbon Buzz categories

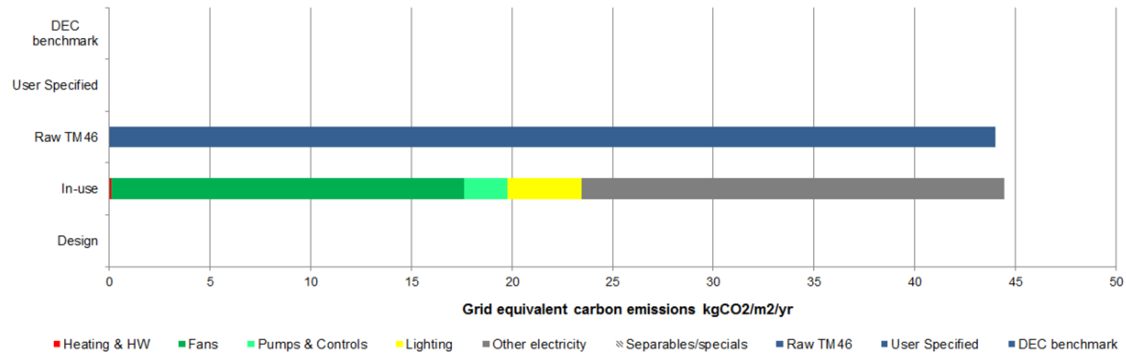

Figure 73 - Grid equivalent electrical carbon emissions by end use against 7 Carbon Buzz categories

6.5 Energy use of Air Handling Units Operation

The operation of air handling units which are assigned to the library, kitchen and student union (AHU6, AHU10, AHU 11 and AHU 12) were originally fixed to set operating hours, reflecting their use.

All other units were set up in accordance with the general 'Main Campus' timetable, from 6.30am till 10.30pm. Opening hours of SRUC (8.00am till 6.00pm) for AHU 4 and AHU 8 didn't influence this setting.

Figures below, illustrating an average daily energy consumption profile, confirm the operating setup of the air handling units (based on a recording period is from 1st of January to 18th of July 2013). Areas described in this section are spaces where operation of certain air handling units can be easily associated with. Refer to Appendix **Error! Reference source not found.** to view air handling units' arrangement on all four levels of the campus.

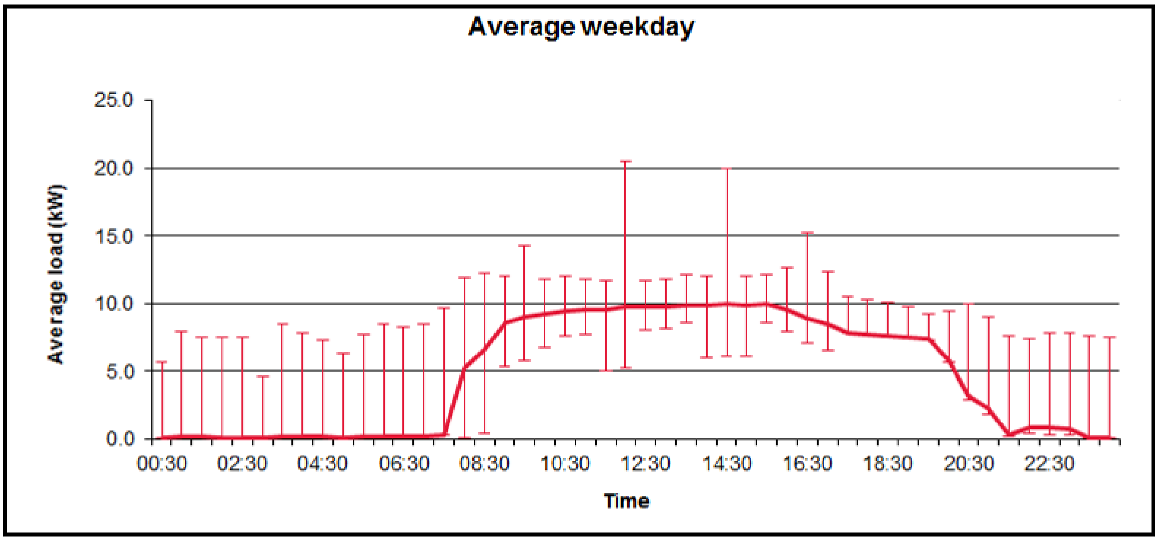

Figure 74 – AHU 6 (library) – average weekly energy consumption

Figure 74 clearly illustrates the energy use by AHU 6 corresponding to the library's working hours. Similarly graphs below reflect working hours during a Friday, Saturday and Sunday. It can be seen that the library closes earlier on a Friday and Saturday and that is not opened on a Sunday.

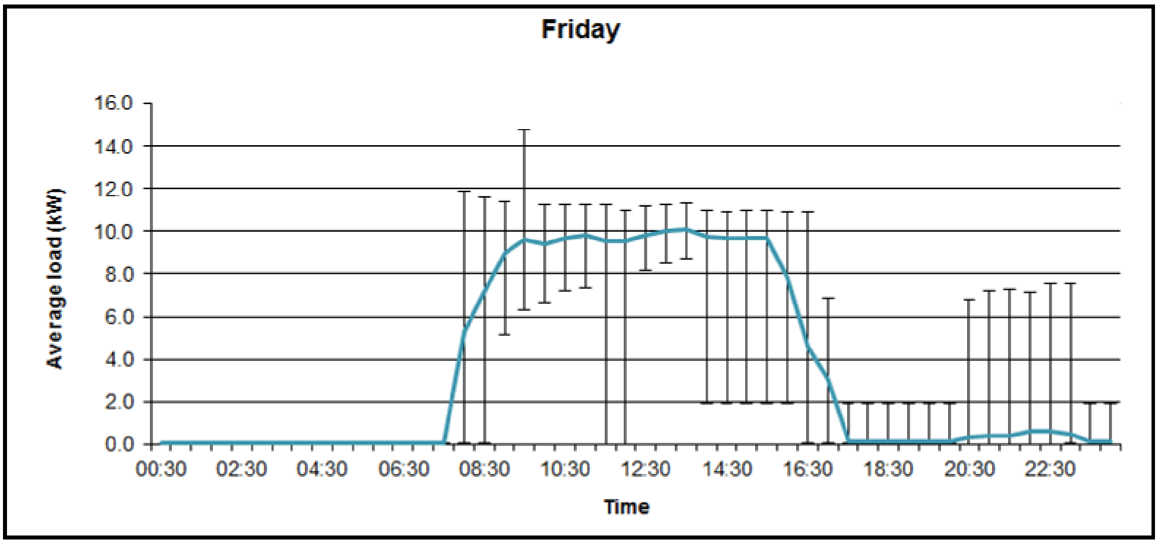

Figure 75 – AHU 6 (library) – average energy consumption on a Friday

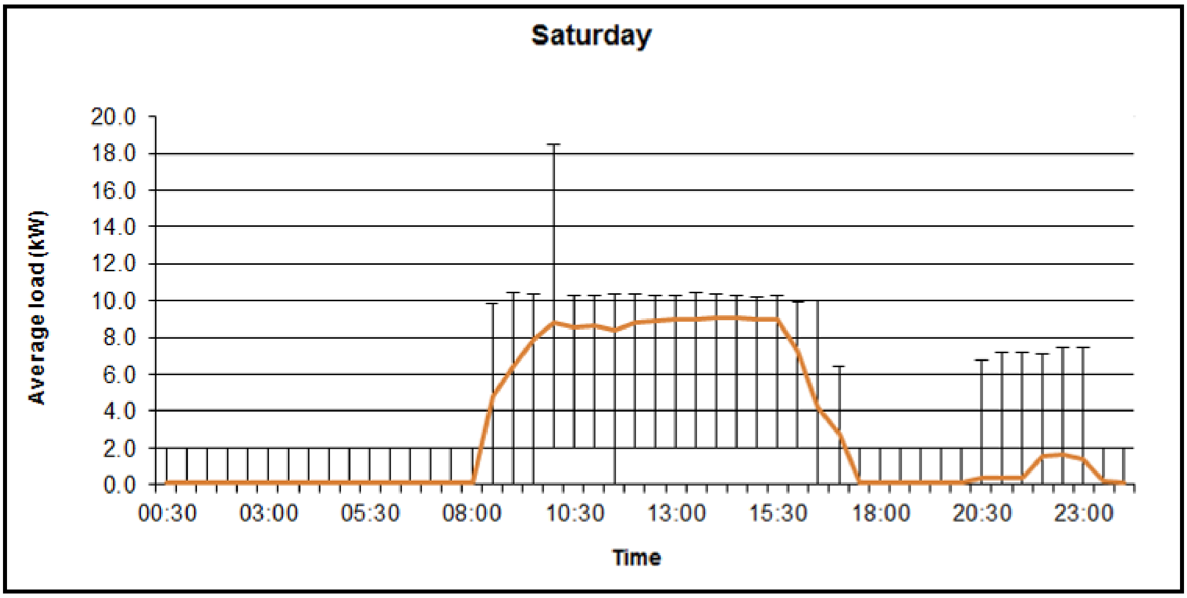

Figure 76 – AHU 6 (library) – average energy consumption on a Saturday

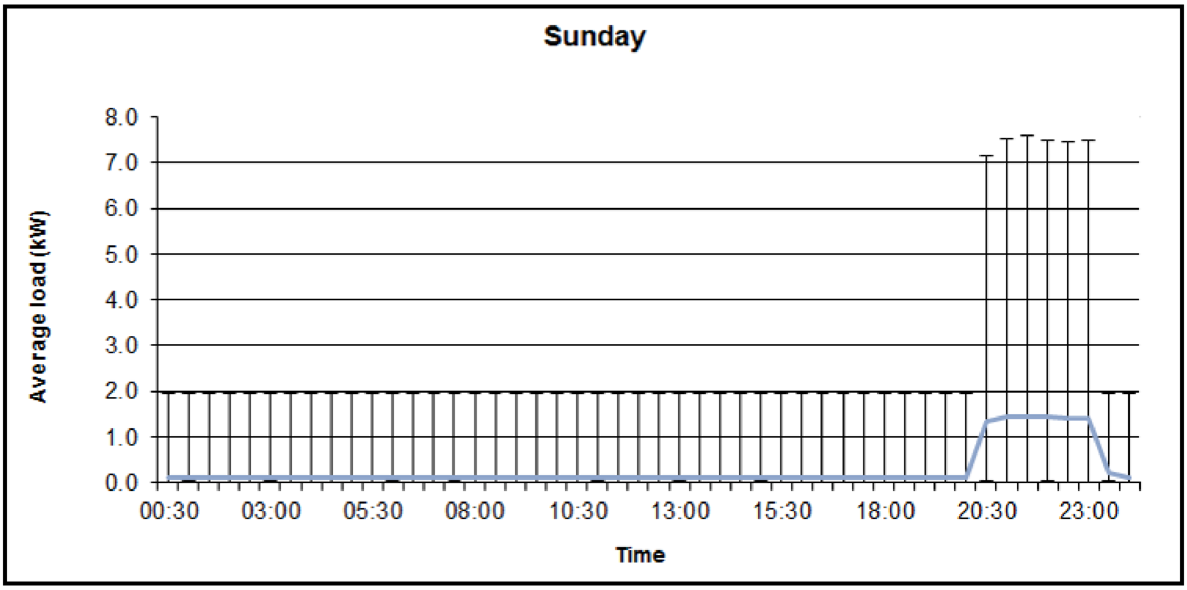

Figure 77 – AHU 6 (library) – average energy consumption on a Sunday

Similar conclusion can be drawn to the operation of AHU 2. It should be set up in the same way as the previously described AHU 6, as is it also serving the library.

Unlike the library, lecture theatres are only used during the week and are closed on a Saturday. Thus, it is recommended to change the operation settings for Saturdays. Additionally, weekly use of those rooms should be reviewed, as it is unlikely that lectures will take place until 10 pm on each weekday. This will be expanded on in a later section.

The graphs below illustrate an average daily energy consumption profile for a weekday and a Saturday for AHU 9. This unit circulates the air within lecture theatre 2, located on the top floor.

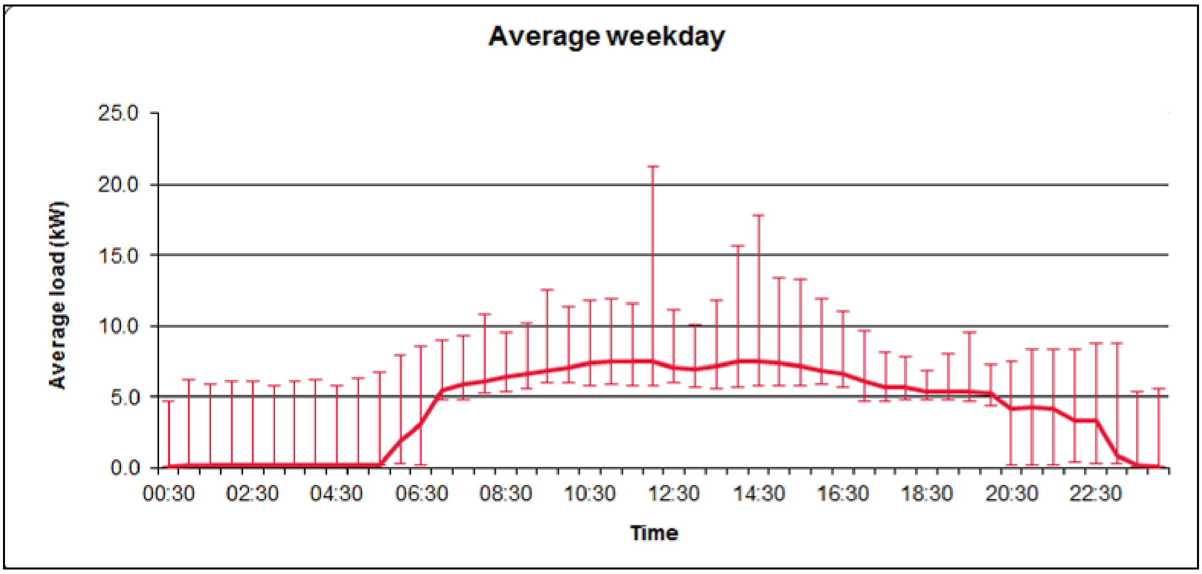

Figure 78 – AHU 9 (lecture theatre 2) – average weekly energy consumption

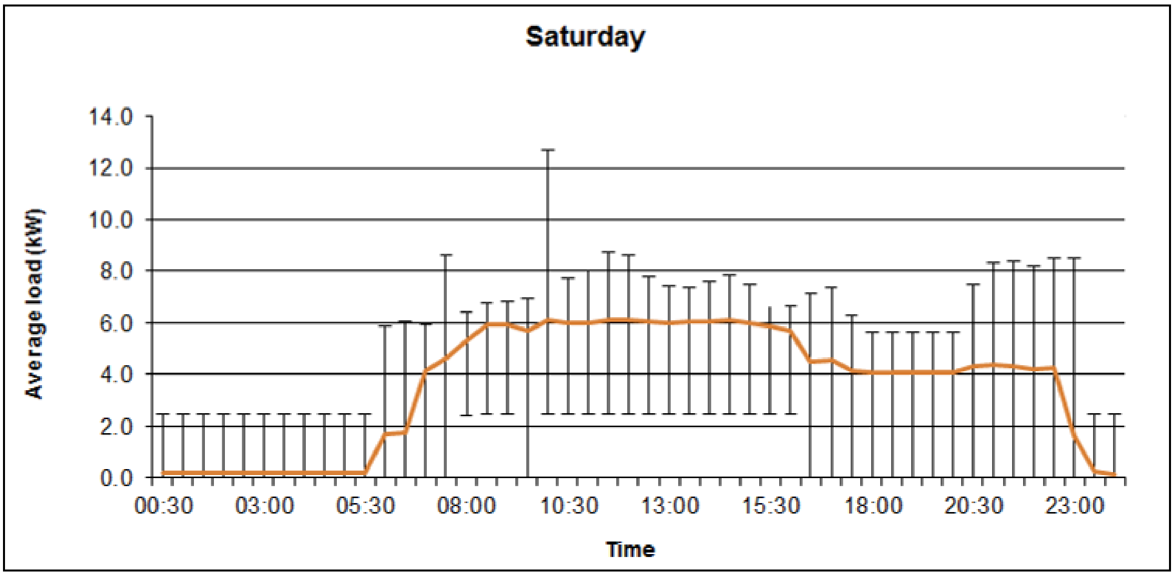

Figure 79 – AHU 9 (lecture theatre 2) – average energy consumption on a Saturday

Clearly electricity consumption of this AHU during Saturdays could be significantly reduced as it is unlikely that this space will be occupied all day (if at all). AHU 10, AHU 11 and AHU12 are linked to the student union and its kitchen. Energy consumption graphs confirm that those spaces are only used during weekdays and do not operate at weekends.

It is recommended that the University Estates department undertake a review of the daily setup of each AHU paying attention to separate settings for Saturdays. Most of the units are not required to operate during Saturdays (except the library). The rooms can be occupied differently during exam diets; some classrooms and lecture theatres will be used during the weekend. To reduce overall energy consumption those weeks should be assessed separately.

The graphs of all other sub-meters' data are available to be viewed in a copy of the half hourly TM22 tool.

The next section will focus on the revision of a teaching timetable for trimester 2 which corresponds to the recording period from January to July 2013. The analysis will be based on the operation of AHUs, as each unit has a separate energy meter and cover individual and separate spaces.

This section focuses on Trimester's 2 timetable. Teaching within this trimester covers a period between 4th Feb and 10th May 2013. This period includes the energy use data from the original analysis report (Jan to July 2013). It should be remembered that the usage patterns will be different during the exam diet in mid-May and during the Easter holiday break. (Note that a full year data is incorporated in the TM22 tool providing an annual overview.)

Lecture theatre 1 and lecture theatre 2 are operated correspondingly by AHU 13 and AHU 9. Figure 80 and Figure 81 below illustrate the maximum use for those spaces. They demonstrate the number of hours in use and also the teaching weeks of trimester 2.

AHU 13 – lecture theatre 1 in-use

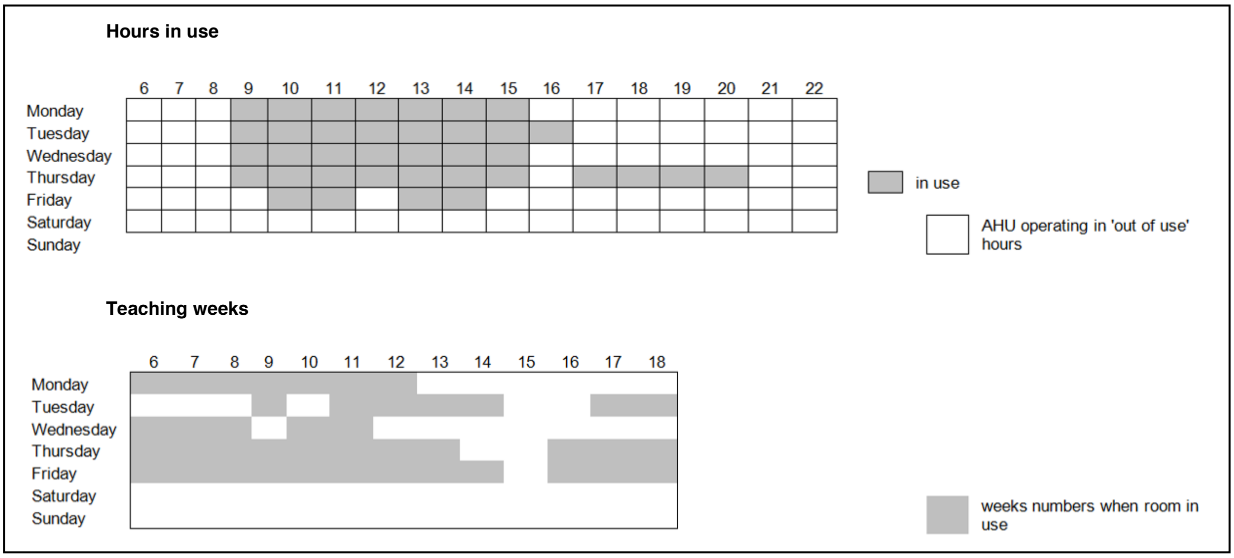

Figure 80 – AHU 13, lecture theatre 1 in-use analysis

It can be seen in Figure 80, that most of lectures taking place in theatre 1 start at 9 am and finish at 4 pm. Thursday is the only day when there are night classes. It is clear from the illustration that this space is used for less than half of the time of the AHU 13 operation. Furthermore, a typical teaching weeks diagram illustrates that there are some teaching weeks/days when the space is not occupied.

Clearly, it is not feasible to switch the AHU on and off every time the rooms are not used. This analysis however, illustrates that significant saving could be achieved by some general operational setup changes.

AHU 9 – lecture theatre 2 in-use

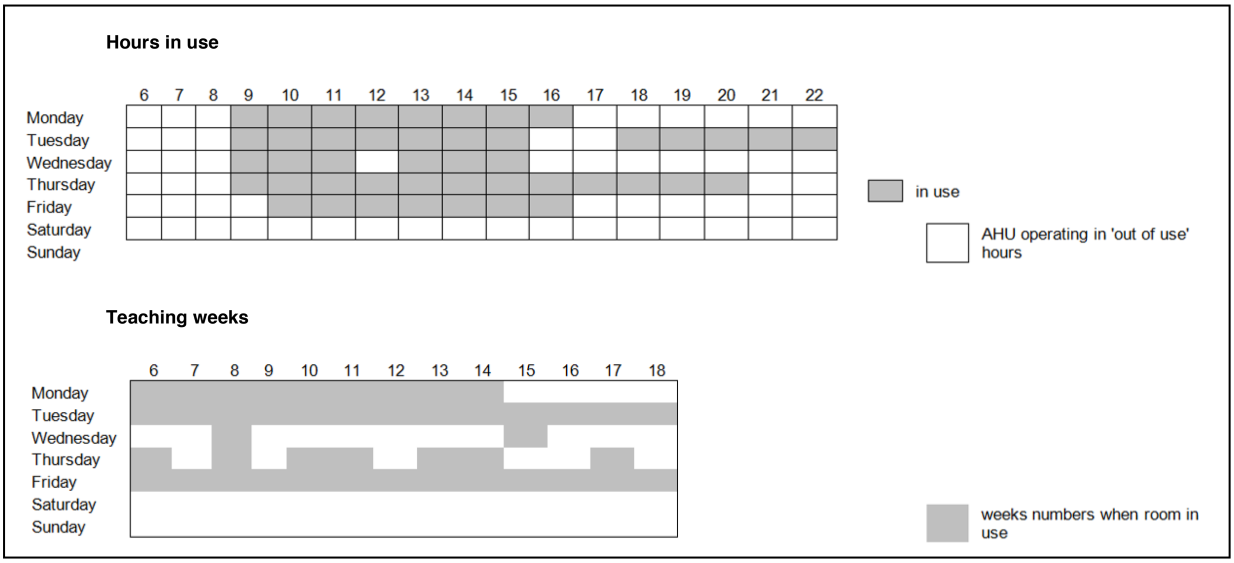

Figure 81 – AHU 9, lecture theatre 2 in-use analysis

Similarly, Figure 81 illustrates that substantial changes could be made in order to reduce the operational cost of AHU 9.

In summary, the diagrams show that there is no need for full AHU operation from 6.30 am to 10.30 pm as both lecture theatres are not occupied after 5 pm on most days.

AHU 3 – rooms in use

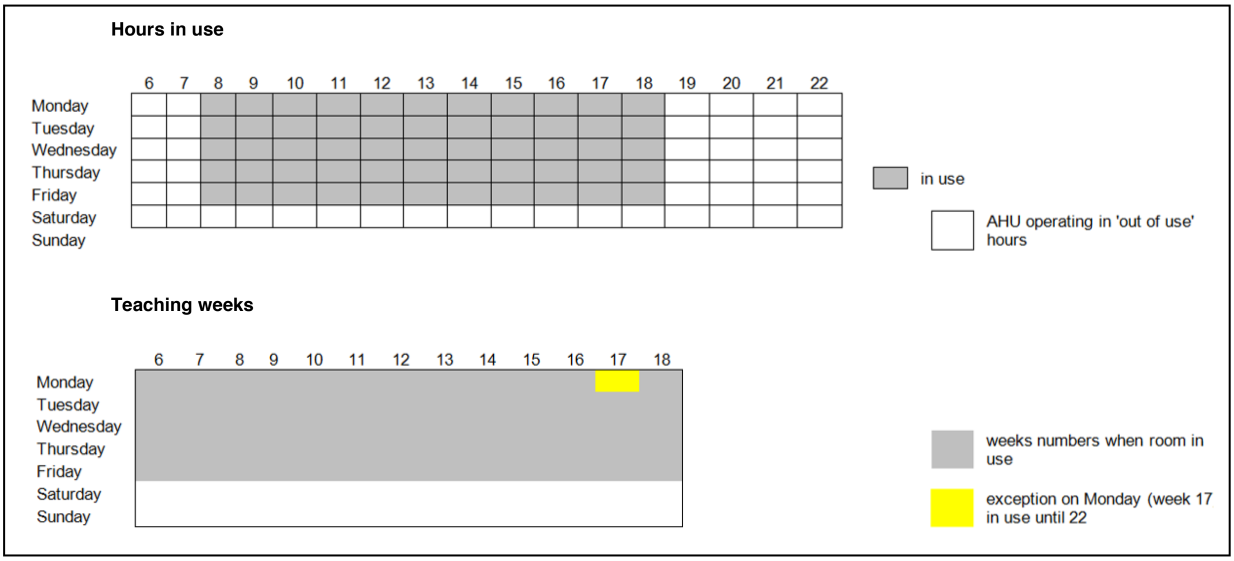

Figure 82 – AHU 3, rooms in-use; TV1, TV2, Computer labs 8 and 9, lecture theatre 3, offices

Figure 82 refers to rooms operated by AHU 3. They include two TV studios, two computer labs, the third lecture theatre and some offices. The illustration simply suggests that the AHU 3 should be operating during core office hours as no spaces are used in late evenings. The only exception to this is Monday during week 17 where some rooms were needed until 10pm. It confirms that additional energy savings could be achieved on this units' operation.

It is clear that revising how spaces are utilised during teaching weeks would be beneficial in terms of energy savings. However, settings should also be reviewed for any bank holidays, Easter and Christmas breaks as well as exam diets. It is recommended to revise the settings of AHUs before each period as this will have a significant influence on utilisation.

Please note that during 'out of use' hours, spaces can be accessed by cleaning staff but also maintenance and security checks can take place. These factors must also be taken into consideration.

One way to minimise variances within the Ayr Campus would be to carry out an in depth analysis of lighting controls for electricity use and a detailed revision of heating control and operation. Additionally, revising the timetable for the campus would support more accurate usage factor figures for classrooms, lecture theatres, studios, etc.

During the BPE the estates team have revised operational hours of air handling units. The settings up to date are captured in Figure 83.

Figure 83 – Revised time settings of air handling units

6.6 Conclusions and key findings for this section

Energy benchmarks and sub-meter assessment

In terms of sub-meter analysis a number of factors can cause a variance between predicted and actual energy readings;

- Complexity of the campus; and
- Assumptions made in terms of predicted energy consumption.

A comparison between predicted and monitored energy consumption is included in Appendix **Error! Reference source not found.**. It includes energy consumption of the building in use compared against the different benchmarks..

Dealing with the performance gap between predicted and actual building performance is one of the key focuses of the construction industry. Carbon Buzz confirms the significance of those gaps by demonstrating results for different building types.

Electricity and fossil fuel consumption of the campus

The building's electricity consumption was found to be significantly higher than benchmarks suggested in TM46 'Energy benchmarks' published by CIBSE and the gas consumption was slightly lower. However, reviewing settings which are currently applied to the building services should help to significantly reduce overall consumption figures, particularly in relation to electrical consumption. Fans are the biggest contributor to electrical consumption in the Campus. Thus, reducing energy consumption of air handling units could be tackled first and should result in a notable difference. The catering area is also a high energy consumer, however it is recognised that this might be difficult to reduce this figure. The usage of ICT equipment, lighting and small power is recommended to be revised. Additional supporting information can be found in chapters;

- 3 Review of building services and energy systems.
- 5 Details of aftercare, operation, maintenance & management

Operation of building services

In terms of additional carbon saving, the rapeseed oil fuel source proved to be very beneficial when compared with gas, however there are no financial incentives for using rapeseed oil and there are also increased maintenance and efficiency issues for the Ayr Campus when using rapeseed oil. The Campus has therefore had to resort to utilising their gas boilers.

There are, however, a number of opportunities for the Campus to help reduce their electricity consumption through more efficient use and programming of services. To help maximise operational efficiencies, it is highly recommended for the University to review the control and timer settings for all building services serving the Ayr Campus building, with particular attention being paid to occupancy patterns and the delivery of services (to help ensure ventilation or heating is not being delivered when it is not required). This should apply to scheduled lectures and tutorials, but also to any additional evening classes or externally booked activities.

In conclusion, to successfully manage these suggested revisions, it is key to improve communication between the facilities manager, administration staff and any other staff members who could provide useful information in relation to occupation and operation of the Campus. Additionally, if there are any booking requirements for similar rooms and activities, it is recommended that these bookings are grouped to ensure that they are within, and serviced by, a similar zone according to the air handling units' arrangement.

The TM22 tool usability and alternative methods of energy data collection

Completion of the TM22 tool was found to be complex and time consuming. Activities included carrying out a detailed building survey, reviewing numerous literature and electrical drawings and estimating the usage profiles along with other parameters. In addition to continued energy consumption collection, the overall task required significantly more time and resource than originally predicted. There were also faulty readings in almost all sub-metred data that had to be rectified where possible. This was corrected and applied to both: originally completed half yearly consumption and then to the full year's data.

Despite the time and significant effort that was allocated to completing the task, the results of this excise are not achieved as BRE had previously hoped. Large variances between actual and predicted energy consumption for each sub-meter can be viewed in Appendix **Error! Reference source not found.**.

TSB requires that on this BPE project, a complete TM22 analysis should be delivered. From this BPE project the following conclusions can be drawn;

- When using the TM22 tool it is highly recommended to create separate periodic files (monthly or seasonal). That approach would enable better comparative analysis between such periods rather than having overall findings.
- Half hourly version of the tool were found to be more beneficial to the purpose of this project. Daily average energy consumption for each sub-meter provided a clear indication of the times when

specific equipment gets used the most (hence air handing units assessment described in section **Error! Reference source not found.**). The requested information is also available through the online METERology monitoring software.

- The completion and full analysis based on the TM22 is recommended to start from design stage if feasible. Having the tool structured alongside all drawings and appropriate literature would help to reduce the risk of error during further completion of the tool. The number and type of services and equipment with their usage within the building should be inputted to the tool as early as possible. This approach would help to ensure the correctness of information.
- Additionally, the AMR system, as described in section 5 of this report, was found to be a well-structured and user-friendly tool. It provides readily available, valuable outputs. It is recommended to consider carrying out an in-use analysis using the AMR or similar. This could significantly reduce time spent on unnecessary activities, such as complex building survey or usage factors' estimations for a large number of equipment and services.

7 Building Fabric

The construction process and quality of finish plays a crucial role in influencing a building's performance as this heavily impacts the building's thermal performance. Generally, two key parameters influence how energy efficient and airtight a building envelope is. Firstly, various layers of building materials, insulation in particular, will contribute to an overall U-value for each building element. The lower the U-value less heat that escapes through a wall, roof or floor. Secondly, the quality of construction detailing and workmanship will help to reduce any unnecessary heat loss through any gaps in the building fabric.

Figure 84 – Building façade: solar shading over curtain walling, horizontal timber cladding around the lecture theatre, composite granite rainscreen cladding.

7.1 Infrared thermography

Infrared thermography enables the photographer to determine the surface temperature of specific areas of the building within the images. BRE trained experts made use of a thermal imaging camera (e.g. Flir E50bx) to detect radiation in the infrared range of the electromagnetic spectrum for the Ayr Campus building. The radiation levels are relative to temperature, allowing the variations in temperature to be captured. The reflectance and emissivity of the material is also considered by the thermographer.

Thermography enables the assessor to identify any thermal anomalies which may require further investigation, such as:

- Continuity of insulation
- Thermal bridging
- Air movement/leakage
- Dampness
- Blocked Pipes and Ducts.

To establish if there are any thermal anomalies at the Ayr Campus, a thermographic survey was undertaken. Using a thermal imaging camera, any problematic areas of the campus could be identified by correctly reviewing and evaluating the thermographic images.

Please note that thermal images are reviewed by a qualified Thermographer, to ensure that they are correctly interpreted. Within thermographic images emissivity, reflection and evaporation can often look similar.

To determine accurate conclusions from the thermographic survey, thermal images should be taken when there is at least a 10°C difference between the internal and external temperature, wind speed should be no more than 10 m/s and there should be no direct solar gain. Weather conditions during the tests are summarised in Table 7. The South side of the Campus is the most exposed to the effects of wind and solar radiation. The surrounding woodland provides some shelter to the North, East and West sides of the building.

Internal Temperature	21°C
External Temperature	0°C - 1°C
Weather Conditions	Easterly wind, cold, dry and overcast
Direct sunlight	No direct solar radiation observed in last 24 hours
Surface Condition	Dry, with no precipitation
Wind speed	Approx. 25 km/h; 6 - 7m/s

Table 12 – Weather conditions during the Ayr Campus infrared thermography tests

Results of infrared thermography (including digital images and corresponding thermal images) are detailed in the following section.

Thermographic Survey – Results Summary

Findings of the thermographic survey can be summarised as follows;

- Continuity of insulation is consistent within the fabric of the external walls, with no identifiable areas of missing or underperforming insulation, as can be seen below in the sample images - Figures 78, 79 and 80.

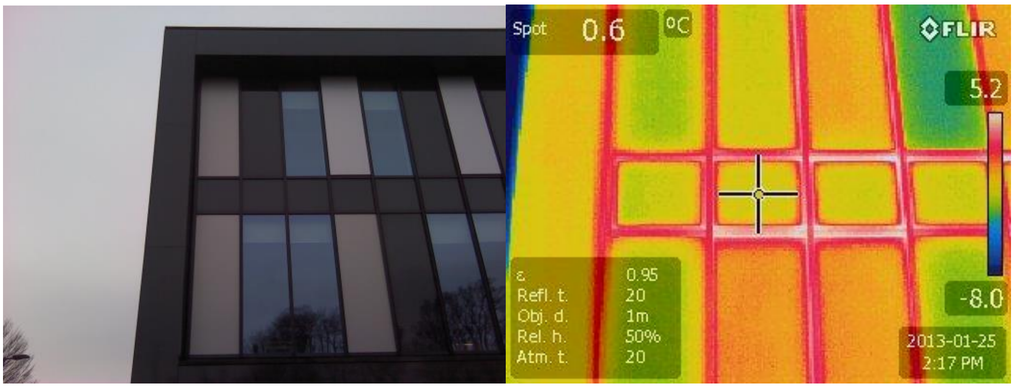

Figure 85 - External Wall fabric 01

Figure 86 – External Wall Fabric 02

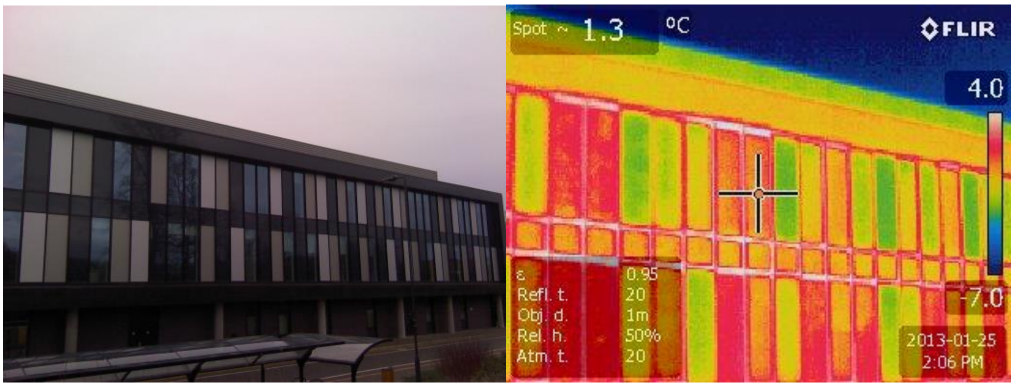

Figure 87 – External Wall Fabric 03

- Continuity of insulation is also consistent within the fabric of the roof and overhang areas, again with no identifiable areas of missing or underperforming insulation. This can be seen below in the sample images - Figures 81, 82, 83 and 84.

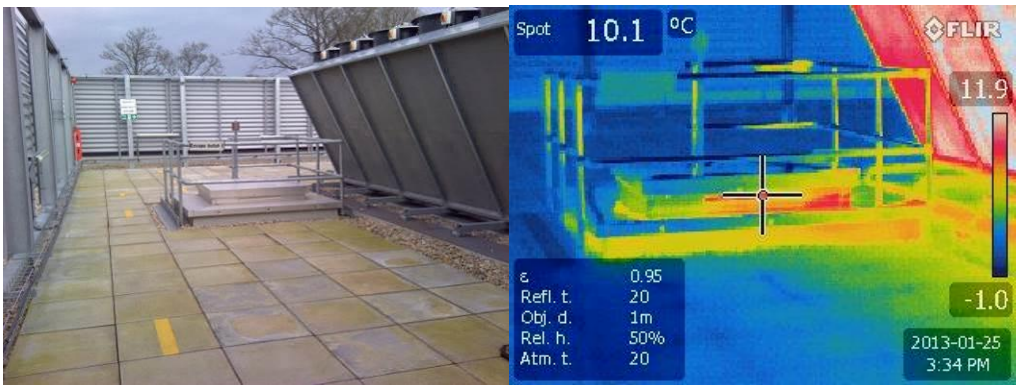

Figure 88 – Roof Fabric 01

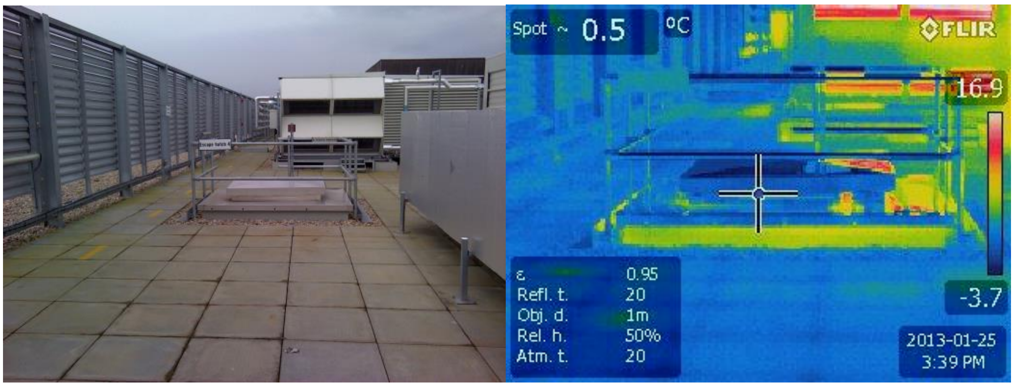

Figure 89 – Roof hatch / access

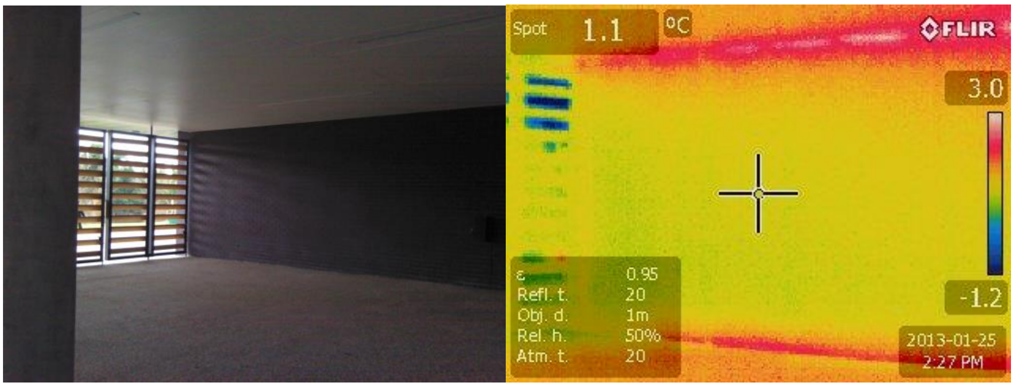

Figure 90 – Underground walkway

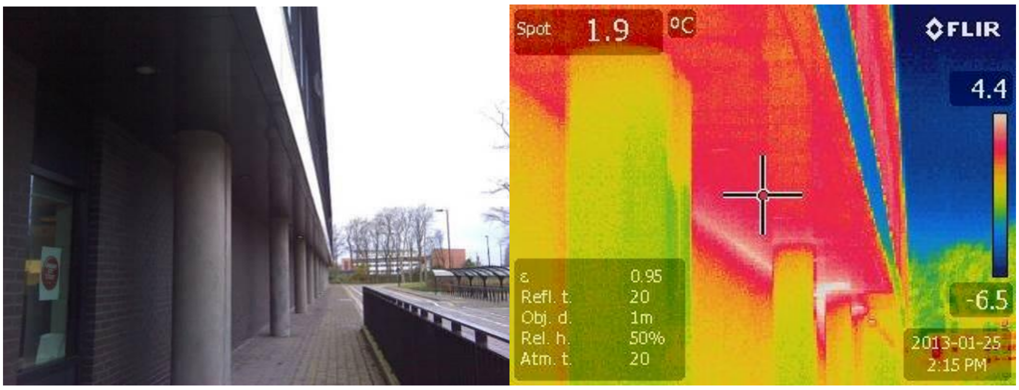

Figure 91 – Overhang 01

- Thermal bridging can also be seen internally, particularly at wall / ceiling junctions. The cold spots and areas indicate a thermal bridge, either by design or as a result of movement / settlement of the new building. Note that no significant cracks within the internal finish were visible. Please refer to figures 85 and 86.

Figure 92 – Ceiling / wall junction (internal) 01

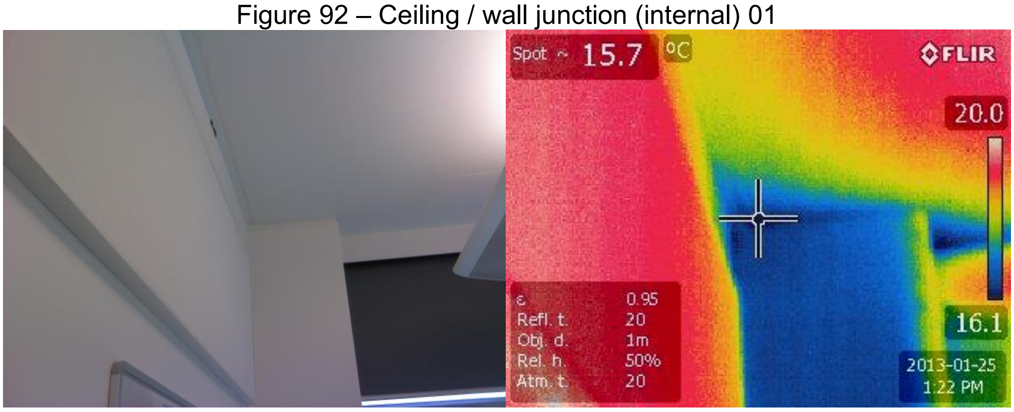

Figure 93 – Ceiling / wall junction (internal) 02

- The majority of building services also appeared to be functioning adequately, with no significant blockages or immediately identifiable issues. Examples of this are provided in Figures 87, 88 and 89.

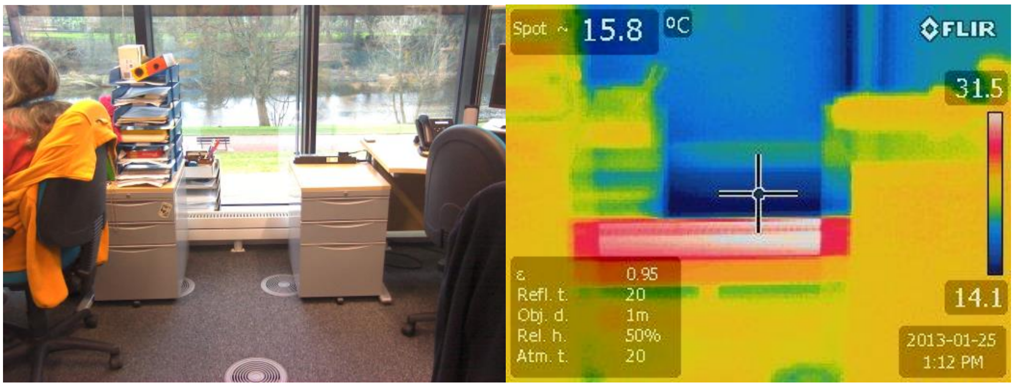

Figure 94 – Radiator system operational

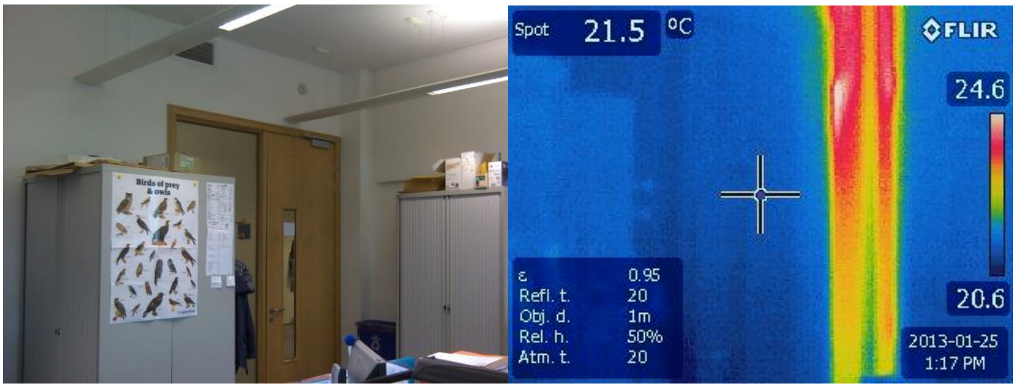

Figure 95 – No blockages within space heating flow and return pipework (located behind plasterboard)

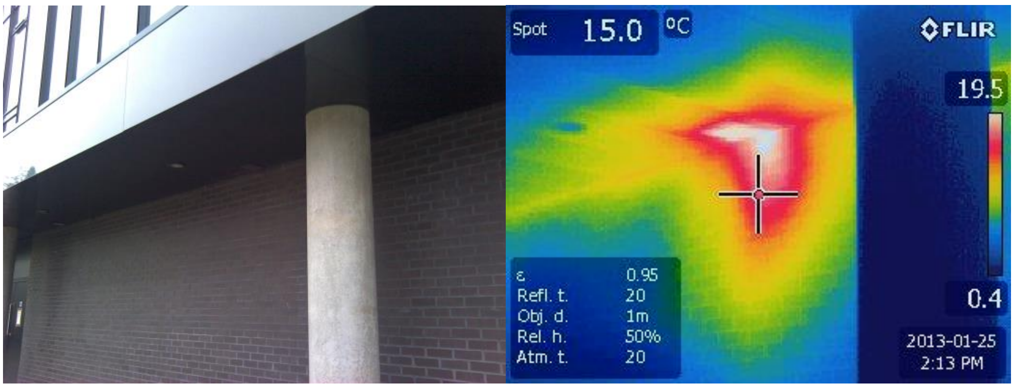

Figure 96 – Extraction ventilation vent to external operational

7.2 In-situ U-value testing

In addition to infrared thermography analysis, in-situ U-value testing was required to ensure a more accurate conductivity analysis of the building fabric. Thus, U-value measurements were carried out to obtain the actual thermal performance of the building fabric.

In practice, the actual U-value can be higher than the theoretical calculation, especially when workmanship is poor or when there are unintended or unexpected air gaps between and around sections of insulation. The presence of mortar snots, wall ties or other debris could also lead to the actual U-value being higher than the calculated value – although given the nature of the construction this is considered unlikely.

Context and Process

To investigate whether the UWS Ayr Campus performs as designed (values below) the in-situ U-value measurements were carried out.

The ‘as designed’ U-values for the UWS Ayr Campus are as follows:

- Roof: 0.17 W/m2K
- Floor: 0.18 W/m2K
- External Wall 0.21 W/m2K
- Windows: 1.42 W/m^{2}K

The process of measuring the flow of heat from the inside to the outside of the building required attaching a heat flux sensor to the internal surface of the building fabric and internal and external temperature sensors. The sensors were then connected to a data logging device.

U-value measurement can be a complex process. Interior and external temperatures inevitably fluctuate and, in addition to this, there are times when heat is temporarily stored within the structure of the building and later released. To allow for any temporary storage of heat in any U-value measurement, the heat flows and temperature readings were carried out over a sufficiently long period to negate the influence of thermal storage (two weeks). The U-value is then derived from the sum of the heat flow readings (expressed in W/m²), with corrections for thermal storage effects, divided by the sum of the temperature difference readings (expressed in K) over the period of the test.

Due to practical limitations, it was only possible to measure the thermal performance of the external walls.

Testing and Results

Heat flow meters were fixed to an appropriate location on the internal surface. The survey was carried out on a typical office location on the first floor of the building.

The area was heated consistently over a two week period. The external leaf of the first floor comprises a cladding exterior. The tests were carried out under the conditions summarised in Appendix **Error! Reference source not found.**.

A thermal imaging camera (Flir E50bx) was used prior to installation of the U-value equipment which enabled BRE to identify if any anomalies (i.e. service pipes, studwork) were present where the U-value measurement was taken.

To measure the external temperature at first floor office locations a ‘Tiny tag’ was used. It was suspended from the window handle with string allowing closure of the window over the string; this minimised any security issues. Images of the heat flow meter attached to the wall surface are included in Appendix 12.13.

The U-value measurements of wall at the first floor office location was carried out using the techniques described in ISO 9869, and provides direct comparisons between the measured U-values and the U-values calculated using the methodology in BS EN ISO 6946. From analysing the graph (Figure 97), the heat flow appears to fluctuate following the initial installation the equipment. After a few days, the U-value measurement appears to reduce towards the designed U-value specification. The fluctuation may be due to the effects of thermal mass.

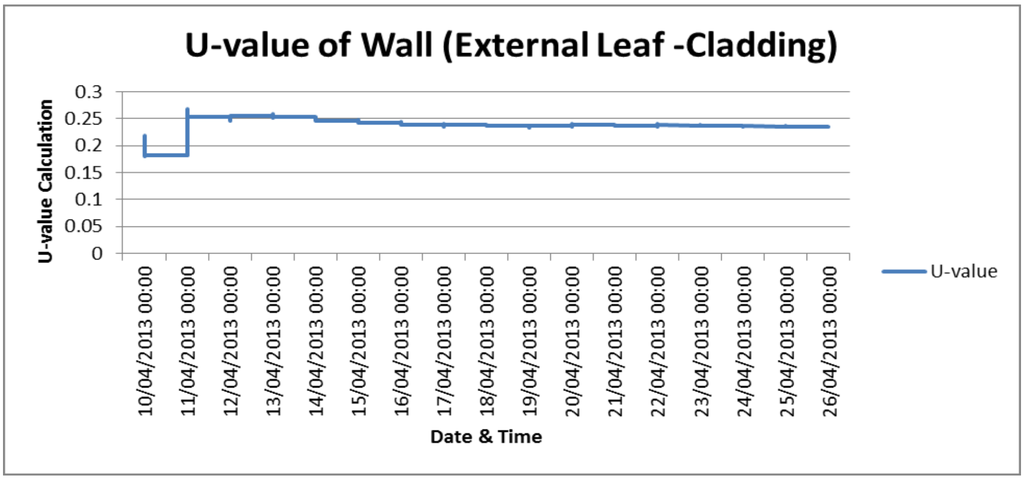

Figure 97 – Wall U-Value Calculation (First Floor)

Table 13 identifies the ‘as designed’ U-value, which is provided to allow comparison with the measured U-value. As can be seen from the figures, the constructed UWS Ayr Campus fabric (at the first floor location) does not meet the design specification. The Design specification for the wall construction on the first floor aimed to achieve a U-value of 0.21 W/m^{2}K. The measured U-value was approximately 14% below this figure measuring 0.24 W/m^{2}K.

Table 13 – Comparative U-Value Results

	As Designed Area weighted average maximum U-Values	Measured U-Values
Wall – First Floor	0.21 W/m^{2}K	0.24 W/m^{2}K (approx.)

The measured U-value is still a significant improvement above the maximum U-value figure, 0.27 W/m^{2}K, (area weighted average U-value) outlined in the Scottish Building Regulations 2011 Section 6 Guidance, ‘Maximum U-values for building elements of the insulation envelope’.

7.3 Air tightness testing

To limit heat loss, any heated building should be designed to limit uncontrolled air infiltration through the building fabric, without compromising on ventilation requirements. This is done by providing a continuous barrier that resists air movement through the insulation envelope and limits external air paths into each of the following:

- The inside of the building;
- The 'warm' side of insulation layers; and
- Spaces between the component parts of exposed building elements, where such parts contribute to the thermal performance of the element.

Areas that need particular consideration in this respect include loading doors, entrance areas and shafts which extend through most of the floors (e.g. lift and stair enclosures).

According to Scottish Building Standards: Domestic: Section 6: Energy, it is recommended that buildings are designed to achieve air permeability performance of a value of 10 m3/(h.m2) @ 50 Pa or better, to allow a balanced approach to managing building heat loss an air tightness test for the whole Ayr Campus was originally carried out at building handover stage as part of a quality control check which confirmed performance levels that contributed to the building's overall improved energy performance, with an air tightness result of 4.12 $m^3/(h.m^2)$ being achieved.

Context and Process

To assess the campuses' air permeability BRE appointed a local, independent, qualified company, namely Thermal Image UK, to carry out a series of air tightness tests. It was not practical to test the whole Campus, due to operational constraints, therefore smaller, individual areas were selected for air tightness testing. BRE selected three rooms which would be a representative of the overall Campus performance, informed by earlier thermography, internal environment monitoring and occupant consultation activity.

In order to successfully complete air tightness testing of these areas, a pressure difference between the external and internal pressures must be created. This is achieved by creating external air movement around the identified spaces. The areas selected for testing are identified on plan drawings in **Error! Reference source not found.** in Appendix12.14. These rooms are on the ground floor of the building and allow safer and more convenient access which enables the required testing conditions to be achieved. The report by Thermal Image UK detailing the process and findings in included in Appendix 12.14 provides a summary of results.

The report suggests that:

- The main areas of air leakage in room 2.005 appeared to be from electrical sockets recessed into the floor.
- The main areas of air leakage in room 2.023 appeared to be from the above the suspended ceiling.
- The main areas of air leakage in room 2.033 appeared to be from electrical sockets recessed into the floor and from the above the suspended ceiling.

	Air Changes per Hour (ACH)	**Air Permeability (m3/h.m2)**	Calculated volume (m3)	Calculated envelope area (m2)
Room 2.005 (Staff Office)	4.31	**3.28**	111.6	146.6
Room 2.023 (Rest Room)	11.95	**8.66**	95.6	131.7
Room 2.033 (Admin Office)	7.35	**4.60**	55.4	88.1
Defined air permeability	-	**6.00**	-	-

Table 14 – Air tightness test results

The specified building air permeability as defined by the client was 6m^3/(h.m^2) @ 50Pa. The testing results confirm that two out of the three test results meet and significantly exceed this target and although the air permeability value of 8.66 m^3/(h.m^2) was achieved in one of the areas)Room 2.023) this figure is still below the maximum air tightness value of 10 m^3/(h.m^2), recommended by building regulations. From the results, it could be assumed that the average air permeability for the Ayr Campus is most likely to be under the client's required air tightness target of 6 m^3/(h.m^2).

Please note that an original air tightness test that was carried out previous to the tests described above and the results are also included in Appendix 12.14. BRE believes that this test, however, is not indicative of the overall building. The poorest results of the initial air tightness test are from an unheated, unoccupied storage room where there are many ducts and where leakage does appear to be present. This type of space and quality of finishing is not typical for this building. This exercise was purely as an information gathering exercise for the client to help identify areas where they could improve air leakage, the exercise is not, however, a reflection of the performance of the majority of areas within the Ayr Campus building.

7.4 Conclusions and key findings for this section

Overall, building fabric of the campus was found to be constructed in accordance to relevant standards;

- Thermal imaging investigation did not suggest any major problems. Some expected leakage areas around ducts and service pipes were found, which highlights an importance of the appropriate levels of workmanship that are required in order to achieve ambitious performance levels.
- U-value tests demonstrated that external wall demonstrates a significant improvement beyond building regulation requirements, however the measured performance was approximately 14% below the desired value.
- Air tightness tests suggest that the majority of areas still continue to meet and exceed the client's original requirement for air permeability (6m3/h.m2) and that the remaining rooms would comply with buildings standards requirements (10m3/h.m2).
- In-situ tests that were undertaken to consider the actual fabric performance provided a valuable quality assurance and led to the following recommendations;
- For a large scale building performance evaluation project, it can be beneficial to carry out air tightness tests on a selection of rooms or areas, particularly when full building testing is not practical. Other building monitoring and occupant consultation activity can help to identify the areas that would be beneficial for testing. External air flow should be provided around a tested space and vents sealed. Tests should be arranged at an appropriate time for the building users, avoiding any disruption or distractions.

- Infrared thermography tests should be carried out by an experienced thermographer during appropriate weather conditions and an investigation should eliminate any confusing results caused by reflection.

8 Internal Environment

As a part of BRE's Building Performance Evaluation of the University of the West of Scotland Ayr Campus, a number of internal environment scientific readings were taken to help to establish the performance of the building in terms of;

- Temperature (°C)
- Humidity (%)
- Air Quality (ppm1)
- Lighting Level (lux)
- Noise Level / Acoustic Performance (dBA[2])

Readings were taken using handheld equipment and effectively provide a 'spot check' for the key conditions that help to create an optimal internal environment for building occupants. The results of this exercise and comparative information are detailed in the following sections.

Figure 98 – Main walkway towards the library and the external view of the rooflights

8.1 Recommended levels

Temperature

Typical thermal comfort levels, in terms of temperature, vary dependent upon the building users clothing type and activity. For an office environment, it is assumed that the majority of activities involve sitting and wearing normal to heavy clothing. Therefore, typical comfort levels should range between 18 to 21°C for most spaces, as detailed in **Error! Reference source not found.**.

[1] ppm – CO_2 levels in parts per million

[2] dBA – A-weighted decibels

Clothing Type	Typical Comfort Levels - Temperature (°c)			
	Strolling	Standing	Sitting	Sleeping
Light clothing	15	23	25	27
Normal clothing	8	19	21	24
Heavy clothing	0	14	18	21
Very heavy clothing	0	10	14	18

Table 15 - Comparative Temperature Levels

Relative humidity

Generally, in a working environment, the recommended relative humidity level should be between 40% and 60%. When humidity is too low there can be a wide range of health implications, including eye, nose and throat irritation, respiratory infections and headaches. Similarly, when humidity is high the internal environment can become very uncomfortable. As the human body feels warmer and cannot cool, overheating can occur and lead to dehydration and chemical imbalances within the body.

Air quality

Air quality is a measurement of the level of CO_2[3] within the internal environment, and is usually measured in parts per million (ppm). Typically, 'Good' practice levels should be below 1000 ppm and ideally less than 600 ppm as when CO_2 levels are in excess of 1000 ppm, drowsiness and lethargy can be common side effects and could contribute towards a noticeable drop in productivity and concentration. Levels of between 1,000 and 2,700 ppm have been shown to have an adverse effect on building occupants wellbeing and up to a 14% reduction in cognitive function.

Lighting levels

Within an internal environment it is important to consider the lighting level (measured in Lux) within each different function area, as specific tasks require varying levels of light. Lighting levels can include both natural and artificial lighting, as is often the case. However, exposure to levels of good quality natural light has multiple benefits, including improved occupant health and wellbeing and can also contribute to the reduction of energy consumed for artificial lighting requirement.

[3] CO_2 – Carbon dioxide

details typical comparative lighting levels that would be expected for various space functions or tasks.

Comparative light levels	Lux
Precision task lighting	1,000
Drawing boards	750
Kitchen preparation areas	500
General reading	300
Entrance halls	150
Corridors or storage	100

Table 16 – Comparative Light Levels

Noise levels

In terms of acoustic performance, it is important that noise levels do not regularly or consistently exceed the recommended sound levels as detailed in table 12. Generally, constant noise levels of 65 dBA or higher can have a negative impact on the wellbeing of the building occupants, such as experiencing fatigue.

Space function	Noise Level (dBA)
Hospital & general wards	55
Small consulting rooms	50
Large offices	45-50
Private offices	40-45
Living rooms	40-45
Small classrooms	40
Large lecture rooms	35
Bedrooms	30-40
Music studios	30

Table 17 – Recommended Noise Levels

8.2 Spot Checks

BRE arranged to record spot readings in order to gain an overall understanding of the internal environment of the Campus. All parameters were measured during a site visit in January 2013, when external conditions were cold, with grey skies. Readings were taken in a number of areas within the campus to investigate whether there are any concerning figures. A summary of those results are listed in **Error! Reference source not found.** in Appendix 12.15.

Temperatures

Temperatures ranged from 19.5 to 25°C. Of the room temperatures that were monitored, 67% of the recorded levels were above the upper limit of the recommended comfortable temperature range of 21°C. The percentage of rooms that fell within the recommended comfortable temperature range of 18 to 21°C was 33%. No rooms were below the recommended comfortable working temperature of 18°C.

The results do not indicate that a room's orientation or occupancy levels have a direct bearing on temperature levels. It is plausible that occupants in certain rooms could report that they feel less comfortable than they would like due to internal temperatures being higher than the recommended comfort level of 21°C.

During the site visit, occupants perceived some rooms to be more comfortable than others as the air was perceived to have more movement. In rooms where the conditions were reported to feel more comfortable than others, some temperatures where still higher than the recommended comfort levels. The CCI area on level 3 recorded a temperature reading of 23°C, however the room was perceived by occupants to be more comfortable as the air had more air movement.

The perceived varying degrees of air movement and the recorded higher temperatures suggest that the HVAC systems and their controls could be adjusted to operate more efficiently and to achieve the desired occupant levels. The operational performance of the HVAC system is determined by a number of factors including the zoning and servicing strategy, temperature set points within the rooms, ventilation rates and the effectiveness of the system controls.

Relative Humidity

The levels of relative humidity were recorded as being between 24.9 and 34.7% this falls below the recommended comfort levels of between 40% and 60%. This would explain why some occupants described the internal environment as 'dry'. Long-term exposure to a 'dry' internal environment could have a negative impact on occupant health and wellbeing where common complaints would likely include dryness, nose and throat irritation, and headaches due to the low levels of humidity. If the building occupants report that this internal comfort issue is of a concern, then further investigation may be required to determine whether incorporating a humidifier within the ventilation systems may have to be considered.

Air quality

The level of CO_2 monitored within the variety of internal spaces in the Campus ranged from between 458 and 1888 ppm. The percentage of rooms that were within the ideal CO_2 levels below 600 ppm was 67%, while 26% of the rooms were within the good practice CO_2 levels below 1000 ppm. The readings show the majority of rooms are below the 1000 ppm good practice level, which indicates that the ventilation systems appear to be regulating the CO_2 to satisfactory levels.

There is a concern with two occupied rooms that recorded CO_2 levels that were well in excess of 1000 ppm. The CCI office (Level 2) recorded CO_2 levels of 1167 ppm while the SRUC – Educational Support office (Level 3) recorded levels of 1888 ppm. In both instances natural ventilation, in the form of occupant openable windows, is in place. The high CO_2 levels suggest that the occupants are not opening the windows frequently enough to ventilate the space which prevents the CO_2 being purged. In both these rooms the temperature results show elevated readings above the recommended comfortable range of 21°C. In the CCI office, temperature readings of 25°C were recorded, the highest recorded temperature in the building, while 23°C was recorded for the SRUC Educational Support office. These elevated readings also suggest that the occupants may not be opening the windows or vents, or if they are the length of time the windows or vents remains open is not sufficient. This could be as a result of the cold external conditions that occupants report to experience when windows and vents are opened during the colder months.

Within the Student Union area it was noted that the comfort heating / cooling unit is sometimes left on by cleaning staff to help dry the wet, washed floor which is consuming additional energy.

Lighting

Teaching spaces and offices within the University of the West of Scotland Ayr Campus are equipped with occupancy and daylight sensors, to carry out two key functions:

- Ensure lighting is automatically switched off when the space is unoccupied; and
- Ensure artificial light is only used when natural light is not sufficient.

In every occupied space that the scientific readings were recorded, the occupants had the artificial lights on; this was the case for both morning and afternoon readings. However, in some of the rooms the occupancy sensors timed out even though these spaces remained occupied. This suggests that the sensor range and timings require some adjustment to operate effectively within the occupied spaces.

From the results 41% of the rooms measured had perimeter lighting levels ranging from between 365 to 1121 lux, while the centre of the room lighting was recorded between 364 to 1010 lux. Typical lighting levels for general teaching and office spaces are expected to be between 300 and 350 lux, however artificial lighting appears to be over specified in some classroom and teaching spaces.

The results confirm that 22% of the monitored rooms recorded natural lighting levels ranging from between 97 and 280 lux, this is below the 300 lux level recommend. When artificial lighting was used to supplement lighting levels within these rooms, the lighting levels were recorded between 415 to 912 lux which indicates surplus artificial lighting is being delivered to some of the spaces. Further investigation is required to determine the programming requirements of the day lighting sensors and the set lighting levels of the artificial light fittings to ensure that these are not over specified in some areas.

From the results, 11% of the rooms monitored recorded natural lighting levels ranging from between 103 and 247 lux and when artificial lighting was used to supplement these levels, lighting levels were below the recommended 300 lux level. Lighting levels in the CCI office (Level 2) were recorded at 247 lux with artificial lighting and 126 lux for natural lighting alone. It was noted that the original installed ceiling lights have since been replaced by two uplighters which may explain the low artificial lighting levels in these areas. The occupants within the CCI office explained that the up lighters are in operation due to the migraines that they believe were induced by the original ceiling lighting and that the new lighting is reportedly delivering more comfortable lighting levels for users. Lighting levels in the CCI Equipment store on Level 2 were recorded at 103 lux and 210 lux for natural and artificial respectively. This is a concern not only because it is under the 300 lux level but because of the activity within the room; the occupants have to store and retrieve equipment from racking for which they need the appropriate lighting levels. It is suggested that occupant satisfaction levels could improve if the artificial light fittings are adjusted to accommodate the end user requirements in these areas. Internal rooms with no natural light provision recorded artificial lighting levels of 431 lux and 449 lux, both of which are above the recommended 300 lux level. The canteen area for both the seating and service areas had recorded lighting levels of 668 and 740 lux respectively. This area is largely non-reliant on any artificial lighting during the majority of operating hours and is pleasantly lit through the abundance of natural light that is enjoyed by users within this space.

Error! Reference source not found. in Appendix 12.15 provides a summary of all readings that are referenced in this section. In summary, the majority of rooms represent conditions that could be considered either too bright or too dark for end users (i.e. the lighting levels fall out with the 300-350 Lux range recommend for office or general teaching spaces).

Noise levels

Of the private offices tested, 50% of readings were within the recommend range of between 40-45 dBA. Only one room was above the recommended limit, which was recorded and just over the upper recommended comfort level at 48dBA. The remaining rooms were private offices and were below the recommended comfort range, with the lowest reading being recorded as 30.2 dBA. The offices had varying occupancy rates, from 0 to 100% capacity and there were no interruptions or conversations over the phone while the readings were taking place.

User feedback in relation to noise levels within the library is mixed. Some occupants enjoy the mix of social and study space whereas others complained about noise levels in the library coming from the canteen area. The recorded noise levels over the three floors the library occupies were recorded between 35dBA and 50 dBA. The upper noise levels was recorded on the entrance level to the library where the main entrance route and doors to the library are located and are left fully open throughout the day and exposed to the noise from the canteen area on the level directly below. The other levels within the library were quieter areas.

The meeting room 3.013 on level 3 recorded noise levels of 52 dBA. It should be noted that background noise from a ventilation system located in the corridor outside of the room could be heard from inside the room, causing this noise level to be higher than expected and should be further investigated.

Overall, 85% of the noise levels that were recorded were below the threshold of 65 dBA. Long-term exposure to noise levels above this threshold can have a have a negative impact on the wellbeing of the occupants. The building areas that recorded noise levels over the recommended threshold are areas with a high volume of transient occupants and the activity within the areas can be described as being social; the canteen seating and service areas (66 and 68 dBA respectively) and the Student Union (75 dBA). Of the rooms tested 100% were below the threshold for hearing damage or pain (125 dBA).

Spot check measurements can be summarised as follows;

- 67% of tested spaces were found to be warmer than recommended, although many users did not complain about higher than expected temperatures in the majority of occupied areas;
- Relative humidity was generally found to be too lower than what would normally be considered comfortable for users;
- The majority of carbon dioxide readings, indicates ideal air quality for most areas in the building;
- Lighting levels, measured in Lux, were either considered to low or too high. This suggests a major revision of lighting settings thought the building would be beneficial for occupants and for system efficiency; and
- 85% of tested rooms were below the noise threshold limit of 65 dBA and all spaces were below the threshold for hearing damage or pain. Most user complaints were in relation to the library area as a result of doors being left opened above the canteen space.

8.3 Continuous Monitoring

Key internal areas were identified by end users, including Estates staff and as a result of the internal scientific monitoring activity, as areas that would benefit from more intense internal environment monitoring and further investigation. As a result data tag monitors were installed in a selection of areas for further data collection and intense monitoring. These areas were further investigated through scientific internal environmental monitoring and the results are provided in the next section of this report. The areas selected for further analysis are summarised in **Error! Reference source not found.**.

Location	Area Description
4th Floor Classroom (4.042)	Large classroom
3rd Floor Staff office (3.035)	5 person office
Library (3rd Floor Level)	Open plan library
Gymnasium (Basement Level	Sports Hall

Table 18 – Areas selected for continuous monitoring

Monitoring activity started with spot readings during a site survey and continued throughout the project. Findings of the site survey along with external weather conditions on that day are summarised in Appendix 12.16. Continuous monitoring of temperature, relative humidity and air quality were carried out to determine impact of occupancy patterns and seasonal changes throughout the year and are described in subsequent sections.

The results of this exercise concluded (detailed within Appendix 12.16 that temperatures within all four selected areas were above the recommend 21°C comfort threshold. General users feedback was that the library, office and classroom area were comfortable in terms of temperature.

Relative humidity within these areas were recorded between varied during the seasons and often fell below recommend comfort levels of between 40% and 60% during the colder months. The gym areas recorded consistently higher levels of humidity than other spaces and during the warmer months higher levels were recorded above the recommended comfort levels. The level of CO_2 within the internal the library and office spaces was intensely monitored during seasonal changes and periods of high and low occupancy and confirmed that the air quality levels were continuously within desirable comfort levels for end users, typically under 600ppm.

Quarterly graphs and summary tables which illustrate temperature and relative humidity recordings within the intensely monitored spaces can be viewed in Appendix **Error! Reference source not found.**. Similarly air quality readings are detailed in Appendix 12.18.

Please note that findings from the intensively monitored spaces described below refer to the following periods:

- Quarter 6 – Autumn 2013 (July – October)
- Quarter 7 – Winter 2013/2014 (October – January)
- Quarter 8 - Spring 2014 (January – March)

Classroom

Temperature and Relative Humidity readings during Quarter 6

During quarter 6 classroom temperatures were intensely monitored during the period 29th of July through to the 8th of August (due to measuring equipment being unexpectedly removed from the monitoring areas BRE was unable to collect further monitoring data). **Error! Reference source not found.** in Appendix 12.17 demonstrated that all temperature readings were recorded to be above the recommended maximum comfort level of 21°C for this space. The highest temperature reading of 31.5°C was logged on the 31st of July during the morning period. It should be noted that external temperatures were higher than usual at this time of year.

In terms of relative humidity most of readings were within an acceptable range of 40% and 60%. Only 9% of recordings were noted to be out of this range. Additionally, the lowest and highest values (37% and 64%) were neither significantly lower nor higher than recommended range.

Temperature and Relative Humidity readings during Quarter 7

With the installed classroom logger installed to record temperature levels being unexpectedly removed, data recordings during Quarter 7 are only partially complete. Hence, **Error! Reference source not found.** displays temperatures for periods only when the logger was in use and then for a period after it was reinstated. Note that the University was closed between 20th December and 5th January. Also, during the first week of January the University operates an exam period for the students. Therefore, the occupancy patterns do change from usual behaviour and as a result the temperature graph illustrates the classroom's internal temperatures at times when the classroom is not in use (the first bar on the graph indicates that the logger was moved from a much warmer space before reinstating this within the monitored classroom). It is evident that the majority of readings are between the recommended limits of 18°C and 21°C.

Error! Reference source not found. illustrates that relative humidity was lower than the recommended minimum for 85% of the time. The lowest reading of 28.5 % was recorded on December 24th when the building was closed. The readings are suggesting that the classroom environment could be described as dry, particularly during the colder months.

Temperature and Relative Humidity readings during Quarter 8

Recordings form quarter 8 represent temperature readings for a period when the classroom was in normal use. **Error! Reference source not found.** confirms that almost all temperatures were higher than the recommended minimum. The highest recorded reading was 24.5°C and most readings were between 22°C and 23°C. Unfortunately, the logger had been removed for a second time. Hence, no temperatures were recorded after the 26th March.

Error! Reference source not found. illustrates that almost all relative humidity readings during Quarter 8 were lower than the recommended minimum comfort levels with the reading being recorded as 25%. This confirms that the air in the classroom during occupied periods could also be describes as dry, which could cause occupants to feel uncomfortable over prolonged periods of time.

Office

Temperature and Relative Humidity readings during Quarter 6

In the monitored administration office recorded temperature readings were similar to those that were recorded for the classroom during its period of use. All readings captured during Quarter 6 were higher than the recommended maximum comfort level of 21°C (please refer to **Error! Reference source not found.**). The readings were relatively constant falling between the 22°C and 24°C range. The highest temperature of 25°C was documented on the 25th of September. Temperatures of over 24°C were recorded on the 27th of September and between the 2nd and 4th of October.

Relative humidity in the office during Quarter 6 falls between the suggested minimum and maximum comfort limits of 40% and 60% for the majority of time (**Error! Reference source not found.**). There were no readings out with the recommended comfort levels during August and only a few readings below 40% were recorded in September. The driest air periods, with humidity levels of 37% or below, were logged between the 9th and the 12th of October.

Temperature and Relative Humidity readings during Quarter 7

Error! Reference source not found. clearly shows that in the monitored office almost all temperature readings were recorded to be higher than the recommended maximum comfort levels. However, informal interviews with the office staff confirmed that they are satisfied with these higher levels. The majority of staff who utilise this area stated that they prefer a warmer internal environment. Lowering internal temperature levels to the recommended comfort range of between 18°C to 21°C could have a negative influence on satisfaction levels in this area. Staff in this space enjoy having a local level of control over their heating (via a Thermostatic Radiator Control Valve).

During Q7, relative humidity readings in the office fell below the recommended minimum comfort levels for approximately 80% of the monitoring period(**Error! Reference source not found.**). The lowest reading of 21% was recorded on several occasions during this period. The monitoring data suggests that the lower levels of humidity are influenced by high temperatures that are maintained within this space and the lack of fresh air and air exchange in the space (due to windows and vents being closed). It is recommended that the Estates staff experiment with the internal environment levels in this area, aiming to create a desirable balance between temperature and humidity. This trial could positively influence comfort and productivity of office staff (although, it should be noted that most staff who occupy this area stated that they are satisfied with their internal environment).

Temperature and Relative Humidity readings during Quarter 8

During Quarter 8 the data logger experienced some technical challenges and did not record for the full period. However, from the available readings for both temperature and relative humidity it is clear that almost all readings fall out with the acceptable comfort ranges. **Error! Reference source not found.** highlights maximum temperature levels of 24 °C being recorded. The lowest relative humidity reading of 25% is highlighted within **Error! Reference source not found.**. Although these readings are only partially completed for the Quarter 8 reporting period, they do reflect the readings that were recorded during Quarter 7.

Air Quality readings during Quarter 8

In addition to the above measurements recorded during Quarter 8, air quality was also monitored. All data, graphs and findings regarding air quality monitoring can be view in Appendix 12.18. **Error! Reference source not found.** represents carbon dioxide levels within the office. It shows that 98% of readings are below an ideal level of 600 ppm confirming acceptable levels of air quality in this space.

Library

Temperature and Relative Humidity readings during Quarter 6

Temperatures within the library were relatively balanced (see **Error! Reference source not found.**). Most readings were recorded between 22.5°C and 24°C. These readings were higher than recommended maximum comfort levels of 21°C. On the 25th of September (as in the office) in the afternoon, the highest reading of 25.5°C was recorded. Other readings above 24°C were recorded on the 29th and 30th of July, the 7th and 8th of August and between the 23rd and 26th of August. During the first half of October high temperatures were logged between the 1st and the 4th and on the 7th.

Error! Reference source not found., illustrating relative humidity within the library, follows a similar pattern as the relative humidity graph for the office. Only 14 % of readings were recorded to be out with the recommended comfort levels. Similarly, none of the recorded readings for August or September were significantly lower of higher than 40 –

60% range. The lowest relative humidity during these months was 37% which was recorded in September. However, in October readings dropped quite dramatically to as low as 29%.

Overall, the driest air during this quarter was logged between the 9th and 12th of October, on exactly the same days as for the monitored office.

Temperature and Relative Humidity readings during Quarter 7

Error! Reference source not found. illustrates that all temperature readings (except during the Christmas break) were recorded above the recommended maximum comfort level of 21°C. The highest reading of 26 °C was recorded on 5th November at around 3.30pm. However, generally temperatures were recorded between 22°C and 24°C. On days when the library was empty, a constant temperature of around 20°C was recorded. It is expected that this would have been a comfortable temperature level for students; however it was unnecessary to maintain this temperature while the space was unoccupied.

In addition to revising heating and ventilation settings during such periods, it is recommended that the University estates staff also review settings for the entire year and match supply with demand during occupied periods. It is particularly important for the library to provide a comfortable learning environment for its users. As temperatures were recorded to be relatively high in comparison to the recommended comfort range, the space could be considered to be, at times, too warm to enable students to work at optimum levels of productivity.

Temperature and Relative Humidity readings during Quarter 8

Quarter 8 data capture uncovered similar findings. Generally, temperatures were higher that the recommended maximum comfort level of 21°C and relative humidity readings fell below the recommended minimum comfort level of 40%. **Error! Reference source not found.** shows the highest temperature reading of 24.5 °C being reached on the 13th and 22nd of January and the 19th of March, recorded between 11 am and 3 pm.

Overall, 97% of relative humidity readings were below 40% and, as it can be seen in **Error! Reference source not found.**, the lowest recording of 21.5 % was noted on the 24th of March, between 3 and 5 pm.

Air Quality readings during Quarters 6 and 7

In addition to continuous monitoring of the above, air quality was also being monitored in the library area during Quarters 6 and 7. Findings from both periods illustrate ideal levels of air quality within the library area. During Quarter 6, 98% of readings were below the desired level of 600ppm, with the highest value only reaching 754ppm. Similarly, 97% of readings during Quarter 7 were below 600 ppm (752 ppm was a maximum reading) indicating good levels of air quality.

Gymnasium

Temperature and Relative Humidity readings during Quarter 6

In the gymnasium, during occupied periods that are dedicated to high levels of occupant activity, comfortable temperatures could be as low as 8°C. This figure represents a recommended temperature for people wearing normal levels of clothing while exercising (please refer to **Error! Reference source not found.** on page 101). Teaching staff, who are not engaging in high levels of practical activity, may be more comfortable in a slightly warmer environment, where internal temperature could be as high as 23°C. This suggests a relatively wide range of allowable temperature levels, but generally, recordings within the space would be expected to be lower than in other areas of the building, such as classrooms, the library and offices.

During Quarter 6 temperatures within the gymnasium, illustrated in **Error! Reference source not found.**, differ significantly from temperatures recorded within the other intensely monitored spaces. Only 25% of temperature readings were above the recommended maximum of 21°C (100% within the office and library). However, during the last

week of July 100% of all of the recorded readings were higher than recommended comfort range with a maximum temperature of 27°C on the morning of the 25th of July being recorded. The highest temperature recorded during Quarter 6 was 28°C which was recorded on the 7th of August. During September and first two weeks of October, only 5% of readings were over 21°C and on only three occasions did the temperature increase above 22.5°C. The University and College students are on their summer break during the month of

July and are therefore not normally exposed to the higher temperature readings within the gym. However, the gym area is utilised by the foreign exchange students during the summer months. During a summer visit to the Ayr Campus, BRE noted that the underfloor heating had been programmed to service the gym area during the morning period. This suggests that the heating programmes and temperature control settings require to be adjusted to accommodate the seasonal changes throughout the year as well as the varying occupancy patterns.

Maintaining optimum relative humidity levels is particularly important in areas where sporting activity takes place. Humans lose heat through the evaporation of sweat. If relative humidity level was too high, for example in excess of 80 %, the increased levels of vapour in the air would prevent the evaporation of sweat from the skin.

In the gym, relative humidity readings differed considerably to the readings previously described for the other intensely monitored areas. These findings are illustrated in **Error! Reference source not found.** for Quarter 6. Most relative humidity readings which fell out with the recommended range were above the recommended maximum comfort level of 60%. The highest recorded relative humidity levels of 70% and above were recorded on the 23rd and 25th of July, the 15th of August and on the 12th of September. The University would be advised to exercise caution to ensure that the gym area is adequately serviced to avoid relative humidity readings from approaching 80% or above.

Temperature and Relative Humidity readings during Quarter 7Error! Reference source not found. confirms that for most of the Quarter 7 period, temperatures readings were recorded between 17°C and 20°C. The highest temperature of 27.5 °C was recorded early in the morning on 20th December at about 6.30am which appears unusual. This could have been caused by the logger being removed from the gym unexpectedly. On a few occasions throughout the course of this project the gym data logger used for monitoring the internal environment was found to have been removed or placed on the heated floor and therefore some data was missing or had to be removed from the analysis (hence the missing data shown in **Error! Reference source not found.**).

During Quarter 7, unlike in the other intensely monitored spaces, relative humidity readings in the gymnasium largely fall into the recommended comfort range of between 40 to 60%. A small number of readings were higher than 60%,with the highest reading of 63% being recorded. Additionally, only 15% of the recorded readings fell below the minimum recommended 40% level. The lowest reading was recorded as 33.5%.

Both temperature and relative humidity analysis demonstrates that for most of the recorded period, the gymnasium offers a comfortable internal environment for users.

Temperature and Relative Humidity readings during Quarter 8

During Quarter 8, most of the temperature readings that were recorded were between 17°C and 20°C (similar to Quarter 7 findings). **Error! Reference source not found.** illustrates a slight temperature increase towards the end of April. This could suggest an influence as a result of external weather conditions as the spring sun could have an impact on the gymnasium's temperatures by contributing to excess heat from solar gain through the large glazed rooflights.

As before, most of the relative humidity readings fall within the recommended comfort range, with 23% of readings being lower than the recommended lower comfort level of 40%, with the lowest recorded reading of 33%.

Summary of findings

Error! Not a valid bookmark self-reference. represents a simplified summary of the intensely monitored internal environment within each of the areas considered, as described in the previous sections of this report. Please refer to Appendix 12.17 for more detailed results.

	Q6 (July – October 2013)			Q7 (October 2013 – January 2014)			Q8 (January – March 2014)		
	Temp* (°C)	RH** (%)	AQ*** (CO_2, ppm)	Temp* (°C)	RH** (%)	AQ*** (CO_2, ppm)	Temp* (°C)	RH** (%)	AQ*** (CO_2, ppm)
Classroom	above max. (100%)	within range	-	within range	below min. (85%)	-	above max. (100%)	below min. (100%)	-
Office	above max. (100%)	within range	-	above max. (100%)	below min. (70%)	-	above max. (90%)	below min. (100%)	below ideal max. (98%)
Library	above max. (100%)	within range	below ideal max. (98%)	above max. (80%)	below min. (60%)	below ideal max. (97%)	above maxi. (100%)	below min. (95%)	-
Gymnasium	above max. (30%)	out of range (30%)	-	within range	out of range (20%)	-	within range	below min. (25%)	-

Table 19 - Intensely monitored spaced – a summary of internal environment findings

* Acceptable range for temperatures: 18 – 21 °C
** Acceptable range for relative humidity; 40 – 60 %
(Note that temperature and relative humidity ranges in the gymnasium can differ in comparison to work/study areas due to different activities in the space)
*** An ideal maximum level of CO_2 within a space is 600ppm (a total maximum is 1000ppm). The table refers to ideal CO_2 levels.

Although the logger used in the intensely monitored classroom (4.042) was unexpectedly removed twice during the recording period, some conclusions can still be drawn from the collected data. It is apparent from the readings from the internal data capture for the classroom, office and the library that some internal environment findings are similar. Temperatures were generally too high and relative humidity too low. During these circumstances, air is often dry and internal temperatures might feel slightly lower than they actually are. However, due to rapid evaporation of water form air and human skin perspiration, air can become too dry. This would confirm why there were more occupant complains about inside air rather than high temperature levels.

It should be also noted that dry air does not only affect human comfort but can lead to unwanted maintenance requirements. For instance, wooden furniture can shrink, causing the covering paint to fracture.

An exception to the above is visible in the Quarter 7 findings. During the winter period, when readings were available for the classroom', internal thermal comfort conditions were maintained at recommended levels. However, this monitoring period refers to the Christmas break when the classroom was not in use. It is then recommended that building services settings should be reviewed and adjusted to suit the room conditions when the areas are occupied.

Additionally, relative humidity during Quarter 6 (as opposed to Quarters 7 and 8) was generally maintained at comfortable levels, between 40% and 60% in all three areas.

In terms of the gymnasium's conditions, it was previously described that temperatures can be and are expected to be lower in comparison with, for example, an office or a study space. **Error! Reference source not found.** in Appendix 12.17, along with relevant graphs, confirms that although the temperatures in the gym area are perhaps slightly higher than are required, rarely falling below 17°C and that there are periods during the summer months when the temperatures levels were generally too high (up to 28°C) during the months of July August, the internal environment in the gymnasium can generally can be classed as comfortable for most of the year.

Additionally, interviews with members of staff confirmed that the users were pleased with the gymnasium and its environment.

In order to help maximise the efficiency and help create optimum internal environments for end users, BRE would recommend that the Ayr Campus Estates team review the settings of the air handling units to ensure that their operation is satisfactory and that the programming complements the occupancy rates and activities within each of the areas that are being served. If dry air conditions are still apparent throughout the Campus, the University may wish to consider the potential benefits of installing humidifiers to help optimise relative humidity levels.

Humidifiers can be categorised as adiabatic or isothermal, taking their thermodynamic characteristic into account. Adiabatic humidifiers would be beneficial as they can help to reduce temperature of air while increasing moisture content. This 'evaporative cooling' process is best suited in hot and dry environments. There are, however, many factors to consider when selecting an appropriate humidification system. These include output requirements, availability of services, constants (noise levels, installation), energy and environmental costs and maintenance. Health and safety considerations should be a priority to ensure any chosen system is appropriately designed to mitigate any risk of Legionnaires' disease.

The internal air quality monitoring of the library and office areas confirmed that the CO_2 levels measured in both areas demonstrated ideal air quality levels. Good air quality levels help to promote overall occupant health and wellbeing levels.

8.4 Conclusions and key findings for this section

This section's findings can be summarised as follows;

- Internal environment in the gymnasium during the monitored period was satisfactory for most of the monitoring period. The recorded temperatures during the summer months were considered uncomfortably high. It is recommended that the programme controls and the set point temperature for the underfloor heating system should be reviewed and adjusted to account for seasonal and occupancy changes.

- Monitoring in the classroom, office and library demonstrated similar internal environment conditions; temperatures that would generally be considered slightly above the recommended comfort levels and relative humidity levels that are in general below what would be considered recommended comfort levels. However, it is recognised that many occupants reported that they are satisfied with these internal conditions, particularly when compared to what they experienced in the old Campus. In order to adjust the internal environment slightly, to achieve a healthier internal temperature and humidity range, BRE would recommend that the Estates team adjust the programming to slightly reduce temperatures and that they continue to monitor humidity levels to identify if it is possible to increase these slightly. This could also help to improve the operational efficiency of the heating system. Subsequently, interviews with staff and students should be carried out to determine if any of these small changes have positively contributed to their comfort levels.

- Installation of humidifiers could be considered, only if overall changes to heating, cooling and ventilation do not improve the relative humidity levels within the building and these are considered to have a negative impact on user wellbeing.

- The monitored air quality levels within the library and office area would be described as ideal and help to promote a healthy and productive environment for end users.

Sample readings results for the monitoring period are illustrated below;

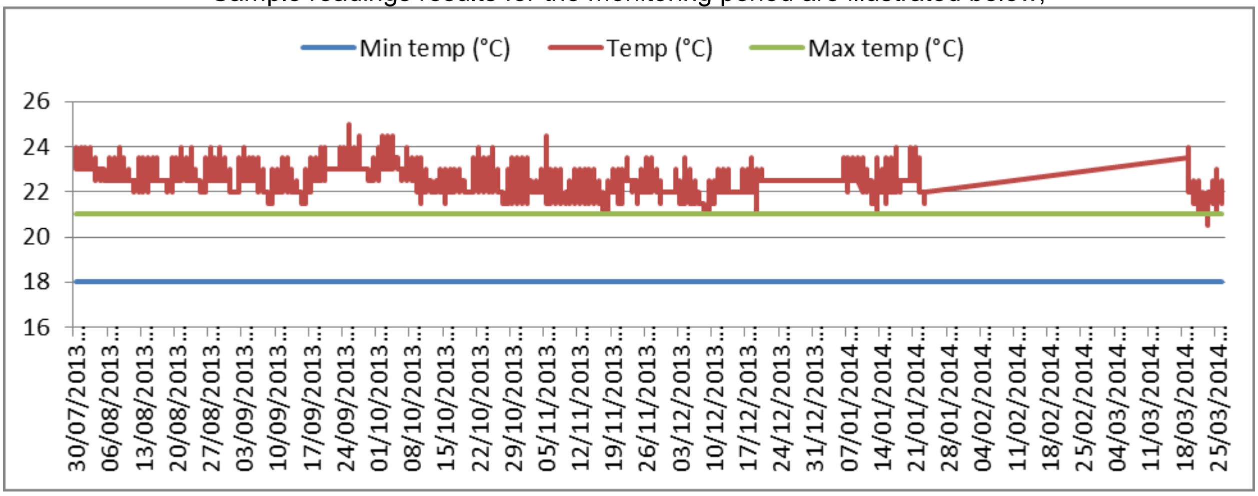

Figure 99 - Temperature readings in the office

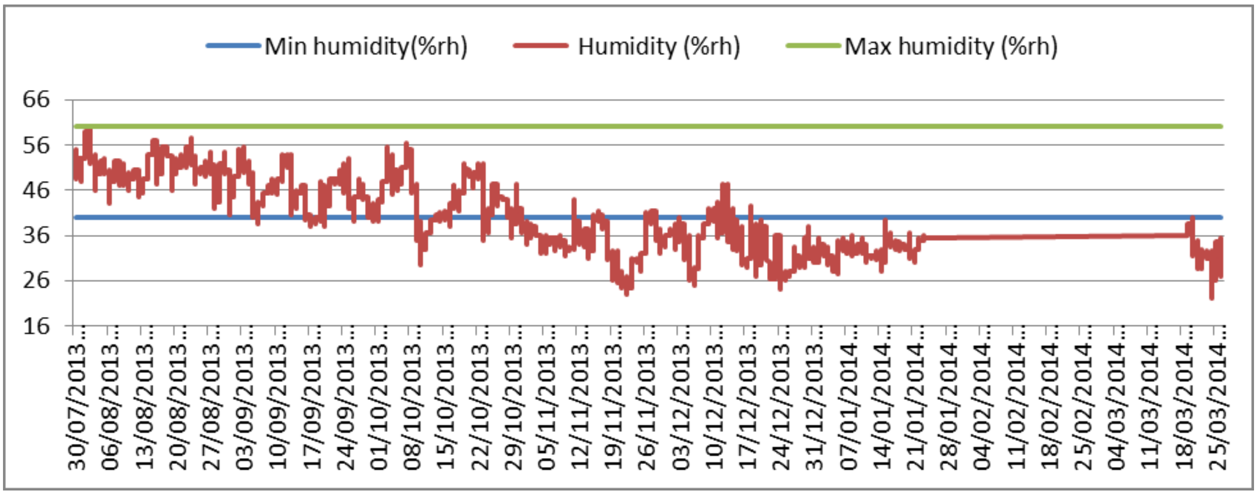

Figure 100 - Relative humidity readings in the office

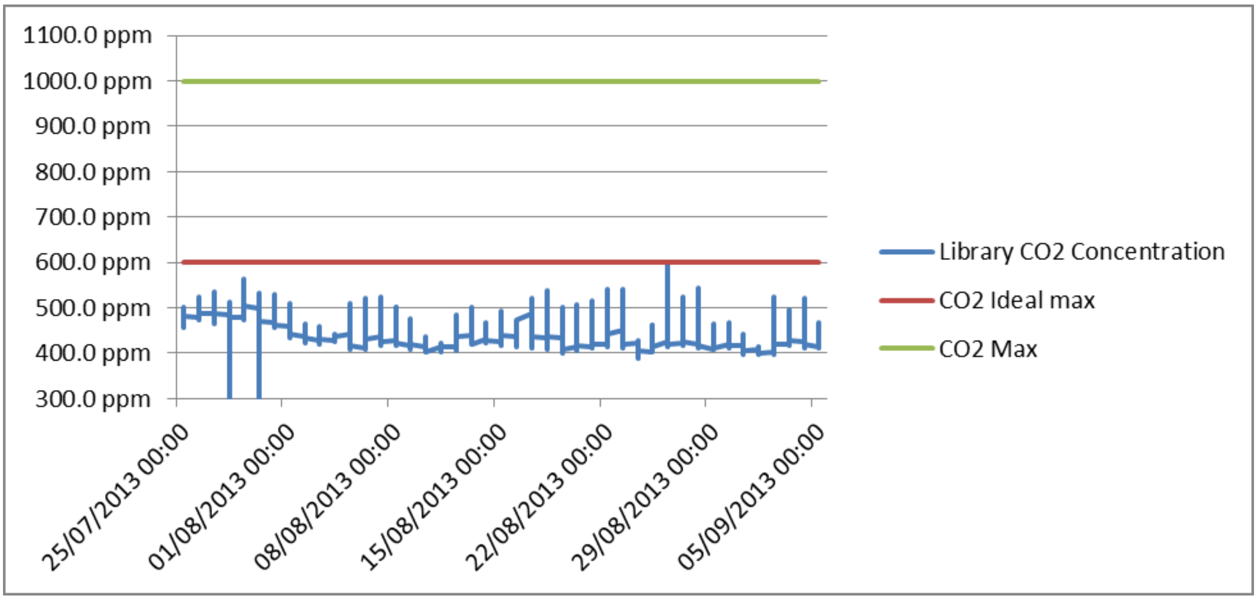

Figure 101 - Air quality redings in the library

9 Technical Issues

This section of the report provides a summary of the technical findings and recommendations in relation to the issues that have been uncovered during this BPE project.

Lighting

One of the most noticeable technical issue that building occupants are challenged with within the Ayr Campus is in relation to the artificial lighting system. The Ayr Campus building benefits from a state of the art DALI artificial lighting control system which provides a single interface for all light sources and lighting controls. The system should help to ensure that the artificial lighting within the Campus is programmed and controlled in the most efficient way possible as well as offering users the capability to easily adjust artificial lighting to the desired level.

However, there have been operational and performance issues with the artificial lighting, which was reported by occupants during the user consultation sessions and document by BRE during the internal environment monitoring exercises. A number of occupants reported their dissatisfaction with the artificial lighting system. Common complaints included; the complexity of lighting controls for the end user, particularly in the lecture theatre area, which prevented users from using the lighting efficiently and effectively; proximity detection of the occupancy detection sensors not detecting movement when activities are desk based and that as a result the artificial lights are switched off when rooms are still occupied; artificial lighting levels in some areas not meeting the required occupant lighting levels for a particular task or function, resulting in some users utilising desk lamps or complaining of uncomfortable internal environments.

It is recognised by the Estates staff that the lighting control system does have the capability of programming and setting each light fitting and sensor control in such a way that it could be adjusted to meet the end user requirements and that it could also help to adjust the lighting settings which would also help the Ayr Campus building recognise operational savings. It is recommended that the University undertakes a mapping exercise to consider the timetabling and activity that is planned for each space to help identify end user requirements which will then allow them to make appropriate adjustments to the lighting controls and settings for each individual light fitting which should help to create better internal environments for the end user as well as helping to accrue operational efficiencies and reducing the overall Campus carbon footprint.

Heating, cooling and ventilation

The University has an aspiration for the Ayr Campus development to demonstrate a ‘best practice’ approach in relation to promoting energy efficiency and successfully operating a low carbon Campus. Biofuel boilers were originally specified by the project services engineers to satisfy the heating and hot water demand for the Ayr Campus development, whilst also helping to mitigate the overall carbon impact of the building when in-use. Unfortunately the biofuel boilers did not operate as efficiently or effectively as UWS initially believed that they would. After a number of maintenance and performance issues the University made the decision to explore alternative options such as alternative feeds and boiler conversions; however no suitable alternative has been identified and the Campus hot water and heating demand is now being met from the gas back-up boilers. These boilers have proved to be a more reliable option to satisfy the Campus heating and hot water demand, however the carbon savings that the University had hoped to achieve have not been realised. There is disappointment from the University in relation to the design decisions and advice that was given which promoted a system that the University now believe was not suitable for the Campus due to the operational problems, lack of fuel suppliers and high maintenance costs that were incurred during the period of operation during the first twelve months after handover.

During the occupant consultation exercises, a number of building occupants raised concerns in relation to the Campus' internal environment. Many raised their concern over the operation, performance and control over the building services, particularly in relation to internal temperatures and relative humidity levels. Many users expressed their frustration over what they believe is limited available control in order to adjust the services that are serving their internal environment and reported that this did impact on their comfort levels. BRE's internal environment monitoring and a review of the BMS programming for building services confirmed that the building services could be more efficiently controlled for the Campus and that the reported issues in relation to user comfort are most likely as a result of how the systems and services are programmed rather than their technical performance or capabilities.

Energy monitoring

The University benefits from having an Automated Meter Reading (AMR) system that monitors the electrical consumption for all of their estate. The AMR system collects half hourly electricity readings for all of the extensive sub-meters that have been installed at the Ayr Campus and provides a variety of formats in which the data can be presented and analysed by the end user, therefore saving time and resource in what could otherwise be resource intensive task. The AMR system has proved to be a beneficial and informative resource for the University and for this project, providing easily accessible information that is presented in a user friendly way that can be incorporated into monthly energy management reports and fed back to a variety of users. The system also helps to promote higher levels of operational efficiency across the Campus by allowing the user to analyse and interrogate actual monitored and consumption data for different areas, services and systems.

At present the AMR system is only accessed and managed from the University's Paisley Campus, meaning that the University Estates team at the Ayr Campus are relying on the Estates team from the Paisley Campus to interact with the system and interrogate the readings. BRE would recommend that the University extend the AMR systems capabilities to the Ayr Campus so that the Ayr Campus Estates team can obtain a better level of awareness over the energy management and consumption for the Ayr Campus. Additionally, it was noted during the project that some readings from installed sub-meters were recording low levels of electricity use, for example for some of sub-metering for the lifts were displaying values that suggested zero energy use. BRE would recommend that these are further investigated and that, where required, meters are re-calibrated to provide accurate readings.

TM22 CIBSE tool

As part of this building performance evaluation project, was a mandatory requirement for the project to make use of and populate the CIBSE TM22 tool. BRE found this to be a very time consuming task and at times a complex activity to manage. For example, the requirement for an accurate in-depth building survey, accounting for all electrical power items in the building, to be undertaken prior to use of the tool was very time intensive for a building of this size and complexity. Every effort was exerted to ensure data capture was as accurate and as informed as it possibly could be, considering the timescales and resource allocation for this project. Understandably, there were a number of challenges in relation to the assumptions that the tool made in terms of end user and system use and the actual use of the building, equipment and services and also the acknowledgement that the electrical items and their use within this building would change day to day, largely as a result of the occupant interaction. Despite significant resource allocation and effort being focussed on completing this task, the outputs and results of this excise were not as BRE had initially believed that they may be. There were large variances between actual and predicted energy consumption for each sub-meter due to the numerous assumptions that had to be made. Having a quality energy monitoring system in place, along with software that enables the end user to view and manipulate data at ease such as the METERology software that is currently being used by the University, enables the University Estates team to produce metered consumption data in a variety of useable graph and output formats for all of the sub-meters that have been installed at the Ayr Campus. BRE made good use the University's energy monitoring system and software and it proved an invaluable and informative resource on this project. Considering the significant resource requirement and levels of accuracy, based on a number of assumptions that are required to be made, of the TM22 tool, BRE would advise the University to continue to make use of their existing monitoring and software system as opposed to continuing with the use of the TM22 tool. BRE would also recommend on future BPE projects, where budget and resource is usually limited, that the requirement for projects to make use of the TM22 tool and the complex process that is involved in order to enable the use of the tool, could be replaced with the requirement to make use of an automated meter reading system as this would saving a significant amount of time and resource on the project and could support a more detailed analysis into areas that are identified as either a concern or where additional efficiencies may be achieved. As a result of this project, BRE would conclude that an AMR system is a more appropriate solution for end users, particularly for a building of this type.

IT equipment

Both staff and students commented on the improvement in IT facilities within the new Ayr Campus building, when compared with the facilities that were available to users within the old Campus. The provision of IT within the dedicated library areas and the access to this has been greatly enhanced and was reported positively by the majority of those who participated in the consultation sessions. However, some staff and students did comment that their IT access speeds at the Ayr Campus and the provision of Wi-Fi around the Campus is something that users felt could be improved. From the consultation sessions and user interviews, BRE recognised that a blended learning approach is something that is embraced on the Ayr Campus and that both staff and students would very much welcome the opportunity to make better use of technology, such as smartphones and tablets, around different areas of the Campus to help support a variety of learning. Some users also commented on compatibility issues with certain software and the computers that are available at Ayr Campus. In order to remain current, to provide students and staff with access to the latest and most appropriate software and to continue to support a variety of learning, BRE would recommend that the University continues to invest in and upgrade their IT facilities throughout the Campus. BRE would also recommend that the University continues to update its green procurement guidance to ensure that detailed guidance is developed and implemented that requires all newly purchased equipment to demonstrate that it benefits from having energy efficient credentials (e.g. energy star listed products).

The technical findings that are highlighted in this section of the report demonstrate that there are a number of areas that the University can address in order to maximise the efficient use of the building services, controls and programmes, which will all help to accrue operational energy savings, particularly electrical energy savings.

10 Key messages for the client, owner and occupier

A key output from this project is to be able to provide the client with useful information on the actual performance of their building. As a result of the research and analysis that has been undertaken on the Ayr Campus, BRE would conclude that the key messages for the University of the West of Scotland are focussed around two key areas; the programming and operation of the building services and the training and education of building users on the use of their building.

Operation of Building services

In order to positively influence the operational performance of the Ayr Campus, ensuring the functional, technical and environmental performance is as expected, it is essential that the building services and systems are programmed correctly to support their efficient and effective operation. This includes the operation of the boilers, heating systems, air handling units, chillers and lighting and other equipment that serves the sizeable 18,000m^2 Ayr Campus building. This complex network of services, wiring, sensors and alarms provides a challenge for the Ayr Campus Estates team to locally manage and maintain efficient control. The Campus benefits from a BMS and an AMR system which both complement each other and provide the University Estates team with the tools that are required to help manage the Ayr Campus and the wider Estate efficiently and effectively.

Ensuring that all building services are programmed correctly, accounting for varying seasonal changes and different occupancy uses, will allow the Ayr Campus to achieve optimum internal environments for the end users and will also help to maximise operational efficiencies. The BMS can help to optimise the programming and control of the building services and the AMR will enable the Estates team to monitor and report on the overall consumption and identify areas where further operational savings have been made. To help maximise operational performance and efficiencies the following is recommended for the University:

Efficient programming of building services

Matching delivery with demand - BRE recommend that the University undertake a mapping exercise to ensure the building services are programmed to serve areas only when they are in use. During this project BRE made use of the Ayr Campus room booking system information to help identify areas that were either being unnecessarily serviced or underserviced by the AHUs dependent on their use / occupancy. This exercise confirmed that there are a number of areas where the programming of the AHUs did not complement the use of certain areas of the building and as a result some areas were being either over serviced when they were unoccupied for several hours at a time or were under serviced when they were occupied, which was witnessed on several occasions when areas were being used out with normal operational hours. It is recommended for the University to repeat this exercise considering all building services to ensure that all spaces are only adequately serviced when required. This should help to maximise the Ayr Campus building operational efficiencies, thus allowing the University to enjoy financial and environmental benefits.

Efficient use of serviced space - The University has detailed information on the zoning strategies of the building services. It is recommended that these are also reviewed in conjunction with the Campus timetabling and room booking requirements. This exercise will allow similar activities (e.g. desk based activities with no requirement for additional heating or cooling or higher intensity activities where additional cooling need is required) to be identified and accommodated within one zone that can then be programmed to ensure that the building services are efficiently and effectively servicing a number of spaces, achieving internal environment conditions that are satisfactory for all of the end user needs.

End user training - The Ayr Campus BMS is a central control hub for a number of the building services. Users can interact with the system to programme services, adjust control settings, manage required seasonal changes and can also use this as an alert system for any failures or required maintenance. If used effectively the BMS could help to ensure the Ayr Campus services are operating efficiently, which would return significant financial and environmental savings for the University. There have been a few staff changes within the Ayr Campus Estates team during the delivery of this project and it has not always been possible for the previous member of staff to provide full handover details to the new member of staff, resulting in new members of staff encountering a period of trial and error in relation to the building systems and services. BRE would recommend that all of the Ayr Campus Estates team are offered specialist training and more local level control of the BMS to help make more efficient and effective use of this system. At present, sub-contractors are appointed to make changes or to manage maintenance issues that are flagged up by the BMS, such as seasonal adjustments and the changing of light bulbs, all of which is having a significant impact on the University yearly budget. A number of these tasks are ones that the Ayr Campus Estates team, with adequate training, could manage themselves, therefore helping to reduce financial spend on operation and maintenance. On completion of any end user training, the Estates team should be granted time to make necessary adjustments to the systems and services in order to help ensure that these are efficiently delivering the optimum internal environment for end users e.g. lux level adjustments to lighting fittings, ensuring that they meet the needs of the end user and space.

There appears to be a limited level of control at a local level over the BMS and also limited access to the AMR from the Ayr Campus and as a result the Ayr Campus Estates staff are not interacting with the system as much as they could be and are therefore not understanding or making use of its full capabilities or programming the building services or systems in such a way that they fully complement the operation of the building. At present the BMS appears to be centrally controlled form the University's Paisley Campus. Engaging the Ayr Campus Estates team and providing them with more control over the BMS, should help to provide them with a better awareness of the control settings, programming and also the energy consumption data for the Ayr Campus. This could help to support more efficient use of the systems and positively contribute to the overall University Carbon Management Plan, through better awareness and engagement at a local level.

Detailed Maintenance Planning

An active, detailed, longer-term, comprehensive maintenance plan is one of the most cost-effective ways of protecting the value of an asset and ensuring that operational efficiencies and performance is realised. The plan can also help the building occupier to identify when routine maintenance and replacement is likely to be required and allows them to plan in advance for this. The University did not benefit from any detailed life cycle costing exercise and as a result does not benefit from having an informed maintenance plan in place for the Ayr Campus. The Campus does, however, have extensive information contained within the Operation and Maintenance manuals that could be used to help inform a maintenance plan for the Campus. A maintenance plan should help to describe the total package of all maintenance requirements required to provide adequate care for the building, its systems and services. It is recommended that a plan is developed for the Ayr Campus as it is crucial to ensure appropriate aftercare is provided to help maintain the Campus to a high standard and to also help avoid any unnecessary spending.

Building User Awareness

Building users benefit from being informed users and can greatly contribute to achieving and maintaining operational efficiencies. Informed users can also gain the most from their building and the systems and services that are in place. It is recognised that the Ayr Campus users are generally proud of their new building, however it was recognised that they could benefit further by having a better awareness of their environment. It is recommended that end user awareness sessions are delivered and that topics could include;

- Lighting systems and controls;
- Occupant and fixed glare control;
- Benefits of natural and mechanical ventilation strategies and how to get the most from these;
- Properties and embodied energy of materials (i.e. exposed thermal mass within the building);
- Actual energy consumption and reduction / efficiency strategies; and
- Provision, access and flexibility of spaces.

A revised Building User Guide could provide the basis for any awareness training / discussion sessions and live information boards or e-news drops could be used to help further disseminate performance information to end users. A simplified guide that is locally available could also help to support awareness raising and more efficient building use.

11 Wider lessons

Summarised below are the key messages, listed in-line with the life of a building, based on the Building Performance Evaluation of the UWS and SRUC Ayr Campus;

The brief

The Ayr Campus project benefited from having a detailed performance brief and defined environmental performance targets, such as achieving an ambitious BREEAM Excellent rating. The BREEAM standard helped to influence and guide the delivery methods and approach for this project, ensuring that the design, construction and handover stages were managed in a responsible way.

The quality and detail of a design brief can greatly influence the quality and performance of a building. A well-developed, well managed and executed brief ensures that the design team are made aware of the client aspirations from the outset and are driven by these throughout, which can often help to progress the design solutions in a more efficient and cost effective process as a result of having clear targets, objectives and benchmarks from the very start.

Informed design

UWS and SRUC were committed to undertaking detailed consultation exercises throughout this project. End user groups were engaged from the initial concept stages, through to the handover stages and then into the building occupation phase. This helped to generate buy-in and support for the project from both end user groups and wider stakeholder groups. The process encouraged users to take ownership of the new Campus building and aimed to ensure that the end user requirements were reflected and satisfied within the final design solutions.

A detailed user consultation exercise can benefit the end design solutions by ensuring that the spaces, systems and services are all fit for purpose. It is essential for the design team to understand the end user needs in order to ensure that the building functions and performs in the required way. During end user consultation exercises, the design team can start to make informed decisions in relation to the appropriate zoning of spaces and the operation of the building services. The layout of a building and its zoning strategies can heavily dictate how effective and functional the building performs, therefore considering these items during the early development stages and gaining user feedback helps to ensure that the most effective and efficient design solutions are achieved.

Life Cycle Costing

A Life Cycle Costing (LCC) or Whole Life Costing (WLC) analysis can help to improve the design, specification and through-life maintenance and operation. The Ayr Campus building did not benefit from a detailed LCC or WLC analysis and as a result does not benefit from having a detailed maintenance and replacement plan for the Campus.

A detailed LCC or WLC analysis undertaken at an early design stage and updated throughout the development of a project can allow the design team to improve design, specification, maintenance and operation. Quite often, a number of specified items can incur additional on-going and maintenance costs and many can also often require the use of costly specialist equipment in order to deliver required maintenance or upkeep. Consideration should be given to such requirements to allow the building users to fully understand and consider the additional operational, maintenance and replacement costs and to allow them to make more informed design decisions.

Detailed handover

At handover stage it is highly recommended that building users ensure a detailed maintenance plan, a seasonal commissioning schedule, a Building User Guide and a training schedule are all in place. The Ayr Campus benefits from having a detailed Building User Guide that allows both the Estates and everyday user access information on the design and operation of the Campus.

In order for a building to generate the predicted or expected operational efficiencies, it is essential that the building users manage and operate the building in an efficient and effective way. In order to achieve this, it is recommended that a training schedule is developed for both the Estates team and the end user groups. Training sessions help to raise user awareness and understanding which will help to create informed building users who understand how to operate and control their environment which should help to maximise operational efficiencies.

In addition to full commission of simple and complex systems, it is also advised that a seasonal commissioning schedule is also developed. This will ensure that the building systems are appropriately adjusted and operate at maximum efficiency levels to account for varying occupancy and seasonal changes throughout the year. All programming adjustments should also be reviewed and adjusted throughout the year (e.g. adjustments to timer controls settings for external lighting).

Operational efficiencies

The Ayr Campus building benefits from an intensive sub-metering strategy linked to an Automated Meter Reading (AMR) system. The system allows users to remotely monitor and analyse energy consumption by end use or area. The UWS Estates team uses the AMR to accurately monitor and benchmark the buildings operational energy performance.

A building which benefits from an extensive sub-metering and energy monitoring system helps to ensure that building users have a better awareness of overall energy consumption and high energy consuming areas or items within their building. This is particularly beneficial when introducing or monitoring the effectiveness of targeted energy reduction strategies as it allows users to monitor the impact and quantify the effectiveness of these strategies.

The Ayr Campus also benefits from a Building Energy Management System (BEMS). This system provides the Estates team with the capability to programme and control the operation and delivery of the building services. If operated effectively a BEMS can help to contribute towards significant operational energy savings and can also help to ensure that the delivery of services satisfy the end user requirements, thus creating comfortable internal environments for the end user. In order to operate the BEMS efficiently and effectively, it is recommended that the end user benefits from an in-depth training session as this will help to ensure that they have the required knowledge and understanding to programme, operate and manage the building in an efficient way so as to accrue operational savings.

Internal environment monitoring gathers data that can provide further information on a buildings performance. It is very useful in terms of providing indicative information in relation to user comfort levels and highlighting where there may be issues in relation to the operational performance of the building fabric, design or services. When evaluating building performance, it is essential to consider the internal environment of a building to ensure that users benefit from spaces that are both comfortable and healthy.

Maintenance

Developing a long term, comprehensive maintenance plan can help to ensure that the value of the asset is protected and operational efficiencies and performance is realised. A maintenance plan should help to inform what building elements require monitoring and inspection, at what frequency and should also provide indicative costs that would normally be associated with any required maintenance, repairs or replacement of services and equipment. It is recommended that the maintenance plan should cover at least 25 years of the buildings' life. As well as helping to maintain the performance and life of the asset, a maintenance plan will also allow building users to plan ahead and to budget for significant replacement costs.

Quality assurance

Real time monitoring, through a building management system and an automated energy monitoring interface enables access to actual building operation performance information, therefore any alarming issues that occur should be more easily identified, helping to provide constant quality assurance.

Physical, on-site testing such as building fabric performance monitoring provides information on the quality of construction and material performance, allowing the user to determine whether the building has been constructed to the desired standards. For example, results from an air tightness test can indicate where minor air leakage is occurring and can allow the building user to remedy this, therefore improving the internal environment sand the operational performance. Similarly, thermography can help to detect any lack in continuity of installed insulation and identify where there are any areas at risk of heat loss of dampness in the building. These physical testing activities can help to identify performance issues that would otherwise most likely go unrecognised for some time before they developed into major performance issues for the building or end users.

In summary, Post Occupancy Evaluation activity provides a valuable overview of the actual performance of buildings against recognised benchmarks and standards, provides feedback on satisfaction levels of the occupants and also investigates if the asset is adequately operated and maintained. The issues highlighted in this section of the report are key lessons that have resulted from delivering this BPE project.